BASIC CIVIL AND MECHANICAL ENGINEERING

G SHANMUGAM | M S PALANICHAMY

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Basic Civil and Mechanical Engineering

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G Shanmugam obtained his BE in Mechanical Engineering in 1951 from the College of Engineering, Guindy, Chennai, and ME in IC Engines in 1958 from Purdue University, USA, where he had an opportunity to serve as a part-time teaching Assistant. During his distinguished academic career, he has been in the teaching profession for the past 65 years, out of which he has taught abroad for 20 years. He has served as Professor of Mechanical Engineering at PSG College of Technology, Coimbatore, University of Basrah, Iraq, and Gulf Polytechnic, Bahrain. As founder Principal, he served in Mepco Schlenk Engineering College for a period of 18 years and developed it as the *numero uno* Technical Institution in Tamil Nadu. The college received the first National Award as the Best Engineering College in 1998 from ISTE, instituted by Bharatiya Vidya Bhavan, Mumbai.

Prof. Shanmugam has received more than 13 personal awards at the regional, state and national levels including the Best Principal Award, Outstanding Engineer Award, Achiever Award and many more. He is a fellow of the Institution of Engineers (India), Kolkata. He is a Life Member of ISTE Quality Forum of India and Acoustic Society of India. At present, even at the age of 88, he is actively serving as Advisor at Kamaraj College of Engineering and Sri Vidya College of Engineering. He is also a member of the Governing Council at Dhanalakshmi College of Engineering, Chennai. He is a widely travelled person having visited more than 17 countries so far. He has recently authored an autobiography titled *Secret of Success* and this book is being distributed to many school, college and polytechnic libraries, free of cost.

M S Palanichamy obtained a bachelor's degree in Civil Engineering from PSG College of Technology and MTech and PhD degrees from the Indian Institute of Technology Madras, Chennai. His teaching experience spans over 43 years.

He was a faculty of Anna University in the Structural Engineering Department for a decade. He served as the Professor and Head of Civil Engineering Department and then as the Principal of Mepco Schlenk Engineering College, Sivakasi. Later he served as the Vice Chancellor of Tamil Nadu Open University, Chennai, for two terms and Vice Chairman of Tamil Nadu State Council for Technical Education. Currently, he is serving as the Advisor of RMK Group of Engineering Colleges, Kavaraipettai, Chennai. He has published six books and 60 papers in his professional career. Also, four candidates have obtained their PhD degrees under his guidance.

He is a member of various professional bodies like American Concrete Institute (AUI), Institution of Engineers (India), Indian Concrete Institute (ICI), Institution of Valuers, etc., and he has also served as the member of National Executive Council of the Indian Society of Technical Educational and All India Council for Technical Education and as member of Engineering Accreditation Committee, NBA, New Delhi. He was the Chairman, Board of Studies, Civil Engineering, of Madurai Kamaraj University and Anna University.

He has been conferred with many awards such as Lifetime Achievement Award and Honorary Fellowship by the Indian Society for Technical Education at State and National Level respectively, Live Award by Loyola College, Chennai, and France Heritage Award by Gavoty Foundation, France.

At present, he is serving in the governing councils of many technical institutions and private universities in Tamil Nadu.

Basic Civil and Mechanical Engineering

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McGraw Hill Education (India) Private Limited
Published by McGraw Hill Education (India) Private Limited
444/1, Sri Ekambara Naicker Industrial Estate, Alapakkam, Porur, Chennai 600 116

Basic Civil and Mechanical Engineering

1 2 3 4 5 6 7 8 9 D103074 22 21 20 19 18

Printed and bound in India.

ISBN (13): 978-93-87572-31-7
ISBN (10): 93-87572-31-5

Vice President—Finance & Operations: *Ashutosh Verma*

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Typeset at APS Compugraphics, 4G, PKT 2, Mayur Vihar Phase-III, Delhi 96, and printed at

Cover Printer:

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Late Sri C Gurusamy Nadar
&
Late Smt. Sivahami Ammal

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Late Sri K M Selliah Thevar
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Late Smt. Seethalakshmi Ammal

– M S Palanichamy

PREFACE

Unit 1, 2 and 3 of this book concisely covers the syllabus for the Civil Engineering part of the Basic Civil and Mechanical Engineering course. It will be useful not only to the first year engineering students, but also to diploma and AMIE students. It will also serve as a good reference material for those preparing for competitive examinations.

