UNIT 1 DESIGN AND SUPERVISION OF BUILDING

Structure

1.1 INTRODUCTION

Both function and aesthetics along with stability and strength are essential for building. You must appreciate form-function relationships design.

In this unit, you will study about the supervision of works, the site organization, planning and the testing of materials

An officer entrusted with the execution of a work is responsible for the soundness and stability of the structure, which can only be ensured by incorporation of right type of materials in the right manner. This is possible only by constant intelligent supervision at all levels. Supervision, if carried out sincerely and intelligently, gives a very good training which is a great asset for carrying out future works.

This unit deals with the mechanics of ‘supervision’ as applied to execution of works in MES.

Objectives

After studying this unit, you should be able to

- describe the basic essential requisites for the supervision of works,
- explain the basic principle of the functional aspects of buildings
- describe the procedure for planning of contract works including stages,

- study the documents to be maintained at site, and
- perform and discuss the procedure of various tests to be carried out during the execution of a contract.

1.2 FUNCTIONAL ASPECTS OF DESIGN OF BUILDINGS

Any building has to satisfy some functional requirements. Aesthetics can be considered as a main function of building. The design of building starts with considerations of some very basic functional needs, as influenced by social, cultural, economic and structural factors. It deals with built forms, space and utility. Different elements of a building have to be arranged in space with correct preparation and relationships to satisfy the functional usage, aesthetics and structural stability. Design is, thus, a creative problem solving technique. A good building design requires a thorough consideration of climatic factors, such as solar radiation, building insulation, acoustics, lighting and ventilation of inside spaces and protections from heat, cold, rain, fire, snow, noise, etc. Modern buildings are also becoming complex in terms of services such as water supply, sevage, electrification, vertical elevator systems, air conditioning, communication lines, e.g. telephony, cable TV and internet wiring, etc. Some special buildings, e.g. sky scrappers, shopping malls, sports complex or international air terminals have complex functional requirements requiring high level of technical and scientific approach.

1.2.1 Forms and Functions

Buildings like any other utilitarian object are required to fulfill some functions. Different elements and parts cater to different functions or even more than one function, for example a window is useful in maintaining airflow in the room, along with visually connecting the inside with outside. Each of the functions requires a particular physical shape and form, dictated by the nature of functions. These can sometimes be quantified, while at other times only specified qualitatively.

Two buildings designed for same functional requirement may look different, one very ordinary while the other very attractive. This emphasizes in role of form in building design. Form, in visual sense, refers to a mass and how it is formed. The form of man-made objects, like buildings, are combinations of basic geometric forms like spheres, cones, cubes and pyramids. They invoke different feelings, because these are made of different materials with different colour and textural qualities. Architecturally form also relates to its structure, which holds the architectural form together and gives it stability and strength. Forms basically are containers of space, which is responsive of the functional requirements, for which the building is commissioned. In buildings, space is created inside that is protected from external influences and qualify its use. Doors and windows are provided to provide space connectivity with different inner spaces between themselves and with outside space.

1.2.2 Principles of Design

Aesthetic Design

Any design is a problem solving process. In architecture, the problems can be classified into two categories, i.e. (a) Functional problems, and (b) Aesthetic problems.

Aesthetic problems relate to usual elements, i.e. occupied and unoccupied space, variety of lines, shapes, form, colour, texture and values. The manner in which these elements are used and combined determines the quality of a good design. In the effort to create meaning and visual effects from the form and materials used, it is observed that by thoughtfully balancing, moving, repeating, emphasizing and contrasting the various elements a usually beautiful and impressive design is created. These can be termed as the principles of aesthetic design.

Balance

It is a sense of stability. Human beings naturally seek balance around themselves. In design, balance is achieved by distributing design elements equally along an axis. Axial balance can be symmetrical where elements are repeated in mirror image on either side of axis, and are generally used in decorative patterns and formal compositions. In another kind of balance the elements are arranged asymmetrical. Here the “weights” and ‘masses’ of elements seem to balance along a virtual axis.

Movement

The movement in a visual composition is observed when the eyes do look at one place but they move from one part of composition to another while looking at it. This eye movement is caused by the way the different elements are arranged. The movement can be linear, circular, concentric or random (Figure 1.1). In building design, such movements can bring out emotional and psychological effects. The upward movement of “Shikhar” of a temple, or spire of a church or, dome of a mosque invokes reverence to some super almighty power.

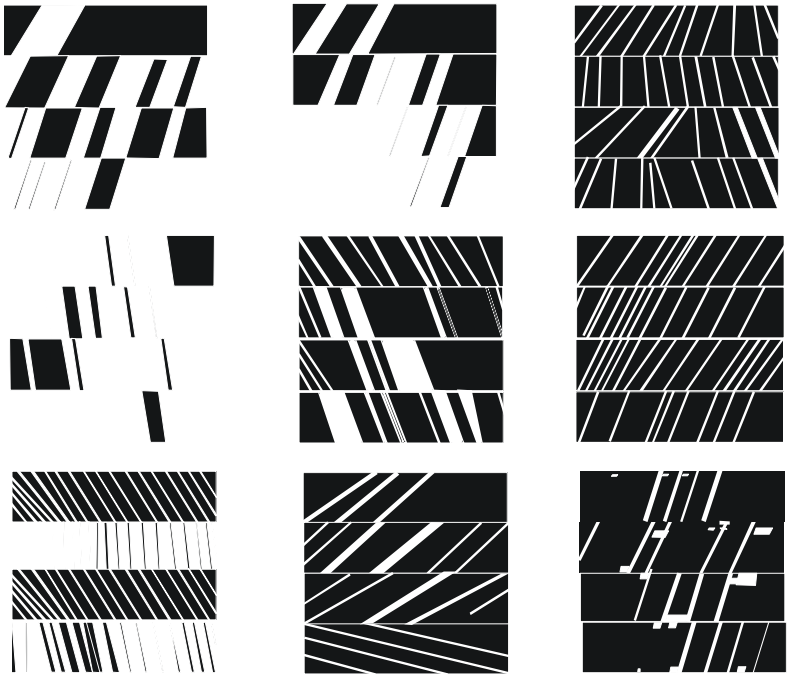


Figure 1.1 : Movement

Repetition, Pattern and Rhythm

When elements, which have some common characteristics, are repeated it is termed repetition. Buildings have doors, windows, beams, columns, etc. which repeat in a different regular or irregular interval causing a rhythmic pattern.

If shapes are exactly alike and repeated at regular interval a more informal interest is created. A judicious repetition and variation of different elements help create rhythm and harmony, which is essential for usual interest and impact.

Emphasis

By emphasizing on certain areas, the architect creates centers of interest, which forces the eye to return again and again. The emphasis attracts the attention to important areas of design and subdues everything else on the picture plane. The entrance or the most important functional element of a building is often emphasized through various visual means, for example, Gopurams in Mandirs in South India. Emphasis can be caused by the use of larger element, bolder details and texture, or brighter colour.

Contrast

The similarity or repetition can cause monotony. A contrasting shape or size or colour often is provided in a design to offer relief from this monastery, e.g. light against dark, large against small, etc. Contrast makes it possible to show difference clearly.

Functional Design

The functional problems in the design deals with how a building function to satisfy its usage for which it is created. Each building provided has its own specific usage and functions to perform. However, there are some basic functions, which are to be satisfied for all types and categories of built facility. All buildings must provide protection to its occupants from climatic elements like rain, heat, cold, wind and storms. A comfortable internal environment is required to be created within the inner space. This requires that designer shall have an adequate knowledge of climatology. To provide this environment and arrange for adequate illumination, a lot of energy is required, in the form of electricity and fuel. Intelligent planning can reduce the energy consumption to a great extent.

All buildings require a noise free space for providing relaxation, comfort and normal working. Hence, it is necessary to provide adequate insulation from external noises simultaneously making provisions for maintaining required quality of sound in it. These sound quality requirements may be different for different types of use, e.g. lecture theatres, concert halls, movie theaters, industries, residential areas, offices and marketing malls, etc. The architect, therefore, must have the requisite knowledge of acoustics and insulation.

Similarly, buildings are to be prevented from fire to be developed and provided with adequate facilities for detecting, warning and fighting the fire. A knowledge of fire prevention and fighting is, therefore, essential. All buildings depend on services such as water supply, sanitation, power, gas, communication lines (telephone, TV and internet cables), lifts and escalaters, ventilation and air conditioning. These services are an integral part of the building to provide comfort and facilities to its inhabitants. Proper planning and construction of these services is crucial for functional efficiency of the built facility created.

All these aspects of functional design and provision are discussed in detail in the present course book.

SAQ 1

(a) How form and functions are related to each other?

(b) Explain different visual elements of design.

(c) Define balance, movement, repetition, pattern, rhythm, emphasis, contrast and space, in relation to aesthetic functions of a building design.

(d) What are the components of an activity-space?

SAQ 2

(a) What are environmental factors and how does a building modulate it?

(b) What are various functions which are common in all types of building types and categories?

(c) What are climate-modulating devices in buildings?

(d) Why is energy conservation important in a building?

1.3 AIMS, ESSENTIAL REQUISITES AND HINTS

The aim of supervision is three fold :

(a) Provide sound and stable structures within allotted time.

(b) Achieve maximum economy of men, material and money.

(c) Achieve a high standard of work in accordance with modern engineering practice.

Supervision in a deeper sense includes the following broad aspects:

(a) The adherence to the standards of materials and craftsmanship specified in the drawing and specification.

(b) The discovery of elements or errors overlooked in the contract drawings/specifications and their early correction.

(c) Inadequacy of the design or specifications.

(d) Prevention of errors, which might result in unnecessary and costly maintenance cost.

(e) The checking of building processes/techniques and the evaluation of the materials to ensure conformity to the specifications.

(f) Elimination of unacceptable substitutes by the contractors.

(g) Avoidance of extra construction cost beyond accepted contract amounts.

(h) Skilled coordination of works of various trades.

(i) Prevention of unfair practices and procedures or attempts at avoidance of contractual obligations.

1.3.1 Essential Requisites

For 'Supervision' to be effective, it is essential to have a sound, well-considered plan for tackling the work. This implies that sound technical planning has preceded the execution, especially in respect of the following :

(a) Proper choice of specification/design.

(b) Feasible phasing of works.

(c) Selection of suitable agency of execution.

(d) Use of suitable machinery/equipment.

(e) Efficient site organisation.

1.3.2 Supervision during Construction

The responsibility of supervision lies mainly with the site Engineer. He should :

(a) Study the drawings, specifications, contract agreement in details to bring out the 'snags'. These should be settled in consultation with GE or referred to higher authorities at the earliest possible stage. To achieve this, an advance set of document is sent to GE/Engineer-in-Charge for comments.

(b) Fix the responsibilities of subordinates in writing.

(c) Check arrangements for site organisation.

(d) Insist on all records being kept up-to-date by periodical check.

(e) Check important stages of construction personally and get certain stages checked by Engineer in charge. Visit site of work frequently and settle difficulties on spot.

(f) Report all difficulties/contractual snags to engineer in charge.

(g) Work order book must be widely used. Important orders must be issued from files.

(h) Works diary should be maintained correctly, daily according to existing orders.

(i) Watch that the orders and instructions are noted by supervisory staff of the contractor and faults remedied. Ensure the same with your staff also. Your staff should give directions and advice and check faults rather than merely stand by while the work proceeds.

(j) Advise, correct and instruct all the time rather than criticise but reject all bad work and make subordinates understand their responsibility.

(k) See that all supervisory staff possesses proper tool bags and use them freely.

(l) Condemn any scaffolding that is dangerous and have it set right without delay and further use.

(m) See that rejected materials are removed from site without delay.

(n) Always watch progress and keep time and progress chart and other registers/charts up-to-date. See that everything goes on smoothly.

(o) Do not interfere unless you have a definite proposal for making improvement.

(p) Warn contractor and your staff that bad work on their part will mean your forfeiting confidence and entail dismantling.

(q) Do not generally punish staff if faults can be corrected by other measures. If you have to, punish drastically after warnings have been given in writing.

(r) Encourage good work of subordinates. It helps much in raising the standard of work.

(s) Ensure co-operation between B/R and E/M staff.

(t) Remember that surrender of funds due to non-completion of a work is better than carrying it out to lower standard.

(u) Any change in design/specification is necessary due to engineering reasons, issue a DO after the approval of the accepting authority before the work is actually carried out.

(v) Measurements are the basis of payment, hence every item of the work must be measured, when necessary, as soon as it is finished, especially so, when it is going to be hidden.

The Engineer in charge is overall incharge of the works in his division. He should ensure that :

(a) Site-engineer associated with the job at as early a stage as possible preferably from the beginning of technical planning.

(b) Site engineer is kept in full picture about all matters connected with the work, e.g. administrative arrangements, proposed deviations/amendments, notices on contractor, stores provisioning.

(c) Important stages of work are passed by Site engineer as per the works passing register.

(d) Periodic inspections are carried out at different times of the day.

(e) Relations with the contractor are maintained on a responsible and impartial basis; dealings with contractors are correct, tactful and firm.

1.3.3Supervision after Completion

A thorough inspection of the work must be carried out by Site Engineer/Engineer incharge after completion of the work. If supervision during construction has been effective, no difficulty need be experienced. The underlying aim of this inspection is to ensure that the work is :

(a) Complete in all respect,

(b) Upto specifications as per contract

(c) Clearly and neatly finished, and

(d) Completed in time period specified in the contract.

Points which often create trouble are the following :

(a) Internal fittings and fixtures.

(b) Doors, windows and built-in-furniture.

(c) Overall finish including site clearance.

If any rectifications are found necessary, the same should be immediately carried out/ordered on to the contractor.

Bad finish is probably the worst and most widespread fault in MES work today, and plays a disproportionately large part in inspiring criticism all round. Finish counts more from the users point of view than quality of materials put into a job. Finish costs nothing extra, if the quality of workmanship is high.

SAQ 3

(a) What are the aims of supervision?

(b) What are the essential requisites for the supervision of contract works?

(c) What do you understand by

(i) Supervision during construction, and

(ii) Supervision after construction.

1.4 PLANNING AND SITE ORGANISATION

Organisational procedure has been evolved to ensure smooth and easy execution of works in the best interest of the organisation. Whatever the nature and scope of work, its execution can be divided into three phases :

(a) Planning and site organisation

(b) Physical execution

(c) Supervision and inspection

This unit deals with the planning and site organisation of works executed through contract or DEL (Directly Employed Labour) agency. If careful technical planning has preceded execution of work, planning at this stage is confined to the following:

(a) Evolving a Time and Progress Chart/Critical Path Method (CPM) Network.

(b) Making out list of basic stores to conform with (a).

(c) Handing over site.

(d) Issuing of stores.

All these stages form a part of technical planning.

1.4.1 Time and Progress Charts/CPM Network

The bar chart indicates the forecast of the dates for commencement and completion of the various trade processes or sections of the work. For all works above 5 lakhs, bar chart must be supported by a CPM network analysis. It is prepared after a detailed appreciation of all factors, e.g. type and scope of work, store position, other workload, budget allotment and User’s requirements.

This chart network is to be prepared in agreement with the contractor after detailed discussions with the contractor/his Engineers at the beginning of the job.

The engineer in charge has to check this chart before he signs the same. In fact contractor may be required to submit his CPM network with the tender.

The agreed bar chart network is signed by the contractor and engineer. It should be kept as a wall chart for constant reference. Updating of bar chart is an essential requirement. Physical progress should be marked by the site engineer (**in red**) at regular intervals. Both site engineer and engineer in charge should periodically review the progress, discuss the hold ups (if any) with the contractor and take remedial action where necessary. In case the contractor is lagging behind due to bad organisation or idling, notices are issued in terms of contract agreements. In the case of CPM networks updating has to be done at desired intervals.

In case of DEL agency, the chart network is a more elaborate document which shows a programme for procurement of stores, employment of labour and equipment and their weekly out turn and the phases of completion of work. It is treated as the basic plan, which enables the executive to assess the progress achieved, and determine future course of action. CPM should be applied in all its details. Detailed discussion of CPM is beyond the scope of this unit.

1.4.2 Basic List of Stores

It is a consolidated list of all engineer stores, whether supplied by owner or procured by the contractor. In case of contract agency, owner is essentially responsible for supply stores (Schedule 'B' stores) whether on payment or for fixing only. Supply of such stores according to the agreed programme constitutes a contractual liability of the owner.

List of procuring stores of contractor's supply enables the executive to correctly assess the progress and anticipate hold ups. In case the contractor is lagging, he should be served with notices to enable him to take necessary remedial action.

In case of DEL, basic list of stores is more detailed. It includes all stores required for completion of the work. Sufficient details, e.g. sizes of timber scantling, RSJs, glass panes must be worked out to enable placing of orders on supply agencies.

1.4.3 Issue of Stores

Control over issue of stores is necessary to prevent wastage/leakage of controlled stores to local market. In case of contract agencies, following should be ensured :

(a) A complete list, compiled in accordance with the bar chart is kept with the SDO/Storekeeper.

(b) Issues are made:

  (i) at the request of contractor,

  (ii) when his arrangements for receipts and storages are satisfactory,

  (iii) when the stage for incorporation (allowing for preliminary operation, e.g. assembly/fabrication) has been reached.

(c) If any deviation/amendment affecting the basic list is made, necessary corrections are carried out and surplus stores (if any already issued) taken back immediately.

(d) Periodical check is carried out to ensure that the contractor is utilising the correct amount of stores in the job.

(e) A complete list of stores, incorporated in the works is prepared after the completion of work; surplus stores (including containers and

cuttings, if so stipulated) are taken back. Percentage allowed for wastage should be based on actual conditions.

(f) In case the contractor does not return the surplus stores, immediate action (as detailed in contract procedure) is taken to recover the cost and penalise the contractor.

In case of DEL, following points should be ensured :

(a) Proper arrangements for receipts/storages are made.

(b) Wastage is kept to the minimum by using suitable size and or making minor modifications in the design.

(c) Issue of stores is regulated to actual requirements.

(d) Unnecessary handling/shifting is avoided.

(e) Containers/cuttings are returned to the stock godowns.

(f) Preservation is carried out where the stores cannot be immediately incorporated.

(g) All principles of material management must be properly observed.

1.4.4 Handing over Site

Making site available to the contractor is a contractual liability. WOs placed on the contractor should clearly stipulate whether/when the site has been/would be handed over. Contractor's acknowledgement should be obtained in writing.

In case of DEL, no formal handing over is necessary. But if the buildings/services are to be released by the user, early arrangements are necessary to avoid idling.

1.4.5 Site Organisation

Site organisation consists of making detailed arrangements for progressing of works in a systematic manner. The aim is to make the best use of labour, materials and time. In case of contract agency, organisation is primarily the responsibility of the contractor. The Site engineer is responsible for the following:

(a) Check arrangements made by the contractor and satisfy himself regarding their suitability and adequacy.

(b) Maintain requisite records/documents.

Contractor is responsible for arranging the following, as necessary, for the job in hand :

(a) Access roads, storage sheds, site office, quarters and ancillaries for labour

(b) Water and electric supply

(c) Supervisory staff

(d) Supply of labour, skilled and unskilled

(e) Supply of stores/equipment/machinery

(f) Medical welfare arrangements.

In checking these arrangements, following points are worth considering :

(a) Access roads are sited with due regard to convenience of construction, subsequent progressing and other commitments in the locality. As far as possible Government land is utilised. Specifications are suitable for the weather conditions obtained during the construction period.

(b) Storage sheds have adequate capacity and will protect the storage against damage/deterioration. Security/preservation aspects are properly considered.

(c) Site Office is centrally located and enables a ready check on all activities.

(d) Labour quarters and ancillaries are conveniently located with regard to access to site of works, marketing centers and civil amenities do not interfere with the execution of work. Specifications are suitable from climatic considerations. Hygiene and sanitation are maintained to a high degree of efficiency.

(e) Transmission/distribution system of electric/water supply are adequate and satisfactory. Necessary safety precautions have been incorporated.

(f) Supervisory staff possess the technical know how and is capable of controlling the labour and supervising the execution.

(g) Arrangements for labour are made sufficiently in advance so as not to create any bottlenecks. Wage rates are reasonable. Payments are made regularly.

(h) Disputes are amicably settled through authorised agencies.

(i) Right type of stores/equipment/machinery is arranged sufficiently in advance. Required quantities of POL/spares and skilled operators are available when required.

(j) First aid facilities are available on the site. Proper arrangements for transfer to nearest hospitals have been made.

(k) Recreational facilities for the personnel have been provided.

(l) Necessary security arrangements have been made.

In case of DEL, all arrangements become owner responsibility. All points mentioned above have to be arranged for by owner. Following additional points require consideration :

(a) Early arrangements are made for construction equipment, e.g. ladders, scaffoldings, formwork, wheel barrows, tools, instruments and machinery required for carrying out the construction.

(b) The transport situation is surveyed and necessary arrangements made in advance.

(c) Supervisory staff should have an idea of the scope of duties and powers. The chain of control should be simple and well defined.

(d) Supervisory staff is trained to plan their day-to-day work. They should foresee snags and arrange for resolving them or report the same immediately to superior authority. They should be trained in CPM technique also.

(e) Store/transport machinery is controlled centrally by a responsible subordinate who is in a position to view demands correctly.

(f) Maintenance of machinery/equipment/transport is carried out to full scale.

(g) Employment of labour is so arranged as to give continuous employment to a class of workmen at a time. Unnecessary retrenchment/re-employment disorganises the whole work and will discourage good artisans from recruiting. Resources levelling and scheduling in CPM refer to this aspect.

(h) Works is sectioned and so arranged that the staff is ready to follow up with the next operation without loss of time.

1.4.6 Work Site Documents

Records and documents are necessary for keeping control over execution and record technical data for future guidance. In case of contract agency these records also serve to bring out an authentic record of factual happening recorded at the time of the occurrence.

Following documents/records are normally maintained at site of work for a large project executed through contract agency :

(a) Detailed layout plan

(b) Copy of contract agreements and drawings

(c) Bar charts and basic list of stores including CPM network

(d) In the Works Site Order Book orders referring merely to day-to-day transactions pertaining to acceptance/rejection of works, imperfect workmanship or inferior materials, are given. There will be no order in the nature of a Deviation Order.

The Works Site Order Book is normally maintained as shown below :

Sl. No.	Date of Orders	Instructions and Orders	Signature of Officers giving the Orders	Remarks/ Signatures of Contractor in Token of Receipt of Order	Compliance of Orders by Executive and Signature of Officers Verifying the Compliance
1	2	3	4	5	6

(e) A separate register known as ‘Works Diary” is maintained in the case of original works over Rs. One lakh and special repairs over Rs. 5 lakhs and is an authentic record incorporating all important day-to-day events in the execution of the work and the administration of the contract. This is maintained in two parts A and B in the same bound book containing normally 200 pages. Part A is to be completed firstly and subsequently also, viz the details of the supervisory staff, details of deviation orders, the record of extension of time, etc. A specimen page is shown below :

1. Name of work……
2. Contract Agreement No……
3. Date of Acceptance……

4. Name and Registered Address of Contractor……

5. Contract Sum and/or % on Schedule of Rates……

6. Period of Contract……..……

7. (a) Name and Address of Contractor/Contractor's Agent/Project Manager……..

   (b) Name and Address of Contractor's site Engineer……..

8. Date of First Work Order……

9. Date of Site handed over to Contractor……

10. Date of Work Commenced……

11. Stipulated Date of Completion of Contract……

12. Suspension Orders Showing Duration and Authority……

13. Extended Date of Completion with Authority……

14. Date of Works Actually Completed……

15. Date of Works Taken over by GE……

16. Date of Expiry of Maintenance Period……

17. Record of Works Orders/Deviation Orders.

WOs / Dos		**Financial Effect**		**Cumulative Amount of Work Ordered**
No	**Date**	+	–	

18. Records of MES Supervisory Staff (B/R, E/M & B/S) and Contractor' site Engineer(s) indicating qualification(s) employed on the work (Changes to be recorded with dates):

Name	**Designation**	**Date**	
		From	**To**

Signature of Engineer in charge

Date ----------

Part B pertains to day-to-day work. The details on the following points are to be entered every day and signed by Engineer-in-Charge and the Contractor/his authorised agent.

(a) Weather.

(b) Labour engaged by the contractor (categories and number).

(c) Important materials brought on site with approximate quantities (rejections if any to be stated).

(d) Details of plant and transport working on site.

(e) Brief particulars of the work in progress.

(f) Important stages completed and passed with signatures of officials passing the work.

(g) Visits of inspecting officers and their remarks.

(f) **Register of Records of Tests on Materials etc. :** In important concrete work, it is preferable to maintain one register for each contract in which the results of the under mentioned tests carried out are recorded.

(i) Cube test for quality concrete.

(ii) Slump test for concrete.

(iii) Bulking of sand for concrete.

(iv) Impurities of sand (for concrete and mortar).

(v) Sieve analysis of aggregates, etc.

A few pages are set apart in the above register for each type of test. The index in the beginning should indicate the test and page numbers allotted for it.

"For all works costing over Rs. 20 lakhs, requisite instruments and testing devices shall be procured from contingencies of the projects and instrument and testing kit should be available at the site of work at all times. For works costing less than Rs. 20 lakhs sets of instruments/testing devices should be held centrally in engineer in charge office for use of Site engineer and other inspecting officers

Tools

(a) Chisel

(b) File

(c) Small hammer

(d) Measuring tape (Steel)

Instruments

(a) Moisture meter

(b) Plumb Bob

(c) Circular disc gauge

(d) Screw gauge

(e) Spirit level

(f) Thermometer

(g) Vernier calipers

(h) Weighing machine with weights.

Engineer-in-Charge (E/M) should have following tools and instruments:

Tools

(a) Ammeter

(b) Anemometer

(c) Current tester

(d) Earth tester

(e) Hydraulic testing machine

(f) Magnet

(g) Meggar (HT, LT)

(h) Micrometer

(i) Multimeter

(j) Sling Psychometer

(k) Tachometer

(l) Voltmeter

(m) Wire gauge

Works Passing Register

This register is for the maintenance of a record of passing of works at various important stages by the Engineer-in-Charge of projects executed under lumpsum contract. This record is necessary to enable the GE to give certificate required with the final bills relating to lumpsum contracts. This register will be produced for inspection and check by the audit as and when called for by him.

The register is maintained in the following form :

	Name of the item			**Page No…….**
Sl. No.	**Important stage of the Item**	**Date passed by Engineer-in-Charge**	**Dated signature of Engineer-in-Charge**	**Dated Signature of Inspecting Officers GE/CWE on each Inspection**
(1)	(2)	(3)	(4)	(5)

(a) On the outer cover of the register the following information should be available :

CA No ……

Contractor …….....

Job No …….....

Date of Commencement …….

Date of Completion …….

(b) An index should be maintained on the first inner sheet of the Register showing all items of the work to be done under the contract and showing page numbers on which the details regarding the passing of such items are recorded.

(c) The stages included in this register must be detailed enough considering each important stage which needs approval before the next process in that trade can be started. For example, in case of painting the stages would be :

(i) Preparatory work including knotting.

(ii) Priming Coat.

(iii) Stopping with putty.

(iv) Under Coat.

(v) Finishing Coat.

Similarly, in case of floors the stages would be :

(i) Earth or moorum filling.

(ii) Layer of hard core.

(iii) Layer of sub base.

(iv) The wearing coat.

Some important stages as suggested in MES E-in-C's Technical Instruction No 23 should be studied by the students.

(d) **Measurement Books (MB) :** This is a very important record and is the basis of all accounts of quantities of work done or of materials received which have to be counted or measured. The description of the work must be lucid so as to admit an easy identification and check. Measurements should, as far as possible be taken by SDOs and not by their subordinates. The instructions for the proper maintenance of MBs are contained in the notes in the beginning of each MB.

Important services carried out by Measurement contracts should be measured by an officer. The CWE may, when possible, arrange for the measurements of such services to be taken by an SW or ASW. Other services should, as far as possible, be measured by an engineer executive not lower in rank than a Supdt Gde I. GE may, however, authorise Supdt Gde II (JE) to take and record measurements relating to minor works and maintenance.

In case of Major Works costing upto Rs 5 lakhs, GE may authorise Supdt Gde II who should be technically qualified by name, to measure and record in MB. In such cases a report must be made to his next superior engineer authority. A copy will also be endorsed to the AAO GE.

(e) A cement register as mentioned above should also be maintained.

These records must be kept up-to-date and periodically analysed to assess the performance. All records referred above must be kept in safe custody. Only necessary records depending upon the type/scope of work should be maintained. Tendency to increase the number of records must be curbed.

SAQ 4

(a) What aspects need to be kept in mind during the planning of contract works?

(b) What are the stages in the planning of contract works?

(c) What documents should be maintained at site?

1.5 TESTING OF MATERIALS AND WORKMANSHIP AS PER SSR PART-II

Standard of Work

The standard of work greatly suffered during the war years. Pressure of erecting temporary structures in the shortest possible time coupled with lack of experienced staff, led to gradual relaxation of pre-war standards. Paucity of essential materials resulted in use of expedients and alternatives. Improvements in knowledge/technique of building construction achieved during the war years could not be taken in full use in important defence works.

In spite of strenuous efforts since the cessation of hostilities, the standard of work has not reached a desirable stage. The problem at present consist of :

(a) Training MES officers and subordinates in latest knowledge/techniques.

(b) Training of artisans and craftsmen of MES.

(c) Insistence on a high standard of work in accordance with specifications and design.

(d) Improvement in standard specifications, drawings and design to conform with latest knowledge/techniques.

Following measures will be of great value in raising the standard of work :

(a) Each CWE/GE must maintain sample rooms where samples of materials, fittings, fixtures and furniture are maintained. Samples rooms are kept ‘alive’ by frequent use and additions.

