BASIC CIVIL ENGINEERING

SATHEESH GOPI

Copyrighted material

www.EngineeringBooksPdf.com

Basic Civil Engineering

Satheesh Gopi

PEARSON

Delhi • Chennai • Chandigarh

Copyrighted material

www.EngineeringBooksPdf.com

Copyright © 2010 Dorling Kindersley (India) Pvt. Ltd

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, resold, hired out, or otherwise circulated without the publisher's prior written consent in any form of binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser and without limiting the rights under copyright reserved above, no part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise), without the prior written permission of both the copyright owner and the above-mentioned publisher of this book.

ISBN 978-81-317-2988-5

First Impression

Published by Dorling Kindersley (India) Pvt. Ltd, licensees of Pearson Education in South Asia.

Head Office: Knowledge Boulevard, 7th Floor, A-8(A), Sector – 62, Noida, UP 201309, India.
Registered Office: 14 Local Shopping Centre, Panchsheel Park, New Delhi 110017, India.

Printed in India by Baba Barkha Nath Printers.

Copyrighted material

www.EngineeringBooksPdf.com

contents

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

preface

The aim of compiling this book has been to give a working knowledge of the important details of civil construction, materials used in civil engineering, including the source of raw materials, their characteristics, the process of manufacture, their defects, structure and uses in the industry, and the basics of surveying and levelling and several other major topics in civil engineering to all engineering students in a systematic way. The book is written in a clear and easy-to-read style, presenting fundamentals of surveying at a level that can be quickly grasped by a beginner. The basic surveying topics deal with modern instruments such as total station, GPS and digital levels, reflecting modern field procedures.

A book on a technical subject is hardly complete without illustrations, and one of the special aims of this book is to present a number of diagrams, which are presented mainly with a view to emphasize the important features of the manufacture, so as not to burden the students with unimportant details. The first part of the book consists of 11 chapters and gives a description of all the materials used for different constructions in the field of civil engineering and the processes involved in the manufacture of the same. The second part of the book discusses briefly about building construction and maintenance of buildings and explains the different stages of construction. It contains 14 chapters. The third part of the book contains two chapters and gives a clear view of basic surveying concepts. The fourth part of the book has five chapters and provides a clear idea about the major topics in civil engineering, viz., geotechnical engineering, transportation engineering, irrigation and water resources engineering and environmental engineering. The fourth part also includes a chapter on Computer-Aided Design (CAD).

The author wishes to thank Dr Sathikumar and Shri N. Madhu, Professors, College of Engineering, Trivandrum, for their help during the writing of this book.

Copyrighted material

www.EngineeringBooksPdf.com

about the author

Satheesh Gopi has over 19 years of experience as a hydrographer and over five years of experience as a civil engineer and is currently the deputy director in the Hydrographic Survey Wing of the Kerala Port Department. He graduated in civil engineering from the College of Engineering, Trivandrum, and also holds a Master's Degree in Information Technology.

He is the author of books such as *Advanced Surveying* and *Global Positioning System, Principles and Applications*. He has published research papers on surveying, GPS and hydrography. He is a life member of the Indian Cartographic Association. His areas of interest include marine construction, advanced surveying, GPS and hydrography.

Copyrighted material

www.EngineeringBooksPdf.com

Part-I

Materials for Construction

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

chapter 1

Stones

Stones form one of the most important building materials in civil engineering. Stones are derived from rocks, which form the earth's crust and have no definite shape or chemical combination but are mixtures of two or more minerals. The mineral is a substance which is formed by the natural inorganic process and possesses a definite chemical combination and molecular structure. They are strong, durable and descent in appearance.

The main uses of stone as a building material are:

1. As a principal material for foundation of civil engineering works, and for the construction of walls, arches, abutments and dams.
2. In stone masonry in places where it is naturally available.
3. As coarse aggregate in cement concrete (crushed form of rock).
4. As a roofing material in the form of slates.
5. As a flag or thin slab for paving.
6. As a soling material in the construction of highways and runways.
7. As ballast for railway tracks.
8. As a veneer for decorative front and interior of buildings.
9. Limestone for construction of important buildings like temples, churches and mosques.
10. Limestone for the manufacture of cement and as a flux in blast furnace.

Numerous examples of magnificent buildings made partly or wholly of stones can be given from different parts of the world. The Taj Mahal, Red Fort and temples of Jagannath, Puri and Mahabalipuram are best-known buildings of our country made up entirely of stones.

1.1 SOURCES OF STONES

Stones are obtained from rocks. A rock represents a definite portion of the earth's surface. They occur almost everywhere in mountainous and hilly areas. It has no definite chemical composition and shape. Stones are available in large quantities in different parts of our country. It is necessary to know the availability of good stones in and around the construction site to make maximum use of this naturally available and cheap building material.

It is known as monomineralic rock, if it contains only one mineral and it is known as polymineralic rock, if it contains several minerals. Quartz sand, chemically pure gypsum, magnesite, etc. are examples of monomineralic rocks and basalt, granite, etc. are examples of polymineralic rocks.

Minerals are the units of which the rocks are made up of. A mineral indicates a substance having definite chemical composition and molecular structure. It is formed by natural inorganic processes. The properties of a rock are governed by the properties of minerals present in the structure. The common rock forming minerals are quartz, feldspars, calcite and mica, hornblende, etc.

Copyrighted material

www.EngineeringBooksPdf.com

1.2 CLASSIFICATION OF ROCKS

Rocks are classified in four different ways:

1. Geological classification
2. Chemical classification
3. Physical classification
4. Practical classification

1.2.1 Geological classification

According to the mode of origin, rocks are divided into three principal classes or groups, namely:

a. Igneous rocks
b. Sedimentary rocks
c. Metamorphic rocks

1.2.1.1 Igneous rocks

The molten material present in the inside portion of the earth's surface is known as magma and this magma occasionally tries to come out to the earth's surface through cracks or weak portions. The rocks which are formed by the cooling of magma are called igneous rocks. The portion of lava which comes outside the surface cools quickly and forms a rock of non-crystalline nature called as trap or basalt. The rest which remains inside the earth undergoes cooling at a slow rate and results in the formation of a rock of crystalline variety known as granite. The igneous rocks are classified into the following three types.

i. *Plutonic rocks:* They are formed by the cooling of magma at a considerable depth from the earth's surface. The cooling is slow and the rocks possess coarsely grained crystalline structure. This rock is mostly used for construction purposes. Granite is the leading example of this type of rock.

ii. *Hypabyssal rocks:* They are formed by the cooling of magma at a relatively shallow depth from the earth's surface. The cooling is quick and, hence, the rocks possess a finely grained crystalline structure. Dolerite is an example of this type of rock.

iii. *Volcanic rocks:* In the case of these rocks, solidification of magma takes place on or near the surface of the earth. The cooling is very rapid as compared to the previous two cases. Hence, the rocks are extremely fine grained in structure. Basalt is an example of this type of rock.

1.2.1.2 Sedimentary rocks

These rocks are formed by the weathering action of natural elements on the original rock and subsequent transportation by air, river, glacier and sea and deposition at a different locality. The following four types of deposits occur:

i. *Residual deposits:* Some portion of the products of weathering remains at the site of origin. Such deposit is known as a residual deposit.

ii. *Sedimentary deposits:* The insoluble products of weathering are carried away in suspension, and when such products are deposited, they give rise to sedimentary rocks.

iii. *Chemical deposits:* Some material that is carried away in solution may be deposited by some physio-chemical process such as evaporation and precipitation. It gives rise to chemical deposits.

Copyrighted material

www.EngineeringBooksPdf.com

iv. *Organic deposits:* Some portion of the product of weathering gets deposited through the agency of organisms. Such deposits are known as organic deposits.

Examples of sedimentary rocks are sandstone, limestone, gypsum, lignite, etc.

1.2.1.3 Metamorphic rocks

These rocks are formed by the change in character of the pre-existing rocks. Igneous as well as sedimentary rocks change in character when they are subject to great heat and pressure. The process of change is known as metamorphism. Table 1.1 gives the names of the original and metamorphic rocks. Mineral composition and texture of a rock represent a system which is in equilibrium with its physio-chemical surroundings. Increase of temperature and pressure upsets this equilibrium and metamorphism results from an effort to re-establish a new equilibrium. In this process, original constituent minerals, which are unstable under the changed conditions, are converted into newer ones, which are more stable under the changed conditions. These minerals are arranged in a manner, that is more suitable to the new environment. It should, however, be noted that changes produced by weathering and sedimentation are not included in metamorphism.

There are three agents of metamorphism, namely heat, pressure and chemically acting fluids. Heat may be supplied by the general rise of temperature with depth or by igneous magma. Pressure may be developed due to the load of rocks or movement of the earth. Chemically acting fluids play a passive role only and they do not take active part in the process of metamorphism. Pressure may be uniform or directed. Uniform pressure may be applied to solids and liquids. Directed pressure or stress can exist only in solids and it is converted into uniform pressure if applied to liquids. Following are the four types of metamorphism that occur with various combinations of heat, uniform pressure and directed pressure.

i. *Thermal metamorphism:* Heat is the predominant factor in this type of metamorphism.

ii. *Cataclastic metamorphism:* At the surface of the earth, temperature is low and metamorphism is brought about by directed pressure only. Such metamorphism is known as cataclastic metamorphism.

iii. *Dynamo-thermal metamorphism:* There will always be a rise in temperature with an increase in depth. Hence, heat in combination with stress brings about the changes in the rock. Such metamorphism is known as dynamo-thermal metamorphism.

iv. *Plutonic metamorphism:* Stress is effective only up to a certain depth. This is due to the fact that rocks become plastic in nature at certain depths. At great depths, a stage is reached when stress cannot exist as it is converted into uniform pressure because of the plasticity of rocks. Metamorphic changes at great depths are, therefore, brought about by uniform pressure and heat. Such metamorphism is known as plutonic metamorphism.

Various types of metamorphic rocks that originated from various types of rocks are given in Table 1.1.

Table 1.1 Various Types of Metamorphic Rock and Its Origin

Name of the original rock		
Igneous	Sedimentary	Name of the metamorphic rock
		Gneiss
Granite	Limestone	Marble
-	Sandstone	Quartzite
	Clay	Slate

Copyrighted material

www.EngineeringBooksPdf.com

1.2.2 Chemical classification

On the basis of dominant chemical composition, the building stone may fall into any of the following three groups:

a. Silicious rocks: In these rocks, silica predominates. These rocks are hard and durable. They are not easily affected by the weathering agencies. Silica, however, in combination with weaker minerals, may disintegrate easily. It is therefore necessary that these rocks should contain maximum amount of free silica for making them hard and durable. Granites, quartzite, etc. are examples of silicious rocks.

b. Argillaceous rocks: In these rocks, clay predominates. Such rocks may be dense and compact or they may be soft. Slates, laterites, etc. are examples of silicious rocks.

c. Calcarious rocks: In these rocks, calcium carbonate predominates. The durability of these rocks will depend upon the constituents present in the surrounding atmosphere. Limestone, marbles, etc. are examples of calcarious rocks.

Classification of Rocks According to Their Chemical Composition

Chemical classification	Composition	Name of the rock
1. Silicious rock	Predominance of silica	Granite, sandstone, basalt
2. Argillaceous rock	Predominance of clay	Slate, laterite, schist
3. Calcareous rock	Predominance of lime	Limestone, marbles, dolomite

1.2.3 Physical classification

This classification is based on the general structure of rocks. According to this classification, the rocks are divided into three types.

a. Stratified rocks: These rocks possess planes of stratification or cleavage and such rocks can easily be split up along these planes. Sedimentary rocks are distinctly stratified rocks.

b. Unstratified rocks: These rocks are unstratified. The structure may be crystalline granular or compact granular. Igneous rocks of volcanic agency and sedimentary rocks affected by movements of the earth are of this type of rocks.

c. Foliated rocks: These rocks have a tendency to be split up in a definite direction only. Foliated structure is very common in case of metamorphic rocks.

Classification of Rocks According to Their Structure

Physical classification	Characteristics	Typical name
1. Stratified rock	Has many strata	Slate
2. Unstratified rock	Does not have strata	Granite
3. Foliated rocks	Has foliated structure	Gneiss

1.2.4 Practical classification

Practical classification is based on the usage. Practically stones have been classified as granite, basalt, laterite, marble, limestone, sandstone and slate.

1.3 DRESSING OF STONES

A place where exposed surfaces of good quality natural rocks are abundantly available is known as 'quarry' and the process of taking out stones from the natural bed is known as 'quarrying'. This is done with the help of hand tools like pickaxe, chisels, etc., or with the help of machines. Blasting using explosives is another method used in quarrying.

Copyrighted material

www.EngineeringBooksPdf.com

The stones after being quarried are to be cut into suitable sizes and with suitable surfaces. This process is known as the dressing of stones and it is carried out for the following purposes:

1. To make the transport from the quarry easy and economical.
2. To suit the requirements of stone masonry.
3. To get the desired appearance for the stonework.

The different stages of dressing are:

1. *Sizing:* This is reducing the irregular blocks to the desired dimensions by removing extra portions. It is done with help of hand hammers and chisels.
2. *Shaping:* This follows sizing and involves removing of the sharp projections. Many stones are used in common construction after shaping.
3. *Plaining:* This is rather an advanced type of dressing in which the stone is cleared off all the irregularities from the surface.
4. *Finishing:* This is done in case of specially dressed stones only and consists of rubbing of the surface of stones with suitable abrasive materials such as silicon carbide.
5. *Polishing:* This is the last name in dressing and is done only on marbles, limestone and granite.

1.3.1 Types of dressing

a. *Hammer dressing:* A hammer-dressed stone has no sharp and irregular corners and has a comparatively even surface to fit well in the masonry (Figure 1.1).

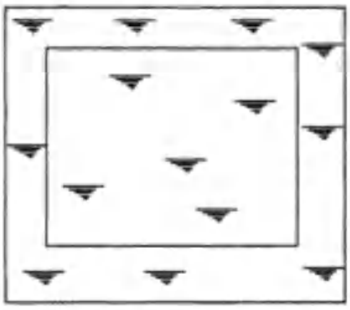


Figure 1.1 Hammer dressing

b. *Chisel drafting:* In this method drafts or grooves are made with help of chisels at all the four edges and any excessive stone from the centre is then removed. These stones are specially used in plinths and corners of buildings (Figure 1.2).

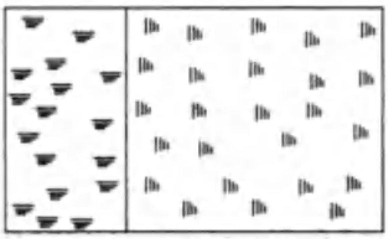


Figure 1.2 Chisel drafting

Copyrighted material

www.EngineeringBooksPdf.com

c. *Fine tooling:* This involves removing most of the projections and a fairly smooth surface is obtained (Figure 1.3).

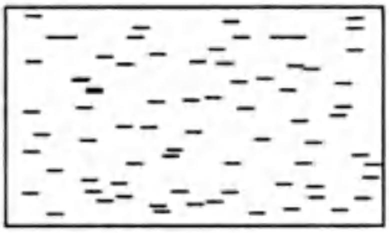


Figure 1.3 Fine tooling

d. *Rough tooling:* A rough-tooled surface has a series of bands, 4-5 cm wide, more or less parallel to tool marks all over the surface (Figure 1.4).

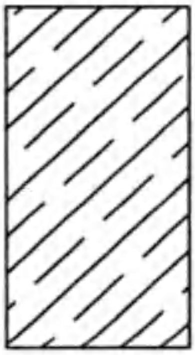


Figure 1.4 Rough tooling

e. *Punched dressing:* A rough-tooled surface is further dressed to show the series of parallel ridges. Chisel marks are left all over the face (Figure 1.5).

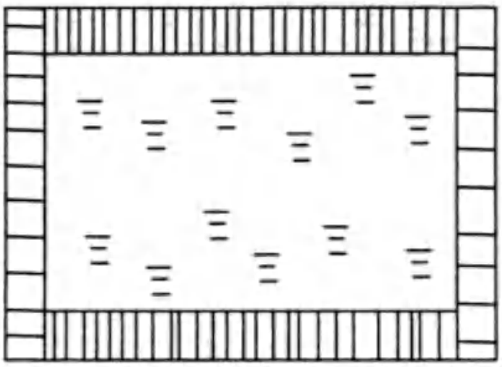


Figure 1.5 Punched dressing

f. *Closed picked dressing:* A punched stone is further dressed so as to obtain a finer surface (Figure 1.6).

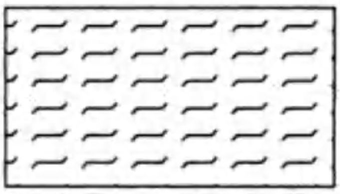


Figure 1.6 Closed picked stone surface

Copyrighted material

www.EngineeringBooksPdf.com

1.4 PROPERTIES OF GOOD STONE

1. *Appearance:* The appearance of a stone in relation to the design is of great importance from an architectural point of view. Appearance depends upon the colour and ease with which the stone can be dressed, rubbed or polished. Deep colours, however, in sedimentary rocks are due to oxides of iron in the cementing material, which, upon exposure to the atmospheric influences, either fade away or disfigure and strain the surface on account of the rusting of iron. The stones which are to be used for face work should be attractive in appearance and should be of uniform colour and free from clay holes, spots of other colour, bands, etc. Stones with lighter shades are preferable, because even if they fade a little they will not show a striking difference and spoil the appearance.
2. *Durability:* It denotes the period in years for which a stone may stand practically unaltered after being used in construction. A variety of factors affect the durability of a stone. Of these, the mineral composition, texture and structure of rocks and their capacity to absorb moisture are very important.
3. *Texture:* Texture relates to the grains or particles composing the stone in the strata. A good building stone should have a compact fine crystalline structure, free from cavities, cracks or patches of soft or loose material.
4. *Crushing strength:* It is also called compressive strength of a stone and is defined as the load per unit area at which a given stone starts cracking or failing. For a good structural stone the crushing strength should be greater than 100 N/mm^2.
5. *Resistance to fire:* The fire resistance of a stone may be defined as its capacity to withstand very high temperature without disintegrating. For this requirement, the different materials constituting the composition of a stone should have different coefficients of expansion. In igneous rocks, like granite, free quartz is the most dangerous material as it undergoes a sudden expansion at less than 600°C and flies into splinters; even timber is able to withstand a much higher temperature (about 800°C). It then crumbles to powder and also increases in bulk. Sandstone with silicates as binding material are fire resistant. Clay stones have good fire resistance but are poor in strength and durability.
6. *Specific gravity:* For a good building stone, the specific gravity should be greater than 2.7 or so. Heavy stones are suitable for construction of abutments, dams, docks, harbours, etc. while lighter varieties are used in building construction.
7. *Hardness:* For use in structures subjected to very heavy loadings, such as for constructing bridges, piers and abutments and marine structures, and particularly where they are subjected to abrasion, hardness of the stone is a necessary requirement.
8. *Water absorption:* Moisture reduces the strength of the rocks and as such rocks that contain or absorb great amounts of moisture show lower strength values. All the stones are more or less porous, but for a good stone percentage absorption by weight after 24 hours should not exceed 0.60.
9. *Weathering:* A good building stone should possess better weathering qualities. It should be capable of withstanding adverse effects of various atmospheric and external agencies such as rain, frost, wind, etc.
10. *Facility of dressing:* For facility of dressing, a stone must be comparatively soft, yet durable, compact-grained and homogeneous. It must be free from veins and planes of cleavage. Such a stone is called freestone. The stones should be such that they can be easily carved, moulded, cut and dressed. It is an important consideration from the economic point of view.

Copyrighted material

www.EngineeringBooksPdf.com

1.5 COMMON BUILDING STONES IN INDIA

The commonly used building stones in India include granite, basalt and trap, limestone, marbles, gneiss, laterite, slate, etc.

1. *Granite:* Granite is essentially an igneous rock and is hard and durable. Most of these rocks possess excellent building properties, like high strength, very low abrasion value, good resistance to frost and other weathering agencies, and are available in different appealing colours. It is used for facing work, walls, bridge piers, columns, steps, etc. These rocks are mainly found in Kashmir, Rajasthan, Punjab, Uttar Pradesh, Bihar, Orissa, Kerala, Tamil Nadu and Gujarat.
2. *Limestone:* They are sedimentary rocks composed mainly of calcium carbonate. They show great variation in their properties and, hence, all types are not useful as building stones. They can be used as road metal for construction of floors, steps, walls, etc. Limestone is also used for the manufacture of cement and lime. The use of limestone as facing stones should be avoided in areas where the air is polluted with industrial gases or in coastal regions where air from the sea can attack them. India has extensive deposits of limestone in Maharashtra, Rajasthan, Delhi, Andhra Pradesh, Madhya Pradesh, Bihar and Bengal.
3. *Marble:* These are metamorphic rocks and have been formed from limestone under high temperatures. Marbles vary greatly in colour, structure and texture and most of them are suitable both as an ornamental stone and as a construction material. These stones can take brilliant polish. India has got fairly widespread deposits of marble and it is mainly exploited from Rajasthan, Maharashtra and Gujarat.
4. *Basalt and Trap:* These are also igneous rocks and are generally heavier and darker than granites and also stronger, but may contain cavities and pores within them. They are extensively used for rubble masonry, foundation work and road construction. They are mainly found in Maharashtra, Bihar, Bengal and Madhya Pradesh.
5. *Sandstone:* These are sedimentary rocks and consist mainly of quartz. Sandstones occur in many colours. The most suitable and durable type is that which is light coloured, having silica, cement and a homogeneous, compact texture. It can be used for steps, facing work, flooring, columns, etc. India has immense reserves of really good quality sandstones in Madhya Pradesh, Uttar Pradesh, Orissa and Bihar.
6. *Laterite:* It is a sedimentary rock composed mainly of oxides of iron and aluminium. Laterites are of dull red or brown colour and their important property is that they are quite soft and plastic when cut from the natural bed rock but become hard on exposure. It is used for rough stone masonry work and is sometimes used in place of bricks. They are mainly found in Maharashtra, Tamil Nadu, Kerala, Karnataka and Andhra Pradesh.
7. *Gneiss:* Gneiss is a metamorphic rock and closely resembles granite in its building properties. But sometimes it may be rich in mica and useless as a building stone. They can be used for street paving, rough stone masonry work, etc. They are mainly found in southern states like Tamil Nadu, Kerala, Karnataka, Andhra Pradesh and also in states like Bihar, Bengal and Orissa.
8. *Slate:* Slate is a metamorphic rock and splits into thin sheets having smooth surfaces along the natural bedding planes. In building construction their use is limited to roofing purpose for ordinary buildings or as paving or insulating materials. Slate occurs in Gujarat, Rajasthan, Andhra Pradesh and Bihar.

Copyrighted material

www.EngineeringBooksPdf.com

9. *Kankar:* Kankar is a sedimentary rock and is a form of impure limestone. It is used as road metal for the manufacture of hydraulic lime, etc. It occurs among the different parts of north and central India.

10. *Murum:* Murum is a metamorphic rock. It is a form of decomposed laterite and is deep brown or red in colour. It is a soft rock and can be used for fancy paths and garden walls. It occurs mainly in Maharashtra, Tamil Nadu, Orissa, Bihar and Madhya Pradesh.

REVIEW QUESTIONS

1. What are the main uses of stone in building construction?
2. How are rocks classified? Briefly discuss the different classification of rocks.
3. Give short notes on
   a. Chemical classification of rocks
   b. Different stages of dressing of stones
   c. Common building stones in India
4. What are the purposes of dressing of stones?
5. What are the different types of dressing of stones?
6. Briefly discuss the properties of a good stone.

Copyrighted material

www.EngineeringBooksPdf.com

chapter 2

Sand

Sand is an important building material. It abundantly occurs in nature and is formed by the decomposition of rocks. Sand particles consist of small grains of silica (SiO_2). It forms a major ingredient in concrete, lime mortar, cement mortar, etc.

2.1 NATURAL SOURCES OF SAND

Sand is formed by the weathering of rocks. Based on the natural sources from which sand is obtained, it is classified as follows:

1. Pit sand
2. River sand
3. Sea sand

2.1.1 Pit sand

This sand is obtained by forming pits in soils. It is excavated from a depth of about 1-2 m from the ground level. This sand is found as deposits in soil and it consists of sharp angular grains, which are free from salts. It serves as an excellent material for mortar or concrete work. Pit sand must be made free from clay and other organic materials before it can be used in mortar. Also, the coating of oxide of iron over the sand grains should be removed.

2.1.2 River sand

This sand is widely used for all purposes. It is obtained from the banks or beds of rivers and it consists of fine rounded grains. The presence of fine rounded grains is due to mutual attrition under the action of water current. The river sand is available in clean conditions. The river sand is almost white in colour.

2.1.3 Sea sand

Sea sand is obtained from the sea shores. It consists of fine rounded grains like the river sand. Sea sand is light brown in colour. Since the sea sand contains salts, it attracts moisture from the atmosphere. Such absorption causes dampness, efflorescence and disintegration of work. Sea sand increases the setting time of cement. Hence, it is the general rule to avoid use of sea sand for engineering purposes even though it is available in plenty. However, after removing the salts by washing, it can be used as a local material.

2.2 CLASSIFICATION OF SAND

Based on the grain size distribution, sand is classified as fine, coarse and gravelly.

Copyrighted material

www.EngineeringBooksPdf.com

1. *Fine sand:* The sand passing through a sieve with clear openings of 1.5875 mm is known as fine sand. Fine sand is mainly used for plastering.
2. *Coarse sand:* The sand passing through a sieve with clear openings of 3.175 mm is known as coarse sand. It is generally used for masonry work.
3. *Gravelly sand:* The sand passing through a sieve with clear openings of 7.62 mm is known as gravelly sand. It is generally used for concrete work.

2.3 BULKING OF SAND

The increase in the volume of sand due to the presence of moisture is known as bulking of sand. This is due to the fact that moisture forms a film of water around the sand particles and this results in an increase in the volume of sand. The extent of bulking depends on the grading of sand. The finer the material the more will be the increase in volume for the given moisture content. Bulking of sand can be expressed in a graphical way as shown in Figure 2.1.

For a moisture content of 5–8 per cent, the increase in volume may be about 20–40 per cent depending upon the gradation of sand. When the moisture content is further increased, the sand particles pack near each other and the amount of bulking is decreased. Hence, dry sand and the sand completely flooded with water have practically the same volume.

The volumetric proportioning of sand depends upon the extent of bulking. It is more with fine sands than with coarse sands. If proper allowances are not made for bulking of sand, the cost of concrete and mortar increases and it results in mixes with inadequate sand. This makes the mix harsh and difficult for working and placing.

2.4 PROPERTIES OF GOOD SAND

Good sand should possess the following properties:

1. It should be clean and coarse.
2. It should be free from any organic or vegetable matter; usually 3-4 per cent clay is permitted.

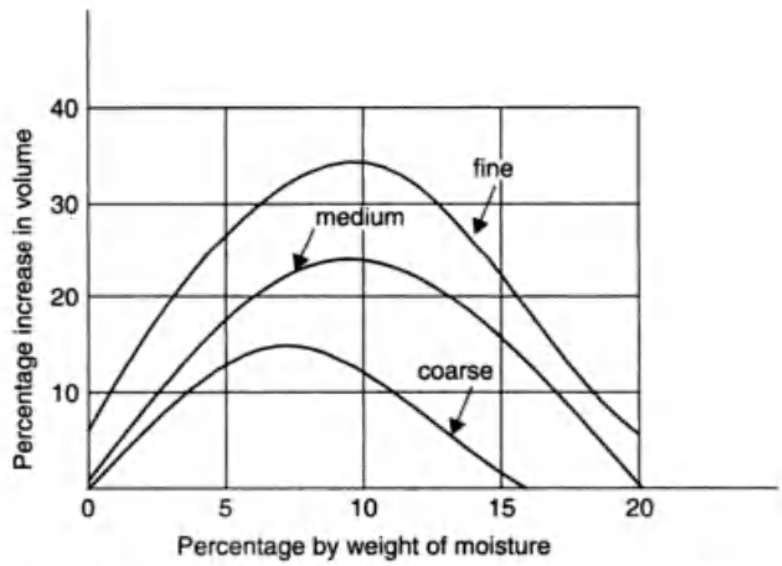


Figure 2.1 Graph showing the percentage increase in volume to the percentage by weight of moisture

Copyrighted material

www.EngineeringBooksPdf.com

3. It should be chemically inert.
4. It should contain sharp, angular, coarse and durable grains.
5. It should not contain salts which attract moisture from the atmosphere.
6. It should be well graded, i.e., it should contain particles of various sizes in suitable proportions.
7. It should be strong and durable.
8. It should be clean and free from coatings of clay and silt.

2.4.1 Functions of sand in mortar

Sand is used in mortar and concrete for the following functions:

a. *Strength:* It helps in the adjustment of the strength of mortar or concrete by variation of its proportion with cement or lime. It also increases the resistance of mortar against crushing.
b. *Bulk:* It acts as an adulterant. Hence, the bulk or volume of mortar is increased which results in reduction of cost.
c. *Setting:* In the case of fat lime, carbon dioxide (CO_2) is absorbed through the voids of sand and setting of fat lime occurs effectively.
d. *Shrinkage:* It prevents excessive shrinkage of mortar in the course of drying and, hence, the cracking of mortar during setting is avoided.
e. *Surface area:* It subdivides the paste of the binding material into a thin film and, thus, more surface area is offered for its spreading and adhering.

2.4.2 Substitutes for sand

Sand has now become a scarce and costly material and extraction of river sand is now said to affect the ecological balance. The use of substitutes for sand has gained great importance.

Surkhi, or finely grained burnt clay, is one of the materials used for this purpose. It can be used in all mortars, except that for plastering.

Processed quarry dust or stone screening is also being used as substitutes. It is abundantly available and if it is properly screened it imparts more strength to the mortar. This is now being industrially manufactured under various trade names.

REVIEW QUESTIONS

1. What is the importance of sand in building construction?
2. What are the sources of sand?
3. How is sand classified?
4. What is bulking of sand and how can it be determined?
5. What are the properties of good sand?
6. Describe the functions of sand in mortar.
7. What are the substitutes of sand used due to the scarcity of sand?

Copyrighted material

www.EngineeringBooksPdf.com

Lime

Lime is one of the most important and largely used building materials. In fact, it used to be the main cementing material before the advent of Portland cement. Egyptians and Romans made remarkable application of this material for various constructional purposes. Even in India, various engineering structures such as big palaces, bridges, temples, forts and monuments were constructed with lime as a cementing material and some of these structures still exist in good condition. This is attributed to some of the unique properties of lime, such as its better workability, early stiffening, good strength and resistance to moisture and excellent adherence to masonry units. Although it has been largely replaced by cement in India and elsewhere, the material still stands comparable to cement in most important properties.

3.1 SOURCES OF LIME

Lime is not usually available in nature in free state. It is chiefly prepared by burning limestone. Depending on the percentage of calcium carbonate ($CaCO_3$) in limestone, lime is classified into A, B and C types, which are used for masonry work, mortar and plaster and white washing, respectively. The type C variety is also known as pure lime or fat lime. Class A variety is only available in slaked form, while class B and C are available in slaked as well as unslaked forms. Lime is also obtained by burning kankar, shells of sea animals and boulders of limestone from beds of old rivers.

The lime that is obtained from the calcination of pure limestone is known as quicklime. It mainly consists of oxides of calcium and it is not crystalline. It shows great affinity to moisture.

3.2 CLASSIFICATION OF LIME

Lime has been conventionally classified into the following three types, namely

1. Fat lime
2. Hydraulic lime
3. Poor lime

3.2.1 Fat lime

This lime is also known as high calcium lime, pure lime, rich lime or white lime. Fat lime is obtained from pure limestone, shell and coral. When it is left in air, it absorbs carbon dioxide (CO_2) from air and gets transformed into calcium carbonate ($CaCO_3$). It is popularly known as fat lime as it slakes vigorously and its volume gets increased to about 2-2½ times the volume of that of quick lime.

The following are the properties of fat lime:

a. It hardens very slowly.

b. It has a high degree of plasticity.

Copyrighted material

www.EngineeringBooksPdf.com

c. Its colour is perfect white.

d. It sets slowly in the presence of air.

e. It slakes vigorously.

The following are the uses of fat lime:

a. It is used in white washing and plastering of walls.

b. With sand, it forms lime mortar, which sets in thin joints. Such mortar can be used for thin joints of brickwork and stonework.

3.2.2 Hydraulic lime

Hydraulic lime is different in composition from quick lime in that it contains a definite amount of clay, which gives it the hydraulic property, i.e., the capacity to set and harden even under water. Quick lime does not set under water. Hydraulic lime contains CaO between 70 and 80 per cent and clay about 15–30 per cent.

Hydraulic lime is generally manufactured from a limestone that is rich in clay, or by adding clay materials to the limestone during burning of limestone. This lime is further divided into feebly hydraulic, moderately hydraulic and eminently hydraulic lime, depending upon its hydraulicity. The comparison between these types of hydraulic limes is shown in Table 3.1.

3.2.3 Poor lime

This lime is also known as impure lime or lean lime. The following are the properties of poor lime.

a. This lime contains more than 30 per cent clay.

b. It slakes very slowly.

c. It forms a thin paste with water.

d. It does not dissolve in water though it is frequently changed.

e. It hardens very slowly.

f. It has poor binding properties.

Table 3.1 Comparison Between the Types of Hydraulic Lime

Number	Item	Feebly hydraulic lime	Moderately hydraulic lime	Eminently hydraulic lime
1.	Clay content	5%–10%	11%–20%	21%–30%
2.	Slaking action	Slakes after few minutes	Slakes after 1 or 2 hours	Slakes with difficulty
3.	Setting action	Sets in water in 3 weeks or so	Sets in water in 1 week or so	Sets in water in a day or so
4.	Hydraulicity	Feeble	Moderate	Eminent
5.	Uses	Mortar produced by this lime is reasonably strong, and hence it can be used for ordinary masonry work	Mortar produced by this lime is strong, and hence it can be used for superior type of masonry work	Mortar produced by this lime is similar to cement and hence it can be used for damp places

Copyrighted material

www.EngineeringBooksPdf.com

g. Its colour is muddy white.

h. It can be used for inferior type of work where there is scarcity of good lime.

3.3 CALCINATION OF LIME IN CLAMPS AND KILNS

3.3.1 Calcination

Lime is manufactured by the burning of limestone to bright red in suitable kilns or clamps. Theoretically, limestone dissociates when heated at 880°C into carbon dioxide and calcium oxide, which is also reversible.

$$CaCO_3 \leftrightarrow CaO + CaO_2$$

The burning or calcination of limestone can be carried out in one of the following ways:

a. Clamps

b. Kilns

  i. Intermittent kilns

  ii. Continuous kilns

3.3.1.1 Clamp burning

It is a very common and quick method of obtaining small supplies of ordinary type of quick lime. No constructions have to be made. Simply the ground is levelled and cleaned and the limestone and fuel are stocked in alternative layers, if the fuel is wood. But if the fuel is coal or charcoal, the limestone and fuel are mixed together and placed in a heap form. Any type of burning material locally available is used. The whole heap is then covered with mud plaster and an attempt is made to preserve as much heat as possible. Small holes are left at the top of the plaster and also at the bottom. When the blue flame at the top disappears, it indicates the completion of the burning of lime. The clamp is then allowed to cool and the pieces of quick lime are hand-picked subsequently. Even though burning is quick and cheap for ordinary type of lime, it is not suitable for large supplies because of the following reasons:

i. It proves to be uneconomical to manufacture lime on a large scale.

ii. The burning is not complete which results in poor quality lime containing unburnt limestone.

iii. Wastage is considerable, both in terms of heat generated and material produced.

iv. The quantity of fuel required is more and hence can only be practised where fuel is abundant (Figure 3.1).

3.3.1.2 Kiln burning

Most of the commercial lime is made by burning limestones in permanent structures called kilns. Kilns used in the manufacture of lime are of a number of variety and designs. A kiln may be of intermittent or continuous type. The kiln may be mixed feed type where the fuel and limestones are mixed up during burning. In separate feed type, the fuel is burnt separately and does not come into contact with the limestones.

Intermittent kilns

This is also known as batch type kiln. They are permanent structures of rectangular, oval or cylindrical shape. It may be made of bricks or stones. The interior of this kiln is lined with refractory bricks and does not break

Copyrighted material

www.EngineeringBooksPdf.com

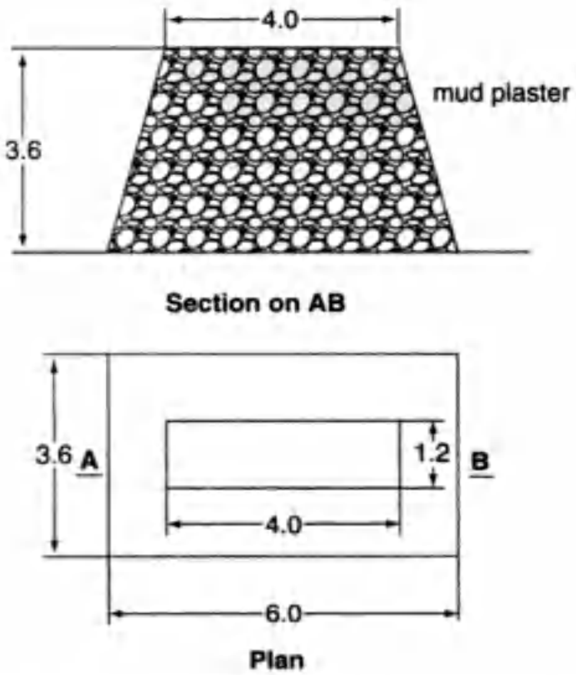


Figure 3.1 Clamp

even at high temperatures. The kiln is provided with openings or flues for supply of air during burning. The roof may be covered or partly covered. An escape hole for gases is always provided at the top.

In mixed feed type, the kiln is first loaded with a calculated amount of fuel and limestone, being deposited in alternative layers. The top of the kiln is covered with unburnt material. The kiln is ignited from the bottom for a required number of days till calcination is complete. It is allowed to cool and then unloaded. The next batch of fuel and limestone is charged to repeat the process (Figure 3.2).

In separate feed type, the fuel is not allowed to come in contact with the limestones. Bigger pieces are stocked in lower regions and smaller pieces above them, leaving open spaces for circulation of hot gases. Fuel is burnt in arch-type gates from where the hot gases rise and circulate between the limestones. When the limestones are sufficiently burnt, the kiln is cooled and unloaded. In this process the burning is more complete

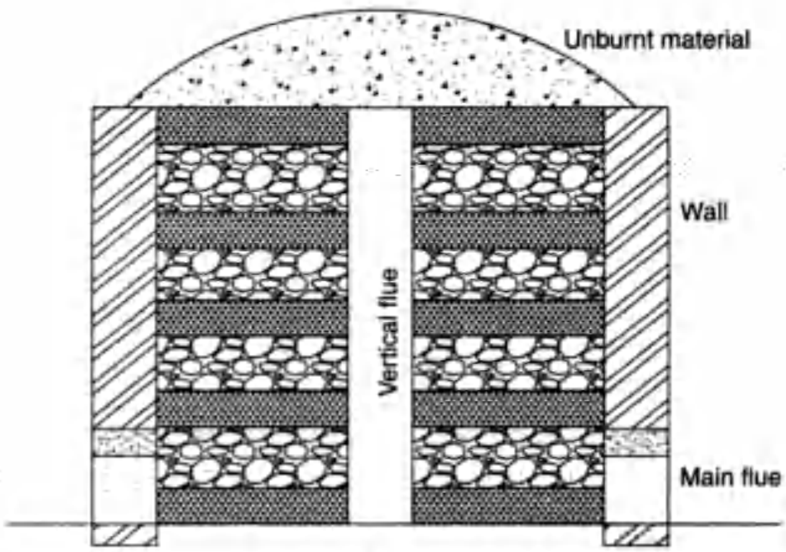


Figure 3.2 Intermittent flame kiln

Copyrighted material

www.EngineeringBooksPdf.com

and mixing of ash and lime is avoided. There is a considerable wastage of lime in intermittent kilns as every operation includes loading, burning, cooling and unloading.

Continuous kilns

These kilns are of such designs that from one end they are charged with raw materials and from the other end finished materials are taken out. Consequently, the kiln is not stopped for emptying or cooling operations. Naturally, the rate of production of lime is much higher.

In continuous flame kiln or mixed feed continuous kiln, the mixture of limestone and fuel is fed from the top. The widening of the middle portion is done so as to accommodate the hot gases of combustion. The bottom is covered by grating with holes. After burning, the lime is collected at the bottom and removed through the access shaft. The kiln is partly under the ground and partly above the ground. The inside surface of the kiln is covered with fire brick lining. The loading platform is provided at the top. As the level of material falls, the required amount of the mixture of fuel and limestone is fed from the top.

In continuous flare kiln or separate feed continuous kiln, the fuel is not allowed to come in contact with the limestone. The kiln consists of two sections. The upper section serves for the storage of limestones. The lower portion is provided with fire brick lining. Initially, a small quantity of fuel is mixed with limestone and ignited. The fuel is then fed through shafts around the lower and upper section of the kiln. The feeding of limestone is from the top. The removal of the calcinated material is done through a grating placed at the bottom of the kiln from where it can be removed (Figure 3.3).

There is a considerable saving in time and fuel, but the initial cost is high. Hence, this method can be adopted to manufacture lime on a large scale.

3.4 SLAKING OF LIME

The process of mixing water in quick lime is known as slaking of lime. It is an important operation in the preparation of lime at site for use in building construction. Improper slaking results in serious defects in mortars and plasters.

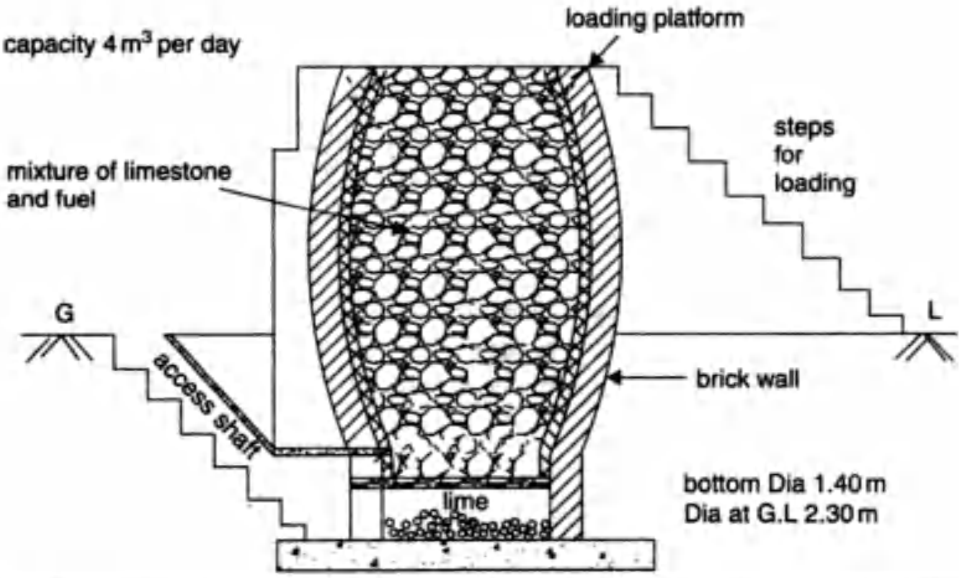


Figure 3.3 Continuous flare kiln

Copyrighted material

www.EngineeringBooksPdf.com

Two methods are commonly used for slaking of lime.

3.4.1 Tank slaking

In this method, two brick lined tanks are required. The first tank is about 45 cm deep and is made at a higher level, whereas the second tank is 60–75 cm deep and is made at a lower level, adjoining the first tank. Water is filled in the upper tank to about three-fourth its depth and quick lime is gradually added to it in small amounts. Water is constantly stirred during the process of addition of lime. This results in the formation of 'milk of lime', which is allowed to fall through a sieve into the lower tank.

After the lime-milk has been allowed to stand for the requisite time (2-3 days), it matures itself and forms lime putty, which is taken for use.

3.4.2 Platform slaking

The method provides dry slaking of lime which can be used as it is or may be converted to putty. A watertight masonry platform is built, over which the lime is spread in a 15 cm layer. Water is then sprayed over it using a hose pipe till lime disintegrates into a fine powder. During the water sprinkling process, the lime heap is turned over and over again. It is then left for 24 hours during which further slaking occurs.

The rate of hydration or slaking is greatly a function of the composition, physical state and degree of burning of lime. It is to be noted that over-burnt or under-burnt limestones do not slake easily. Hence, such undesirable pieces should be removed before slaking. It is also necessary to convert all lumps into powder or pulp form. It is observed that one part of fat quick lime is converted into about 1½ parts in paste form and about 2 parts in powder form.

The quantity of water required for hydrating 100 kg of lime is 32 litres, but practically even 100 litres of water may have to be added. This is generally determined by experience and depends on other factors like composition of quick lime, method of slaking and the form in which hydrated lime is required, i.e., either as putty or powder form.

3.5 COMPARISON BETWEEN FAT LIME AND HYDRAULIC LIME

Number	Item	Fat lime	Hydraulic lime
1	Composition	It is obtained from comparatively pure carbonate of lime containing only 5% of clayey impurities.	It is obtained from limestones containing 5%–30% clay and some amount of ferrous oxide.
2	Slaking action	Slakes vigorously, volume is increased to about 2–2½ times the volume of quick lime. The slaking is accompanied by sound and heat.	Slakes slowly and its volume is only slightly increased. The slaking is not accompanied by sound and heat.
3	Slaking action	Sets slowly in presence of air. It absorbs carbon dioxide from air and forms calcium carbonate.	Sets under water. It combines with water and forms crystals of hydrated tricalcium aluminate and dicalcium silicate.
4	Hydraulicity	Does not possess hydraulic property.	It possesses hydraulic property.
5	Colour	Perfectly white in colour.	Its colour is not as white as fat lime.
6	Strength	It is not very strong. Hence, it cannot be used where strength is required.	It is strong and cannot be used where strength is required.
7	Uses	For plastering, whitewashing, etc. and for preparing mortar with sand or surkhi.	For preparing mortar for thick walls, damp places, etc.

Copyrighted material

www.EngineeringBooksPdf.com

3.6 USES OF LIME

Lime can be used for the following purposes:

1. *Lime mortar:* Lime mortar has been extensively used in construction work from times immemorial. Lime mortar is used as a building medium in brick, stone and other masonry works as well as for plastering and pointing. The composition of the lime mortar for building work depends on:

   a. The type of masonry
   b. Situation/location of work
   c. Load which the masonry will have to take
   d. Condition of exposure to weather or soil conditions
   e. In case of hydraulic structures, weather conditions under water.