This book is presented in a simple and comprehensive manner. Solved problems and illustrative diagrams have been included to explain the various concepts. Exercises are appended at the end of each chapter to provide adequate practice to the students and to help them comprehend the subject. It covers all the latest topics included in the syllabi to help students in learning and teachers in classroom teaching.

I am thankful to the Management of Mepco Schlenk Engineering College, Sivakasi, and R M K Group of Engineering Colleges, Kavaraipettai, Chennai, for their encouragement in completing this project. I express my gratitude to the faculty of Civil Engineering Department for the help extended to me at various stages of the project, when I was serving at Mepco Schlenk Engineering College.

I convey my thanks and appreciation to McGraw Hill Education (India) in bringing out this high-quality edition in a short span of time.

M S Palanichamy

Unit 1, 4 and 5 of this book covers the syllabus for the Mechanical Engineering part of the Basic Civil and Mechanical Engineering course, which caters to the first year engineering students.

Throughout the text, an attempt has been made to present the subject matter in a simple, lucid and precise manner. More than two illustrations, supported by simple theoretical presentations, help in easy understanding of the concepts. Great care has been taken to make the text student- and teacher-friendly. Varieties of questions are appended at the end of each chapter to provide adequate practice to the students and to help them comprehend the subject. All the topics have been included as per the latest syllabus.

I express my gratitude to the support rendered by my son, Dr S Ravindran, Mechanical Engineering Department, Hindustan Institute of Science and Technology, Hindustan University, Chennai, in helping me with preparation and finalization of the manuscript.

I convey my thanks and appreciation to McGraw Hill Education (India) in bringing out this high-quality edition in a short time span.

G Shanmugam

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UNIT-1

SCOPE OF CIVIL AND MECHANICAL ENGINEERING

Chapter 1
SCOPE OF CIVIL ENGINEERING

1.1 CIVIL ENGINEERING

Civil Engineering is the field of engineering concerned with planning, design and construction for environmental control, development of natural resources, buildings, transportation facilities and other structures required for health, welfare, safety, employment and pleasure of mankind.

The main scope of civil engineering or the task of civil engineering is planning, designing, estimating, supervising construction, execution, and maintenance of structures like building, roads, bridges, dams, etc.

Population demographics along with increasing urbanization have facilitated the need for sustainable and efficient infrastructure solutions. Development in green buildings, sensor-embedded roads and buildings, geopolymer concrete, and water management will stimulate global civil engineering industry growth.

1.1.1 Field of Civil Engineering

Civil engineering is a wide field and includes many types of structures such as residential buildings, public buildings, industrial buildings, roads, bridges, tunnels, railways, dams, canal and canal structures, airports, harbours, ports, water treatment plants, waste water treatment plants, water supply networks, and drainage networks. It also covers environmental protection, irrigation and water resources, soil investigations and foundations, transport systems management, etc.

1.1.2 Specialized Disciplines in Civil Engineering

Civil engineering may be divided into the following fields:

- Building materials
- Building construction
- Structural engineering
- Geotechnical engineering
- Hydraulics, water resources and irrigation engineering

- Water supply and sanitary engineering
- Environmental engineering
- Transportation engineering
- Town planning and architecture
- Surveying
- Drawing
- Estimation and specification
- Management techniques
- Computer application

1.1.3 Building Materials

- Shelter is the basic need of civilized society. Stones, bricks, timber and lime concrete are the traditional materials used for the construction of houses and other buildings.
- The invention of cement and concrete has provided durable buildings.
- Reinforced concrete which is composite construction of steel and concrete has helped in building large structures.
- Steel, aluminium, glass, plastics, glazed tiles, plaster of Paris, linoleum, paints and varnishes have improved the quality of buildings.
- Improved versions of many building materials keep on appearing in the market regularly. A civil engineer has to make use of all these materials judiciously.

1.1.4 Building Construction

Construction Engineering is a professional discipline that deals with the designing, planning, construction, and management of infrastructures such as roads, tunnels, bridges, airports, railroads, facilities, buildings, dams, utilities and other projects. It is considered a professional sub-practice area of civil engineering or architectural engineering.

The following stages are carried out for any type of project:

1. In the beginning, technical feasibility, environmental impact assessment and economical viability of the project are studied.
2. Soil investigation includes collecting data regarding soil and bearing capacity of soil. Soil investigations are done for the purpose of foundation design.
3. Surveying includes preparing site plan, contour map and measurement of field dimensions and levels.
4. On the basis of the data collected, planning and designing are carried out and drawings are prepared. Buildings are planned according to the fundamental principles of planning and by laws of local municipal bodies. Building planning also requires basic knowledge of principles of architecture.