(b) The contractors must be ordered in writing to produce samples in respect of important materials and iron mongery/fittings, etc. for approval first before incorporating in the works.

(c) Contractors are asked to produce samples of workmanship for prior approval.

(d) All workmanship not conforming to specifications is rejected and ordered for demolition. Principles of SQC (Statistical Quality Control) and sampling techniques be applied wherever possible and provided for in contracts.

(e) Special note is kept about the maintenance periods of each contract, the works are thoroughly inspected and rectifications ordered in this period.

(f) Junior officers/subordinates are attached to experienced colleagues for training.

(g) Technical literature relating to construction materials/techniques is obtained and circulated among the staff. Similarly, various pamphlets issued by E-in-C regarding supervision of works should be circulated to supervisory staff.

(h) All problems where satisfactory results have not been obtained are referred to research institutions and their advice obtained, which should then be tried/decimated among the staff.

(i) Whenever specialist advice/service is employed, attachment of MES staff for gaining experience should be a condition of the contract. Only suitable hands are sent on such attachments.

(j) Subordinates are encouraged to write out reports on the works executed by them, which should bring out the knowledge and lessons learnt by experience. Such reports are then circulated along with comments of senior officers.

1.5.1 Tests to be Carried Out for Materials

Specific tests are required to be carried out on various materials, for ensuring that the quality of materials is as specified. The following table gives the frequency of tests and their level of testing.

Specific Tests on Materials and their Frequencies

Sl. No.	Material	Tests	Method of Testing	Frequency of Tests			Level of Tests
1.	Bricks	(a) Visual and dimensional characteristics	IS : 1077	As per Table 1 of IS : 1077 given as under :			A
				Lot size	Sample Size	Permissible No. of defective bricks	
				2001-10000	20	1	
				10001-35000	32	2	
				35001-50000	50	3	
		(b) Compressive Strength	IS:3495 (Part I)	As per Table 2 of IS : 5454 as given under :			A
				Lot size (Nos.)	Sample Size (Nos.)	Permissible No. of defective bricks	
				2001-10000	5	0	
				10001-35000	10	0	
				35001-50000	15	1	A*
		(c) Water Absorption	IS : 3495 (Part-I)	..do..			A
		(d) Efflorescence	IS : 3495 (Part-II)	..do..			B
2.	Coarse Aggregate (for concrete)	(a) Sieve Analysis	IS : 2386 (Part-I)	As per Table 3 of IS : 2430			A
				Lot Size (m^3)	No. of Samples		
				Upto 100	1		
				101 to 500	3		
				501 to 1500	5		
				1501 to 5001	7		
		(b) Flakiness Index	..do..	..do..			A
		(c) Estimation of deleterious materials	IS : 2386 (Part-II)	..do..			A
		(d) Organic Impurities	..do..	..do..			C
		(e) Moisture content	..do..	..do..			A
		(f) Specific gravity	..do.. (Part-III)	..do..			B

		and water absorption					
3.	Fine aggregate (for concrete)	(a) Sieve Analysis	IS : 2386 (Part-1)	As per Table 3 of IS : 2430			A
				Lot Size (m^3)	No. of samples		
				Upto 100	1		
				101 to 500	3		
				501 to 1500	5		
				1501 to 5001	7		
		(b) Test for clay silt and impurities	..do.. (Part-I)	..do..			A
		(c) Specific gravity and water absorption	..do.. (Part-III)	..do..			B
		(d) Test for organic impurities	..do.. (Part-I)	..do..			C
		(e) Moisture Content	..do..	..do..			A
4.	Cement	(a) Setting time	IS : 4031	Once for each consignment of 50 MT or part thereof:			B, C
		(b) Soundness	..do..	..do..			B, C
		(c) Compressive strength	..do..	..do..			B, C
		(d) Fineness	..do..	..do..			B, C
5.	Structural concrete	(a) Compressive strength	IS : 516	Quantity of conc. (in m^3)	No. of Sample		B, C
				1 – 5	1		
				6 – 15	2		
				16- 30	3		
				31 – 50	4		
				51 and above	4 plus one addl. sample for each additional 50 m^3 or part thereof.		
		(b) Slump/ compaction factor for workability	..do..	..do..			A
6.	Structural steel sections	(a) Tensile strength	IS : 1608/ IS : 1663/ IS : 1894	One test for every 25 tonnes of steel or part thereof.			B, C
		(b) Bend test	IS : 1403/ IS : 1599/ IS : 2329	One test for every 10 tonnes of steel or part thereof.			B, C
		(c) Impact test	IS : 1403/ IS : 1599/ IS : 1500	..do…			B, C

		(d) Hardness test	..do..	..do…			B, C
7.	PCC hollow blocks (for walls)	(a) Dimension and visual defects	IS : 2185	20 blocks from every consignment of 5000 blocks or part thereof.			A
		(b) Compressive strength	..do..	8 blocks out of 20 randomly selected blocks			A
		(c) Drying shrinkage	..do..	3 blocks out of 20 randomly selected blocks			B
		(d) Moisture movement	..do..	3 blocks out of 20 blocks			A
		(e) Density	..do..	3 blocks out of 20 blocks			B
8.	PCC solid blocks (for walls)	(a) Dimension and visual defects	IS : 2185	20 blocks from every consignment of 5000 blocks or part thereof.			A
		(b) Compressive strength	..do..	8 blocks out of 20 randomly selected blocks			A
		(c) Drying Shrinkage	..do..	3 blocks out of 20 randomly selected blocks			B
		(d) Moisture movement	..do..	3 blocks out of 20 randomly selected blocks			A
		(e) Density	..do..	3 blocks out of 20 randomly selected blocks			B
9.	Flooring tiles – PCC/ Terrazzo	(a) Flatness, perpendicularity, thickness of wearing layer	IS : 1237	18 tiles from each source of supply			A
		(b) Water absorption	IS : 1237	6 tiles out of 18 randomly selected tiles			A
		(c) Wet transverse strength	IS : 1237	6 tiles out of 18 randomly selected tiles			C
		(d) Resistance to wear	IS : 1237	6 tiles out of 18 randomly selected tiles			C
10.	Burnt clay roof tiles (Hand made) as per IS : 2609 (Part-II)	(a) Water absorption	IS:3495 (Part II)	As per Table 2 of IS : 5454 given as under :			
				Lot size	Sample Size	Permissible No. of defects	A
				2001-10000	5	0	
				10001-35000	10	0	
				35001-50000	15	1	
		(b) Compressive	IS : 3495	..do..			A

		Strength	(Part-1)				
11.	Mangalore pattern roof tiles	(a) Dimension and weight	IS : 654 (Appx. 4)	Lot size (Nos.)	Sample Size (Nos.)	Permissible no. of defects	
				Upto 3000	32	3	A
				3001 to 10000	50	5	
				10001 to 35000	80	7	
				35001 to above	125	10	
		(b) Water Absorption	..do.. (Appx-C)	6 tiles out of 32 samples tiles			A
		(c) Breaking load	..do.. (Appx-C)	6 tiles out of 32 samples tiles			A
12.	Timber for wood work	(a) Specific gravity and weight	IS : 1708	As per clause 3.3 of IS : 8720 (Amendment-1)			B
				Lot Size (Nos.)	No. of Scantings		
				Upto 150	20		
				151-300	32		
				301-500	50		
		(b) Moisture content	..do..	..do..			A
13.	Water for Construction purpose	(a) Test for acidity and alkalinity (pH Value)	IS : 456	Once at the stage of approval of source of water			C
		(b) Test for soil contents	..do..	..do..			C
14.	Welding of steel work	Visual Inspection test	IS : 811	100% by visual inspection			A
15.	Timber paneled and glazed door/ windows	(a) Dimension, sizes, workmanship and finish	IS : 1003 (Part-I)	As per Table 4 of IS : 1003 given as under :			
				Lot Sizes (Nos.)	Sample Size (Nos.)	Permissible No. of defects	A
				26-50	5	0	
				51-100	8	0	
				100-150	13	1	
				151-300	20	2	
				301-500	32	3	
				501-1000	50	5	
				1001 and above	80	7	
		(b) Strength test	..do..	..do..			C
		(c) Slamming	..do..	..do..			C
		(d) Impact indentation	..do..	..do..			C
		(e) Shock resistance	..do..	..do..			C

		(f) Edge loading	..do..	..do..			C
16.	Plywood (IS : 303)	(a) Moisture content	IS : 1734 (Part-1)	As per Table 1 of IS : 7638 For value of acceptance Quantity Level (AQL) = 1.5%			
				Lot Size (nos.)	Sample Size (Nos.)	Permissible No. of defects	A
				Upto 50	5	0	
				51-150	8	0	
				151-300	13	0	
				301-500	20	0	
				501-1000	32	1	
				1001-3000	50	2	
				For value of AQL = 2.5%			
				Lot size (Nos.)	Sample Size (Nos.)	Permissible No. of defects	
				Upto 50	5	0	
				51-150	8	0	
				151-300	13	0	
				301-500	20	1	
				501-1000	32	2	
				1001-3000	50	3	
				For value of AQL = 4%			
				Lot size (Nos.)	Sample Size (Nos.)	Permissible No. of defects	
				Upto 50	5	0	A
				51-150	8	0	
				151-300	13	0	
				301-500	20	1	
				501-1000	32	2	
				1001-3000	50	3	
		(b) Water Resistance test	IS : 1734 (Part-VI)	..do..			C
17	Wooden particle board (Medium Density, IS:3457)	(a) Density	IS : 635	Refer Table 1 of IS : 7638			C
		(b) Moisture content	..do. (Part-III)	..do..			A
		(c) Water Absorption	..do. (Part-XVI)	..do..			A
		(d) Swelling due to surface absorption	..do. (Part-XVII)	..do..			A
		(e) Swelling in water	..do.	..do..			A
		(f) Modulus of rupture	..do. (Part-IV)	..do..			B
		(g) Screw and nail withdrawal	..do. (Part-XIV)	..do..			C

		strength					
18.	Glazed tiles	(a) Water absorption	IS : 777	Lot size (nos.)	No. of samples		
				3000-10000	32		A
				Over 10000	50		
		(b) Crazing	..do..	..do..			C
		(c) Chemical resistance	..do..	..do..			C
		(d) Impact strength	..do..	..do..			C
19.	Aggregate of all sizes for WBM, BM, AC, PMC etc. for road and pavement	(a) Impact	IS : 2386	1 test per 100 m^3			B, C
		(b) Crushing value	IS : 2386 (Part-IV)	1 test per source			B, C
		(c) Loss angles abrasion value	IS : 2386 (Part-IV)	..do..			B, C
		(d) Flakiness	IS : 2386 (Part-II)	1 test per 100 m^3			A
		(e) Water absorption	IS : 2386 (Part-III)	..do..			A
		(f) Specific gravity	IS : 2386 (Part-III)	1 test per source			B, C
		(g) Density	IS : 2386 (Part-III)	..do..			B, C
		(h) Stripping value of aggregate for BM/AC	IS : 2386 (Part-III)	..do..			B, C
20.	Bitumen for road pavement works	(a) Penetration value	IS : 73	1 test per batch of bitumen supplied in bulk of drums			B,C
		(b) softening points	..do..	..do..			B, C
		(c) Elongation	..do..	..do..			B, C
		(d) Wax content	IS : 1209	..do..			B, C
		(e) Flash Point/Fire Point	IS : 1208	..do..			B, C
		(f) Ductility	IS : 1208	..do..			B, C

Note :

(a) The tests mentioned above are to be conducted on receipt of materials at site.

(b) Requirements of tests to be conducted by manufacturers ex-factory for certain materials, like cement, steel, tiles, pipes, manufactured or fabricated items, paints, bitumen's products, pre-laminated boards, electrical and mechanical equipment, etc. shall be as per the relevant IS Code provisions. For ensuring required quality in materials, these tests shall be carried out. Accepting officer may decide to accept the manufacturers test certificate(s), call for third party tests or decide to have these tests in presence of his representative.

(c) Where factory manufactured or fabricated materials are to be used, the approved sources may be decided based on proven past track/IS embossed/ISI certified/conforming to IS specifications.

Legend : A – Site Lab

B – Zone Lab

1.5.2 Testing of Workmanship

The following table gives various tests required on workmanship during the execution of work :

Specific Test on Workmanship

Sl. No.	Description of Work	Tests	Method of Testing	Frequency of Test	Level of Test	Remarks
1.	Structural concrete (M-15 grade and above)	(a) Slump test or compacting factor or Vee-Bee Time	IS : 109	Minimum frequency of sampling of concrete of each grade shall be as under:	A	Random sampling shall be carried out to cover all mixing units.
		(b) Compressive strength	IS : 516	Qty of Concrete / No. of samples 1-5 / 1 6-15 / 2 16-30 / 3 31-50 / 4 51 and above / 4 + 1 for each addl. 50 m^3 or part thereof	A	
2.	Pile Concrete	(a) Initial Load test	IS : 2911 (Part-IV)	Minimum 2 nos. or as specified in contact	A	Integrity tests are recommended for 100% bored case in situ piles cast by remix method for piles longer than 10 m.
		(b) Routine load tests	..do..	As required	A	
3.	Structural Steel work for hangars and industrial sheds	(a) Test for sample weld (i) Tensile test (ii) Bend Test (iii) Impact Test (iv) Load Test	IS : 821	One for each test	B, C	
		(b) Test for workmanship of welds in structure	IS : 821	Frequency and extent of tests will be as per IS provisions	C @	@ Third party inspection and testing of works shall be catered for in tender documents.
4.	Plumbing (a) Soil Pipes	Smoke test under a pressure of 2.5 m head of water		1 Test for 15 min before embedding	A	
	(b) Drain and sewers	Smoke test under a pressure of 4.5 m head		As required before embedding in soil/concrete	A	

	(c) Sanitary appliances	Water test/Smoke test		As required	A	
5.	Bituminous work in roads BM/AC/PMC					
		(a) Test for spread of bitumen	SP-11 of IRC	1 test/500 sqm	A	**BM**– Bituminous
		(b) Thickness of layer of BM/AC/PMC etc	..do..	1 test/500 sqm	A	Macadam
		(c) Density by sand replacement	IS : 2720 (Part-28)	1 test/500 sqm	A	**AC**– Asphalt concrete
		(d) Surfaces evenness	SP-11 of IRC	As required	A	**PMC** – Premix concrete
6.	WBM and soling in roads	Density by core cutting/sand replacement method	IS : 2720 (Part-28)	1 test/500 sqm	B,C	**WBM** – water bound macadam
7.	Pavements					
	(a) Bituminous CRL/BM/ AC			1 test per batch of bitumen supplied in bulk or drums	A	**CRL** – Crack relief layer
		(a) Tray Test	SP-11	..do..	A	**BM** – Bituminous macadam
		(b) Bitumen extraction	SP-11	..do..	A	**AC** – Asphalt Concrete
		(c) Density of Mix	SP-11	..do..	A	
		(d) Marshal stability and flow value	SP-11	..do..	A	
	(b) Concrete	(a) Workability	ASTM	1 test per 10 m^3 of concrete	A	
		(b) Cube crushing strength	IS: 516	..do..	A	
		(c) Flexural strength		-do-	B	
		(d) Core cutting		As required	B	
		(e) Surface evenness		..do..	A	
8.	Water Supply pipe lines	(a) Hammer test for each pipe before laying		1 test per 300 m length	A	
		(b) Pressure tests after laying section wise for each		1 test per 300 m length	A	

		300 m length				
9.	Electric supply					
	(a) Internal wiring	Insulation resistances test	IS : 732	1 test for each circuit before commissioning	C	Commissioning of equipment only after inspection of electrical inspector
	(b) Cable work for external electrification	Insulation resistance test	IS : 1255	..do..	C	
	(c) OH lines LT and HT	High Voltage test	IS : 207 (Part I)	..do..	C	
	(d) Transformers		IS : 10028 (Part II)			
		(a) Insulation tests		1 test after erection	A	
		(b) Phasing tests	..do..	..do..	A	
		(c) Test for dielectric strength of oil	..do..	..do..	C	
		(d) Earth resistance test	..do..	..do..	A	
		(e) Injection test	..do..	..do..	C	
		(f) Load tests	..do..	..do..	C	
10.	Other E/M equipment					
	(a) Generating set	Load tests	IS : 13364 (Part-I/Part-II)	After erection	By BOO headed by SO1E/ M of Zone	
	(b) OHT crane	Load tests/sag test	IS : 14470	After erection		
	(c) Pumping set	Performance test	IS : 9137	After erection		Load test in presence of IEM
	(d) Lift	-do-	IS : 6383	After erection		Completion only after all tests
11.	Air Conditioning plants					
	(a) Central A/C plants	(a) Smoke test for ducts	IS : 655	As required during execution	By BOO	During execution
	(b) Package type A/C plants	(b) Phase-I Performance test		Before final completion	By BOO	After provisional completion
		(c) Phase-II Performance test (summer, Monsoon, Winter)		After completion	By BOO	Final completion only after all tests

SAQ 5

(a) What tests are carried out for the testing of concrete?

(b) What tests will you carry out for the testing of cement?

1.6 SUMMARY

It is of utmost importance that in order to maintain quality of works in MES, supervision be done sincerely, both during and after the construction. The site needs to be organized systematically and various tests of materials carried out as per the laid down procedure. This aspect has been covered in this unit. In the next unit, you will study about the maintenance and supervision of building, the role of staff, MES and the users and the procedure for making annual maintenance plan and its execution.

The next unit deals with the maintenance and supervision of buildings. The role of various participants of maintenance viz. staff, MES and users will also be explained. The priorities and the method of planning maintenance of building would be studied and finally the method of execution of maintenance of works.

1.7 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

UNIT 2 MAINTENANCE OF BUILDING

Structure

2.1 INTRODUCTION

In Unit 1, you studied about the supervision of contract works, its planning, documentation and various tests carried out during the execution of works. Now you will study the aspect of maintenance and supervision of MES buildings, which is an important duty of MES in order to provide longevity to the Government assets.

Objectives

After studying this unit, you should be able to

- explain the aim of maintaining buildings,
- discuss the steps involved in the planning of annual maintenance programme,
- appreciate the priority to be kept in mind during planning,
- describe the role of MES in organizing maintenance,
- describe the role of staff in this regard, and
- explain how users can assist in preventing maintenance.

2.2 AIM AND CLASSIFICATION

Planning of repairs is an important function of the executive in MES. The executive control is vested in CsWE, GEs, SDOs and their subordinates.

The aim of planning repair is two fold :

(a) to maintain defence assets at a high level of efficiency,

(b) to ensure that the allotments placed at the disposal of engineers are fully utilised to the best interest of the state.

An essential prerequisite for achieving this aim is to evolve a regulated monthwise programme which should :

(a) impose an even load on the executive staff and contractors,

(b) take full advantage of the construction season, and

(c) cater for other commitments.

As allotments are not known at that time, planning is based on the allotments of the previous financial year. The programme, so framed, can then be varied (curtailed/expanded) to suit the actual allotments of funds.

2.2.1 Planning of Annual Maintenance

A financial year is divided into four quarters :

(a) April to June (First)

(b) July to September (Second)

(c) October to December (Third)

(d) January to March (Fourth)

For planning purposes it is best to work on the basis of a calendar year. Thus, planning for a financial year is started in the fourth quarter of the previous financial year as by then the final allotments of the year are firmly known.

Planning is carried out in the following steps :

(a) Assessment of the repair tasks which are required to be carried out from engineer/user angle.

(b) Calculating the net available funds for carrying out the tasks at (a).

(c) Co-relation of (a) with (b) and decision taken on the tasks which can be carried out from available funds and the agencies of execution.

(d) Based on (c), the following are finalised

  (i) Programme for requisitions to be prepared.

  (ii) Programme of placing WOs on TC.

  (iii) Programme of provisioning of stores.

  (iv) Programme for letting out contracts.

2.2.2 Assessment of Tasks

A list of repairs is compiled from previous programmes (left-overs), quarterly inspection, unit demand registers or fresh inspection, where necessary. Any works considered necessary from an engineering angle are also included. The tasks listed are then categorised on a priority system as under :

(a) Works required for safety/stability of a structure/service.

(b) Periodical services.

(c) Works which will enhance the life and utility of the structure/service.

(d) Improvements necessary from engineering considerations.

In preparing these lists, adequate attention must be paid to needs of all units and care taken to avoid any preferential treatment.

Station/Sub Area Commander should be consulted before this programme is finalised so that user angle is fully appreciated.

Decision regarding which accommodation is required to be included in the programme lies with the staff while decision regarding suitability and manner of carrying out repairs lies with engineers.

This list should be finalised by 15th January of the year.

Out of the anticipated allotment, following charges are deducted :

(a) Cost of periodical services.

(b) Cost of permanent DEL works (salaries and cost of stores) and casual seasonal gangs (assessed).

(c) Fixed annual charges, e.g. contribution payable to Cantonment/Civil authorities on account of services rendered, funds payable to units for carrying out works on a self help basis.

(d) Anticipated debits which are carry over from the previous financial year.

(e) This gives the net amount available for carrying out repair tasks in the year.

SAQ 1

(a) What is the aim of maintaining building?

(b) What are the steps for planning Annual Maintenance of MES assets?

2.3 ROLE OF STATION HEADQUARTERS AND MES

In preparing maintenance programme and allotting priorities in a station, adequate attention will be paid to the genuine and equitable needs of all units.

The programmers should clearly lay down the periodicities or work, the allotment of funds, the time by which the buildings or furniture will be handed over to the MES, and the time of commencement and completion of works, it would be apt to earmark some funds and MES effort as a reserve to cater for any unforeseen requirements.

The maintenance programme for the entire station, unitwise for the entire station, unitwise for the ensuing year, will be drawn up and published in station orders by the end of January. Based on this, MES will prepare a work programme specifying, for each work, the agency and resources, including time allotted. Maintenance programme once issued will be adhered to strictly unless there are compelling reasons for change.

Inspecting Officer should also check the maintenance programmes, their execution and record their findings in their reports or tour notes.

SAQ 2

(a) What role does station HQ staff play in the planning of maintenance of building?

(b) What role does MES staff play in the preparation of maintenance programme?

2.4 ROLE OF USERS

As regards the role of the users, the following points need emphasis.

The users are generally not fully aware of the capabilities, limitations and constraints of the MES; quite often users tend to make calls beyond the resources of MES and thereafter decry the MES when these are not met in an environment where mutual confidence between the users and the station authorities on one hand and the MES on the other is lacking; neither can the MES personnel give their best nor those among them who are negligent, rude or insolvent brought to book simply because there are glaring shortcomings on the part of users also.

It is perhaps not known to a large number of users that maintenance works bills are not passed by the auditors unless these are accompanied by the users certificate with regard to the completion of the work.

Most users are neither concerned of their own responsibilities towards maintenance and upkeep of Government assets nor have any qualms about misusing/neglecting government property. To bring about awareness in this regard, E-in-Cs works pamphlet No. 14 hints on Care and Upkeep of Domestic Accommodation. The following are some typical examples of disregards towards upkeep of Government assets by the users :

- Undue damage to sanitary fitting, e.g. Wash basins and WCs due to rough use or mishandling;
- Theft of stop cocks, manhole covers, float valves even from within unit premises, this besides reflecting on lack of security consciousness in the unit results in wastage of water, careless accumulation of water on roofs causing seepage in walls and dampness;
- Forcing garbage down the kitchen and toilet drains or the sewage system resulting in choking of the same;
- Indiscriminate driving of nails in walls thus spoiling the plaster and colour wash;
- Chopping wood or hammering things directly on floors thereby breaking the same;
- Non-cleaning of roofs or terraces before start of rainy season or during the rainy season to keep water spouts and drain down pipe clear of refuse and dirt;
- Extensive damage to wires, switches and plugs and very often, resulting in fires; and
- Misuse of furniture for purposes other than what it is meant.

2.5 PRIORITIES AND MAINTENANCE PROGRAMME

The annual maintenance programme will be prepared jointly by the GE or AGE and the users, keeping in view the requests of users and availability of funds in each station. Preferably, a board of offices should be convened for the purpose. A conference should then be held by the Station Commander with GE or AGE with unit Commanders and their QMs to discuss and finalize maintenance programme for the station as a whole.

2.5.1 Priorities

The following priorities are recommended to ensure proper maintenance planning and correct utilization of resources.

Priority 1

Works required for ensuring structural soundness, enhanced life and utility of Government assets as well as safety of these assets against damage due to natural or unnatural causes.

Priority 2

Maintenance and repairs necessitated for ensuring a high standard of hygiene, sanitation as also providing hazard-free and secure occupancy to users.

Priority 3

Periodical services.

Priority 4

Items, which might have been left from the previous year maintenance programmes.

Priority 5

Other general repairs and maintenance.

Similar action will be taken for the formulation of maintenance and repair programmed in respect of furniture.

SAQ 3

List out the priorities while preparing annual maintenance programme?

2.6 METHOD OF EXECUTION

Repairs works can be executed through the following agencies :

(a) Term Contractor (TC).

(b) Contracts for certain specific repairs grouped as one work.

(c) Casual maintenance gangs or Directly Employed Labour (DEL) on permanent basis.

(d) Troops.

Term contracts are finalised on a zonal basis (zone may include one or more station or a station may be divided in one or more zones) to cater for repairs and minor work. Term contracts are let out for a period of 12 months, which preferably run from June to June. Contract for periodical services and maintenance is separated to yield more realistic rates.

Repairs of alike nature, e.g. re-roofing, replacement of E/M fittings, plaster, floor can be grouped and separate contract finalised. This may be resorted to for obtaining more competitive rates or restricting the workload on the Term Contractor.

MES engage certain temporary maintenance gangs for carrying out urgent seasonal repairs. The composition and strength of the gangs is approved by CWE and should be kept to the minimum commensurate with the anticipated works load (e.g. monsoon repairs, clearance of storm drains, restoration of storm damaged buildings back to habitable condition, etc.).

Permanent DEL is employed for immeasurable regular repairs, furniture repairs, E/M repairs, urgent repairs and other petty works excluded from the scope of term contract.

Permanent DEL should be employed to the barest minimum as experience has shown that :

(a) it is not economical,

(b) it is not susceptible to rigid control,

(c) it imposes an additional burden on supervisory staff,

(d) skilled labour is difficult to obtain at the rates laid down in MES or by Station Commander (nerrick rates),

(e) the quality of works generally suffers, and

(f) there may not be sufficient work to keep them busy all the time.

2.6.1 Execution of Repairs

In executing repair works following points are important :

General

(a) All necessary precautions against damage/collapse of structure are taken, e.g. shoring, protection to floors, walls decorative features.

(b) All preliminary/preparatory operations are carried out before the works are taken up.

(c) Repair works are carried out in right sequence. As far as possible, convenience of the user and early completion of individual buildings is aimed at.

(d) All demolition stores are properly accounted for.

(e) Standard of maintenance is kept high. Full advantage is taken of the latest research on repairing techniques, use of suitable materials and preservation treatment.

Term Contractor

(a) An even load in conformity with the estimated value (in ‘Notice of Tender’) is placed on the contractor.

(b) The nature and type of works ordered in each month should be such as to take full advantage of the working season. See **Appendix 'C'** attached.

(c) Stores are issued as per requirements of the work. Surplus stores are immediately taken back.

Permanent DEL

(a) A definite programme is chalked out so that labour are not kept idle.

(b) Tasks are allotted on a 'Priority' basis.

(c) Unnecessary shifting from one set of unit lines to another is avoided.

(d) Personnel are gradually trained to supervise and raise the standard of work.

(e) Stores are properly arranged for and dispatched with the labourers.

2.6.2 Minor Work

These may be executed by contract or DEL. Contract work constitutes that bulk of the work for which requisition are prepared, sanctioned & orders placed on the contractors.

DEL is usually utilised in the execution of urgent petty repairs, which are unsuitable for ordering on TC.

2.6.3 Maintenance by Units

Unit commanders may, with the approval of CsWE, be allowed to carry out white washing and tarring of walls in unit lines under their own arrangements. Colour washing within colour limits as approved by the MES may also be similarly allowed .GE's are empowered to issue materials to unit commanders for this purpose, on the understanding that work is carried out by the soldiers themselves. The cost of such materials will be adjusted against the maintenance estimates concerned. Employment of contractors by units for this purpose is not permitted. The work will be approved at the time of quarterly inspections by a rep of MES.

2.6.4 Maintenance of Heritage Buildings

The maintenance and repairs of heritage buildings cannot be given to INTACH for paucity of funds. It is essential to ensure that while carrying out repairs/maintenance of these buildings, their old character and old specification are retained.

SAQ 4

(a) What are the agencies for carrying out repair works?

(b) Can users play any role in the maintenance of buildings? Elaborate.

2.7 CONSTRAINTS

It is a well-known fact that existing accommodation, both married and OTM, are inadequate. Notwithstanding our constant efforts to upgrade the financial

allocation for Capital Works, only limited funds will be available for construction of new accommodation and furniture in the foreseeable future. Therefore, there is an imperative need to preserve and maintain the existing assets.

It has been observed that inspite of various instructions issued from time to time planning and execution of maintenance in most stations is far from satisfactory. It must be understood and impressed on all ranks that maintenance and care of our assets is not entirely the responsibility of the MES but the users also have to develop a purposeful sensitivity to this.

To get maximum benefit from the meager funds available for maintenance, it is imperative that considerable thought is given to the planning and execution of maintenance programmes. Maintenance planning involves the users, Station Staff and the MES. A deliberate and coordinated effort on the part of all the three agencies in every station is essential to draw up a meaningful maintenance programme annually and to ensure its subsequent execution.