2. *Plastering:* Plastering serves the following functions:

   a. To smoothen the surface of masonry
   b. To protect the masonry surface from weathering
   c. To cover unevenness of masonry
   d. To prepare surface for decorative treatment.

3. *Whitewashing:* Whitewashing is applied on internal and external plastered surface as a decorative feature. Apart from decorative effect, the whitewashed outer surface reflects away the sun's rays and reduces the heating effect.
4. *Lime concrete:* In situations where quick setting and high strength are not required, lime concrete serves as an economical substitute. Lime concrete can be used for foundation, terraced roofing, flooring, ditches for sullage water, etc.
5. *Lime sand bricks:* It is a pearl gray brick like dry pressed burnt clay brick. This can be used for low-cost constructions and as a refractory material for lining open hearth furnaces.
6. It is used as a chemical raw material in the purification of water and for sewage treatment.
7. It is used for soil stabilization and for improving soil for agricultural purposes.
8. It is used as a flux in the metallurgical industry.
9. It is used for the production of glass.

REVIEW QUESTIONS

1. Explain the importance of lime as a building material.
2. What are the different sources of lime?
3. Briefly discuss the classifications of lime.
4. What is fat lime? What are the properties of fat lime?

Copyrighted material

www.EngineeringBooksPdf.com

5. What is poor lime? What are the properties of poor lime?

6. What is clacination of lime? How is clacination of lime carried out?

7. Explain briefly

   a. Clamp burning of lime
   b. Kiln burning of lime
   c. Hydraulic lime
   d. Slaking of lime
   e. Uses of lime

8. What is slaking of lime? What are the different methods used for slaking of lime?

Copyrighted material

www.EngineeringBooksPdf.com

Cement

Natural cement is brown in colour. It sets very quickly after the addition of water and is not as strong as artificial cement, and hence it has limited use.

It was in the eighteenth century that the most important advances in the development of cement were made, which finally led to the invention of Portland cement. In 1756, John Smeaton showed that the hydraulic lime which can resist the action of water can be obtained not only from hard lime but also from a limestone which contains a substantial proportion of clay.

In 1796, Joseph Parker found that the modules of argillaceous limestone made excellent hydraulic cement when burnt in the usual manner. Later, several experiments with several mixtures of limestone and argillaceous were carried out so that the properties of the product could be kept under more uniform and proper control by using varying lime and clay proportions. In 1824, Joseph Aspidin of Leeds in England introduced Portland cement.

4.1 PROPERTIES OF CEMENT

The properties of cement are:

1. It gives strength to the masonry.
2. It acts as an excellent binding material.
3. It offers good resistance to moisture.
4. It possesses good plasticity.
5. It stiffens or hardens early.
6. It is easily workable.

4.2 INGREDIENTS OF CEMENT

1. *Lime (CaO):* The chief constituent of cement is lime. Its proportion varies from 60 to 67 per cent. The lime in excess makes the cement unsound and causes the cement to expand and disintegrate and also retards the setting property. On the other hand, if lime is in deficiency, it reduces the strength of cement.
2. *Silica (SiO_2):* It forms 17 to 25 per cent of Ordinary Portland Cement. It imparts strength to the cement due to the formation of dicalcium and tricalcium silicates. Excess of silica increases the strength of cement, but at the same time the setting time is prolonged.
3. *Alumina (Al_2O_3):* It acts as a flux and lowers the clinkering temperature. It imparts quick setting property to cement. If in excess, it weakens the strength of cement.

Copyrighted material

www.EngineeringBooksPdf.com

4. *Calcium sulphate ($CaSO_4$):* This ingredient is in the form of gypsum. It is generally added in very small amounts (2 per cent of wt.) to cement towards the last stage of manufacture with a view of retarding the setting time of cement.
5. *Iron oxide (Fe_2O_3):* This is responsible for imparting the characteristic grey colour to cement. Its percentage varies from 0.5 to 6 per cent.
6. *Magnesia (MgO):* Magnesia varies from 0.1 to 45 per cent. Excess of magnesia reduces the soundness of cement. It imparts hardness and colour to the cement.
7. *Sulphur:* It varies from 1 to 2.5 per cent. If it is in excess, it makes the cement unsound.
8. *Alkalies:* Most of the alkalies present in raw materials are carried away by the flue gases during heating. If they are in excess in cement, they result in alkali-aggregate reaction, efflorescence and staining when used in masonry work.

4.2.1 Harmful constituents of cement

The presence of alkali oxides like K_2O and Na_2O and magnesium oxides like MgO adversely affects the quality of cement. If the amount of alkali oxides exceeds 1 per cent, it leads to the failure of concrete. If the content of magnesium oxide exceeds 5 per cent, it causes cracks after mortar and the concrete hardens. Table 4.1 shows the admissible average (in %) and limits (in %) of ingredients in ordinary cement.

Table 4.1 Admissible Average (in %) and Limits (in %) of Ingredients in Ordinary Cement

Ingredient	Limits (%)	Average (%)
1. Lime	60–66	63.5
2. Silica	18–25	22.5
3. Alumina	3–8	6
4. Iron oxide	0.5–5	2.5
5. Magnesia	1–5	1
6. Sodium and potassium oxides	0.5–5	1
7. Sulphuric anhydride	0.5–5	1

4.3 SETTING TIME OF CEMENT

When water is added to cement, the ingredients of cement react chemically with water and form a complicated chemical compound. The mixing of cement with water results in a sticky cement paste and it gradually goes on thickening in course of time. It is found that ordinary cement achieves 70 per cent of its final strength in 20 days and 90 per cent in 1 year or so.

The time of setting is greatly influenced by the following factors:

1. The temperature at which the cement paste is allowed to set.
2. The percentage of water mixed to cement in making the paste.
3. The humidity at which the setting is allowed.

Setting time is distinguished into initial setting time and final setting time on the basis of the time taken by the test specimen to set to a specified minimum depth.

A Vicat needle apparatus is used for the determination of setting time (Figure 4.1).

Copyrighted material

www.EngineeringBooksPdf.com

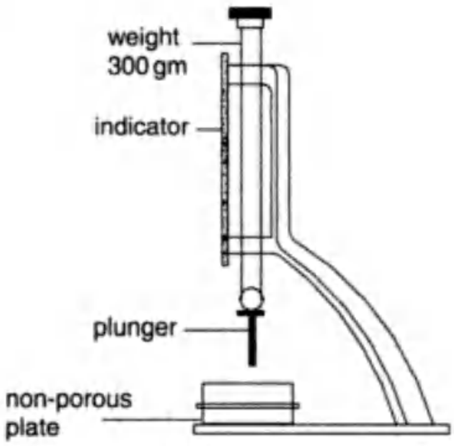


Figure 4.1 Vicat apparatus

Apparatus

1. It consists of a frame with a movable rod fitted with a cap.
2. A needle of 1 mm square cross section is attached to the lower end of the rod for the determination of initial setting time. The total weight of the rod along with the needle is 300 g.
3. Another needle like the above mentioned but with a hollow metallic attachment with a circular cutting edge of 5 mm diameter and having a 0.5 mm projection at the end is used to determine the final setting time.
4. A standard Vicat mould in which the specimen is allowed to set.

4.3.1 Initial setting time – procedure

a. Take 300 g by weight of cement and mix with 0.85 times the water required to give a paste of standard consistency.

b. Start the stop watch at the instant water is added to the cement.

c. Fill the Vicat mould with the cement paste and smooth the surface.

d. Place the square needle of cross section 1 mm to the moving rod of the Vicat apparatus.

e. Lower the needle gently bringing it in contact with the surface and quickly release allowing it to penetrate the paste.

f. In the beginning the needle will completely pierce the test block. Repeat the procedure in a fresh place until the needle, when brought in contact with the test block and released, fails to pierce the block for 5 mm measured from the bottom.

The initial setting time is the interval between the addition of water to the cement and the stage when the needle fails to pierce the test block for 5 mm measured from the bottom.

4.3.2 Final setting time – procedure

a. Replace the needle for initial setting time by the needle with an annular attachment for the final setting time.

Copyrighted material

www.EngineeringBooksPdf.com

b. The cement shall be considered as finally set, when upon applying the needle gently to the surface of the test block, the needle makes an impression thereon while the attachment fails to do so.

The final setting time is the interval between the addition of water to the cement and the time at which the needle makes an impression while the attachment fails to make an impression on the surface of the test block. The following table shows the initial and final setting time of various grades of cements.

Table 4.2 The Initial and Final Setting Time of Various Grades of Cements

Type of cement	Initial setting time	Final setting time
1. Ordinary	It shall not be less than 30 minutes.	It shall not be more than 10 hours.
2. Rapid hardening	It shall not be less than 30 minutes.	It shall not be more than 10 hours.
3. Low heat	It shall not be less than 60 minutes.	It shall not be more than 10 hours.

4.4 MANUFACTURE OF CEMENT

4.4.1 Wet process

In the earlier part of the century, from 1913 to 1960, the wet process was used for the manufacture of cement.

4.4.1.1 Mixing of raw materials

The calcareous materials such as limestones are crushed and stored in silos or storage tanks. The argillaceous materials, such as clay, are thoroughly mixed with water in a container known as wash mill and they are stored in basins. Now in correct proportions, the limestones from storage tanks and wet clay from basins are allowed to fall in a channel. This channel leads the material to grinding mills where they are brought to form a slurry. The grinding is carried out in either ball mill or tube mill or both. The slurry is lead to correcting basins where it is constantly stirred and at this stage the chemical compositions are adjusted as necessary. This corrected slurry is then stored in a different storage tank from where it is fed to the rotary kiln for burning.

4.4.1.2 Burning

The burning is carried out in the rotary kiln. The rotary kiln is formed of steel tubes whose diameter varies from 250 to 300 cm. The length varies from 90 to 120 m. It is laid at a gradient of 1 in 25 to 1 in 30. The kiln is supported at intervals by columns of masonry. A refractory lining is provided inside the kiln. It is arranged in such a way that the kiln rotates at 1–3 revolutions per minute about its longitudinal axis. The corrected slurry is charged into the rotary kiln for the wet process. Coal in finely pulverized form, fuel oil and gas are the common fuels for burning these kilns. The portion of the kiln near its upper end is known as dry zone and in this zone the water of the slurry is evaporated. As the slurry descends to the next zone, there is a rise in temperature from where the carbon dioxide from the slurry is evaporated. Small lumps known as nodules are formed at this stage. These nodules gradually pass through zones of rising temperature and ultimately reach the burning zone where temperature is around 1,500°C. In the burning zone, the calcined product is formed and nodules are converted into small, hard, dark, greenish blue balls which are known as clinkers. The size of the clinkers varies from 3 to 20 mm. Rotary kilns of small size are provided to cool down the clinkers and the cooled clinkers having temperature around 95°C are collected in containers of suitable sizes.

4.4.1.3 Grinding

The clinkers obtained from the rotary kiln are finely ground in ball mills and tube mills. During grinding, a small quantity, around 3-4 per cent, of gypsum is added. Gypsum controls the initial setting time of cement. If gypsum

Copyrighted material

www.EngineeringBooksPdf.com

is not added, the cement would set as soon as water is added. After grinding, the product is stored in storage tanks and finally they are packed in bags of different types to ensure a 50 kg net weight of cement bag with ±200 g. Each bag contains 50 kg or about 0.035 m^3 of cement. The bags are automatically discharged from the packer to the conveyor belt to different loading areas and are carefully stored in the right place (Figure 4.2).

4.4.2 Dry process

Nowadays the dry process of manufacture of cement is most often adopted and this improves the quality of cement produced, with less consumption of power. In this process, the raw materials which are ground to about 25 mm size in crushers are dried by passing dry air over it. They are then pulverized to a very fine powder in ball mills and tube mills. This is done separately for each raw material and then they are mixed in the correct proportion and made ready for the feed of the rotary kiln.

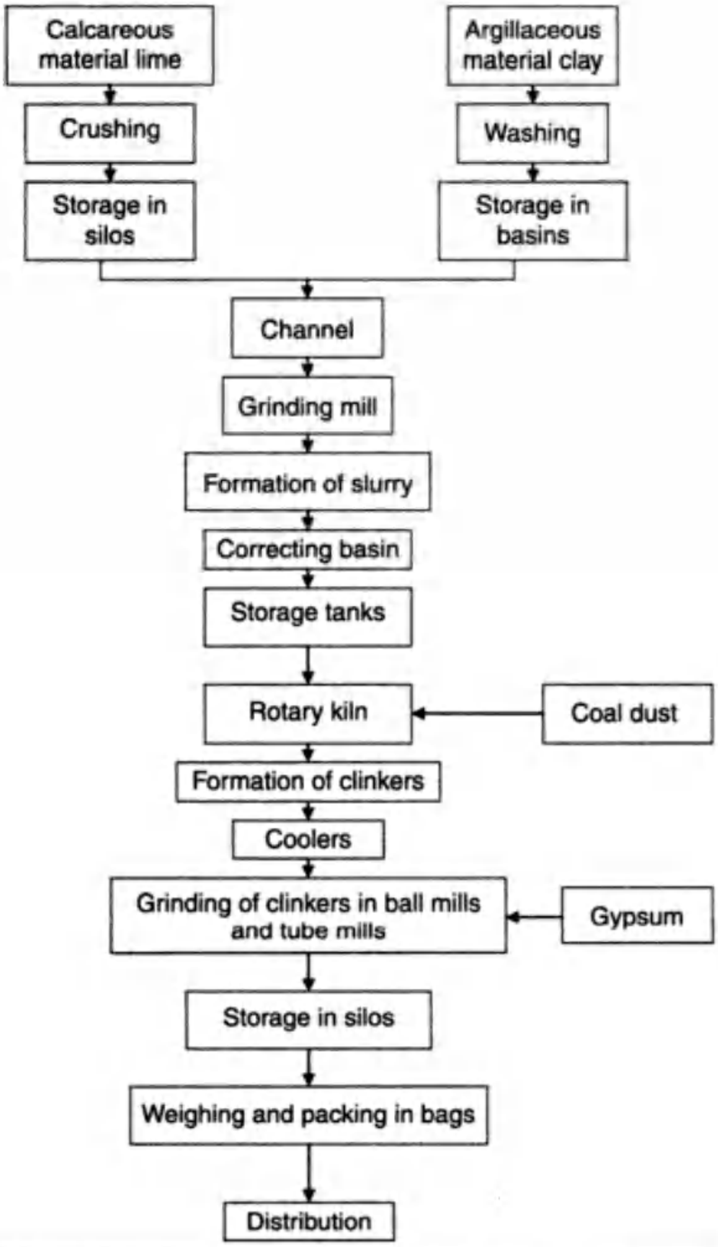


Figure 4.2 Schematic diagram of different processes involved in the manufacturing of cement

Copyrighted material

www.EngineeringBooksPdf.com

4.5 DIFFERENT TYPES OF CEMENT AND USES

1. *Ordinary Portland Cement:* It derives its name from the name of a stone (Portland) which resembles its colour. It is the most commonly used building material in mortar for masonry work, in mortar for plastering and pointing and as a binding medium in cement concrete, reinforced cement concrete and prestressed cement concrete construction.

2. *Rapid hardening cement:* The rapid hardening property is imparted to the cement primarily by burning at a higher temperature and secondly by finer grinding of the particles. The initial and final setting time of the cement is the same as ordinary cement, but it attains high strength in the early stages. It is useful in emergency situations as it develops the same strength in 4 days which ordinary cement acquires in 28 days. It is comparatively costlier than Ordinary Portland Cement. The uses and advantages of this cement are:

   a. It can be used when the construction has to be carried out fast.

   b. When the formwork of the concrete has to be removed earlier.

   c. It is light in weight.

   d. It is not damaged easily.

   e. The structural members constructed out of this cement can be loaded earlier.

   f. This cement requires short period of curing.

   g. It allows higher permissible stresses in the design.

3. *Low heat cement:* It is a type of Portland cement which sets and hardens with the evolution of very low heat of hydration. It contains low percentage of tricalcium aluminate, of about 5 per cent, and higher percentage of dicalcium silicate, of about 45 per cent. This is the ideal cement for construction of dams as it reduces the development of cracks in the structure.

   Heat of hydration is the heat produced during the chemical action between cement and water. In mass concreting like construction of dams, this heat produced will be high and will affect the stability of the structure. So, there is a necessity to control the amount of heat produced and it is in these situations that the use of this type of cement comes into play.

4. *Quick setting cement:* It is produced by adding a small percentage of aluminium sulphate and by finely grinding the cement. It contains very little or no retarding substances like gypsum. The setting action of the cement starts within 5 minutes after addition of water and it becomes hard in less than 30 minutes. The mixing and placing of concrete should be done in a very short time. This type of cement can be used for construction under water.

5. *High alumina cement:* It is obtained by adding bauxite (Al_2O_3) of about 55 per cent and lime (CaO) of about 35–45 per cent. The advantages are:

   a. It is highly resistant to attack by sea water.

   b. It rapidly hardens.

   c. It does not expand while setting.

   d. It can stand very high temperatures.

   e. It resists the action of frost.

Copyrighted material

www.EngineeringBooksPdf.com

The disadvantages are:

a. It cannot be used for massive concrete work.

b. It is much costlier.

c. Extreme care should be taken to see that it does not come in contact with ordinary cement or lime as it reduces the strength.

6. *Coloured cement:* This cement will produce a surface of desired colour and is manufactured by the addition of a small proportion of some colouring material, generally a mineral pigment to the clinker. The amount of colouring material may vary from 5 to 10 per cent. Chromium oxide gives green colour and cobalt imparts blue colour. Iron oxides in different proportions give brown, red and yellow colour and manganese dioxide produces black and brown colour.

7. *Expanding cement:* This cement is used to neutralize the effect of shrinkage of ordinary concrete. It is produced by adding an expanding medium like sulpho-aluminate and a stabilizing agent to the ordinary cement. It is used for the construction of water-retaining structures and also for repairing damaged concrete surfaces.

8. *Hydrophobic cement:* It contains admixtures which decrease the wetting ability of cement. The admixtures usually used are acidol, naphtenesoap, etc. These substances form a thin film around the cement grains. When water is added to this cement, the absorption films are torn off the surface and they do not in any way prevent the normal hardening of cement. However, in the initial stage the gain of strength is less as the hydrophobic films of cement grains prevent the interaction with water.

9. *Air entraining cement:* Air content of 2–6 per cent is introduced in the cement by grinding air entraining agents with the cement clinker during the manufacture of cement. The addition of air entraining agents introduces large amount of air which results in the formation of voids and increases the workability of concrete. The weight as well as the strength of the concrete is reduced.

10. *White cement:* White cement is manufactured from china clay and white chalk in place of limestone and clay. It is used as a decorative feature for high-quality plasterwork. The white colouring effect is due to the absence of iron oxide. The cement is about four times costlier than Ordinary Portland Cement. It has quick drying properties, high strength and superior aesthetic values. It is used in swimming pools where it replaces the use of glazed tiles with coloured shades, for moulding sculptures and statues, for painting garden furniture and for fixing marbles and glazed tiles.

11. *Blast furnace slag cement:* The iron and steel industry produces large quantities of blast furnace slag as a by-product. The slag is a waste product in the manufacturing of pig iron and it contains the basic elements of cement, namely alumina, lime and silica. The clinkers of cement are ground with 60–65 per cent of the slag. This cement has a slow rate of hardening and less heat of hydration. It is not affected by sea water and, hence, is used for marine structures. Its strength in the early days is less and, hence, requires longer curing period.

4.6 DIFFERENT GRADES OF CEMENT

Prior to 1987, there was only one grade of Ordinary Portland Cement which was governed by IS 269-1976. After 1987 higher-grade cements were introduced to India. The Ordinary Portland Cement was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. If the 28-day strength is not less than 33 N/mm^2, it is called 33 grade cement. If the 28-day strength is not less than 43 N/mm^2, it is called 43 grade cement. If the 28-day strength is not less

Copyrighted material

www.EngineeringBooksPdf.com

than 53 N/mm², it is called 53 grade cement. But the actual strength obtained by the cement at the factory is much higher than the BIS specification. Table 4.3 shows compressive strength of different grades of cement.

Table 4.3 Compressive Strength of Different Grades of Cement

		Compressive strength			
Sl. No.	**Type of cement**	**1 day min. MPa**	**3 days min. MPa**	**7 days min. MPa**	**28 days min. MPa**
1	33 grade OPC (IS 269-1989)	N.S.	16	22	33
2	43 grade OPC (IS 269-1989)	N.S.	23	33	43
3	53 grade OPC (IS 269-1989)	N.S.	27	37	53

N.S. – Not specified

The compressive strength of Ordinary Portland Cement increases with time. For example, 33 grade OPC (IS 269-1989) acquires a compressive strength of 16 N/mm² at 3 days, 22 N/mm² at 7 days and 33 N/mm² at 28 days.

4.7 STORAGE OF CEMENT

Cement absorbs moisture from nature and gets hardened. So suitable precautions should be taken in storing cement.

An absorption of 5 per cent moisture means the cement becoming useless and so the cement is to be stored in a moisture-free atmosphere. It is advisable not to store cement in jute bags for a period of more than 3 months. The cement bags should be stored in piles of one above the other, at a minimum distance of 300 mm from the exterior walls. Between the piles, a passage of 900 mm width should be kept. The top and bottom of the piles should be covered and waterproofed for long storage.

Storage for longer periods makes the cement weaker, even under favourable conditions.

REVIEW QUESTIONS

1. What are the properties of cement?
2. Briefly discuss the ingredients of cement.
3. What is the setting time of cement and what are the factors affecting it?
4. How is the setting time of cement determined? Explain briefly.
5. What is the difference between initial and final setting time of cement?
6. How is cement manufactured in the wet process?
7. Draw a schematic diagram showing the different processes involved in the manufacture of cement.
8. What are the different types of cement?
9. Write short notes on
   a. Low heat cement
   b. Quick setting cement
   c. Rapid hardening cement
10. What are the different grades of cement and how is it stored?

Copyrighted material

www.EngineeringBooksPdf.com

Bricks

Manufacture of bricks is mostly a village industry. Bricks have been produced since the dawn of civilization in the sun dried form. The Great Wall of China was made of both burnt and sun dried bricks. Bricks have been used all over the world in every class and kind of building. In places where plenty of clay is available, brickwork is cheaper. The cost of construction work is less with bricks. Bricks resist fire and, hence, they do not easily disintegrate. The atmospheric effects are resisted by bricks of good quality.

5.1 COMPOSITION OF GOOD BRICK EARTH

The constituents of good brick earth are:

1. *Alumina:* A good brick earth should contain 20–30 per cent of alumina. It imparts the property of plasticity to the earth. An excess of alumina causes shrinkage and warping of bricks during drying and burning and it becomes too hard when burnt.
2. *Silica:* Silica forms 50–60 per cent of good brick earth. It is seen either in the free or combined state. In the free state, it is mechanically mixed with clay and in the combined form it exists in a chemical composition with alumina. The cracking, shrinking and warping of raw bricks are being prevented by the presence of silica. The durability of bricks depends upon the proportion of silica. An excess of silica destroys the cohesion between particles and the bricks become brittle.
3. *Lime:* A good brick earth should contain lime not exceeding 5 per cent. It should be present in a very finely powdered state in order to prevent the flaking of bricks. Lime prevents the shrinkage of bricks. An excess of lime causes the bricks to melt and, hence, to lose its shape.
4. *Oxides of iron:* A small quantity of the oxide of iron to the extent of 5-6 per cent is desirable in good brick earth. It imparts red colour to the bricks. But excess of lime makes the colour dark blue or blackish. On the other hand, if the quantity of lime is less, the bricks will be yellowish in colour. It also helps to fuse sand and, thereby, increases the hardness of bricks.
5. *Magnesia:* Presence of magnesia in small quantity imparts a yellowish tint to the bricks and decreases the shrinkage. But if in excess, it causes the decay of bricks.

The ingredients which are undesirable in the brick earth include excess of lime, the presence of iron pyrites, pebbles, alkalies, vegetation and organic matter.

5.2 MANUFACTURE OF BRICKS

The manufacture of bricks is carried out in a number of stages. It includes the following:

1. Selection and preparation of clay
2. Shaping and moulding of units

Copyrighted material

www.EngineeringBooksPdf.com

3. Drying
4. Burning

5.2.1 Selection and preparation of clay

As a practise, suitable deposits of clay are first located and thoroughly tested for the quality for brick making. Clay for bricks is prepared in the following order.

a. *Unsoiling:* The top layer of the soil is taken out. This is because the clay in the top layer is full of impurities and, hence, it is to be rejected for the purpose of preparing bricks.

b. *Digging:* The clay which is dug out is spread on a level ground, just little deeper than the general ground level. The height of the heap of clay is about 60–120 cm.

c. *Cleaning:* The clay should be made free from stones, pebbles and vegetable matter. If these particles are in excess, the clay is to be washed and screened, which is considered to be uneconomical.

d. *Weathering:* The softening of clay is done by exposing it to the atmosphere. The period of exposure varies from weeks to full seasons.

e. *Blending:* The clay is made loose and any ingredient to be added is spread out at its top. Blending indicates intimate mixing. A small portion of clay is taken every time for mixing.

f. *Tempering:* In this stage, the clay is brought to a proper degree of hardness and it is made fit for moulding. Water in the required quantity is added and the whole mass is mixed so as to form a mass of uniform character. A large-scale tempering is usually done in a pug mill. The process of grinding clay with water and making it plastic is known as pugging.

A pug mill consists of a conical iron tub with a cover at the top. It is fixed on a timber base which is made by fixing two wooden planks at right angles. The diameter of the pug mill at the bottom is about 80 cm and at the top is about 1 m. A vertical shaft with horizontal arms is provided at the centre of the iron tub. The small wedge-shaped knives of steel are fixed on the horizontal arms. Openings are provided at the top and bottom for charging clay and water and removing the mix respectively. The height of the pug mill is about 2 m.

5.2.2 Moulding

Moulding is the process of making rectangular-shaped brick units from properly tempered clay. The two types of moulding are

a. Hand moulding
b. Machine moulding.

5.2.2.1 *Hand moulding*

This is presently the most common method for brick manufacture. This is adopted where manpower is cheap and readily available. The moulds used for hand moulding are rectangular boxes made from well-seasoned wood or steel open at the top and bottom. Hand moulding is of two types:

i. Ground moulding
ii. Table moulding

Copyrighted material

www.EngineeringBooksPdf.com

Ground moulding

In this method, the ground is first levelled and fine sand is sprinkled over it. The mould is dipped in water and placed over the ground. The clay is pressed in the mould in such a way that it fills all the corners of the mould. Any surplus earth from the top of the mould is removed using a cutting wire or a metal with a sharp edge, which has to be dipped in water every time it is used. The mould is then lifted up and the brick is left on the ground. The mould is dipped in water and placed close by and another brick is moulded in the same way. If the mould is dipped in water every time, such preparation of bricks is known as slope moulded bricks. If fine sand or ash is sprinkled on the inside surface of the mould instead of dipping the mould in water, such bricks are called sand moulded bricks.

In pallet moulding, bricks of higher quality and with frogs are produced. The frogs are made using a pair of pallet boards and a wooden block. A frog is a mark of depth about 10–20 mm made on raw bricks during moulding. The frog is provided for mainly two purposes:

i. It serves as a key of mortar when other bricks are placed over it.
ii. It indicates the trade name of the manufacturer.

Table moulding

The process of moulding operations are carried out on a specially designed moulding table. The clay, the mould, water pots, stock board, etc. are placed on this table. The bricks are moulded similar to the ground moulding on the table. The cost of brick moulding increases when table moulding is adopted.

5.2.2.2 Machine moulding

The moulding can also be achieved by using machines. It is quite economical when bricks are produced in huge amounts. The machine moulding is broadly classified into two categories:

i. Plastic clay machines
ii. Dry clay machines

Plastic clay machines

The machines contain rectangular openings of size equal to the length and width of a brick. The pugged clay is placed in the machine and as it comes out through the openings it is cut into strips by wires fixed in frames. Hence, it is known as wire cut bricks.

Dry clay machines

In this machine, the strong clay is first converted to powder form. A small quantity of water is added to the stiff plastic paste. Such paste is placed in the mould and pressed by machines to form well-shaped hard bricks. These bricks are known as pressed bricks.

The machine moulded bricks have regular shape, sharp edges and corners; they are heavier and stronger than hand moulded bricks.

5.2.3 Drying

The drying of bricks is necessary, firstly to make them strong enough for rough handling during subsequent stages and secondly to save fuel during burning. For drying the bricks are laid longitudinally in stocks of bricks with width equal to two bricks. Drying of bricks is achieved by either natural or artificial methods.

Copyrighted material

www.EngineeringBooksPdf.com

The important facts to be remembered while drying of bricks are as follows:

a. The bricks are generally dried by natural process. But when bricks are to be rapidly dried, artificial drying may be adopted. In artificial drying, bricks are made to pass through driers in the form of tunnels or hot channels or floors. The tunnel driers are more economical than hot floor driers.

b. The brick in stocks should be arranged in such a way that sufficient air space is left between them for circulation of air.

c. Special drying yards should be prepared and accumulation of rainwater should be prevented.

d. The period of drying depends upon the prevailing weather conditions.

5.2.4 Burning

Burning of dried bricks is essential to develop the desired engineering properties, like hardness, durability and resistance to decay. Three chemical changes are known to take place in the brick earth during burning, namely dehydration, oxidation and vitrification.

Dehydration is completed within 425–750°C temperature range and it results in expulsion of most of the water from the bricks.

During oxidation, carbon and sulphur are eliminated as oxides, whereas the fluxes are also oxidized. Oxidation starts at the range of dehydration temperatures and is completed at about 900°C.

Vitrification is the extreme reaction and occurs when heating is carried out beyond 900°C. This is commonly not required in building bricks although in other clay products like sewer pipes it is necessary.

Burning of bricks is either done in clamps or kilns. Clamps are temporary structures while kilns are permanent structures. Clamps are adopted to manufacture bricks on a small scale while kilns are adopted to manufacture bricks on a large scale.

5.2.4.1 *Clamps*

The shape of the clamp is generally trapezoidal. The brick wall is constructed on the short end and a layer of fuel is placed on the prepared floor. The fuels generally used are cow dung, litter, husk of rice, wood, coal, etc. The thickness of fuel layer varies from 70 to 80 cm. The layer consisting of 4 or 5 courses of raw brick is then put up. Sufficient space for circulation of air is provided. Alternate layers of fuel and bricks are placed over this. The total height of the clamp is around 3-4 m. When nearly one-third of the height is reached, the lower portion of the clamp is ignited so as to burn the bricks in the lower part when the construction of bricks in the upper part is in progress. After construction is complete, it is completely plastered with mud in order to prevent the escape of heat. The clamp is allowed to burn for 1 or 2 months and cooling is also done for 2 months and later the burnt bricks are taken out.

5.2.4.2 *Kilns*

The kilns used for the manufacture of bricks are of two types:

i. Intermittent kilns

ii. Continuous kilns

Intermittent kilns

These kilns may be underground or overground in model. They are classified in two ways:

Copyrighted material

www.EngineeringBooksPdf.com

Intermittent up-draught kilns These kilns are in the form of rectangular structures with thick outside walls. Doors are provided at each end for loading and unloading of kilns. The flues are channels or passages which are provided to carry flames or hot gases through the body of the kiln. A roof is provided to protect the raw bricks from rain.

The quality of the bricks is not uniform; the bricks at the bottom are overburnt and at the top are underburnt. The supply of bricks is not continuous and there is a considerable wastage of fuel in the kiln.

Intermittent down-draught kilns These kilns are rectangular or circular in shape. They are provided with permanent walls and a closed tight roof. The floor of the kiln has openings which are connected to a common chimney stacked through flues. They are so arranged that in this kiln the hot gases are carried through the vertical flues upto the level of roof and then released. As a result the bricks are evenly burnt and the performance is much better than intermittent up-draught kilns. Here, there is close control of heat and the bricks obtained are evenly burnt.

Continuous kilns

These kilns are continuous in operation where loading, firing, cooling and unloading are simultaneously carried out.

Bull's trench kiln This is one of the continuous type kilns. These kilns are rectangular, circular or oval shaped in plan. These kilns are constructed in a trench excavated on the ground. It may be fully underground or partially projecting above the ground. The outer and inner walls are to be constructed in bricks. Openings are provided on the outer walls to act as flue holes. Iron plates are used to divide the kiln into suitable sections. The fuel is placed in flues and is ignited after covering the top surface with earth to prevent the escape of heat. Usually, two movable iron chimneys are employed to form draught. The chimneys are placed in advance of the firing sections so that the warm gases leaving the chimney warm up the bricks in the next section. As the section has burnt, the flue holes are closed and allowed to cool down. Later the fire is advanced to the next section.

Hoffmann kiln This kiln is constructed under ground, is circular in plan and consists of a number of chambers. A permanent roof is provided so that the kiln can function even in the rainy season. The chamber in Hoffmann's kiln is provided with a main door for loading and unloading bricks. Communicating doors should act as flues in the open condition. A radial flue connected with a central chimney and fuel holes are also provided. The advantages are that the bricks are uniformly, equally and evenly burnt and that there is no air pollution in the locality. Also, there is saving in fuel and a high percentage of good bricks are produced.

Tunnel kiln This type of kiln is in the form of a tunnel, which is oval, circular or straight in plan. It contains a stationary source of fire. The raw bricks are placed in trolleys which are then moved from one end to another end of the tunnel. The raw bricks get dried and preheated as they approach the zone of fire and in the zone of fire the bricks are burnt and pushed forward for cooling. Later, after cooling, they are unloaded.

Table 5.1 shows the comparison between clamp and kiln burning.

Copyrighted material

www.EngineeringBooksPdf.com

Table 5.1 Comparison Between Clamp and Kiln Burning

Number	Item	Clamp burning	Kiln burning
1.	Structure	Temporary	Permanent
2.	Initial cost	Very low as no structures are to be built	Very high as permanent structures are to be built
3.	Cost of fuel	Low as grass, cow dung etc. is being used	High as coal dust is being used
4.	Quality of bricks	Percentage of good bricks is less, around 60%	Percentage of good bricks is more, around 90%
5.	Supervision	Not necessary throughout the process	Skilled supervision required
6.	Wastage of heat	More	Less
7.	Capacity	About 20,000–1,00,000 bricks at a time	25,000 bricks per day
8.	Suitability	For small scale	For large scale
9.	Time for burning and cooling	2–6 months	24 hours for burning and 12 days for cooling

5.3 SIZE AND WEIGHT OF BRICKS

Bricks are prepared in various sizes. If the bricks are too large, it is difficult to burn them and handle them. But, on the other hand, if the bricks are small, more quantity of mortar is required while placing.

In India, the standard size recommended by the Bureau of Indian Standards (BIS) is 19 cm × 9 cm × 9 cm and the size of brick including the mortar thickness is 20 cm × 10 cm × 10 cm, which is known as the nominal size of the brick.

The test carried out for inspecting the size is that 20 bricks of standard size (19 cm × 9 cm × 9 cm) are stacked length wise, along the width and along the height. For good quality bricks the results should be within the following permissible limits:

Length: 368–392 cm

Width: 174–186 cm

Height: 174–186 cm

The weight of 1 m^3 of brick earth is 18 kN. Hence, the average weight of a brick will be around 30–35 N.

5.4 QUALITIES OF A GOOD BRICK

A good brick should possess the following properties:

1. The brick should be uniform in shape and should be of standard size.
2. The brick when broken should show a uniform compact and homogeneous structure free from voids.
3. The brick should not absorb water more than 20 per cent for first-class bricks and 22 per cent for second-class bricks when soaked in cold water for a period of 24 hours.
4. The brick should be hard enough. No impression should be left when scratched.

Copyrighted material

www.EngineeringBooksPdf.com

5. The brick should not break into pieces when dropped from a height of 1 m.
6. The brick when soaked in water for 24 hours should not show deposits of white salts when allowed to dry in shade.
7. The brick should have low thermal conductivity and should be sound proof.
8. The crushing strength of brick should not be below 5.5 N/mm^2.
9. The brick should be table moulded, well burnt and free from cracks with sharp and square edges.
10. The colour should be uniform and bright.
11. The bricks should give a good metallic sound when struck with each other.

Concrete blocks, hollow blocks and bricks made of various materials like fly ash are being used successfully as substitutes.

5.5 FALG BRICKS

The rapid increase in the capacity of thermal power generation in India has resulted in the production of a huge quantity of fly ash, which is approximately 50 million tons per year. The prevailing disposal methods are not free from environmental pollution and ecological imbalance. Large stretches of scarce land, which can be used for shelter, agriculture or some other productive purposes, are being wasted for disposal of fly ash. Fly ash, lime and gypsum (FALG) can be used to make bricks and hollow blocks of adequate strength, an economical alternative to conventional burnt clay bricks will be available. Lime and gypsum are either available from mineral sources or can be procured from industrial wastes.

Fly ash bricks are made of fly ash, lime, gypsum and sand. Fly ash, lime sand and gypsum are manually fed into a pan mixer where water is added in the required proportion for intimate mixing. The proportion of the raw material is generally in the ratio of 60–80 per cent of fly ash, 10–20 per cent lime, 10 per cent Gypsum and 10 per cent sand, depending upon the quality of raw materials. The mixture is slow-setting pozzalona cement mix. After mixing, the mixture is shifted to the hydraulic/mechanical presses. A specially designed machine which gives a very high pressure load at slow rate (in the order of 280–350 kg/inch) is used to mould the bricks. Holding the pressure at specific times gives more strength to the finished product. The moulded bricks are then transferred to hydraulic-operated wooden pellets manually and stored in covered space for 3 days (minimum) for setting.

Then the bricks are taken to the yard for water curing for 15–20 days. Then it is sorted and tested before despatch. These can be extensively used in all building constructional activities similar to that of common burnt clay bricks. The fly ash bricks are comparatively lighter in weight and stronger than common clay bricks. Fly ash bricks are used in multi-storeyed apartment houses for non-load bearing purposes and in making curtain and partition walls of these houses. Use of fly ash bricks in this type of construction is meant mainly to achieve economy and make profits. The domestic buildings of low- or middle-income groups mostly have single or two-storied dwelling units. Therefore the cost effectiveness along with the strength and durability of fly ash bricks are very important for them.

5.6 FLY ASH BRICKS

Fly ash is one of the residues generated in the combustion of coal. It is generally captured from the chimneys of coal-fired power plants and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being

Copyrighted material

www.EngineeringBooksPdf.com

burnt, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO).

Fly ash has been used for over 50 years to make concrete building blocks. They are widely used for the inner skin of cavity walls. They are naturally more thermally insulating than blocks made with other aggregates.

Fly ash bricks have been used in house construction since the 1970s. There is, however, a problem with the bricks in that they tend to fail. This happens when the bricks come into contact with moisture and a chemical reaction occurs causing the bricks to expand.

REVIEW QUESTIONS

1. What are the constituents of good bricks?
2. What are the different stages involved in the manufacture of bricks?
3. Write short notes on
   a. Moulding of bricks
   b. Drying of bricks
   c. Different types of kilns used for the manufacture of bricks
   d. Size of bricks
   e. Fly ash bricks
4. What are the qualities of a good brick?
5. Briefly discuss FALG bricks.

Copyrighted material

www.EngineeringBooksPdf.com

chapter 6

Tiles

Tiles can be defined as thin slabs or bricks, which are burnt in kilns. The tiles are thinner than bricks. Tiles are classified into two types: common tiles, which are available in different shapes and sizes and used for paving, flooring and roofing, and encaustic tiles, which are used for decorative purposes in floors, walls, ceilings and roofs.

6.1 DIFFERENT TYPES OF TILES

The different types of tiles are

1. Drain tiles
2. Flooring tiles
3. Roofing tiles

6.1.1 Drain tiles

Drain tiles are prepared in such a way that they retain their porous texture after burning. Hence, they are suitable to be laid in waterlogged areas. They allow water to pass. They are also used to convey irrigation water. These drains may be circular, semicircular or segmental.

6.1.2 Flooring tiles

The flooring tiles should be hard enough to resist wear and tear. They are thin tiles of thickness 12–50 mm and can also be adopted for ceilings. Colouring substances can be added to the clay during preparation to impart colour to floor tiles. Low-strength floor tiles can be used for fixing on the surface of walls. They are easier to lay as they are small in size and much lighter than mosaic and marbles. They do not require polishing. They are scratch, stain and damp proof in nature.

6.1.2.1 Wood tiles

Wood flooring requires a protective coating such as varnish or wax. This type is suitable for gymnasium, skating rinks and air-conditioned rooms.

6.1.2.2 Cork tiles

Different colours and designs are available. These are warm, quiet and resilient but not durable.

6.1.2.3 Cement concrete tiles

Plain concrete tiles, plain coloured tiles and terrazo tiles are the three different types of tiles coming in this category. These are easy to clean and shine well if the quality is good. Their cost is comparatively reasonable.

Copyrighted material

www.EngineeringBooksPdf.com

6.1.2.4 Magnesium flooring tiles

This flooring is used as a substitute for asphalt flooring.

6.1.2.5 Ceramic tiles

These are non-slippery and used in wet areas like bathrooms, kitchens, etc. They are available in a wide range of colours and textures. They are used in living rooms also.

6.1.3 Roofing tiles

They act as a covering to the roof. The important varieties of roofing tiles are as follows.

6.1.3.1 Allahabad tiles

They are tiles made from clay. The moulding is done under pressure in machines. Interlocking facility is attained by the projection provided in the tiles. These tiles can also be adopted for the hip, ridge and valley portions of the roof.

6.1.3.2 Corrugated tiles

Corrugations are provided for the side lap when they are placed in position. These tiles give a pleasing appearance. The placing of tiles gives an appearance of corrugated iron sheets.

6.1.3.3 Mangalore tiles

These tiles are provided with suitable projections so that they interlock with each other. These tiles are of flat pattern but special Mangalore pattern tiles are available for the hip, valley and ridge portions. The life of these tiles is estimated as about 25 years. These are red in colour and it is found that 15 Mangalore tiles are required for covering 1 m^2 of roof area.

These are the most commonly used roofing tiles in Kerala. The length of the tiles varies from 32 to 35 cm and width from 21 to 23 cm. Maximum water absorption percentage is 20 and minimum average breaking load is 1.00 kN. More than 40 per cent of the tiles get broken due to wrapping. The number of breakages can be reduced by adding a small amount of aluminium chloride to the clay.

6.1.3.4 Guna tiles

They are hollow, tapered, burnt tiles. They are conical in shape with a base of 100 mm diameter at the broader end and 75 mm at the narrower end. These may be made of suitable shapes, like parabolic, elliptical, etc.

6.1.3.5 Pan tiles

They are short and heavy. They are first moulded as flat sections and later given the required curvature by moulding in suitable forms. These tiles have a length between 30 and 40 cm and width between 20 and 30 cm.

6.1.4 Encaustic tiles

They are manufactured from ordinary clays with colouring materials and finer clays. The encaustic tiles consist of three layers: body which is made of coarser clay, face which comprises of 6 mm coat of finer clay and colouring material and back which is a thin coat of clay to prevent the tile from warping.

Copyrighted material

www.EngineeringBooksPdf.com

6.2 CHARACTERISTICS OF A GOOD TILE

1. It should possess uniform colour.
2. It should give an even and compact structure when seen on its broken surface.
3. It should be sound, hard and durable.
4. It should be regular in shape and size.
5. It should fit in properly when placed in the proper position.
6. It should be free from cracks, bends and warps.

6.3 PORCELAIN GLAZED TILES

The purpose for which glazing is done are:

1. To improve the appearance.
2. To produce decorative effects.
3. To provide smooth surfacing.
4. To protect the surface from the action of atmospheric agencies.
5. To make the particles durable.

The term porcelain is used to indicate fine earthenware which is white, thin and transparent. Clay of sufficient purity and possessing high degree of tenacity and plasticity is used for preparing porcelain. It is hard, brittle and non-porous. It is prepared from clay, feldspar, quartz and minerals. Porcelains are of two types – low-voltage porcelain and high-voltage porcelain. Low-voltage porcelain is prepared from dry process and high-voltage porcelain is prepared from wet process.

Porcelain enamelling is a common process for making the surface smoother, chemical proof and resistant to deterioration. The process involves fusing thoroughly the mixture of raw materials in a furnace and then grinding the mixture to a fine powdered stage. The material to be enamelled is then given a coating of this powder either directly by dusting the powder over the surface or by mixing the mixture with water and spraying on the surface. They are adopted for various uses like sanitaryware, electrical insulators, storage vessels, etc.

REVIEW QUESTIONS

1. Write short notes on
   a. Different types of tiles used for building construction
   b. Flooring tiles
   c. Mangalore pattern roofing tiles
2. What are the different types of tiles used for building construction?
3. What are the characteristics of a good tile?
4. What are the purposes of glazing of tiles?
5. How is glazing done for the tiles?
6. What is porcelain enamelling?

Copyrighted material

www.EngineeringBooksPdf.com

chapter 7

Timber

Timber denotes wood which is suitable for building or carpentry and for various engineering and other purposes. The word timber is derived from an old English word 'timbrian' which means to build. Timber or wood as a building material possesses a number of valuable properties, such as low heat conductivity, amenability to mechanical working, low bulk density and relatively high strength.

Timber has been a very important structural member from time immemorial. It has been extensively used as beams, columns and plates in construction in a variety of situations, such as foundation, flooring, stairs and roofing. Even today its use as a building material is quite popular, though it has to face tough competition from structural steel and reinforced concrete.

7.1 CLASSIFICATIONS OF TREES

Trees are classified into two types, namely,

1. Endogenous
2. Exogenous

7.1.1 Endogenous

In the endogenous trees, a plant grows by the addition of new cells only at the tip or end, i.e., the trees grow inwards and fibrous mass is seen in their longitudinal section. Such trees show very little branches. The timber from these trees has very limited engineering applications. The examples of endogenous trees are bamboo, cane, palm, etc.

7.1.2 Exogenous

These trees increase in bulk by growing outwards and distinct consecutive rings are formed in the horizontal section of such trees. These rings are known as annual rings, because one such ring is added every year. Such trees grow bigger in diameter as well. The timber, which is mostly used for engineering purposes, belongs to this category.

The exogenous trees are further classified as

a. Conifers
b. Deciduous

Conifers: The conifers are known as evergreen trees. These trees bear cone-shaped fruits. These trees yield soft woods, which are generally light in colour, resinous, light in weight and weak.

Deciduous: They are also known as broad leaf trees. The leaves of these trees fall in autumn and new ones appear in spring. Timber for engineering work is mostly derived from deciduous trees.

Copyrighted material

www.EngineeringBooksPdf.com

Trees can also be classified based on hardness into the following categories.

a. Hard wood

b. Soft wood

The soft wood forms a group of evergreen trees while the hard wood forms a group of broad leaf trees. Examples of soft woods are deodar, pine and other conifers. Hard woods include sal, mahogany, teak, oak, etc.