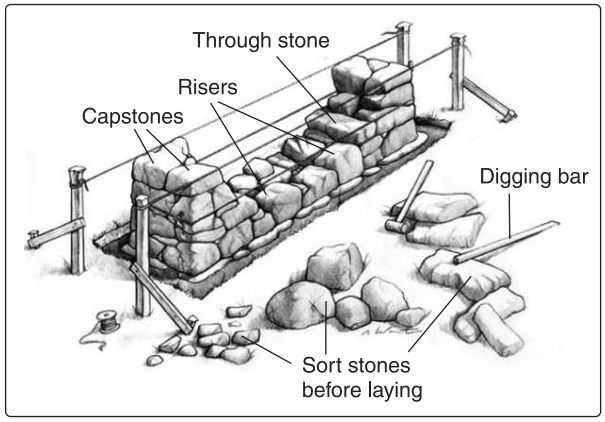

Fig 1.1 *Bonding of Stone Masonry*

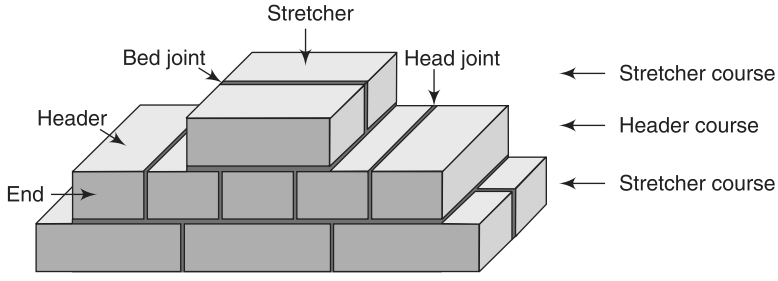

Fig 1.2 *Bonding of Brick Masonry*

5. Estimates are prepared to know the probable cost of completion of work and detailed planning and scheduling are prepared to carry out different activities in time without any delay.

I. During Construction Owner, engineer and contractor are the three constituents of a construction team in engineering profession, hence continuous liaison among themselves is very essential for the speedy progress of the work. Execution of work is actual construction carried out on the site with materials and equipment, by skilled and unskilled work force, under the technical guidance and supervision of engineer in charge. During construction, engineer has to supervise the work carried out as per the specifications for quality control. Costing is the accounts procedure of arriving at the actual cost of construction.

II. After Construction Maintenance and repairs, valuation after the construction, regular maintenance of structures are to be carried out. Valuation is carried out for the purpose of sale, purchase and many others.

III. Importance of Construction Management and its Functions

- It gives guidelines regarding the execution of construction work to be carried out.

- It helps in preparing construction schedule. Schedule is a systematic path of different activities carried out one after another. It helps in defining goals and planning procedure.
- It helps in proper management of material, labour and equipment.
- It helps in arranging for finance and due to proper construction management, there is financial and overall control on the work.
- Due to proper construction management, project can be completed in estimated completion cost and time.

IV. Functions of Construction Management

1. Project is divided into different phases.
2. Planning and preparing construction schedule.
3. Estimating requirements of material and labour.
4. Procurement of material plant, machinery and employing labours.
5. Arranging for finance and payment of material, and salaries of labours.
6. To establish communication between various sections.
7. To have overall control which includes financial control of the project and to maintain quality and workmanship.

1.1.5 Structural Engineering

This branch of civil engineering deals with structural analysis and design of structures.

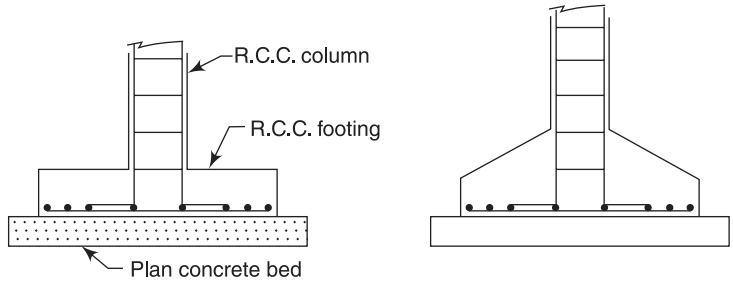

Fig 1.3 *Reinforced Concrete Structures – Footings and Columns*

The object of structural analysis is to determine the internal forces and the corresponding displacements of all structural elements as well as those of the entire structural system. The safety and proper functioning of the structure can be ensured only through a thorough structural analysis.