The procedure for drawing up maintenance programmes at present is not systematic and, therefore, not effective. Unit commanders do not intimately associate themselves with maintenance planning but generally leave it to the Quartermaster. For various reasons, adhoc priorities are given to certain maintenance works though they do not figure in the programme thereby upsetting the scheduled programme. At other times large expenditure is incurred on renovating offices and residences of senior officers without providing for the same in the maintenance programme. Such arbitrary actions and deviations tend to result in degradation of services and structures.

SAQ 5

Are there any constraints in the maintenance of buildings? Elucidate.

2.8 SUMMARY

MES assets need maintenance like any other assets. This needs careful planning at staff and MES level. There are some stations where maintenance and upkeep of our assets is very well planned and executed. Naturally, the users satisfaction level in these stations is high. This has been made possible by a coordinated and concerted effort by Commanders, Staff Officers and MES not only with the systematization of the repair and maintenance process, but also by educating the users and devoting more attention to this aspect.

2.9 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

UNIT 3 FIRE PROTECTION IN BUILDING

Structure

3.1 INTRODUCTION

Fire is a very serious hazard. When a fire breaks out it can have a devastating effect causing loss of precious human life in addition to loss of property and damage to created facility. Some of the factors which make fire a dangerous hazard could be the speed with which it can spread, poisonous smoke fumes generated and large numbers of people who can be affected particularly in a high rise building. The havoc created by fires in a picture hall in Delhi and Victoria Park in Meerut, is still alive in the memory of public. In addition to the dangers to the life and property, a fire can cripple business to a very great extent resulting in a loss of many million of rupees or even pushing the affected organization out of business making them bankrupt.

To help prevent fire from breaking out, eliminating fire accidents and to control it when unfortunately it does occur, it is essential to understand some basic ideas about the nature of the fire and how it reacts.

Fire is defined as a process of combustion characterized by the emission of heat accompanied by smoke of flame.

When a fuel (inflammable material) and sufficient heat comes together in presence of air (oxygen) a volatile and dangerous situation develops and fire breaks out creating more heat thus more fires in a cascading phenomenon. Removal of any one link can prevent fire breakout or in case of fire, extinguishing

it. Flames are generated in any fire as regions of reacting gases releasing chemical energy. The flame gases are turbulent and fluctuating, radiating heat and light from partially burnt carbonaceous particles (smoke and soot). Being higher than surrounding air, these flame gases become diluted by entrained air.

Objectives

Fire is a serious hazard having devastating effect on building resulting in destruction of created facility and human life and property. Fire protection of building is, therefore, an essential requirement.

After studying this unit, you should be able to

- explain the basic nature of fire, its causes and classifications,
- describe the fire loads and fire resistivity of different building materials,
- discuss the different methods of fire prevention, fire protection and fire fighting, and
- explain the fire safety provisions in buildings and its elements.

3.2 FIRE CAUSES IN BUILDING

There are several factors, which may cause the initiation of a fire development. Most of the fire accidents in buildings and on construction sites are caused by a combination of several factors. Some of these factors are discussed below :

Ignorance

Most of the persons occupying the building or working on construction sites may not be even aware of the fire dangers and hazards. Even smaller numbers may know how to deal with fire accident if and when they occur or the preventive measures or precautions they can take to minimize their occurrences and the havocs caused by them.

For an effective fire prevention and fighting strategy it is important that every worker at site and user of the constructed facility have the basic knowledge of the nature of fire, and of the procedures, tasks, materials and operations associated with the site and facility. Fire safety is every person's responsibility and every person shall be exposed to the understanding of fire hazards. Basic knowledge about fire is essential. It may be noted that hundreds of devastating fires are being caused by carelessness in throwing glowing cigarettes butts and matchs, or burning sigris in the closed rooms.

Poor Judgement

People often become careless, even when they know of the fire causes and hazards. They do many things, which they know they shouldn't do ignoring their own commonsense. They may try to start a fire using petrol, fail to store flammable liquids and other materials carefully or place them too close to heaters or stoves. A fire does not discriminate between ignorance and poor judgement and its effects can be catastrophic. People may have a tendency to ignore thinking about safety, even neglecting some basic precautions.

Lack of Thought and Breaking Rules

The major reason of fire accidents is due to the failure to follow instructions even when the fire safety procedures and signs are scientifically prepared and enforced. Most of the people have developed a culture of negligence and making the assumption that the rules are made to be followed by others, they personally are above the rules. The basic tendency of "SAB CHALTA HAI", developed in our culture, results frequently in keeping the fire doors propped open, fire extinguishers not working or even closed in cupboards, sand buckets empty and firewater hoses broken. The fire codes are regularly breached as a rule rather than examples. Human error has a much larger part to play in the causes of fire occurrence and fire accidents.

3.3 EFFECTS OF FIRE

3.3.1 Safety Hazards

The fire safety of buildings can be considered from the type of hazard risks experienced by them. These hazards risks or effects of fire can be broadly classified as personal hazard, internal hazard and exposure hazard.

Personal Hazard

The risk of possible damage or loss to human life is termed as personal hazard.

Internal Hazard

It is the hazard risk of fire spreading, inside the building or in the campus area surrounding the building or construction site.

Exposure Hazard

This is the hazard risks of fire spread from the fire occurrence location to adjoining buildings and other areas.

It is estimated that nearly 15000 people are killed every year in India by fire accidents, resulting in a loss of more than 1000 crores. These are expanding exponentially every year. Even in the technologically advanced country like USA it is reported that a fire breaks out every 37 seconds per day. In case of a fire hazards, the greatest loss occurs due to heat, smoke and flames. Even more critical is the panic created by a fire accident. Probably more lives are lost in stampede due to panic rather than the fire itself.

The occupied buildings contain different materials during use, which produce different gases when ignited. These gases could be carbon monoxide, carbon dioxide, nitrogen dioxide, hydrogen sulphide, etc. Some of them are toxic. These gases create either barrier to oxygen intake, or other serious affects. Smoke during fire hampers vision and thinking process.

3.3.2 Fire Load

From hazard risk point of view fires are classified in severity depending upon the fire load; Fire load is a measure of amount of heat librated in a fire accident and is expressed in terms of kilo Joules of energy released per square meter of floor area of the building or of any component of the building (kJ/m^2), generated by the combustion of the content of the building and the combustible part of the building itself. IS : 1641 : 1960 divides the fire load in three categories :

(a) Low Fire Load	(b) Moderate Fire Load	(c) High Fire Load
Not exceeding 1.15×10^6 kJ/m^2	between $1.1.5 \times 10^6$ to	2.30×10^6 to 4.60×10^6 kJ/m^2

(or 2.75 × 10^5 k Cal /m^2)	2.30 × 10^6 kJ/m^2 (or 2.75 ×10^5 to 5.50 ×10^5 k Cal/m^2)	(or 5.50 ×10^5 to 11.0 ×10^5 k Cal/m^2)

Buildings with fire loads of more than 4.60 ×10^6 kJ/m^2 or 11.0 ×10^5 k Cal/m^2 are considered unfit for occupancy.

It may be noted that different materials, having the same weight and same calorific values, may cause different hazards due to their combustion properties, e.g. rate of ignition, speed of burning, libration of toxic fumes, etc. hence materials are also graded according to their potential hazards, as discussed in Section 3.3.4.

IS : 1641 gives the types of occupancy of building as per their fire load grading. These are given in Table 3.1.

Table 3.1 : Building Occupancy as Per Fire Load

Fire Load	Energy Limits (kJ/m^2)	Occupancy
Low	< 1.15 × 10^6 kJ.m^2 < (2.75 ×10^5 k Cal/m^2)	Residential buildings, hotels boarding houses, restaurants, schools, hospitals, worship places, etc.
Moderate	>1.15 ×10^6 KJ/m^2 < 2.30 × 10^6 kJ/m^2 > 0.275 ×10^6 < 0.55 ×10^6 k Cal /m^2	Retail shops, markets, shopping malls, emporium, factories, workshops, etc.
High	> 2.30 ×10^6 kJ/m^2 < 4.60 ×10^6 kJ/m^2 > 0.55 ×10^6 k Cal/m^2 < 1.10 ×10^6 k Cal/m^2	Godowns, warehouses and similar buildings used for bulk storage of non-hazardous materials and goods.

3.3.3 Fire Grading of Materials

For assessing the fire grading of materials, these are broadly categorized as :

(a) non-hazardous (NH),

(b) hazardous (H), and

(c) extra hazardous (EH).

For this classification it is usual to consider and evaluate following characteristics :

(a) Difficulties in extinguishing the fire when materials is burning,

(b) Generation of heat energy when burning,

(c) Spontaneous combustion tendencies (lighting temperature/Flash point),

(d) Tendency to intensify the fire,

(e) Tendency to expand fire zone,

(f) High inflammability, and

(g) Explosive tendencies.

Non-hazardous materials are those which are non-combustible. These may be decomposed and absorb the heat energy endothermically during fire when high temperature are reached. Hence these may be damaged but do not contribute to the growth or spread of fire. Stones, bricks, concrete, metals, glass and clay products are example of non-combustible non-hazardous materials. The structural

elements of the building such as floors, load bearing elements, e.g. walls, slabs, beams, columns, etc. and roof are constructed of these materials.

Hazardous materials are combustible materials, which combine exothermically with oxygen, librating huge heat energy and high temperature zones like flames. Timber and timber products, fibre boards, strawboards, PVC, etc. are examples of combustible materials and are hazardous with a risk of fire initiation and spread.

Extra hazardous materials have abnormal fire risks like :

(a) ammunitions,

(b) explosive and fuels,

(c) compressed, liquefied and dissolved gases like natural gas or LPG,

(d) Substances which become explosive when exposed to air or water, e.g. oxidizing agents,

(e) all materials with low flash points (below 65^{o}C) e.g. oil, fats, waxes, rubber, bitumen, etc.

(f) corrosive and poisonous substances, and

(g) readily ignitable, e.g. wood shavings, fabrics, cotton, coal dust, paper etc.

The use and storage of such materials are not governed by normal municipal rules and bylaws. These are governed by Indian explosive rules as applicable and modified from time to time.

The structural elements of the building are graded by Bureau of Indian Standards depending upon their fire resistance properties. IS: 1641-1960 have given five grades as reproduced in Table 3.2 indicating class of fire, fire load and the period of minimum resistance against standard fire.

Table 3.2 : Classification of Building Materials

Class of Fire	Fire Load in kJ/m^2	Time in Hours for Resisting Standard Fire	Grade No.
Very high	4.60×10^6 and over	6	1
High	2.10×10^6 to 4.60×10^6	4	2
Medium	1.15×10^6 to 2.10×10^6	2	3
Low	Less than 1.15×10^6	1	4
Very low		½	5

3.3.4 Fire Resisting Properties of Building Materials

While grading the fire resistance, and assessing the properties of commonly used building materials, following characteristics of materials are taken into consideration :

(a) Material composition should be such that it does not get damaged and disintegrated at high temperatures generated by intense heat during fire accidents.

(b) The thermal expansion/contraction of materials under such temperatures and heat energy shall not be excessive as to induce instability and strength loss in the structure particularly its load bearing capacity. It may be noted that the catastrophic damage to world trading centre NY in USA on 11th September occurred not primarily due to airplane collision, but melting of encased steel

columns of the building at high temperatures created by burning of aviation fuel of the airplanes on collisions.

(c) The material contraction due to sudden cooling because of water sprinkling during fire fighting operations, should not cause its disintegration or loss of stability and strength.

(i) Stone is a bad conductor of heat and is non-combustible hence a good building material, but it has a tendency to disintegrate into small pieces when suddenly heated and cooled during fire and fire fighting operations. Granite in particular explodes at high temperatures, while limestone crumbles even at low temperature fires. Probably sand stone exhibits moderate fire resistance without any serious cracking or damage.

(ii) Bricks are non-combustible, and bad conducting material, which can withstand fairly successfully temperatures upto 1300^{o}C. with good workmanship and mortar quality. Bricks are fairly good fire resistant building materials.

(iii) Concrete is an effective fire resistant material due to its thermal stability and bad conductance of heat. It offers better resistance to fire than other commonly used materials of construction. There is practically zero strength loss upto 250^{o}C, though it looses some strength beyond 300^{o}C. The reduction rate gradually increases upto about 900^{o}C at which temperature, the strength is nearly 20 percent of its strength at normal temperatures.

The actual behaviours of concrete under fire will depend upon the quality of cement and aggregate used. Cement expands upon heating but the expansion is counter balanced by shrinkage due to loss of water. Normally the shrinkage and contraction is more than the thermal expansion leading to crack formation in concrete. The expansion of aggregate coupled with this contraction of cement may cause spalling of concrete surface. The depth up to which the effect of fire temperature has influence will depend upon the surface temperature and time of exposure. For half an hour exposure at surface temperature of above 700^{o}C, the temperature of concrete recorded in experimental studies was 510^{o}C at 12.7 mm, 320^{o}C at 25.40 mm and only 110^{o}C at 50.8 mm. It can thus be concluded that cover plays a critical and significant role in fire resistance of reinforced and prestressed concrete. A normal RCC structure is observed to behave adequately in fire accidents with surface temperatures upto 1000^{o}C and exposure period of several hours.

Metals

Though steel is highly non-combustible but it is a very good heat conductor, hence heat spread in it is very fast in case of fire. Another weakness of steel is that it looses its strength rapidly with increase in temperature. Its yield stress at 600^{o}C is about 30 percent of its normal value. Under fire accidents producing intense heat beams sag, columns buckle and structures collapse. However its non-combustibility helps in fire comfinement. In plate or sheet from steel effectively prevents spreading of flames.

Aluminium is another metal widely used in buildings. It is highly heat conductive and is poor fire resistant. Hence cast iron, steel or aluminium,

whenever used in construction, are generally encased either by brickwork or concrete to increase its fire resistance.

Timber

This is widely used in construction. Most of the houses in hilly regions, earthquake prone zones and in areas surrounded by forests, are constructed in timber. Even in other areas it is widely used for doors, windows, ventilators, cup boards and furnishings. As a general rule timber is highly combustible, it is easily ignited and assist in rapid development and spreading of fire. However, timber is a very bad conductor of heat, hence in heavy sections, it requires sufficient heat to develop to initiate flame formation. This increases heat/fire resistance of timber. The fire resistance properties can be further enhanced by coating its surface with chemicals such as ammonium phosphate and sulphate, borax and boric acid, zinc chloride, etc. This surface coating will retard the temperature rise during fire.

Glass

It is non-combustible and poor heat conductor with thermal expansion but it shatters and cracks when heated and cooled. Certain thermal glasses are developed which can resist high temperatures but these are very costly to be of general use. Glass can be made highly fire resistant by reinforcement with steel wire, it makes glass to withstand sudden changes in temperature. This glass may crack and fracture but it remains in original position due to reinforcement.

Asbestos

It is another construction material widely used for industrial roofing and partitions. It is non-combustible, low conductor of heat and low thermal expansion. It is also widely used for providing protective covering for structural members of steel/concrete to increase their fire resistance.

3.4 FIRE PROTECTION AND PREVENTION

The fire resistance, protection and prevention is a process designed to protect a large area from fire accidents. It can be considered to be consisting of four basic and distinct operations, which are, interrelated and interdependent. These are :

(a) Fire detection,

(b) Fire alarms and signals,

(c) Fire fighting, and

(d) Fire prevention.

3.4.1 Fire Detection

The first step in fire protection of a building is to be able to detect the occurrence of fire as soon as it starts to build up. Early fire detection will help in taking timely and adequate measures to prevent its escalation and putting it out or taking other measures to fight the fire and prevent the damage to life and property. There are several types of fire detectors, developed and used. These detectors may be installed in the building by the experts.

3.4.2 Fire Alarm Systems

These are installed in the buildings with an objective of giving a warning alarm as soon as fire/flame/smoke is detected by the fire detection system or otherwise. It

has been widely recognized that first few minutes of a fire accident are vitally important in fire protection than the next five hours. Earlier the fire is detected and alarm given, better will be the effectiveness and efficiency of the subsequent protection exercise.

Alarm systems could be visual, audio or mixed type either operating manually or automatically or both. The manual alarm system may consists of a hand bell or similar system by which the occupants and users of the services are warned about the fire accident. The alarm circuit may also be triggered by pushing a press button or breaking a glass seal. In automatic alarm system the warning mechanism is activated by triggering action caused by fire detector. The automatic fire alarm sends the information to be nearest control point along with an S.O.S. message to the nearest fire brigade station. It is usually installed in large industrial or other such buildings, e.g. libraries, offices, cinema halls and marketing malls, etc.

National Building Code has divided the fire alarm systems in fine categories as given below :

(a) Manually operated electric fire alarm systems.

(b) Automatic fire alarm systems using heat sensitive detectors or fusible link or bimetallic/pneumatic rate of rise type.

(c) Automatic system of thermistor type.

(d) Automatic alarms with smoke detectors.

(e) Automatic alarm and fire fighting system with carbon dioxide or halon.

In air-conditioned areas, smoke detector systems are provided, while thermistor/bimetallic/pnuematic tube detectors systems are provided above false ceiling. Rate of risk types along with fixed temperature detectors are used in cold storages while fusible link type detectors are provided in non air-conditioned areas.

Laboratories employing delicate and costly equipment are provided with automatic fire extinguishing systems like sprinklers, fixed CO_2, or foam type fire extinguisher systems.

3.4.3 Fire Fighting Systems

National building code and other laws relating fires, prescribe that adequate fire fighting measures must be provided and regularly serviced and maintained in operative conditions. Every person, occupying or using the building or its facilities must know about their location and operation and should also be trained what to do in case of a fire.

If the persons understand the chemistry of fire, they have a better chance to fight and extinguish it. On the basis of three components of a fire, e.g. fuel, oxygen and heat, following three actions can be taken.

Heat Removal

This is typically achieved using a fire extinguisher, fire blanket or some other form of cooling the heat.

Cutting Off Oxygen

An effective way to control the fire is to cut off the supply of oxygen from fire effected area. In buildings, fire doors are provided. These door and other doors and windows of buildings are kept closed whenever not in use

to prevent spread of fire in buildings and cutting of the free flow of oxygen. Some types of fire equipment and extinguishers also achieve this objective.

Elimination of Fuel

One of the main reason of fire accidents in building is by short-circuiting in electrical wiring. Switching off the electric supply in case of fire in such cases can effectively control the spreading of fire.

Based on these three basic principles, various modes of fire fighting commonly employed are listed below :

(a) Automatic fire fighting systems, e.g. water sprinklers and multifire systems, carbon dioxide and halon systems, etc.

(b) Mobile fire fighting systems, e.g. fire extinguishers, fire blankets, etc.

(c) Water systems, e.g. fixed hydrant type or dry or wet riser.

(d) Fire fighting provisions in planning, designing and construction of buildings.

(e) First aid arrangements.

3.4.4 Automatic Systems

In this arrangement, pipes and sprinklers are provided in the building in such a way that these operate automatically by heat of the generated fire and discharge water upon the fire working on the principle of heat cooling. Number of overhead pipes are fixed in the ceiling at about 3 m c/c and are provided with fusible plugs at suitable intervals. Water is supplied to these pipes from storage tanks. The fuse in the sprinkler nearest the fire location melts due to heat generated during fire, allowing the water to sprinkle on fire automatically. For systems to become more effective, automatic alarm devices are fitted with the sprinklers to give warning alarm simultaneously with water sprinkling.

3.4.5 Mobile Fire Fighting Systems

These are portable fire fighting equipment, which are provided for immediate use in case of fire breakout. These may consists of water buckets, sand buckets or asbestos blankets, kept in readiness all the time, to be used in case the fire is observed, and to quench it immediately at its occurrence. More effective portable fire extinguishers depends on its capacity and lasts from a short duration of 10 seconds to as much as 120 seconds. Safety regulations and building laws provide that adequate numbers of fire extinguishers of the right type and capacity shall be provided throughout the buildings and continuously serviced and maintained in operative conditions.

Five different types of fire extinguishers are commonly used in different fire environments. These are painted in red with a triangle, stupe or lettering in different colours to differentiate between them.

Red Mark

These are using water for spray and are the most common type of extinguishers. These can be used on wood, paper, textile, etc. but never on electrical apparatus or burning liquids. These may also be unsafe for a number of different chemicals.

Black Mark

Fire extinguishers contain carbon dioxide gas and can be used on flammable liquids and high voltage electric apparatus. They work on principle of cutting off the oxygen supply from fire areas and are less

effective than red marked on paper or other such materials. Carbon dioxide is a clean,
non-corrosive and non-combustible gas.

Blackish Mark

Similar to CO_2, halon is used for fire extinguishing. Halon is a specific family of chemicals, which are produced by replacing one or more hydrogen atoms with halogen atoms. It contains number of carbon, fluorine, chlorine, bromine and iodine atoms in their molecules. Most commonly used is the halon 1301, which is non-toxic at low concentrations. It is contained in cylinders under pressure in liquid form and is released through nozzles.

Cream Mark

Extinguishers contain foam and are safe for use on all flammable liquids. Mechanical foam is formed by passing a foam producing liquid and water through an agitation device, generating an aggregate of bubble filled air. It forms a continuous blanket over the entire flammable liquid surface thus effectively cutting off oxygen supply from it. However, these are unsafe for electrical installations and are also extremely messy in use.

Blue Mark

Fire extinguishers contain dry chemical powder, which is extremely good general fire extinguisher. It is provided in cylinders along with an expellant gas such as compressed nitrogen, and fitted with a release mechanism and nozzles for discharging the dry chemical in hazard areas.

Different types of fire extinguisher used in different classes of fires along with corresponding BIS codes is given in Table 3.3.

Table 3.3

Sl. No.	Extinguisher	Test Pressure for 3 Minutes	Test Period in Years	Type of Fire				
				A	B	C	D	E
1.	Soda Acid (IS : 934 –1976)	1.75 Pa	2	S	NS	NS	NS	–
2.	Water type of a cartridge (IS : 940 –1976)	1.75 Pa	2	S	NS	NS	NS	–
3.	Water type Bucket pump (IS : 924-1973)	–	–	S	NS	NS	NS	–
4.	Water type stored pressure (IS : 6239 – 1971)	–	1	S	S	NS	NS	–
5.	Carbon monoxide (IS : 2878 –1976)	2.1 Pa	5	NS	S	S	NS	–
6.	Carbon Tetra Chloride (CTC)	–	–	NS	S	S	NS	S
7.	Chemical Foam IS : 933-1976	1.75 Pa	2	S	S	NS	NS	–
8.	Aqueous film foam	–	–	S	S	NS	S	NS
9.	Dry powder IS : 2171-1976	1.75 Pa	3	NS	S	S	NS	–
10.	Combustible Metal	–	–	–	–	S	–	–
11.	CBM, BCF, MB	–	–	NS	S	S	NS	S
12.	Ferion	–	–	S	S	NS	S	NS
13.	High Rate Discharge container	–	–	S	S	S	S	S
S : Suitable; NS : Not Suitable								

3.4.6 Water Systems

Fixed water systems like hose reels, fire hydrants, dry risers, water spray systems, wet riser systems, in isolation or in combination are provided depending on the size of premises, and the diversity and processes of the use of the building facility Such a provision is quite expensive though necessary. These need significant investment and precise design calculations, hence can be installed only after obtaining the experts advice.

(a) Hydrant system consists of hydrants located at strategic points, which can either be operated manually or automatically. The hydrant valve is designed for the required discharge under pressure to create a jet of water to reach the desired elevation. It is generally the backbone of all the fire fighting operations and is provided under mandatory legal requirements. These are essential for all important buildings, e.g. multistoried apartments, power plants, industrial buildings, hospitals, warehouses, airports, etc.

One hydrant per 4000 to 10000 m^2 of service area is generally provided based on population density and importance.

These are also provided one at each crossing of street not more than 90 to 120 meters distance from remotest building.

Two types of hydrants are in use which are

(i) Pillar or post hydrant, or

(ii) Flush or flunk hydrant.

A vertical pipe of firehose is screwed on the hydrant when required, water jet is obtained from the nozzle of the hose pipe.

(b) **Water Spray Systems** : Water spray is used to extinguish the fire. Depending upon the type of spray required, the system could be

(i) Multifire system designed to have a coarse water spray discharged at high velocity to reach up to the base of flame zone of fire, and

(ii) Protecto spray system designed to have a fine spray at low velocity to cool the burning surface and creating an inert vapour in the combustion zone.

(c) **Wet Riser System** : Vertical GI pipes of 100 to 150 mm diameter are provided at strategic locations, known as risers. These are fed from underground storage tanks with the help of pumps creating a pressure of a minimum of 3 kN/mm^2 at top outlet. Suitable connections at each floor level at a multistorey facility are provided to supply adequate quantity of water in case of fire occurrence.

3.5 FIRE SAFETY IN BUILDINGS

The prime objective of building planners and designer is to create a structure which offers sufficient protection against fire accidents. A truly fire resistant building is fully protected against any fire, which may occur during its lifetime usage. It may be noted that it is too expensive to make all the buildings fully fire proof hence the effort is made to reduce the loss in case of fire breaking out. The efficiency of fire resistance provision is measured in terms of the amount spent on fire resistance and the corresponding reduction in loss due to fire occurrence. The

degree of fire resistance required will largely depend upon the building usage and its importance. Experience world over has shown that if escape in a tall building is not effected within 10 to 15 minutes of the fire breakout, the temperatures built up (as high as 800^{o} C) and toxic smoke and gases can fatally trap the people within the building. The fire fighting equipment normally used cannot go beyond 10 storeys.

The buildings are planned and designed such that structural elements and components can withstand the fire for specified time duration for its particular type and use. Efforts are made to contain and minimize fire spread. Adequate means of escape are provided for occupants to evacuate the building quickly and safely. All structural elements, e.g. columns, slabs, beams, walls, etc. are designed to withstand fire and continue to function without failure for adequate duration to allow safe evacuation of occupants. These are essentially constructed from fire resisting materials. Escape elements, e.g. corridors, stairs, lobbies and exit entrance are planed and designed for additional fire resistance and are separated from main building areas to remain operative during fire.

Details of fire protection in buildings are provided in Part IV of National Building Code of India in the chapter on fire protection. This code classifies the construction of buildings into four categories, e.g. Type 1, Type 2, Type 3 and Type 4 depending upon the fire resistance offered by the building components for fire duration of 4 hours, 3 hours, 2 hours and 1 hour, respectively. All the major building components are designed to withstand fire as an integrated system.

Following building elements are considered critical to evaluate fire resistance capability of the building.

(a) Load bearing element, e.g. walls and columns,

(b) Roof slabs, beams and floors,

(c) Wall openings, and

(d) Fire escape elements, e.g. entrances, exits, corridors, stairs, lifts, etc.

3.5.1 Load Bearing Elements

These are very critical components as structural stability and safety of the entire building system depends on them during any fire accident. They are designed so that they can withstand the effect of heat and higher temperature for large duration, longer than other components. Thick and specially treated timber elements gets their surface charred, thus retard the fire damage. Steel columns have a tendency to melt and soften during fire and buckle, hence must be encased in bricks or concrete to increase fire strength and durability. Concrete is a good fire resistant material for such members provided that adequate cover over rebars and prestressing tendons is ensured. BIS recommends a minimum cover of 50 mm for all structural elements. Walls, both load bearing and partitions, shall be of larger thickness as these acts as vertical barriers to the passage of fire flames and heat flow. For masonry load bearing elements bricks are superior to stones from fire resistance point of view. Partition walls should also preferably be of fire resistant material, e.g. RCC, concrete blocks, bricks, burnt clay tiles or asbestos cement boards. Cavity wall provides better fire resistance. Steel sections may be covered with gypsum plasterboards, clay tiles, gypsum tiles, foamed slag blocks, etc. as shown in Figure 3.1.

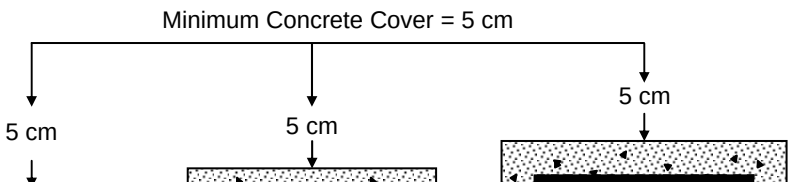


Figure 3.1

3.5.2 Roofs and Floors

These acts as horizontal barriers to fire spread in addition to providing structural strength. They cut off vertical spread of fire if constructed from fire resistant materials. Floorings made of concrete, bricks, ceramic and burnt clay tiles, terrazzo, etc. are fairly good fire resistant. When use of combustible material like timber, rubber, cork, linoleum becomes necessary from functional and practical considerations, these should be protected by an insulating cover like terracotta, ceramic tiles, special plaster, etc. Fire stops and barriers should be provided at adequate spacing.

3.5.3 Openings

Openings in walls and floors, necessary for free vertical and horizontal movement of materials and personnel in the building, are very critical elements from the fire spread point of view. These have greatest potential of spreading of fire and the resulting fire damage. As a basic precaution these openings must be reduced and minimized as far as practicable. Great precaution must also be taken to provide adequate arrangements to protect these openings in case of a fire breakout. Properly designed, provided and protected, these openings provide excellent exit for evacuation of the building during any fire accident. Any negligence in above is dangerous to safety, as openings will provide a potential source of spreading of fire flames and heat increasing the fire damage many fold. The important

precautions to be followed in protecting the openings can be listed briefly as follows :

(a) Doors and window shall preferably be of steel with wire glass panels for windows and rolling shutters for doors for effectively preventing the fire spread. Solid timber doors, if used shall have a minimum thickness of 40 mm. All openings shall preferably have double fire proof doors.

(b) Windows shall allow to work as secondary fire escapes and allow access to fire fighting persons in case of fire, though they should not be designed to act as fire escape route. Any windows exposed to the roof of other structure shall be protected by fire proof shutters. Windows carried down to the floors, are to be provided with a projecting slab beyond the outer wall face to act as horizontal barrier to fire spreading.