7.2 STRUCTURE OF A TREE

From the visibility aspect, the structure can be divided into two categories:

1. Macrostructure
2. Microstructure

7.2.1 Macrostructure

The structure of wood visible to the eye or at a small magnification is called a macrostructure. The following are the different components (Figure 7.1).

a. Pith: The pith or medulla is the innermost part, seen only in old and immature trees. Wood of this zone is of black, brown or grey appearance. It is normally found in the first year of growth of the tree.

b. Heartwood: The inner annual rings surrounding the pith constitute the heartwood. It indicates the dead portion of the tree. It does not take active part in the growth of a tree. However, it imparts rigidity to the tree and, hence, forms durable timber for engineering purposes.

c. Sap wood: The sap wood comprises of new and lighter cells that line nearer to the skin of the tree. It indicates recent growth and contains sap. It takes active part in the growth of a tree and the sap moves in an upward direction through it.

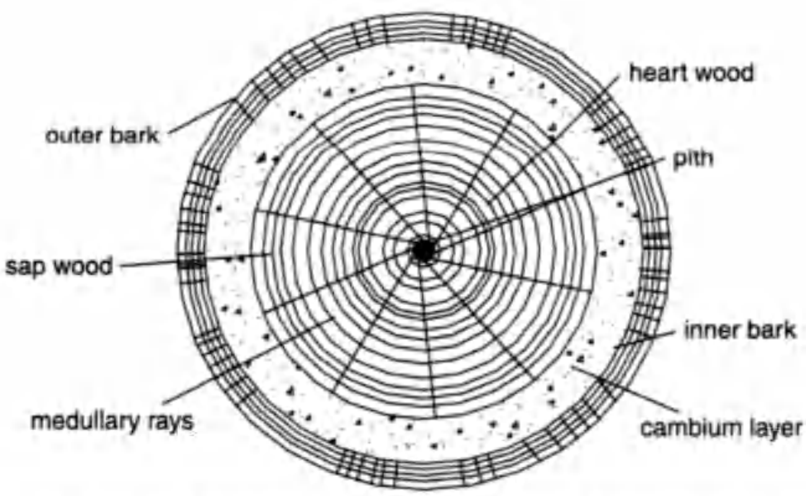


Figure 7.1 Cross section of an exogenous tree

Copyrighted material

www.EngineeringBooksPdf.com

d. Cambium: The thin layer of wood between the sap wood and the inner bark is known as cambium layer. If the bark is removed for any reason, the cambium layer gets exposed and results in the death of the tree.

e. Bark: It is the outermost zone and makes the skin of the tree. The function of the bark is to protect the inner tissue from heat, rain and injury. Sometimes a second thin membrane is also present inside the bark and it is called the inner bark.

f. Medullary rays: The thin radial fibres extending from the pith to the cambium is known as medullary rays. The function of it is to hold together the annual rings of hard wood and sap wood.

7.2.2 Microstructure

The structure of the wood apparent only at great magnification is called microstructure. A living cell consists of four parts, namely membrane, protoplasm, sap and core. The cells according to their function are classified into conductive cells, mechanical and storage cells.

The conductive cells serve mainly to transmit nutrients from the roots to the branches and leaves. The mechanical cells impart strength to the wood and the storage cells serve to store and transmit nutrients to the living cells.

7.3 QUALITIES OF GOOD TIMBER

The following are the qualities of a good timber:

1. *Appearance:* A freshly cut surface of timber should exhibit a hard and shining appearance.
2. *Colour:* The colour of the timber should be preferably dark. A light colour indicates low strength.
3. *Hardness:* A good timber should be hard, i.e., it should offer resistance when it is being penetrated by another body. The chemical present in heartwood and the density of wood imparts hardness to timber.
4. *Durability:* A good timber should be durable. It should be capable of resisting the action of fungi, insects, chemicals, physical agencies and mechanical agencies.
5. *Strength:* A good timber should be strong for working as a structural member such as joist, beams and rafter. It should be capable of taking loads slowly or suddenly.
6. *Structure:* The structure should be uniform and the medullary rays should be hard and compact. The annual rings should be regular and should be closely located.
7. *Mechanical wear:* A good timber should not deteriorate easily due to mechanical wear or abrasion. This property is essential for places where timber would be subjected to traffic, like wooden floors and pavements.
8. *Toughness:* A good timber should be tough. It should be capable of offering resistance to shocks due to vibrations.
9. *Elasticity:* This is the property by which the timber returns to the original shape when load causing deformation is removed. This property is essential when timber is used for bows, carriage shaft, etc.
10. Fire resistance: Timber is a bad conductor of heat. A dense wood offers good resistance to fire and it requires sufficient heat to cause a flame.
11. *Defects:* A good timber should be free from serious defects such as dead knots, flaws and shakes.

Copyrighted material

www.EngineeringBooksPdf.com

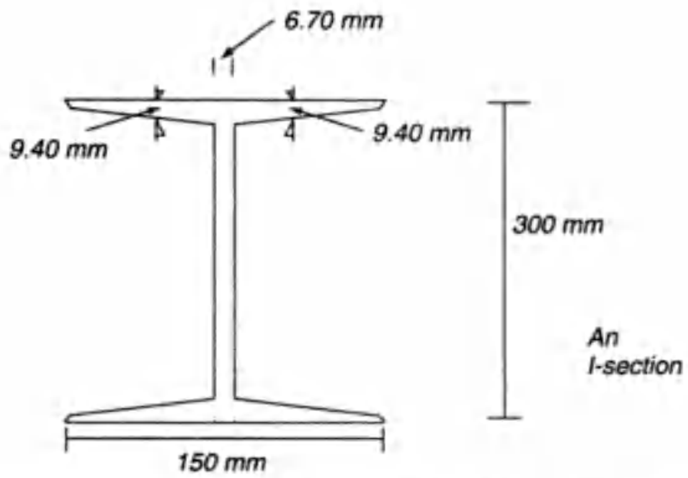


Figure 8.5 An I-section

shows a joist of size 300 mm × 150 mm at 37.70 kg. Wide flange beams are also available in sizes varying from 150 mm × 100 mm at 17.00 kg to 600 mm × 250 mm at 145.10 kg. Beams suitable for columns are available in H-sections which vary in sizes from 150 mm × 150 mm at 27.10 kg to 450 mm × 250 mm at 92.50 kg. The ISI has classified the I-sections into junior beams, light beams, medium beams, wide flange beams and heavy beams, and they are accordingly designated as ISJB, ISLB, ISMB, ISWB and ISHB respectively.

8.3.7 Plates

The plate sections of steel are available in different sizes with thickness varying from 5 to 50 mm. The corresponding weights per square metre are 39.20 kg and 392.50 kg, respectively. They are used mainly for the following purposes in structural steel work.

a. To connect steel beams for extension of the length.

b. To serve as tension members of steel roof truss.

c. To form built-up sections of steel.

8.3.8 Ribbed-torsteel bars

These bars are produced from ribbed-torsteel which is a deformed high-strength steel. These bars have ribs or projections on their surface and they are produced by controlled cold twisting or hot-rolled bars. Each bar is to be twisted individually and it is tested to conform to the standard requirements. Ribbed-torsteel bars are available in sizes varying from 6 to 50 mm diameter, with the corresponding weight per metre length as 0.222 kg and 15.41 kg. These bars are widely used as reinforcement in concrete structures, such as buildings, bridges, docks and harbour structures, roads, irrigation works, pile foundations and pre-cast concrete structures. The following are the advantages of ribbed-torsteel bars (Figure 8.6).

a. It is possible to bend these bars through 180 degrees without formation of any cracks or fractures on their outer surface.

b. It is possible to weld certain types of ribbed-torsteel bars by electric flash butt-welding or arc welding.

c. There is an overall reduction in reinforcement cost to the extent of about 30–40 per cent when these bars are used.

Copyrighted material

www.EngineeringBooksPdf.com

d. *Sound Insulation and Fire Resistance:* The insulation against sound and fire should be provided in the case of upper floors as they act as horizontal barriers for the passage of sound and fire in a vertical direction.

12.1.5 Doors and windows

The main function of doors in a building is to serve as a connecting link between internal parts and to allow free movement to the outside of the building. Windows are generally provided for proper ventilation and lighting and their number should be determined according to the requirements.

Doors and windows should satisfy the following requirements:

a. *Weather Resistance:* They should be strong enough to resist the adverse effects of weather.

b. *Sound and Thermal Insulation:* They should be capable of being made air tight to achieve insulation against sound and heat.

c. *Damp Prevention and Termite Prevention:* They should not be affected by white ants and the moisture penetration as this will reduce the strength and durability.

d. *Fire Resistance and Durability:* They should offer fire resistance and should be durable.

e. *Privacy and Security:* They should offer sufficient privacy without inconvenience or trouble and security against theft.

12.1.6 Sills, lintels and weather shades

Window sills are provided between the bottom of the window frame and the wall below to protect the top of the wall from wear and tear. The openings are provided in the wall of a building to accommodate the doors and windows. The actual frame of a door or window is not strong enough to support the weight of the wall above the opening and a separate structural element is, therefore, introduced between the top of the window frame and the wall coming over it. This is known as the ***lintel.*** Weather shades are generally combined with lintels of windows to protect them from the weathering agencies.

12.1.7 Roofs

A roof is the uppermost part of a building whose main function is to enclose the space and to protect the same from the effects of weather elements. A good roof is just as essential as a safe foundation. As a well-designed foundation secures the building against destruction starting at the bottom, similarly a good roof affords protection for the building itself and what the building contains and prevents destruction from the top.

A roof should satisfy the following requirements:

a. *Strength and Stability:* The roof structure should be strong and stable enough to take up the anticipated loads safely.

b. *Weather Resistance:* The roof covering should have adequate resistance to resist the effects of weather elements.

c. *Heat Insulation:* The roof should provide adequate insulation against heat.

d. *Sound Insulation:* The roof should have adequate insulation against sound from external sources.

e. *Fire Resistance:* The roof should offer an adequate degree of fire resistance in order to give protection against the spread of fire from any adjacent buildings and to prevent early collapse of the roof.

Copyrighted material

www.EngineeringBooksPdf.com

The form of construction should also be such that the spread of fire from its source to other parts of the building by way of roof cannot occur.

f. *Day Lighting:* The roof provides daylight in buildings with large floor area.

12.1.8 Steps and stairs

A step usually consists of a tread and riser supported by strings. A stair is a structure consisting of a number of steps leading from one floor to another. Location of stairs in all types of residential and public buildings should be such as to afford the easiest and quickest service possible to the building. The main function of the stairs is firstly to provide a means of communication between the various floors. Secondly, it also acts as an escape from the upper floors in the event of fire.

Steps and stairs should satisfy the following requirements:

a. *Strength and Stability:* The stairs should be designed like floors such that they are strong and stable enough to carry the anticipated loads safely due to the weight of the people using them and also the weight of the furniture or equipment being carried up or down through them.

b. *Fire Resistance:* The stairs should be made of fire-resisting material and should be connected to different floors, such that they provide safe means of escape in the event of fire.

c. *Sound Insulation:* The stairs should have adequate insulation against sound from external sources.

d. *Weather Resistance:* The stairs if exposed to open air should offer sufficient resistance to weather elements such as rain and heat.

e. *Comfort:* The proper design of steps and proper location of stairs in a building offer several advantages such as comfort and efficiency in vertical movement, natural light and ventilation and safety in emergency.

12.1.9 Finishes for walls

Finishes of several types such as pointing, plastering, painting and distempering and decorative colour washing are applied on the walls. The main functions of these finishes are as follows:

a. They protect the structure, particularly the exposed surfaces, from the effects of weather.

b. They provide a true, even and smooth finished surface and also improve the aesthetic appearance of the structure as a whole.

c. They cover up the unsound and porous materials used in the construction.

12.2 PLANNING REGULATIONS

12.2.1 Building line and control line

The 'building line' refers to the line of building frontage, i.e., the line up to which the plinth of the building adjoining the street or an extension of street or on a future street may lawfully extend. This line is often known as set back or front building line and is laid down in each case, parallel to the plot boundaries, by the authority, beyond which nothing can be constructed towards the plot boundaries. Certain buildings, such as factories and business centres that attract large number of vehicles, should further set back a distance apart from the building line. The line that accounts for this extra margin is known as 'control line'(Table 12.2).

Copyrighted material

www.EngineeringBooksPdf.com

Table 12.2 Distances of Building Lines and Control Lines

Type of road	In open and agricultural country		Ribbon development along approaches		Actual limits in urban area	
	Building line (m)	Control line (m)	Building line (m)	Control line (m)	Building line (m)	Control line (m)
National and state highways	30	36	18	30	30	45
Major district roads	24	45	9	15	15	24
Other district roads	15	24	6	9	9	25
Village roads	12	18	6	9	9	15

12.2.2 Built-up area

The built-up area of a plot means the plot area minus the area of open spaces in it (Table 12.3).

12.2.3 Open space requirements

For attaining natural ventilation, open spaces are necessary around the building. As per the Kerala Building Rules 1984, the minimum open space requirements are given as below.

a. For buildings upto 10 m height.
   i. Every building shall have at least front and backyards of a minimum of 3 m.
   ii. A clear open space of not less than 1.5 m shall be there on the sides other than front and rear.

b. For buildings above 10 m and upto 25 m height, there shall be an increase in the minimum open spaces at the rate of 0.5 m per every 3 m exceeding 10 m or fraction of it.

12.2.4 Size of the rooms

The minimum area required for the individual rooms is also specified. For example, the minimum area required for a kitchen is specified as 4.5 m^2. The bathroom is to have a minimum size of 1.5 m × 1.2 m or an area of 1.8 m^2, while a combined bathroom and water closet is to have a minimum floor area of 2.8 m^2, with a minimum width of 1.2 m.

The minimum height of an individual room is specified as (i) 2.75 m for habitable rooms, (ii) 2.2 m for bathrooms and WC and (iii) 2.55 m for kitchens. The specifications for maximum height of buildings are given in Table 12.4.

Table 12.3 Limitation of Built-up Area for Residential Buildings

Area of plot (m^2)	Maximum permissible built-up area
Less than 200	60% with two-storeyed structure
200–500	50% of the site
500–1,000	40% of the site
More than 1,000	33.33% or 1/3rd of the site

Copyrighted material

www.EngineeringBooksPdf.com

c) Residual deposits of shattered and broken bed rock and hard shale, cemented material	9.0	
d) Soft rock	4.5	
2) Non- cohesive soils		
a) Gravelly sand and gravel, compact and offering high resistance to penetration when excavated by tools	4.5	Dry means that the groundwater level is at a depth not less than a width of foundation below the base of the foundation
b) Coarse sand, compact and dry	4.5	
c) Medium sand, compact and dry	2.5	
d) Fine sand, silt (dry lumps easily pulverized by the fingers)	1.5	
e) Loose gravel or sand gravel mixture, loose coarse to medium sand, dry	2.5	
f) Fine sand, loose and dry	1.0	
3) Cohesive soils		
a) Soft shale, hard or stiff clay in deep bed, dry	4.5	This group is susceptible to long-term consolidation settlement
b) Medium clay, readily indented with thumb nail	2.5	
c) Moist clay and sand clay mixture which can be intended with strong thumb pressure	1.5	
d) Soft clay indented with moderate thumb pressure	1.0	
e) Very soft clay which can be penetrated several centimetres with the thumb	0.5	

13.2.2 Methods for improving the bearing capacity of soil

It happens sometimes that the required safe bearing capacity of the soil is not available at shallow depth or it is so low that the dimensions of the footings work out to be very large and uneconomical. Therefore, on such circumstances, depending on the site conditions it becomes necessary to improve the safe bearing capacity.

a. *By increasing the depth of foundation:* In most of the cases, the bearing capacity increases with the depth due to the confining weight of the overlying material. This method is not economical because the cost of construction increases with the depth and the load on the foundation increases with increase in depth. This method should not be used on silts where the subsoil material grows wetter as the depth increases.

b. *By draining the soils:* The presence of water decreases the bearing capacity of the soil. The studies show that around 50 per cent of bearing capacity is lost in sandy soils due to the presence of excess water. Suitable drains should, therefore, be provided in the foundation channel to drain off the excess water.

c. *By compacting the soil:* The compaction of soils results in increase in density and strength and, hence, the bearing capacity. Better compaction is achieved in two ways. (1) By hand packing the rubble boulders or spreading broken stone gravel or sand and thereafter ramming well in the bed of trenches. (2) By driving piles either of wood or concrete or driving and withdrawing the piles and filling the holes with sand and concrete.

d. *By confining the soil:* The movement of soil under the action of load can be prevented by confining the ground by the use of sheet piles. These confined soils can be further compacted for better strength. This method is especially useful for sand soils underlying shallow foundations.

e. *By increasing the width of the foundation:* By increasing the width of the foundation the bearing area increases and, hence, the intensity of pressure decreases. This method has limited use, since the width of the foundation cannot be increased indefinitely.

Copyrighted material

www.EngineeringBooksPdf.com

f. *By replacing the poor soils:* The poor soil is first removed and then the gap is filled by superior materials such as sand, rubble stone, gravel or other hard materials. First the foundation trenches are excavated to a depth of 1.5 m, then filled in stages of 30 cm by hard material and finally rammed.

g. *By grouting:* In poor soil bearing strata, sufficient number of boreholes are driven. Then the cement grout is injected under pressure, because it scales off any cracks or pores or fissures which otherwise reduce the bearing capacity of the soil. This method is employed for materials having pores, fissures or cracks underneath the foundation.

h. *By chemical treatment:* The chemicals like silicates of soda and calcium chloride with soil particles form a gel-like structure and develop into a compact mass. This is called chemical stabilization and is used to impart additional strength to soft soils at deeper depth. However, the chemicals are added in traces only, but even then it has proved to be costly and, hence, is adopted in exceptional cases.

i. *By using geotextiles:* This is a method of reinforcing weak soils to improve their bearing capacity. Coir geotextiles are found to be very useful in this context.

13.3 PLATE LOAD TEST

This is one of the most commonly used methods for determining the allowable bearing capacity of soils.

13.3.1 Working principle

In this test the loading platform, consisting of a bearing plate of steel or cast iron or composite material made of wooden sleepers and steel joist, is subjected to a gradual increment of load and the corresponding settlement values are noted. The load settlement curve is then plotted from which the ultimate bearing capacity is found as based on settlement considerations for cohesive and non-cohesive soils. Finally, by dividing this ultimate bearing capacity by the suitable factor of safety, the allowable bearing capacity of soil is found out.

13.3.2 Test set-up

The test pit should be at least five times as wide as the test plate. The test plate is made to rest in the centre of the pit in a depression which is of the same size as that of the test plate and the bottom level of which shall correspond to the level of the actual foundation. The depth of the hole shall be such that the ratio of depth to the width of loaded area is the same as for the actual foundation. The test plate is 2.5 cm in thickness and the following are their sizes for different soils.

a. Clayey soils, sandy and silty soils – size, 60 cm square

b. Gravelly and dense sandy soils – size, 30 cm square

Larger sizes up to 75 cm square can be used depending upon practical considerations.

The test plate should be machined on the sides and edges. The sides of the pit are lined with wooden sheeting if the soil is soft. The test plate shall be bedded to the soil by plaster of paris, aluminous cement slurry or fine sand. At the start of the test, the platform will be preloaded with a load of 0.7 kg/cm^2 and released.

13.3.3 Testing procedure and observations

The load is applied through a column by means of deadweights such as sand bags or pig iron on lead bars or by a reaction frame which may be a truss frame anchored to the soil by anchors or jacking against a loaded platform with a steel joist placed centrally underneath. The hydraulic jack should butt against the joist with

Copyrighted material

www.EngineeringBooksPdf.com

a ball bearing placed in between. The load is increased in regular increments of 200 kg or one-fifth of the approximate ultimate bearing capacity or until the ultimate load is reached.

The settlements should be recorded at least to an accuracy of 0.02 mm with the help of at least two dial gauges to take care of any differential settlement that may occur. Settlements should be observed for each increment of load after an interval of 1, 4, 10, 20, 40, 60 minutes and thereafter at hourly intervals. In the case of clayey soils, the time-settlement curve should be plotted at each load stage and the load should be increased to the next stage either when the curve indicates that the settlement has exceeded 70–80 per cent of the expected ultimate settlement at that stage or at the end of a 24-hour period. For soils other than clayey soils, each load increment shall be kept for not less than 1 hour and up to the time when no further measurable settlement occurs. The next increment of load shall then be applied and the observation is repeated (Figure 13.1).

13.3.4 Limitations of plate load test

a. *Size effect:* The results of the plate load test reflect the strength and the settlement characteristics of the soil within the pressure bulbs. As the pressure bulb depends on the size of the loaded area, it is much deeper for the actual foundation as compared to that of the plate. The plate load test does not truly represent the actual conditions if the soil is not homogenous and isotropic to a large depth.

b. *Scale effect:* The ultimate bearing capacity of saturated clays is independent of the size of the plate, but for cohesionless soils it increases with the size of the plate. To reduce the scale effect it is desirable to repeat the plate load test with plates of two or three different sizes, extrapolate the bearing capacity for the actual foundation and take the average of the values obtained.

c. *Time effect:* A plate load test is essentially a test of short duration. For clayey soils, it does not give the ultimate settlement. The load settlement curve is not truly representative.

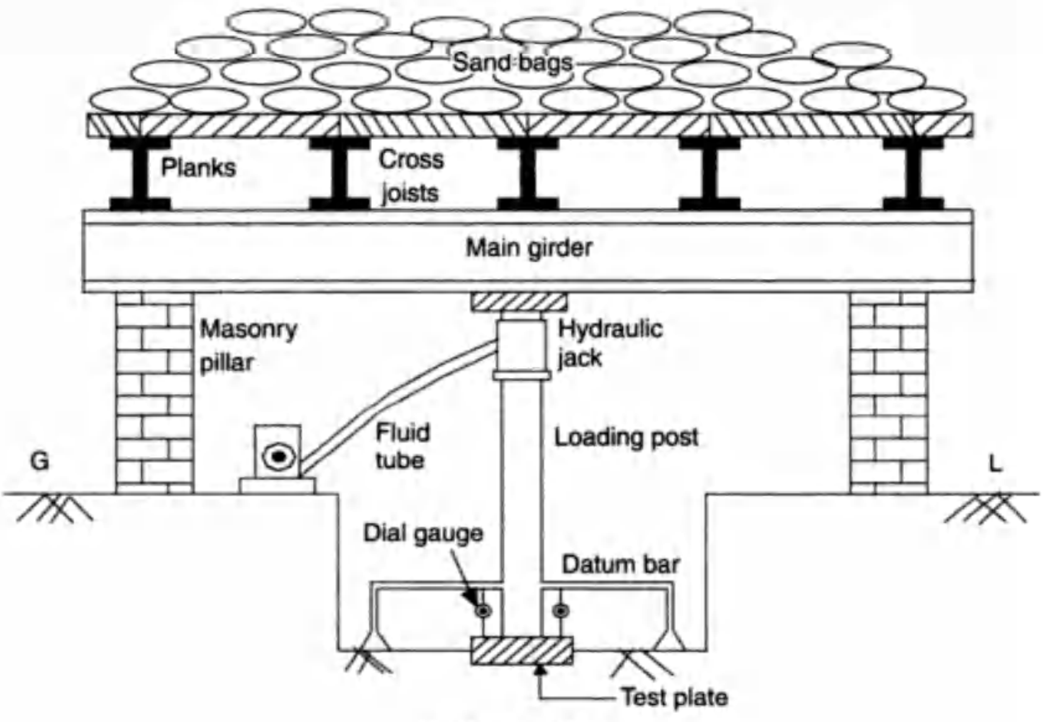


Figure 13.1 Plate load test

Copyrighted material

www.EngineeringBooksPdf.com

d. *Interpretation of failure load:* A failure load is well defined, except in the case of a general shear failure. An error of personal interpretation may be involved in other types of failure.

e. *Reaction load:* It is not practical to provide a reaction of more than 250 KN and, hence, the test on a plate of size larger than 0.6 m width is difficult.

f. *Water table:* The level of water table affects the bearing capacity of the sandy soils. If the water table is above the level of the footing, it has to be lowered by pumping before placing the plate. The test should be performed at the water table level if it is within 1 m below the footing.

13.4 VARIOUS TYPES OF FOUNDATIONS WITH SKETCHES

13.4.1 Spread footing

This is the most common type of foundation and can be laid using open excavation by allowing natural slopes on all sides. This type of foundation is practicable for a depth of about 5 m and is normally convenient above the water table. The base of the structure is enlarged or spread to provide individual support. This type of footing is given for structures of moderate height built on sufficiently firm ground and for light structures. They have only one projection beyond the width of the wall on either side (Figure 13.2).

13.4.2 Stepped footing

Here, we have more than one projection on either side of the width of the wall as shown in Figure 13.3.

The depth of each layer is at least twice the projections and its base width should be twice the width of the layer above that. Generally, the projections provided are kept as 15 cm on either side. The depth is generally limited to 0.9 m in general cases.

13.4.3 Isolated and combined footing

They are used to support individual columns. They can be either of stepped type or have projections in the concrete base. In the case of heavy loaded columns, steel reinforcement is provided in both the directions

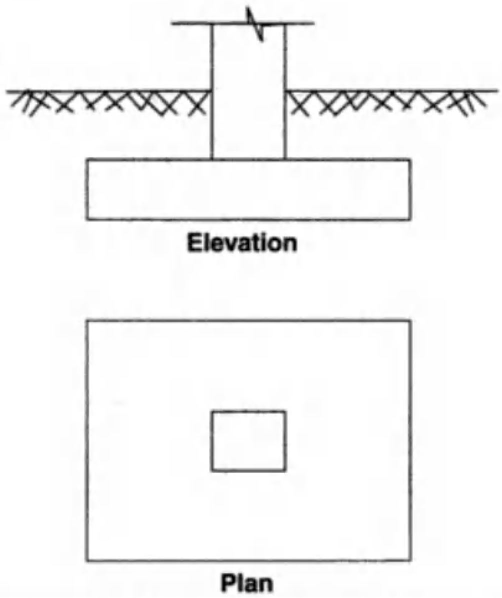


Figure 13.2 Spread footing

Copyrighted material

www.EngineeringBooksPdf.com

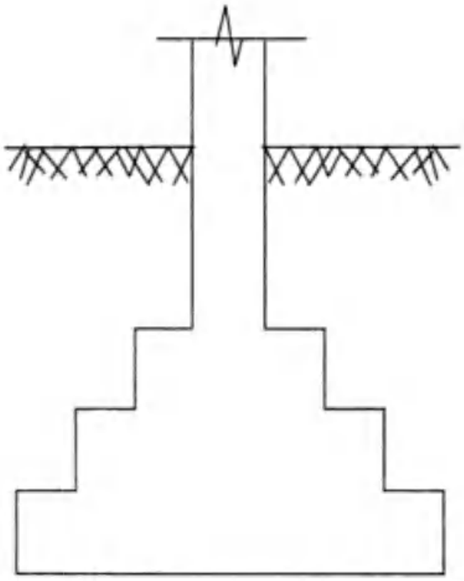


Figure 13.3 Stepped footing

in the concrete bed. Generally, 15 cm offset is provided on all sides of the concrete bed. In the case of brick masonry columns, an offset of 5 cm is provided on all the four sides in regular layers. The footing of concrete columns may be slab, stepped or sloped ones.

A combined footing supports two or more columns in a row. The combined footing can be rectangular if both the columns carry equal loads or can be trapezoidal if there are space limitations and carry unequal loads. Generally, they are constructed of reinforced concrete (Figure 13.4).

13.4.4 Mat or raft foundation

The raft or mat foundation is a combined footing that covers the entire area beneath the structure and supports the columns. If required the beam and slab construction in reinforced cement concrete (RCC) can also be carried out. When the allowable soil pressure is low or the structural loads are heavy, the use of spread footings would cover more than one-half of the area and it may prove more economical to use raft foundation. A raft may undergo large settlements without causing harmful differential settlement. For this reason almost double the settlement of that permitted for footings is acceptable for rafts. Usually, when hard soil is not available within 1.5–2.5 m, a raft foundation is adopted. The raft foundations are useful for public buildings, office buildings, school buildings, residential buildings, etc. (Figure 13.5).

13.4.5 Pile foundation

The pile foundation is a construction for the foundation supported on piles. A pile is an element of construction composed of timber, concrete or steel or a combination of them. Pile foundation may be defined as a column support type of foundation, which may be cast in situ or precast. The piles may be placed separately or they may be placed in the form of a cluster throughout the length of the structure. This type of construction is adopted when the loose soil extends to a great depth. The load of the structure is transmitted by the piles to the hard stratum below or it is resisted by the friction developed on the sides of piles.

Copyrighted material

www.EngineeringBooksPdf.com

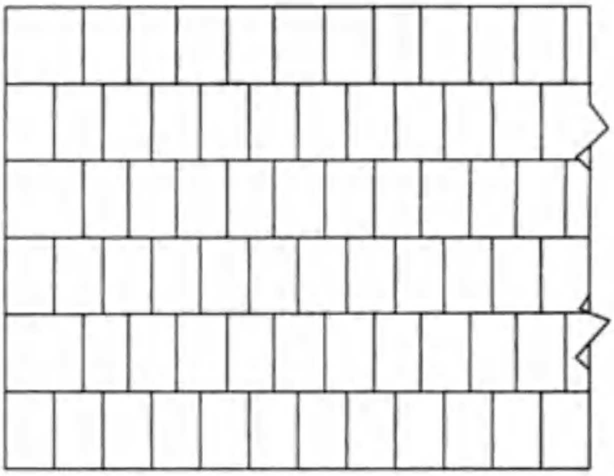


Figure 15.10 Header bond

15.6.2 Header bond

In this type of bond, all the bricks are laid with their ends towards the face of the wall. Thus, the bond does not have the strength to transmit pressure in the direction of the length of the wall. This bond is used for curved surfaces (Figure 15.10).

15.6.3 English bond

In this type of bond, alternate courses of headers and stretchers are laid. It is necessary to place queen closers after the first header in the heading course for breaking the joints vertically (Figures 15.11, 15.12 and 15.13).

a. A queen closer must be provided after a quoin header or first header. A header course should never start with a queen closer.
b. Each alternate header should be centrally placed over a stretcher.
c. Continuous vertical joints should not be allowed except at the stopped end.
d. In case the wall thickness is equivalent to an even number of half bricks, the wall shall present similar appearance in both faces.
e. In case the wall thickness is equivalent to an odd number of half bricks, the same course shall have stretcher on one face and header on the other face.
f. Only headers should be used for the hearting of the thicker walls.
g. The joints on the header course should be made thinner than those in the stretcher course. This is because of the fact that the number of vertical joints in the stretcher course is half the number of joints in the header course.

15.6.4 Flemish bond

In this type of bond, the headers are distributed evenly and, hence, it creates a better appearance than the English bond.

Copyrighted material

www.EngineeringBooksPdf.com

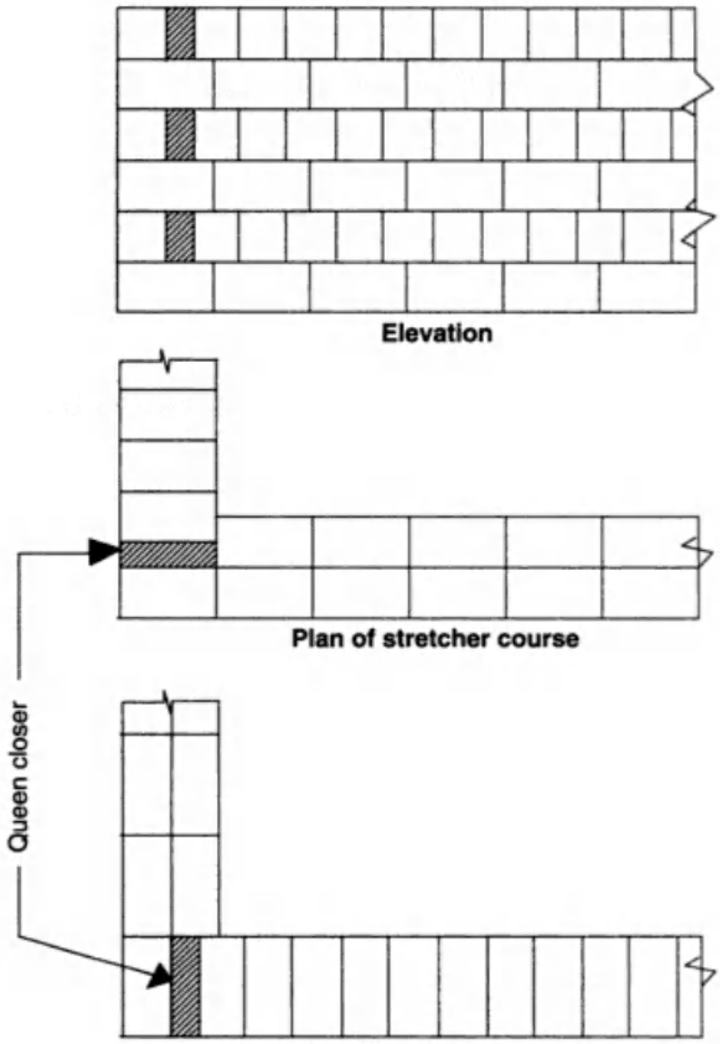


Figure 15.11 English bond – 1 brick thick

In the flemish bond, for every course the headers and stretchers are placed alternatively. The queen closer is put next to the quoin header in alternate courses to develop the face lap. Every header is centrally supported over a stretcher below it.

The flemish bond is divided into two groups.

15.6.4.1 Double Flemish bond

In this bond, alternate headers and stretchers are laid to each course. This type of bond is better in appearance than the English bond. The facings and the bracings are of the same appearance. Brickbats are used in the case of walls having thickness equivalent to an odd number of half bricks. The queen closer is placed next to the quoin header in alternate courses in order to break the continuity of the vertical joints (Figure 15.14).

15.6.4.2 Single Flemish bond

The face elevation is of flemish bond and the filling as well as backing are of the English bond. This type of bond is an attempt to combine the strength of the English bond with the appearance of the flemish bond.

Copyrighted material

www.EngineeringBooksPdf.com

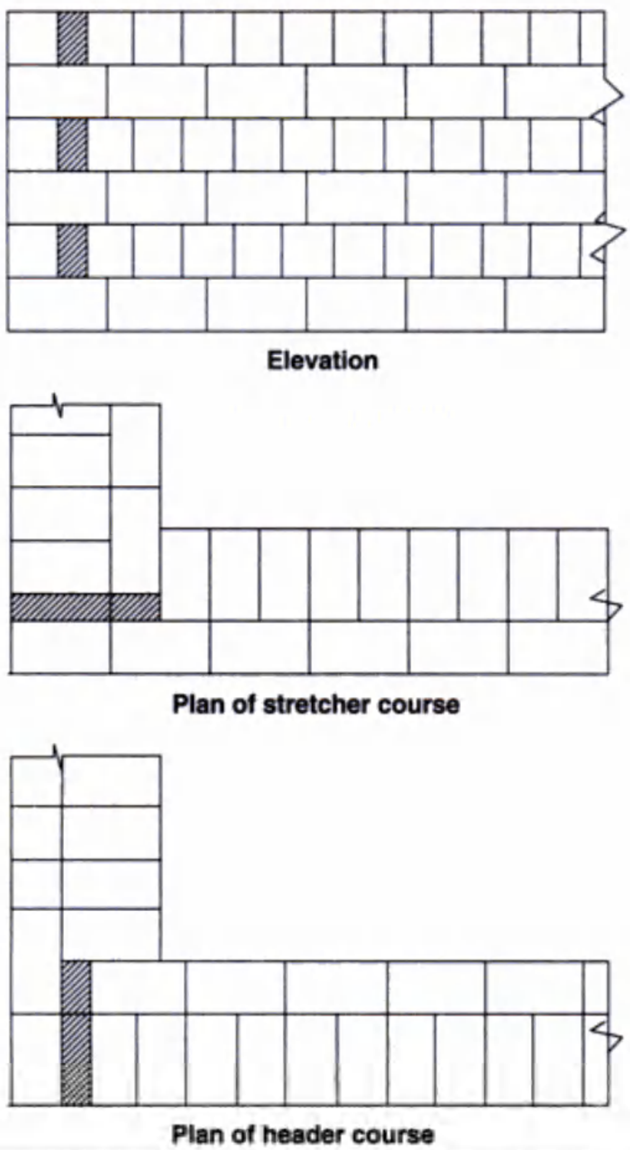


Figure 15.12 English bond – 1½ brick thick

In order to construct this bond, a wall of minimum thickness of 1½ bricks is required. The bricks in the same course do not break joints with each other. The joint is straight. In this bond, short continuous vertical joints are formed. The following table gives the comparison between English and Flemish bonds.

A Comparison Between English and Flemish Bonds

English bond	Flemish bond
More compact and strong for walls having thickness more than 1½ bricks	Less compact and less strength
Less pleasing in appearance from facing	Better appearance in the facing
Strict supervision and skill are not required	Good workmanship and careful supervision required
More in cost	Cheaper in cost

Copyrighted material

www.EngineeringBooksPdf.com

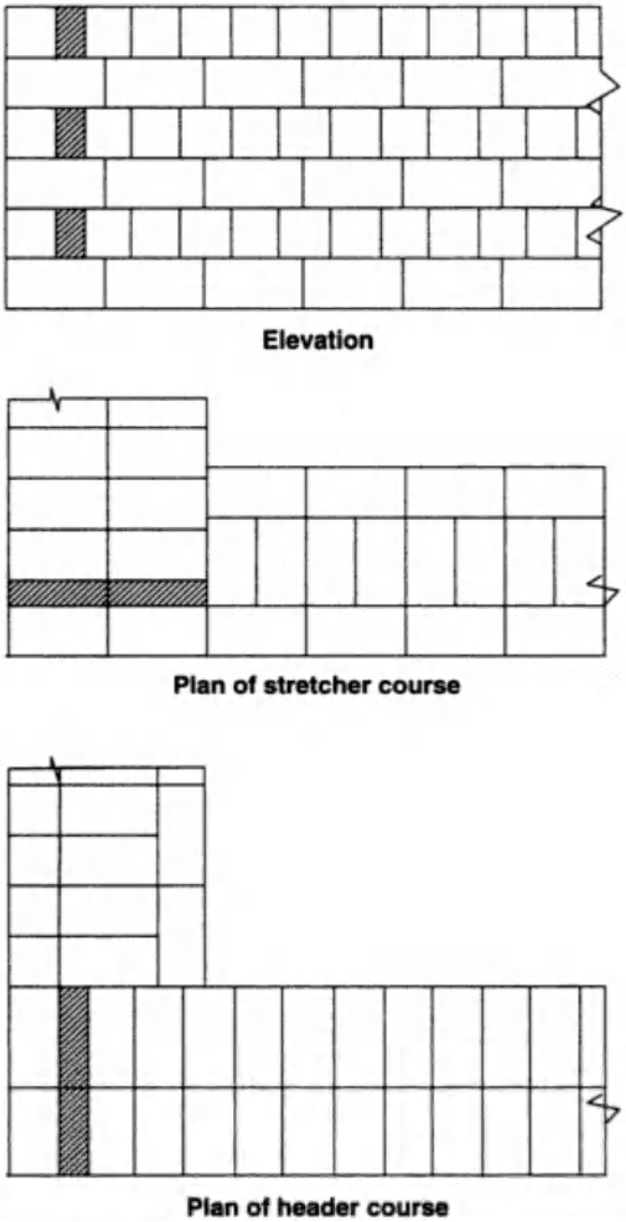


Figure 15.13 English bond – 2 bricks thick

15.6.5 Garden-wall bond

This type of bond is employed for the construction of garden walls, compound walls, boundary walls, etc.

15.6.5.1 English garden-wall bond

This type of bond comprises of one course of header to three or five courses of stretchers. In order to break the continuity of vertical joints, a queen closer is laid next to the header of the heading course and the middle course of stretchers is started with a header (Figure 15.15).

Copyrighted material

www.EngineeringBooksPdf.com

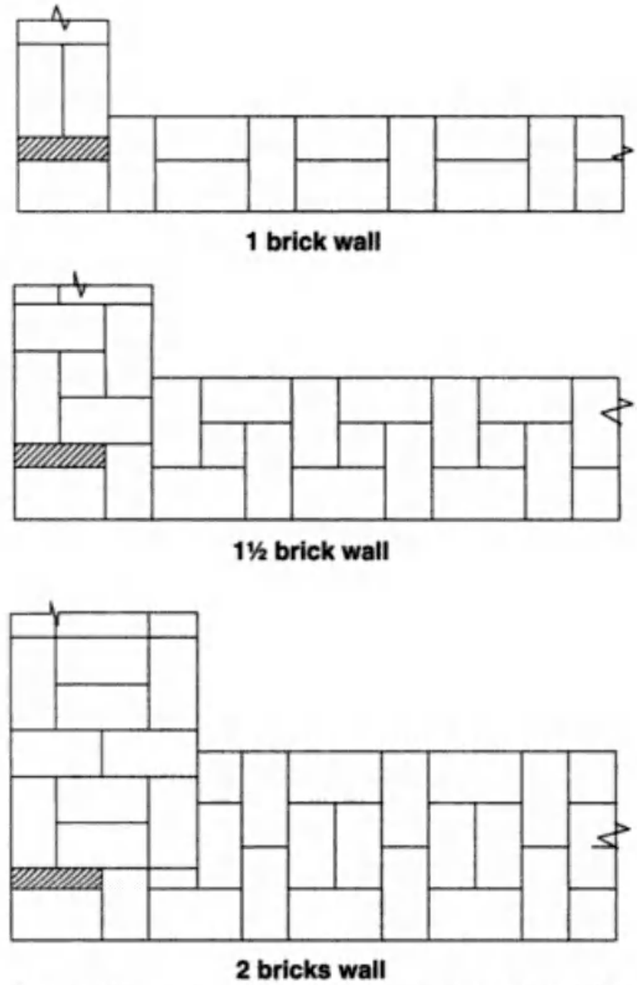


Figure 15.14 Courses 2, 4, 6, etc. of double Flemish bond

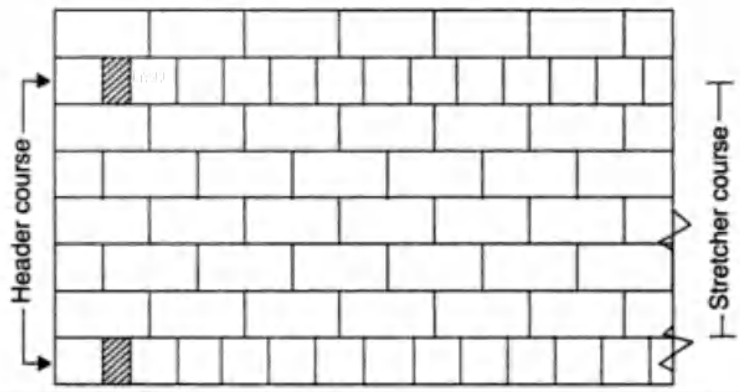


Figure 15.15 Garden-wall English bond

15.6.5.2 Flemish garden-wall bond

In this type, each course contains one header to three or five stretchers. A three-fourth brickbat is placed next to the quoin header in every alternate course to develop the necessary lap. A header is placed centrally over each middle stretcher (Figure 15.16).

Copyrighted material

www.EngineeringBooksPdf.com

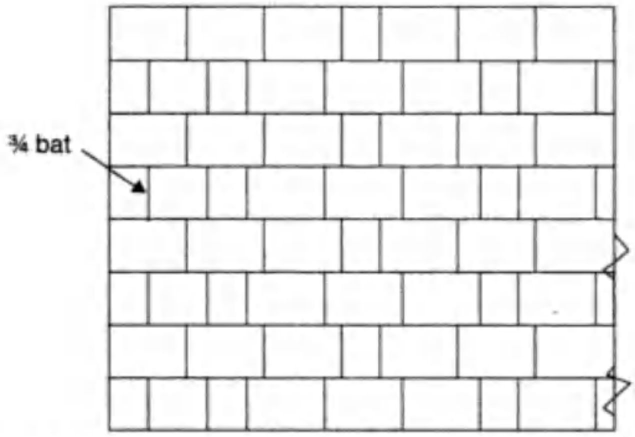


Figure 15.16 Garden-wall Flemish bond

15.6.6 Dutch bond

This type of bond is a modified form of English bond. The corners of the wall provided with the Dutch bond are quite strong. The alternate courses in this type of bond are headers and stretchers. In the stretchers course, a three-fourth bat is used as quoin. A header is placed next to the three-fourth bat in every alternate stretcher (Figure 15.17).

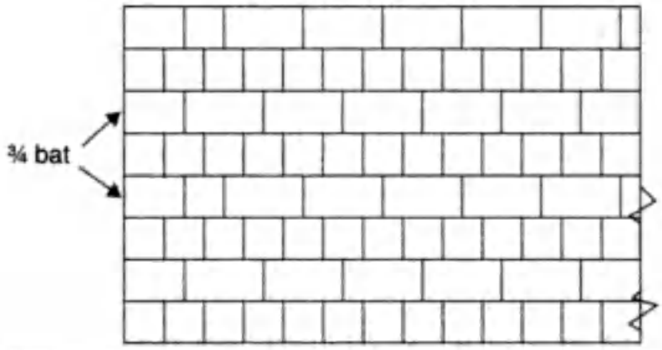


Figure 15.17 Dutch bond

15.6.7 Herringbone bond

In this bond, the bricks are placed at an angle of 45 degrees from the central line in both the directions. This type of bond is used in the case of walls having thickness of more than four bricks or for paving (Figure 15.18).

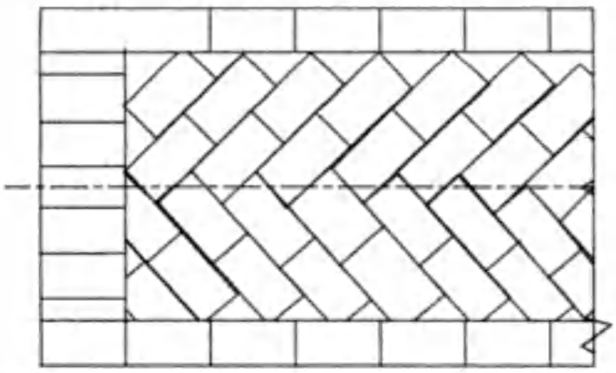


Figure 15.18 Herringbone bond

Copyrighted material

www.EngineeringBooksPdf.com

15.6.8 Zigzag bond

This type of bond is very much similar to the herringbone bond. The only difference in this type of bond is that the bricks are laid in a zigzag way. It is adopted mainly in paving brick floors (Figure 15.19).