Structural engineering theory is based upon applied physical laws and empirical knowledge of the structural performance of different materials and geometries. Structural engineering design utilizes a number of relatively simple structural elements to build complex structural systems.

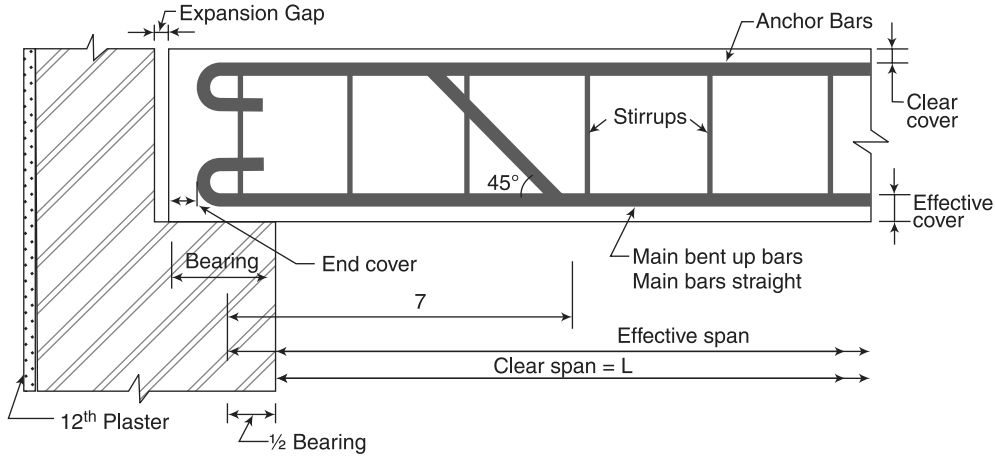

Fig 1.4 *Reinforced Concrete Structures – Beams*

The aspects of analysis and design are as follows:

- Structural analysis is done to calculate stresses in structural components, on the basis of loads acting on structures.
- Before building a structure, it should be analyzed and designed to decide about its size to resist the possible forces coming on it.
- The structure should be safe and at the same time its components should be as small as possible.
- Requirement of large column free structures gave rise to analysis and design of shell roofs (curved surfaces), geodetic towers and tension structures.
- Up to mid-1960s, lot of improvements were seen in the classical methods of analysis. Need of tall structures and improvements in computers gave rise to matrix method and finite element method of analysis.

The role of structural engineers is as follows:

- Structural engineers are trained to understand, predict, and calculate the stability, strength and rigidity of built structures for buildings and nonbuilding structures.
- Develop designs and integrate their design with that of other designers, and supervise construction of projects on site.
- A structural engineer has to not only give a safe structure but he has to give an economical structure also. Hence, there is need for studying mathematical optimization techniques.
- Structural engineers are responsible for making creative and efficient use of funds, structural elements and materials to achieve these goals.
- Disasters due to earthquakes have made civil engineers to study earthquake forces and build earthquake resistant structures. It needs the knowledge of structural dynamics.

- They can also be involved in the design of machinery, medical equipment, and vehicles where structural integrity affects functioning and safety.

1.1.6 Geotechnical Engineering

Geotechnical engineering is that field of civil engineering which deals with soil investigation and design of proper foundations of structures.

1.1.6.1 Soil Investigation Geotechnical engineering uses principles of soil mechanics and rock mechanics to investigate subsurface conditions and materials. It deals with determination of the relevant physical/mechanical and chemical properties of these materials; evaluates stability of natural slopes and man-made soil deposits; assesses risks posed by site conditions.

Soil investigation includes collection and testing of soil samples. Soils are considered as three-phase materials composed of rock or mineral particles, water and air. The voids of soil, the spaces in between mineral particles, contain water and air. The engineering properties of soils are affected by four main factors: the predominant size of the mineral particles, the type of mineral particles, the grain size distribution, and the relative quantities of mineral, water and air present in the soil matrix. Fine particles (fines) are defined as particles less than 0.075 mm in diameter.

All structures have to finally transfer the load acting on them to soil safely. Soil property changes from place to place. Even in the same place it may not be uniform at different depth and in different seasons. Hence, a civil engineer has to properly investigate soil and decide about the safe load that can be spread on the soil. Geotechnical engineering includes measurement of soil parameters and safe bearing capacity.

1.1.6.2 Foundation Design Foundations built for above-ground structures include shallow and deep foundations. Retaining structures include earth-filled dams and retaining walls. Apart from finding safe bearing capacity for foundation of buildings, geotechnical engineering involves various studies required for the design of pavements, tunnels, earthen dam, canals and earth retaining structures. It involves study of ground improvement techniques also. It also includes construction and design of simple foundations, pile foundations, well foundations, caissons, coffer dams, construction of foundation of dams, construction of tunnels, sub base of road, earthen dams, and earth related constructions.