(c) All escape doors are designed to provide free circulation to persons in corridors, passages, stairs, etc. These should be given special attention and provided with fittings, which remain uneffected even at high temperatures. These should open in the direction of traffic flow. All the fillings shall be maintained in good working order so that these may be easily opened to allow quick escape. All fire proof doors shall conform to IS : 1648-961.

(d) All exits shall be so placed that these are always immediately accessible and able to handle all the evacuating persons in that area. Alternative escape routes shall be provided in case any one of them become non-operative or unusable in case of a fire. Escape routes shall be well lighted and ventilated and are capable of draining out the smoke or fumes of the fire effecting the crowd of evacuees.

3.5.4 Fire Escape Elements

As per National Building Code and other safety regulations, the buildings shall be provided with sufficient means to provide free escape in the case of a fire breakout. This is of critical importance in designing buildings like multistoried complex, cinema halls, shopping malls, hospitals, airports and other such public buildings. These safe escape routes also serve as important means of access to the rescuing personnel. The exit provisions should be such that persons on any storey which catches fire and of the floors just above and below this storey are able to get a safe exit of escape in a reasonably quick time. The corridors, passages, stairs and lifts size and location should be properly designed to meet the safety requirements. All these fire escape elements are constructed of fire resistant material and preferably be separated from the main building.

Stairs and lifts shall be located near the exterior walls and accessible easily from any floor in the direction of flow towards exit. In multistorey complexes, the number and location of stair cases shall be chosen to provide equitable distribution of evacuees among all the staircases. NBC dictates that there shall be a minimum of two emergency staircases provided wherever possible.

Lift shafts and stair ways invariably serves as flues or funnels thus escalating the fire by increasing the draft similar to the action of chimney. These shall be surrounded with enclosure walls of fire resistant materials and vented at top to allow smoke and hot gases to escape. Their design should be such that it prevents the development of chimney action and thus reduce the possibility of fire spread.

The lifts and escalators cannot be considered as fire escape exit. Electrical and/or mechanical lifts are reliable under normal conditions, but cannot be relied upon for escaping in the event of fire. Electric supply to the building is inadvertently cut off or interrupted during fire. Hence the only reliable mean of fire escape is through stairways. All external stairs like fire escape stairs, spiral stairs, steep ladders and ramps shall be treated as additional or supplementary escape routes, in addition to properly designed and constructed internal stairs as main or primary escape route. The travel distance of remotest building corner to stairway shall not be more than 22.50 m for residential educational and institutional buildings varying to 45.0 m for business buildings. For buildings taller than six storeys, it has been recommended to provide at least one independent fire tower as the escape route.

SAQ 1

(a) Define fire process and causes of fire accidents in buildings.

(b) What do you understand by fire prevention and fire protection of a building?

(c) Briefly state the characteristic requirements of an ideal fire resistance material, and briefly describe the fire resisting properties of commonly used building materials.

(d) Describe various methods of fire prevention and fire fighting you will recommend in view of ensuring fire safety of a multistorey residential complex.

(e) Write short notes on :

(i) Fire classification

(ii) Fire load

(iii) Fire grading of materials

(iv) Fire proofing of building

3.6 SUMMARY

After going through this unit, you should have understood the basic causes of fire occurrences, its classifications and hazards and thus have the knowledge of fire resistant properties of building materials and methods of fire safety, protection, prevention and fighting.

3.7 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

UNIT 4 STRUCTURAL STEEL WORKS

Structure

4.1 INTRODUCTION

Steel, particularly mild steel, is extensively used in building construction, almost on same scale as concrete and bricks. For heavy, complex and long span structures, e.g. multistorey complexes, auditoriums, cinema halls, indoor stadiums, industrial structures and large bridges, steel is preferred to be employed in comparison to other construction materials. It is equally strong in compression and tension and is found to be more economical for high-rise and long span structures. Mild and cold deformed steel in bar forms is also extensively used as reinforcement in reinforced cement concrete structures while high strength steel in rod form or wire tendons is used in prestressed concrete.

For high rise buildings and long span bridges, steel framework of beams and columns in buildings and in truss form in bridges, can be economically employed in combination with other construction materials, e.g. RCC for slabs and floors and bricks for walls and partitions. The basic advantages of steel construction over masonry, RCC and prestressed concrete construction is its smaller self-load, sleekness of shape, ease of prefabrication and speed of construction. The disadvantage is its loss of strength and stability at high temperatures during fire and susceptibility to corrosion and rusting in hazardous environment, which require special treatment e.g. encasing with fire resistance covering like brick masonry or concrete and regular painting with anticorrosive paints.

The structural steel is the steel used for manufacturing or rolled steel sections, and other structural elements. It is an alloy of iron, small quantities of carbon and varying percentage of other elements. The structural properties of steel, e.g. hardness, strength, and ductility, depends on the percentage of carbon in the alloy. The different types of steel are classified according to percentage of carbon and other elements in it, e.g. mild steel (or low carbon steel), medium carbon steel, high carbon steel, low alloy steel or high alloy steel, etc. Mild steel is manufactured in the form of rolled structural sections, rivets and bolts, etc. Weldable steel is used for steel members subjected to dynamic loads where welding is used for fabrication. High strength steel is obtained by addition of small quantities of one or more alloying elements to improve its tensile strength and resistance to corrosion.

The masonry members like walls, arches and columns and RCC members like beams, slabs and columns are solid in cross section and usually do not have the problem of structural instability or buckling under compression because of their adequate sizes. On the other hand because of their much higher strength, the area of steel members required is comparatively much smaller. The tension members in steel are, therefore, much thinner in sections, steel ropes can also be used for carrying the tensile forces in many cases like cables of suspension bridges. However, for flexture sections, e.g. for beams, large moment of inertia is required ($\sigma = \frac{M}{Z}$ where $Z = \frac{I}{d/2}$). Maximum stress occurs in flexural members in elements farthest from neutral axis while it is zero at NA and very small in areas surrounding the NA (Figure 4.1(a)). Hence a rectangular section in steel will have large volume of material located in places with very little stress hence very uneconomically utilized.

For achieving efficiency and economy it is desirable to remove material from areas of small stresses and place it in areas of maximum stress. This will increase the flexural strength of member several times for same quantity of material utilized (Figure 4.1(b)).

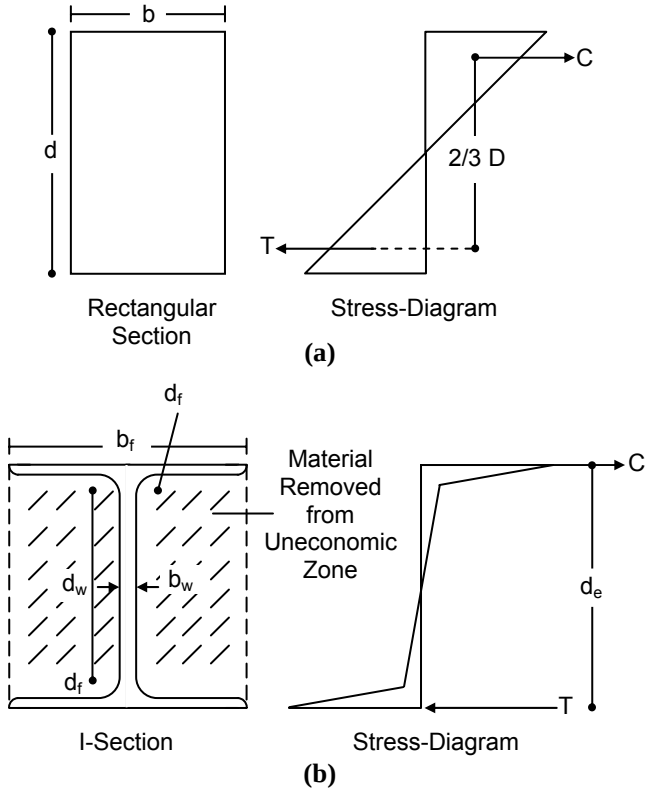


Figure 4.1 : Economical Shape of Bending Members

Similarly for compression members, because of high strength and modulus of elasticity, very thin sections of steel members are required from point of view of strength but these thin sections fail $\left(\sigma_c = \frac{\pi^2 EI}{l_e^2}\right)$ because of small moment of inertia hence buckling. Sections are, therefore, required to be built so as to provide larger I for same area of cross section similar to flexural members.

Hence unlike timber, masonry or concrete construction where the structural members are made at site, economic and efficiency dictate that steel sections are made in standard shapes and sized in steel mills. The sections are usually made by rolling process in steel mills, hence are known as rolled steel sections.

The steel elements have high strength resulting in smaller member size and lighter self-loads. They also have longer service life due to high density and homogeneous nature. Modifications, alterations and strengthening of steel elements is easy, if required later for changed functional uses. The fabricated members can be readily disassembled and replaced with larger salvage value. Fabrication, assembly and erection is comparatively quick and easy.

Objectives

Steel is very commonly used building material for a variety of functional requirements like structural framing, trusses, elements of doors, windows, ceilings, furniture, etc. and important constituent of reinforced and prestressed concrete as reinforcement and prestressing tenders.

After studying this unit, you should be able to

- explain the advantages and disadvantages of steel usage in construction,
- describe different shapes of rolled and built-up steel sections, e.g. I, C, channel etc., their development, advantages and IS designations, and
- discuss different methods of connecting steel elements and members like bolting, riveting and welding and their salient features.

4.2 ROLLED STEEL SECTIONS, SHAPES AND BIS DESIGNATIONS

The commonly available shapes, in which rolled steel sections are available, could be as follows :

(a) Angle sections, (b) Channel sections,

(c) I-sections, (d) T-sections,

(e) Flat round and square bars, (f) Plates,

(g) Corrugated sheets, and (h) Expanded metals.

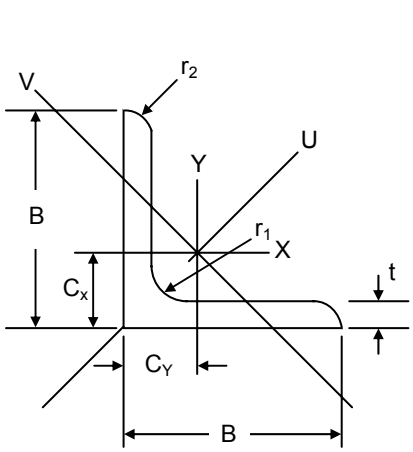
The gross cross sectional properties of rolled steel sections are specified in corresponding Indian Standards.

Steel sections are manufactured with standard specifications for the area (a), per meter weights (w), distance of centroid from edges (xx, yy), thickness (T_1, T_w) and size of leg (D, B), moments of inertia (I_{xx}, I_{yy}, I_{ww}, I_{vv}), section modulus (Z_{xx}, Z_{yy}, Z_{ww}, Z_{vv}), product of inertia (I_{xy}, I_{uv}) radius of gyration (r_{xx}, r_{yy}, r_{uu}, r_{vv}) and radii at toes (r_z) and roots (r_i) and slope of flanges (θ) etc. (Ref. Steel Tables).

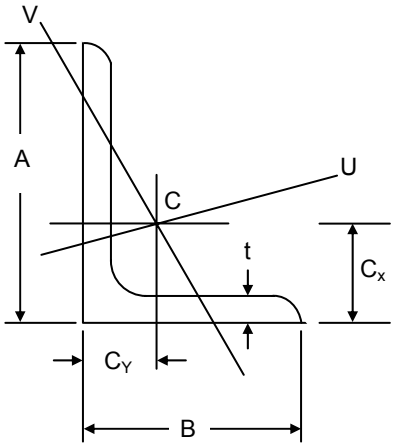
Angle Section

The angle sections could be of equal leg lengths or unequal leg lengths as shown in Figure 4.2. These are extensively used for cleats, purlins and members of a truss and also as elements of built up sections and bracings.

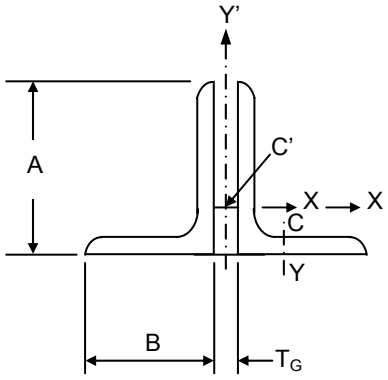
The range of equal angles is normally from ISA 2020 to ISA 200200 while for unequal angles it is ISA 3020 to ISA 200140. In market equal angles manufactured by SAIL are available. Angles with same leg lengths are available with four different thicknesses.



(a) Equal Angle (I_v is Minimum)



(b) Unequal Angle



(c) Two Unequal Angles (I_v is Minimum)

Figure 4.2 : Angles Sections (IS : 808 (Part VI-1976))

Channel Sections

These are extensively used for purlins, braces and for light beams. These are also employed as elements of a built up section to be used as columns, beams, plate girders and heavy truss members. These are available in three weight categories (junior, lightweight and medium), i.e. ISJC, ISLC and ISMC depending upon the leg thickness and weight per meter, e.g. ISJC 100 @ 4.8 kg/m (IS : 808-1964), ISLC 100 @ 7.9 kg/m (IS : 808-1964) and ISMC 100@ 9.2 kg/m (IS : 808 (Pt-III)-1979).

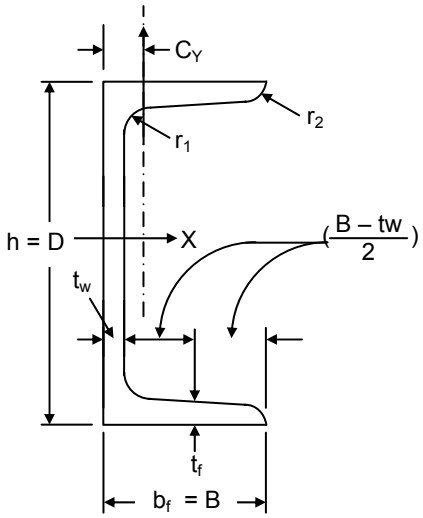
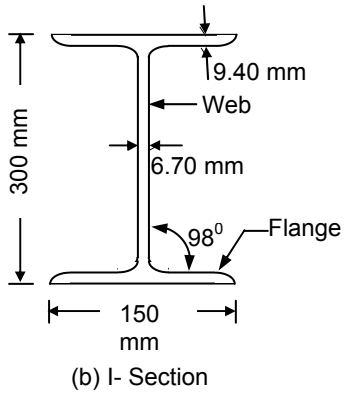


Figure 4.3(a) : Channel Section

I-Sections

These are commonly referred as joints or beams consisting of two flanges connected by a web as shown in Figure 4.3(b) and are available in depths ranging from 74 mm to 600 mm. Bureau of Indian Standards have categorized I sections into junior sections (ISJB), medium beams (ISMB), wide flange beams (ISWB) and heavy beams (ISHB).

I-sections can be used economically as flexural members by achieving material economy by concentrating the material in two flanges where flexural stresses are maximum. H-sections are normally used for columns.

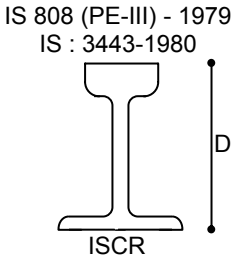


(b) I- Section

Figure 4.3 (b) : I-Section

Rail Sections

These are modified I-sections as shown in Figure 4.3(c), where top flange is formed in a bulb shape to provide solid surface for free movements of wheels of crane bridge or railway wagons while large lower flange provides wider surface for fixing it on supporting structures/sleepers and proper distribution of concentrated loads on large areas. These are designated as ISRC.



Crane Rails

Figure 4.3(c) : Rectangular Section

T-Sections

As shown in Figure 4.3(d), T-sections consist of a flange and a web. It is designated by overall dimensions and thickness and are available in sizes varying from 20 × 20 × 3 mm to 140 ×140 ×10 mm and used as elements of built up sections for roof trusses, etc. These are designated by BIS as ISNT (normal) ISDT (Deep legged), ISLT (Light weight), ISMT (medium weight) and ISHT (Heavy) as specified in IS : 1173-1969 and are available in the range varying from 20 mm to 200 mm.

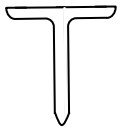


Figure 4.3(d) : T-Section

Bars

These are available in different shapes depending upon specific use, e.g. flat, square and round. Flat bars are manufactured in size ranges from 24 mm × 4 mm to 400 mm × 40 mm. These are widely used for steel grills of windows and gates, etc. and also used for bracing and lacings of built up sections provided as columns, beams or truss members.

Square bars with size ranging from 4 mm × 4 mm to 300 × 300 mm are used in construction of grills or widows and doors. Round bars have circular cross section with diameters ranging from 4 mm to 300 mm. Bars even in diameters up to 400 mm are also used though not that frequently. Round bars are extensively used as reinforcement in RC members, e.g. slabs, lintels, beams columns, etc. These are of two types

(a) Plane round bars, and

(b) Ribbed torsteel bars.

Ribbed torsteel bars are deformed high strength steel bars, having ribs or projections on their surfaces provided to increase their bonding with concrete.

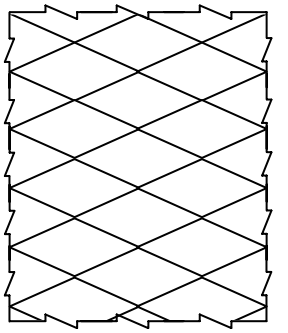
Plates

These are wider section flat bars with width more than 400 mm and thickness varying from 4 mm to 40 mm. Standard widths are 900 mm to 2400 mm, usually in increments of 100 mm. While standard lengths are from 200 to 12400 mm. These are widely used for providing joints in girders for extension, etc.

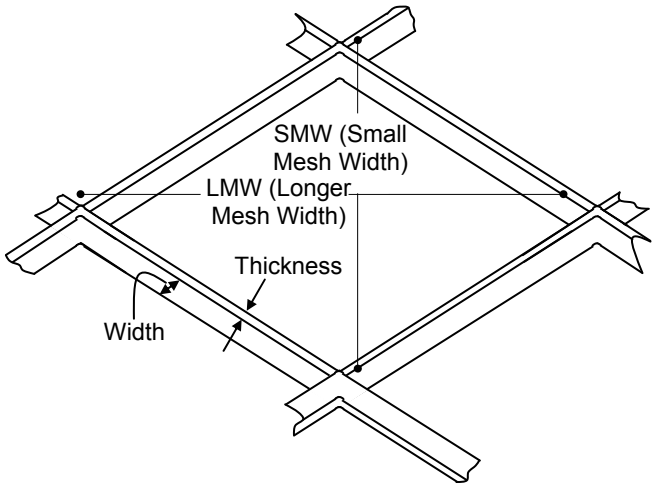
Expanded Metal

A plain expanded metal is prepared from sheets of mild steel, which are machine cut and drawn out or expanded. A diamond mesh appearance is thus formed through out the sheet area. (Figure 4.4(a)).

Meshes are available with SWM of 3 mm and LWM of 14 mm to SWM of 100 and LWM of 240 mm for different uses. Expanded metal sheets are widely used for reinforcing floors, roads, foundation bases, also as lathing material and for partitions.



Expanded Metal Sheet



Expanded Metal Sheet

Figure 4.4 (a)

Corrugated Sheets

These are formed by passing steel sheets through grooves which bend and press steel sheets to form the corrugations. These are widely used for roof coverings, and sometimes as panels for steel doors and manufactured from galvanized iron sheets, also called GI sheets. Ordinarily, 0.80 mm thick (22 gauge) sheets are used for common roofs, laid at a slope not flatter than 1 in 4, with a purlin spacing of 1.80 m. Thicker sheets, e.g. 1.0 mm (22 gauge), 1.24 mm (20 gauge), and 1.60 mm (16 gauge) are also used if purlin spacing is larger. Sheets are laid with a minimum end laps of 140 mm and side laps of two corrugations on each side (Figure 4.4(b)). Curved roofs up to 9 m span with 6 m radius can be made from 18 gauge sheets without providing trusses.

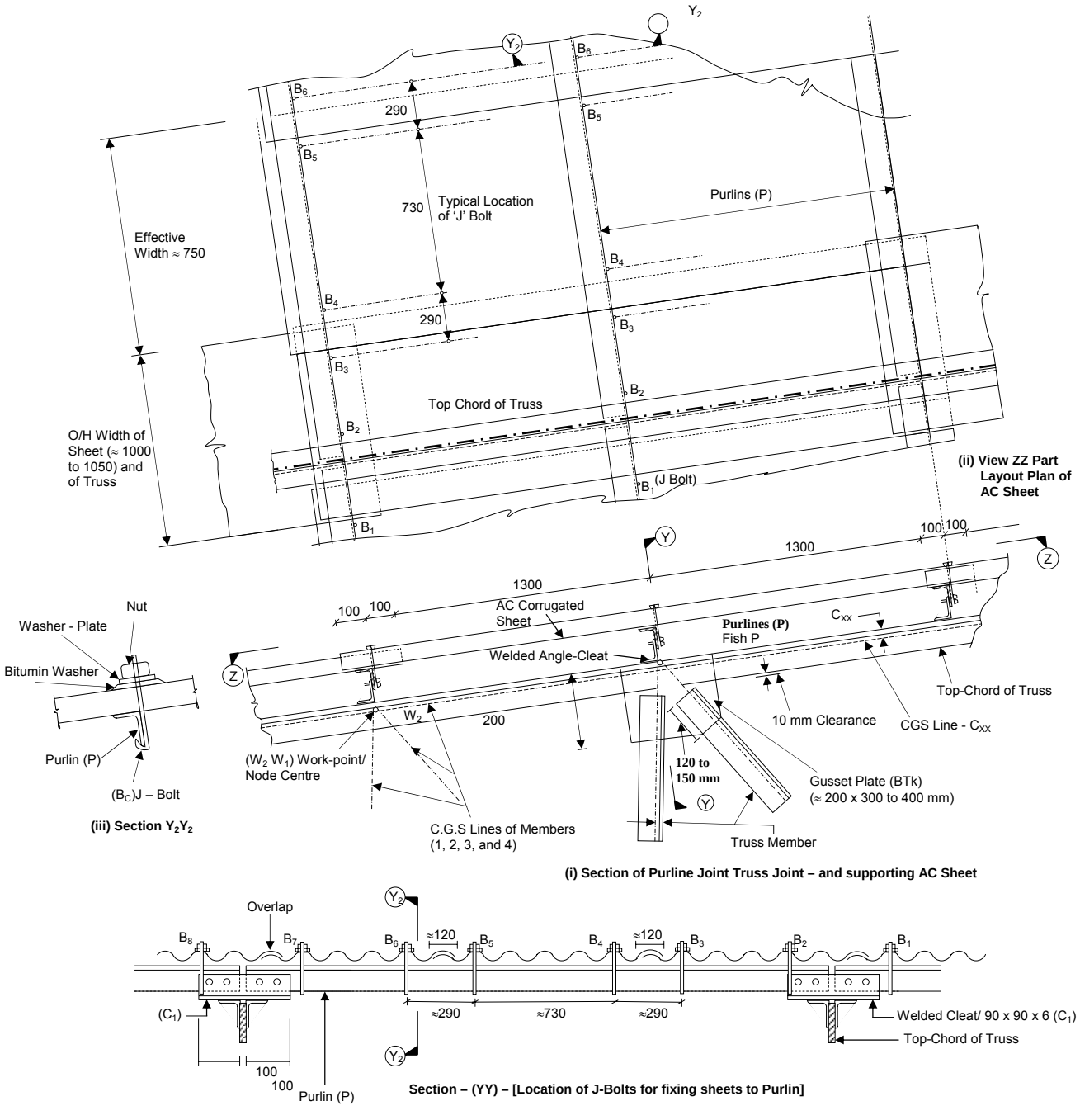


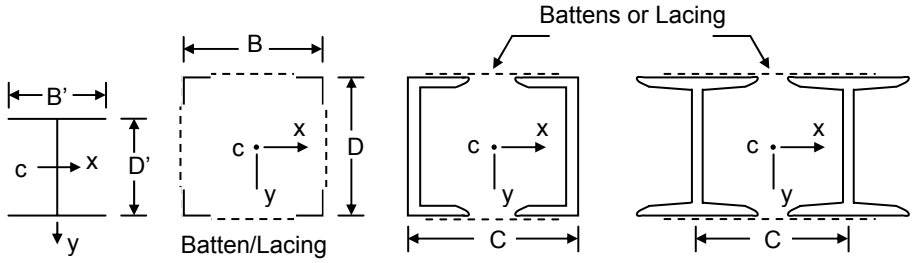
Figure 4.4(b) : Layout Plan and Elevation of AC Sheets and other Constructional Details

Built-up Sections

For achieving better economy in large works and getting structural sections of strength not attainable by rolled sections alone, built-up sections of steel

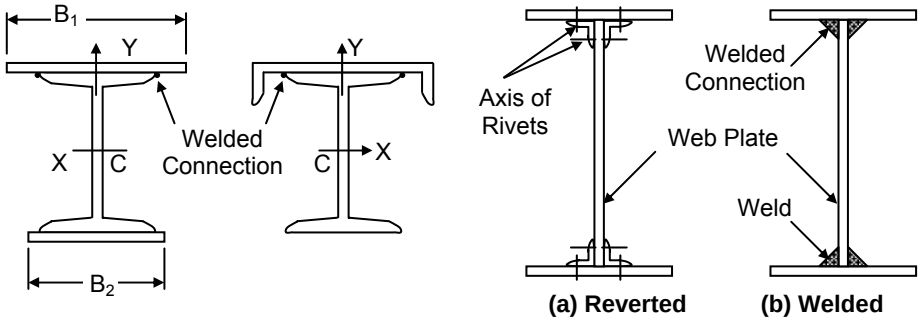
are fabricated as shown in Figure 4.4. With combining different rolled steel sections as elements, structural engineers can obtain the required strength desired as per design requirements, e.g. built-up columns, gantry girders, plate girders, roof and bridge trusses, etc.

The basic concept of built-up section is to provide increased moment of inertia about major axis for minimum area required, to enhance the flexural strength of beams and girder, with some additional expense of fabrication and achieve the overall economy. For compression members the requirement is to increase the moment of inertia about both the axis to obtain same effective slenderness ratio while achieving maximum material economy.



(i) ISBH **(ii) 4 Angles Area** **(iii) 2 Channels Area $(2A_2) > 4A_1$** **(iv) 2 I-section Area $(2A_2)$**

Figure 4.5(a) : Various Types of Built-up Section



(i) Compound Beam **(ii) Gantry Girder** **(a) Reverted** **(b) Welded** **(iii) Plate Girder**

Figure 4.5(b) : Built-up Section of Beams

4.3 CONNECTIONS IN STEEL STRUCTURES

The steel members used in steel structures are required to be connected to each other to safely transfer the load. Unlike reinforced concrete, where members can be cast monolithically to form an integrated structural system to transfer all the vertical and horizontal loads ultimately to foundation, steel members are required to be adequately joined together for this purpose. Furthermore, for fabricating the built-up sections, individual rolled steel elements are to be connected together to get an integrated composite member.

This jointing or connection between different elements of a structural member and between different members of the structural system is achieved by following techniques :

(a) Bolting,

(b) Riveting, and/or

(c) Welding.

Whatever technique of connection is employed some basic precautions are required in structural steel connections. Some of the critical considerations can be listed as follows :

Members Meeting at a Joint

Eccentricity of members meeting at a joint shall be avoided. The centre of resistance of a connection shall be on the line of action of the load to avoid moments arising due to eccentricity. For triangular frame of a truss all joining members at the joint should have their centroidal axis meeting at c.g. of the connection. If, however, some eccentricity does occur due to unavoidable reasons, the individual members and the connections shall be so designed as to provide adequate strength to resist resulting moments.

Beam Column Connections

The beams shall be connected to columns through a bottom bracket and top cleat wherever practicable, even if no bending moment is required to be transferred. Where web cleats are not provided, the bottom bracket must be designed to transfer the entire reaction.

Auxiliary Elements

Auxiliary elements, e.g. gussets, packings, lug angles, separators and diaphragms shall be properly designed and provided. Gussets in truss member joints shall be designed to resist the shear, direct stress and bending action on its weakest section. No slipping of elements is permitted and packing is provided wherever needed. Usually rivets and bolt transfer the shear through a packing.

Lug angles are used to provide smoothness of stress flow at joints. Separators are provided when two or more rolled sections are used as beams, and connected by bolts.

4.3.1 Bolted Connection

Bolt connections are provided usually when members are required to be joined temporarily or semi-permanently. For permanent type of connections, riveting or welding is preferred. Bolt may also be preferred where riveting is difficult, like in-situ connections at greater heights, where both riveting and welding becomes difficult.

A bolt has two parts, a shank and the head. The shank of the bolt is cylindrical and is threaded at the tail end for adequate length, long enough to engage a nut and its tightening. Head shape depends on the purpose and usage. For distributing the clamping pressure of the nut and of the bolt on the member, steel washers are provided under the bolt as well as under the nut. Whenever there is a risk of nuts becoming loose due to vibrations, impact or steel reversal use of lock nuts is advised.

Commonly used bolts in structural steel can be classified as :

(a) unfinished bolts,

(b) turned bolts,

(c) ribbed bolts,

(d) high strength bolts, and

(e) interference bolts, etc.

Ordinary common rough or black bolts are termed unfinished bolts and are normally used under static loads for light structures like bracings, purlins, etc. These are fitted in bolt holes, which are 1.6 mm more than the bolt dia. These are governed by the provisions of IS : 800-1984.

Shank of turned bolts are formed from a hexagonal rod and have larger bearing and shear strength conforming to IS : 2491-1969. These are machined to fit in the hole with very small tolerance.

Ribbed bolt offers more resistance to vibrations as their longitudinal ribs cut grooves in the connected members while tightening them. These are also called fluted bolts.