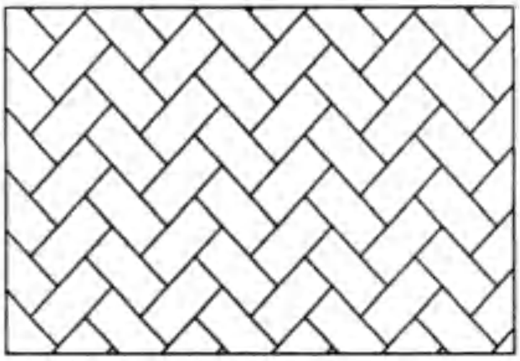


Figure 15.19 Zigzag bond

15.6.9 Brick on edge bond

In this type of bond, the bricks are laid on edge instead of bed. This bond is economical as it consumes less number of bricks and less quantity of mortar. However, it is not strong and, hence, is used for the construction of garden walls, compound walls, partition walls, etc. In this bond, the bricks are laid as headers and stretchers in alternate courses in such a way that the stretchers are laid at the edge.

15.6.10 Facing bond

In this type of bond, bricks of different thickness are used in the facing and backing of the walls. In this case, a header course is placed after several stretcher courses. The distance between the successive heading courses is equal to the least common multiple of the thickness of backing and facing bricks.

15.7 GENERAL PRINCIPLES IN BRICK MASONRY

1. The bricks used should be hard, well burnt and tough with uniform colour, shape and size.
2. The bricks should be laid on their beds with the frogs pointing upwards.
3. The courses should be truly horizontal and should have truly vertical joints.
4. Use of brickbats should be avoided to the maximum possible extent.
5. Generally, the height of the brick masonry construction in a day is limited to 1.5 m.
6. In order to ensure continuous bond, the walls should be stopped with a toothed end at the end of each stage of construction.
7. Finished brickwork should be cured for at least 2-3 weeks where lime mortar is used and for 1-2 weeks where cement mortar is used.

Copyrighted material

www.EngineeringBooksPdf.com

Estimated Quantities of Materials Required Per Cubic Metre of Brickwork

No.	Nominal mix Cement	Nominal mix Sand	Water cement ratio	Cement By weight in kg	Cement By number of bags	Sand in litres	Bricks 19 cm × 9 cm × 9 cm (nos)
1	1	3	0.40	151.5	3.03	315.6	450
2	1	4	0.53	118.5	2.37	329.1	450
3	1	5	0.62	101.3	2.03	339.6	450
4	1	6	0.70	84.0	1.68	350.1	450
5	1	8	0.90	66.0	1.32	366.6	450

Assumption is that one cubic metre of brick masonry is made of 70 per cent bricks and 30 per cent mortar

REVIEW QUESTIONS

1. How are masonry works classified?
2. Define course, phase, stretcher, header and lap of masonry works.
3. What is the difference between king closer and queen closer in a masonry work?
4. What is the difference between frog and bat in masonry work?
5. What are the criteria for the selection of material for stone masonry?
6. What are the general principles of stone masonry?
7. How is stone masonry classified?
8. On what factors does the strength of rubble masonry depend?
9. With a neat sketch explain uncoursed rubble masonry and random rubble masonry.
10. Write short notes on
    a. Flint rubble masonry
    b. Ashlar masonry
    c. Flemish bond
    d. Zigzag bond
11. What are the different types of joints used in stone masonry?
12. What are the different types of brick masonry?
13. What are the different bonds used in brick masonry? Explain about English bond 1-brick thick and 2-brick thick wall masonry using a neat sketch.
14. What are the general principles in brick masonry?

Copyrighted material

www.EngineeringBooksPdf.com

Concrete

Cement concrete is an artificial building material that is obtained by mixing together cement, water and some other inert materials. The mixture in a plastic condition when allowed to set becomes as hard as stone. By suitably adjusting the proportions of various ingredients, concrete with sufficient compressive strength for various uses can be developed. The strength of concrete depends mainly on its ingredients, their relative quantities and the manner in which they are mixed and placed.

Because of its high strength, it is used extensively for construction of roads, heavy structural member-like columns, gravity dams, etc., and also for foundations.

In addition to its strength, concrete also possesses other qualities such as high durability, better appearance, ease of construction, greater fire resistance and economy.

As plain concrete is weak in tensile strength, reinforcing with steel is done to increase the tension carrying capacity.

16.1 INGREDIENTS OF CONCRETE AND THEIR FUNCTIONS

Cement concrete is a composite mixture that consists mainly of relatively inert mineral matter in the form of particles or fragments held together by a binding medium, which gives concrete its solidity and strength. Sand and stone chips or boulders are inert materials and a combination of Portland cement and water is the binder. The inert material, called 'aggregate', is normally graded in size from fine sand to boulders or fragments of stone.

There are four ingredients, which make up the composite material of cement concrete:

1. Cement
2. Sand (fine aggregate)
3. Stone chips or boulders (coarse aggregate)
4. Water

1. **Cement:** The function of cement in the concrete is to bind the coarse and fine aggregate particles together by setting and hardening around such particles. There are different types of cement and each type is used under certain conditions due to its special properties. However, for ordinary construction, generally Ordinary Portland Cement is used. When water is mixed with cement, a chemical reaction takes place because of which the cement paste first loses its plasticity and becomes stiff, at the same time it acquires hardness and strength.
2. **Fine aggregate:** This is the inert or chemically inactive material, most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material. The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles, and thus by decreasing the porosity of the final mass, its strength is considerably increased. Sand is universally used as a fine aggregate although many other materials have been developed for special-purpose concretes.

Copyrighted material

www.EngineeringBooksPdf.com

3. **Coarse aggregate:** The inert material, most of which is retained on a 4.75 mm sieve and contains not more than 0–10 per cent of finer materials, is known as coarse aggregate. The function of the coarse aggregate is to act as the main load-bearing component of the concrete. When a good number of coarse aggregate fragments are held together by a binding material, their behaviour towards the imposed loads is just like a rock mass. Gravels and crushed stones are commonly used for this purpose.
4. **Water:** This is the least expensive but most important ingredient of concrete. It governs the important properties related to cement concrete such as durability, strength and watertightness. The purposes of mixing water are (a) to damp the aggregates and prevent them from absorbing the water vitally necessary for the chemical combination between cement and water which is called 'hydration' (b) to flux the cementing material over the surface of the particles of aggregates and (c) to make the concrete workable so that it can be placed easily and uniformly between the reinforcing bars and in the corners.

16.2 PROPORTION OF MIX USED FOR DIFFERENT WORKS

The process of selection of relative proportions of cement, sand, coarse aggregate and water to obtain a concrete of desired quality is known as proportioning the concrete. There are various methods for determining the volumetric proportions of various components, like the arbitrary method, fineness modulus method, minimum voids method and maximum density method.

The recommended mixes of concrete for various types of construction are given in the following table. The maximum sizes of aggregates are also mentioned in the table. The proportions are by volume.

Proportion of concrete mix	Maximum size of aggregate	Nature of work
1:1:2	12–20 mm	Heavily loaded RCC columns and RCC arches of long span
1:2:2	12–20 mm	Small precast members of concrete, such as poles for fencing telegraphs, long piles, watertight constructions and heavily stressed members of the structures.
1:1½:3	20 mm	Water-retaining structures, piles, precast products, etc.
1:2:3	20 mm	Water tanks, concrete deposited under water, bridge construction and sewers
1:2½:3½	25 mm	Footpaths and roadworks
1:2:4	40 mm	For all general RCC works in building, such as stair, beam, column, weather shed, slab and lintel, machine foundation subjected to vibration and RCC piles.
1:3:6	50 mm	Mass concrete works in culverts, retaining walls, etc.
1:4:8 or 1:5:10 or 1:6:12	60 mm	Mass concrete work for heavy walls, foundation, footings, etc.

16.3 FINE AGGREGATE AND COARSE AGGREGATE

16.3.1 Fine aggregate

Fine aggregate is the inert or chemically inactive material, most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material. They may be classified as follows:

a. Natural sand: Fine aggregate resulting from the natural disintegration of rocks and which has been deposited by streams or glacial agencies.

Copyrighted material

www.EngineeringBooksPdf.com

b. Crushed stone sand: Fine aggregate produced by crushing of hard stone.

c. Crushed gravel sand: Fine aggregate produced by crushing of natural gravel.

The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and considerably increases its strength. Usually, natural river sand is used as a fine aggregate. However, at places, where natural sand is not available economically, finely crushed stone may be used as a fine aggregate.

16.3.2 Coarse aggregate

The inert material, most of which is retained on a 4.75 mm sieve and contains not more than 0–10 per cent of finer materials, is known as coarse aggregate. They may be put under the following categories:

a. Uncrushed gravel or stone which results from the natural disintegration of rocks.

b. Crushed gravel or stone which results from crushing of gravel or hard stone.

c. Partially crushed gravel or stone which is a product of the mixture of the above two types.

The function of the coarse aggregate is to act as the main load-bearing component of the concrete. The nature of work decides the maximum size of the coarse aggregate. For thin slabs and walls, the maximum size of the coarse aggregate should be limited to one-third the thickness of the concrete section. The aggregates to be used for cement concrete work should be hard, durable and clean. The aggregates should be completely free from lumps of clay, organic and vegetable matter, fine dust, etc. The presence of all such debris prevents adhesion of aggregates and, hence, reduces the strength of concrete.

16.4 SIGNIFICANCE OF SAND IN CONCRETE

Sand or the fine aggregates form an important constituent of concrete. It helps to increase the bulk or volume of concrete, which results in the reduction of cost. It helps in the adjustment of the strength of concrete by variation of its proportion with cement. It also increases the resistance to crushing. The aggregates reduce shrinkage and affect economy. Earlier, aggregates were considered as inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of the aggregate and paste. The sand together with the coarse aggregate forms 70–80 per cent of the volume of concrete. The fine aggregate also helps in filling the voids formed by the coarse aggregates.

16.5 WATER–CEMENT RATIO

Cement and water are the only two chemically active elements in concrete. By their combination they form a glue-like binder paste, which surrounds and coats the particles of the inert mineral aggregates, sets and upon hardening binds the entire product into a composite mass. Next only to cement, water is the most important element in concrete governing all the properties of cement concrete like durability, strength and watertightness.

The functions of mixing water are (a) to damp the aggregates and prevent them from absorbing the water vitally necessary for the chemical combination between cement and water which is called 'hydration' (b) to flux the cementing material over the surface of particles of aggregates and (c) to make the concrete workable so that it can be placed easily and uniformly between the reinforcing bars and in the corners.

One of the most recent improvements in concrete manufacture is the control of water in the mixture. The ratio of the amount of water to the amount of cement by weight is known as 'water–cement ratio', and the strength of concrete depends on this ratio.

Copyrighted material

www.EngineeringBooksPdf.com

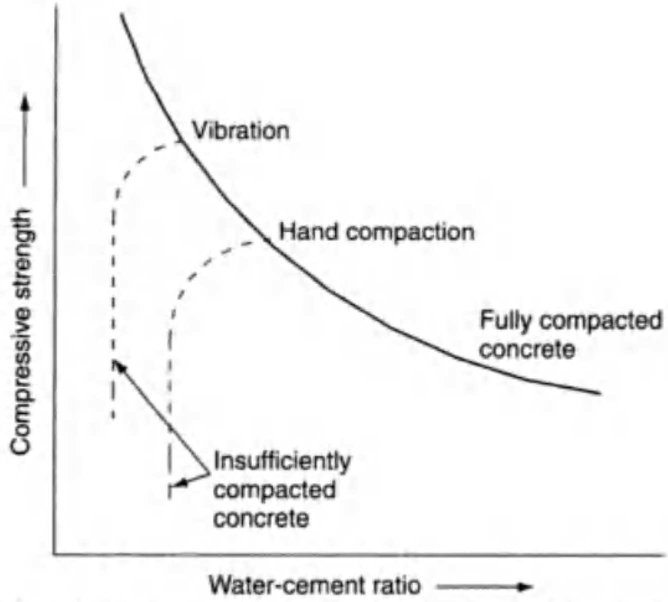


Figure 16.1 Relation between strength and water–cement ratio of concrete

Abram's water/cement ratio law states that the strength of concrete is dependent upon water–cement ratio, provided the mix is workable. The relation between water–cement ratio and the strength of concrete is shown in Figure 16.1.

It can be seen that lower water–cement ratio could be used when the concrete is vibrated to achieve higher strength, whereas comparatively higher water–cement ratio is required when concrete is hand compacted. In both cases, when the water–cement ratio is below the practical limit, the strength of concrete falls rapidly due to introduction of air voids. The graph showing the relationship between the strength and water–cement ratio is approximately hyperbolic in shape.

16.6 PROPERTIES OF CONCRETE

Cement concrete possesses the following important properties:

1. It possesses a high compressive strength.
2. It is free from corrosion and there is no appreciable effect of atmospheric agents on it.
3. It gives a hard surface capable of resisting abrasion.
4. It is more economical than steel, as sand and coarse aggregate, which constitutes the bulk of concrete, are generally available at a cheaper rate. Formwork can be reused for other construction works.
5. Improved appearance and various types of finishes can be given to the concrete surface.
6. It continues to harden and attains more strength as time passes. It is this property of cement concrete that gives it a distinct place among the building materials.
7. It can develop good bondage with steel. Steel reinforcement is usually placed in cement concrete at suitable intervals to take up the tensile stresses, as plain concrete is weak in tension. This is termed as Reinforced Cement Concrete or RCC.

Copyrighted material

www.EngineeringBooksPdf.com

8. Due to the presence of voids in the concrete, which are formed during its placing, it has a tendency to be porous. This can be checked by
   i. The use of minimum water–cement ratio
   ii. The proper grading of aggregates and
   iii. Better compaction after placing the concrete.
9. Due to loss of moisture with time, the cement concrete has a tendency to shrink. The shrinkage can be reduced by proper curing of the concrete.
10. The concrete mixes are designated as M_{10}, M_{15}, M_{20}, M_{25}, M_{30}, M_{35} and M_{40}. 'M' refers to the mix and the number denotes the ultimate strength of concrete mix in N/mm^2 at the end of 28 days.

16.6.1 Strength

Concrete is to be strong enough to withstand the stresses caused on it with a required factor of safety. The strength of the concrete is measured in N/mm^2 as said earlier and it is the ultimate compressive strength of 15 cm cubes after 28 days of curing (sometimes 7-day curing strength is also found out).

The tensile strength of concrete is about 8–12 per cent and shear strength is 8–10 per cent of its compressive strength.

16.6.2 Durability

Concrete should be able to resist the forces of disintegration owing to natural and chemical causes. The durability of concrete can be increased by using good quality materials, adopting optimum water–cement ratio, using dense graded aggregates, careful mixing and placing through compaction and adequate curing.

16.6.3 Workability

Workability is the easiness with which the concrete mix can be mixed, handled, transported, placed, moulded and compacted. A workable concrete should not show any segregation or bleeding, i.e., the materials should not separate out or the excess water should not come up to the surface.

The workability of concrete can be measured by two tests, namely the slump test and the compacting factor test.

16.6.3.1 Slump test

The slump test is carried out to have a rough estimate of the workability of concrete. It does not measure all factors contributing to workability, nor is it always representative of the placeability of the concrete. However, it is conveniently used as a control test and gives an indication of the uniformity of the concrete from batch to batch.

The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having internal dimensions as follows:

Bottom diameter	-	20 cm
Top diameter	-	10 cm
Height	-	30 cm

Copyrighted material

www.EngineeringBooksPdf.com

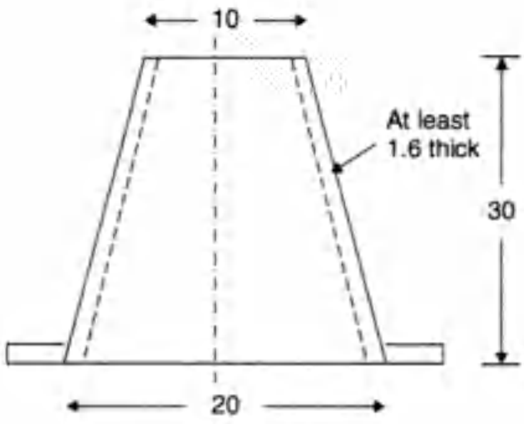


Figure 16.2 Typical mould for slump test

Figure 16.2 shows the details of the slump apparatus.

The internal surface of the mould is thoroughly cleaned and freed from any superfluous moisture. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each approximately one-fourth of the height of the mould. For tamping the concrete, a steel tamping rod of 16 mm diameter and 0.6 m length with a bullet end is used. Each layer is tamped 25 times by the tamping rod. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. The difference between the height of the mould and that of the subsided concrete is measured in mm and this is referred to as the slump of concrete.

It is seen that the slump test gives good consistent results for a plastic mix. This test is not sensitive for a stiff mix. Despite many limitations, the slump test is very useful on site to check the day-to-day or hour-to-hour variation in the quality of the mix.

16.6.3.2 Slumps for different works

The recommended slump for concrete for different types of works is shown in the table.

Number	Type of concrete	Slump
1	Concrete for road construction	20–40 mm
2	Concrete for top of curbs, parapets, piers, slabs and walls that are horizontal	40–50 mm
3	Concrete for canal linings	70–80 mm
4	Concrete for arch and side walls of tunnels	90–100 mm
5	Normal RCC work	80–150 mm
6	Mass concrete	25–50 mm
7	Concrete to be vibrated	10–25 mm

16.6.3.3 Factors affecting workability of concrete

The major factors affecting the workability of concrete are given below:

i. Water content

ii. Mix proportions

Copyrighted material

www.EngineeringBooksPdf.com

iii. Size of aggregates
iv. Shape of aggregates
v. Grading of aggregates
vi. Use of admixtures

i. **Water content:** Water content in a given volume of concrete will have a significant influence on the workability. The higher the water content per cubic metre of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. However, increasing the water content must be the last option to be taken for improving the workability. More water can be added, provided a correspondingly higher quantity of cement is also added to keep the water–cement ratio constant, so that the strength remains the same.

ii. **Mix proportions:** Aggregate–cement ratio is an important factor affecting workability. The higher the aggregate–cement ratio, the leaner is the concrete. In the case of lean mix, less quantity of paste is available for providing lubrication and, hence, the mobility of aggregate is restrained. On the other hand, in the case of rich concrete with lower aggregate–cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

iii. **Size of aggregates:** The bigger the size of aggregates, less quantity of water and paste will be required. Hence, for a given quantity of water and paste, bigger size of aggregates will give greater workability. The above will be true within certain limits.

iv. **Shape of aggregates:** The shape of aggregates greatly influences the workability. Angular, elongated or flaky aggregates make the aggregate very harsh when compared to round- or cubical-shaped aggregates. Contribution to greater workability of rounded aggregates is due to the fact that for a given volume or weight it will have less surface area and less voids than angular or flaky aggregates.

v. **Grading of aggregates:** This is one of the factors which will have maximum influence on workability. A well-graded aggregate is the one which has least amount of voids in a given volume. Other factors being constant, when the total voids are less, excess paste should be available to give better lubricating effect.

vi. **Use of admixtures:** Of all the factors, which affect workability, the most important factor is the use of admixtures. Admixture is defined as a material, other than cement, water and aggregates, that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Plasticizers and superplasticizers are admixtures that greatly improve the workability many folds. The use of air entraining agents reduces the internal friction between the particles and gives easy mobility to the particles. Similarly, the fine glassy pozzolana materials, in spite of increasing the surface area, offer better lubricating effects for increasing the workability.

16.7 MIXING OF CONCRETE

Thorough mixing of the materials is necessary for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. There are two methods adopted for mixing of concrete.

1. Hand mixing
2. Machine mixing

Copyrighted material

www.EngineeringBooksPdf.com

16.7.1 Hand mixing

Hand mixing is practised for small-scale unimportant concrete works. As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method.

Hand mixing should be done on an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse and fine aggregate in alternate layers. Pour the cement on top of it and mix them dry by shovel, turning the mixture repeatedly until uniformity of colour is achieved. Water is then sprinkled over the mixture and simultaneously turned over. This operation is continued until a good, uniform and homogeneous concrete is obtained. It is of particular importance to see that the water is not poured but only sprinkled. Water in small quantity should be added towards the end of the mixing to get just the required consistency. At this stage, even a small quantity of water makes a difference.

16.7.2 Machine mixing

Mixing of concrete is invariably carried out by machine for reinforced concrete work and for medium- or large-scale concrete work. Machine mixing is not only efficient and fast but also economical when the quantity of concrete to be produced is large.

The mixers for mixing concrete can be classified as batch mixers and continuous mixers. Batch mixers produce concrete batch by batch with intervals whereas continuous mixers produce concrete without stoppage. Continuous mixers are used in large works such as dams. In normal concrete work, the batch mixers are used. Batch mixers may be of pan type or drum type. The drum type may be further classified as tilting, non-tilting and reversing or forced action type.

To get better efficiency, the sequence of charging the loading skip is as described below. Firstly, about half the quantity of coarse aggregate is placed on the skip over which about half the quantity of fine aggregate is poured. On that the full quantity of cement is poured, over which the remaining portion of coarse and fine aggregate is deposited in sequence. This prevents spilling of aggregate while discharging into the drum and also the blowing away of cement in windy weather.

Before the loading skip is discharged into the drum, about 25 per cent of the total water required for mixing is introduced into the mixer drum to wet the drum and to prevent any cement from sticking to the blades or the bottom of the drum. Immediately on discharging the dry materials, the remaining 75 per cent of water is added to the drum.

Concrete mixers are generally designed to run at a speed of 15–20 revolutions per minute. On the site, the normal tendency is to reduce the mixing time to increase the outturn. This results in poor quality of concrete. On the other hand, if the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption. Therefore, it is of importance to mix the concrete for such a duration that will give optimum benefit. It is seen that the quality of concrete in terms of compressive strengths will increase with increase in the time of mixing, but for mixing time beyond 2 minutes the increase in compressive strength is not very significant.

Concrete mixers are often used continuously without stopping for several hours for mixing and placing. It is of utmost importance that a mixer should not stop in between the concreting operation. For this, the mixer must be well maintained. The mixer is placed on the site at a firm and levelled platform. The drum and blades must be kept clean at the end of the concreting operation. The drum must be kept in tilting position or kept covered when not in use to prevent the collection of rainwater. The skip is operated carefully and it must be provided with proper cushion such as sand bags.

16.8 TRANSPORTING AND PLACING OF CONCRETE

Soon after mixing, the concrete has to be transported and placed in the moulds. A maximum time limit of 1½ hours is allowed between the moment of actual mixing and placing of concrete. It should never be disturbed once the setting has commenced.

Copyrighted material

www.EngineeringBooksPdf.com

While transporting and placing of concrete, care should be taken to avoid segregation and loss of water added.

The surface on which the concrete is to be placed should be cleaned, prepared and well watered. The formwork or moulds should be given a coating of grease or some other material to prevent adhesion of concrete. Concrete should always be laid in even and thin layers and each layer should be well compacted before the next is placed, usually layers of 15–45 cm thickness is adopted. Concrete should never be thrown from a height. Concrete pumps are also now available to place the concrete. The reinforcement should be kept in a fixed position and should never be disturbed.

16.9 COMPACTION OF CONCRETE

Compaction of concrete is the method adopted for expelling the entrapped air from the concrete. If the air is not removed fully, the concrete loses strength considerably. Figure 16.3 shows the relation between loss of strength and air voids left due to lack of compaction.

It can be seen from Figure 16.3 that 5 per cent voids reduce the strength of concrete by about 30 per cent and 10 per cent voids reduce the strength by over 50 per cent. Therefore, it is imperative that 100 per cent compaction is one of the most important points to be kept in mind in good concrete-making practices.

16.9.1 Methods of compaction

The following methods are generally adopted for the compaction of concrete:

a. ***Hand compaction***
   i. Rodding
   ii. Ramming
   iii. Tamping

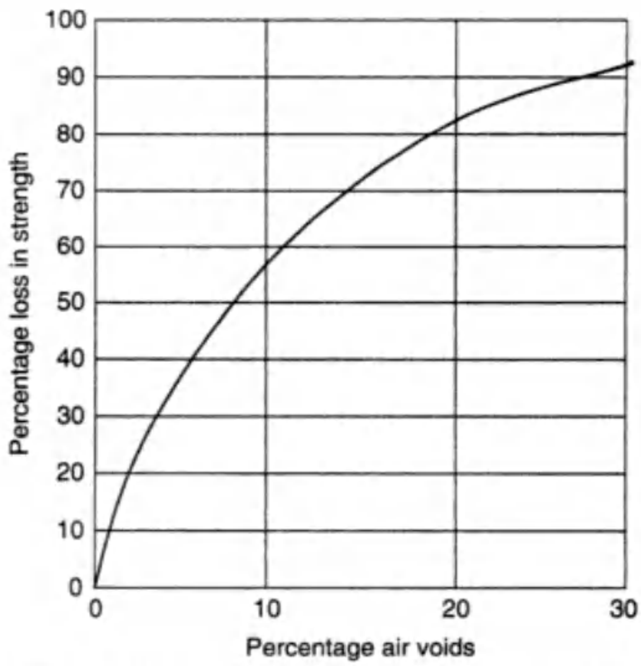


Figure 16.3 Relation between percentage loss in strength and percentage air voids

Copyrighted material

www.EngineeringBooksPdf.com

b. ***Compaction by vibration***

 i. Internal Vibrator (Needle vibrator)

 ii. External Vibrator (Formwork vibrator)

 iii. Table vibrator

 iv. Platform vibrator

 v. Surface vibrator (Screed vibrator)

 vi. Vibratory roller

c. ***Compaction by pressure and jolting***

d. ***Compaction by spinning***

16.9.1.1 Hand compaction

Hand compaction is adopted in the case of small unimportant works. This method is also used in situations where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. When hand compaction is adopted, the consistency of concrete is maintained at a higher level. Hand compaction consists of rodding, ramming or tamping.

Rodding is nothing but poking the concrete with a rod about 2 m long and 16 mm diameter to pack the concrete between the reinforcement and sharp corners and edges. Rodding is done continuously over the complete area to effectively pack the concrete and drive away entrapped air.

Ramming should be done with care. Light ramming can be permitted in unreinforced foundation concrete or in ground floor constructions. Ramming should not be permitted in the case of reinforced concrete or in upper floor constructions, where the concrete is placed on formwork placed on struts.

Tamping is one of the usual methods adopted in compacting roof or floor slabs or road pavement where the thickness of concrete is comparatively less. Tamping consists of beating the top surface by a wooden cross beam. Since the tamping bar is sufficiently long, it not only compacts but also levels the top surface across the entire width.

16.9.1.2 Compaction by vibration

To compact concrete with low water–cement ratio, mechanically operated vibratory equipments must be used. Compaction of concrete by vibration has almost completely revolutionized the concept of concrete technology, making possible the use of low slump stiff mixes. Different methods for vibrating the concrete can be adopted.

Internal vibrator

Of all the vibrators, the internal vibrator is the most commonly used. It is also called 'needle vibrator', 'immersion vibrator' or 'poker vibrator'. This essentially consists of a power unit, a flexible shaft and a needle. The needle's diameter varies from 20 to 75 mm and its length varies from 25 to 90 cm. A bigger needle is used in the construction of mass concrete dam.

External vibrator (Formwork vibrator)

Formwork vibrators are used for concreting columns, thin walls or in the casting of precast units. The machine is clamped to the external wall surface of the formwork. The vibration is given to the formwork so that the concrete in the vicinity of the shutter gets vibrated. Since the vibration is given to the concrete indirectly through the formwork, it consumes more power and its efficiency is less than the internal vibrator.

Copyrighted material

www.EngineeringBooksPdf.com

Table vibrator

This is a special type of formwork vibrator, where the vibrator is clamped to the table or the table is mounted on springs, which are vibrated transferring the vibrations to the table. It is commonly used for vibrating concrete cubes. It is adopted mostly in laboratories and in making small, precise precast RCC members.

Platform vibrator

Platform vibrator is nothing but a table vibrator, but it is larger. It is used in the manufacture of large prefabricated concrete elements such as electric poles, railway sleepers and prefabricated roofing elements.

Surface vibrator

Surface vibrators are also known as 'screed board vibrators'. A small vibrator placed on the screed board gives an effective method of compacting and levelling thin concrete members. Mostly, floor slabs and roof slabs are so thin that an internal vibrator or any other type of vibrator cannot be used. In such cases, the surface vibrator can be effectively used.

Vibratory roller

One of the recent developments of compacting very dry and lean concrete is the use of vibratory roller. Such concrete is known as roller compacted concrete. This method is mainly used for the construction of dams and pavements. Heavy roller, which vibrates while rolling, is used for the compaction of dry lean concrete.

16.9.1.3 Compaction by pressure and jolting

This is one of the effective methods of compacting very dry concrete. This method is often used for compacting hollow blocks, cavity blocks and solid concrete blocks. The stiff concrete is vibrated, pressed and given jolts. By employing great pressure, a concrete of very low water–cement ratio can be compacted to yield very high strength.

16.9.1.4 Compaction by spinning

Spinning is one of the recent methods of compaction of concrete. This method of compaction is adopted for the fabrication of concrete pipes. The plastic concrete when spun at a very high speed gets well compacted by centrifugal force.

16.10 CURING OF CONCRETE

Concrete derives its strength by the hydration of cement particles. The quality of the product of hydration and consequently the amount of gel formed depend on the extent of hydration. Theoretically, water–cement ratio of 0.38 is required to hydrate all the particles of the cement and to occupy the space in the gel pores. In the field, even though higher water–cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place, particularly in the top layer.

Curing can be considered as creation of a favourable environment during the early period for an uninterrupted hydration. The desirable conditions are a suitable temperature and ample moisture content. Concrete while hydrating releases heat of hydration. This heat is harmful from the point of view of volume stability. The heat generated can also be reduced by means of water curing.

Copyrighted material

www.EngineeringBooksPdf.com

The curing methods may be broadly divided into the following categories:

1. Water curing
2. Membrane curing
3. Application of heat

16.10.1 Water curing

This is considered as the best method of curing as it satisfies all the requirements of curing, namely promotion of hydration, elimination of shrinkage and absorption of the heat of hydration. Water curing can be done in the following ways:

a. Immersion
b. Ponding
c. Spraying or Fogging
d. Wet covering

The precast concrete items are normally immersed in curing tanks for a certain duration. Pavement slabs, roof slabs, etc. are covered under water by making small ponds. Vertical retaining walls or plastered surfaces or concrete columns, etc. are cured by spraying water. In some cases, wet coverings such as wet gunny bags, jute matting and straw are wrapped to the vertical surface for keeping the concrete wet. For horizontal surfaces, saw dust, earth or sand are used as wet coverings to keep the concrete in wet condition for a longer time.

16.10.2 Membrane curing

The quantity of water normally mixed for making concrete is more than sufficient to hydrate the cement, provided this water is not allowed to go out from the body of concrete. For this reason, concrete could be covered with a membrane that will effectively seal off the evaporation of water from concrete. In addition, if concrete works are carried out in places where there is acute shortage of water, the lavish application of water for water curing is not possible due to reasons of economy.

Sometimes, the concrete is placed in some inaccessible, difficult or far off places. The curing of such concrete cannot be properly supervised. In such cases, it is much safer to adopt membrane curing than to leave the responsibility of curing to workers.

Large number of sealing compounds have been developed in recent years. The idea is to obtain a continuous seal over the concrete surface by means of a firm impervious film to prevent moisture in the concrete from escaping by evaporation. Some of the materials that have been used for this purpose are bituminous compounds, polyethylene or polyester film, waterproof paper, rubber compounds, etc.

16.10.3 Application of heat

The development of the strength of concrete is a function of not only time, but also of temperature. When concrete is subjected to higher temperature, it accelerates the hydration process resulting in faster development of strength. The exposure of concrete to higher temperature is done in the following manners:

a. Steam curing at ordinary temperature
b. Steam curing at high temperature
c. Curing by infra red radiation
d. Electrical curing

Copyrighted material

www.EngineeringBooksPdf.com

16.10.3.1 *Steam curing at ordinary temperature*

This method is often adopted for prefabricated concrete elements. Application of steam to in situ construction will be a difficult task. For steam curing, the concrete elements are stored in a chamber. The chamber should be large enough to hold a day's production. The door is closed and steam is applied. The steam may be applied either continuously or intermittently. An accelerated hydration takes place at this higher temperature and concrete attains the 28-day strength of normal concrete in about 3 days. In large prefabricated factories, they have tunnel curing arrangements. However, concrete subjected to higher temperature at the early period of hydration is found to lose some of the strength gained at a later stage.

It has been emphasized that a very young concrete should not be subjected suddenly to high temperature. A certain delay period after casting the concrete is desirable. In India, steam curing is often adopted for precast elements, especially precast concrete sleepers.

16.10.3.2 *Steam curing at high temperature*

The high-pressure steam curing is something different from ordinary steam curing, in that the curing is carried out in a closed chamber. The superheated steam at high temperature and high pressure is applied on the concrete. This process is also called 'autoclaving'. The following advantages are derived from the high-pressure steam curing process:

i. High pressure steam cured concrete develops in 1 day or less, the strengths developed at 28 days of normally cured concrete. In addition, it does not lose the strength at a later stage.

ii. High-pressure steam cured concrete exhibits higher resistance to sulphate attack, freezing and thawing action and chemical action. It also shows less efflorescence.

iii. High-pressure steam cured concrete exhibits lower drying shrinkage and moisture movement.

16.10.3.3 *Curing by infra red radiation*

Curing of concrete by infra red radiations has been practised in very cold climatic regions of Russia. It is claimed that much more rapid gain of strength can be obtained than with steam curing and does not cause a decrease in the ultimate strength as in the case of steam curing at ordinary pressure.

16.10.3.4 *Electrical curing*

Another method of curing concrete, which is applicable mostly to very cold climatic regions, is by the use of electricity. This method is not likely to find much application in ordinary temperatures due to economic reasons.

16.11 FORMWORK

When concrete is placed, it is in plastic state. It requires to be supported by temporary supports and casings of the desired shape till it becomes sufficiently strong to support its own weight. This temporary casing is known as the formwork.

16.11.1 Requirements of a good formwork

a. ***Easy removal:*** The design of formwork should be such that it can be removed easily with least amount of hammering. This will also prevent the possible injury to the concrete, which has not become sufficiently hard. Further, if the removal of formwork is easy it can be made fit for reuse with little expenditure. The

Copyrighted material

www.EngineeringBooksPdf.com

operation of removing the formwork is commonly known as stripping, and when stripping takes place, the components of the formwork are removed and then reused for another part of the structure. Such forms whose components can be reused several times are known as panel forms.

b. ***Economy:*** It is noted that the formwork does not contribute anything to the stability of the finished structure, and hence it will be desirable to bring down its cost to a minimum, consistent with safety. The various steps such as reduction in the number of irregular shapes of forms, standardizing the room dimensions, use of component parts of commercial size and putting the formwork in use again as early as possible may be taken to affect the economy in the formwork. The formwork should be constructed of that material which is easily available at low cost and which can safely be reused several times.

c. ***Less Leakage:*** The formwork should be so arranged that there is minimum leakage through the joints. This is achieved by providing tight joints between sections of the formwork.

d. ***Quality:*** These forms should be designed and built accurately so that the desired size, shape and finish of the concrete are attained.

e. ***Rigidity:*** The formwork should be rigid enough to retain the shape without any appreciable deformation. For visible surfaces in the completed work, the deflection is limited to 1/300 of span and that for hidden surface is limited to 1/150 of span. It should be noted that a rigid formwork would be robust and stiff enough to allow repeated use.

f. ***Smooth Surface:*** The inside surface of formwork should be smooth to turn out a good concrete surface. This is achieved by applying crude oil or soft soap solution to the inside surface of formwork. This also makes the removal of formwork easy.

g. ***Strength:*** The formwork should be sufficiently strong enough to bear the dead load of wet concrete as well as the weights of equipments, labour, etc. required for placing and compacting the concrete. This requires careful design of the formwork. The overestimation of loads results in expensive formwork and the underestimation of loads results in the failure of formwork. The loads on vertical forms are to be assessed from various considerations such as density of concrete, dimension of section, concrete temperature, slump of concrete, reinforcement details, stiffness of forms and rate of pouring of concrete.

16.11.2 Steel formwork

Steel is used for formwork when it is desired to reuse the formwork several times. The initial cost of steel formwork is very high. However, it proves to be economical for large work requiring many repetitions of the formwork. The erection and removal of steel formwork are simple and it presents a smooth surface on removal.

16.11.2.1 Advantages

i. It can be reused several times, nearly ten times more than timber formwork.

ii. It does not absorb water from concrete and, hence, the chances of formation of honey-combed surface are brought down to the minimum level.

iii. It does not shrink or distort and, hence, it is possible to achieve higher degree of accuracy and workmanship by its use as compared to timber formwork.

iv. It is easy to install and dismantle and, hence, there is saving in the labour cost.

v. It gives excellent concrete surfaces requiring no further finishing treatment. The surface obtained by the use of timber formwork invariably requires plastering for getting the desired finish of the concrete surface.

Copyrighted material

www.EngineeringBooksPdf.com

vi. It possesses more strength and is more durable than timber formwork.

vii. The design calculations for the steel formwork system can be made precisely because of the known characteristics of steel.

16.11.3 Timber formwork

When formwork is required for small works requiring less repetition, timber is preferred to steel. Timber formwork is cheap in initial cost and it can be easily adopted or altered for new use. The timber to be used as formwork should be well seasoned, free from loose knots, light in weight and easily workable with nails without splitting.

a. The timber formwork should be neither too dry nor too wet. If it is too dry, the timber will swell and get distorted when wet concrete is laid on it and honey-combed surface will appear on removal of the formwork. On the other hand, if it is too wet, the timber will shrink on hot weather resulting in gaps in the formwork through which concrete will flow out. Hence, ridges will be formed on the concrete surface. It is found that a moisture content of about 20 per cent is appropriate for the timber formwork.

b. The dimensions of components of the timber formwork will depend upon the loads to be carried and the availability of timber sections. However, generally the latter is the governing factor as the former can be adjusted by suitable spacing of the supports.

c. Minimum number of nails should be used in timber formwork and the nail heads should be kept projecting so as to facilitate easy removal.

d. The timber formwork proves to be economical for buildings with minimum number of variations in the dimensions of the rooms. Thus, the cutting of timber pieces is brought down to the minimum.

e. It is common practise to support formwork for slab in buildings with the timber ballies, which are cut to approximate sizes with wedges below them for final adjustments. It leads to the formation of weak points, which are seldom prevented from displacement. The timber ballies are generally not straight and they do not transmit the load axially.

Plywood as formwork is becoming popular at present over the timber formwork because:

a. It can be reused several times as compared to ordinary timber formwork. Under normal conditions the plywood formwork can be used 20–25 times and the timber formwork can be used 10–12 times.

b. It gives surfaces which are plain and smooth and, hence, it may not require any further finishing treatment.

c. It is possible to cover up more area by using large size panel and, hence, there is considerable reduction in the labour cost of fixing and dismantling formwork.

16.11.4 Failures of formwork

Safety must be given importance in the design, construction, erection and stripping of formwork systems. The general rules to be observed to avoid the failure of formwork for concrete structures are as follows:

a. If high shoring is not suitably strengthened by diagonal braces, there are chances for formwork failure to occur.

b. It should be remembered that the forms are continuously supported structures and as such they must be provided with uniform bearing at each support.

Copyrighted material

www.EngineeringBooksPdf.com

c. The entire work should be carried out under the strict and direct supervision of skilled persons or engineers only.

d. The design of formwork should provide for possible shocks and vibrations.

e. The details that are difficult to perform should be avoided as in many cases such details will not be satisfactorily performed and may become the starting point for causing a formwork failure.

f. The stripping of form and reshoring should not be carried out in an unbalanced way. It will otherwise lead to unnecessary stresses in freshly laid concrete.

g. The wedging of posts to counterbalance load compression must be carried out with extreme care so that the assembled form support remains undisturbed.

16.11.5 Formwork for columns

The column formwork consists of a box prepared for four separate sides (Figure 16.4). The four sides of the box are held in position by wooden blocks, bolts and yokes. The important features in the RCC column are:

a. The formwork should be designed to resist the high pressure resulting from the quick filling of the concrete.

b. The spacing of yokes is about 1 m. However, it should be carefully determined by working out the greatest length of the formwork, which can safely resist the load coming on the formwork.

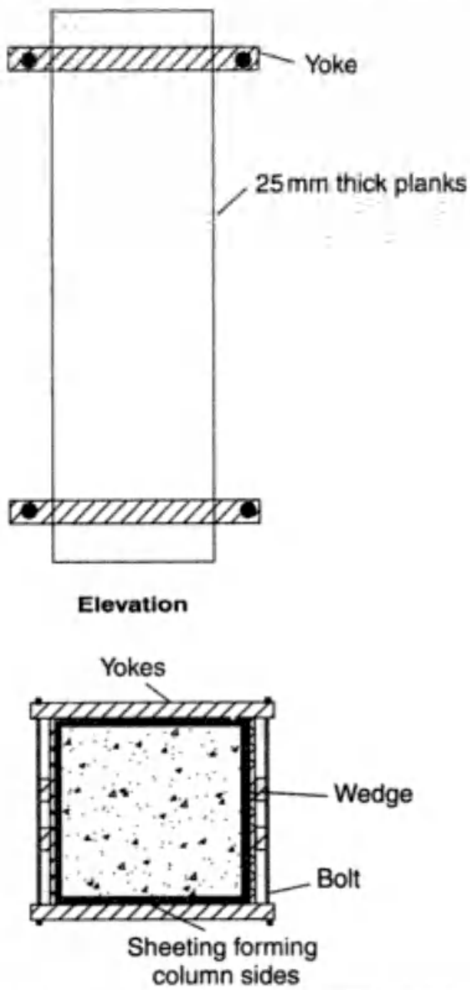


Figure 16.4 Wooden formwork for rectangular or square column

Copyrighted material

www.EngineeringBooksPdf.com

3. What are the roles of fine aggregate and coarse aggregate in concrete?
4. What is the significance of sand in concrete?
5. What is water–cement ratio and what is its importance in concrete?
6. What are the properties of concrete?
7. What is workability of concrete and how is it found out?
8. What do you mean by strength of concrete?
9. What is slump test and explain the factors affecting workability of concrete?
10. How is concrete mixed?
11. What are the criteria for transporting and placing of concrete?
12. What do you mean by compaction of concrete and explain the various methods of compaction?
13. How is concrete cured and why is curing required for concrete?
14. What is the application of formwork and explain the requirements of a good formwork?
15. Explain the important feature in the formwork for columns.
16. What are the general rules to be observed to avoid the failure of formwork of concrete structures?
17. Write short notes on
    a. Formwork for walls
    b. Stripping time for formwork
    c. Timber formwork
    d. Steel formwork
    e. Curing of concrete by infra red radiation.
    f. Water curing of concrete
    g. Hand compaction of concrete
    h. Compaction of concrete by vibration.

Copyrighted material

www.EngineeringBooksPdf.com

Doors and Windows

A door is a movable barrier secured in an opening, known as the doorway, through a building wall or partition for the purpose of providing access to the inside of a building or rooms of a building. A door is held in position by doorframes, the members of which are located at the sides and top of the opening or doorway. Sills may or may not be provided at the bottom of doorways. A window is defined as an opening in a wall of a building to serve one or more of the functions like natural light, natural ventilation and vision.

The main function of a door in a building is to serve as a connecting link between the internal parts and to allow free movement to the outside of the building. Windows are generally provided for the proper ventilation and lighting of a building and their size and number should be properly determined as per the requirements. To perform their basic functions, the following functional requirements should be satisfied in their design and construction.

i. *Weather resistance:* They should be strong enough to resist the adverse effects of weather such as wind and rainfall.

ii. *Sound and thermal insulation:* They should be capable of being made airtight to achieve insulation against sound and heat. They should act as vertical barriers like walls for the passage of sound, heat and fire.

iii. *Damp prevention and termite proofing:* They should not be affected by termite and moisture penetration as they reduce their strength and durability.

iv. *Fire resistance and durability:* They should offer fire resistance and should be durable.

v. *Privacy and security:* They should offer sufficient privacy without inconvenience or trouble and security against burglars.

17.1 LOCATION OF DOORS AND WINDOWS

The designer or planner should observe the following rules while deciding the location of doors and windows:

1. The number of doors should be kept minimum for each room because larger numbers cause obstruction and decrease the utility of the accommodation. The location and size of the doors should be based on their functional requirement.
2. From the viewpoint of utility and privacy of the occupants, doors should preferably be located near the corner of a room.
3. For good ventilation and free air circulation inside the room, the doors should be located in opposite walls facing each other.
4. The location, number and size of the windows are decided considering various factors, like desired daylight, vision, privacy, ventilation and heat loss.

Copyrighted material

www.EngineeringBooksPdf.com

5. The sill of a window should be located at a height of 0.75–1 m above the floor level. However, windows when exposed to public places like shopping centres and cinema theatres are located at a higher level say about 2 m. This is essential for achieving privacy in buildings on the ground floor.
6. Doors and windows should be located by keeping in view the interior decoration of the room and views of the building owner.

17.2 DOORS

From the operational point of view, the doors are classified as below.

17.2.1 Swinging doors

In these doors, the shutter is hung to the door frame on hinges or butts fixed to one side of the shutter, so that they swing on a vertical axis. The doors may be single swinging, double swinging or double acting type.

In single swinging type doors, if a person is standing on the outside of a door and the hinges are at his left, the door is a left-hand door, but if they are at his right it is a right-hand door.

In double swinging doors, the shutters are hinged at opposite sides of an opening. These doors are extensively used at the entrances of buildings. In double acting doors, the shutters are provided with special hinges, which keep the door closed when it is not held open. Doors of this type can be easily pushed in either direction.

17.2.2 Folding doors

These doors are usually single or as folding partitions so that two rooms may be used together as a single room or separately. They are made of wood or metal and are used for very large openings. Doors are also hinged together.

17.2.3 Sliding doors

Sliding doors that slide sideways were extensively used in the past for residences. The door shutters can also slide either upward or downward. These doors do not cause any obstruction in movements. The vertical sliding doors are pulled up by cables or chains and are used for large openings in industrial and freight elevator doors. The right angle doors are suspended from an overhead track and are used to a very limited extent for garages.

17.2.4 Rolling doors

This is a modification over sliding doors. These doors are generally made of steel or slates of sheet metal and can be easily closed or opened by slightly pulling or pushing the shutter. They do not require much space and are commonly used for garages, show rooms, shops, etc.

17.2.5 Revolving doors

These doors are extensively used where frequent opening and closing of doors are to be avoided due to heavy foot traffic, like markets, public buildings, hotels, stores, theatres and hospitals. The arrangements are made to rotate the door to about one side of the shutter and get it closed automatically whenever pushed and left.