Sound knowledge of geology and geotechnical engineering is necessary for construction of earth related structures. Earthworks include embankments, tunnels, dikes and levees, channels, reservoirs, deposition of hazardous waste and sanitary landfills.

Geotechnical engineering is also related to coastal and ocean engineering. Coastal engineering can involve the design and construction of wharves, marinas, and jetties. Ocean engineering can involve foundation and anchor systems for offshore structures such as oil platforms.

The fields of geotechnical engineering and engineering geology are closely related, and have large areas of overlap. However, the field of geotechnical engineering is a specialty of engineering, whereas the field of engineering geology is a specialty of geology.

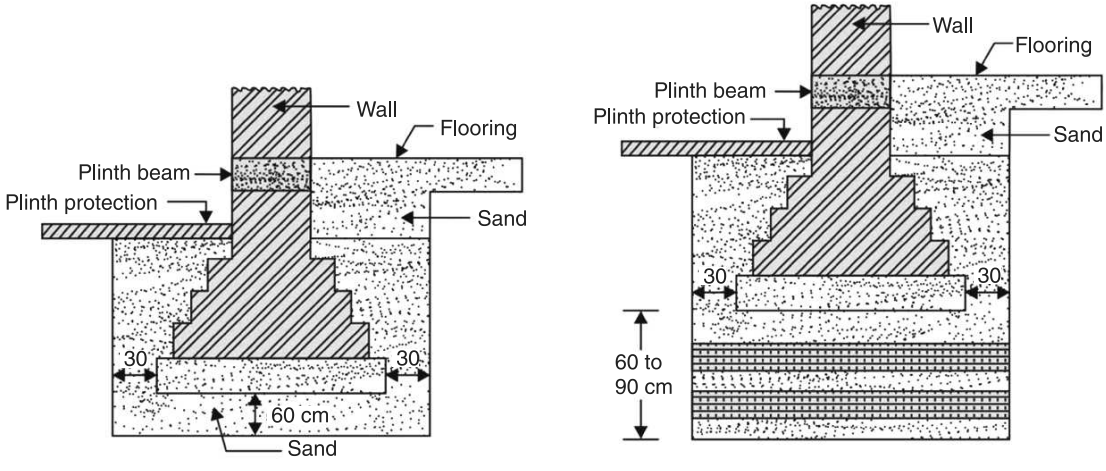

Fig 1.5 *Cross Section of Foundation*

Geotechnical engineering is important in civil engineering, but it also has applications in military, mining, petroleum and other engineering disciplines that are concerned with construction occurring on the surface or within the ground.

1.1.7 Hydraulics, Water Resources and Irrigation Engineering

Water is an important need for all living beings. Study of mechanics of water and its flow characteristics is another important field in civil engineering and it is known as hydraulics. Requirement of water in cities for domestic purpose and for industries is continuously increasing.

Water resource engineering means measurement, utilization and development of water resources for agriculture, municipal and power generation purpose. Rural areas need water for agricultural field also. Hence, civil engineers have to look for new water resources and for storing them. It involves the design of new systems and equipment that help manage human water resources. Water resource engineering deals with planning, designing and developing water resources by constructing several hydraulic structures like dams, barrages, hydropower stations, canal and pipe networks, etc.

Water stored in reservoirs by building bunds and dams should be brought to agricultural fields through canals and distributories. Study connected with this aspect is known as irrigation engineering. It also includes watershed planning, water harvesting techniques, soil conservation and soil reclamation. Hydrology is also a part of water resource engineering. It includes study of sources of water, measurement of rainfall, study of rainfall, runoff, and flood control.

1.1.8 Water Supply and Sanitary Engineering

When water is required for drinking purpose, it should be purified and made potable. Purification of water and the technology involved in taking it to the houses is known as water supply engineering. Waste water and solid waste should be treated and disposed so that they do not create health hazard. This branch of civil engineering is known as sanitary engineering.

The five essential requirements for human existence are air, water, food, heat and light. Contamination of these elements may cause serious health hazard not only to man but also to animal and plant life. The use of water by man, plants and animals is universal. Without it, there can be no life. Every living thing requires water.