High strength bolts are manufactured from medium carbon steel and are governed by provisions of IS : 3747-1972 and IS : 4000-1967. Because of their high tensile strength, these grip the connected members tightly and transfer additional shear due to friction created and are primarily used for heavy construction, e.g. high rise buildings, bridges and heavy machines. These are also called friction bolts.

Interference bolts are modified version of high strength bolts whose diameter is slightly larger than hole diameter, and are fitted by pushing/hammering. It can be used with simple tightening machine and provided for structures like towers, masts, etc.

Foundation bolts are used for fixing vibrating machines and heavy structural frames to their foundations. For stationary machines and structural elements, eye foundation bolts are used which are made from mild steel and placed in a bolt hole in foundation in required position with the help of a template. The surrounding space between the hole surface and bolt is then filled with cement mortar or concrete. If the lower portion of the bolt shank increases in width, to provide better fixity when grouted, it is termed rigbolt. Cotter bolt is used in case of heavy machines.

4.3.2 Riveted Connections

Riveted connections are made by insertion of mild steel rivets in the drilled holes of the members to be connected. Different types of head normally provided are shown in Figure 4.6.

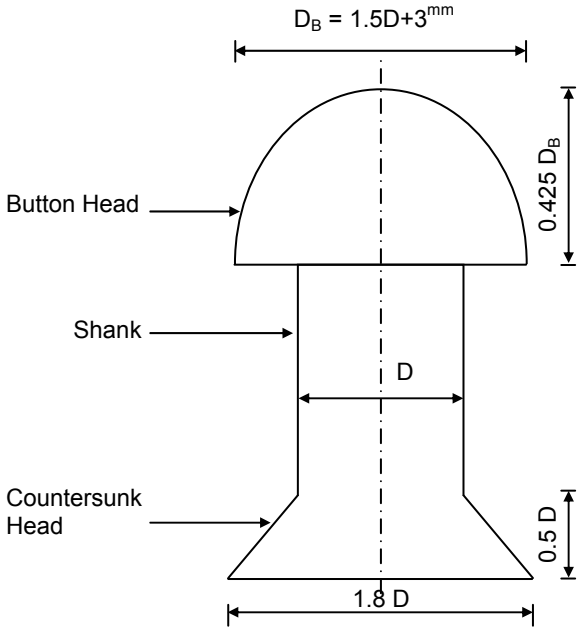
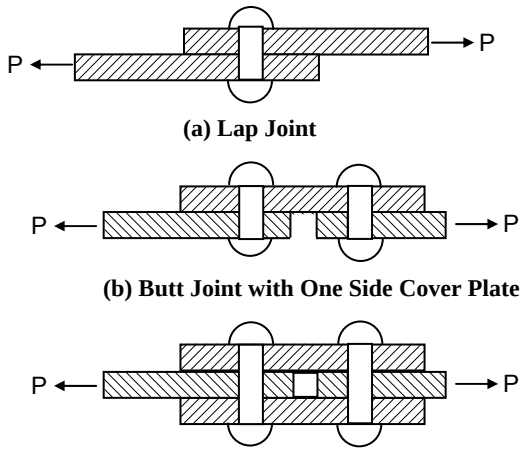


Figure 4.6 : Rivet Heads

Holes are drilled, bored or punched in the members to be connected, and heated rivets with heads on one end as shown in Figure 4.6 are inserted in holes. Another head is then formed at the other end by a pneumatic or hydraulic hammer or riveter. This process makes an effective connection to members at the joint, which can fail only when the rivet itself will fail.



(a) Lap Joint

(b) Butt Joint with One Side Cover Plate

(c) Butt Joint with Cover Plate Both Sides

Figure 4.7 : Types of Connections

The rivet material follows the specifications of IS : 1929-1961 or IS : 2144-1962. High strength rivets conform to IS : 1149-1982. The design of riveted connection is done as per the provision of IS : 800-1984.

Riveted connections are usually provided in two forms

(a) Lap joint, or

(b) Butt joint.

In lap joint connecting plates are lapped over one another and riveted (Figure 4.7(a)) while in butt joints the connecting plates are place coaxially and connected together with cover plates on one side (Figure 4.7(b)) or on both the sides (Figure 4.7(c)). The spacing of rivets, their pitch, gauge length, edge distance and numbers depend upon several requirements of designs. Rivet can also be provided in one or more rows depending upon the width of member to be connected (Figure 4.8).

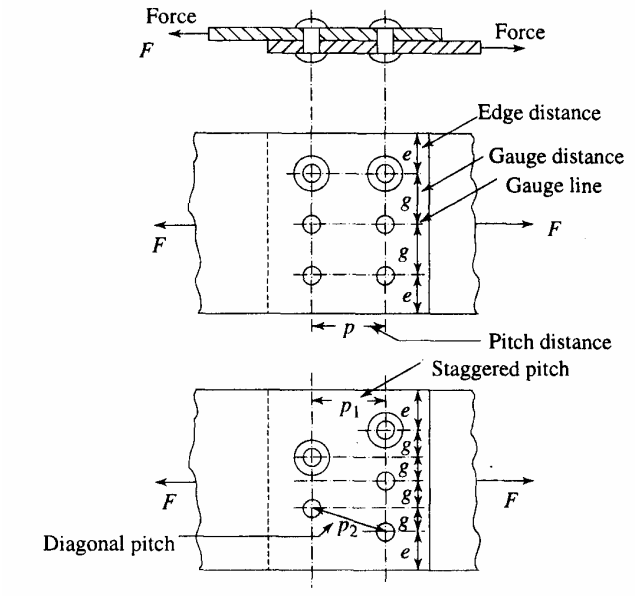


Figure 4.8 : Pitch of the Rivets/Bolts

In Figure 4.8,

p = Pitch = The distance between the centers of two consecutive rivets measured along a row of rivets.

g = Gauge length = distance between adjacent rivet lines

As shown in Figure 4.8, rivets should be placed apart at a sufficient distance to permit effective provisions of rivets to reduce the length of connection and gusset plate as much as practicable and to ensure that plates between the rivets do not fail. The maximum pitch is also required to be specified to avoid looseness of connection and relative motion at joint between connected members. The maximum distance between the connecting rivets is also required to prevent local buckling of connecting elements. Rivet holes also should not be placed too close to edges to avoid tearing of plate in tension.

Tacking rivets are provided when two or more elements are connected to act as a single member between the joints to enable elements to act as a single member and prevent local buckling.

Since both rivets and bolts transfer the load by same action their design requirements are same.

4.3.3 Welded Connections

Due to development and refinements in welding process, both riveting and bolting of steel structural elements is greatly replaced by welding. For most of the prefabrication work, welding is almost invariably being preferred these days. Most commonly used methods of welding structural steel is either

(a) electric arc welding, or

(b) oxyacetylene gas welding.

In both these welding technologies, fusion of material of connecting member is achieved by heating the edges of members by electric arc or gas flame so that the metal melts and fuses together. It is then allowed to cool to form a uniform material. Additional material is supplied with the aid of a metallic rod to reinforce the weld at joint, acting simultaneously as an electrode. A welded connection properly made has almost same strength as that of the solid member (almost 94 to 98% efficiency). In electric arc welding, an electric arc flame is formed between electrode connected to one terminal of the current supply source and the member being connected to the second terminal. The heat produced by the arc raises the temperature as high as 3000 to 4000^{o} C locally to melt the metal. The metal of the electrode mixes with the melted metal of the members being welded forming a pool or crater of metal at joint, which solidifies on cooling to form a uniform mass.

The advantages of the welded connections are given below :

(a) This requires much less time than riveting and is more economical.

(b) Entire cross section of the member is utilized in taking/resisting the stress, even in tension members as there are no rivet holes.

(c) Additional saving of materials can be achieved in many cases by eliminating the use of gusset and cover plates, reducing the overall weight of structure.

The use of proper welding wire or electrodes is an important factor in making satisfactory welded joint. The rod size depends on the thickness of the members being connected and weld size adopted, ensuring that melting of member and welding rod takes place in the molten pool only.

The welding is done in flat position as far as practicable with connection member serenely fixed in position by clamps or spot welds. These members shall not contain any impurity or rust at welding surface. There shall not be any cavity or pockets of burnt metal, gas or slags in the weld edge, particularly at the root of the weld.

In general, two types of weld – Butt welds and Fillet welds – are used in structural steel works. Fillet welds are more commonly used in structures.

Butt Welds

When the structural members axes are in line as shown in Figure 4.10. These could J, U, V or double J, U or V type in shape.

The edges of the steel members to be connected are aligned and leveled V or U grove is made at the end. The trough so formed is then filled with molten metal. The butt welding is adopted for structural members in direct tension or compression. Extra weld metal is placed at top to make the throat dimension at least 10 percent more than the member thickness for reinforcing the butt weld, which, however, shall not be more than 3 mm.

The effective throat thickness for design calculations is usually taken as $4/8^{th}$ of the thickness of the thinner member being joined. When full penetration butt weld is used.

Fillet Weld

For overlapping members and when members to be joined are not coaxial, fillet weld is provided (Figure 4.9). These transfer the stress by developing shear stresses and can be either concave or convex. Concave fillet welds are preferred for members subjected to fluctuating forces. The weld size is determined from the distance between the weld root to the toe of the weld known as leg length of the weld.

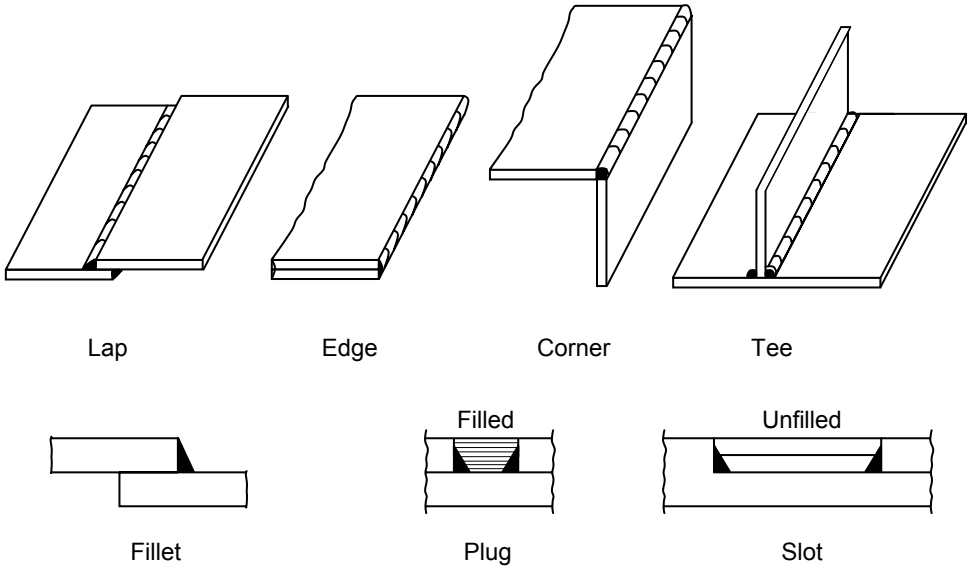


Figure 4.9

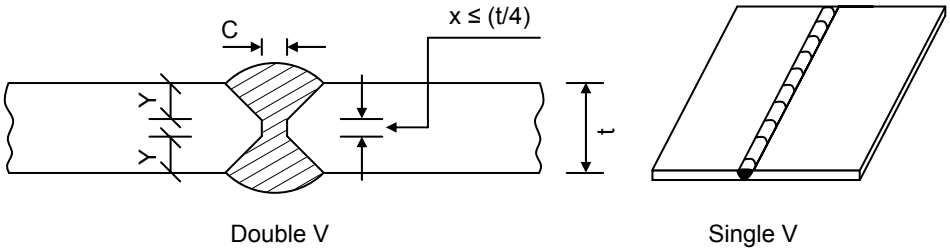


Figure 4.10 : Butt Weld

The transverse spacing between fillet welds shall not be more than 32 t or 300 mm whichever is less.

Welding process is controlled by the provisions of following specifications of Bureau of Indian Standards :

IS : 816-1969; IS : 819-1947, IS : 1024-1979; IS : 261-1949; IS : 1323-1982 and IS : 9494-1980, while their design is governed by IS : 800-1984.

There are many advantages of welding connection over other types of connection. It is economical in use eliminating noise produced in process of riveting. It ensures the effectiveness of entire sectional area of the structural members in tension elements while only net area (Total area – Rivet hole area) in case of riveted or bolted connections. The connections can be made very rapidly. It is possible to fabricate members in any desired architectural shape and effect by joining members flush with a smooth and pleasing surface.

4.4 TUBULAR STRUCTURES

Tubular members are increasingly used in recent times for fabrication of structural members, particularly trusses. Before refinement in the welding technology, angles and other rolled sections were preferred over tube as it was difficult to get correct end profile for jointing members at angles. This handicap is now completely eliminated by the welding techniques. Use of steel tubes is greatly economical in industrial buildings, warehouses and large space structures, transmission line towers, masts and offshore structures, etc. NBC and IS : 1161 specifies tubes graded as Y_{SE} 22, Y_{st} 24 and Y_{st} 34 and hot finished welded (HFW), hot finished seamless (HFS), and electric resistance or induction welded (ERW) tubes.

The tubular shape with uniform radius of gyration along all the axes makes it highly suitable for use as compression members. It also has a very high torsional strength and higher frequency of vibration than other rolled sections.

SAQ 1

(a) Write a note on scope of steel as a building material, its merits and demerits. Also describe usual sections used as

(i) Compression members

(ii) Tension members

(iii) Flexural member

giving suitable sketches.

(b) Explain with the help of neat sketches, the built-up section of structural elements you would suggest for

(i) Stanchion

(ii) Compression members of a steel bridge

(iii) Plant girder

Justify the section you have proposed.

(c) Described briefly various methods used for making connections in steel structures, discussing the salient features and advantage of each.

4.5 SUMMARY

After going through this unit, you should have gained sufficient information about different shapes of rolled and built-up sections commonly used in

construction and how to connect them efficiently and effectively to fulfill their structural and functional applications.

4.6 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

UNIT 5 ACOUSTICS AND VENTILATION

Structure

5.1 INTRODUCTION

Acoustics is the science relating to sound production and listening, it deals with clear transmission of sound speech, lectures and music throughout the hall or building as a whole without any distortion. Good acoustics promote comfortable living and working efficiency of occupants and increase the pleasure and satisfaction of listeners of music and speech in auditoriums.

For comfortable occupancy of a building and meeting functional requirements, proper acoustics and sound insulation are required. It is a matter of experience, proven by experimentation that high noise level in buildings cause fatigue, mental strain and loss of efficiency. It may even lead to deafness and nervous breakdown. For some buildings, proper acoustics and sound insulation is of paramount importance, e.g. for radio and television studios, auditoriums, hospitals and educational institutions, etc.

To provide a controlled environment inside the building is a prime necessity for a quality life of its occupants. The acoustics of the building shall be such that noise free sound of good quality free from echoes and distortions can be listed in the building simultaneously keeping the interior isolated from exterior noises. Similarly, the continuous removal of vitiated and foul air from inside the building and replacing it with air of desired purity, humidity and temperature at pleasant velocity is essential for quality life.

Objectives

After studying this unit, you should be able to

- describe the characteristics of sound and its transmittance which help in understanding the acoustical requirements of a building,
- explain different acoustical defects in general using areas and particular buildings like picture halls and auditorium, etc.,
- discuss the features of acoustical design to prevent acoustical defects and meet the general requirements of good acoustics, and
- describe the general requirements of good ventilation system in a building and means to control its velocity, humidity and temperature.

5.2 ACOUSTICS AND SOUND INSULATION : GENERAL PRINCIPLES

Sound insulation and proofing is almost as important as good acoustics. Proper control of disturbance due to noise, both from external as well as internal source, is of paramount importance. Noise is defined as unwanted sound and may be caused due to frequency of sound and or its intensity. High frequency noise is more unpleasant and harmful than low frequency noise. The noise which have an outside source as original are termed outdoor noise like road/aeroplane/railway traffic, or loud speakers so frequently used in our country. Noises which have an indoor source of origin are called indoor noise such as loud conversation, blaring music, banging of doors and window panels, or running machines in industrial buildings.

Noises can be transmitted by air directly to ear or propagate through the structure. The objective of sound insulation is to minimize the hazardous effects of noise on building occupants by proper planning, adopting sound proofing constructional measures, e.g. use of airtight windows, cavity walls and suspended ceilings, etc. and by reducing sound transmission through walls, floors, partitions, etc. and provision of sound absorbing materials, e.g. compressed straw or cork slabs, felt, slag wool, etc.

Characteristics of Sound and Principles of Acoustics

Basically sound is a series of alternate compression and rarefaction of air or any other medium, produced by a vibrating body. These longitudinal sound waves travel all around through any material in solid, liquid or gaseous form. These waves travel in air with a velocity of 340 m/sec at normal temperature and pressure. This velocity of sound depends on density, temperature, pressure and nature of medium of transmission. Higher the density, greater will be the sound velocity. In vacuum (with theoretical density of zero), sound cannot be transmitted, i.e. it travels with zero velocity.

Sound waves are characterized by its three properties as below :

(a) Frequency,

(b) Intensity, and

(c) Tone.

Frequency or pitch is defined as vibration cycles per second. The highest frequency which an human ear can identify as audible is 20000 cps while the lowest audible frequency is 20 cps. An human ear cannot listen a sound of frequency lower than 20 cps or higher than 20000 cps. The **sound intensity** measures the flow of sound energy through a unit area normal to the wave direction. The variation range of sound intensity is very large indicating different levels of noise created, normally indicated in decibels, ranging from nearly 140 decibels created by aeroplanes causing pain to barely audible intensity of less than 20 decibels produced by whisper or rustle of leaves. National Building Code gives the intensity levels of different sound sources and acceptable noise levels in buildings from viewpoint of comforts. Another sound characteristic is called **tone** by which sounds are differentiated from one another.

Designing an acceptable building from point of view of sound comfort is based on the principles of acoustics depending upon the behaviours of sound and its effects. When a sound originates at any source, it is transmitted in all directions till it is obstructed by some surface. At the obstruction, part of the sound energy is absorbed while the remaining is reflected back or transmitted through the obstruction on its other side. The portion of sound energy which is absorbed by or transmitted through the obstruction is represented as “Absorption Coefficient” of the object. Higher the absorption coefficient larger will be the amount of sound energy dissipated by the object.

The quality of sound in the building will depend upon the reflectiveness of obstruction, relating to enhancement of loudness, clarity of hearing and other sound qualities. The reflected sound energy will remain in the interior space represented by “Reflection Coefficient”. The reduction in sound intensity in passing through the obstruction can be termed as “transmission loss” which is the measure of the effectiveness of barrier surface in sound insulation. This reflection and absorption of sound will determine and influence the acoustical efficiency of the building. Unless these parameters are not adequately and efficiently controlled, the building cannot be made acoustically comfortable and sound insulated resulting in presence of acoustical defects in the building.

The efficient acoustical design requires the understanding, the nature and causes of these acoustical defects and taking measures to minimize their impacts on building behaviour.

5.3 ACOUSTICAL DEFECTS

5.3.1 General Principles of Acoustics

A building is said to be acoustically efficient when an average sound rises to a suitable intensity in the every nook and corner of the room, with no distortion or echo and then dies down rapidly before reaching of the succeeding sound wave. This condition is sought to be achieved by minimizing all acoustical defects. The probable acoustical defects can be broadly classified as follows :

(a) Echoes

(b) Reverberation

(c) Sound foci and dead spots

(d) Loudness

(e) Outdoor noise level.

5.3.2 Echoes

When the sound wave is reflected by any building element, e.g. wall, ceiling, roof furniture and fittings, etc., it reaches the listener just after the direct wave has reached him/her, a repletion of sound is heard by the observer's ears. Hence the listener hears two distinctive sounds, one by direct sound wave and other by reflected sound wave from the same sound source. This phenomenon is termed "Echo" formation. This can occur when the time lag between these two sound wave fronts is about 1/17 of a second and causes disturbance and unpleasantness in hearing. Echo formation is encouraged by the presence of curved and smooth surfaces in the room/hall. The unpleasantness of echoes and their formation can be minimized by selecting a proper shape of the room and providing reflective surfaces of rough and porous materials.

5.3.3 Reverberation

When the sound wave travels through a medium, say air, it is absorbed by surfaces in the form of heat energy produced by friction between the wave and air particles and between the wave and contact surface.

Some interval of time must lapse in this transformation of energy and thus dying out of the sound. In addition, part of sound energy is reflected by barrier surface resulting in formation of echoes. This reflection of sound continues even after the original sound at source has stopped or died out. Sound reflecting from a number of reflecting surfaces produce multiple echoes. These multiple reflections occur several times before the entire sound energy is absorbed. This phenomenon of dying out is prolongated particularly in enclosed space with smooth surfaces. This prolongated process of energy transformation and absorption is known as reverberation.

Reverberation is thus defined as the time period in seconds taken to reduce the sound energy by 60 dB after sound source has stopped. It depends upon the volume of room and absorption qualities of reflecting surfaces. More is the porosity and roughness of surface more will be the friction and hence quicker will be the loss of sound energy. It is given by Sabine's formula as given in Eq. (5.1).

$$t = 0.16\ V/\Sigma\ A_s \qquad \ldots (5.1)$$

where t = Reverberation time in seconds,

V = Volume of room/enclosed space, and

$\Sigma\ A_s$ = Sum of the absorption of various barrier surfaces.

It can be observed that certain amount of reverberation is necessary for maintaining and even improving the sound quality while a larger reverberation period will interfere with hearing process causing overlapping of speech and unpleasantness. The selection of desirable reverberation is essential for ensuring the good acoustics. This is termed as "optimal reverberation time" and will depend upon the functional requirement of use. A reverberation period between 0.50 to 1.50 second is excellent for sound quality while 3 to 5 seconds is bad. Any period of above 5.0 sec is highly undesirable. Table 5.1 gives the recommended values for Indian conditions for various uses and under different levels of occupancies.

Table 5.1 : Optimum Reverberation Time

Optimum Reverberation Period in Seconds	1.3 to 1.5	1.0 to 1.5	1.5 to 2	1.8 to 3	2 to 5
Activity in Hall	Picture halls	Committee rooms/ conference halls/court room/assembly halls	Music concerts/class rooms/public lecture halls	Churches / Temples	Large halls
Degree of Occupancy	2/3	1/3	1/3	2/3	Full

5.3.4 Foci and Dead Spots

Sound waves get reflected when they are met with a barrier surface across their path of travel. If this surface is concave shaped like a domed ceiling, the reflected sound waves may pass through a common point (Figure 5.1) creating a sound of large intensity with unusual soundness. These points of unusual soundness are termed sound foci. Because reflected sound waves get concentrated at foci, some other points are created in space at which intensity of sound get negligibly small, i.e. barely audible.

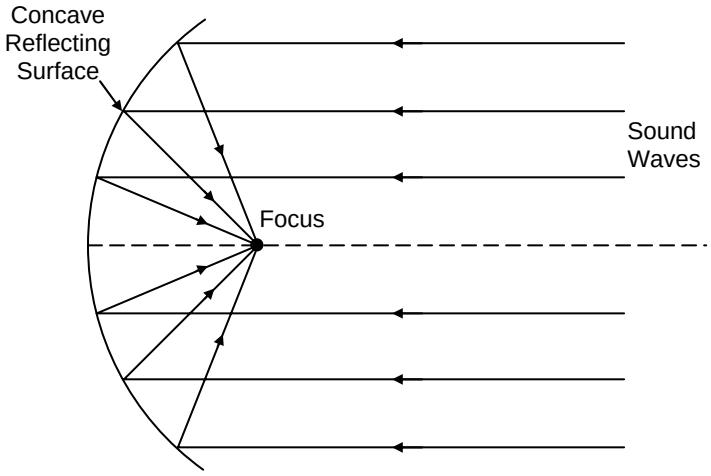


Figure 5.1 : Sound Focus

These are called “dead spots”. These foci and dead spots are created primarily due to curvature of the reflecting surfaces. It can be realized that for better hearing comfort and acoustic in the room the hall shall be planned and designed such that a uniform distribution of sound is achieved in the hall avoiding formation of sound foci and dead spots. This can be achieved by modifying the geometry of the reflecting walls and ceilings and by providing suitable absorbing material on their surfaces.

5.3.5 Loudness

The essential requirement for sound comforts in a building is that vocal communication can be efficiently ensured for the users of the facility amongst themselves. For example, it is desirable that speaker’s voice or music notes originating at stage in an auditorium be distributed uniformly with sufficient intensity at its every nook and corner, enabling audience in any part of the hall to have comfortable hearing. This has to be achieved by proper geometrical design of the interior and correct selection of material. It may be noted that in case of the auditorium, the side and far walls shall be flat and sound absorbent to minimise

echoes, dead spots, sound foci, etc. while the barrier just behind the performer be provided with a curvature whose focus is at location of performer and its surface shall be having maximum reflection with theoretically nil absorption. This will ensure uniform distribution of sound waves in the hall with adequate intensity.

5.3.6 Noise

As described earlier, noises are of two distinctive types. These are

(a) interior noise or indoor noise generated in the same or adjacent rooms of the building, e.g. crying of babies, radio/TV/VCR playing, furniture movements, working of machines, generators, etc., and

(b) exterior or outdoor noise created outside the building by moving traffic, loudspeakers, machines, etc.

The noise can be transmitted in the room through walls, ceilings, floors, open doors and windows, etc. or by forced or impact vibration of the structure itself. This noise transmission can create unpleasant and uncomfortable conditions for the occupants and users of the building and is increased by poor building insulation.

Sound insulation indicate the reduction of noise level during its transmission to the interior of the hall/building. It is entirely different from sound absorption which represents the reduction of sound reflection. Porous materials are good sound absorbers but poor insulators. The maximum level of noise which do not create unpleasantness to occupants and does not damage the acoustics is termed "Acceptable Noise Level" and is decided by type and use of facility under consideration, nature and time of fluctuation of noise, etc. The acceptable noise levels for different structures are given in Table 5.2 as reference.

Table 5.2 : Acceptable Noise Level

Sl. No.	Acceptable Noise Level in dB	Type of Building
1.	25 to 30	Radio stations and TV studios
2.	35 to 40	Concert halls and auditoriums
3.	40 to 45	Small offices, libraries, court rooms, etc.
4.	40 to 45	Schools/Educational Institutions/Hospitals
5.	45 to 55	Residential buildings
6.	50 to 60	Restaurants, Public offices, Banks, Stores
7.	60 to 65	Factories

5.4 ACOUSTICAL DESIGN OF BUILDINGS

The acoustic design of building consists of applications of principles of acoustics for the planning, designing and construction of buildings and of different rooms in the building. Some buildings, e.g. concert halls, radio and TV studios, auditoriums, conference halls, etc. require special acoustical design and treatments, where it is essential to provide optimum conditions for producing and listening, free from acoustical defects and effects of internal and external noises.

The acoustical design of buildings essentially consists of

- study of requirements of good acoustics,
- general features of acoustical design, and

- special features of acoustic designs of particular buildings.

5.4.1 Requirements of Good Acoustics

These are briefly summarized in the following :

(a) The original sound generated shall be of adequate intensity (loudness) so that it can be heard clearly throughout the enclosed space (hall/room) without strain or discomfort.

In case of large halls the generated sound intensity may require amplication artificially by a good sound amplification system. The amplification shall not be too loud to cause discomfort.

(b) The generated sound should be evenly and uniformly spread to every nook and corner of the hall area. Development of echoes, foci and dead spots shall be avoided.

(c) The sound produced should be of desired quality. It should be clear and distinct in halls used for lectures and speeches while enriched for total quality and sound blending so as to reach audience with same frequency and louder in concert halls and dancing rooms.

(d) All noises, whether internal or external, shall be minimized so that these do not interfere with normal performance.

5.4.2 General Features of Acoustic Design

The requirements of good acoustics as listed above can be incorporated in buildings by its proper acoustic design. The important design parameters are

(a) Site selection and planning

(b) Volume and shape

(c) Reverberation

(d) Sound absorption and treatment of interior surfaces

(e) Seats and seating arrangement

Site

Most important factor in selecting a site of building from considerations of acoustics is the prevailing noise level in the area, both existing and predicted. As far as practicable, building sites, particularly for studios and auditoriums, shall not be near the automobile traffic on busy streets or highways, railway lines, airports and large factories, otherwise costly treatments will be required to be given to the buildings to make them acoustically efficient. The building orientation has to be so planned as to minimize the transmission of external noises to the building interior. The orientation, layout and structural arrangements are planned so as to provide maximum sound insulation and reducing background noise levels.

Shape and Volume

Shape and volume of room/hall play an important role in planning for good acoustics. The hall should have adequate volume, keeping in view the loudness and intensity of sound desired to be developed in the hall. Concrete halls provided for musical events shall be quite large to ensure enough space for sound to spread uniformly while maintaining the tone, timber and quality of sound generated. Auditoriums and lecture halls

mainly used for public speeches shall have smaller volumes to account for weak sound generated during speech.

A multipurpose halls to be utilized for both music and speeches obviously will have volumes of intermediate range. As a rough guide, following values can be recommended as given in Table 5.3.

Table 5.3

(a)	Musical or concert halls	4.0 to 5.5. m^3 per person
(b)	Cinema halls	3.7 to 4.2 m^3 per person
(c)	Public lecture halls	2.8 to 3.7 m^3 per person

The floor area of the hall excluding stage shall be roughly between 0.60 to 0.90 m^2 per person. Height of wall is probably more important factor than floor area (i.e. length and breadth of the hall), because even a small increase in height will cause substantial volume increase. The height may vary from 6.0 m for small halls to 7.50 m for large auditoriums. The volume requirement is influenced also by the ventilation provided, extent of a balcony projection and type of performance planned. Normally flat ceilings are preferred. An increased height in central portion of hall is desirable.