Copyrighted material

www.EngineeringBooksPdf.com

17.2.6 Collapsible doors

These doors consist of a mild steel frame, which is made up of light steel channel sections. They are provided with rollers at the bottom and top to roll on rails when they open or collapse. These doors work without hinges and can be opened or closed by a slight pull or push. These doors are extensively used for residential buildings, public buildings, schools, etc.

17.3 WINDOWS

17.3.1 Fixed window

It is fixed in the wall and makes no provision for natural air circulation.

17.3.2 Double hung window

In this type, both sashes slide vertically with the weight balanced by the sash weight, spiral springs or tape spring balances.

17.3.3 Horizontal sliding window

In this type, either one or both sashes are arranged to slide horizontally. Sashes are sometimes suspended from rollers operating on overhead tracks. Heavy sashes are often provided with nylon rollers at the bottom for ease in operation.

17.3.4 Casement window

Any hinged window, which may swing out or in like doors, is termed as casement window. These windows usually swing on extension hinges provided on the sides. There are out-swinging and in-swinging casement windows with two sashes. Extension hinges are used to make the sash swing clear of the inside surface of the wall.

17.3.5 Folding window

It is a form of out-swinging casement window with the two sashes hinged together on its meeting stile, rather than each to its outside stile. The projection arms are so arranged that the sashes operate symmetrically.

17.3.6 Pivoted window

Horizontally pivoted sash windows are often arranged in a row to form a continuous window in a sawtooth roof or monitor and they operate in harmony from the floor by a mechanical operation.

17.3.7 Top- and bottom-hinged window

Sash windows may be top-hinged out-swinging or top-hinged in-swinging or bottom-hinged in-swinging type.

17.3.8 Projected window

A window with a ventilation sash that projects outwards or inwards is called a projected window. In this type, the ends of the arms are pivoted to the side of the sash and to the frame.

Copyrighted material

www.EngineeringBooksPdf.com

17.3.9 Hopper window

Any inward projecting window when located at or near the bottom of a window is termed as hopper window.

17.4 TYPES OF DOORS

The doors commonly used in buildings are classified into various types depending upon several factors or aspects like materials used in the manufacture of doors, arrangement of door components, method of construction and their working operation.

17.4.1 Battened and ledged door

This is the simplest form of door, which is frequently used for narrow openings. The use of this type of door is preferred where cost is the main factor rather than the strength and appearance. This door consists of vertical boards known as battens, which are secured by horizontal pieces known as ledges. Usually, there are three ledges, namely top ledge, middle ledge or lock edge and bottom edge. The outer edges of the ledges are generally chamfered. The bottom and middle ledges are sometimes wider than the top ledges. The battens secured by means of tongued and grooved joint are either V-jointed or beaded (Figure 17.1).

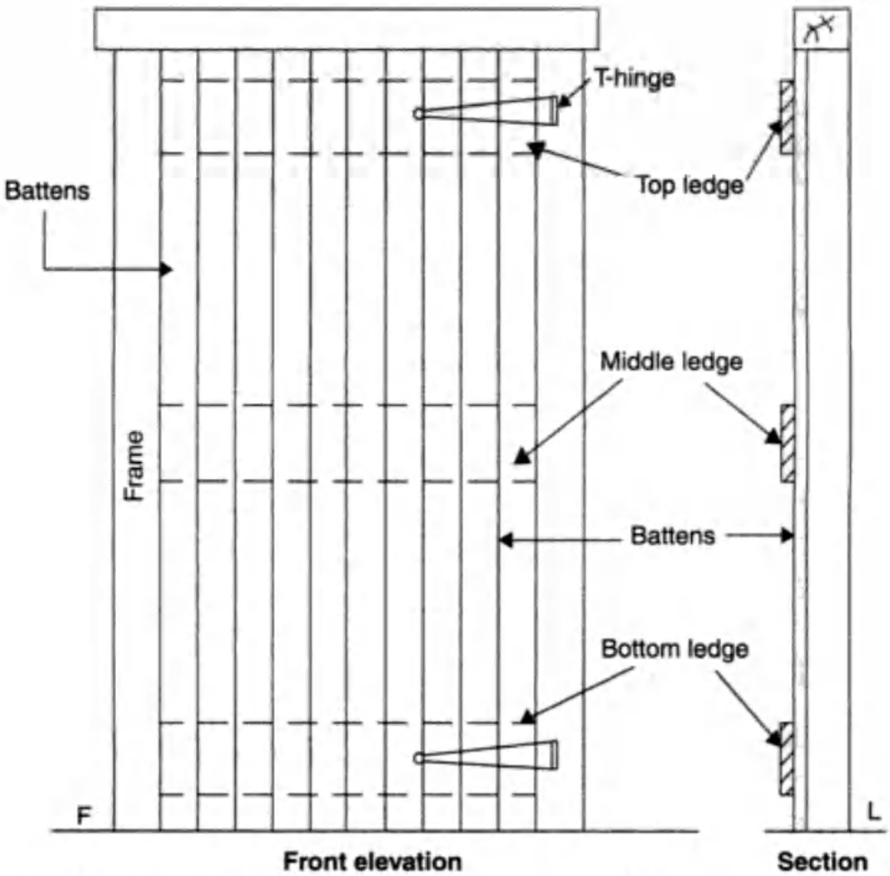


Figure 17.1 Battened and ledged door

Copyrighted material

www.EngineeringBooksPdf.com

The sizes of the door components are as follows:

a. Vertical battens: width is 10–20 cm; thickness is 2–4 cm
b. Top ledge: width is 10 cm; thickness is 3-4 cm
c. Middle and bottom ledge: width is 15–20 cm; thickness is 3-4 cm

17.4.2 Battened, ledged and braced door

This door is a modification over battened and ledged doors in which additional diagonal members called braces are provided to increase its rigidity and, hence, the strength. These braces act as struts as they are made to incline upwards from the hanging edge. By doing so, the tendency of dropping at the nose, in the case of wider doors, is prevented. Thus, these types of doors can be used for wider openings.

Braces: width is 10–15 cm; thickness is 3-4 cm. All other members are of the same size as in the above case.

This door is commonly adopted for bathrooms where the appearance is not so important as economy (Figure 17.2).

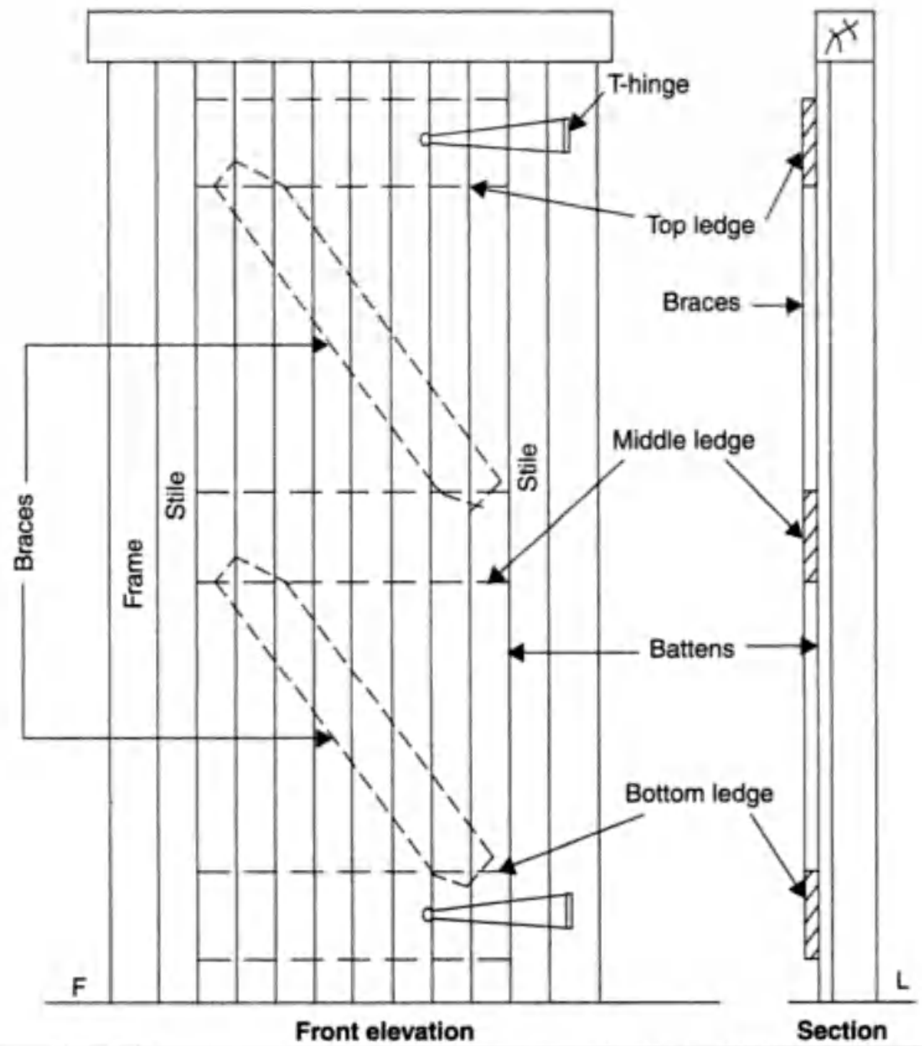


Figure 17.2 Battened, ledged and braced door

Copyrighted material

www.EngineeringBooksPdf.com

17.4.3 Battened, ledged and framed door

This door is provided with a framework for shutters to have better strength and appearance than the ordinary battened and ledged doors. This door consists of two vertical styles, three ledges or rails, bottom, top and middle and battened fixed in the framework. Battens and ledges are provided as usual. Stiles are generally 10 cm in width and 4 cm in thickness (Figure 17.3).

17.4.4 Battened, ledged, framed and braced door

This door is a modification over the previous type in which additional members known as braces have been introduced to increase its strength, durability and appearance. This type of door is largely used for external work. This door has a framework consisting of two stiles, three ledges on rails, battens and two inclined braces. Generally, the thickness of the top rail and the stiles is same and equal to that of the braces and batten together. The braces are 1.5 × 12 cm (Figure 17.4).

17.4.5 Framed and panelled door

This type of door is very commonly used and is constructed in various designs. The object of using such a door is to obtain a framework in which the tendency of shrinkages is reduced and the appearance enhanced. This type of door consists of a frame in which the panels are fitted. A double-leafed door is with modular dimensions of frame as 120 cm width and 10 cm height.

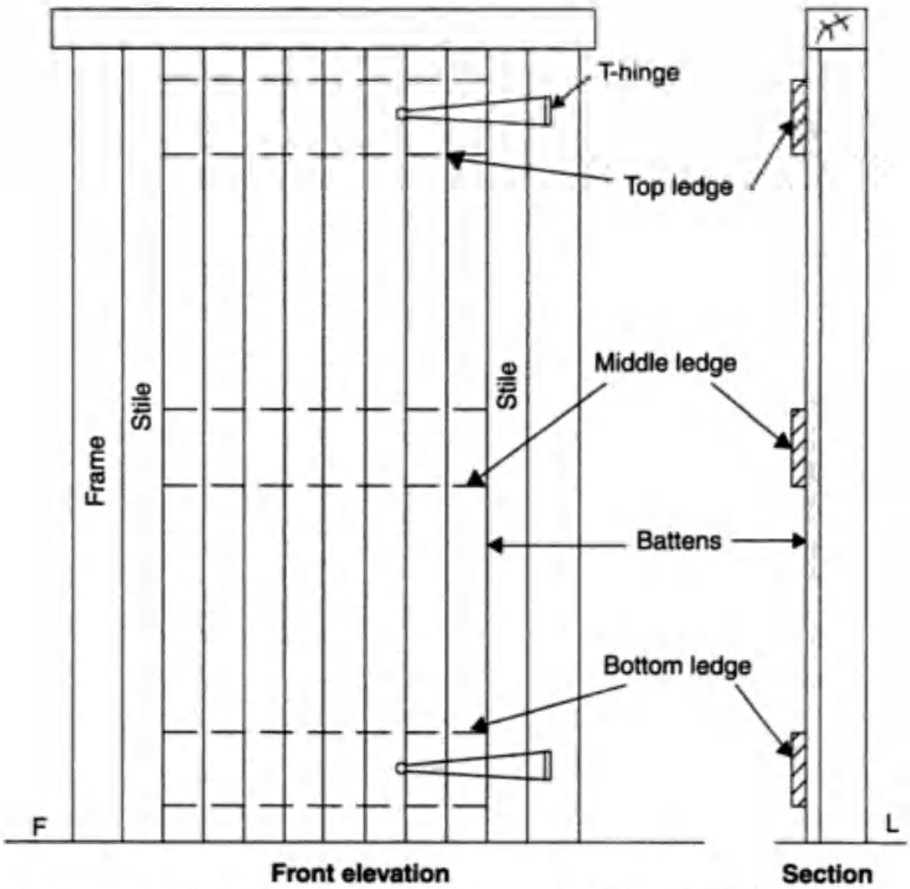


Figure 17.3 Battened, ledged and framed door

Copyrighted material

www.EngineeringBooksPdf.com

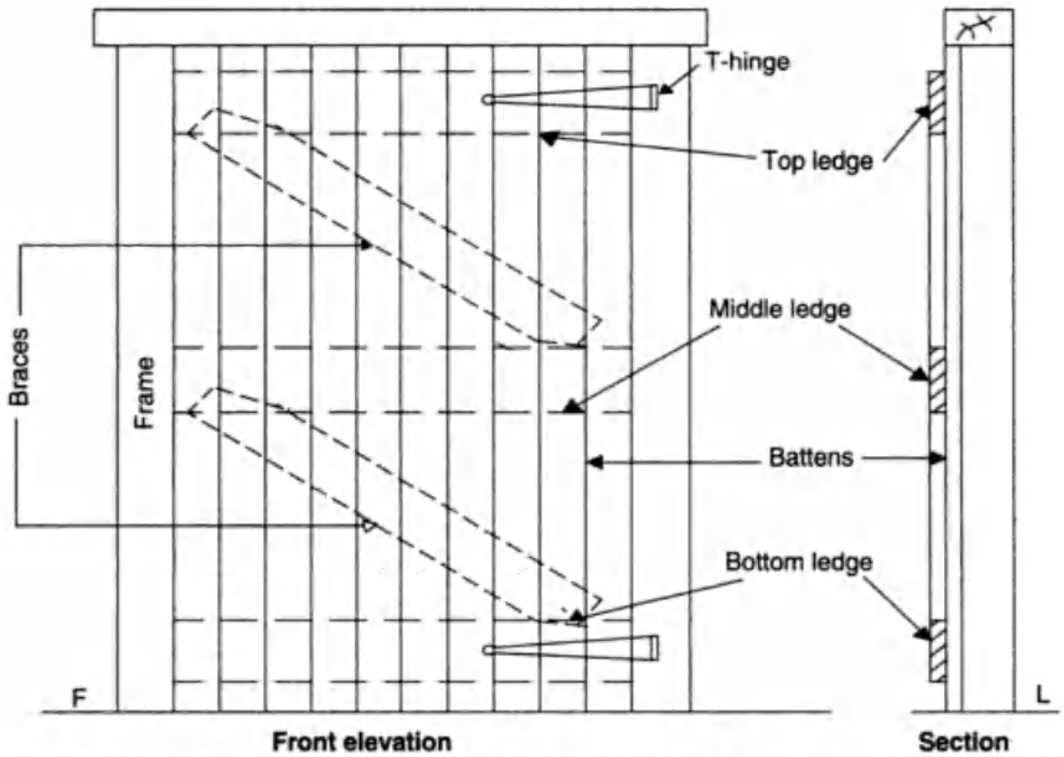


Figure 17.4 Battened, ledged, framed and braced door

a. The stiles are continuous from top to bottom for the full height.

b. The rails, top rail, bottom rail and lock rail, are jointed to the stiles.

c. The frame consists of narrow pieces, mortised and tenoned to each other and grooved on all the inside faces to receive the panels.

d. Bottom and lock rails are made of bigger size and are stronger than top and frieze rails.

e. It is generally recommended that the minimum width of stiles should not be less than 10 cm and for lock and bottom rails not less than 15 cm. The thickness of the shutter frame is usually kept 4-5 cm, but the actual value depends upon several factors like door size, situation of door, type of work, thickness of panels and size of the moulding (Figure 17.5).

17.4.6 Glazed or sash door

Sometimes, the doors either fully glazed or partly glazed and partly panelled are used to supplement the natural lighting provided by windows or to make the interior of one room visible from another (Figure 17.6). The glazed or sash door is extensively used these days in residential as well as public buildings. When sufficient light is required to be admitted through doors then fully glazed doors are provided (Figure 17.7). In the case of partly glazed and partly panelled doors, the usual proportion of glazed portion to the panelled portion is kept 2:1.

17.4.7 Flush door

Flush doors are becoming more popular these days for residential and public buildings because of several good characteristics like pleasing appearance, simplicity of construction, economy, strength and high durability.

Copyrighted material

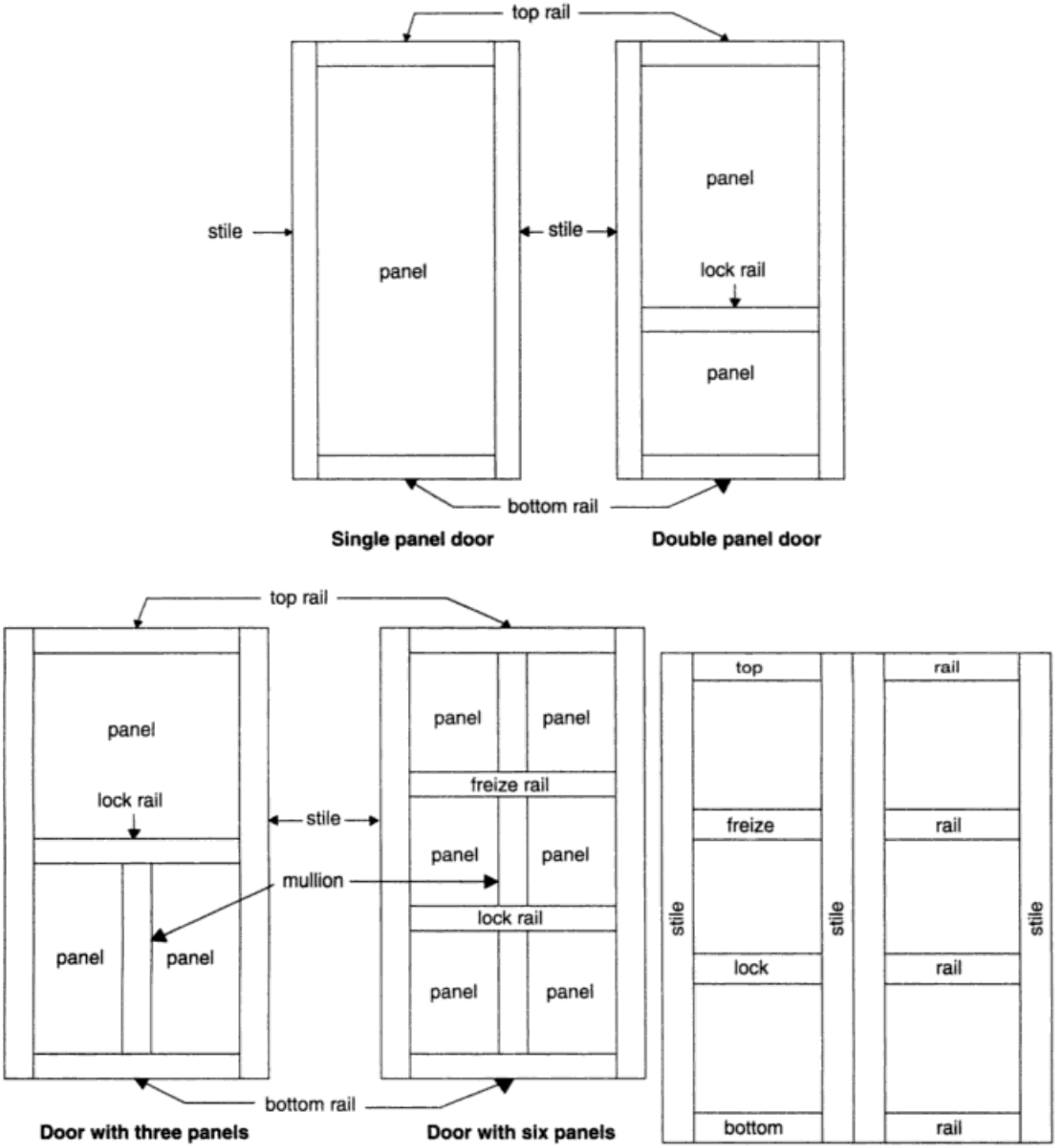


Figure 17.5 Framed and panelled door

Copyrighted material

www.EngineeringBooksPdf.com

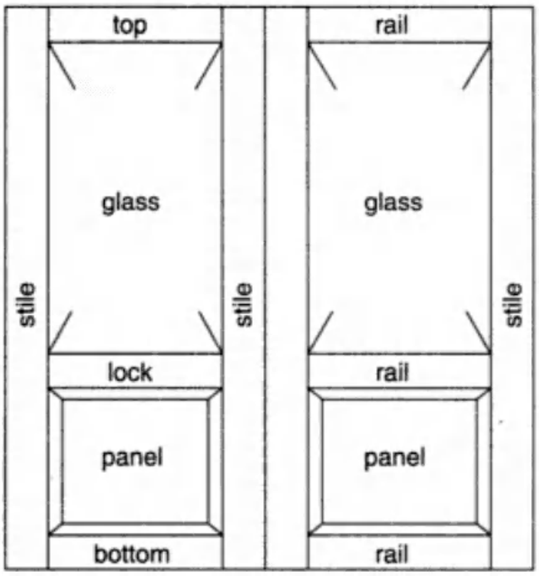


Figure 17.6 Partly panelled and partly glazed door

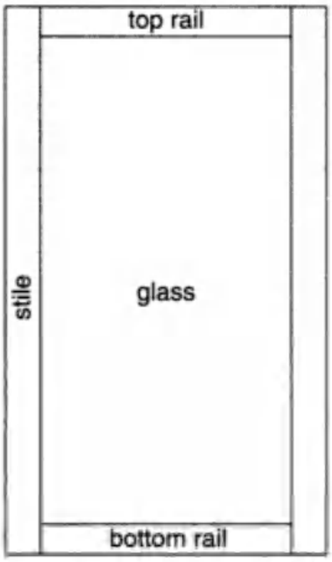


Figure 17.7 Fully glazed door

A flush door consists of a skeleton or a hollow framework of rails and stiles and it is covered on both the sides with laminated boards or plywood. This door has, therefore, fewer perfectly flush and joint surfaces on both the sides. The nominal thickness of flush door shutters varies from 25 to 40 mm depending upon the type of door (Figure 17.8).

a. *Solid Core Flush Door:* This door consists of a core of strips of a wood glued together under great pressure and faced on each side by plywood sheets. The laminated strips are not less than 20 mm in width and are glued edge to edge. The solid core or limited flush doors are heavy and require more material for their construction.

b. *Hollow and Cellular Core Flush Door:* In this type, the frame consists of stiles and top, bottom and intermediate rails, each not less than 7.5 cm wide, and this frame is covered on both the sides by

Copyrighted material

www.EngineeringBooksPdf.com

17.4.10 Collapsible steel door

The collapsible steel door neither requires hinges for opening and closing the shutters nor any frame for hanging them. This door is extensively used for the main entrance of residential buildings, shops, garages, etc. where the width of the door is large and the space is sufficient to provide two-leafed hinged shutters. This door being very strong can be used in exposed situations to safeguard against robbers. It may be made of single or double shutters depending upon the size of the opening.

It is fabricated from vertical pieces of rolled steel channels 16–20 mm wide, joined together with the hollows of the channel on the inside, leaving a vertical gap of 12–20 mm between them. Rollers are provided both at their top and bottom or at the top in some case. The doors can be opened or closed by a slight pull or push. The vertical channel pieces are spaced at 10–12 cm centre to centre and are joined to one another by means of hoop iron cross pieces or flats 16–20 mm wide and 5 mm thick, which allow the door to open or fold (Figure 17.9).

17.4.11 Rolling steel shutter door

This door is capable of being rolled up at the top easily and causes no obstruction either in the opening or floor space. It is commonly used for the main entrance of shops, garages, godowns, etc. It is sufficiently strong and offers proper safety to the interior when closed. A rolling steel door consists of a frame, a drum and a shutter of thin steel plates or iron sheets of thickness about 1 mm and width varying up to 6 m. Steel guides are provided on the sides for the movement of shutters. The door is counterbalanced by means of helical springs enclosed in the drum.

17.4.12 Revolving door

This door provides entrance on one side and exit on the other side simultaneously. It keeps the opening automatically closed when it is not in use. These doors are provided where there is constant foot traffic of people entering and leaving the entrance of public buildings. Revolving doors consist of four upright cross

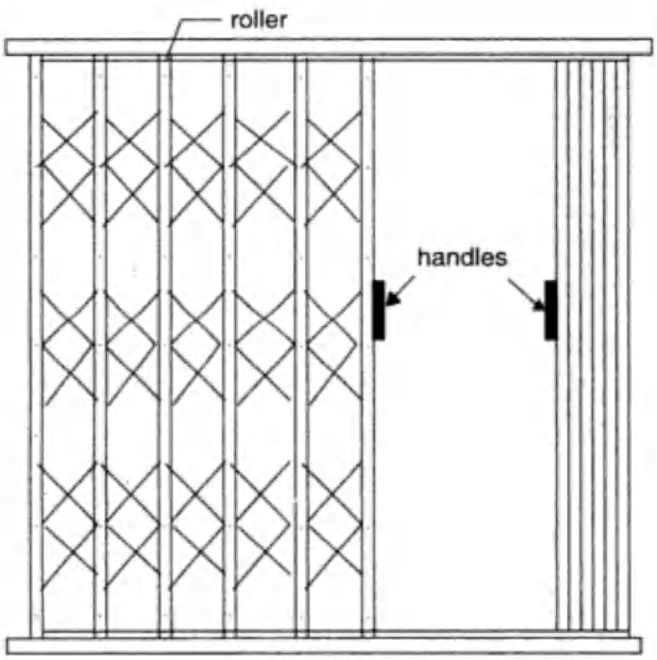


Figure 17.9 Collapsible door

Copyrighted material

www.EngineeringBooksPdf.com

17.6 FIXTURES AND FASTENINGS FOR DOORS AND WINDOWS

The various fixtures used are:

1. Hinges
2. Bolts
3. Locks
4. Handles

The most commonly used type of hinges is the butt hinge whose length varies from 1 to 20 cm. Various other types of hinges like counter flap hinges, spring hinges and parliamentary hinges are also being used.

Barrel bolts and tower bolts are the most commonly used type and their length varies from 10 to 40 cm. Hook and eye is another type which is commonly used for windows. Hasp and staple bolt and Aldrop bolt is used where padlocks are used.

Mortice locks are used for thicker doors and are embedded in the door frame. Otherwise, pad locks are also used.

REVIEW QUESTIONS

1. What are the main functions of doors and windows in a building?
2. What are the functional requirements for doors and windows to perform their basic functions?
3. What are the rules to be observed while locating doors and windows in a building?
4. Briefly discuss the classification of doors according to the operational point of view.
5. Briefly discuss the classification of windows according to the operational point of view.
6. Briefly discuss
   a. Battened and ledged doors
   b. Battened, ledged and braced doors
7. Briefly discuss framed and panelled doors and flush doors.
8. With a neat sketch give a brief description about collapsible doors.
9. Depending upon the material used how are windows classified?
10. What are the general fixtures and fastenings used for doors and windows?

Copyrighted material

www.EngineeringBooksPdf.com

3. ***Hip roof:*** This roof slopes in four directions such that the end formed by intersection of slopes is a sloped triangle.
4. ***Gambrel roof:*** This roof like the gable roof slopes in two directions but there is a break in the slope on each side.
5. ***Mansard roof:*** This roof like the hip roof also slopes in four directions but there is a break in slopes.
6. ***Ridge:*** It is an apex line of a sloping roof.
7. ***Ridge piece or ridge beam or ridge board:*** This is a wooden piece or board, which runs horizontally at the apex (highest point on the roof). The common rafters are fixed to this piece and are supported by it.
8. ***Common rafters or spans:*** These are inclined wooden members supporting the battens or boarding to support roof covering. They run from a ridge to the eaves (edges). They are normally spaced at 30–45 cm centre to centre depending upon the roof covering material.
9. ***Hip:*** It is the line produced when two roof surfaces intersect to form an external angle, which exceeds 180°. Hipped end is a portion of the roof between two hips.
10. ***Jack rafters:*** These are common rafters shorter in length, which run from a hip to the eaves or from a ridge to a valley. A hip or valley is formed by the meeting of jack rafters.
11. ***Valley rafters:*** These are sloping rafters which run diagonally from ridge to the eaves for supporting valley gutters. They receive the ends of the purlins and ends of jack rafters on both sides.
12. ***Valley:*** A valley is the reverse of a hip. It is formed by the intersection of two roof surfaces having an external angle, which is less than 180°.
13. ***Eaves (edges):*** These are the lower edges of the inclined or pitched roof from which the rainwater from the roof surface drops down. Normally, gutters are fixed along the eaves to collect and drain the rainwater.
14. ***Eaves board:*** This is a wooden board fixed to the feet of the common rafters at eaves. The ends of the lower most roof covering material rest upon it. The eaves gutter can also be secured against it. Normally, eaves board is 15–20 cm wide and 20–25 mm thick.
15. ***Barge boards:*** These are wooden planks on boards fixed on the gable end of a roof. They connect the ends of ridges, purlins and wall plates.
16. ***Battens:*** These are thin strips of wood which are fixed on the common rafters or on the top of ceiling boards to support the roofing materials.
17. ***Cleats:*** These are small blocks of wood or steel that are fixed on the principal rafters to support the purlins.
18. ***Purlins:*** These are horizontal wooden or steel members laid on principal rafters on wall to wall to support common rafters of a roof when the span is large.
19. ***Wall plates:*** These are long wooden members, which are embedded from the sides and bottom in masonry on top of walls, almost at the centres of their thickness. This is essential to connect the walls to the roof. The feet of the common rafters are fixed to the wall plates by means of simple notching and nails.
20. ***Truss:*** A roof truss is a framework of triangles designed to support the roof covering or ceiling over rooms. The use of interior columns is avoided.

Copyrighted material

www.EngineeringBooksPdf.com

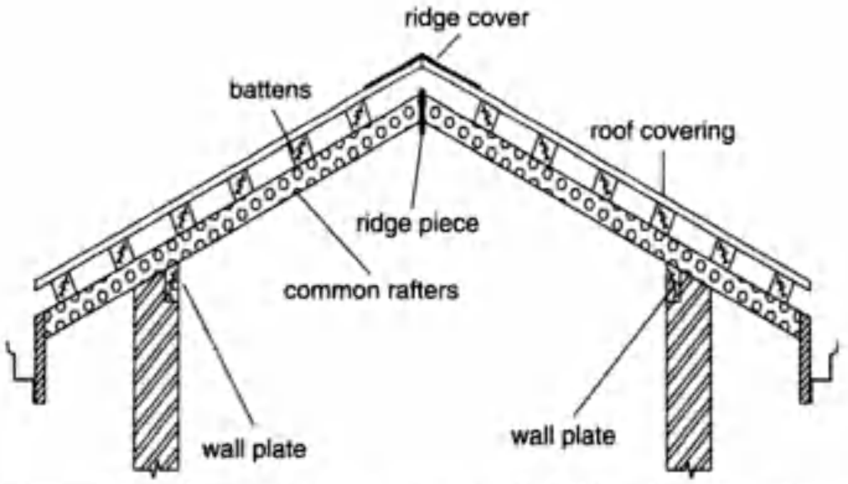


Figure 18.2 Couple roof

of dovetailed halved joint, but for inferior work the ties are just spiked to the rafters. Under normal loading conditions this type of roof can be used for a maximum span of 4.5 m. However, for increased spans or greater loads the rafters have a tendency to sag in the middle. To check this tendency a couple close roof is supported by a central vertical rod known as king rod or king bolt between the ridge piece and the centre of the tie beam (Figure 18.3).

18.2.4 Collar beam roof

It is used for spans between 4 and 5.5 m. A collar of the same width as the rafter is fixed to every pair of rafters and it is attached at a height of half to one-third of the vertical height between the wall and the ridge. The collar is dovetailed with the rafter and the bolts can be used for additional safety. It is desirable to place the collar as low as possible to provide maximum strength to the roof (Figure 18.4).

18.2.5 Collar and tie roof

It is used when the roof spans exceed 5.5 m. It is a combination of collar beam roof and couple close roof. The rafters are supported by purlins and the purlins rest at the ends on walls. A collar and strut are employed

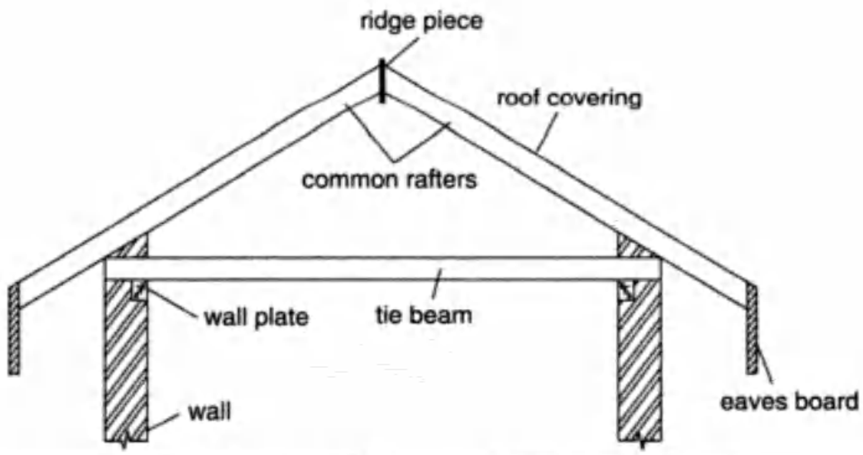


Figure 18.3 Couple close roof

Copyrighted material

www.EngineeringBooksPdf.com

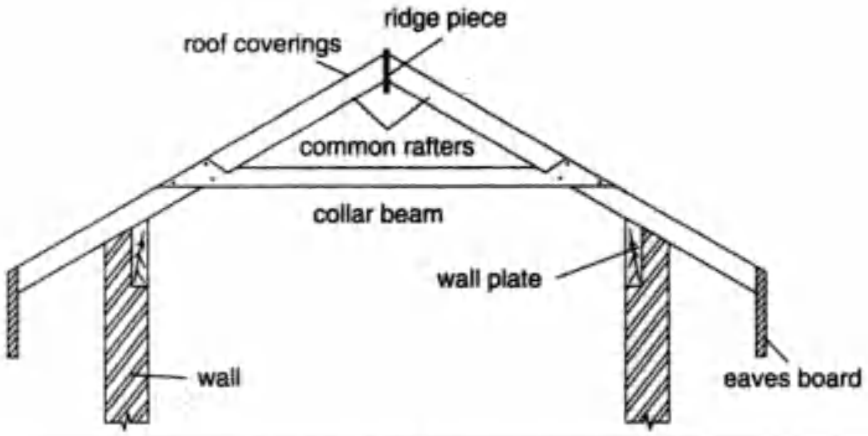


Figure 18.4 Collar beam roof

to support the purlins and rafters. Its use is recommended when purlins may be supported at the ends with reasonable economy.

18.2.6 King post truss

For spans greater than 4.8 m, when no intermediate supporting walls for the purlins are available, framed structures known as trusses are used. The spacing between trusses is guided by the load coming on the roof, material of the truss, span and the location of cross walls.

In a king post truss, the central vertical post called as king post provides a support for the tie beam. The inclined members are known as struts and are used to prevent the principal rafters from bending at the centre. A king post truss can be used economically for spans 5–8 m.

The joint between the king post and the tie beam is an ordinary mortise and tenon joint. An iron stirrup is also provided to strengthen the joint further. For joining principal rafters and the king post, a tenon is cut in the principal rafter and the corresponding mortice into the head of the king post. A bridle joint is provided to connect the principal rafter with the tie beam. Joints between the king post and the strut are also mortice and tenon joints (Figure 18.5).

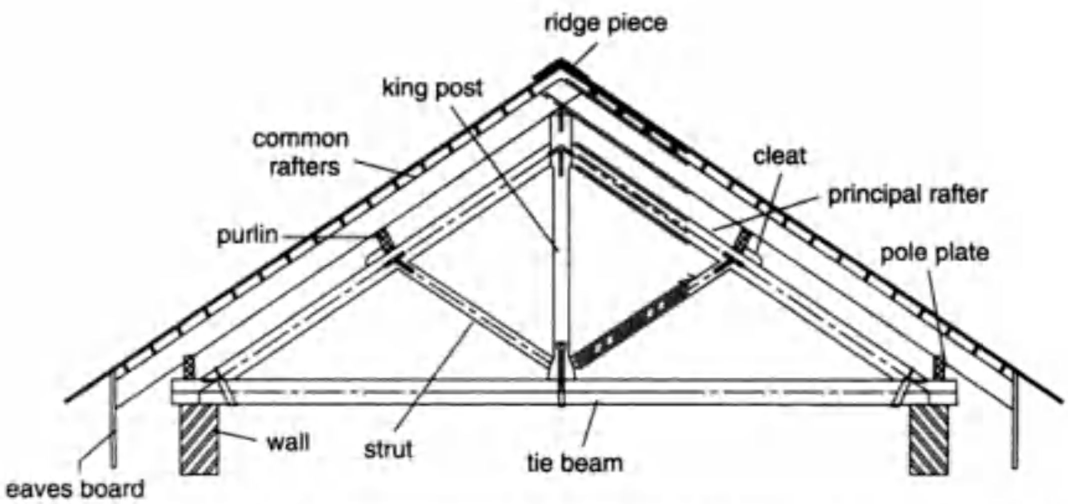


Figure 18.5 King post truss

Copyrighted material

www.EngineeringBooksPdf.com

18.2.7 Queen post truss

It can be used for spans 9–14 m. It varies from the king post truss in having two vertical members known as queen posts. The heads of the queen posts are put apart by a horizontal member known as straining beam. The head of the queen post is made wider to receive the principal rafter and the straining beam. The top end of the principal rafter and the end of the straining beam are tenoned into the widened head of the queen posts. A three-way iron or mild steel strap is fixed to further strengthen the joint. The bottom end of the queen post is tenoned into the tie beam and a steel stirrup strap is fixed by jibs and cotters to make the joint stronger. The tenon of the inclined strut is inserted into the splayed shoulder of the queen post. The other joints in this truss are similar to that of the king post truss (Figure 18.6).

18.2.8 Mansard truss

It is a combination of king post truss and queen post truss. The upper portion has the shape of a king post truss and the lower portion resembles a queen post truss. The truss has two pitches. The upper pitch varies from 30 to 40° and the lower pitch varies from 60 to 70°. This type of truss is economical and in the span an extra room may be provided. This type of truss is now rarely used due to its ugly appearance. The construction of various joints is similar to that of the king post trusses.

18.2.9 Belfast roof trusses

This truss is in the form of a bow and is also called bow string or latticed roof truss. It is made of thin sections of timber. This truss can be used for big spans up to 30 m provided light roof coverings are used. The central rise in this type of truss is usually kept about one-eighth of the span.

18.2.10 Steel trusses

The use of steel trusses has become economical for spans greater than 12 m. Various standard shapes and sizes of rolled steel are available for the fabrication of steel trusses. This type of truss is designed in a manner that members are either in compression or in tension and bending stress is not allowed to develop in them.

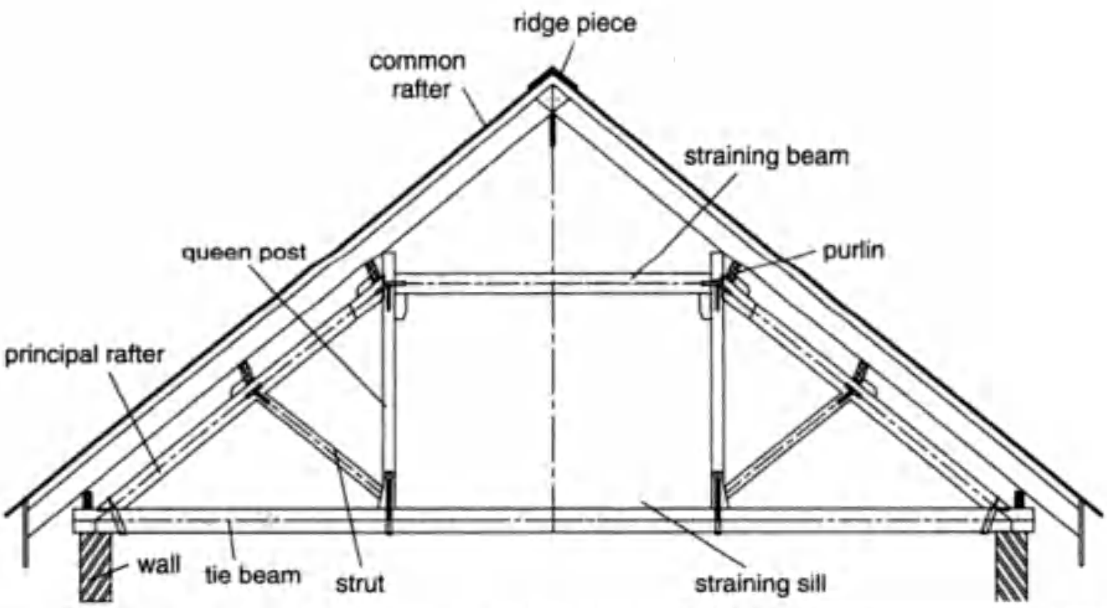


Figure 18.6 Queen post truss

Copyrighted material

www.EngineeringBooksPdf.com

The size and type of the truss depends upon the roof slope, span, centre-to-centre distance of the trusses and the load coming over the roof. T-sections are best suited for use as principal rafters, whereas angle iron or channel section is used as struts. The tension members should preferably be of a flat or round section. The different members of the truss may be fabricated with two or more sections joined together. The members of a truss are joined by rivets or bolts or by welding the plates known as gusset plates. The minimum spacing of the rivets should not be less than 3 times the diameter and the maximum spacing is limited to 15–20 cm in compression and tension members.

The minimum number of rivets to be used at any joint should not be less than two. Gusset plates are designed for the forces coming at the junction but the least thickness should be adopted as 6 mm. The ends of the trusses are placed on bed plates provided on the walls. The bed plate maybe of stone or concrete. The ends of the truss are bolted down with lewis or rag bolts which hold down the truss firmly. The small trusses are pre-fabricated in the workshop on the ground and are then placed in the required position. The bigger trusses are pre-fabricated in smaller parts and then erected in the required position and fixed by gusset plate and riveting or welding.

The relative advantage of steel roof trusses over timber sloping trusses are as follows:

a. Steel sections forming the roof truss are light in weight and can be fabricated in different shapes and sizes. It suits the structural as well as architectural requirements.

b. Steel trusses being made of mild steel sections are free from the attack of white ants and dry rot.

c. Steel trusses are much stronger than timber trusses and they are equally strong in tension and compression.

d. These trusses have a greater resistance against fire and hence are especially suited where fireproof construction is desired.

e. Timber trusses can only be used up to a minimum span of 14 m or so, whereas there is no span restriction in case of steel trusses. Steel trusses are used for structures requiring large spans such as industrial buildings, large sheds, assembly halls, hangers and auditoriums.

f. The various sections forming a steel truss can be easily machined and shaped in the workshop and subsequently packed and transported to the site for assembling. Moreover, there is no wastage in cutting.

g. The erection of steel trusses from the rolled sections is very easy, rapid and economical.

18.3 FLAT ROOFS

A roof which is approximately flat is called a flat roof. It is becoming more popular with the introduction of suitable building materials. It may be constructed in reinforced cement concrete (RCC), flag stone supported on rolled steel joist, bricks, concrete or tiled arches. This roof is provided with a slight slope in one direction to drain off the rainwater easily. The construction of flat roofs is similar to the construction of floors except that the top surface is protected against rainwater.

18.3.1 Advantages of flat roof

a. The roof can be used as a terrace for playing or for sleeping or for other domestic purposes.

b. The construction and maintenance of the flat roof is simpler.

c. It provides better architectural appearance to the building.

Copyrighted material

www.EngineeringBooksPdf.com

7. ***Resistance to fire:*** The roof covering should offer sufficient resistance in the event of fire. From the fire resistance point of view, roof covering of slates, AC sheets, GI sheets, etc. are considered to be quite satisfactory, whereas thatch and shingles are unsatisfactory for this purpose.
8. ***Heat insulation:*** The roof covering should offer adequate insulation against heat so that the inside of rooms can be kept cool and comfortable for living. This is particularly important in tropical countries.
9. ***Weight of roofing material:*** The weight of roof covering affects the design, weight and the cost of roof deck as well as supporting structure and frame work. Heavier roof covering requires stronger supporting structure, which adds to the cost.
10. ***Appearance:*** It is an important factor for residential and other public buildings but is of less significance in the case of industrial buildings. The appearance depends upon the architectural style of the building and the class of occupancy.

18.7 ROOF COVERING MATERIALS

Roof covering material provides protection to the roof and the structure. It prevents rainwater, moisture, heat, dust, etc. from entering into the building from top. The roof covering does not share load in the building. It is rigidly fixed to the roofing structure with various types of fittings and fixtures. The various types of roof covering materials used include the following.

18.7.1 Thatch covering

This form of covering is extensively used in sheds, low-cost houses and village buildings. It is considered suitable for rural areas because it forms the cheapest and the lightest material as a roof covering.

The frame work for supporting the thatch consists of round bamboo rafters spaced at 30 cm and tied with split bamboos or bamboo reapers laid at right angles to the rafters. The thatch is tightly secured to the framework or battens with the help of ropes or twines dipped in tar. Sometimes fire-resisting properties are imparted to the thatch by soaking it in specially prepared fire-resisting solutions that are very costly. For adequate drainage of rainwater the thatch covering should be at least 15 cm thick and laid with a slope of 45°.

18.7.2 Shingles

The use of wood shingles as a roof covering is generally restricted to hilly areas where wood is easily and cheaply available in abundance. Wood shingles are nothing but the sawn or split thin pieces of wood resembling slates or tiles. These sawn shingles, which are obtained from well-seasoned timber, are dipped in creosote to impart preservative qualities. Shingle strips are driven on rafters and shingles are nailed on their top. Shingles are commonly obtained in length varying from 30 to 50 cm and in width varying from 5 to 25 cm.

18.7.3 Tiles

The use of tiles is one of the oldest method of roof covering. The tiles are named according to their shape and pattern and they are manufactured in a similar manner as bricks. The clay tiles are of various types such as flat tiles, pan tiles, pot tiles or half-round country tiles and patent tiles such as Mangalore and Allahabad tiles. Sometimes cement concrete tiles are also used, but is limited on account of high cost and the difficulties in their manufacture. Clay tiles have been widely used as a roof covering material for residential buildings.