Man and animals not only consume water, but they also consume vegetation for their food. Vegetation, in turn, cannot grow without water. Growth of vegetation also depends upon bacterial action, while bacteria need water in order to thrive. The bacterial action can convert vegetable matter into productive soil. New plants, which grow in this soil, grow by sucking nutrients through their roots in the form of solution in water. Thus, an ecological chain is maintained. Water maintains an ecological balance, i.e., balance in the relationship between living things and environment in which they live.

The use of water is increasing rapidly with our growing population. Already there are acute shortages of both surface and undergroundwaters in many parts of the country. Careless pollution and contamination of the streams, lakes, reservoirs, wells and other underground sources has greatly impaired the quality of available water. This pollution results because of improper disposal of waste water – both domestic as well as industrial. Organized community life requires twin services of water supply and sewage disposal.

Good sanitation cannot be maintained without adequate water supply system. Without proper disposal, the wastes of a community can create intolerable nuisance, spread diseases and create other health hazards. The planning, designing, financing and operation of water and waste water systems are complex undertakings, and they require a high degree of skill and judgement.

1.1.8.1 Need for Protected Water Supplies It is necessary that the water which is supplied to the public must be invariably free from all types of impurities both suspended and/or dissolved in it, any kind of bacteria and any other contamination which may cause serious harm to the health of the public. It is therefore imperative to plan and build such a water supply scheme which would provide potable water free from any kind of contamination.

In general, the water obtained from wells or springs, i.e., groundwater, is free from impurities and it may be supplied to public without adopting any method of purification. This is so because, in the course of its movement through the porous sub-strata, the water is completely relieved of its suspended impurities. However, before supplying to the public this water may have to be disinfected by chlorination (i.e., by adding chlorine or chlorine compound to water) or any other methods, in order to remove any harmful bacteria responsible for causing diseases.

The Water obtained from any of the surface source needs to be purified before it can be supplied to the public. The most commonly adopted method of purification of water is filtration. In the process of filtration, water is allowed to pass through sand beds and gravel whereby minute suspended and dissolved particles are removed. It has been found that the process of filtration is greatly accelerated if water is pretreated with certain substances, which when added to water forms large masses of precipitates or flocs out of the impurities present which in the process settle down and are ultimately removed. This prefiltration treatment of water is known as coagulation which involves the use of alum.

The water having undergone through the process of filtration is still found to contain some harmful disease producing bacteria which are minutely-sized living organisms not visible to naked eye. As such in order to ensure protected supplies of water free from any health hazard, it is necessary to kill these bacteria by disinfecting water. The most commonly adopted method of disinfecting is chlorination which is a process of adding chlorine or chlorine compound to water. Other methods of disinfecting water viz., treatments through ozone or ultraviolet rays or excess lime are also in use.

Thus, it may be seen that a public water supply system should be such that it is able to provide an adequate and reliable supply of water catering to all the public needs and also ensure that the supplies so made are not only potable but also fully protected against any inflection which might pollute water and cause epidemics resulting in human suffering and loss.

1.1.8.2 Objectives of Public Water Supply System The main objectives of any public water supply system are as follows:

- To supply safe and wholesome water to the consumers
- To supply water in adequate quantity
- To make water available within easy reach of the consumers so as to encourage the general cleanliness.

1.1.8.3 Planning of Water Supply Scheme for A Town or City In planning a water supply scheme for a town or city the following points need to be considered:

- Sources of water
- Quality of water
- Population
- Rate of consumption
- Topography of area
- Financial aspects
- Trends of future development

1.1.8.4 Sources of Water The various sources of water available on the earth can be classified into the following two categories:

1. Surface sources of water
2. Sub-surface or underground sources of water

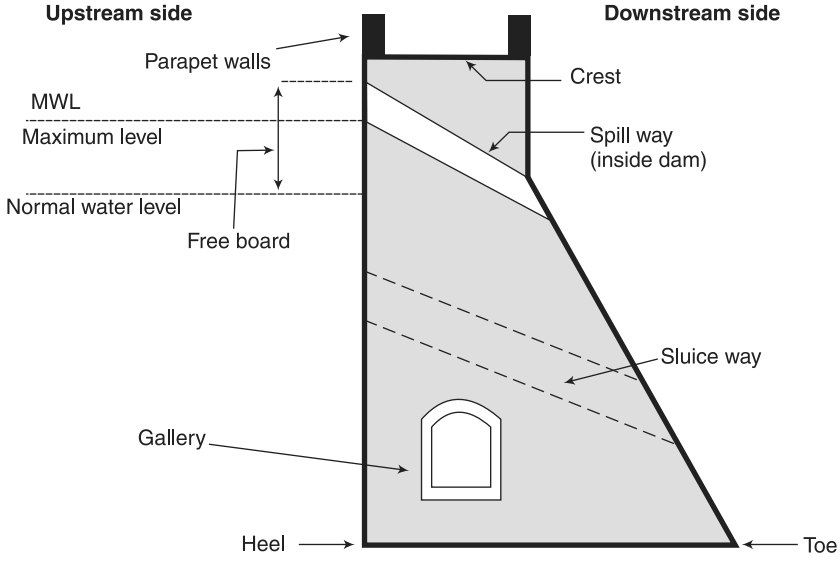

Fig 1.6 *Cross Section of Storage Reservoir*

1. Surface sources of water These are those sources of water which are available at the ground surface. The various sources of water included in this category are as follows:

(a) Lakes and Ponds
(b) Streams or rivers
(c) Storage reservoirs
(d) Oceans

(a) Lakes and Ponds A large natural depression or hollow formed in the earth's surface, which gets filled with water is called a lake. The surface runoff from the catchment area contributing to a lake enters the lake through small natural streams. The groundwater may also enter a lake through springs.

The quantity of water available from a lake depends upon its size, catchment area, annual rainfall and geological formations. The quality of water available from a lake mainly depends upon the characteristics of its catchment. Thus water in a lake would be relatively pure and of good quality if it draws water from uninhabited upland hilly areas free from soluble salts. On the other hand the water in a lake would be contaminated if it draws from low land areas containing large quantities of soluble salts and other impurities. Moreover, a small lake containing still water may have plenty of algae, weed and other vegetable growth imparting bad smell, taste and colour to the water.

Thus, if a sufficient quantity of good quality water is available from a lake then it will be a very useful source of water supply from which water may be supplied without any treatment or with some preliminary treatment. However, if the water

in the lake is of relatively poor quality then it should be properly analyzed and treated before supplying to the public.

A pond is a man-made body of standing water smaller than a lake . The ponds are formed by digging of ground and they are filled up with water in rainy season. The quantity of water in a pond is generally very small and often it contains many impurities. As such pond water is generally not suitable for drinking purposes and it can be used only for bathing, washing of clothes or for animals.

(b) Streams or Rivers A stream or river is a natural channel which carries surface runoff received by it from its catchment or drainage basin. It also carries the groundwater flow added to it and the runoff resulting from the melted snow. Rivers are the most important sources of water supply. It is a well-known fact that several big and important cities of the world are situated on the banks of important rivers. Some of the examples in our country are the cities such as Delhi, Calcutta, Ahmedabad, etc. This is due to the availability of large quantity of the water from rivers for water supply throughout the year.

The rivers may be either perennial or non-perennial. Perennial rivers are those in which water is available throughout the year. Such rivers are fed by rains during the rainy season and by melting of snow during the summer season. On the other hand, non-perennial rivers are those in which water is not available throughout the year. Generally, from perennial rivers, water may be utilized directly for public supplies without any arrangement for storage of water. However, if during dry weather periods, the flow in the river is considerably reduced, either the arrangement for raising the water level in the river or the arrangement for storage of water will have to be made to ensure the supply of water in the required quantity. This may be achieved either by constructing a weir or barrage, or by constructing a dam and creating a storage reservoir. Evidently, non-perennial rivers can be used for water supply only by providing necessary storage arrangements.

Close to the point of origin in the mountains, the river water is fairly pure but as the river approaches plains, the quality of its water deteriorates considerably, because it picks up lot of suspended matter, clay, silt, etc., and becomes muddy appearances. Further, the disposal of the untreated or ever treated sewage into the river is liable to contaminate the river water. As such the river water must be properly analyzed and treated before supplying to the public.

(c) Storage reservoirs The flow rate of a river or natural stream may vary considerably during different periods of the year. It may carry little or no water during dry weather periods and may carry huge amount of water during rainy season. Thus, if water is drawn directly from a river then during extremely low flows it may not be possible to meet the demands of the consumers, while during high flows there may be operational problems. As such it is essential to create a storage reservoir or an artificial lake by constructing a dam across the river, which can store excess water that flows in the river during the periods of high flows, for use during the periods of low flows or draughts.

The quality of water in a storage reservoir mainly depends on the quality of the water flowing in the river on which the reservoir is created. As such the water from a storage reservoir also needs to be properly analyzed and treated before supplying to the public.

The storage reservoirs are the main sources of water supply for big cities. However, the storage reservoirs are created not only for water supply but also for other purposes such as irrigation, hydropower generation, navigation, flood control, etc. A storage reservoir for supplying water for more than one purpose is termed as multipurpose reservoir.