Shape of hall is rather more important factor in proper acoustical design. It influences the good acoustical performance by reducing the acoustical defects like echoes, foci and dead spots. It is observed that reflection of sound waves by wall and ceiling surfaces governs the occurrence or correction of acoustical defects in the hall, thus making the geometrical design of hall more important. For better distribution of sound intensity in shape is perhaps more critical than hall volume. The concave walls or curved ceilings tends to concentrate the reflected waves at certain points called foci and dead points, creating defects while convex shape minimizes such effects. Use of plane surfaces is fairly good. Similarly, the concave shape of reflective material surface behind the sound source at stage helps in distributing sound waves with good intensity uniformly all over the hall area.

There are no definite rules to decide the length-breadth-height ratio of a hall from the acoustic point of view. However, following rough guidelines can be recommended for different type of buildings.

Table 5.4

Type of Functional Use	Volume in m^3 per Person	Ratio of H : W : L	Approximate Capacity of Hall
(1) Musical or concert halls	4.0 to 5.5	1 : 2.5 : 5	500 to 1000
(2) Cinema or theaters (a) Normal	3.7 to 4.2	1 : 2 : 3	800 to 1000
(3) Lecture halls			
(a) with loud speakers	4.0 to 4.5	1 : 2.5 : 5	500 to 1000
(b) Big Halls	2.8 to 3.7	1 : 2 : 4	300 to 500
(c) Small Halls	2.0 to 3.0	1 : 1½ : 3	150 to 300

It is observed that a fan shaped floor plan is preferred because it gives better reflection performance as shown in Figure 5.2. Distance of the farthest seat from the stage/screen shall preferably be not more than 23.0 m, so that the

observer can comfortably discern facial expression of the actor performing on stage. Also the time lag between the direct sound wave and all its reflections shall not be more than 45 milliseconds to avoid echo formation, i.e. the path difference between two waves shall not be more than 12 m. Rear extreme walls shall be provided with absorbing surface to eliminate multiple reflection of sound wave which distorts sound quality in the hall.

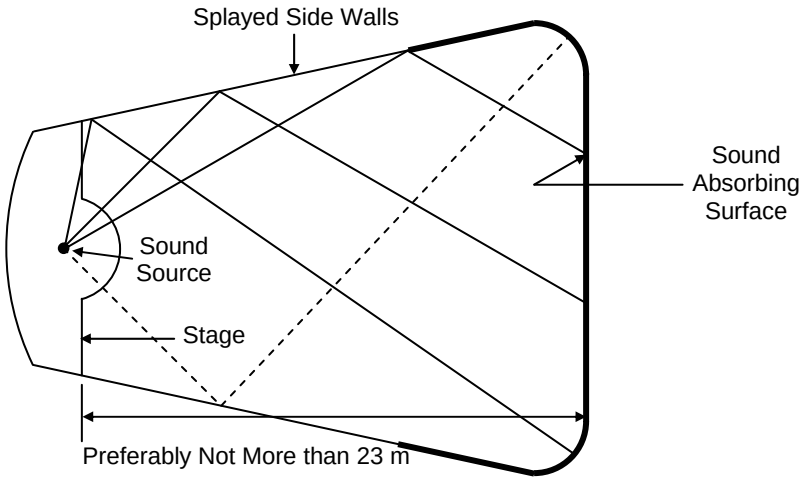


Figure 5.2 : Fan Shaded Floor Plan

Reverberation

The excessive reverberation is perhaps the most common acoustical defect in many auditoriums. It results in prolonging the presence of once generated sound for a longer duration in the hall causing multiple echoes and confusion. Optimum reverberation time is recommended in Table 5.1 for different types of buildings. A shorter optimum reverberation time is required for reproduced sound like recorded music or film sound. For direct sound created in orchestral music, the required reverberation period is about fifteen to forty percent more than for ordinary speech, to facilitate better blending of musical tones. To improve the reverberation performance, suitable absorbent material is used for extreme walls and ceilings.

Absorption and Interior Surface Treatment

As described earlier, adequate and proper absorbing surfaces are required to be properly provided in the hall to regulate the reverberation to its optimum required value. The areas of application along with the properties of absorbing materials are carefully considered and analyzed before recommending its specifications and design. It may be noted that material placed near the wall edges with ceilings is 2 to 3 times more effective than material placed in other positions. Sound absorption capacity of soft plaster is 3 to 4 times more than that of hard plaster. Distemper is more efficient than paints. Cushioning of seats and backs, along with floor carpeting can increase absorption capacity of the hall. Other areas which need special treatment are back walls, balcony parapet and concave surfaces. The absorption capacity of walls can be further enhanced by hanging heavy curtains over them. Generally the absorption treatment should be distributed uniformly over the surface at desired positions rather than concentrating them over some points.

The treatment of interior surfaces in the hall is very important in controlling the acoustical performance. The ceilings and side walls are provided with favourable reflections to reinforce the sound to reach in the remotest

corners while back walls are treated with absorbing material as shown in Figures 5.2 and 5.3. Plain side walls are normally provided.

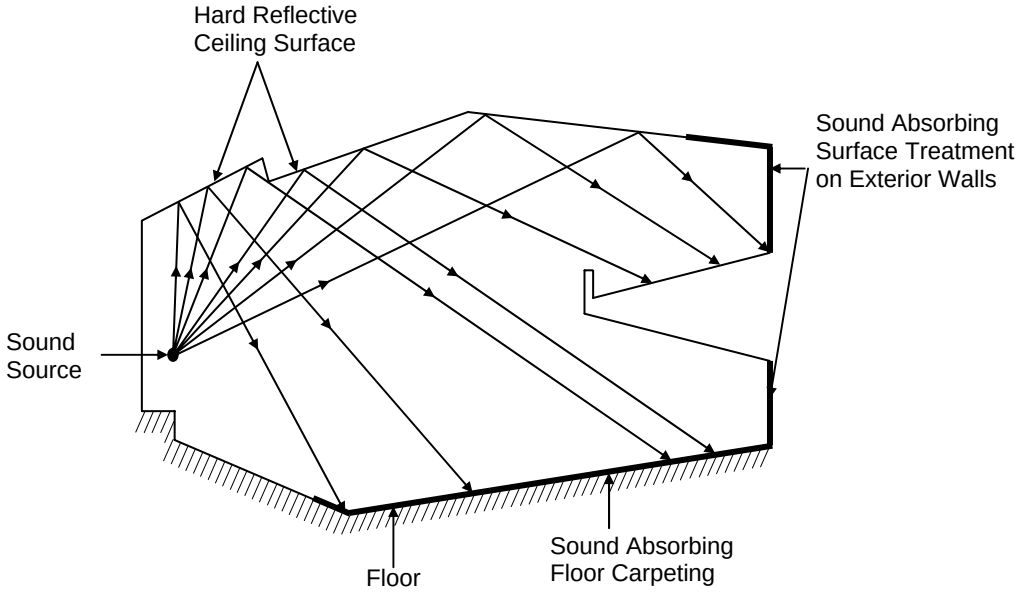


Figure 5.3 : Typical Ceiling and Rear Wall Treatment

Various types of absorbent materials normally available are :

(a) Hair felt.

(b) Acoustic plaster or fibrous plaster consisting of granular insulation material mixed with cement. Acoustic plaster boards are also available which can be directly fixed on the walls.

(c) **Acoustical Tiles :** These are factory built and can be fixed easily though they are costlier than acoustical plaster.

(d) **Straw Board :** These are available in thickness of 13 mm and a density of 2.4 kN/m^3 with good absorption coefficient.

(e) **Pulp Boards :** Manufactured from compressed pulp are quite cheap and effective and can be easily fixed.

(f) Compressed fibre boards either in non-perforated or perforated form with high absorption coefficient are available so also the compressed wood particle boards. These can also be suitably painted.

(g) **Perforated Plywood :** Composite panels are formed from perforated plywood with mineral wool and cement asbestos or hardboards, and can be used as false ceiling with high efficiency.

(h) Quilts and mats prepared from mineral wools or glass wool and are fixed as acoustical mats and blankets.

The sound absorption coefficients of some elements are given in Table 5.5.

Table 5.5

Building Elements	Absorption Coefficient

	Low Frequency	Medium Frequency	Large Frequency
Brick Wall	0.02	0.03	0.05
Carpet on solid concrete floor	0.10	0.30	0.50
Cork slabs/wood blocks/rubber/ linoleum floor/wall paneling	0.05	0.05	0.10
(a) Curtains in folds (b) With heavy folds	0.1 0.4	0.40 0.75	0.40 0.75
Ply wood paneling fixed on battens with air gap of 25 mm	0.30	0.15	0.10
Plaster, lime or gypsum on layers	0.30	0.10	0.04
Sound absorbent or acoustic material	0.40	0.50	0.50

Seats and their Arrangements

Seats, their arrangements and audiences present in the hall constitute an important parameter of acoustical performance of the building. Seats are preferably arranged along the concentric arcs of the circles. The centre of these circles is located at a large distance from the centre of the curtain line, almost as much as the length of the auditorium. The seats are so provided that the head of person in a row does not intercept the direct sound to the person in the row just behind him, and simultaneously ensuring good visibility. The minimum back-to-back distance between seats in rows and between the seats is about 450 mm to 1000 mm depending upon the decided degree of comfort.

The seats and its backs are covered or upholstered to improve the acoustical performance. A proper design and selection of seat and back cushions can minimize the effect of fluctuating occupancy of the hall on its acoustical performance.

In halls with uncovered seats, e.g. churches and class rooms the largest contribution to sound absorption is obtained from audience present.

5.4.3 Sound Insulation

It has been established beyond doubt that noise level in building has very strong effect on human comfort and endurance. It induces fatigue, inefficiency and strain in users, increases blood pressure, and may even result in temporary deafness and nervous breakdown. When the created sound waves are regular, periodic and of long duration, e.g. music has a pleasing effect while the non-periodic, irregular, short duration and loud sound waves termed as noise create unpleasant and annoying effects. The elimination or prevention of noise effects is called sound insulation or sound proofing. It is desirable in all types of buildings but is essential for auditoriums, radio and TV studios, hospitals, schools, etc.

A noise whether produced outside or inside the building can be transmitted through air, openings, walls, frames, ceilings or floors. The prevention of this transmission of noise into the hall or room is the basic requirement of sound insulation, while prevention or reflection of waves of noise either created internally or got transmitted from the outside by absorption is the objective of sound absorption. Both these techniques are required to be applied judiciously for an effective noise elimination programme.

The first step in noise elimination programme is to prefer a noise map or sound topography. It consists of

(a) A fairly accurate sketching of location of all noise sources, e.g. machines in and around the building under consideration.

(b) Noise contours of the building and its surrounding are plotted by measuring noise levels at pre selected and marked grid points/locations and drawing contour lines joining the points of equal sound levels on the map.

This noise contour plan of the building will greatly help in locating the zones of critical noises and devising methods to prevent and/or absorb them. The method of sound insulation to be used will depend upon the degree of insulation desired and the nature and intensity of noise present. These can be broadly classified into following three main categories.

(i) When the noise source is internal,

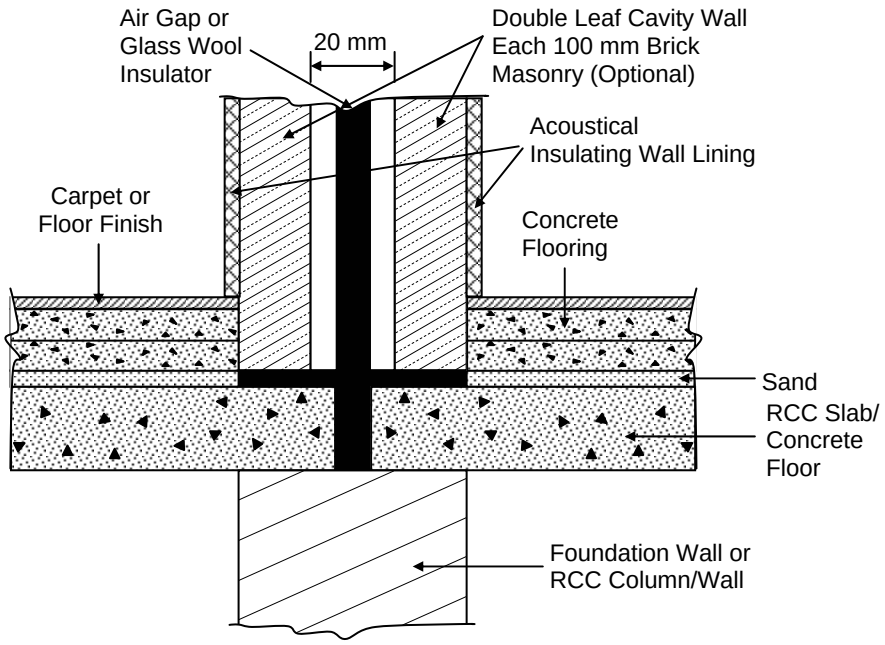
(ii) When the noise is transmitted by air, and

(iii) When the noise is transmitted through structure.

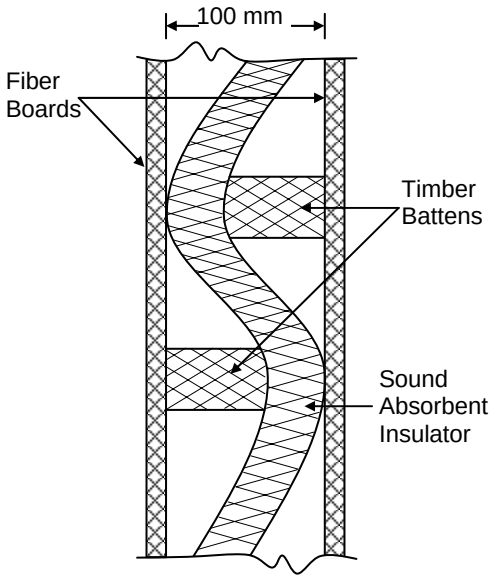
For internal noises, the insulation can be achieved by improving the working conditions and suppressing the noise at source itself. For example, if the internal noise source in an industrial building is a machine, the impact sound can be controlled by mounting the machines on flexible mounting with corks, rubber or springs. The transmission of noise by vibration can be minimized by making the structural elements, e.g. walls, frames, or floors, etc., rigid and massive. The best way of insulating against air borne noise is to isolate it at its source. Air tight enclosures and separate rooms for noisy machines can achieve this isolation. In general internal noise can be controlled by acoustical treatment of enclosing walls, floors and ceilings by provision of sound absorption paints, varnishes and sound absorbing mountings on the surfaces near the source of noise. It is also possible to reduce the noise by at least 20 to 30 dBs using personal protective devices like earplugs, etc.

(c) For airborne noises, the harmful effects can be minimized by having double wall, floating floor and suspended ceiling construction and providing solid non-porous homogeneous or porous material partitions. These methods can be termed as constructional measures of noise control.

It is observed that double walls are better sound insulators than a single solid wall, acting as a vertical barrier to air borne transmission of noise. These walls partitions could be of plaster or fiber boards with an air space of about 100 to 120 mm (Figure 5.4). In order to make the partition more effective the number of structural connections between the parts of the walls are reduced to minimum.



(a) Double Buck Wall



(b) Fibre Board Partition Wall

Figure 5.4 : Composite Double Wall Partition

Floors and Ceilings

These act as a horizontal barrier to transmission of noise. Solid floors and ceilings provide very effective barrier against air borne noise but simultaneously transmit the noise through structural vibrations and impact. The floors and ceilings are to be suitably designed to prevent the noise transmitted by any method.

A concrete floating floor, as shown in Figure 5.5, acts as an effective insulator. The solid concrete floor acts as an effective insulation against airborne noise while a floating floor separated from base floor by a layer of resilient material, e.g. mineral or glass wool blanket, provide insulation against impact and structure borne noises.

The insulating layer could also be of cork, rubber, felt, etc.

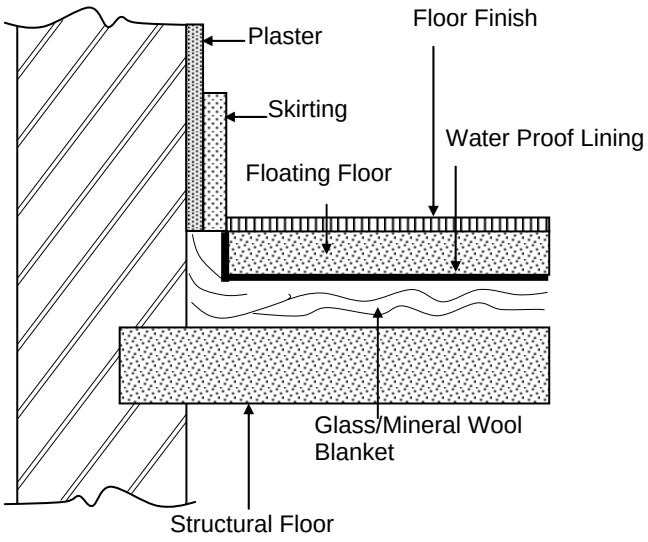


Figure 5.5 : Floating Floor (Concrete)

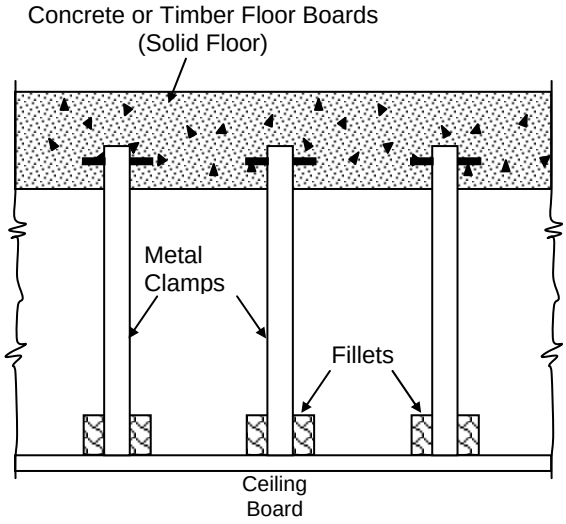


Figure 5.6 : False Ceiling

The floating floor could be concrete screed, light weight concrete or timber boards, etc. or simply any soft floor finish or covering depending upon the level of insulation required.

Similarly, an independent false ceiling below the structural floor can be provided to increase the sound insulation of roof/floor. This is achieved by suspending the false ceiling by metallic hangers, acoustic clips, etc. from solid or timber floors creating an air gap between them (Figure 5.6).

The construction offers good insulation against both the structure borne and airborne noises.

Doors and Windows

The openings provided by doors and windows act as good transmitters of airborne exterior noise. It is essential for good noise insulation to very carefully designing them. Sound can effectively be transmitted through the thin cracks/space between the enveloping walls and the door/window frames. Sound insulation can be improved by making them air tight as much as possible by filling all the gaps and cracks at the pan edges and jambs, with sound absorbing materials. The glass pans, if provided in doors or windows, shall be increased in thickness to improve sound insulation. The sound insulation can also be increased appreciably by providing glazed

windows with double and triple panes of glasses with air spaces of 20 to 30 mm between two successive panes.

Sanitary Fittings

Water closets can be a bad source of internal noise creation. WC Pan and cistern shall be noise insulated by mounting them on a thin pad of felt, cork, or rubber either below the pan or to the brackets supporting them. Water closets shall preferably not be provided next to the bed room or above living room unless adequately insulated.

Planning

Good sound insulation can be achieved by proper planning of the building and arrangement of the rooms within the buildings much more economically than using construction methods of sound insulation. Residential buildings should preferably be located in a quiet area away from busy streets, factory areas and other such noisy surroundings. The buildings should be properly oriented with respects to roads so that no door or window faces the noise source. Bed rooms particularly should be located away from the noise source and should not be near the staircase or lift wall. They should also preferably be separated from other rooms. The different building units should be properly planned to reduce the noise as much as practicable within the acceptable levels. The mechanical equipment such as refrigerators, washing machines, and lifts required special considerations for sound insulation. A rational approach to overall town planning by dividing the town into suitable zones is essential, like providing residential zones away from industrial area, main bazaars, railway lines and aerodromes, etc.

5.5 VENTILATION

Ventilation is an essential functional requirement of a building. It refers to free passage of clean air in the interior environment of the buildings. The used and ventilated air is required to be sucked out from the living area and replaced by fresh air from the outside. There will be excessive amount of foul air and carbon dioxide, present in a poorly ventilated house. For a comfortable living the carbon dioxide concentration in the air shall be less than 0.6 percent by volume. The degree of uncomfort rises with the increase in concentration of CO_2 and when it is more than six percent, person residing in the area may even loose consciousness. The fresh air replacing the foul air by ventilation shall be free of dust and other impurities, e.g. smoke, odours, germs and bacteria concentrations, etc. Proper ventilation also helps in removal of body heat created by occupants or other heats generated by functional use, e.g. cooking, etc. It is, therefore, essential that required air changes must be provided in the building to ensure maintenance of quality air and environment in the building. The quality of air does not represent only the breathing comfort but also on other factors such as concentration of dust, odour, bacteria, and smoke, etc. within the acceptable limits and maintaining the temperature and humidity within a comfortable range. The simultaneous control of all these parameters of purity, air circulations, humidity and temperature is collectively termed as “Air conditioning”.

5.5.1 Functional Requirements

The comfort level of facility users from consideration of ventilation depend upon following factors which can be called the functional requirements of the ventilation system in a building.

(a) Air changes and rate of supply of fresh air

(b) Humidity

(c) Temperature

(d) Purity of air.

5.5.2 Air Changes and Rate of Supply of Fresh Air

All facilities created where people reside, rest, recreate or work must have proper ventilation system, so that air changes and moves regularly in the premises. The quantity of fresh air to be provided in the premises will depend upon its functional use and other factors, e.g. number of persons present, type of period of occupancy, etc. The minimum rate of fresh air supply for some common functional uses are given in Table 5.6.

Table 5.6 : Minimum Rate of Fresh Air Supply for Habitat Uses

Sl. No.	Type of Functional Use	Min. Rate of Supply in m^3 per Person per Hour
1.	Residential Buildings (a) Bed rooms/Living rooms (b) Halls and passages (c) Kitchens/Bathrooms/Toilets	 50 m^3 (3 air changes/hr) 20 m^3 (1 air change/hr) 100 m^3 (6 air changes/hr)
2.	Assembly halls, shopping malls, restaurants	25-30 m^3 (2 air changes/hr)
3.	Factories, workshops	20 m^3
4.	Schools	20 – 25 m^3
5.	Gymnasiums	80 to 100 m^3
6.	Office buildings	30 m^3 to 15 m^3 from occupancy of 5.5 m^3/pp to 11.0 m^3 pp
7.	Hospitals (a) OT/X ray room (b) Wards	 10 air changes/hr 3 air changes/hr

Air change/hr is volume of fresh air compared to room volume. The minimum rate of air change per hour anywhere is 1 air change per hour while maximum air change is limited to 60 per hour. If it is above this rate the large wind velocity created due to speed of air change will cause uncomfortable conditions. The air movement so ensured by good ventilation system shall be fairly uniform throughout the entire area and eliminate creation of any still spot or pockets of stagnant air. Under natural conditions cross ventilation of building ensures adequate degree of air movement, while in case of mechanical ventilation, air movement is created by circulatory fans, and exhaust fans, etc.

5.5.3 Humidity and Temperature

The amount of water vapours present in the air is called humidity and determines the comfort level of the space. It is measured as its ratio in relation with the maximum water vapour it can contain (i.e. full, saturated). This ratio is called relative humidity. The saturated water vapour content of air depends on the temperature. Higher the air temperature larger amount of water vapour will be required for saturation. Too wet or too dry air is uncomfortable for living and working even when the prescribed air changes and volume of fresh air are provided. It is reported that the comfort zone for living and working can be

achieved with relative humidity between 30 to 70% at air temperature of 21°C. For higher temperatures lower relative humidity and larger air changes are required for same comfort level. Higher humidity is recommended for assembly halls and auditoriums.

Similarly, it is desirable that the incoming air should be cool in summer and warm in winter. The usual temperature difference between inside and outside for good ventilation should not be more than 8°C to 10°C. However, the comfort level temperature of the room will depend upon the type of activity, geographical conditions and age of the occupants. This temperature is also termed as effective temperature. Normally, this varies between 20 to 25°C and indicates the feeling of coolness and warmth in hot and cold seasons, respectively. It may be noted that effective temperature only decides the coolness or warmth.

The degree of human comfort is indicated by synchronization of effective temperature, humidity and movement of air. Comfort zone in India extends from 25°C with 60% relative humidity to about 30°C at 45% relative humidity.

5.5.4 Air Purity

It is obvious that proper ventilation should also ensure the air free from smoke, dust, germs and bacteria, odours, and similar other impurities to achieve the desired comfort level. Simply maintaining the required supply of air at desired temperature, humidity and air movement will not be sufficient. The extent of impurities in the atmosphere depends on the general hygienic conditions of the surrounding, environmental pollution level and also the habits of the occupants. The location of entry of ventilating air shall be away from toilets, kitchens, industries, busy streets, etc.

Thus, it can be concluded that functional requirements of a ventilation system is to provide required purity and quantity of fresh air with desired humidity and effective temperature with uniform and comfortable movement velocity.

5.6 VENTILATION SYSTEM IN BUILDING

The ventilation system of a building could be broadly classified into

(a) *Natural ventilation system*, in which the fresh air is supplied in the building through corridors, doors, windows, ventilators shafts and similar other openings, and

(b) *Mechanical or artificial ventilation*, where the supply of air is achieved by use of a mechanical equipment like fans or exhausts.

The entry of fresh air can be achieved either by positive ventilation (e.g. fan) or by exhaust creating pressure difference with reduced inside pressure.

In normal condition, either of the two or their combination may be used to provide artificial ventilation. For an ideal solution, effort is made to ensure as much natural ventilation as possible to be supplemented by mechanical means when natural methods are not sufficient to provide the desired degree of ventilation.

5.6.1 Natural Ventilation System

Doors, windows, ventilators and sky lights are used in coordination to provide a natural ventilation system. This system is effective in case of small buildings, e.g. residences, bungalows, etc. and are very economical and energy efficient. Many engineers and architects have developed innovative methods to provide efficient

ventilation and thermal control even for large buildings like schools, colleges, and hospitals, etc. making them energy efficient and can be used where precise control over the air conditions and rate of air changes is not required.

In natural ventilation system, natural fresh air is supplied through wall openings, e.g. doors, windows, ventilators, skylights, shafts, etc. The velocity of wind outside the building creates pressure difference between inside and outside of the area to be ventilated. Higher the wind velocity, more will be the pressure difference and larger will be the rate of air change. The rate of air change mainly depends on the location of inlet and outlet, design of opening, and temperature difference between inner and outerside of building.

Cooler air, being heavy, enters from the bottom and warmer air leaves from the top (Figure 5.7). The type of ventilation depends on the direction of wind and difficult to control the air quality. The air change rate is influenced by the convection currents generated by temperature and pressure difference between interior and exterior of the room.

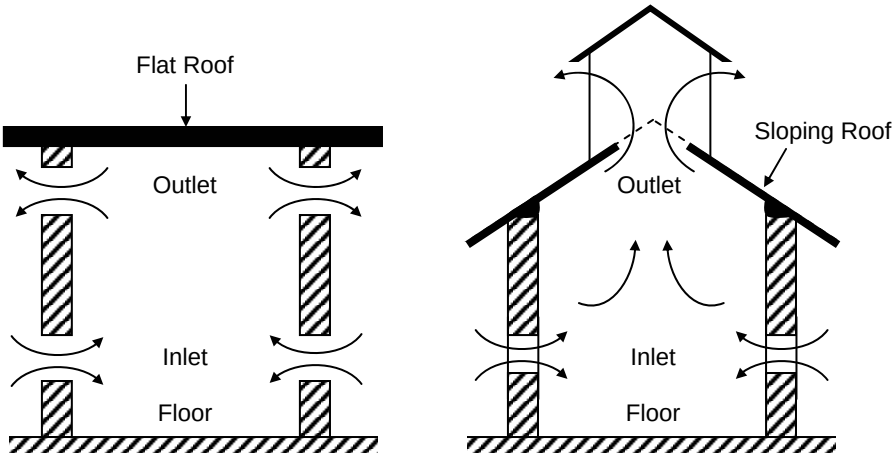


Figure 5.7 : Natural Ventilation

The inlet openings shall be adequately distributed over the entire room/building particularly on its windward side in the lower level portions. While outlet openings be preferably provided at higher levels on the leeward side as near the ceiling as practicable. For maximum efficiency area of both these openings shall be nearly equal. Higher ceiling increases air flow due to stack effect. It is advisable to provide inlets and outlets be on opposite walls to achieve cross ventilation. Ventilation through windows can be improved appreciably by combining their functioning with a radiator, deflector and an exhaust duct (Figure 5.8).