Copyrighted material

www.EngineeringBooksPdf.com

Floors

Floors are provided to divide a building into different levels for creating more accommodation one above the other within a certain limited space. The bottom floor near the ground is known as the ground floor and the other floors above it are termed as upper floors, like first floor and second floor. If there is any accommodation constructed below the natural ground level, it is known as basement and the floor provided in it is known as the basement floor.

A floor may consist of two main components:

a. A sub-floor that provides proper support to the floor covering and the superimposed loads carried on it.

b. A floor covering which provides a smooth, clean, impervious and durable surface.

19.1 FACTORS AFFECTING SELECTION OF FLOORINGS

Each type of floor has its own merits and there is not even a single type which can be suitably provided under all circumstances, and more so when floors have to serve different purposes in different types of building.

1. ***Initial cost:*** The cost of construction is very important in the selection of a type of floor. A floor covering of marbles, granite, special clay tiles, etc. is considered to be very expensive, whereas a flooring of cork, slate, vinyl tile, etc. is moderately expensive. The floors made of concrete and brick offer the cheapest type of floor construction. It should be ensured during the comparison of cost for different floors that the cost of both covering and sub-floor has been accounted for.

2. ***Appearance:*** Flooring should produce the desired colour effect and architectural beauty in conformity with its use in the building. Generally, flooring of terrazzo, tiles, marble and cement mortar provides a good appearance whereas the asphalt covering gives an ugly appearance.

3. ***Cleanliness:*** A floor should be non-absorbent and capable of being easily and effectively cleaned. All joints in flooring should be such as to offer a watertight surface. Moreover, greasy and oily substances should neither spoil the appearance nor have a destroying effect on the flooring materials.

4. ***Durability:*** The flooring material should offer sufficient resistance to wear and tear, temperature, chemical action, etc. so as to provide long life to the floors. From the durability point of view, flooring of marble, terrazzo, tiles and concrete is considered to be of the best type. Flooring of other materials such as linoleum, rubber, cork, bricks, wood blocks, etc. can be used where heavy floor traffic is not anticipated.

5. ***Damp-resistance:*** All the floors, especially ground floors, should offer sufficient resistance against dampness in buildings to ensure a healthy environment. Normally, floors of clay tiles, terrazzo, concrete, bricks, etc. are preferred for use where the floors are subjected to dampness.

6. ***Sound insulation:*** According to modern building concepts, a floor should neither create noise when used nor transmit noise. Sometimes, it is required that any movement on the top floors should not

Copyrighted material

www.EngineeringBooksPdf.com

disturb the persons working on the other floors. Suitable flooring is provided which is somewhat noiseless when travelled over.

7. ***Thermal insulation:*** It should be possible for a building to maintain constant temperature or heat inside the building irrespective of the temperature changes outside. Thermal insulation is needed to reduce the demand of heating in winter and refrigeration in summer. It is important in the case of wooden floors where heat losses are considerable and in solid floors with heating pipes or cables where the heat losses at the edges of the floor slab can be higher. Floors of wood, cork, etc. are best suited for this purpose.
8. ***Smoothness:*** The floor covering should be of superior type as to exhibit a smooth and even surface. However, at the same time, it should not be too slippery which will otherwise endanger safe movements over it, particularly by old people and children.
9. ***Hardness:*** It is desirable to use good quality floor coverings, which do not give rise to any form of indentation marks, imprints, etc. when used for either supporting the loads or moving the loads over them. Normally, the hard surfaces rendered by concrete, marble, stone, etc. do not show any impressions, whereas the coverings like asphalt, cork, plastic, etc. do form marks on the surfaces when used in traffic.
10. ***Maintenance:*** It is always desired that the maintenance cost should be as low as possible. Generally, a covering of tiles, marble, terrazzo or concrete requires less maintenance cost as compared to the floors of wood blocks, cork, etc. It should, however, be noted that the repairing of a concrete surface is more difficult than the floorings of tiles, marbles, etc.

19.2 TYPES OF FLOOR

The various types of floor commonly used are as follows.

19.2.1 Basement or ground timber floor

Timber floors are constructed on ground floors, generally in theatres. Several sleeper walls or dwarf walls of half brick thickness or full brick thickness are constructed at an interval of 1.5 m to support the timber floor. Wall plates are placed on walls and sleeper walls to support the joists supporting the floors. The joists are provided at a distance of about 30 cm and the timber planks are closely fitted over the joists to provide the floor. The arrangement for proper air circulation is made in the floor, otherwise timber will be attacked by dry rot. The following precautions are recommended:

a. Well-seasoned timber should be used in the construction of such floors.
b. Plain cement concrete 1:2:4 of 10 cm thickness is to be provided over the soil beneath the timber floor.
c. The empty space between the floor and the concrete base should be filled up with sand.
d. The damp proofing courses are to be placed in the external walls and at the top of the sleeper walls.

19.2.2 Single joist timber floor

This type of floor is used for residential buildings where spans are comparatively small and the loads are lighter. The wooden joists are placed at about 30 cm centre to centre, spanning the rooms in the shorter direction. Wooden planks are laid over these joists. The timber joists are supported on wall plates. Corbels

Copyrighted material

www.EngineeringBooksPdf.com

may be required to support the joists if the width of the wall is not sufficient. Joists must be strong enough to withstand the loads and at the same time they should not deflect too much. If the length of the joist is more than 3.5 m, then struts are provided in the joists to check side buckling. The wooden planks are about 4 cm thick and 10–15 cm wide.

19.2.2.1 Advantages

i. Single joist timber floors are simple to construct.

ii. They require less initial cost.

iii. Distribution of loads on the wall is more uniform as the joists are spaced closely.

19.2.2.2 Disadvantages

i. The joists may sag and, hence, cracks will develop in the ceilings.

ii. They are not soundproof.

iii. Deep joists are required for larger spans that increase the weight and construction cost of the floor.

iv. The loads are transmitted to the openings such as windows or door lintels because of evenly spaced joists.

19.2.3 Double joist timber floor

This type of floor is stronger than the single joist timber floor. They are used for longer spans of 3.6–7.5 m and prevent the travel of sound waves to a great extent. Intermediate supports called binders are placed for bridging the joists. Binders are spaced at a centre-to-centre distance of about 2 m. The ends of binders are kept on wooden or stone blocks and they should not be embedded in the masonry wall. The ceilings may be fixed to the bottom of the binders by fixing a ceiling joist to the binders. Lathing is fixed to the ceiling joist.

19.2.3.1 Advantages

i. The loads are transmitted to the wall at certain specified points and, hence, door and window openings may be avoided.

ii. This is a more rigid type of flooring and, hence, there is less chance of developing cracks in the plastered ceiling.

iii. It is more soundproof.

iv. The use of additional binders near the walls can eliminate the need of wall plates.

19.2.3.2 Disadvantages

i. More labour is required

ii. The depth of the floor is considerably increased and, thus, the head room is reduced

19.2.4 Framed timber floor

This type of timber floor is used for spans of more than 7.5 m. Girders are placed between the walls and the binders are put on the girders and the bridging joists rest on the binders. The spacing between girders depends

Copyrighted material

www.EngineeringBooksPdf.com

19.3.3 Stone floor covering

Square or rectangular slabs of stones are used as the floor covering. Generally, 20–40 mm thick stone slabs of size 30 cm × 30 cm, 45 cm × 45 cm, 60 cm × 60 cm, 45 cm × 60 cm, etc. are used. The stone should be hard, durable, tough and of good quality. The earthen base is levelled, compacted and watered. On this surface a layer of 10–15 cm thick concrete is laid and properly rammed. Over this concrete bed the stone slabs are fixed with a thin layer of mortar. Before fixing the stone slabs in position, they are dressed on all the edges and the joints are finished with cement. The stone surface may be rough or polished. A rough surface is provided in rough works like godowns, sheds, stores, etc. and a polished surface is provided in superior type of works. A slope of 1:40 should be provided in such type of floor covering for proper drainage.

19.3.4 Concrete floor covering

The concrete flooring consists of two layers:

a. A base course or the subgrade and
b. A wearing course

The concrete flooring consists of a topping of cement concrete 2.5–4 cm thick laid on a 10–15 cm thick base of either lime or cement concrete. The actual construction operation consists of:

a. Ground preparation
b. Formation of base course
c. Laying of topping concrete
d. Laying of wearing coat
e. Grinding and polishing and
f. Curing

19.3.4.1 Merits

i. It is non-absorbent and, hence, offers sufficient resistance to dampness. This is used for water-retaining floors as well as stores.
ii. It possesses high durability and, hence, is employed for floors in kitchens, bathrooms, schools, hospitals, etc.
iii. It provides a smooth, hard, even and pleasing surface.
iv. It can be easily cleaned and overall has proved economical due to less maintenance cost.
v. Concrete being a non-combustible material offers a fire-resistant floor required for fire-hazardous buildings.

19.3.4.2 Demerits

i. Defects once developed in concrete floors, whether due to poor workmanship or materials, cannot be easily rectified.
ii. The concrete flooring cannot be satisfactorily repaired by patchwork.
iii. It does not possess very satisfactory insulation properties against sound and heat.

Copyrighted material

www.EngineeringBooksPdf.com

19.3.5 Tiled floor covering

Clay tiles of different sizes, shapes, thickness and colours are prepared and they are used as floor coverings. They are placed in position on a concrete base with a thin layer of mortar. When these tiles are to be fixed on timber floors, special beds of emulsified asphalt and Portland cement are used.

19.3.5.1 Merits

i. It provides a non-absorbent, decorative and durable floor surface.

ii. It permits quick installation or laying of floors.

iii. It is easily repaired in patches.

19.3.5.2 Demerits

i. It is generally costly in initial cost as well as in maintenance cost.

ii. On becoming wet, it provides a slippery surface.

Vitrified tiles

Vitrified tiles have zero water absorption property. They resemble granite but offer a great variety in terms of finish, colour and design options. Polished vitrified tiles such as mirror stone, granamite and marbogranite are cheaper than marble and granite.

Ceramic tiles

Ceramic tiles are non-slippery and are used in wet areas like bathrooms and kitchens. They are available in a variety of interesting shapes, wide range of colours and textures. They are used in living rooms also. Ceramic tiles are usually embedded in mortar. Special tile adhesives and tile grouts are also available which allow easy laying and render the tiled area useable within 24 hours.

Laying of tiles

Use a waterproof, floor tile adhesive which allows slight flexibility when set. Follow the manufacturer's instruction and use a notched or plain trowel, as directed, to spread the adhesive on the floor over a manageable area for laying approximately 10 tiles.

Use a layer of adhesive on the back of the tile and press into the desired position. It is very important to lay the first tile correctly, as its position will determine the position of all the other tiles in the room. Use a batten nailed to the floor to give a straight edge to guide the positioning of the tiles. Remember to use plastic spacers or a thick card to regulate the distance between the tiles. These areas will be grouted when the floor is complete and must be equally spaced for neat, accurate results.

Use a spirit level to check the horizontal level and a straight edge to continually check the position of the tiles on the floor. Continue across the room and work towards the door. Leave the room for 24 hours. Then remove the battens and cut the border tiles and fix in a similar way. Remove the plastic spacers or thick card and grout the tiles.

Grout is available in a variety of colours, but the standard colours are white, grey or brown. However, most floor tiles are grouted with a mortar mix. Use a plastic scraper or a rubber blade to push the grout between the gaps in the tiles. Make sure all the spaces are evenly filled and then wipe the grout off the tile surface before it dries. Use a blunt edge of a stick or tool carefully to smooth the surface of the grout in the gaps, but do not

Copyrighted material

www.EngineeringBooksPdf.com

'dig down' into the grout. Remove any excess grout before it dries. Allow the floor to dry completely before polishing the surface of the tiles with a dry cloth.

19.3.6 Wooden floor covering

This type of floor covering is the oldest type, but nowadays it is used for some special-purpose floors such as theatres and hospitals. It possesses natural beauty and has enough resistance to wearing. Wooden floor covering may be carried out in one of the following three types:

a. Strip floor covering: This is made up of narrow and thin strips of timber which are joined to each other by tongue and groove joints.
b. Planked floor covering: In this type of construction, wider planks are employed and these are joined by tongue and groove joints.
c. Wood block floor covering: It consists of wooden blocks which are laid in suitable designs over a concrete base. The thickness of a block is 20–40 mm and its size varies from 20×8 to 30×8 cm. The blocks are properly joined together with the ends of the grains exposed.

19.3.7 Mosaic floor covering

This type of floor covering is commonly used in operation theatres, temples, bathrooms, etc. A concrete base is constructed for laying the floor covering. Over this base lime or cement mortar is placed to a depth of about 2 cm and it is levelled up. A layer of cementing material about 3 mm in thickness is spread. The cementing material consists of two parts of slaked lime, one part of powdered marble and one part of pozzolana. After 4 hours of laying this cementing material, a mixture of coloured cement and chips are laid. This surface is left for 24 hours and then it is rubbed with pumice stone to get a smooth and polished surface. The polished surface is left for about 2 weeks before use.

19.3.8 Rubber floor covering

It consists of pure rubber mixed with cotton fibre, granulated cork or asbestos fibre and the desired colouring pigments. A small amount of sulphur is also added. Its thickness varies from 3 to 10 mm and it is available in many designs and patterns. It is available in the form of tiles or sheets and can be directly laid over the floor by the vulcanizing process. It is mostly used in hospitals, radio stations, etc. The flooring is elastic, attractive, comparatively warm and soft.

19.3.9 Linoleum floor covering

It is the fabricated form of a mixture of resins, linseed oil, gums, pigments, wood flour, cork dust and other filler materials. It is available in the market in rolls of width about 2–4 m. The thickness varies from 2 to 6 mm. These tiles are also manufactured in various sizes, shapes and patterns. This floor covering is laid over an effective damp-proof course. It is cheap, durable, attractive, comfortable and moderately warm. It can be cleaned easily.

19.3.9.1 Merits

i. It provides an attractive, resilient durable and cheap surface.
ii. It offers a surface that can be easily washed and cleaned.

Copyrighted material

www.EngineeringBooksPdf.com

iii. Being moderately warm with cushioning effect, it provides comfortable living and working conditions.

iv. It offers adequate insulation against noise and heat.

19.3.9.2 Demerits

i. It is subjected to rotting when kept wet for sufficient time and its use is not recommended for basements.

ii. It does not offer resistance against fire, being combustible in nature.

iii. This covering when applied over a wooden base may get torn under excessive sub-floor movements.

19.3.10 Glass floor covering

It is used when it is desired to admit light to the floor below. Structural glass is available in the form of slabs or tiles. They are fitted within frames of different types. The members of the frame are closely spaced such that the glass floor covering can take up the superimposed loads without breaking. This type of floor covering is not commonly used.

19.3.11 Magnesite floor covering

It is known as composite flooring or jointless flooring. It is composed of a dry mixture of magnesium oxide, a pigment and inert filler materials, e.g., wood flour, asbestos or sawdust. Liquid magnesium chloride is mixed to this powder and a plastic material is obtained in situ. This plastic material is laid over the floor and the surface is levelled with a trowel. It can be directly laid over stone, concrete or wooden floor base. It is cheap and is used as floor covering for office buildings, schools, factories, etc.

19.3.12 Plastic floor covering

Thermoplastic tiles can be economically used as floor covering on the concrete floor base. It is generally not laid on a wooden floor base as the preparation of the wooden surface for receiving the tiles is very costly. Plastic floor covering has been used with success in all types of buildings like offices, hospitals, shops, schools and residential buildings.

19.3.13 Terrazzo floor covering

Terrazzo is a mixture of cement and marble chips and the surface is polished with carborundum stone to obtain a smooth finish at the top. The base for this type of floor covering is concrete and is laid in the ordinary way. On the 3 cm concrete (1:3) base, a thin layer of sand is sprinkled evenly and it is covered by tarred paper. A layer of rich mortar is spread over it and then terrazzo mixture is placed over it evenly. Marble chips of 3–6 mm are mixed with white or coloured cement in the proportion 1:2 or 1:3 to get the terrazzo mixture. Dividing strips of metal, 20 gauges thick, are inserted into the mortar base to form the desired pattern and in these small bays the terrazzo mixture is laid alternatively. The terrazzo is levelled in position by a trowel. If required some additional chips are also added at the surfaces so that about 70 per cent of the surface area is covered by the marble chips.

When the terrazzo has hardened, the surface is rubbed by coarse and fine carborundum stones, respectively, to get a smooth finished surface. It is kept wet with water while rubbing. The surface is cleaned with water and soap solution and then ax polish is applied to the surface. This type of floor covering is very costly and is used to obtain a clean, attractive and durable surface in public buildings, hospitals bathrooms, etc.

Copyrighted material

www.EngineeringBooksPdf.com

chapter **20**

Stairs

A few technical terms generally used for the design of stairs are defined below:

1. ***Baluster:*** It is a vertical member supporting the handrail. The combined framework of handrail and baluster is known as balustrade.
2. ***Flight:*** It is a series of steps without any platform or landing or break in their direction.
3. ***Tread:*** It is an upper horizontal part of a step on which the foot is placed while ascending or descending a stairway.
4. ***Step:*** This is a portion of a stair which comprises the tread and riser. This permits ascending or descending from one floor to another.
5. ***Riser:*** This is a vertical member between two treads. This provides support to the tread.
6. ***Rise:*** This is the vertical distance between the upper faces of any two consecutive steps.
7. ***Flier:*** It is a straight step having a parallel width of tread.
8. ***Landing:*** This is a platform provided between two flights.
9. ***Nosing:*** This is the outer projecting edge of a tread. This is generally made round to give an appearance that is more pleasing and makes the stair easy to negotiate.
10. ***Going:*** This is the width of the tread between two successive risers. In other words it is the horizontal distance between the faces of two consecutive risers.
11. ***Winders:*** They are tapering steps used for changing the direction of a stair.
12. ***String or Stringer:*** This is a sloping member which supports the steps in a stair.
13. ***Newel Post:*** This is the vertical post placed at the top and bottom ends of flights supporting the handrails.
14. ***Run:*** This is total length of stairs in a horizontal plane, including landings.
15. ***Soffit:*** This is the underside of a stair.
16. ***Header:*** This is a horizontal structural member supporting stair stringers or landings.
17. ***Carriage:*** This is a rough timber supporting the steps of wooden stairs.
18. ***Staircase:*** It is the space or enclosure or room which contains the complete stairway.

20.1 REQUIREMENTS OF A GOOD STAIR

1. Stairs should be so located that they can be easily accessible from the different rooms of the building.
2. It should have provision for adequate light and proper ventilation.

Copyrighted material

www.EngineeringBooksPdf.com

3. It should have sufficient stair width to accommodate a number of persons in peak hours or emergencies. Generally, for interior stairs the clear width may be required to be at least 50 cm in one and two family dwellings, 90 cm in hotels, motels, apartment building and industrial buildings and 1.1 m for other types of occupancy.
4. The number of steps in a flight should generally be restricted to a maximum of 12 and minimum of 3.
5. Ample head room should be provided not only to prevent tall people from injuring their head, but also to give a feeling of spaciousness. Vertical clearance should never be less than 2.15 m.
6. Sizes of risers and treads should generally be proportioned from the comfort point of view. Treads should be 25–32.5 cm wide, exclusive of nosing. Treads less than 25 cm width should have a nosing of about 25 cm. The most comfortable height of the riser is 17.5–18.5 cm. Generally the following formulae should be used:
   a. Product of riser and tread must be between 400 and 410.
   b. Riser plus tread must equal 42.5–43.5 cm.
   c. Sum of the tread and twice the riser must lie between 60 and 64 cm.
7. Stair width depends upon the purpose and importance of the building. In the case of residential buildings it should be kept as 1 m.
8. The number of stairways required should be controlled on the maximum floor area contributory to a stairway. The number of persons that may be served by stairs per floor per 55 cm unit of stair width should be 15 for such buildings as hospitals and nursing homes, 30 for other institutional and residential buildings, 45 for storage buildings, 60 for mercantile, business, educational, industrial buildings, theatre and restaurants, 80 for churches, concert halls and museums, and 320 for stadium and amusement structures.
9. The minimum width of landing should be equal to the width of the stairs.
10. The maximum and minimum pitch should be 40° and 25° respectively in any stairs.
11. Winders should be provided at the lower end of the flight, only when it is essential. Generally, the use of winders in a staircase should be avoided.
12. In open-well stairs in order to avoid the danger of accidents balustrade must be provided.
13. The live loads to be considered on stairs have been stipulated by IS:875-1964. The stairs and landings should be designed for a live load of 300 kg/m^2 in buildings where there are no possibilities of overcrowding. In the case of public buildings and warehouse, where overcrowding is likely, the live load may be taken as 500 kg/m^2.

20.2 TYPES OF STAIRS

Generally, stairs are of the following types (Figure 20.1):

1. Straight stairs
2. Quarter turn stairs
3. Half turn stairs
4. Three quarter turn stairs

Copyrighted material

www.EngineeringBooksPdf.com

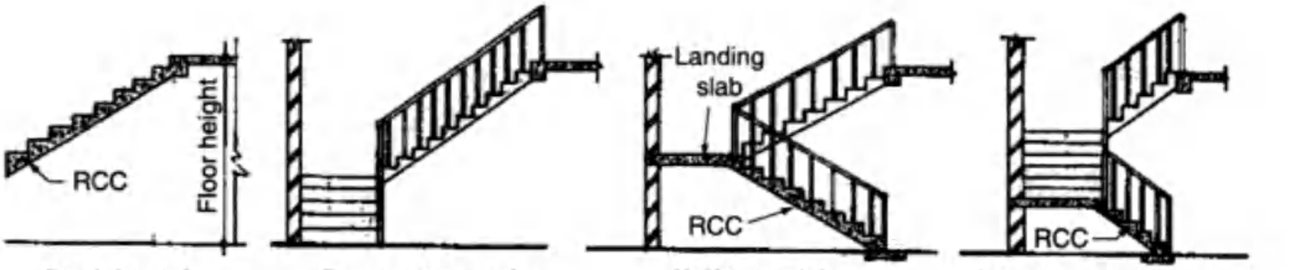


Figure 20.1 Different types of stairs

5. Circular stairs
6. Spiral stairs
7. Curved stairs
8. Geometrical stairs
9. Bifurcated stairs

20.2.1 Straight stairs

These are the stairs along which there is no change in direction on any flight between two successive floors. The straight stairs can be:

a. Straight run with a single flight between floors
b. Straight run with a series of flights without change in direction
c. Parallel stairs
d. Angle stairs
e. Scissors stairs

Straight stairs can have a change in direction at an intermediate landing. In case of parallel stairs, the stairs require a complete reversal of direction. In case of angle stairs, the successive flights are at an angle to each other. Scissor stairs are comprised of a pair of straight runs in opposite directions and are placed on opposite sides of a fire-resistive wall.

20.2.2 Quarter turn stairs

They are provided when the direction of flight is to be changed by 90°. The change in direction can be effected by either introducing a quarter-space landing or by providing winders at the junctions.

20.2.3 Half turn stairs

These stairs change their directions through 180°. It can be either 'dog-legged' or 'open newel type'. In case of dog-legged stairs, the flights are in opposite directions and no space is provided between the flights in plan. On the other hand, in open newel stairs, there is a well or opening between the flights and it may be used to accommodate a lift. These stairs are used at places where sufficient space is available.

Copyrighted material

www.EngineeringBooksPdf.com

20.2.4 Three quarter turn stairs

This type of stairs change their directions through 270°. In other words, direction is changed three times with its upper flat crossing the bottom one. In this type of construction an open well is formed.

20.2.5 Circular stairs

These stairs, when viewed from above, appear to follow a circle with a single centre of curvature and large radius. These stairs are generally provided at the rear of a building to give access for servicing at various floors. All the steps radiate from a newel post in the form of winders. These stairs can be constructed in stone, cast iron or RCC.

20.2.6 Spiral stairs

These stairs are similar to circular stairs except that the radius of curvature is small and the stairs may be supported by a centre post. Overall diameter of such stairs may range from 1 to 2.5 m.

20.2.7 Curved stairs

These stairs, when viewed from above, appear to follow a curve with two or more centres of curvature, such as an ellipse.

20.2.8 Geometrical stairs

These stairs have no newel post and are of any geometrical shape. The change in direction in these stairs is achieved through winders. The stairs require more skill for its construction and are weaker than open newel stairs. In these stairs, the open well between the forward and the backward flights is curved.

20.2.9 Bifurcated stairs

These stairs are so arranged that there is a wide flight at the start which is subdivided into narrow flights at the mid-landing. The two narrow flights start from either side of the mid-landing. Generally, these stairs are more suitable for public buildings.

20.3 STAIRS OF DIFFERENT MATERIALS

The following materials are used in the construction of stairs:

20.3.1 Stone stairs

The stones employed in the construction of stairs are hard, durable, weather resistant and fire resistant. The stone steps can be either

a. Cantilevered from the wall

b. Built into the wall at both ends

20.3.2 Brick stairs

They are rarely used except as entrance steps. A brick stair may be built of solid masonry work. The surface of the stair may be given any suitable type of floor finish.

Copyrighted material

www.EngineeringBooksPdf.com

chapter **21**

Plastering

Plastering is the process of covering rough walls and uneven surfaces in the construction of houses and other structures with a plastic material, called plaster, which is a mixture of lime or cement concrete and sand along with the required quantity of water.

21.1 REQUIREMENTS OF GOOD PLASTER

1. It should adhere to the background and should remain adhered during all climatic changes.
2. It should be cheap and economical.
3. It should be hard and durable.
4. It should be possible to apply it during all weather conditions.
5. It should effectively check the entry or penetration of moisture from the surfaces.
6. It should possess good workability.

21.1.1 Objective of plastering

a. To provide an even, smooth, regular, clean and durable finished surface with improved appearance.
b. To conceal defective workmanship.
c. To preserve and protect the surface.
d. To provide a base for the decorative finish.
e. To cover up the use of inferior quality and porous materials of the masonry work.

21.2 METHODS OF PLASTERING

The plaster may be applied in one or more coats, but the thickness of a single coat should not exceed 12 mm. In the case of inferior or cheaper type of construction, the plaster may usually be one coat. For ordinary type of construction, the plaster is usually applied in two coats, whereas for superior type of works it is applied in three coats. The final setting coat should not be applied until the previous coat is almost dry. The previous surface should be scratched or roughened before applying the next coat of plaster. In plastering, the plaster mix is either applied by throwing it with great force against the walls or by pressing it on the surface.

Copyrighted material

www.EngineeringBooksPdf.com

Table 21.1 Plaster in Three Coats with Lime Mortar

	Name of coat	Thickness	Remarks
First coat	Rendering coat	12 mm	This is left for a period of 2 days to set and is not allowed to dry.
Second coat	Floating coat	6–9 mm	This coat is applied with trowels and rubbed with a straight edge. The water is sprinkled on the surface and the surface is well rubbed with floats to make it an even surface.
Third coat	Setting coat or finishing coat	3 mm	This coat is applied after 5 days. Neeru or sagol is used to prepare a smooth surface. After giving a rest of 24 hours to the plastered surface, the work should be watered well for a fortnight or so.

The methods of applying the following common types of plasters are as follows.

21.2.1 Lime plastering

Lime plastering is the process of covering the surfaces by lime plaster or mortar in various proportions depending upon the nature of work and the number of coats to be applied (Table 21.1).

21.2.1.1 *Preparation of a surface for plastering*

When a surface is to be plastered, the surface is prepared in the following manner:

i. All the mortar joints of the wall to be plastered are left rough and projecting, so as to give a key or hold to the plaster. All the joints and surfaces are well cleaned with a wire brush and ensured that they are free from oil, grease, etc. If the surface is smooth or the wall to be plastered is an old one, then the mortar joints are raked out at least to a depth of 12 mm to give bond to the plaster.

ii. Projections more than 12 mm over the surface are knocked off so as to obtain a uniform surface of wall and also to reduce the consumption of plaster.

iii. Similarly, all the cavities and holes inside the surface are properly filled up in advance.

iv. All woodwork to be plastered is roughened.

v. Finally, the mortar joints and surfaces of the wall are well washed, wetted with water and kept for at least 6 hours before plastering.

21.2.1.2 *Groundwork of plaster*

In order to obtain a true surface and uniform thickness, vertical strips called screeds and bands are formed on the wall surface by fixing dots. These dots are first of all applied horizontally and vertically at a distance of about 2 m, covering the entire wall surface. These dots are fixed by laying a small quantity of plaster on the surface in the forms of squares (15 cm × 15 cm) having thickness of about 10 mm. The verticality of dots, one over the other, is checked by means of a plumb bob. After fixing dots, the vertical strips of plaster known as screeds are formed in between the dots. These screeds serve as the gauges for maintaining even thickness of the plaster being applied. Mortar is then applied on the wall between groundworks of screeds so prepared.

21.2.1.3 *Application of plaster coats*

i. *First coat (or rough course of plastering or rendering coat):* It is usual to provide an average thickness of first coat of plaster equal to 12 mm over brick or ashlar masonry and 20 mm on rubble masonry, the

Copyrighted material

www.EngineeringBooksPdf.com

larger thickness on rubble masonry being due to the roughness of its surface and the necessity of providing a minimum covering of 6 mm of mortar to rubble. The first coat (rendering coat) of plaster is generally applied by dashing against the wall surface between the screeds mentioned above. It is then sprinkled frequently with sufficient quantity of water and rubbed well by means of floats.

If a second coat, called floating coat, is to be applied, the surface of the first coat is left exposed to air for a period of 2 days to set but not to dry. After this period, the surface of the first coat is swept clear of any dust or loose particles, sprinkled with water and well beaten with thin strips of bamboo or cane. The surface of the first coat is kept wet till the second coat is applied.

ii. *Second coat or floating coat:* The second coat is applied after preparing the surface of the first coat as mentioned above. The second coat is spread out uniformly with trowels. It is pressed and rubbed with a wooden straight edge, to obtain the desired surface. It is finally finished by slightly sprinkling water over the plastered surface and rubbing it with the floats. The thickness of the second coat is usually between 6 and 9 mm.

iii. *Third coat or final coat or finishing coat:* This coat is applied after 5 days of the second coat. This coat consists of a cream of white or fat lime (called neeru or plaster's putty) and fine white sand in the ratio of 1:2 laid in thickness of 3 mm with straight plane and is rubbed with a straight edge. The surface is well rubbed with a wooden float and then finally finished with a trowel to obtain the desired surface. A polishing stone is used to obtain a fine polished surface.

21.2.2 Cement plastering

Cement plastering is an ideal plastering for external renderings. It is specially suited for damp conditions such as bathrooms, reservoirs, water tanks, floors, copings, etc. where non-absorbent surfaces are desired. Cement plaster is usually applied in a single coat. However, in certain cases when the thickness of the plaster is more than 15 mm or it is desired to have a finer finish, the plaster is applied in two coats (Table 21.2).

The process of cement plastering in two coats is as follows:

a. *First coat or rough coat:* Usually, the average thickness of the first coat of plaster is 12 mm on brick masonry or ashlar masonry and 23 mm on rubble masonry. In the case of concrete masonry, this thickness varies from 9 to 15 mm depending upon the nature of work. For the first coat, cement plaster with mix proportions as 1:3 or 4 (1 cement:3 or 4 sand) is generally used. The first coat of plaster is placed between the spaces or bays formed by the screeds on the wall surface. This plaster is applied with a mason's trowel. The surface is then levelled by means of flat wooden floats and wooden straight edges and finally finished by polishing with a trowel. If a second coat or fine coat is to be applied, the surface of the first coat is not polished, but roughened with a scratching tool to form a key to the second coat of plaster.

Table 21.2 Plaster in Three Coats with Cement Mortar

	Name of coat	Thickness	Remarks
First coat	Rendering coat	9-10 mm	This is left for a period of 3-4 days to harden. Its surface is kept rough.
Second coat	Floating coat	6–9 mm	The purpose of this coat of plaster is to bring the work to an even surface.
Third coat	Setting coat or finishing coat	3 mm	This coat is similar to the second coat of a two coat plaster.

Copyrighted material

www.EngineeringBooksPdf.com

b. *Second coat or fine coat:* Before applying the second coat, the first coat is left to set for at least 7 days and is roughened to form a proper key with the second coat. The second coat, consisting of pure Portland cement mixed with sufficient quantity of water, is applied after 6 hours. This second coat is laid in a thin layer of 3 mm maximum thickness over the rough and moist surface of the first coat. Finally, this coat is well trowelled and rubbed smooth. Each coat should be kept damp continuously by curing for at least 5–10 days.

21.2.3 Mud plastering

This is the cheapest type of plastering, generally employed in the construction of village houses, temporary sheds and structures of temporary importance. Besides being cheap it provides insulation against heat and keeps the house cool for comfortable living. Mud plastering (in two coats) is then carried out as below:

a. The mud plaster, consisting of well-tempered clay, chopped straw and cow dung, is prepared in a homogenous mass as described earlier.

b. The preparation of the wall surface and groundwork for plastering is done exactly in the same manner as that for lime or cement plastering.

c. The first coat is then applied in a thickness of 12 mm by dashing the plaster or by placing it in the spaces formed by the screeds. The surface is then finished by means of a straight edge and a wooden float.

d. After 24 hours of setting (but not drying) of the first coat, the second coat is applied in a thickness of 6 mm.

e. No curing is done in this case but the surface is given a wash of fine white earth, cow dung and cement in a mix proportion of 3:2:1 respectively.

REVIEW QUESTIONS

1. Why is plastering required for walls?
2. What are the requirements of a good plaster?
3. What are the objectives of plastering?
4. Briefly discuss the different types of plastering.
5. Briefly discuss the process of cement plastering in two coats.
6. How is cement plaster prepared?

Copyrighted material

www.EngineeringBooksPdf.com

Painting

Paints are coatings of fluid materials which are applied as a final finish to surfaces like walls, ceiling, wood and metal works.

Painting is done to protect the surface from the effects of weathering, to prevent wood from decay and metal from corrosion, to provide a decorative finish and to obtain a clean, hygienic and healthy living atmosphere.

22.1 TYPES OF PAINTS

1. **Enamel paints:** These paints are available in numerous shades. They mainly consist of white lead or zinc white, resinous matter and petroleum spirit. Their formation into hard, impervious, decay-resistant enamel-like surface soon after application protects it from being affected by acids, alkalies, fumes and gas, hot and cold water, etc. They can be used for internal as well as external purposes.
2. **Cement paints:** These include a variety of paints in which cement is the main constituent responsible for the hardness and durability of the painted surface. They are available in dry, powder form. They are waterproof. It is desirable to provide cement paint on a rough surface rather than a smooth surface because its adhesion power is more on rough surface than on smooth surface. They prove to be economical as compared to oil paints. They are suitable for painting fresh plasters having high alkalinity because cement paints are not likely to be attacked by the alkalinity of the masonry surface. It is not necessary to remove the existing paint for the application of new paint.
3. **Oil paints:** They are generally applied in three different layers with varying composition. These are termed as primes, undercoats and finishing coats. The dampness of the wall affects the life of the oil paint, hence it must not be applied during damp weather.
4. **Cellulose paints:** They are prepared from nitro cotton, celluloid sheets, photographic films, etc. The cellulose paints harden by evaporation of thinning agents. The surface painted with cellulose can be washed and cleaned easily. They are little costlier than other paints.
5. **Aluminium paints:** Finely ground aluminium is suspended in either quick-drying spirit varnish or slow-drying oil varnish as per requirement. As the spirit or oil evaporates, a thin film of aluminium is formed on the surface. This paint forms a better protective surface over steel and iron. They are impervious to moisture and possess high electrical resistance. They have a good appearance and are visible in darkness.
6. **Emulsion paints:** These paints contain polyvinyl acetate, synthetic resins, etc. They are easy to apply and are retained for a long period and can be cleaned easily with water. For a rough plastered surface, a thin coat of cement paint may be first applied to smoothen the surface. It is necessary to have a sound surface to receive the paint.
7. **Anticorrosive paints:** These consist of oil and a strong drier. The pigments such as chromium oxide, lead or zinc chrome is taken and after mixing it with a small quantity of very fine sand it is added to the paint. These are cheap and last for a long duration. They are black in colour.

Copyrighted material

www.EngineeringBooksPdf.com

to the unit by the reflection prism used as the target at the other point. Using the time required by the ray to come back, the distance travelled by the ray is calculated and displayed by the EDM.

The most advanced form of EDM is the laser meter which can be used to measure distances upto 30 m without using any target and upto 100 m using the target. So for small distance measurements even an assistant is not required. If you measure the length, breadth and height together using this instrument, it can be used to compute the area and volume automatically.

26.2.2 Electronic total station

A total station is a combination of electronic theodolite, an electronic distance-measuring device (EDM) and a microprocessor with memory unit. With this device, one can determine angles and distances from the instrument to the points to be surveyed. With the aid of trigonometry, the angles and distances may be used to calculate the actual positions (x, y and z or northing, easting and elevation) of surveyed points in absolute terms.

The measurements are taken with the help of a telescope, which is mounted on a tripod and levelled and focussed on to the prisms held as targets at the points to be surveyed. The instrument is attached with an alphanumeric key board and LCD display. This works with the help of a rechargeable compact battery. The instrument has a built-in automatic atmospheric sensor that measures the atmospheric pressure and temperature in real time and automatically applies the necessary corrections.

The total station can be used to make linear measurements to an accuracy of 0.1 mm and angle measurements to 1" accuracy. All the measurements are done with speed and accuracy and are recorded with the help of a memory card (usually a PCMCIA card or so). The range of the equipment varies from 2,000 to 3,000 m using single prism and from 3,000 to 3,600 m using multiple prisms. All the calculations can be carried out automatically and the data can be transferred to any computer using communication software and a cable. Any required drawings such as contours can then be prepared using any standard software. The instrument is very compact and light in weight and can be used for various other purposes such as area calculation, traverse, road mapping and three-dimensional cross sectioning (Figures 26.9–26.12).

Figure 26.9 An electronic total station

Courtesy: M/s. Sokkia, Japan.

Copyrighted material

www.EngineeringBooksPdf.com

Figure 26.10 Typical standard rod (w/bubble level)

Figure 26.11 Typical standard prism and sight

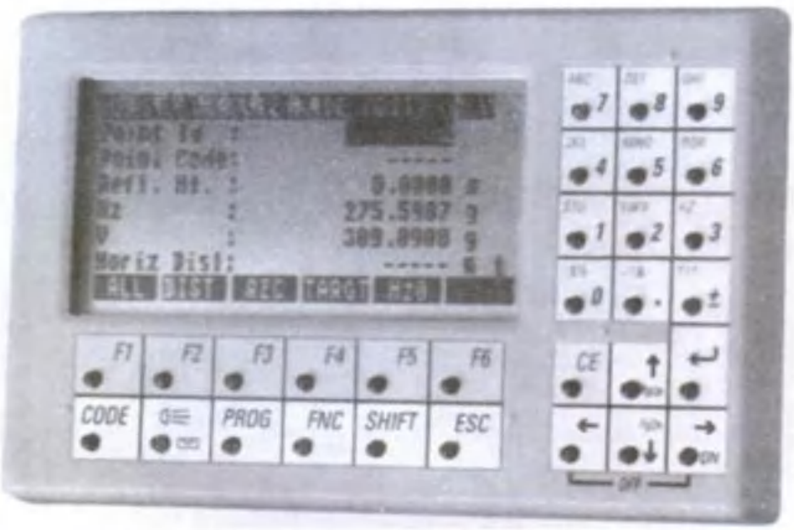


Figure 26.12 Display (Leica)

Copyrighted material

www.EngineeringBooksPdf.com

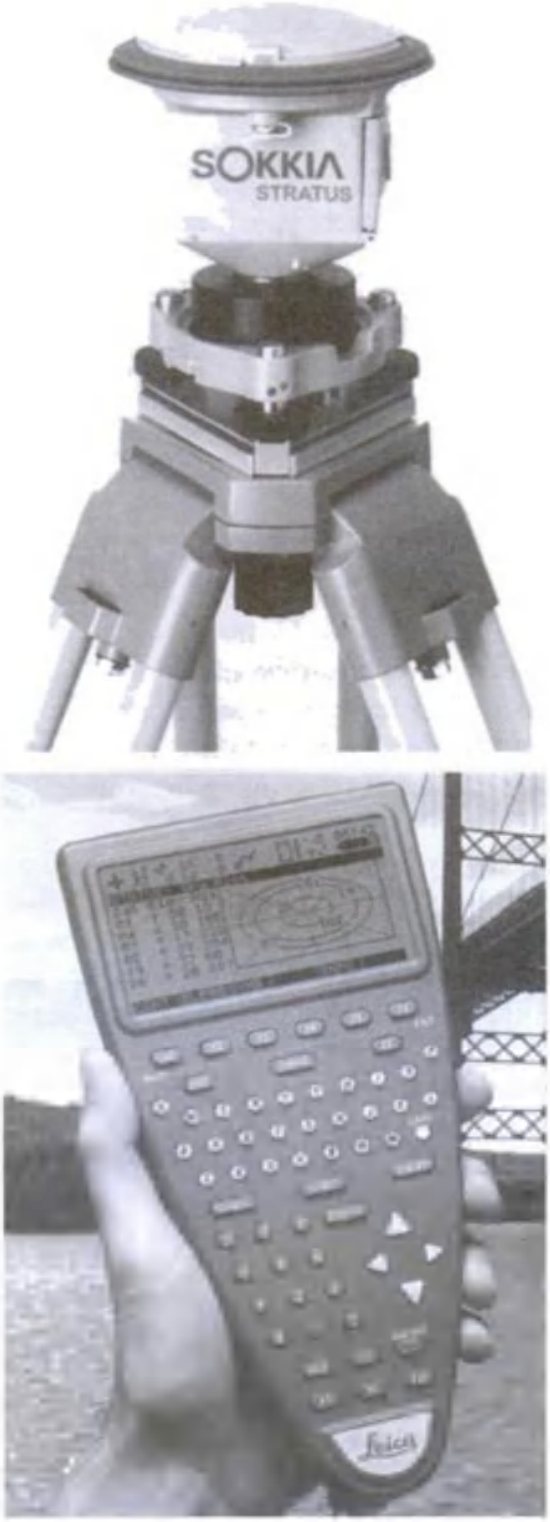


Figure 26.13 GPS and receiver (courtesy M/s. Sokkia and M/s. Leica)

They can be simply mounted on a tripod and can be set up and the circular bubble brought to the centre easily even on an angled and uneven surface. The instrument is equipped with an automatic compensator which is wire suspended and magnetically damped, which makes it suitable even under unstable conditions. Automatic focusing and weather proof telescope makes it useful even under unfavourable weather conditions (Figure 26.14).

Copyrighted material

www.EngineeringBooksPdf.com

Figure 26.14 Automatic level (Pentax)

26.2.5 Digital level

Figures 26.15 and 26.16 show a digital level and a bar code levelling staff. This level features digital, electronic image processing for determining heights and distances, with the automatic recording of data for later transfer to the computer. The digital level is an automatic level (pendulum compensator) capable of normal optical levelling with rod graduated in feet or metres. When used in electronic mode, with the rod face graduated in barcode, this level will, with the press of a button, capture and process the image of the bar-code rod. This processed image of the rod reading is then compared with the image of the whole rod, which is stored permanently in the level's memory module, to determine height and distance values (Figures 26.15 and 26.16).

After the instrument has been levelled the operator must focus the image of the barcode properly. Next, the operator presses the measure button to begin the image processing, which takes about 4 seconds. Although the heights and distances are automatically determined and recorded, the horizontal angles must be read and recorded manually in this case. All the readings are digitally displayed and recorded for transfer to the computer.

Figure 26.15 A digital level (courtesy of Sokkia corp.)

Copyrighted material

www.EngineeringBooksPdf.com

Figure 26.16 A digital level and bar code staff (courtesy of M/S. Leica geo-systems)

26.2.6 Microptic theodolite

It is a reliable, convenient, highly precise and easy to use instrument used for most surveying tasks including engineering and mining applications. It is equipped with a magnetically damped vertical circle compensator for fast and accurate zenith angle compensation. The optical plummet provided makes it easy to centre the instrument over the survey point with the help of a shifting tribrach. Coincident image projection is used to read the horizontal and vertical scales and thus possibility of any type of error in reading is eliminated. The readings can be directly read looking through the micrometer eye piece, which is illuminated using reflectors.

This instrument can be used in combination with an EDM (Figure 26.17).

26.2.7 Electronic digital theodolite

This functions in the same manner as that of an ordinary transit theodolite, except that it is more accurate, error free and easy to operate. There is an electronic compensator provided, which simplifies the levelling process and improves the accuracy by compensating the faulty adjustments. A laser plummet is provided for accurate centring. Electronic display of all the readings is automatically available. It works on rechargeable batteries.

26.2.8 Digital planimeter

Planimeter is an instrument used to measure the area of irregular shapes. The original version consists of tracing the boundaries with the arm of the planimeter and then converting the obtained reading into area of the figure, using the specified formula. Here, the possibility of error is very high and the procedure is not so easy (Figure 26.18).

Now, digital planimeters which work on rechargeable batteries and directly display the area required are available. These give a more accurate and quick measure of the area and in addition they allow calculations of line lengths, circumference, coordinates, angles, arc and circle radii and many other functions. LCD display, attached printers and computer compatibility are added advantages.

Copyrighted material

www.EngineeringBooksPdf.com

5. Explain briefly the field works involved in chain surveying.
6. Explain the different components of chain with neat sketches.
7. Explain the different types of tapes used for distance measurements.
8. What are the advantages and disadvantages of tapes?
9. With a neat diagram explain ranging rods and arrows.
10. What is cross staff and give the classifications of cross staff?
11. What is the difference between direct and indirect ranging?
12. What are the advantages of total station?
13. What do you mean by Global Positioning System and how can it be used in surveying?
14. What is automatic level and what is its advantage over ordinary level?
15. Explain briefly
    a. Digital level
    b. Microptic theodolites
    c. Electronic theodolite
    d. Digital planimeter

Copyrighted material

www.EngineeringBooksPdf.com

chapter **27**

Levelling

Levelling is the art of determining the relative elevations of different objects or points on the earth's surface. This is done by taking measurements in the vertical plane. Hence, this branch of surveying deals with measurements in vertical planes.

For the execution of civil engineering works such as major buildings, highways, dams, canals, water supply and sanitary schemes, it is necessary to determine elevations of different points along the alignments of a proposed project for the design and execution of the project. Success of the projects depends upon accurate determination of elevations of the ground control points as well as control points of the structures. Levelling is employed to provide an accurate network of heights, covering the entire area of the project. Levelling is of prime importance to the engineers, both in acquiring necessary data for the design of the project and also during execution.