(d) Oceans Oceans carry huge amount of water which is estimated to be about 94 to 97 percent of the total quantity of water available on our planet Earth. However, the ocean water being highly saline cannot be used for water supply unless the excessive salt content of the water is removed. The process of removing salt from water is known as desalination and the salt free water so obtained is known as fresh water. As indicated, several methods of desalination have been developed later for the conversion of salt into fresh water. However, because of the tremendous cost involved, the procurement of fresh water for water supply by desalination of ocean water has not become common.

2. Sub-Surface or Underground sources of water The underground (or sub surface) sources of water are of the following four forms.

(a) Infiltration galleries
(b) Infiltration wells
(c) Springs
(d) Wells

From each of the first three forms, relatively small quantity of groundwater is obtained and hence, these may be considered as the minor forms of underground sources of water. On the other hand, most of the groundwater is extracted from the last form viz., wells, and hence it is a major form of underground source of water.

(a) Infiltration galleries. An infiltration gallery is horizontal or nearly horizontal tunnel usually rectangular in cross-section having permeable boundaries so that groundwater can infiltrate into the same, and hence it is also sometimes known as horizontal well. It is generally provided in highly permeable aquifers with high water table so that adequate head is available for gravity flow of groundwater into the gallery. It is frequently located near a perennial recharge source and hence, it is usually placed along the bank or under the bed of river. The usual depth at which the gallery is placed ranges from 3 to 10 m below the ground surface.

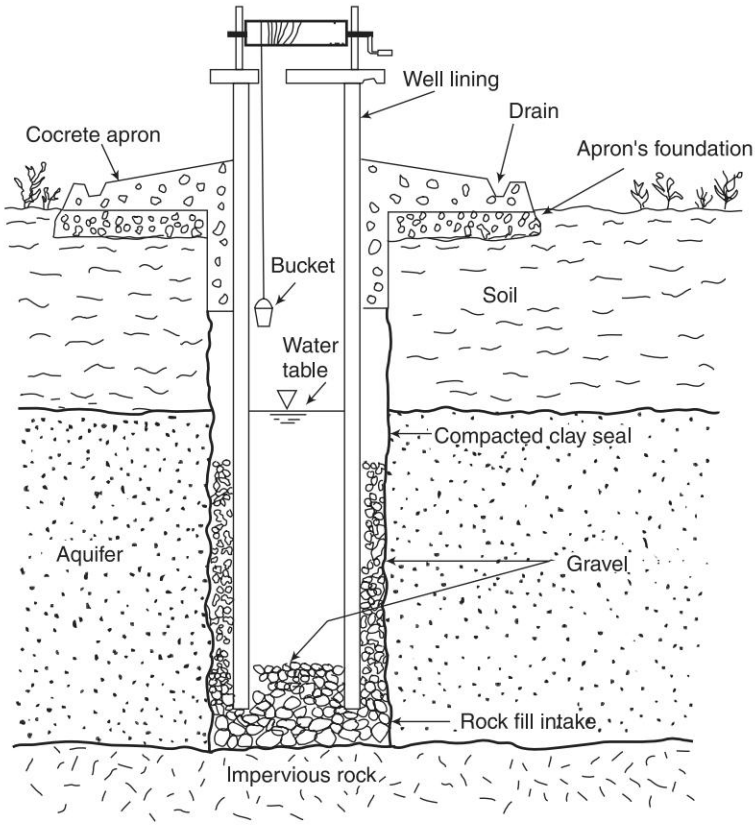

Fig 1.7 *Cross Section of Infiltration Gallery*

(b) Infiltration wells. Infiltration wells are the shallow wells constructed in series along the banks of river to collect the water seeping through the banks of the river. The wells are closed at top and open at bottom. These wells are constructed of brick masonry with open joints. For the purpose of inspection, manhole is provided in the top cover of the well. The water infiltrates through the bottom of these wells and as it has to pass through sand bed it gets purified to some extent.

The various infiltration wells are connected by porous pipes to a collecting sump well known as jack well. The water collected in the infiltration wells flows by gravity into the jack well. The water from the jack well is pumped to treatment plant and supplied to the consumers.

(c) Springs. A spring is natural outflow of groundwater which appears at the ground surface as a current or stream of flowing water. Springs may be classified into (i) those resulting from gravitational forces, and (ii) those resulting from non-gravitational forces.

(i) Gravity springs results from water flowing under hydrostatic pressure. The following are the different types of gravity springs.