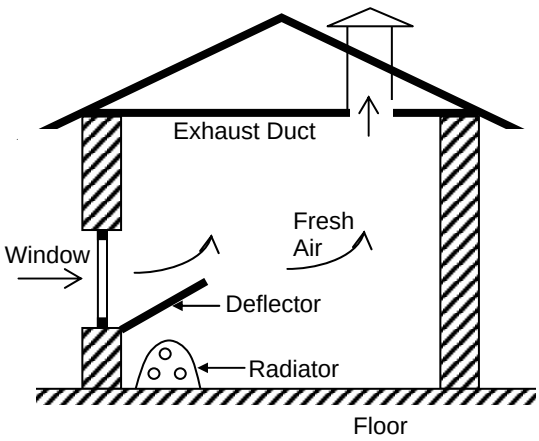
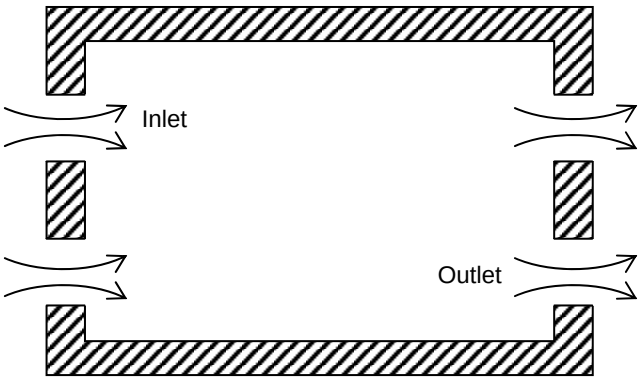


Figure 5.8 (a)



(b) Cross Ventilation

Figure 5.8

5.6.2 Artificial Ventilation

The purpose of a good ventilation is not only to supply fresh air economically but to control. The quality, humidity and temperature along with supply of required quantity of fresh air at desired rate of change. It is difficult to achieve this degree of control of environment by natural means alone. Hence, in modern times, it is becoming necessary to provide this control by mechanical means, which are costly but make it possible to provide the degree of desired comfort level to increase the efficiency of occupants. The mechanical methods commonly employed in artificial ventilation system could be classified as follows :

(a) Exhaust system, supply system and their combination.

(b) Plenum process.

(c) Air conditioning.

Exhaust and Supply Systems

A partial vacuum is sought to be created in the interior of the building by removing the used air by exhaust fans of propeller type or blowers. This partial vacuum set up the current of fresh air into the interior through doors and windows. These blowers or exhaust fans are located near the sources of fumes, gases and odours, e.g. kitchens, fireplaces, WCs, etc. These are placed near the outer walls in larger buildings and connected by air ducts which are provided near the foul air sources. Fresh air is supplemented by providing input fans near the outside walls, nearest to source of pure air. Exhaust system or supply system alone or a combination of the two can be adopted depending upon the requirement.

Plenum Process

In this method, better quality of air is pushed inside the building by means of inlet fans placed near the source of purer air. Openings in the buildings are provided with screens and/or filters and a fine stream of water is sprayed in the incoming air path. The removal and/or killing of germs and bacteria, etc. is achieved by ozonizing the inlet air, thereby improving the comfort parameters of humidity, temperature and purity. The ducts in the plenum process of ventilation are designed and constructed carefully so that any draught condition is not created. This may necessitate provision of separate dampers in each room.

Ventilation by this method could be either downward or upward. Inlet air is introduced in the room from duct openings near the ceilings and taken outside through outlets placed near the floor level in the downward type while reverse process is followed in upward type. The foul air is allowed to leave the room by itself or it extracted by exhaust fans.

This method is particularly useful for large offices, auditoriums, factories, etc. and also as a source of inlet air for more elaborate and expansive air conditioned systems.

Air Conditioning

The air-conditioning system is a process of completely treating the air regarding purity, humidity and temperature and ensuring the requirements of air distribution and changes. In India it is used in luxury apartments and residences for healthy and comfortable living. In commercial premise it is used to improve the working environment and comfort of consumers, i.e. in theaters, auditoriums, offices and shopping malls, etc. Since major portion of India is very hot during summers and fairly hot in major part of the year, the major object of air conditioning is to cool and dehumidify the air, called summer air conditioning. Only during very small winter duration in major part of country and in northern Himalayan regions, winter air conditioning is resorted to involving air heating and humidification.

Depending upon the requirements of the facility and location of A/C plants, the air conditioning could be local (or unitary self contained), or central system or a combination of the two. In unitary system, special portable air conditioners are placed inside the room, preferably near the ceiling and in attractive cabinets blending with the interior decoration of the room. In the central system, the A/C plant of larger capacity is provided at strategic location and conditioned air is distributed in different rooms/locations in the entire building through properly designed ducting system.

Whatever air-conditioning system is adopted according to the size of structure, technique of heating/cooling of air, volume and type of cooling system, etc., the following will form its essential elements

(a) filters,

(b) heating element,

(c) cooling element,

(d) humidification/dehumidification devices, and

(e) fan/blower system for air circulation.

5.7 THERMAL INSULATION

The major objective of a ventilation system is to maintain a controlled air circulation in the building for efficiency and comfort of its occupants. Temperature control is one of the major requirement by cooling or heating the interior air during hot/cold seasons. The buildings are, therefore, required to be designed and constructed in such a way as to minimize the heat gain during hot seasons and heat loss during cold ones, due to the process of heat transfer from hotter to cooler regions. This process of heat transfer by conduction, convection and radiation is called thermal transmittance and occurs in a building through its

components like walls, roofs, floors, doors and windows, etc. The objective of minimising the heat transfer is termed thermal insulation of the building. A properly provided thermal insulation of the building will considerably reduce the demand of heating/cooling required, achieving fuel economy and in better living and working conditions inside the building economically.

The transfer of heat from one region to other will greatly depend on the surface area of contact between the regions and the thermal property of the material used in these surfaces (which is known as thermal conductivity and surface coefficients). The thermal conductivity of a material depends on its density, porosity, fiber size, moisture content, etc. while the surface coefficient is the amount of heat transferred per unit surface area, per unit temperature difference. It is observed that low-density material and presence of air pockets in it increase the thermal resistivity while higher density and moisture content reduce it.

5.7.1 Principles of Thermal Insulation

The orientation of building greatly influence the thermal insulation. Depending upon the sun's travel path in the region, the buildings are located in such a way that there is minimum transfer of solar energy in summer while it is maximum during winter in hotter regions like India. While it has to be just opposite in colder regions, like Europe and Canada, etc. The exposed area of the exterior building surface shall be reduced to minimum possible value for reducing the heat transfer. The air passages like openings, cracks and recesses shall not be allowed in enclosing surfaces of roofs and walls, etc. and the areas of doors and windows on the exposed walls shall be minimum. Glazing increases the heat transfer by as much as three times the normal wall. The material used in the construction of exterior envelop must have low conductivity. The envelope thickness shall also be adequate as heat resistivity of any element varies directly with its thickness. Construction techniques like cavity walls and false ceilings, etc. which provides air gap between two components of the element can greatly increase the thermal insulation capacity of the envelope. Provisions of special devices like sun shades, sun breakers, increased ceiling heights and trees/plantations preventing direct exposure of element of sunrays plays vital role in thermal insulation.

5.7.2 Methods of Thermal Insulation

As described earlier the heat transfer between the building and its surrounding takes place through enveloping elements like walls, roofs, doors, windows and ventilators, etc. Methods have been developed to provide insulation to these elements. The choice of a particular method will depend on the extent of insulation required, area of exposure, cost of air conditioning and the cost of insulation provisions. It is interesting to note that most of the materials and techniques used for thermal insulation also provide effective sound insulation.

Thermal Insulation of Walls

For economic air conditioning of interior space, it is desirable that the thermal transmittance of exposed exterior walls shall be less than 8 k Joules (2 k Col) per m^2/h/per degree centigrade. To achieve this, it is desirable to increase the wall thickness depending upon the degree of insulation required. The use of hollow or cavity wall may provide same degree of insulation for smaller material quantity consumed. The outside and inside of the exterior wall may be provided with thermal insulating treatment to reduce heat transmittance (Figure 5.9).

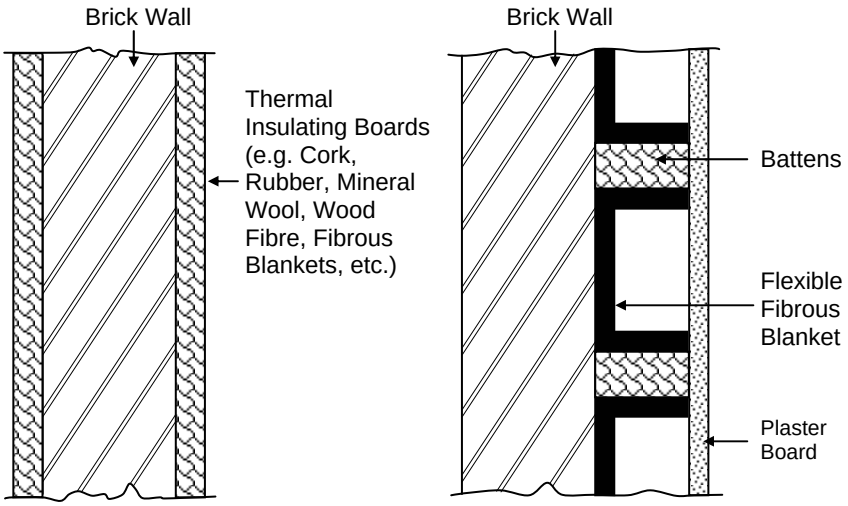


Figure 5.9 : Wall Insulation

Light coloured white wash (reflective surface) or distemper on exposed surface reduce heat inflow. If structurally permitted exterior walls can be constructed from insulating material.

Thermal Insulation of Roofs

Like walls the heat transmittance through the roof shall also be not more than 2 k/cal/m^2/^{o}C. The excessive heat transmittance is prevented by special treatment of external or internal roof surface. The internal treatment consist of providing false ceiling as shown in Figure 5.10(a).

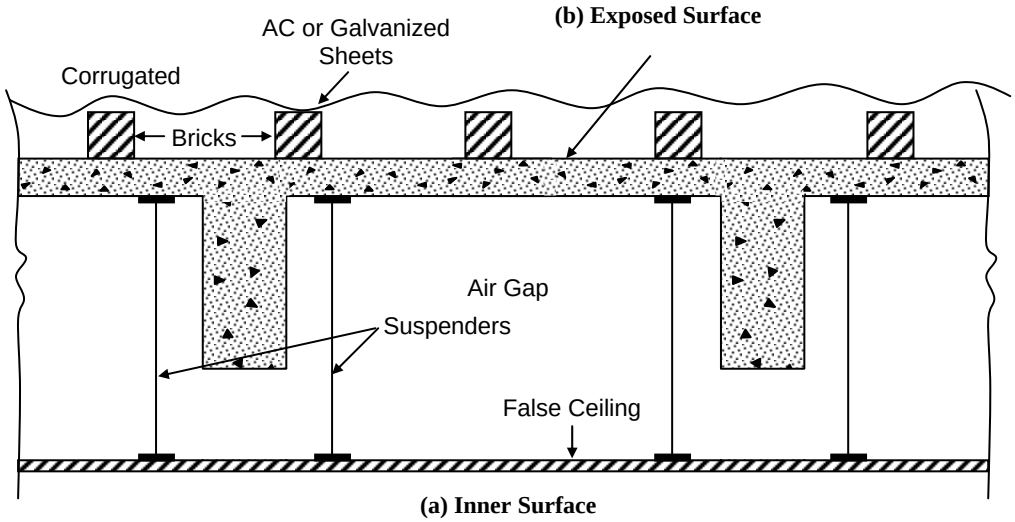


Figure 5.10 : Roof Insulation

The insulation boards are suspended from the roof by means of ceiling joints, hooks and suspenders or light insulating material is pasted by suitable adhesive to the lower side of the roof.

The external treatment of the exposed roof surface may consists of keeping the roof cool by stored or sprayed water over roof surface. Fine or coarse sand may also be spread on the roof to retain the water for longer duration and is continuously kept wet by sprinkling it with water at regular interval.

Shining or reflective insulation materials may also be laid on the top of roof to reduce heat exposure of roof by radiation. An air space may also be created by providing AC or galvanized iron sheets over bricks as shown in Figure 5.10(b). An indigenous method of thermal insulation of flat roof is

providing a layer of 25 mm thick coconut pitch cement concrete over the flat roof. Once this layer has dried, any crack occurred in it during the drying period should be properly treated with additional material, the surface is given the usual water proofing treatment.

Insulation or Exposed Openings

Openings in the exterior walls like doors, windows and ventilators are a great source of heat transmittance and loss. Special attention is required to be given to these elements for proper thermal insulation. The incidence of solar heat is sought to be minimized by providing external shading such as shutters, chajjas, sun breakers, louvered shutters, heavy curtains, venetian blinds, etc. Where glazed panes are provided, the heat transmission can be reduced by provision of insulated glass or double glass with air gap. The air leakages are plugged by rubber or PVC gaskets and beadings.

SAQ 1

(a) Explain briefly the characteristics of a good audible sound, and its use in acoustics of buildings.

(b) Write a detailed note on acoustical defects in a building and commonly adopted methods of removing them.

(c) Write a note on different sound absorbents materials. How you are going to decide their suitability and effectiveness?

(d) Describe in detail the noise control and sound insulation of a building.

(e) Describe briefly the requirements of a good ventilation system of a building, and its needs.

(f) Discuss the necessity and requirements of a good thermal insulation of a building, describing various factors contributing to the heat transmittance and transference.

(g) Explain natural and artificial methods of ventilation and air conditioning of the building discussing their merits, demerits and limitations.

5.8 SUMMARY

After going through the study of this unit, you will learn the basic principles and requirements of a good acoustical, ventilation and insulation systems in building. You will be able to understand both natural and artificial methods of these functional requirements and able to rectify the defects, if any, in the systems. Thermal and acoustical insulation of a building is an essential requirement for maintaining quality environment inside the building, preventing external effects of noise and temperature fluctuations. Acoustics is essential, particularly in cases of theaters and auditoriums, to present the quality and clearity of sound and increasing hearing pleasure. Similarly, ventilation is essential to maintain hygienic and healthy conditions for building users.

5.9 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

UNIT 6 CONSTRUCTION PLANTS

Structure

6.1 INTRODUCTION

Road Rollers, Concrete Mixers, Stone Crushers and Asphalt Plants are the Construction Plants used in Construction Works. These plants have different output capacities.

Selection of the specific plants depends upon the project requirements since various types of plant are available with different capacities.

The main focus of study of this unit will be limited to Road Rollers, Concrete Mixers, Stone Crushers and Asphalt Plants, etc.

We will study their types, control and parts, operation and maintenance, troubleshooting and safety measures needed during operation.

Objectives

After studying this unit, you should be able to

- explain various types of road roller, concrete mixer, stone crusher and asphalt plant,
- describe their controls and explain their different parts,

- discuss the operation, maintenance and troubleshooting of construction plants, and
- explain the safety measures to be adopted during the operation.

6.2 ROAD ROLLERS

The Road Rollers are used for various types of compaction works. Compaction is a process in which material particles are constrained to pack more closely through reduction of air void content by mechanical means.

The quality of road construction will depend upon the quality of compaction, the better the compaction, the better will be shear strength, density and bearing capacity of the individual layers. All checks should be exercised for controlling the desired degree of compaction.

The type of the roller to be selected depends on the type of job to be performed, type of surface to be compacted and amount of compaction required. Number of passes also depends on degree of compaction required.

6.2.1 Types of Road Roller

Following are the main types of Road Roller :

(a) Sheep's Foot roller

(b) Smooth-wheel roller

(c) Tandem roller

(d) Pneumatic-tyred roller

(e) Vibratory roller.

6.2.2 Controls and Parts

Sheep's Foot Roller

Sheep's foot roller (Figure 6.1) is made up of watertight metal drum, which has metal teeth on the entire outer surface. The teeth are similar and function like the feet of the sheep's and known by this name. The teeth projection is usually15 cm to 20 cm.

These rollers are also called tamping rollers. The rollers have compaction action due to kneading action of the projections. These rollers are generally 0.9 m to 1.5 m in length and 0.75 m to 1.5 m in diameter. The weight of these rollers varies from 20 kN to 130 kN.

The Sheep's foot roller can be single drum or multiple drums. These rollers are either self-driven or tractor driven.

Figure 6.1 : Sheep's Foot Roller

Smooth-wheel Roller

Smooth-wheel roller (Figure 6.2) is most commonly used roller. The compaction is being done by static weight. It consists of two wheels at the rear and a single wheel at the front.

Figure 6.2 : Smooth-wheel Roller

Hence it is also known as three-wheel roller. If needed, the weight of the roller can be increased by adding extra weight on it.

These rollers are designated in terms of weight, which is stated in tonnes. An 8/10 tonnes indicates that minimum weight of machines is 8 tonnes and it can be ballasted to give a maximum weight of 10 tonnes. The weight of the roller is about 8 to 10 tonnes (80 kN to 100 kN).

Vibratory Tandem Roller

Vibratory tandem roller (Figure 6.3) is similar to smooth-wheel rollers. This utilizes two rolls of approximately same width, one at the front and other at the rear of the roller.

Figure 6.3 : Vibratory Tandem Roller
(*Courtesy* : www.kingequipment.com.au)

Pneumatic-tyred Roller

This roller (Figure 6.4) is towed or pulled type. The compaction is done by kneading actions of the tyres. It has a body, mounted on a number of rubber-tyred wheels.

The number of wheels varies from 9 to 13. The wheels are mounted in two lateral rows, one in the front, and the other at the rear of the body.

The rear row has one more wheel than the front row and is staggered, so as to cover whole width of the ground traversed by the roller. The maximum weight of this roller goes upto 2000 tonnes.

Figure 6.4 : Pneumatic-tyred Roller
(*Courtesy* : www.teknomak.com.tr)

Vibratory Roller

The vibratory roller (Figure 6.5) exert static and a dynamic load due to the vibration action of the roll. With this arrangement it can provide compaction equivalent to a smooth wheel non-vibrating roller of about twice its own weight. The weight of vibratory roller ranges from 120 kN to 300 kN.

Figure 6.5 : Vibratory Roller

6.2.3 Operation

Sheep's Foot Roller

The feet penetrate and compact the soil as the roller travels forwards. The teeth are designed to pull out the material without disturbing it, as the drum moves ahead.

In general, these rollers are used for cohesive soil like clay and silt of low moisture content. They are not effective in compacting clean sand, gravel or crushed rock without clay or other binder material.

It is used for trench work, sub-grade and small base compaction jobs on road, airfield and dam construction and site preparation.

The maximum depth it can compact is about 5 cm more than the length of foot. Around 12 numbers of passes are found sufficient for average ground. The top layer has to be finished with smooth wheel rollers.

Smooth-wheel Roller

This roller is the best type of rollers, where crushing action is needed. This can be used for initial as well as final rolling of Water Bound Macadam, Tar Macadam and Bituminous Pavements and for compaction of Sub-grade, sub-base and base of pavements.

It is not effective on uniformly graded sand, or coarse silt and on overmoist cohesive soil due to poor traction. It can compact in both the directions of its travel.

Tandem Rollers

With this roller, greater compaction is achieved as both the rolls (front and rear) move in succession on the same area. The compaction done by this roller has better degree, since the weight of the roller is evenly distributed between front and rear wheels. This roller also compacted in both the direction of its travel. Tandem roller is preferred as a finishing roller on wearing course.

Main advantage of Tandem roller is that it gives a continuous rolling width with minimum of roll making through the reduction of roll edges.

Pneumatic-tyred Roller (PTR)

The rubber tyres rotate and wobble and thus produce a kneading action, giving very good compaction. This type of roller (Figure 6.4) gives best result in compacting fine-grained soils, and in particular, closely graded sands, base and bitumen mix, surface compaction, and seal coat operation.

PTR provides a more uniform compaction effect than steel-wheel compactors. The performance depends on the area of contact between tyres, and the ground, and hence, care should be taken to see that all tyres are inflated to the same and proper pressure.

Unlike a steel-wheel roller, the rubber-tyred roller does not push the asphalt material ahead of it. The flexibility of the tyre actually fold over the initial contact point and impart a vertical force on the material. Therefore, cracks produced after steel rollers are eliminated by using the rubber-tyred rollers.

Advantages of rubber-tyred rollers over steel-wheel rollers are :

(a) Surface of the layer is not bridged.

(b) Bituminous layers, which are compacted with a rubber-tyred roller, are better sealed to keep out the dirt and moisture.

(c) When rubber-tyred rollers are used, post-compaction by traffic will be negligible.

The compaction effect of the forces supplemented by the elasticity of the rubber tyres provides a kneading effect, resulting in a better surface compaction and surface sealing.

Vibratory Roller

This roller (Figure 6.5) is effective on non-cohesive soil. It may also be used for compaction of bituminous material used in footpath, repair and cycle tracks, play grounds and trench covering, by providing desired frequency, and matching amplitude of vibration to the vibrating roll.

SAQ 1

(a) What is compaction?

(b) Explain various types of road roller.

(c) Explain how a roller is designated.

(d) How does a Sheep's foot roller compact the earth?

(e) Explain working of a smooth wheel roller.

(f) What is the advantage of a tandem roller?

(g) How are pneumatic-tyred roller used in earth compaction?

(h) What is vibratory roller?

(i) State the type of rollers used in compaction of cohesive soils, water bound macadam, fine grained soil.

(j) Which roller is used in compaction of non-cohesive soils?

6.3 CONCRETE MIXERS

The concrete mixers are used to mix the concrete ingredients such as aggregate, cement and water in a definite proportion in order to produce a homogeneous mix. This mix is known as concrete.

The concrete mixers are available in various sizes and are specified by the volume of the mixed concrete produced after mixing.

Generally, the mixers are specified by two quantities. The total volume of unmixed ingredients is given first in cu ft, cu m or lit, whereas volume of mixed concrete is given afterwards in the same units, i.e. 10/7 mixer takes 10 cu ft of unmixed material and gives 7 cu ft of mixed concrete. The concrete mixers are either stationary or portable.

6.3.1 Types of Concrete Mixer

Following types of mixers are common :

(a) Hand-fed tilting-drum mixers

(b) Loader-fed tilting-drum mixers

(c) Reverse drum-mixers

(d) Roller-pan mixers

6.3.2 Controls and Parts

Hand-fed Tilting-drum Mixers

These are the smaller capacity mixers (Figure 6.6) and are generally used at places where less quantum of work is required. The hand-fed tilting-drum mixer has revolving tilting drum.

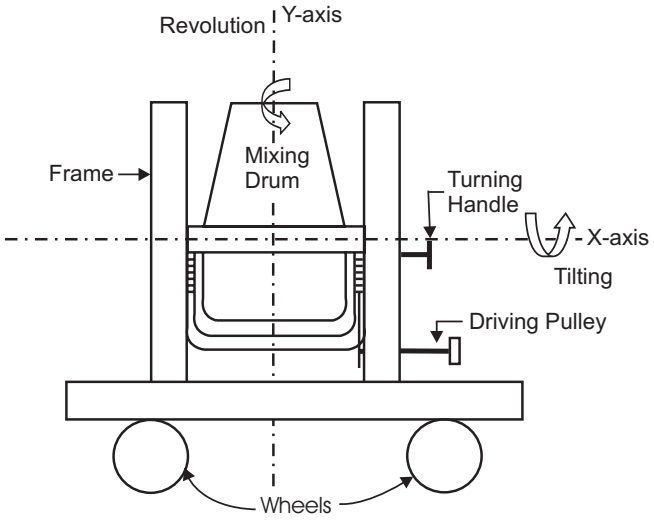


Figure 6.6 : Hand-fed Tilting-drum Mixer

The drum has set of blades. The drum with cast base and steel plate body rotates on bearings through gear mechanism. The drum contains set of blades inside, which gives continuous agitation to the material during mixing and produces homogeneous mix.

Loader-fed Tilting-drum Mixers

These mixers are of large capacity as compared to hand-fed tilting-drum mixers. It has a loading hopper, operated by a wire rope for feeding the aggregate and cement into the drum. Water is supplied from a measuring tank directly to the drum. The mixing drum is supported on solid cast iron yoke and can be tilted on either side. Mixer is mounted on wheels.

Reverse Drum Mixers

This mixer (Figure 6.7) is used for large works. The mixing drum is in horizontal position and is non-tilting type. It has two blades, one blade mixes the mix, while drum is rotated in one direction, and the other set of blades discharges the mix when the drum rotation is reversed.

Figure 6.7 : Reverse Drum Mixer

Roller-pan Mixers

These mixers (Figure 6.8) are mainly used for mixing mortar. It has rollers and mixing blades. These mixers are driven either by diesel engine or electric motor. It is generally used where the quantum of work is less.

Figure 6.8 : Roller-pan Mixer

6.3.3 Operation

Hand-fed Tilting-drum Mixers

The aggregate, cement and water are fed into the drum by hand with the help of bucket directly to the drum. The maintenance is easy and simple.

The drum is washed by water once the mixing is over. It is necessary to clean the drum before drying up of the concrete inside the drum.

Loader-fed Tilting-drum Mixers

The aggregate and cement is feeded directly into the drum by loading hopper. The water is supplied to the drum from a measuring tank. The principle of mixing is same as that of hand-fed mixer.

Reverse Drum Mixers

A loading hopper feeds the drum. The hopper is lifted upwards by wire rope winding and unwinding on power-operated drum. Discharge gate of hopper opens through a lever when it reaches its discharge position.

Water storage tank, measuring tanks and pumps, etc. are provided to supply desired quantity of water at desired time. These mixers are driven either by diesel engines or electric motors.

Roller-pan Mixers

The rollers and mixing blades rotate in a pan and mix the material and produce a homogeneous mortar.

SAQ 2

(a) What do you understand by concrete mixer?

(b) What are various types of concrete mixer?

(c) How mixers are designated?

(d) Explain the working of Hand-fed tilting-drum mixer.

(e) Explain the working of Reverse drum mixer.

6.4 STONE CRUSHERS

It is the equipment used for reducing size of hard material such as rocks to smaller and more uniform sizes known as aggregates.

Aggregates of various sizes are required for most of the construction activities, e.g. construction of roads, buildings, bridges, canals, tunnels, dams, airfields and other concrete structures.

The crushing plant may be 'Mini Crushers' with a production capacity from 3 Tons to 10 Tons per hour. Mini plants are used for very small works.

6.4.1 Types of Stone Crusher

Following are the main types of Stone Crusher :

(a) Jaw Crusher

(b) Impact Crusher

(c) Roller Crusher

(d) Cone Crusher

Crushers can also be classified according to the stage of crushing such as primary and secondary. Primary crushers receive the stone directly from the quarry and produce the first reduction in size.

The output of the Primary crusher is fed to the Secondary crusher, which further reduces the size of the stone.

Crushers are heavy machines, surface of which are made up of special alloys and are removable. The selection of crushing equipment is done on the basis of :

(a) kind of stone to be crushed,

(b) size of aggregate required, i.e. range for example 15 to 20 mm aggregate size,

(c) method of feeding crushers, and

(d) required capacity of plant.

6.4.2 Controls and Parts

Jaw Crusher

These crushers (Figure 6.9(a) and 6.9(b)) have two Jaws – one is fixed Jaw and another is 'Swing Jaw'. The Swing Jaws are made of either manganese chrome steel or heavy duty cast steel, annealed and stress relieved to withstand the tough crushing operations.

Figure 6.9(a) : Double Toggle Jaw Crusher

The fixed jaws made up of heavy jaw plates are reversible for longer life. The capacity of the crusher is influenced by the size of the product, nature and type of rock or ore, i.e. feeding material.

Figure 6.9(b) : Single Toggle Jaw Crusher

The main components of Jaw Crusher are as follows :

Frame

Jaw is constructed with a heavy fabricated steel frame.

Hinge Pin and Jaw

A rigid steel hinge pin is clamped with frame.

Jaw Plates

Crushing surface of the jaw plates depends on the application.

Jaw Adjustment for Product Size Control

The size of the product depends upon the distance between the two jaws on the full forward position of the swing jaw. This is known as closed side setting and can be changed quickly and easily as per requirement.

Toggles

Toggle ends are precision machined, polished and hardened.

Pitman

The pitman is a strong steel member and always remains in compression.

Eccentric Shaft and Bearings

The eccentric shaft is precision machined and polished. It rotates in a heavy duty; self-aligning roller bearings, held firmly in housing arm, an integral part of the ride frame. All loads are transmitted directly to the steel frame and all bearing pressures are in direct ratio to the eccentric stokes and swings jaw travel.

Flywheel

These are made of solid gray cast iron with counter balance weights. One fly-wheel being grounded for Vee rope drive, the crusher may be driven by Vee belts or by means of flat belt.

Impact Crusher

Impact crusher (Figure 6.10) is used where materials are too hard and abrasive and finished product requirement is for cubical shape well graded material.

In this type of crusher, stones are broken by means of impact and not by compression as in Jaw Crusher.

The impact crushers are fitted with one or two rotors and the hammers may be fixed or allowed to swing on pivots. These are used for primary or secondary crushing.

Since impact is instantaneous, the breeding almost eliminates the possibilities of the development of hidden crackes in the product.

Figure 6.10 : Impact Crusher

Following are the types of Impact Crusher :

(a) Impact breaker.

(b) Hammer mills.

The main difference in these two is that, the breaker plates are rigidly fixed on the rotor in an impact breaker, but in hammer mill type the breaker plates are swinging.

These crushers have following advantages :

(a) Lower initial cost.

(b) Have fewer parts to maintain.

(c) Wide range of product gradation can be selected.

(d) These produce well graded cubical shaped product.

Impact crushers can crush hard materials like basalt and granite. The impact crushers have the following part :

(a) Casing

(b) Repulsion Plane

(c) Rotor

Roll Crushers

The Roll Crusher is a reduction crusher and follows a primary breaker in the crushing circuit. It is suitable for all type of materials; whether it is gravel, rock, limestone, or the toughest ore.

In these crushers, the crushing members are two manganese steel shells mounted over two roll shafts positively driven, rotating towards each other. These are supported on the anti-friction roller bearings.

The roller crushers can be adjusted to produce a wide range of sizes of materials by changing the discharge opening.

The materials are fed into the crushers by means of a feeder discharging into the hopper.

Advantages

(a) It produces more per hour of material of specified size considering weight of the crusher.

(b) It can handle any material from hardest to softest without clogging problem.

(c) It produces uniform material.

(d) It is economical for a given capacity and reduction ratio.

(e) Maintenance is simple.

(f) It consumes less power per ton of material crushed to specified size.