27.1 PURPOSE OF LEVELLING

1. To find the elevations of given points with respect to a given or assumed datum (datum is an arbitrarily assumed level surface to which elevations are referred).
2. To establish points at a given elevation with respect to a given or assumed datum.

The instruments used in levelling are as follows:

1. A level
2. A levelling staff
3. A measuring tape

27.2 MAJOR PARTS OF LEVELLING INSTRUMENT

The level furnishes a horizontal line of sight. The level consists of the following main parts.

1. A telescope to provide the line of sight
2. A level tube to make the line of sight horizontal
3. A levelling head to bring the bubble in its centre of run
4. A tripod to support the instrument.

27.2.1 Telescope

Telescope is an optical instrument for magnifying and viewing the images of distant objects. The telescope of a levelling instrument is a metallic tube having an eyepiece at one end and an object glass at the other end. The telescope, which is fitted in levels, is generally of two types.

Copyrighted material

www.EngineeringBooksPdf.com

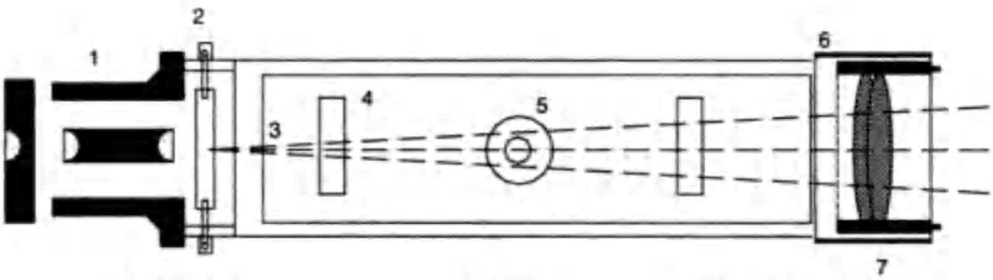
a. External focusing telescope

b. Internal focusing telescope

The external focusing telescopes were used in old model levels and the internal focusing telescopes are being used in modern survey instruments.

27.2.2 External focusing telescope

The telescope in which focusing is achieved by the external movement of either the objective glass or eye-piece is known as an external focusing telescope. In an external focusing telescope, the body is formed by two tubes at the ends of which the objective and eyepiece are fitted. One of the tubes is made to slide axially within the other by means of a rack and pinion arrangement attached to the focusing screw of the telescope (Figure 27.1).

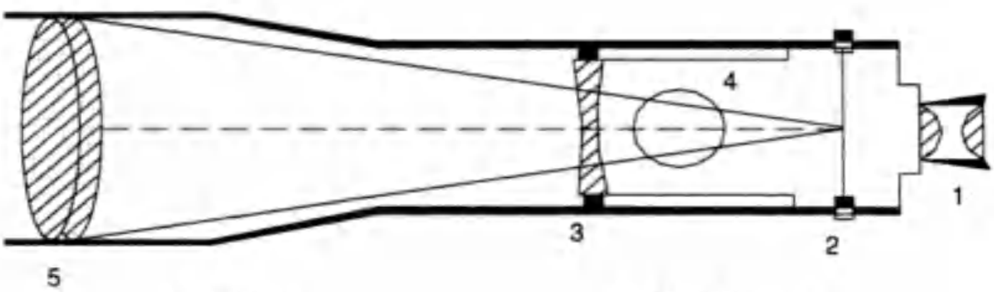


1. Eyepiece
2. Diaphragm screws
3. Diaphragm
4. Stops
5. Focusing screw
6. Ray shade
7. Objective glass

Figure 27.1 An external focusing telescope

27.2.3 Internal focusing telescope

The telescope in which focusing is achieved internally with a concave lens is known as internal focusing telescope. In an internal focusing telescope, the objective and eyepiece are kept at a fixed distance and focusing is achieved by a double concave lens mounted in a short tube capable of sliding axially between the eyepiece and the objective with a rack and pinion arrangement attached to the focusing screw (Figure 27.2).



1. Eyepiece
2. Diaphragm screw
3. Focusing lens
4. Focusing screw
5. Object glass

Figure 27.2 An internal focusing telescope

Copyrighted material

www.EngineeringBooksPdf.com

The objective is a compound lens consisting of a front double convex lens made of crown glass and the back concave-convex lens made of flint glass (Figure 27.3). The two lenses when cemented together with balsam at their common surface are generally known as achromatic lens. In such lenses, the spherical and chromatic aberrations known as optical serious defects are practically eliminated.

The eyepiece is composed of two plane convex lenses with a distance of two-third the local distance. The convex surfaces are turned towards one another. The Ramsden eyepiece is used in most surveying telescopes.

To provide a definite line of sight, horizontal and vertical cross hairs held in a flat metal ring called reticule are fitted into the diaphragm. The diaphragm is a flanged metal ring held in the telescope barrel by four capstan headed screws. With the help of the capstan headed screws, the position of the cross hairs inside the tube can be adjusted slightly, horizontally, vertically and rotationally. The hairs or lines are arranged in different ways as shown in Figure 27.4.

The telescope is used to read the levelling staff and the cross hairs enable the surveyor to take the staff reading.

27.2.4 Types of levelling instrument

The chief types of levels are

a. Dumpy level
b. Wye (or Y) level
c. Reversible level
d. Tilting level

27.2.5 Dumpy level

A dumpy level consists of a telescope tube firmly secured in two collars fixed by adjusting screws to the stage carried by a vertical spindle. In the modern form, the telescope tube and the vertical spindle are cast in one

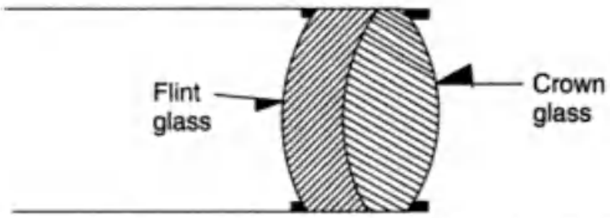


Figure 27.3 An objective

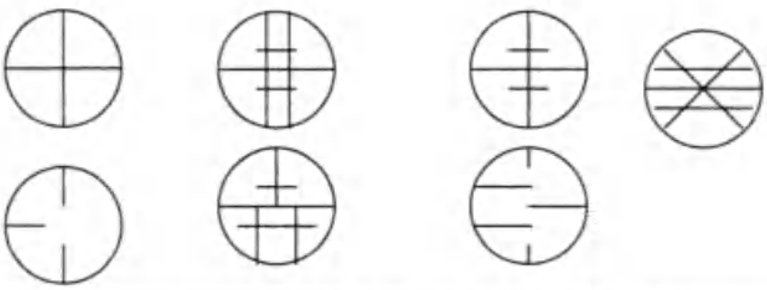


Figure 27.4 Different types of cross hairs

Copyrighted material

www.EngineeringBooksPdf.com

piece and a long bubble tube is attached to the top of the telescope. It can neither be rotated about its longitudinal axis nor can be removed from its supports. Figure 27.5 shows the elevation of a dumpy level showing different parts.

In some instruments, a clamp screw is provided to control the movement of the spindle about the vertical axis. For a small or precise movement, a slow motion screw or tangent screw is also provided. The levelling head generally consists of two parallel plates with three foot screws. The upper plate is known as tribrach and the lower plate is known as trivet, which can be screwed on to a tripod (Figure 27.6).

27.2.5.1 Advantages of a dumpy level

It is simple in construction with a few movable parts. It requires fewer permanent adjustments. Adjustments once carried out remain for a longer period.

Figure 27.5 A dumpy level

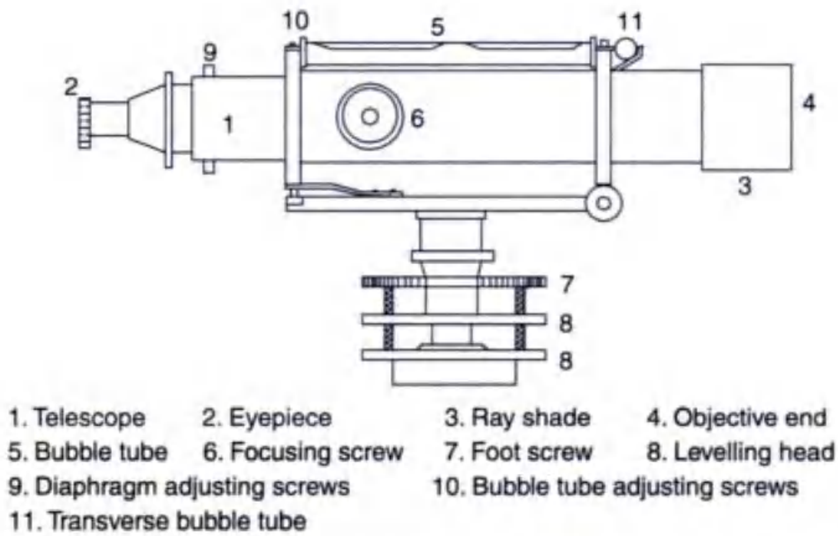


Figure 27.6 A dumpy level

Copyrighted material

www.EngineeringBooksPdf.com

27.3.1.2 *Folding or hinged staff*

A folding staff is made of well-seasoned timber. It is 4 m long and consists of two portions, each being 2 m long and hinged together. The width and thickness of the staff is kept at 75 mm and 18 mm, respectively. The foot of the staff is provided with a brass cap to avoid wear and tear due to usage. Sometimes, a plummet is also provided to test the verticality of the staff. Each metre length is subdivided into decimetres and each decimetre is further divided into 20 equal divisions of 5 mm width. Decimetre numerals 1–9 for each metre length are marked in black and metre numerals in red. The graduations are marked inverted so that they appear erect when viewed through the telescope. In modern levelling staff, the graduations are marked erect. The staff may be folded together so that one 2 m piece is capable of folding on the other when not in use and two pieces are detachable from one another so that one half may be used while working in plain areas.

27.3.1.3 *Telescopic or sopwith type staff*

It is made up of three pieces. The top piece is solid 1.25 m long, whereas the central piece of 1.25 m length and the lower piece of 1.5 m length are hollow. The top portion slides into the central portion telescopically. When fully extended, the total length of the staff is 4 m. The upper two pieces are held by brass spring catches. The smallest division of this type of levelling staff is also 5 mm. The metre numerals, which are shown on the left, are marked in red. The decimetre numerals 1–9 are shown on the right and marked in black. The decimetre number 10 of each metre length is omitted and letter M is marked to indicate the end of the metre length. Graduation is marked erect and when viewed through the telescope it appears inverted. While using a telescopic staff it may be ensured that the three parts are fully extended in length when using the full length, i.e., 4 m

27.3.2 Target staff

The target staff consists of two rods, one sliding over the other. The two rods are held together by means of brass clamps. Raising the sliding can extend the length of the staff. The face of each rod is graduated in feet, tens and hundredth of a foot, while the back of a sliding rod is similarly graduated, but from top downwards. The staff is provided with a movable target equipped with a vernier. With the help of this vernier, one can read up to 0.001 ft. The sliding rod carrying the target is bisected by the line of sight.

27.3.3 Holding a staff for taking a reading

Care should be taken to hold the levelling staff truly vertical while the reading is being taken. To hold the staff in a vertical position, the person holding the staff should stand behind the staff with his heels together, having the heel of the staff between his toes and holding it in his hand at the height of his face. When the level of the required point is very much higher than the height of the instrument, inverted staff reading is to be taken.

27.3.4 Relative merits of self-reading and target staff

a. With the self-reading staff, the readings can be taken quicker than with the target staff.

b. In the case of target staff, the services of trained personnel are necessary.

c. The reading with the target staff can be taken with greater fineness. But if the staff man does not direct accurately to make the line of sight bisect the target, it gives more apparent readings.

d. The surveyor himself takes the reading on a self-reading staff. But in the case of target staff, the staff man is responsible for noting down the readings.

e. It is tedious to adjust the target such that the line of sight bisects it accurately.

Copyrighted material

www.EngineeringBooksPdf.com

27.3.5 Fundamental axes of levelling instrument

a. Line of collimation or principal line of sight: It is the imaginary straight line which joins the optical centre of the object glass with the point of intersection of cross hairs of the diaphragm.

b. Axis of bubble tube: It is an imaginary line tangential to the longitudinal curve of the tube at its middle point. It is also known as bubble line. It is horizontal when the bubble is centred.

c. Axis of telescope: It is a line joining the optical centre of the object glass to the centre of the eyepiece.

d. The vertical axis: It is the imaginary line passing through the centre line of the axis of rotation.

e. The height of the instrument (HI): The height of the instrument is the elevation of the plane of collimation or plane of sight when the instrument is correctly levelled. When a level in adjustment is accurately levelled, the line of collimation will revolve in a horizontal plane known as the plane of collimation or plane of sight.

27.4 TECHNICAL TERMS USED IN LEVELLING

1. *Level surface:* A level surface is any surface parallel to the mean spherical surface of the earth. It is a curved surface, which at each point is perpendicular to the direction of gravity at that point. Every point on a level surface is equidistant from the centre of the earth (Figure 27.8).

2. *A level line:* A level line is a line lying in a level surface. It is normal to the plumb line at all points (Figure 27.9).

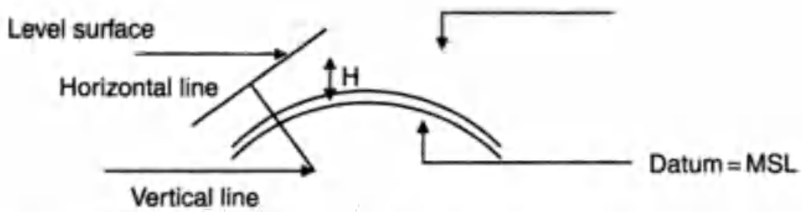


Figure 27.8 Level surface

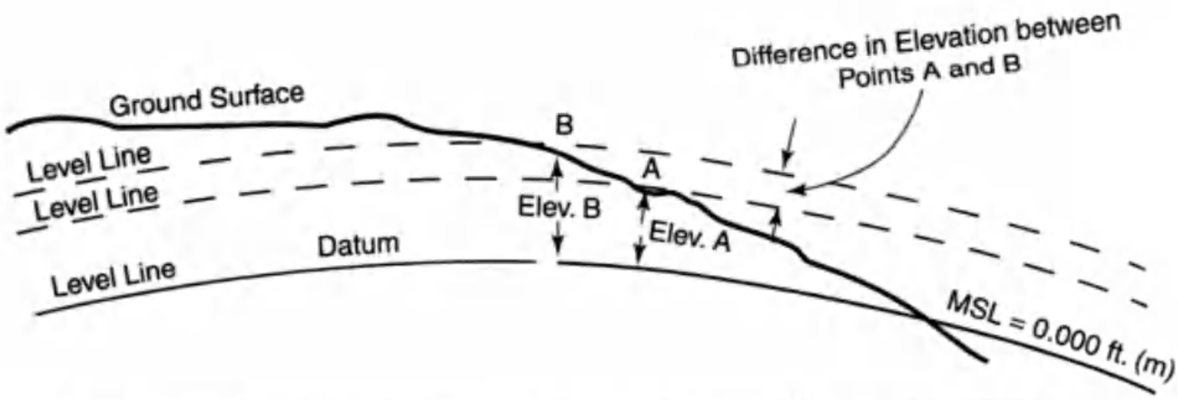


Figure 27.9 Figure showing level line, datum, mean sea level and ground surface

Copyrighted material

www.EngineeringBooksPdf.com

3. *A horizontal plane:* A horizontal plane through a point is a plane tangential to the level surface at that point.
4. *A horizontal line:* A horizontal line is any line lying in the horizontal plane.
5. *A vertical line:* A vertical line at any point is a line normal to the level surface through that point.
6. *Elevation:* The elevation of a particular point is the vertical distance above or below a reference surface. Usually the mean sea level is used as reference.
7. *Mean sea level (MSL):* Mean sea level is obtained from the average height of the sea's surface for all the stages of the tide, over a period of 18.6 years.
8. *Datum:* Datum is any arbitrarily assumed level surface to which elevations are referred.
9. *Reduced level (RL):* The reduced level of a place is its elevation or vertical distance above or below the datum or any fixed point.
10. *Line of sight:* It is the imaginary line joining the intersection of the cross hairs of the diaphragm to the optical centre of the object glass and its continuation.
11. *Back sight (BS):* A back sight is the first staff reading taken after setting up the instrument at any position. This will always be a reading on a point of known elevation. It ascertains the amount by which the line of sight is above or below the elevation of the point. Back sight enables the surveyor to obtain the height of the instrument.
12. *Fore sight (FS):* A fore sight is the last staff reading taken before shifting the instrument. This will always be a reading on a point whose elevation is to be determined. This reading indicates the shifting of the instrument. It is also generally known as minus sight as the fore sight reading is always subtracted from the height of the instrument (except when the staff is held inverted) to obtain the elevation.
13. *Intermediate sight (IS):* An intermediate sight is any staff reading, taken on a point of unknown elevation, after the back sight and before the fore sight. This is necessary when more than two staff readings are to be taken from the same position of the instrument. It may be noted that for one setting of a level there will be only a back sight and a fore sight but there can be any number of intermediate sights.
14. *Change point (CP):* This is an intermediate staff position and it is used for the purpose of shifting of the instrument. Both back sight and fore sight are taken from this intermediate staff position. Great care is necessary in taking readings at the change point since an error in reading affects every succeeding point of observation (elevation). Any firm point, which can be easily found, may serve as a change point.
15. *Bench mark (BM):* A bench mark is a fixed point of known elevation and the elevation of this point will be noted on it with respect to a datum. The reduced level of bench mark is used to determine the reduced levels of other points. The bench mark is usually taken as the plinth of an important building, top of parapets of bridges, etc. It will be marked by an identifying mark like cross mark or a circle with a dot at its centre.

There are four kinds of bench marks.

a. Great trigonometric bench marks (GTS)
b. Permanent bench marks
c. Arbitrary bench marks
d. Temporary bench marks

Copyrighted material

www.EngineeringBooksPdf.com

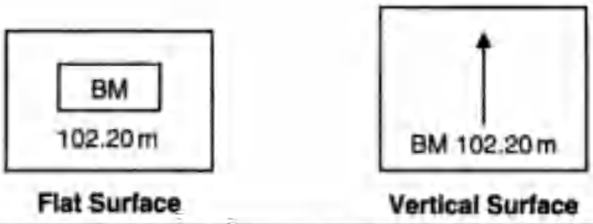


Figure 27.10 Figure showing a permanent bench mark

Great trigonometric bench marks (GTS) are established by the Survey of India Department. They will be marked with very high accuracy at intervals, all over the country by this department. Their positions and elevations above the standard datum are given in the catalogue published by that department.

Permanent bench marks are established when the distance between the GTS bench marks is very large. Hence, fixed reference points are established at closer intervals. They are established by the Government agencies such as the local surveying departments, on clearly defined and permanent points such as the top of a parapet wall of a bridge or culvert, a corner of the plinth of a building, a gate pillar and a kilometre stone. On a vertical surface there will be a broad arrow and a horizontal groove, the centre of which is the point of reference (Figure 27.10).

In small levelling works, the surveyor can assume a well-defined point for reference. The reduced level of that point is arbitrarily assumed (say as 100.00, 50.00 etc.). These are called arbitrary bench marks.

Temporary bench marks are the reference points established at the end of a day's work or when there is a break in the work. This becomes necessary when the whole levelling work cannot be completed at a stretch. The work when started again is continued with reference to these bench marks. They should be carefully established on definite and comparatively permanent objects, which can be easily described and found, such as the top of a stone gate, posts, spikes in the roots of the tree and highest point of solid rock.

27.5 LEVELLING – FIELD WORK

The survey work is mainly divided into two: (1) field work and (2) office work.

In the field, necessary adjustments are done and the results are recorded in a systematic manner as explained below.

27.5.1 Adjustments of a level

A level needs two type of adjustments, i.e.,

a. Temporary adjustments
b. Permanent adjustments

27.5.1.1 Temporary adjustments

The adjustments which are made for every setting of a levelling instrument are called temporary adjustments. These include the following:

i. Setting up the level
ii. Levelling up
iii. Elimination of parallax

Copyrighted material

www.EngineeringBooksPdf.com

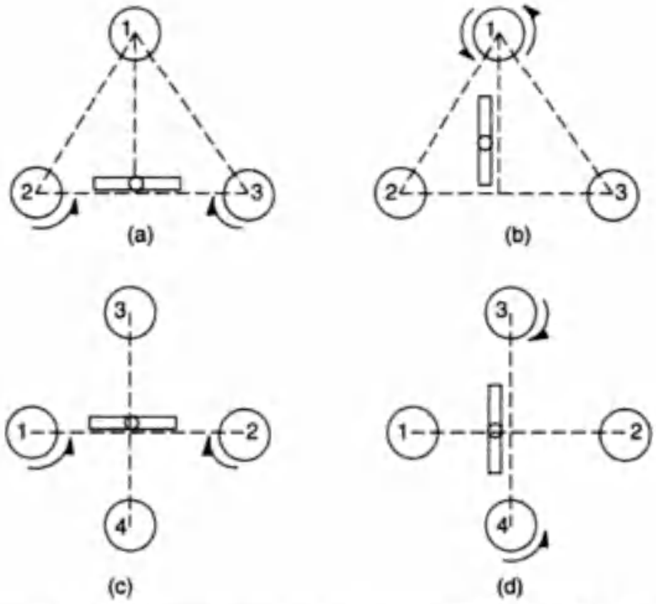


Figure 27.11 Levelling the instrument

become difficult. Elimination of parallax is done by focusing the eyepiece for distinct vision of cross hairs and focusing the objective to bring the image of the object in the plane of the cross hairs as explained below.

- *Focusing the eyepiece:* To focus the eyepiece for a distinct vision of cross hairs, either hold a white paper in front of the objective or sight the telescope towards the sky. Move the eyepiece in or out till the cross hairs are seen sharp and distinct.
- *Focusing the objective:* After the cross hairs have been properly focused, direct the telescope on a well-defined distinct object and intersect it with a vertical wire. Focus the objective till a sharp image is seen. Moving the eye slowly to one side may check removal of the parallax. If the object still appears intersected, there is no parallax. If on moving the eye laterally, the image of the object appears to move in the same direction as the eye and the observer's eye and the image of the object are on the opposite sides of the vertical wire, the image of the object and the eye are brought nearer to eliminate the parallax. This parallax is called far-parallax. If, on the other hand, the image appears to move in a reverse direction to the movement of the eye and the observer's eye and the image of the object are on the same side of the vertical wire, then the parallax is called near-parallax. It may be removed by increasing the distance between the image and the eye.

27.5.2 Classification of levelling

Levelling may be classified into two categories:

a. Simple levelling
b. Differential levelling

27.5.2.1 Simple levelling

When two points whose level difference is to be found out are situated in such a way that both of them are visible from a single position of level, this method is adopted.

Copyrighted material

www.EngineeringBooksPdf.com

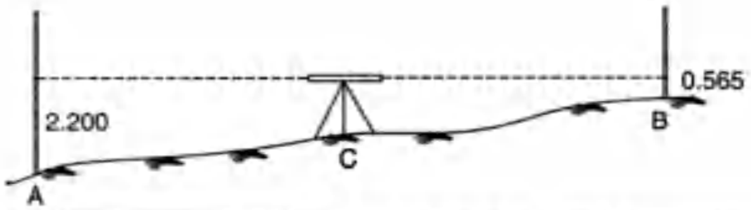


Figure 27.12 A simple levelling work

Suppose A and B are two such points and the level is set up midway between A and B. After the instrument is correctly levelled, the telescope is directed towards the staff held vertically on A and focused. The reading at which the horizontal hair of the diaphragm appears to cut the staff is then taken carefully. Make sure that the bubble is central while the staff is being read. Then the staff is held vertically on B and the telescope of the level is directed on to the staff held at B, is focused and the reading at B is noted. Let the respective reading on A and B be 2.200 and 0.565. The difference between these two readings gives the difference in level between A and B, which is equal to 2.200 − 0.565 = 1.635 m (Figure 27.12).

Assume the reduced level of A as 100.000 m.

Height of instrument at station C = Reduced level atof A + staff reading at A
= 100.00 + 2.200 = 102.200 m

Reduced Level of B = 102.200 − 0.565 = 101.635 m

27.5.2.2 Differential levelling

The method of levelling for determining the difference in elevation of two points either too far apart or obstructed by an intervening ground is known as differential levelling. In this method, the level is set at a number of points and the difference in elevation of successive points is determined as in the case of simple levelling. This levelling process is also known as fly levelling, compound levelling or continuous levelling.

Hence, this method is adopted when the points are too far apart, if the difference in elevation between them is too great or if there are obstacles between them.

In this case, the level is set up at different positions (points) for the execution of the levelling operations as in Figure 27.13 below. Consider two points A and E as in Figure 27.13; it is required to find the level difference between these two points. Set up the level at a convenient point, let it be at 'a'. The work is started by taking back sight to a bench mark or a known point and then fore sight is taken to a point to fix its level at A. Take a staff reading at A, let it be 'a1'. Select a firm point b, so that the distance from C to 'b' is approximately equal to the distance from A to 'a'. Hold the staff at B and take the staff reading. Let it be 'b1'. This forms first stage in the levelling series. Keeping the staff at B, shift the instrument to 'b'. Take a back sight at B, let it be 'b2'. With the levelling instrument at 'b' shift the levelling staff to a third position at 'C' and the work is continued till the point E is read.

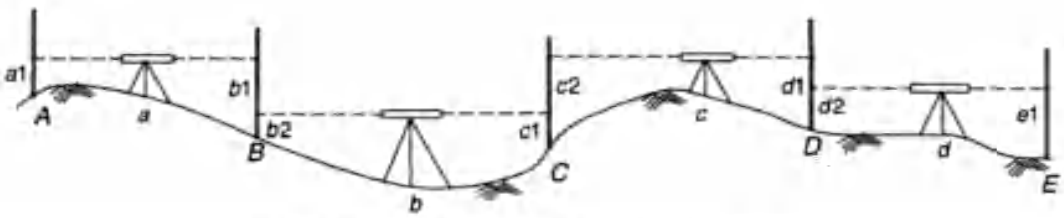


Figure 27.13 Execution of a direct levelling operation

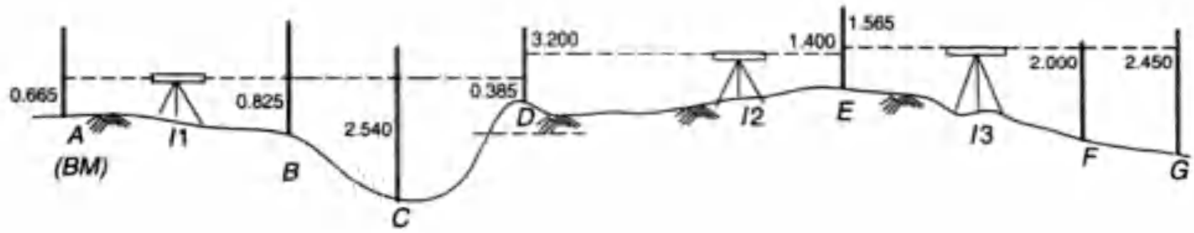
Copyrighted material

www.EngineeringBooksPdf.com

27.8 COMPUTING REDUCED LEVELS USING HEIGHT OF COLLIMATION METHOD (HI METHOD)

In this method, the reduced levels of points are computed by calculating the reduced levels of the plane of collimation for each set up of the instrument.

The height of collimation is obtained by adding the staff reading, which must be back sight to the known reduced level of the point on which the staff stands. Reduced levels of all the other points are obtained by subtracting the staff reading from the height of collimation. When the instrument is changed to a new station, a new height of collimation is obtained by adding the new back sight with the reduced level of the last point obtained from the previous set up of the instrument. The steps involved in booking and reading the level in the height of collimation method are illustrated with the help of an extract from a field book given below.



Station	BS	IS	FS	HI	RL	Remarks
A	0.665			100.665	100.00	BM
B		0.825			99.840	
C		2.540			98.125	
D	3.200		0.385	103.480	100.280	CP
E	1.565		1.400	103.645	102.080	CP
F		2.000			101.645	
G			2.450		101.195	

In this table, the back sight, intermediate sight and fore sight are the readings taken in the field and in the remarks column bench marks and change points are specified. Then, with the help of this available data the height of the instrument and reduced levels are calculated and the usual checks are carried out.

1. To begin with, the elevation of the plane of collimation of the first instrument station (I_1) is to be calculated. This is done by adding the back sight to the reduced level of the bench mark. The reduced level of the bench mark, i.e., point A, is taken as 100.00 and back sight is taken by holding a staff at point A (i.e., 0.665).

$$\text{Elevation of the plane of collimation} = 100 + 0.665 = 100.665$$

   This is entered as the height of the instrument (HI) as seen in the table.

2. Then, from the same instrument station, readings are taken of the staff held at B and C and entered as the intermediate sight. Then the reduced level of B and C are calculated.

$$\text{For example, RL of B} = \text{HI} - \text{IS} = 100.665 - 0.825 = 99.840$$

Copyrighted material

www.EngineeringBooksPdf.com

3. Now the instrument is shifted to the next point I_2 and the back sight and fore sight are taken. Then, the HI and reduced level at this point are calculated.

$$\begin{aligned} RL &= \text{HI at first point} - FS \\ &= 100.665 - 0.385 \\ &= 100.280 \end{aligned}$$

$$\begin{aligned} HI &= RL + BS \\ &= 100.280 + 3.200 \\ &= 103.480 \end{aligned}$$

4. This procedure is followed till the last point is reached.
5. Now the checks are carried out to ascertain the correctness of the readings.

   i.e., $\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$
   $\Sigma BS = 5.430$; $\Sigma FS = 4.235$; First RL = 100.00; Last RL = 101.195
   $5.430 - 4.235 = 101.195 - 100 = 1.195$

Hence checked.

Problem-1

Complete the levelling table given below.

Station	BS	IS	FS	HI	RL	Remarks
BM	3.10				193.62	BM
1		2.56				
2		1.07				
3	1.92		3.96			CP
4	1.20		0.67			CP
5		4.24				
6	0.22		1.87			CP
7		3.03				
8			1.41			

Solution: The levels are computed as below.

Station	BS	IS	FS	HI	RL	Remarks
BM	3.10			196.72	193.62	BM
1		2.56			194.16	
2		1.07			195.65	
3	1.92		3.96	194.68	192.76	CP
4	1.20		0.67	195.21	194.01	CP
5		4.24			190.97	
6	0.22		1.87	193.56	193.34	CP
7		3.03			190.53	
8			1.41		192.15	
	Σ 6.44		Σ 7.91			

Copyrighted material

www.EngineeringBooksPdf.com

Check: ΣBS – ΣFS = Last RL – First RL
ΣBS =6.44; ΣFS = 7.91; Last RL = 192.15; First RL = 193.62
i.e., 6.44 – 7.91 = –1.47 m
192.15 – 193.62 = –1.47 m

Hence checked.

Problem-2

Compute the levels from the levelling field book using HI method.

BS	IS	FS	HI	RL	Remarks
3.39				23.10	BM
	2.81				
	2.51				
	2.22				
2.61		1.88			CP
	2.32				
	1.92				
		1.54			

Solution. The levels are computed as below.

BS	IS	FS	HI	RL	Remarks
3.39			26.49	23.10	BM
	2.81			23.68	
	2.51			23.98	
	2.22			24.27	
2.61		1.88	27.22	24.61	CP
	2.32			24.90	
	1.92			25.30	
		1.54		25.68	
Σ 6.00		Σ 3.42			

Check: ΣBS – ΣFS = Last RL – First RL
ΣBS = 6.00; ΣFS = 3.42; Last RL = 25.68; First RL = 23.10
i.e., 6.00 – 3.42 = 2.58 m
25.68 – 23.10 = 2.58 m

Hence checked.

Problem-3

The following are the staff readings taken while making levels of a field. The back sights are underlined. Tabulate the levels in a field book and compute the level difference using HI method. <u>0.813</u>, 2.170, 2.908, 2.630, 3.133, <u>3.752</u>, 3.277, 1.899 and 2.390,

Here, in this problem, the readings have to be entered in a book form, entries checked and the reduced levels found.

Copyrighted material

www.EngineeringBooksPdf.com

BS	IS	FS	HI	RL	Remarks
0.813			40.376	39.563	BM
	2.170			38.206	
	2.908			37.468	
	2.630			37.746	
3.752		3.133	40.995	37.243	CP
	3.277			37.718	
	1.899			39.096	
		2.390		38.605	
Σ4.565		Σ5.523			

Check: ΣBS – ΣFS = Last RL – First RL
ΣBS = 4.565; ΣFS = 5.523; Last RL = 38.605; First RL = 39.563
4.565 – 5.523 = –0.958
38.605 – 39.563 = –0.958

Hence checked.

27.9 COMPUTING REDUCED LEVEL USING RISE AND FALL METHOD

This method consists in determining the difference of level between consecutive points by comparing each point, after the first, with that immediately preceding it. The difference between their staff readings indicates rise or fall depending on whether the staff reading at the point is smaller or greater than that at the preceding point. The reduced level of each point is then found by adding the rise to, or subtracting the fall from, the reduced level of the preceding point.

It is to be noted that the terms 'rise' and 'fall' always refer to rise or fall from the first point to the second point, second point to the third point and not conversely.

The steps involved are as follows:

1. It consists in determining the difference of levels between the consecutive points by comparing their staff readings.
2. Obtain the rise or fall by calculating the difference between the consecutive staff readings. Rise is indicated if the back sight is more than the fore sight, and a fall if the back sight is less than the fore sight.
3. Find out the reduced levels of each point by adding the rise to, or by subtracting the fall from, the reduced level of the preceding point.

Check: ΣBS – ΣFS = ΣRise – ΣFall = Last RL – First RL

Example-2

The following readings were extracted from a level field book.

Station	BS	IS	FS	Rise	Fall	RL	Remarks
A	0.665					100.000	BM
B		0.825			0.160	99.840	
C		2.540			1.715	98.125	
D	3.200		0.385	2.155		100.280	CP

(continued)

Copyrighted material

www.EngineeringBooksPdf.com

27.10 THEODOLITE

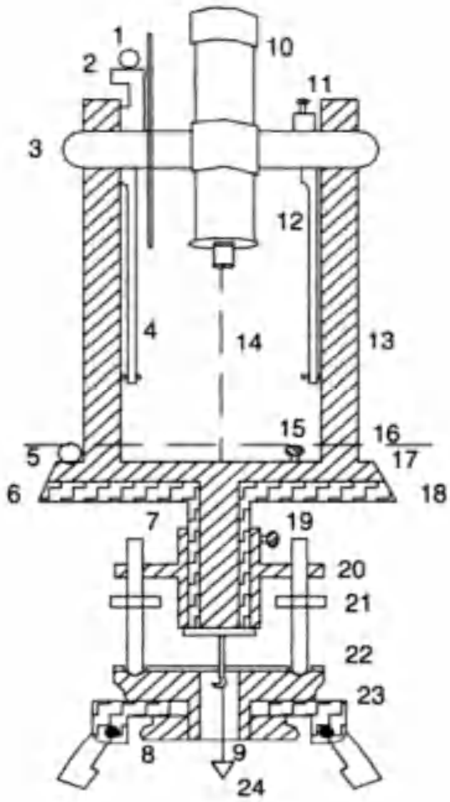
The theodolite is the most accurate instrument used mainly for measuring horizontal and vertical angles. It can also be used for locating points on a line, prolonging survey lines, finding the differences in elevations, setting out grades, ranging curves, etc.

Depending upon the facilities provided for the reading of observations, the theodolites may be classified as simple vernier theodolite, micrometer theodolite, optical (glass arc) theodolite and electronic theodolite.

A modern theodolite is compact, light in weight, simple in design and can be used rough. All the movable parts and scales are fully enclosed and virtually dust and moisture proof. Its lower graduated circle defines the size of a theodolite. For example, a 20 cm theodolite means the diameter of the graduated circle of the lower plate is 20 cm. The size of the theodolites varies from 8 to 25 cm.

Theodolites may be classified into transit and non-transit theodolites. A theodolite is said to be a transit one when its telescope can be revolved through 180° in vertical plane about its horizontal axis, thus directing the telescope in exactly opposite directions.

A theodolite is said to be a non-transit one when its telescope cannot be revolved through 180° in a vertical plane about its horizontal axis. Such theodolites are obsolete nowadays. Examples are the Y-theodolite and everest theodolite (Figure 27.15).



1. Vertical circle	2. Altitude bubble	3. Horizontal axis
4. Vernier arm	5. Plate bubble	6. Graduated arc
7. Spindle	8. Clamping nut	9. Vertical axis
10. Telescope	11. Vertical circle clamping screw	12. Arm of the vertical circle clamp
13. Standard	14. Line of collimation	15. Upper plate clamping screw
16. Axis of plate	17. Upper plate	18. Lower plate bubble
19. Lower plate	20. Tribrach	21. Foot screw clamping screw
22. Trivet	23. Tripod top	24. Plumb bob

Figure 27.15 Theodolite

Copyrighted material

www.EngineeringBooksPdf.com

Figure 27.16 Theodolite

An instrument used for measuring horizontal and vertical angles accurately is known as theodolite (Figure 27.16).

27.10.1 Classification of theodolites

Theodolites are primarily classified as

a. Transit theodolite
b. Non-transit theodolite

a. *Transit theodolite:* The theodolite whose telescope can be transited is called a transit theodolite. A transit telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane.

b. *Non-transit theodolite:* The theodolite whose telescope cannot be transited is called a non-transit theodolite. A non-transit telescope cannot be revolved through a complete revolution about its horizontal axis in vertical plane.

Non-transit theodolites are inferior as compared to transit theodolites. These have become almost outdated nowadays.

The theodolites are classified as follows

a. Vernier theodolite: In this type of theodolites, verniers are provided for reading horizontal and vertical graduated circles.

b. Glass arc theodolite: In this type of theodolites, micrometers are provided for reading horizontal and vertical graduated circles.

Copyrighted material

www.EngineeringBooksPdf.com

27.10.2 Technical terms

a. *Vertical axis:* The axis about which the theodolite may be rotated in a horizontal plane is called vertical axis. Both upper and lower plates may be rotated about the vertical axis.

b. *Horizontal axis:* The axis about which the telescope along with the vertical circle of a theodolite may be rotated in a vertical plane is called horizontal axis. It is also called as transverse axis.

c. *Line of collimation:* The line that passes through the intersection of the cross hairs of the eyepiece and optical centre of the objective and its continuation is called line of collimation. The angle between the line of collimation and the line perpendicular to the horizontal axis is called error of collimation. The line passing through the eyepiece and any point on the objective is called line of sight.

d. *Axis of telescope:* The axis about which the telescope may be rotated is called axis of telescope.

e. *Axis of the level tube:* The straight line that is tangential to the longitudinal curve of the level tube at its centre is called axis of the level tube. When the bubble of the level tube is central, the axis of the level tube becomes horizontal.

f. *Centreing:* The process of setting up a theodolite exactly over the ground station mark is known as centreing. It is achieved when the vertical axis of the theodolite is made to pass through the ground station mark.

g. *Transiting:* The process of turning the telescope in a vertical plane through 180° about its horizontal axis is known as transiting. The process is also sometimes known as reversing or plunging.

h. *Swing:* A continuous motion of the telescope about the vertical axis in the horizontal plane is called swing. The swing may be in either direction, i.e., left or right. When the telescope is rotated in clockwise (right) direction, it is known as right swing. If it is rotated in the anticlockwise (left) direction, it is known as left swing.

i. *Face left observations:* When the vertical circle is on the left of the telescope at the time of observations, the observations of the angles are known as face left observations.

j. *Face right observations:* When the vertical circle is on the right of the telescope at the time of observations, the observations of the angles are known as face right observations.

k. *Changing face:* It is the operation of changing the face of the telescope from the right to left and vice versa.

l. *A measure:* It is the determination of the number of degrees, minutes and seconds or grades contained in an angle.

m. *A set:* A set of horizontal observation of any angle consists of two horizontal measures, one on the face left and the other on the face right.

n. *Telescope normal:* A telescope is said to be normal when its vertical circle is to its left and the bubble of the telescope is up.

o. *Telescope inverted:* A telescope is said to be inverted or reversed when its vertical circle is to its right and the bubble of the telescope is down.

27.10.3 Fundamental lines of a transit

The fundamental lines of a transit are as follows:

a. The vertical axis

b. The axis of plate bubble

Copyrighted material

www.EngineeringBooksPdf.com

Adjustment of the telescope level

The object of this adjustment is that the line of collimation should remain horizontal when the bubble of the level tube, fitted on the telescope, is brought at the centre of its run. This adjustment is essential when the theodolite is used as a level and also when vertical angles are observed.

27.10.5 Measurement of horizontal angles

27.10.5.1 Direct method of measuring the angle

To measure the horizontal angle between BA and BC the following procedure is adopted (Figure 27.19):

i. Set up, centre and level the theodolite over the ground point B.

ii. Loosen the upper plate, set the vernier to read zero and clamp the upper plate.

iii. Loosen the lower plate and swing the telescope until the left point A is sighted. Tighten the lower clamp. Accurate bisection of the arrow held on station A is done by using the lower tangent screw. Read both the verniers and take the mean of the readings.

iv. Unclamp the upper plate and swing the telescope in clockwise direction until the point C is brought in the field of view. Tighten the upper clamp and bisect the arrow on station C accurately using the upper tangent screw.

v. Read both the verniers and take the mean of the readings. The difference of the means of the readings to stations C and A is the required angle ABC.

vi. Change the face of the instrument and repeat the whole procedure. The measure of the angle is again obtained by taking the difference of the means of the readings to C and A on face right.

vii. The means of the two measures of the angle ABC on the two faces is the required angle ABC.

27.10.5.2 Measurement of angle by method of repetition

Let ABC be the required angle between sides BA and BC to be measured. For accurate and precise work, the method of repetition is generally used. In this method, the value of the angle is added several times mechanically and the accurate value of the angular measure is obtained by dividing the accumulated reading by the number of repetitions (Figure 27.20).

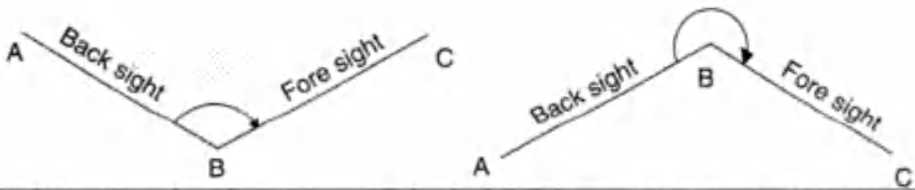


Figure 27.19 Measurement of horizontal angles

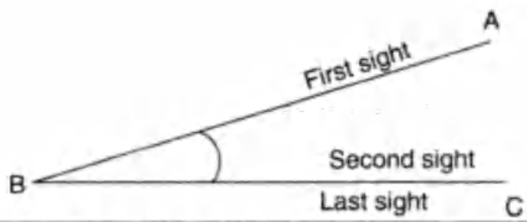


Figure 27.20 Repetition method

Copyrighted material

www.EngineeringBooksPdf.com

29.7 GEOTECHNICAL INVESTIGATION

Geotechnical investigations are performed by geotechnical engineers or engineering geologists to obtain information on the physical properties of soil and rocks around a site to design earthworks and foundations for proposed structures and for repair of distress to earthworks and structures caused by subsurface conditions. A geotechnical investigation will include surface exploration and subsurface exploration of a site. Sometimes, geophysical methods are used to obtain data about sites. Subsurface exploration usually involves soil sampling and laboratory tests of the soil samples retrieved.

Surface exploration can include geologic mapping, geophysical methods and photogrammetry, or it can be as simple as a geotechnical professional walking around on the site to observe the physical conditions at the site. To obtain information about the soil conditions below the surface, some form of subsurface exploration is required. Methods of observing the soils below the surface, obtaining samples and determining physical properties of the soils and rocks include test pits, trenching (particularly for locating faults and slide planes), boring and in-situ tests.

29.7.1 Soil sampling

Borings come in two main varieties, large-diameter and small-diameter borings. Large-diameter borings are rarely used due to safety concerns and expense, but are sometimes used to allow a geologist or engineer to visually and manually examine the soil and rock stratigraphy in situ. Small-diameter borings are frequently used to allow a geologist or engineer examine soil or rock cuttings from the drilling operation, to retrieve soil samples at depth and to perform in-place soil tests.

Soil samples are obtained in either 'disturbed' or 'undisturbed' condition; however, 'undisturbed' samples are not truly undisturbed. A disturbed sample is one in which the structure of the soil has been changed sufficiently such that tests of structural properties of the soil will not be representative of in-situ conditions, and only properties of the soil grains can be accurately determined. An undisturbed sample is one where the condition of the soil in the sample is close enough to the conditions of the soil in situ to allow tests of structural properties of the soil to be used to approximate the properties of the soil in situ.

29.7.2 Soil samplers

Soil samples are taken using a variety of samplers; some provide only disturbed samples, while others can provide relatively undisturbed samples.

a. *Shovel:* Samples can be obtained by digging out soil from the site. Samples taken this way are disturbed samples.

b. *Hand/Machine-driven auger:* This sampler typically consists of a short cylinder with a cutting edge attached to a rod and handle. The sampler is advanced by a combination of rotation and downward force. Samples taken this way are disturbed samples.

c. *Continuous flight auger:* A method of sampling using an auger as a corkscrew. The auger is screwed into the ground and then lifted out. Soil is retained on the blades of the auger and kept for testing. Soil sampled this way is considered disturbed.

d. *Split-spoon/SPT sampler:* Utilized in the 'standard test method for standard penetration test (SPT) and split-barrel sampling of soils' (ASTM D 1586), this sampler is typically a 18"–30" long, 2.0" outside diameter (OD) hollow tube split in half lengthwise. A hardened metal drive shoe with a 1.375" opening is attached to the bottom end, and a one-way valve and drill rod adapter at the sampler head. It is driven into the ground with a 140-pound hammer falling 30". The blow counts

Copyrighted material

www.EngineeringBooksPdf.com

chapter 30

Transport, Traffic and Urban Engineering

30.1 INTRODUCTION

Transport engineering or transportation engineering is the science of safe and efficient movement of people and goods. It is a sub-discipline of civil engineering. Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced, whether it is food, clothing, agricultural products, industrial products or medicine, needs transportation at all stages from production to distribution. In the production stage, transportation is required for carrying raw materials like seeds, manure, coal, steel, oil, etc. In the distribution stage, transportation is required from the production centres, namely, farms and factories to the marketing centres and later to the retailers and consumers for distribution.

30.2 THE PLANNING AND DESIGN ASPECTS OF TRANSPORT ENGINEERING

The planning aspects of transport engineering relate to urban planning and involve technical forecasting decisions and political factors. Technical forecasting of passenger travel usually involves an urban transportation planning model, requiring the estimation of trip generation (how many trips for what purpose), trip distribution (destination choice), mode choice (such as what mode is being taken) and route assignment (such as which streets or routes are being used). More sophisticated forecasting can include other aspects of traveller decisions, including auto ownership, trip chaining and the choice of residential or business location. Passenger trips are the focus of transport engineering because they often represent the peak of demand on any transportation system.

The design aspects of transport engineering include the sizing of transportation facilities (how many lanes or how much capacity the facility has), determining the materials and thickness used in pavement and designing the geometry such as vertical and horizontal alignment of the roadway or track.

Operations and management involve traffic engineering, so that vehicles move smoothly on the road or track. Older techniques include signs, signals, markings and tolling. Newer technologies involve intelligent transportation systems, including advanced traveller information systems (such as variable message signs), advanced traffic control systems and vehicle infrastructure integration. Human factors are an aspect of transport engineering, particularly concerning driver–vehicle interface and user interface of road signs, signals and markings. Transportation engineering is related to design and analysis of highways, railways, airports, urban and suburban road networks, parking lots and traffic control signal systems.

30.3 DIFFERENT MODES OF TRANSPORT

The basic modes of transport are by land, water and air. Land has given scope for development of road and rail transport. Water and air have developed waterways and airways, respectively. The roads or highways not only include the modern highway system but also the city streets feeder roads and village roads, catering to a wide range of road vehicles and pedestrians. Railways have been developed both for long distance transportation and for urban travel. Waterways include oceans, rivers, canals and lakes for the movement of ships and boats.

Copyrighted material

www.EngineeringBooksPdf.com

Aircrafts and helicopters use the airways. Apart from these major modes of transportation, other modes include pipelines, elevators, belt conveyors, cable cars, aerial ropeways and monorails.

The four major modes of transportation are:

1. Roadways or highways
2. Railways
3. Waterways
4. Airways

Transport by air is the fastest among the four modes. Air travel also provides more comfort apart from saving in transportation time for the passengers and goods between the airports. Transportation by water is the slowest among the four modes, but it is the most economical mode of transport. Water transport needs minimum energy to haul unit load through unit distance. Transportation by water is possible between the ports on the sea routes or along the rivers or canals where inland transportation facilities are available.

Transportation through the railways could be advantageous between stations both for the passengers and goods, particularly for long distances. Railway tracks serve as arteries for transportation by land and the roads could serve as feeder systems for transportation to the interior parts and to the intermediate localities between the railway stations. The energy requirement to haul unit load through unit distance by the railway is only a fraction (one fourth to one sixth) of that required by road. Transportation by road is the only mode that could give maximum service to one and all. This mode also has the maximum flexibility for travel with reference to route, direction, time, speed of travel, etc. through any mode of road vehicle.

30.4 HIGHWAY ENGINEERING

Highway engineering handles the planning, design, construction and operation of highways, roads and other vehicular facilities as well as their related bicycle and pedestrian realms. It estimates the transportation needs of the public and then secures the funding for the project and analyzes locations of high traffic volumes and high collisions for safety and capacity. Highway engineering uses civil engineering principles to improve the transportation system. A highway is defined as the main road intended for travel by the public between important cities and towns.

30.5 RAIL ENGINEERING

Railway engineers handle the design, construction and operation of railroads and mass transit systems that use a fixed guideway (such as light rail or even monorails). Typical tasks would include determining horizontal and vertical alignment design, station location and design and construction cost estimation. Railroad engineers can also move into the specialized field of train dispatching, which focusses on train movement control.

30.6 PORT AND HARBOUR ENGINEERING

Port and harbour engineers handle the design, construction and operation of ports, harbours, canals and other maritime facilities. This is not to be confused with marine engineering.

30.7 AIRPORT ENGINEERING

Airport engineers design and construct airports. Airport engineers must account for the impacts and demands of aircrafts in their design of airport facilities. One such example is the analysis of predominant wind direction to determine runway orientation.

Copyrighted material

www.EngineeringBooksPdf.com

Irrigation and Water Supply Engineering

31.1 INTRODUCTION

Irrigation is defined as the process of artificial supply of water to soil for raising crops. It is a science of planning and designing an efficient, low-cost, economic irrigation system tailored to fit natural conditions. It is the engineering of controlling and harnessing the various natural sources of water, by constructing dams and reservoirs, canals and headworks, and finally distributing the water to the agricultural fields. Irrigation engineering includes the study and design of works in connection with river control, drainage of waterlogged areas and generation of hydroelectric power. India is basically an agricultural country and all its resources depend on the agricultural output.

The scope of irrigation is not limited to the application of water to the soil. It deals with all aspects and problems extending from watershed management to the agricultural field. It deals with the design and construction of all works, such as dams, weirs, head regulators, etc., in connection with the storage and diversion of water as well as the problems of subsoil drainage, soil reclamation and water–soil–crop relationship. The scope of irrigation can be divided into two heads.

1. Engineering aspect
2. Agricultural aspect

The engineering aspect deals with the following:

1. Storage, diversion or lifting of water
2. Conveyance of water to agricultural fields
3. Application of water to agricultural fields
4. Drainage and relieving waterlogging
5. Development of water power

The agricultural aspect deals with the study of:

1. Proper depths of water necessary in a single application of water for various crops
2. Distribution of water uniformly and periodically
3. Capacities of different soils for irrigation water and the flow of water in soils
4. Reclamation of waste and alkaline lands

31.2 BENEFITS OF IRRIGATION

Apart from increase in the production of food, there are many indirect benefits or advantages of irrigations such as:

1. Protection from famine
2. Cultivation of cash crops

Copyrighted material

www.EngineeringBooksPdf.com

3. Addition to the wealth of the country
4. Increase in prosperity of people
5. Generation of hydroelectric power
6. Domestic and industrial water supply
7. Inland navigation
8. Canal plantations
9. Improvement in the groundwater storage
10. General development of the country
11. Storage of water for various purposes

31.3 TYPES OF IRRIGATION

Irrigation has the following main classes:

Flow Irrigation: Flow irrigation is that type of irrigation in which the supply of irrigation water available is at such a level that it is conveyed onto the land by gravity flow. Flow irrigation may be further divided into perennial irrigation system and inundation or flood irrigation system. In perennial irrigation system, the water required for irrigation is supplied in accordance with the crop requirements throughout the crop period. Inundation irrigation is carried out by deep flooding and through saturation of the land to be cultivated, which is then drained off prior to the planting of the crop.

Lift Irrigation: Lift irrigation is practised when the water supply is at too low a level to run by gravity onto the land. In such systems, water is lifted up by mechanical means.

31.4 DAM AND WEIRS

A dam is a barrier that impounds water or underground streams. Dams generally serve the primary purpose of retaining water, while other structures such as floodgates, levees and dikes are used to manage or prevent water flow into specific land regions.

31.5 HISTORY OF DAMS

Early dam building took place in Mesopotamia and the Middle East. Dams were used to control the water level, for Mesopotamia's weather affected the Tigris and Euphrates rivers, and could be quite unpredictable. The earliest known dam is situated in Jawa, Jordan, 100 km northeast of the capital Amman. The Ancient Egyptian Sadd Al-Kafara at Wadi Al-Garawi, located about 25 km south of Cairo, was 102 m long at its base and 87 m wide. The structure was built around 2800 or 2600 BC as a diversion dam for flood control, but was destroyed by heavy rain during construction or shortly afterwards. The Romans were also great dam builders, with many examples such as the three dams at Subiaco on the river Anio in Italy. Many large dams also survive at Mérida in Spain.

The oldest surviving and standing dam in the world is believed to be the Quatinah barrage in modern-day Syria. The dam is assumed to date back to the reign of the Egyptian pharaoh Sethi (1319–1304 BC), and was enlarged in the Roman period and between 1934 and 1938. It still supplies the city of Homs with water.

Copyrighted material

www.EngineeringBooksPdf.com

The Kallanai is a massive dam of unhewn stone, over 300 m long, 4.5 m high and 20 m wide, across the main stream of the Kaveri river in India. The basic structure dates to the second century AD. The purpose of the dam was to divert the waters of the Kaveri across the fertile delta region for irrigation via canals.

In the Netherlands, a low-lying country, dams were often built to block rivers in order to regulate the water level and to prevent the sea from entering the marshlands. Such dams often marked the beginning of a town or city because it was easy to cross the river at such a place, and often gave rise to the respective place's names in Dutch. For instance, the Dutch capital Amsterdam started with a dam through the river Amstel in the late twelfth century, and Rotterdam started with a dam through the river Rotte, a minor tributary of the Nieuwe Maas. The central square of Amsterdam, believed to be the original place of the 800-year-old dam, still carries the name Dam Square or simply the Dam.

31.6 TYPES OF DAMS

Dams can be formed by human agency, natural causes or even by the intervention of wildlife such as beavers. Man-made dams are typically classified according to their size or height and intended purpose or structure.

31.6.1 By size

International standards define large dams as higher than 15–20 m and major dams as over 150–250 m in height. The tallest dam in the world is the 300 m high Nurek Dam in Tajikistan.

31.6.2 By purpose

The intended purposes include providing water for irrigation to a town or city water supply, improving navigation, creating a reservoir of water to supply for industrial uses, generating hydroelectric power, creating recreation areas or habitat for fish and wildlife, retaining wet season flow to minimize downstream flood risk and containing effluents from industrial sites such as mines or factories. Few dams serve all of these purposes but some multi-purpose dams serve more than one.

A saddle dam is an auxiliary dam constructed to confine the reservoir created by a primary dam either to permit a higher water elevation and storage or to limit the extent of a reservoir for increased efficiency. An auxiliary dam is constructed in a low spot or saddle through which the reservoir would otherwise escape. On occasion, a reservoir is contained by a similar structure called a dike to prevent inundation of nearby land. Dikes are commonly used for reclamation of arable land from a shallow lake. This is similar to a levee, which is a wall or embankment built along a river or stream to protect adjacent land from flooding.

An overflow dam is designed to be over-topped. A weir is a type of small overflow dam that is often used within a river channel to create an impoundment lake for water abstraction purposes and which can also be used for flow measurement.

A check dam is a small dam designed to reduce flow velocity and control soil erosion. Conversely, a wing dam is a structure that only partly restricts a waterway, creating a faster channel that resists the accumulation of sediment.

A dry dam is a dam designed to control flooding. It normally holds back no water and allows the channel to flow freely, except during periods of intense flow that would otherwise cause flooding downstream.

A diversionary dam is a structure designed to divert all or a portion of the flow of a river from its natural course.

31.6.3 By structure

Based on the structure and material used, dams are classified as timber dams, arch-gravity dams, embankment dams or masonry dams with several subtypes.

Copyrighted material

www.EngineeringBooksPdf.com

31.6.3.4 Embankment dams

Embankment dams are made from compacted earth and are of two main types, rock-fill and earth-fill dams. Embankment dams rely on their weight to hold back the force of water, like the gravity dams made from concrete.

31.6.3.5 Rock-fill dams

Rock-fill dams are embankments of compacted free-draining granular earth with an impervious zone. The earth utilized often contains a large percentage of large particles, hence the term rock fill. The impervious zone may be on the upstream face and made of masonry, concrete, plastic membrane, steel sheet piles, timber or other material. The impervious zone may also be within the embankment in which case it is referred to as a core. In the instances where clay is utilized as the impervious material, the dam is referred to as a composite dam. To prevent internal erosion of clay into the rock fill due to seepage forces, the core is separated using a filter. Filters are specifically graded soil designed to prevent the migration of fine grain soil particles. When suitable material is at hand, transportation is minimized leading to cost savings during construction. Rock-fill dams are resistant to damage from earthquakes. However, inadequate quality control during construction can lead to poor compaction and sand in the embankment, which can lead to liquefaction of the rock fill during an earthquake. Liquefaction potential can be reduced by keeping susceptible material from being saturated and by providing adequate compaction during construction.

31.6.3.6 Earth-fill dams

Earth-fill dams are constructed as a simple embankment of well-compacted earth. A homogeneous rolled-earth dam is entirely constructed of one type of material but may contain a drain layer to collect seep water. A zoned-earth dam has distinct parts or zones of dissimilar material, typically a locally plentiful shell with a watertight clay core. Most modern zoned-earth embankments employ filter and drain zones to collect and remove seep water and preserve the integrity of the downstream shell zone. Rolled-earth dams may also employ a watertight facing or core in the manner of a rock-fill dam. An interesting type of temporary earth dam occasionally used in high latitudes is the frozen-core dam, in which a coolant is circulated through pipes inside the dam to maintain a watertight region of permafrost within it. Earthen dams can be constructed from materials found on-site or nearby and, hence, they can be very cost effective.

31.6.3.7 Asphalt-concrete core

Another type of embankment dam is built with asphalt concrete core. Such dams are built with rock and/or gravel as the main fill material. Almost 100 dams of this design have now been built worldwide since the first such dam was completed in 1962. All asphalt-concrete core dams built so far have an excellent performance record. The type of asphalt used is a viscoelastic plastic material that can adjust to the movements and deformations imposed on the embankment as a whole, and to settlements in the foundation. The flexible properties of the asphalt make such dams especially suited in earthquake regions.

31.6.4 Cofferdams

Cofferdam is a temporary barrier constructed to exclude water from an area that is normally submerged. Made commonly of wood, concrete or steel sheet piling, cofferdams are used to allow construction on the foundation of permanent dams, bridges and similar structures. When the project is completed, the cofferdam may be demolished or removed. Common uses for cofferdams include construction and repair of offshore oil platforms. In such cases, the cofferdam is fabricated from sheet steel and welded into place under water. Air is pumped into the space, displacing the water, allowing a dry work environment below

Copyrighted material

www.EngineeringBooksPdf.com

the surface. Upon completion, the cofferdam is usually deconstructed unless the area requires continuous maintenance.

31.6.5 Timber dams

Timber dams were widely used in the early part of the industrial revolution and in frontier areas due to ease and speed of construction. Rarely built in modern times by humans due to relatively short lifespan and limited height to which they can be built, timber dams must be kept constantly wet in order to maintain their water retention properties and limit deterioration by rot, similar to a barrel. The locations where timber dams are most economical to build are those where timber is plentiful, cement is costly or difficult to transport and either a low-head diversion dam is required or longevity is not an issue. Timber crib dams were erected of heavy timbers or dressed logs in the manner of a log house and the interior filled with earth or rubble. The heavy crib structure supported the dam's face and the weight of the water. Timber plank dams were more elegant structures that employed a variety of construction methods utilizing heavy timbers to support a water-retaining arrangement of planks. Very few timber dams are still in use.

31.6.6 Steel dams

A steel dam is a type of dam that uses steel plating and load-bearing beams as the structure. Intended as permanent structures, steel dams were an experiment to determine if a construction technique could be devised that was cheaper than masonry, concrete or earthworks, but sturdier than timber crib dams. The spillway can be gradually eroded by water flow, including cavitations or turbulence of the water flowing over the spillway, leading to its failure. Erosion rates are often monitored, and the risk is ordinarily minimized, by shaping the downstream face of the spillway into a curve that minimizes turbulent flow, such as an ogee curve.

31.7 PURPOSES FOR CONSTRUCTION OF DAMS

The common purposes for the construction of dams are as follows:

1. **Power generation:** Hydroelectric power is a major source of electricity in the world. Many countries have rivers with adequate water flow that can be dammed for power generation purposes.
2. **Water supply:** Many urban areas of the world are supplied with water abstracted from rivers pent up behind low dams or weirs. Other major sources include deep upland reservoirs contained by high dams across deep valleys.
3. **Stabilize water flow/irrigation:** Dams are often used to control and stabilize water flow, often for agricultural purposes and irrigation.
4. **Flood prevention:** Dams that are created for flood control.
5. **Land reclamation:** Dams are used to prevent ingress of water to an area that would otherwise be submerged, allowing its reclamation for human use.
6. **Water diversion:** Dams that are constructed for diverting water for various purposes.
7. **Recreation:** Dams built for any of the above purposes may find themselves displaced by the time of their original use. Nevertheless, the local community may have come to enjoy the reservoir for recreational and aesthetic reasons.

Copyrighted material

www.EngineeringBooksPdf.com

31.8 IDENTIFYING A LOCATION FOR THE CONSTRUCTION OF A DAM

One of the best places for building a dam is a narrow part of a deep river valley; the valley sides can then act as natural walls. The primary function of the dam's structure is to fill the gap in the natural reservoir line left by the stream channel. The sites are usually those where the gap becomes a minimum for the required storage capacity. The most economical arrangement is often a composite structure such as a masonry dam flanked by earth embankments. The current use of the land to be flooded should be dispensable. Significant other engineering and engineering geology considerations when building a dam include:

1. Permeability of the surrounding rock or soil
2. Earthquake faults
3. Landslides and slope stability
4. Water table
5. Peak flood flows
6. Reservoir silting
7. Environmental impacts on river fisheries, forests and wildlife (see Section 31.13, Functions of a weir)
8. Impacts on human habitations
9. Compensation for land being flooded as well as population resettlement
10. Removal of toxic materials and buildings from the proposed reservoir area

31.9 IMPACT ASSESSMENT

Impact is assessed in several ways:

1. The benefits to human society arising from dams, such as agriculture, water, floods and hydroelectric power.
2. Harm to nature and wildlife (especially rare species) and impact on the geology of an area.
3. Whether the change to water flow and levels will increase or decrease stability, and the disruption to human lives.

A large dam can cause the loss of entire ecospheres, including endangered and undiscovered species in the area, and the replacement of the original environment by a new inland lake.

31.10 HUMAN SOCIAL IMPACT

The impact on human society is also significant. For example, the Three Gorges Dam on the Yangtze River in China will create a reservoir 600 km long, to be used for hydro-power generation. Its construction required the loss of over a million people's homes and their mass relocation, the loss of many valuable archaeological and cultural sites, as well as significant ecological change. It is estimated that to date 40–80 million people worldwide have been physically displaced from their homes as a result of dam construction.

Copyrighted material

www.EngineeringBooksPdf.com

31.11 ECONOMICS

Construction of a hydroelectric plant requires a long lead time for site studies, hydrological studies and environmental impact assessment, and are large-scale projects by comparison to traditional power generation based upon fossil fuels. The number of sites that can be economically developed for hydroelectric production is limited; new sites tend to be far from population centres and usually require extensive power transmission lines. Hydroelectric generation can be vulnerable to major changes in the climate, including variation of rainfall, ground and surface water levels and glacial melt, causing additional expenditure for the extra capacity to ensure that sufficient power is available in low water years.

31.12 WEIR

A weir, also known as a low-head dam is a small overflow-type dam commonly used to raise the level of a river or stream. Weirs have traditionally been used to create mill ponds in such places. Water flows over the top of a weir, although some weirs have sluice gates, which release water at a level below the top of the weir. The crest of an overflow spillway on a large dam is often called a weir.

31.13 FUNCTIONS OF A WEIR

Weirs are used in conjunction with locks, to render a river navigable and to provide even flow for navigation. In this case, the weir is made significantly longer than the width of the river by forming it in a 'U' shape or running it diagonally, instead of the short perpendicular path. Since the weir is the portion where water overflows, a long weir allows a lot more water with a small increase in overflow depth. This is done in order to minimize fluctuation in the depth of the river upstream with changes in the flow rate of the river. Doing so avoids unnecessary complication in designing and using the lock or irrigation diversion devices.

A weir allows a simple method of measuring the rate of fluid flow in small- to medium-sized streams, or in industrial discharge locations. Since the geometry of the top of the weir is known, and all water flows over the weir, the depth of water behind the weir can be converted to a rate of flow. The calculation relies on the fact that fluid will pass through the critical depth of the flow regime in the vicinity of the crest of the weir. If water is not carried away from the weir, it can make flow measurement complicated or even impossible. A weir may be used to maintain the vertical profile of a stream or channel, and is then commonly referred to as a grade stabilizer.

A weir will typically increase the oxygen content of the water as it passes over the crest, and hence it can have a detrimental effect on the local ecology of a river system. A weir will artificially reduce the upstream water velocity, which can lead to an increase in siltation. The weir may pose a barrier to migrating fish. Fish ladders provide a way for fish to get between the water levels. Mill ponds provide a water mill with the power it requires, using the difference in water level above and below the weir to provide the necessary energy.

A walkway over the weir is likely to be useful for the removal of floating debris trapped by the weir, or for working staunches and sluices on it as the rate of flow changes. This is sometimes used as a convenient pedestrian crossing point for the river. Even though the water around weirs can often appear relatively calm, they are dangerous places to boat, swim or wade; the circulation patterns on the downstream side can submerge a person indefinitely.

31.14 TYPES OF WEIRS

There are different types of weirs. It may be a simple metal plate with a V-notch cut into it, or it may be a concrete and steel structure across the bed of a river. A weir that causes a large change of water level behind it, compared to the error inherent in the depth measurement method, will give an accurate indication of the flow rate.

Copyrighted material

www.EngineeringBooksPdf.com

1. Sharp crested weir
2. Broad crested weir (or broad-crested weir)
3. Crump weir (named after the designer)
4. Needle dam
5. Proportional weir
6. Combination weir
7. MF weir
8. V-notch weir
9. Rectangular weir
10. Cipolletti (trapezoidal) weir
11. Labyrinth weir

REVIEW QUESTIONS

1. Define irrigation and explain the scope of irrigation.
2. What are the benefits of irrigation?
3. Explain the different types of irrigation.
4. What is a dam and how are dams categorized?
5. Write short notes on:
   a. Arch dams
   b. Masonry dams
   c. Gravity dams
6. How are dams categorized by their purpose?
7. Briefly discuss cofferdams.
8. What are the purposes for constructing a dam?
9. What is a weir? What are the different types of weirs?
10. Briefly discuss identifying a location for the construction of a dam.

Copyrighted material

www.EngineeringBooksPdf.com

32.3 CAPABILITY OF CAD

Since 1980, the development of readily affordable CAD programs that could be run on personal computers began a trend of massive downsizing in drafting departments in many small- to mid-size companies. As a general rule, one CAD operator could readily replace at least three to five drafters using traditional methods. Additionally, many engineers began to do their own drafting work, further eliminating the need for traditional drafting departments. This trend mirrored the elimination of many office jobs traditionally performed by a secretary. Now a days word processors, spreadsheets, databases, etc. became standard software packages that everyone was expected to learn. In the field of product development, there are often immense costs associated with the testing of a new product. Every new product must undergo at least a small measure of physical testing, not only to ensure that it meets minimum safety standards but also to ensure that it will successfully operate under the range of conditions to which it can expect to be exposed. For instance, wing of an aeroplane must undergo stress tests to ensure that it will retain its integrity even under the most gruelling weather and turbulence conditions before it is approved for use.

32.4 NUMERICALLY CONTROLLED MACHINES

Before the development of CAD, the manufacturing world adopted tools controlled by numbers and letters for manufacturing complex shapes in an accurate and repeatable manner. During 1950s, these numerically controlled (NC) machines used the existing technology of paper tapes with regularly spaced holes punched in them to feed numbers into controller machines that were wired to the motors positioning the work on machine tools. The electro-mechanical nature of the controllers allowed digital technologies to be easily incorporated as they were developed. In late 1960s, NC machining centres were commercially available, incorporating a variety of machining processes and automatic tool changing. Such tools were capable of doing work on multiple surfaces of a work piece, moving the work piece to positions programmed in advance and using a variety of tools -- all automatically. What is more, the same work could be done over and over again with extraordinary precision and a very little additional human input. NC tools immediately raised automation of manufacturing to a new level once feedback loops were incorporated. What finally made NC technology enormously successful was the development of the universal NC programming language called automatically programmed tools (APT).

32.5 AUTOCAD

AutoCAD is a CAD software application for 2D and 3D design and drafting, developed and sold by Autodesk, Inc. Initially released in late 1982, AutoCAD was one of the first CAD programs to run on personal computers, and notably the IBM PC. Most CAD software at the time ran on graphics terminals connected to the mainframe computers or mini-computers.

In earlier releases, AutoCAD used primitive entities, such as lines, poly-lines, circles, arcs, etc., as the foundation for more complex objects. Since the mid-1990s, AutoCAD has supported custom objects through its C++ Application Program Interfaces. Modern AutoCAD includes a full set of basic solid modelling and 3D tools. With the release of AutoCAD 2007, improved 3D modelling functionality came, which meant better navigation when working in 3D. Moreover, it became easier to edit 3D models. Through AutoCAD 2010, Autodesk introduced parametric functionality and mesh modelling. AutoCAD supports a number of APIs for customization and automation. These include AutoLISP, Visual LISP, VBA, .NET and ObjectARX. ObjectARX is a C++ class library, which was also the base for products extending AutoCAD functionality to specific fields, to create products such as AutoCAD Architecture, AutoCAD Electrical, AutoCAD Civil 3D or a third-party AutoCAD-based applications.

Copyrighted material

www.EngineeringBooksPdf.com

DWF files are not a replacement for native CAD formats such as AutoCAD DWG. The sole purpose of DWF is to allow designers, engineers, project managers and their colleagues to communicate design information and design content to anyone needing to view, review or print design information – without these team members needing to know AutoCAD or the other design software. DWF is a file format developed by Autodesk for representing design data in a manner that is independent of the original application software, hardware and operating system used to create that design data. A DWF file can describe design data containing any combination of text, graphics and images in a device independent and resolution independent format. These files can be one sheet or multiple sheets, very simple or extremely complex with a rich use of fonts, graphics, colour and images. The format also includes intelligent metadata that captures the design intent of the data being represented.

32.11 ALTERNATIVES FOR DWF

PDF is an internationally recognized open, secure file format developed by Adobe Systems for the efficient distribution and communication of rich design data to anyone who needs to view, review or print design files.

Scalable vector graphics (SVG) is an open, XML-based file format. It is suitable for use both as a format for creating and editing drawings and as a format viewing and publication. For instance, Inkscape uses SVG as its native format, and both the Firefox and Opera browsers natively display SVG.

32.12 DWG (DRAWING) (FILE EXTENSION IS .DWG)

DWG is a format used for storing 2D and 3D design data and metadata. It is the native format for several CAD packages including AutoCAD, Intellicad (and its variants), Caddie and DWG are supported non-natively by many other CAD applications. DWG (denoted by the .dwg filename extension) was the native file format for the Interact CAD package, developed by Mike Riddle in the late 1970s, and subsequently licensed by Autodesk in 1982 as the basis for AutoCAD. From 1982 to 2007, Autodesk created versions of AutoCAD which wrote not less than 18 major variants of the DWG file format, none of which is publicly documented. The DWG format is probably the most widely used format for CAD drawings. Autodesk estimates that in 1998 there were in excess of two billion DWG files in existence.

There are several claims to control of the DWG format. It is Autodesk who designs, defines and iterates the DWG format as the native format for their CAD applications. Autodesk sells a read/write library, called RealDWG, under selective licensing terms for use in non-competitive applications. In the year 1998, Autodesk added a file verification to AutoCAD R14.01, through a function called DWGCHECK. This function was supported by an encrypted checksum and a product code (called a "watermark" by Autodesk), written into DWG files created by the program. In 2006, in response to Autodesk users experiencing bugs and incompatibilities in files written by reverse-engineered DWG read/write libraries, Autodesk modified AutoCAD 2007 to include "TrustedDWG technology", a function which would embed a text string within DWG files written by the program: Autodesk DWG. This file is a trusted DWG last saved by an Autodesk application or Autodesk licensed application. This helped Autodesk software users to ensure that the files they were opening were created by an Autodesk, or a RealDWG application, reducing risk of incompatibilities. AutoCAD would pop up a message, warning of potential stability problems, if a user opened a 2007 version DWG file which did not include this text string.

In 2008, the Free Software Foundation asserted the need for an open replacement for the DWG format by placing 'Replacement for OpenDWG libraries' in the 9th place on their high-priority free software projects list. In 2008, Autodesk and Bentley (the company which made the famous "Microstation" software) agreed on exchange of software libraries, including Autodesk RealDWG, to improve the ability to read and write the companies' respective DWG and DGN formats in mixed environments with greater fidelity.

Copyrighted material

www.EngineeringBooksPdf.com

In addition, the two companies will facilitate work process interoperability between their AEC applications through supporting the reciprocal use of available APIs.

32.13 AUTOCAD DXF (FILE EXTENSION IS .DXF)

AutoCAD DXF is a CAD data file format developed by Autodesk for enabling data interoperability between AutoCAD and other programs. DXF was originally introduced in December 1982 as part of AutoCAD 1.0, and intended to provide an exact representation of the data in the AutoCAD native file format, DWG, for which Autodesk for many years did not publish specifications. Because of this, correct imports of DXF files have been difficult. Versions of AutoCAD Version Release 10 and above support both ASCII and binary forms of DXF. Earlier versions support only ASCII. As AutoCAD has become more powerful, supporting more complex object types, DXF has become less useful. Many CAD applications use the DWG format which can be licensed from Autodesk or non-natively from the Open Design Alliance.

32.14 FILE STRUCTURE OF DXF

ASCII versions of DXF can be read with a text-editor. The basic organization of a DXF file is as follows.

1. **HEADER** section – This section contains the general information about the drawing. Each parameter has a variable name and an associated value.
2. **CLASSES** section – This section holds the information for application-defined classes whose instances appear in the BLOCKS, ENTITIES and OBJECTS sections of the database. Generally does not provide sufficient information to allow interoperability with other programs.
3. **TABLES** section – This section contains definitions of named items.
   a. Application ID (APPID) table
   b. Block Record (BLOCK_RECORD) table
   c. Dimension Style (DIMSTYPE) table
   d. Layer (LAYER) table
   e. Linetype (LTYPE) table
   f. Text style (STYLE) table
   g. User Coordinate System (UCS) table
   h. View (VIEW) table
   i. Viewport configuration (VPORT) table
4. **BLOCKS** section – This section contains Block Definition entities describing the entities comprising each block in the drawing.
5. **ENTITIES** section – This section contains the drawing entities including any block references.
6. **OBJECTS** section – This section contains the data that apply to non-graphical objects, used by AutoLISP and ObjectARX applications.
7. **THUMBNAILIMAGE** section – This section contains the preview image for the DXF file.
8. **END OF FILE.**

Copyrighted material

www.EngineeringBooksPdf.com

The data format of a DXF is called a "tagged data" format which means that each data element in the file is preceded by an integer number that is called a group code. A group code's value indicates what type of data element follows. This value also indicates the meaning of a data element for a given object (or record) type. Virtually all user-specified information in a drawing file can be represented in DXF format.

32.15 SOFTWARE WHICH SUPPORTS DXF

The following software supports .dxf format:

A9Cad, Adobe Illustrator, AGI32, AI4CAD 3D, Alibre Design, Altium, ArchiCAD, ArcMap, AutoCAD, Blender – Using an import script , BRL-CAD, Cadwork, Corel Draw, DWGeditor, Draw-base, Easy-PC, Epanet, Eye-Sys, EnRoute, FASTechnologies NC-CAM, Geosoft Oasis montaj, Google SketchUp, GraphCalc – Export only, Inkscape - export only as of version 0.46, IntelliCAD. Harness Expert, Hevacomp, Kabeja, Leica Geo Office, Lenel OnGuard, LD Assistant, Lightcalc, Manifold System, Maple 12, Mathematica, MetaCAM, Microlux, Microsoft Visio, Microstation, miniPLAN, Modo (software), OmniWin Cadnest, Paint Shop Pro, PETRA, Photopia, Pro/Engineer, pdf2cad, Qcad, RackTool, Rhinoceros 3D, Solid Edge, Solidworks, VariCAD, VectorWorks, ViaCAD and Visual

32.16 THE INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)

The Initial Graphics Exchange Specification (IGES) (pronounced *eye-jess*) defines a neutral data format that allows the digital exchange of information among CAD systems. The official title of IGES is Digital Representation for Communication of Product Definition Data, first published in January, 1980 by the National Bureau of Standards as NBSIR 80-1978. Using IGES, a CAD user can exchange product data models in the form of circuit diagrams, wireframe, freeform surface or solid modelling representations. Applications supported by IGES include traditional engineering drawings, models for analysis and other manufacturing functions.

The IGES project was started in 1979 by a group of CAD users and vendors, including Boeing, General Electric, Xerox, Computervision and Applicon, with the support of the National Bureau of Standards (now known as NIST) and the US Department of Defense (DoD). The name was carefully chosen to avoid any suggestion of a database standard that would compete with the proprietary databases then used by the different CAD vendors.

An ANSI standard since 1980, IGES has generated warehouses full of magnetic tapes and CD-ROMs of digital PMI for the automotive, aerospace and shipbuilding industries, as well as for weapons systems from missile guidance systems to entire aircraft carriers. These part models may have to be used years after the vendor of the original design system has gone out of business. IGES files provide a way to access these data decades from now. Today, plugin viewers for Web browsers allow IGES files created 20 years ago to be viewed from anywhere in the world.

An IGES file is composed of 80-character ASCII records, a record length derived from the punch card era. Text strings are represented in "Hollerith" format, the number of characters in the string, followed by the letter "H", followed by the text string, *e.g.*, "4HSLOT" (this is the text string format used in early versions of the FORTRAN language). Early IGES translators had problems with IBM mainframe computers because the mainframes used EBCDIC encoding for text, and some EBCDIC-ASCII translators would either substitute the wrong character or improperly set the Parity bit, causing a misreading.

32.17 COMPUTER-AIDED ENGINEERING (CAE)

Computer-aided engineering (often referred to as CAE) refers to the use of information technology to support engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis and repair. Software tools that have been developed to support these activities are considered CAE tools. CAE tools are

Copyrighted material

www.EngineeringBooksPdf.com

being used, for example, to analyze the robustness and performance of components and assemblies. The term encompasses simulation, validation and optimization of products and manufacturing tools. In future, CAE systems will be major providers of information to help support design teams in decision making. In regard to information networks, CAE systems are individually considered as a single node on a total information network and each node may interact with other nodes on the network. CAE systems can provide support to businesses. This is achieved by the use of reference architectures and their ability to place information views on the business process. Reference architecture is the basis from which information models such as product models and manufacturing models are developed.

CAE tools are very widely used in the automotive industry. In fact, their use has enabled the automakers to reduce the product development cost and time while improving the safety, comfort and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulations rather than physical prototype testing. Even though there have been many advances in CAE and it is widely used in the engineering field. Physical testing is still used as a final confirmation for subsystems due to the fact that CAE cannot predict all variables in complex assemblies (i.e. metal stretch and thinning).

Softwares such as Altair RADIOSS, LSTC's LS-DYNA, Cranes CAE suite and ESI's PAM-CRASH are used for automotive crashworthiness and occupant safety. Tools like eta/VPG, NISA, Altair HyperWorks, BETA CAE Systems', MSC's Patran, MSC's ADAMS, LMS's Virtual.Lab, SIMPACK, NEi Nastran and UGS's Scenario and Nastran packages are used in a variety of structural and dynamic analysis tasks. Other tools like LMS's AMESim are used to analyze functional performance of multi-disciplinary systems.

32.18 COMPUTER-AIDED MANUFACTURING (CAM)

Computer-aided manufacturing (CAM) is the use of computer-based software tools that assist engineers and machinists in manufacturing or prototyping product components. CAM is a programming tool that makes it possible to manufacture physical models using computer-aided design (CAD) programs. CAM creates real life versions of components designed within a software package. CAM was first used in 1971 for car body design and tooling. Traditionally, CAM was considered to be a numerical control (NC) programming tool, wherein three-dimensional (3D) models of components generated in CAD software are used to generate CNC code to drive NC machine tools. Although this remains the most common CAM function, CAM functions have expanded to integrate CAM more fully with CAD/CAM/CAE PLM solutions.

As with other 'Computer-Aided' technologies, CAM does not eliminate the need for skilled professionals such as manufacturing engineers and NC programmers. CAM, in fact, both leverages the value of the most skilled manufacturing professionals through advanced productivity tools, while building the skills of new professionals through visualization, simulation and optimization tools.

The first commercial applications of CAD were in large companies in the automotive and aerospace industries, for example, UNISURF in 1971 at Renault for car body design and tooling. Integration of CAD with other components of CAD/CAM/CAE PLM environment requires an effective CAD data exchange. Usually, it had been necessary to force the CAD operator to export the data in one of the common data formats, such as IGES or STL, that are supported by a wide variety of software. The output from the CAM software is usually a simple text file of G-code, sometimes many thousands of commands long, that is then transferred to a machine tool using a direct numerical control (DNC) program.

CAM packages could not, and still cannot, reason as a machinist can. They could not optimize toolpaths to the extent required for mass production. Users would select the type of tool, machining process and paths to be used. While an engineer may have a working knowledge of G-code programming, small optimization and wear issues compound over time. Mass-produced items that require machining are often initially created through casting or some other non-machine method. This enables hand-written, short and highly optimized

Copyrighted material

www.EngineeringBooksPdf.com

G-code that could not be produced in a CAM package. Over time, the historical shortcomings of CAM are being attenuated, both by providers of niche solutions and by providers of high-end solutions. This is occurring primarily in three arenas:

1. Ease of use
2. Manufacturing complexity
3. Integration with PLM and the extended enterprise

For the user who is just getting started as a CAM user, out-of-the-box capabilities, providing process wizards, templates, libraries, machine tool kits, automated feature based machining and job function specific tailorable user interfaces, build user confidence and speed up the learning curve. User confidence is further built on 3D visualization through a closer integration with the 3D CAD environment, including error-avoiding simulations and optimizations.

The manufacturing environment is increasingly complex. The need for CAM and PLM tools of the manufacturing engineer, NC programmer or machinist is similar to the need for computer assistance of the pilot of modern aircraft systems. The modern machinery cannot be properly used without this assistance. Today's CAM systems support the full range of machine tools, including turning, five axis machining and wire EDM. Today's CAM user can easily generate streamlined tool paths, optimized tool axis tilt for higher feed rates and optimized Z axis depth cuts as well as driving non-cutting operations such as the specification of probing motions.

The largest CAM software companies (by revenue by the year 2005) are UGS Corp (now owned by Siemens and called Siemens PLM Software, Inc) and Dassault Systèmes, both with over 10 per cent of the market; CAMWorks, PTC, Hitachi Zosen and Delcam have over 5 per cent each; while Planit-Edgecam, Tebis, TopSolid, CATIA, CNC (Mastercam), SolidCAM, DP Technology's ESPRIT, OneCNC, and Sescoi between 2.5 per cent and 5 per cent each. The remaining 35 per cent is accounted for by other niche suppliers like T-Flex, Dolphin CAD/CAM, MecSoft Corporation, SurfCAM, BobCAD, Metamation, GibbsCAM and SUM3D.

32.19 ELECTRONIC DESIGN AUTOMATION

Electronic design automation (EDA) is the category of tools for designing and producing electronic systems ranging from printed circuit boards (PCBs) to integrated circuits. This is sometimes referred to as ECAD (electronic computer-aided design) or just CAD.

The term EDA is also used as an umbrella term for computer-aided engineering, computer-aided design and computer-aided manufacturing of electronics in the discipline of electrical engineering. The segments of the industry that must use EDA are chip designers at semiconductor companies. Large chips are too complex to be designed by hand. EDA for electronics has rapidly increased in importance with the continuous scaling of semiconductor technology. EDA tools are also used for programming design functionality into FPGAs.

Before EDA, integrated circuits were designed by hand and manually laid out. Some advanced shops used geometric software to generate the tapes for the Gerber photoplotter, but even those copied digital recordings of mechanically-drawn components. The process was fundamentally graphic, with the translation from electronics to graphics done manually. By the mid-70s, developers had started to automate the design and not just the drafting. The first placement and routing (place and route) tools were developed. The proceedings of the Design Automation Conference cover much of this era.

The next era began more or less with the publication of 'Introduction to VLSI Systems' by Carver Mead and Lynn Conway in 1980. This groundbreaking text advocated chip design with programming languages that compiled to silicon. The immediate result was a hundredfold increase in the complexity of the chips that could be designed, with improved access to design verification tools that used logic simulation. Often the

Copyrighted material

www.EngineeringBooksPdf.com

chips were not just easier to lay out but more correct as well, because their designs could be simulated more thoroughly before construction. The earliest EDA tools were produced academically, and were in the public domain. One of the most famous was the 'Berkeley VLSI Tools Tarball', a set of UNIX utilities used to design early VLSI systems. Another crucial development was the formation of MOSIS, a consortium of universities and fabricators that developed an inexpensive way to train student chip designers by producing real integrated circuits. The basic idea was to use reliable, low-cost, relatively low-technology IC processes and pack a large number of projects per wafer, with just a few copies of each projects' chips. Cooperating fabricators either donated the processed wafers, or sold them at cost, finding the program helpful for their own long-term growth.

1981 marked the beginning of EDA as an industry. For many years, the larger electronic companies, such as Hewlett Packard, Tektronix and Intel, had pursued EDA internally. In 1981, managers and developers spun out of these companies to concentrate on EDA as a business. Daisy Systems, Mentor Graphics and Valid Logic Systems were all founded around this time, and collectively referred to as DMV. Within a few years there were many companies specializing in EDA, each with a slightly different emphasis.

In 1986, Verilog, a popular high-level design language, was first introduced as a hardware description language by Gateway. In 1987, the US Department of Defense funded the creation of VHDL as a specification language. Simulators quickly followed these introductions permitting direct simulation of chip designs—executable specifications. In a few more years, back-ends were developed to perform logic synthesis. Many of the EDA companies acquire small companies with software or other technology that can be adapted to their core business. Most of the market leaders are rather incestuous amalgamations of many smaller companies. This trend is helped by the tendency of software companies to design tools as accessories that fit naturally into a larger vendor's suite of programs. (On digital circuitry, many new tools incorporate analog design and mixed systems. This is happening because there is now a trend to place entire electronic systems on a single chip.)

Current digital flows are extremely modular. The front ends produce standardized design descriptions that compile into invocations of 'cells', without regard to the cell technology. Cells implement logic or other electronic functions, using a particular integrated circuit technology. Fabricators generally provide libraries of components for their production processes, with simulation models that fit standard simulation tools. Analog EDA tools are much less modular, since many more functions are required, they interact more strongly, and the components are less ideal.

32.20 MULTIDISCIPLINARY DESIGN OPTIMIZATION

Multidisciplinary design optimization (MDO) is a field of engineering that uses optimization methods to solve design problems, incorporating a number of disciplines. It is also known as multidisciplinary optimization and multidisciplinary system design optimization (MSDO). MDO allows designers to incorporate all relevant disciplines simultaneously. These techniques have been used in a number of fields, including automobile design, naval architecture, electronics, computers and electricity distribution. However, the largest number of applications has been in the field of aerospace engineering, such as aircraft and spacecraft design. For example, the Boeing blended wing body (BWB) aircraft concept has used MDO extensively in the conceptual and preliminary design stages. The disciplines considered in the BWB design are aerodynamics, structural analysis, propulsion, control theory and economics.

32.21 3D COMPUTER GRAPHICS SOFTWARE

3D computer graphics software refers to programs used to create 3D computer-generated imagery. There are typically many stages in the 'pipeline' that studios use to create 3D objects for film and games, and this chapter only covers some of the software used. Note that most of the 3D packages have a very plugin-oriented

Copyrighted material

www.EngineeringBooksPdf.com

17. Softimage (Autodesk)
18. solidThinking (solidThinking Ltd).
19. SolidWorks (SolidWorks Corporation)
20. trueSpace (Caligari Corporation)
21. Vue 7 (E-on Software)
22. ZBrush (Pixologic)
23. RealFlow
24. Realsoft3D Real3D
25. Rhinoceros 3D
26. Seamless3d NURBS
27. Terragen and Terragen 2 (Both are freeware scenery generators)
28. Wings 3D

32.23 BASIC COMMANDS IN AUTOCAD

You can start the AutoCAD by using the following procedure:

1. In Windows: on task bar click start and then choose programs then choose AutoCAD from the menu
2. Otherwise, it is possible to open AutoCAD by double clicking the short cut placed in the desktop

32.24 THE AUTOCAD INTERFACE

When you first start AutoCAD, the initial screen contains the menu bar at the top, the status bar at the bottom, the drawing window, the command window and several tool bars. Tool bars contain icons that represent commands. The menu bar contains the menu. The status bar displays the cursor coordinates and the status the modes such as Grip, Snap, OSnap, OTrack, etc. Mode names are always visible in the status bar as selectable buttons. Double click to turn it on.

32.24.1 Utility commands

32.24.1.1 New

New lets you start a new drawing from scratch or use an existing drawing as a template for a new drawing.

To create a new drawing—Command line: New, Ctrl+N

Menu: File → New

Options

- Open a Drawing: Use Open a Drawing to locate and open the first AutoCAD drawing in your session.

Copyrighted material

www.EngineeringBooksPdf.com

Command line: Ellipse, El

Menu: Draw → Ellipse Center/Axis, End/Arc

Options

- Axis Endpoint: Allows you to enter the endpoint of one ellipse axes. Other endpoints of the axis appear after you have defined one point of the ellipse axes. Enter the distance from the center of the ellipse to the second axis point.
- Center: Allows you to pick the center point of ellipse.
- Arc: Creates an elliptical arc. The angle of the first axis determines the angle of the arc.

REVIEW QUESTIONS

1. What is Computer Aided Design? Give a brief description about the importance CAD in engineering.
2. What are the capabilities of CAD?
3. What is CAM? Differentiate between CAD and CAM.
4. Write Short Notes on:
   a. Numerically controlled machine
   b. AutoCAD
   c. AutoCAD LT
5. What is .dwg file? What is its importance in AutoCAD?
6. Discuss briefly about .dxf file format used in CAD applications.
7. What is the importance of DWF in CAD?
8. Explain about the file structure of DXF.
9. What is IGES and what is its importance in CAD?
10. What are the differences between .dxf and .dwg files?
11. What is CAE and what is its importance?
12. What is EDA and what is its importance in circuit design?
13. Write short notes on:
    a. MDO
    b. 3D computer graphics software

Copyrighted material

www.EngineeringBooksPdf.com

index

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

Copyrighted material

www.EngineeringBooksPdf.com

BASIC CIVIL ENGINEERING

SATHEESH GOPI

Basic Civil Engineering is designed to provide students of non-civil branches of engineering with the preliminary conceptual knowledge about civil engineering. The coverage includes materials for construction, building construction, basic surveying and other major topics like environmental engineering, geo-technical engineering, transport traffic and urban engineering, irrigation and water supply engineering, and CAD.

Key Features

- Discusses the quality and standard of materials used along with its cost effectiveness.
- Modern field procedures for surveying such as Total Station, GPS and digital levels
- Building services like air conditioning, fire protection systems, lifts, escalators, etc., as well as the repair and maintenance of structures.
- A chapter on CAD, highlighting its importance in civil engineering.

ISBN 978-81-317-2988-5

9788131729885

PEARSON

www.pearsoned.co.in

Copyrighted material

www.EngineeringBooksPdf.com