Types of Roll Crusher

(a) Both roll shells smooth.

(b) Double toothed roll crusher.

(c) One smooth and one corrugated shell.

(d) Corrugated rolls.

(e) Spiked roll crusher.

Cone Crushers

Cone Crushers (Figure 6.11) are used to produce the final product, since they can receive and crush smaller size of stones of ore and produce more fine aggregates.

The crushing surface in the clearance between the concave and mantle is made of wear resistant high grade manganese steel for heavy duty operation and reduced wear.

Figure 6.11 : Cone Crusher

The crusher's head has a gyratory, swinging motion so that the crushing is done by direct pressure. This results in a cubic product and less wear linings. The swinging motion is produced by an economic sleeve rotating in a bronze bushing.

Cone crusher setting is adjusted by rotating the crushing bowl (drum) which has its thread. A hydraulic device is used to do this. After the adjustment, the thread is locked in the crushing position.

6.4.3 Operation

Crushing operation involves feeding of aggregate to crusher, crushing, screening to screen different sizes of aggregates and transportation of the materials.

Jaw Crusher

Jaws crush the stones by compression. The jaw crushers are used as either primary or secondary crushers but are considered best for primary crushing. These are suitable, where lesser fines are desired.

Size of Jaw Crushers

Feed size is the basis for determining the size of the crusher. Mouth opening of the jaws denotes the crusher size. Thus a jaw crusher having a mouth opening of 1200 × 1000 mm is called a 1200 × 1000 mm crusher.

The optimum use of jaw crusher is ensured by following :

(a) The entry of bigger size should not be allowed in the crusher mouth.

(b) Material fed should not be of same size. Mixed feed of all sizes of material gives best result.

(c) For best results ratio of gap to jaw setting should be 5 : 1 to 7 : 1.

Impact Crusher

These crushers are used where materials are too hard and abrasive and finished product requirement is for cubical shape well graded material. In this type of crusher, stones are broken by means of impact and not by compression as in jaw crusher. In the impact breaker, stone is normally fed into the top of a breaking chamber and struck by rotating hammers while it

is in suspension. The hammers rotate repeatedly through the material against breaker bars forming the roof of the breaker chamber.

Stones are charged into the casing through charging chute. These stones are then collision-crushed by the hammer attached to the highly rotating rotor, where the stones are struck in the tangential direction towards the movable-type repulsion plates next collide against the plates and crushed. Also at the same time rebounded stones collide with each other into smaller sized-ones.

This cycle of operation is repeated and the crushed stones pass and fall down between the preadjusted repulsion plates and hammer, and then discharged from the outlet.

The crushed product size depend upon the following :

(a) Effect of charging stone's size.

(b) Effect of amount of charging stone.

(c) Effect of Rotor's peripheral speed (revolving speed).

(d) Effect of gap between repulsion plate and hammer.

With the passage of time following parts wear out :

(a) Hammer

(b) Casing liner

(c) Repulsion plate

Impact crusher has a provision for replacing the above parts.

Roll Crushers

The roll crusher is a reduction crusher and follows a primary breaker in the crushing unit. It is suitable for all type of materials, whether it is gravel, rock, limestone, or the toughest ore.

Cone Crushers

Cone crushers are used to produce the final product, since they can receive and crush smaller size stones of ore and produce more fine aggregates.

The stones are fed through feed chute, evenly into the crushing chamber where they are crushed quickly and uniformly.

The stones from the feed chute first fall on a distributor plate, which helps in distributing the feeding material in cone crusher.

SAQ 3

(a) What is crusher?

(b) Explain various types of crusher.

(c) Explain primary and secondary crushers.

(d) What are advantages of Impact Crusher?

(e) Name the various components of Jaw Crusher.

6.5 ASPHALT PLANTS

Asphalt is a mixture of bitumen and inert mineral aggregate, mix in a proper proportion and is utilized in construction of various places such as

(a) Bitumen macadam or bitumen base coarse.

(b) Surface coarses including binder coarse and wearing coarse.

Bitumen macadam is an open graded asphalt mix using coarse aggregate bound together with bitumen. Bitumen may be incorporated in macadam construction either by penetration or by mixing.

The asphalt plants are used to prepare asphalt. Hot and Cold mix plants are common for preparation of asphalt mix.

6.5.1 Types of Asphalt Plant

Following are the types of plant :

(a) Cold Mix Plant

(b) Hot Mix Plant

Cold Mix Plant

Following are the types of cold mix plant :

(a) Fixed vane type

(b) Paddle mixer (Pug Mill)

Hot-mix Plant

Following are the types of hot mix plant :

(a) Batch type

(b) Continuous mixing type

The capacity of hot-mix plant is indicated by two capacities, viz., 60/90 TPH. This means the plant has a maximum capacity of 60 tonnes per hour when dry aggregates having initial surface moisture content of 6% by weight and a terminal temperature 180^{o}C and whereas it has a maximum capacity of 90 tonnes per hour at 2% moisture content.

In order to maintain optimum operation and output, the feed to the plant should be in the proportion of the end product.

A high proportion of graded stone will slightly increase the output of the drier for given moisture content and terminal temperature, whilst a high proportion of fines will slightly reduce the output.

Functions

(a) Heating and drying the aggregates.

(b) Screening the aggregates into required sizes and measuring the required quantities of the aggregate, the filler and bitumen.

(c) Mixing the aggregate, the filler and the bitumen in required proportion and to produce homogeneous mix.

6.5.2 Controls and Parts

Cold Mix Plant

Fixed Vane Type

This consists of a rotating cylindrical drum having set of vanes inside. These plants are operated manually, like hand drum mixers and are used for preparing mix for patch works.

Paddle Mixer (*Pug Mill*)

It consist of the following component :

Chassis	The plant is mounted on strong steel chassis having four heavy-duty pneumatic road wheels and used for movements.
Prime Mover	Diesel engine is used for operation; it can be operated either by battery or manually.
Drive	It transfers the power from prime mover.
Loading skip	This feeds the batches of unmixed materials to mixer.
Mixer	The material received from the loading skip, mixed in the mixer.
Bitumen measuring bucket and the pump	The bitumen is supplied from the measuring bucket, which is suspended on brackets.

Hot-mix Plant

Batch Type

This consists of the following :

(a) The **cold aggregate feeding bins**, to feed the aggregate to the drier drum.

(b) The **drier**, revolving cylindrical drums where the aggregates are heated. The drum is also provided with a burner. A dust collector is also usually provided.

(c) The **screens**, which are provided in deck form, separates the aggregates into the required sizes, throwing out the oversized stones.

(d) **Aggregate weighing system**, weighs various sizes of aggregates and allow them for mixing in a desired proportion. In some hot mix plants, aggregate proportioning is done by volume.

(e) **Bitumen storage tanks** have heating system with a thermostat to keep the bitumen at a constant temperature. These tanks are provided with the heat insulators.

(f) The **mixing unit**, which consist of a box with two horizontal shafts rotating in opposite directions. These shafts are fitted with removable mixing paddles. These mixing boxes have an opening gate at the bottom at a

sufficient height to discharge into the waiting dump trucks.

6.5.3 Operation

Cold Mix Plant

Fixed Vane Type

It has a rotating cylindrical drum, which consists of set of rotating vanes inside. The aggregate is properly coated by bitumen while the drum rotates. Drum should be cleaned every time for proper functioning.

Paddle Mixer (*Pug Mill*)

The aggregate is fed through loading skip to the paddle mixer. The loading skip is elevated by wire rope, which discharges the content. If the capacity of the plant is less, the material is fed by basket and bucket. The aggregate material is dumped into the mixer and the bitumen through bitumen measuring bucket and mixed thoroughly in mixer and transferred through truck or by wheelbarrow.

Hot Mix Plant Batch Type

Operation of each unit of plant is given below

Bin Feeder

Generally, four hoppers are provided which feed the coarse as well as fine aggregates. The feed hoppers are loaded through loader or directly by the dump trucks. The material is extracted from each hopper by means of an extractor belt. From the control cabin, operator can increase or decrease the output by increasing or decreasing the speed of extractor belts.

Figure 6.12 : Asphalt Batch Hot Mix Plant

Figure 6.13 : Bin Feeder

Drier

Drier consist of a long hollow steel cylinder with firebricks lining and containing projecting radial fins. Heat is supplied by a jet of flame, fed by air-vaporized oil. The aggregate is passed from the drier and to get dried aggregate for mixing.

Figure 6.14 : Drier

Dust Collector

The dust collectors are, therefore, provided which traps the fine particles and returns them to the heated aggregates below the drier. The dust collector may be of either :

(a) cyclone type dry dust collectors, which returns the fines to the aggregates, or

(b) wet dust collectors, which collects the dust by means of atomised water, or

(c) dust bag filters.

Filter Storage Bins

Hot recovered fines are stored in these storage bins and additional materials are also stored in these filler storage bins. These are also provided with metering systems so as to feed filler material in required proportion.

Figure 6.15 : Filter Storage Bins

Screening, Weighing and Mixing Units

The vibrating screen of four sizes separates the aggregates into the required size throwing out the oversized stones. The four sizes of aggregates are collected in four aggregate storage bins. Each size of the aggregates is weighed accurately in a weighing hopper. The weights are indicated on a dial provided in the operators cabin. The hot aggregate is then fed directly to the mixing unit also known as pug mill.

The gates for discharging the hot mix open at pre set timing, to allow the mix to fall directly into the truck standing below it. These twin discharge gates are controlled pneumatically.

Bitumen Heating System

Bitumen heating can be done in following two ways :

Bitumen Storage and Heating Tank

These are used where the bitumen is transported in bulk from refinery to hot mix plant in bitumen carriers.

Figure 6.16 : Bitumen Heating System

Melting Furnace for Bitumen in Drums

The hot chamber for drum decantation holds number of drums. The lifting and positioning of the drum is effected by a hoist and hydraulic pusher for positioning and causing the exit of the materials to empty drum. The melting tank is insulated and has a burner, which uses diesel as fuel. It also has a thermometer. It also feeds the bitumen into the mixing unit through a pump.

Control Cabin

Control cabins are located at a place from where operator can observe complete hot mix plant. The cabin is dust proof and air-conditioned.

Good Quality Mixing

In order to ensure good quality hot mix, following precautions should be adopted :

(a) Aggregate feeding

(b) Drying

(c) Screening and hot aggregate storage

(d) Bitumen

(e) Material proportioning

(f) Mixing

Drum Mix Asphalt Plants

Drum mix asphalt plants are becoming more and more popular because, initial capital investment cost of these plants is less than that of conventional batch type asphalt mix plants and running costs are also greatly reduced due to fewer moving and wearing parts.

These plants consist of following main components :

(a) Cold aggregate feeder with mineral filler supply system.

(b) Dryer and mixing unit with dust collection system.

(c) Bitumen storage, heating and delivery system.

(d) Mix storage unit.

(e) Operator cabin and controls.

Advantages of Drum Mix Plant over Conventional Plant

Like conventional plant, these do not have the hot stone elevator screen, hot stone bins weigh hoppers for gradation control, and pedal mixers and their associated wearing parts. This feature results in following main advantages :

(a) Expenditure on spare parts reduces considerably.

(b) Expenditure on man-hour for maintenance is also reduced.

(c) This reduces the requirement of power.

(d) Initial cost of the plant is less than that of a similar capacity conventional plant.

It produces the good quality coating even at a lower temperature; hence it saves the cost of fuel per unit quality of mix. These plants are simple, easy to operate and easy to transport from one site to another.

Most important advantages of this type of plant is that the chimney of this type of plant emits less dust than a traditional plant.

This is because the heating and mixing process is carried out in the same drum which renders self dust collection in this type of plant.

Thus, the plants are economical, energy efficient, highly mobile, and environment friendly. These produce high quality coated material besides having lower capital investment and maintenance costs.

The following defects are generally noticed in asphalt mixes :

(a) Mix too cold

(b) Overheated mix

(c) Excess bitumen

(d) Lack of bitumen

(e) Poor mixing

(f) Poor grading.

SAQ 4

(a) What is asphalt?

(b) Explain what is Hot and Cold mix plant?

(c) Explain various components and working of Hot Mix Plant.

6.6 MAINTENANCE

The proper maintenance of the machines is essential in order to have a smooth and efficient working. Periodical checking is carried out on machines in order to make sure that machines are working properly. It improves the productivity and also helps in keeping the machines in a state of maximum efficiency with economy.

Maintenance can be divided in the following :

(a) Servicing

(b) Field repair

(c) Inspection

Servicing

It includes the following :

(a) Cleaning

(b) Cooling

(c) Lubrication

(d) Check-ups

Cleaning

It has been seen that dirt is a major cause of breakdown in the equipment and damages bearings due to its abrasive action and clog ventilation passages. It should be blowed with dry compressed air or using water under pressure.

Cooling

Entire cooling system should be checked and adjustment should be made whenever necessary. Cooling system checking includes checking of fan belt and its tension, water pump, pump seals, radiator, etc. The compressed air or soft and clear water is preferred for cleaning the radiator system.

Lubrication

Lubrication plays an important function in servicing and is meant for applying right type of lubricant at the right place at the right time and in a right quantity.

Since construction equipment are used to work in adverse conditions, these should be provided full attention for proper lubrication to reduce breakdowns and to improve the performance of the equipment.

Check-ups

All components need to be checked-up properly, which are sensitive while servicing is done. All nuts and bolts found loose during servicing should invariably be checked. Loose chains and belt drives should also be tightened. Inflation pressure in the tyres, proper adjustment of track, checking of ropes, cutting blades, etc. are important aspect of servicing.

Field Repair

The day-to-day repair works is being carried out at field level and with the help of field staff itself.

Inspection of Equipment

The equipment should be inspected in order to find out the defects so that it can be repaired timely which ultimately saves the time. Inspection covers all the important components including battery, electric line, fuel supply line, water cooling system, tyres, wire ropes, engine sound, color of exhaust, oil pressure, engine cooling, water temperature, working of brakes, clutches, cutting edges, hydraulic oil pressure, etc.

It must also be thoroughly checked for the abnormal heating, noise and vibration of any moving part.

It is important to give more stress on the maintenance of main component such as :

(a) Engine
(b) Power transmission system
(c) Hydraulic system
(d) Electrical system
(e) Tyres
(f) Excavation attachment
(g) Track
(h) Blade and Rippers
(i) Undercarriage of crawlier equipment.

SAQ 5

(a) Explain the term maintenance.
(b) List various components, which needs inspection.
(c) What do you understand by servicing?

6.7 TROUBLESHOOTING

Since various equipment are used in Construction Industry, an authorized operator should be allowed to operate a particular type of equipment. It has been seen that sometime the equipment does not function properly due to various faults.

In order to avoid stoppage/interruption of work due to these faults it is highly essential that equipment should be properly serviced/inspected before operations.

The operator must be given sufficient basic knowledge of the common troubleshooting informations, so that work should run smoothly.

Following are the main troubleshooting :

Engine Problems

(a) Engine starting difficulty.

(b) Engine starts at low speed.

(c) Engine lacks power.

(d) Engine overheating.

(e) Engine knocking.

(f) Improper exhaust gas.

(g) Excessive fuel consumption.

(h) Excessive engine oil consumption.

Gear Problems

Hard shifting gear.

Clutch Problems

(a) Clutch slipping.

(b) Grabbing and chattering clutch.

(c) Dragging clutch.

(d) Rapid wear of lining.

Steering Problems

(a) Hard steering.

(b) Excessive play.

(c) Steering becomes erratic when brakes are applied.

(d) Vehicle pulls to one side.

(e) Steering wheels return poor.

Brakes Problems

(a) Brakes drag.

(b) One wheel drags.

(c) Springy or spongy brake pedal.

Battery Discharge Early

(a) Battery not charging.

(b) Starting current excessive causing early discharge of battery.

(c) Excessive lamp current.

(d) Other reasons.

It is recommended to check the equipment before staring of the work in order to avoid delays. The details of checking may be summarized as :

(a) Cleaning of the equipment.

(b) Fuel, lubricant oil, other oil levels and top up if required. Drain some fuel to clear out the water, if present in the tank.

(c) Water level in radiator.

(d) Air pressure in tyres and inflate, if necessary.

(e) Air filters and cleans, if necessary.

(f) Grease and lubricate important points and moving parts, which requires daily attendance. Wipe the grease nipples before and after use.

(g) Cleaning of battery top and terminals.

(h) Air tank to drain out condensed air (water).

It is recommended to check the equipment before closing of the work. The details of checking may be summarized as :

(a) Clean the equipment.

(b) Fill up fuel tank.

(c) Never stop the running engine suddenly. Keep it running for a few minutes before shut off.

(d) Drain air tank.

(e) Jam the wheels before leaving the equipment, with the help of wooden block.

(f) Park the equipment as far as practicable on level ground.

(g) Cover the equipment, especially exhaust pipe.

SAQ 6

(a) What do you understand by troubleshooting?

(b) List and explain various troubleshootings.

6.8 SAFETY MEASURES

It is an important aspect in construction industry but generally neglected due to various reasons. Civil Contract are normally executed on contract basis. In order to achieve maximum production, the executive agency does not comply with the full contracts norms, which results accidents and sometime fatal.

The main objectives behind the safety measures are :

(a) To minimize incidents and accidents.

(b) Identification and elimination of risks before losses occurred.

(c) Developing confidence in the workers.

(d) Avoiding loss of time, life, machinery and ultimately work.

The work force deployed at site must be given proper training in general and specific job trainings before start of new activity/days works. Efforts should be made to develop safety culture among the work force so that near misses and accidents could be avoided by conducting daily toolbox meetings.

The work supervisor conducts the toolbox meetings. During toolbox meetings, the risk involved in activity, safety measures required are discussed. The purpose of toolbox meeting is to educate the workers about the specific works. The safety equipment required for a particular activity is also discussed.

Following are the safety measures related to equipment :

(a) Equipment should be well maintained and kept in a good operating condition.

(b) Unsafe equipment should not be operated.

(c) All controls, gauges and instructions, etc. should be known properly by the operator.

(d) Never smoke, when refueling and always stop the engine.

(e) Look around, before starting and give warning to nearby people that you are about to start up your equipment.

(f) Never leave the machines unattended with its engine running.

(g) Park the equipment on firm and level ground, whenever possible or at right angle to any slope and away from traffic.

(h) Operate the machine only from the driving seat/platform.

(i) Never use a naked flame to inspect battery or any leakage.

(j) Never carryout servicing, adjustment and repair when the machine is running.

(k) Never permit unauthorized persons to sit on the equipment. Operators should be familiar with the capacities and limitations of the equipment.

(l) Ensure driving/operating platforms are safe and free from oil and grease before operation.

(m) The driver/operator must have the maximum unrestricted view of the operating area.

(n) Use warning signals like cordoning, red light, etc. when parking the equipment.

(o) Ensure that the engine is switched off and immobilized against unauthorized use.

(p) Do not leave the control when the machine is working.

(q) Exercise care when removing the radiator cap after the engine has been running.

(r) Replace all protective guards, if these have been taken down.

(s) Do not leave the equipment with the load suspended in the air.

(t) Use handholds/rails and steps where mounting or dismounting the equipment.

(u) Watch clearance when traveling near overhead and avoid running into and side obstructions.

(v) If the equipment comes into contact with a charged electric line either stay on the equipment or jump off and do not step off. Also do not allow anyone on the ground to touch the machine.

(w) While lifting a load be sure of the weight.

(x) Keep blade or bucket low for good stability and visibility while traveling.

(y) Always face and look in the direction the machine is traveling.

(z) A sufficient safety clearance.

(aa) Give right of way to loaded machine.

(bb) Keep safe distance from the vehicle ahead.

(cc) Avoid jerky swings and hoist or sudden brakes.

(dd) Periodically inspect all the cables of the equipment.

(ee) Do not get under the equipment unless it is shut off and park properly.

(ff) Do not operate the machine after sunset or in dim visibility without proper lights.

(gg) Equipment should be carefully inspected at regular intervals.

(hh) Operator should be aware of what other equipment are in operation at the work site.

(ii) Never run machines above their recommended speeds.

(jj) First-aid boxes with adequate supplies should be made available.

(kk) Use proper tools in proper way.

(ll) Hydraulic pressure should be released before working on hydraulic system.

SAQ 7

(a) Explain the term Safety Measures.

(b) What are the main objectives behind taking Safety Measures?

(c) List various Safety Measures.

6.9 SUMMARY

We have seen that Construction Plants are very important in Construction Industry and are used in various works. They are essential tools. The success of the project depends upon the efficiency, production and maintenance of the plants.

Various types of roller are used for compaction. The use of particular roller depends upon the nature of material compacted or place of compaction.

Sheep's Foot rollers are used for compacting cohesive soil of low moisture content. Sheep's foot rollers can be single or multiple drums.

Smooth wheel steel rollers are used in compaction of water bound macadam, tar macadam and bituminous pavements and for compaction of sub-grade and sub-base of pavements.

Tandem rollers are similar to smooth wheele roller and has certain advantages. This produces an absolutely smooth even surface.

Pneumatic tired rollers used for compacting fine grained soils and in particular, closely graded base and bitumen mix, surface compaction and seal coat operation.

Vibratory rollers are used for compacting bituminous pavements. Power rammer and frog rammer are used for compaction of narrow and restricted areas, trench backfilling, bridge abutments, etc.

Concrete mixers are used for mixing concrete. The selection of a particular mixer depends upon the size of project/volume of the work involved. Normally, four types of control mixers – hand fed lifting-drum mixers, loader fed tilting-drum mixers, reverse drum mixers and roller-pan mixers – are available.

Stone crushers are important in construction industry since construction utilizes mostly different sizes of aggregate. Jaw crushers, impact crusher, roller crushers and cone crushers are generally available.

Asphalt plant is an important plant, which produces good quality mixes in bulk since major road works are constructed by asphalt.

6.10 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section 'Further Reading' given at the end to get the answers of SAQs.

UNIT 7 MODERN TRENDS IN CONSTRUCTION

Structure

7.1 INTRODUCTION

Building construction is one of the earliest activities associated since the beginning of the human civilisation as man has always needed a shelter against natural enemies and predator and also to protect himself from the vagaries of nature and the extremities of climatic and weather conditions. Thus, through all these centuries there evolved a variety of materials used for building purposes. The applications of these materials, natural as well as manufactured by man, have itself been subject to wide variations and innovations. Research and development has never stopped, but has ever continued to evolve newer materials and better techniques to apply them to the needs of the construction activities. Recent decades have witnessed the introduction of a large numbers of new materials and new types of construction methods to improve and economise upon the previous methods, and much development has been done both in India as well as abroad in this field. The objectives of this unit is to give you an idea of the new materials developed and the new techniques evolved in construction industry, especially prefabrication and pre-casting techniques, which are important from the point of view of providing mass-housing for a growing population.

Objectives

After studying this unit, you should be able to

- describe the latest materials used in construction,
- discuss the modern trends in materials usage, and
- explain the prefabrication methods and their applications.

7.2 TYPES OF MATERIALS IN MODERN TRENDS AND THEIR USES

Rapid technological progress in the recent decades has caused a big change in the production techniques of the traditional building materials like bricks, tiles, timbers, cement, concrete, etc. At the same time newer materials like polymers, bituminous compounds and plywood products have come into greater use in the construction industry.

7.2.1 Bricks and Tiles

Bricks and tiles are important materials in any building constructions. It has a very long history of its development from man-made/hand-made bricks to mechanised factory-made bricks as available in the market.

Mechanised Methods of Production

The age-old method of producing bricks from clay consists of the following four operations :

(a) Soil Preparation

(b) Moldings

(c) Drying

(d) Firing.

Earlier the whole process was mostly manual. But in certain developed countries big plants using advanced method of production capacity (50,000 to 100,000 bricks per day) have been evolved. These are cost effective for only very large projects in countries where labour is costly, hence not advantageous for Indian conditions. CBRI and other organisations have developed semi-mechanised methods with a production rate of 2500 bricks per hour using a 60 kW machine, which are more relevant for us.

Soil Preparation and Molding

The upper deck of the machine is a clay mixer where pugging and chopping is done after mixing water to proper consistency. The clay is then fed to the lower deck, which houses the main auger. Here clay is compacted and extended in the form of rectangular bars. While traveling over the cutting table it is cut into bricks by steel wire-frames.

Drying

It is then dried in the drying shed before stacking. The safe drying is achieved by the following ways :

(a) Clay preparation before brick formation by adding ingredients like grog, fly ash, salt solution, etc. and by proper grinding, mixing and weathering of clay mass.

(b) Controlled drying conditions after formation of bricks are essential, so that shrinkage cracks, etc. may not develop. This is done by controlling the humidity and temperature and circulating fresh air, etc.

Firing of Bricks

Most brick manufacturers had been using continuous kilns of the bulls trench type for the past 100 years or so. These kilns have a low thermal efficiency and, therefore, consume lot of fuel. Recently, better kilns, e.g. high draught kilns have been developed. This is a top fed, coal fired continuous kilns in which the fire follows a zigzag path. There are 24 chambers out of which two are fired per day. The output capacity is 15000 to 30000 bricks per day. The fire draught is quite high (17-18 m/day), which is three times the bulls trench kilns. It is thermally efficient and more cost effective kiln.

Special Bricks

Some special bricks are being produced to cater for the special needs as required as following :

Engineering Bricks

These bricks are exceptionally strong (crushing strength 65 MPa minimum) and are used for paving, acid resistant and water proofing purposes. They have low water absorption (0.1-0.2%) and are of regular size and shape.

Coloured Bricks

These bricks are of yellow chocolate colour *and* are mostly used for facing of walls and other decorative purposes in building construction.

Perforated Bricks

Bricks having about 30-35% perforations are light weight and saves in clay, fuel and drying time. It has thermal insulation properties and are used for walls in multistoried building and also used for thermal insulation in walls and for light construction purposes.

Modular Bricks

In India bricks of different sizes are used in different regions. However, modular bricks (19 cm × 9 cm × 9 cm) have been adopted as the standard size of bricks. This is a advantageous from the point of view of manufacturing process and application. The thickness of walls are smaller (19 cm as against the conventional 23 cm); hence floor area is larger. The weight is 87% of the ordinary brick, hence reduces transport cost as well as dead weight of the structures.

7.2.2 Cement and Concrete

Cement and **Concrete** are the main materials for the construction of many structures. In India, standard specifications are available for twelve different types of cements (Table 7.1). Out of these only nine are commercially produced of which three types, e.g. Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) are commonly used.

Table 7.1 : Utilisation of Various Cements

Sl. No.	IS Specification No.	Type of Cement	Uses
1.	IS : 269 - 1976	Ordinary Portland Cement	General Purpose Cement
2.	IS : 269 - 1976	Low Heat Cement	Mass Concreting
3.	IS : 1489 - 1976	Portland Pozzolana Cement	General Purpose
4.	IS : 455 - 1976	Portland Slag Cement	General Purpose
5.	IS : 8041 - 1976	Rapid Hardening Cement	General Purpose and High Early Strength Requirements
6.	IS : 8112 - 1976	High Strength Cement	Precast Concrete and Railway Sleepers, High grade of Concrete
7.	IS : 3456 - 1967	Masonry Cement	Mortars and Plasters
8.	IS : 6452 - 1972	High Alumina Cement	For High Early Strength in Cold Climate
9.	IS : 6906 - 1973	Supersulphated Cement	Sulphate-resistance Applications
10.	IS : 8042 - 1976	White Portland Cement	Tiles, Flooring
11.	IS : 8043 - 1976	Hydrophobic Portland Cement	Storage in High Humid Conditions
12.	IS : 8229 - 1976	Oil Well Cement	Oil Wells

Manufacture of Portland Cement : Recent Trends

The principal methods of manufacturing of Portland cement are:

(a) Wet Process

(b) Dry Process

(c) Semi-dry process

The dry process is being preferred due to its fuel economy. Addition of minerals, e.g. flourides, sulphates, phosphates, etc. also reduces fuel consumption. Use of precalciner improves the process technology. Utilisation of the waste heat from the exit gases, and use of coal in place of liquid fuels for firing the kilns is also adapted.

Gypsum ($CaSO_4$, $2H_2O$)

It is now getting more use as a building material. It is used in gypsum plaster. The gypsum producing regions in India are Rajasthan, Tamilnadu, Andhra Pradesh and Gujarat. Gypsum has fire resisting properties and is used in fibrous gypsum plaster board and acoustic tiles to reduce echo effects in auditoriums.

Concrete

In addition to the traditional cement concrete, new types of concrete which are gaining increased use as building materials are as follows :

Lightweight Aggregate Concrete

These are manufactured from light weight aggregates, e.g. cinder, foamed slag, sintered fly ash aggregate, bloated clay aggregate, etc. The weight is 320-1920 kg/m^3 (as compared to 2300-2400 kg/m^3 of ordinary concrete). It has high strength/density ratio, better thermal insulation and fire resistance properties.

Cellular Concrete (*Aerated Concrete*)

It is the lightest form of concrete, which is produced by entrapping or generating numerous small bubbles of air (or other gases) in a cement mix, by a mechanical or chemical process. These types have been covered by IS : 4582-1969 and have properties as given in Table 7.2.

Table 7.2

Sl. No.	Use	Bulk Density (kg/m^3)	Compressive Strength (N/mm^2)
1.	Heat insulating	500	2.5
2.	Structural and Heat Insulating type	500 – 800	7.5 – 15
3.	Structural Type	7400	7.5 – 15

They are widely used as load bearing wall panels in multistoried structures, as precast lentals and roof-slabs, partition walls, insulating cladding to outer walls and as ornamental facing to walls.

Admixtures in Cement Concrete

In recent years a large variety of chemicals have been developed, which when added to concrete modifies its properties and improves upon its applications. A few examples are :

Cold Weather Concreting

It is possible by adding calcium-chloride and air entraining agents.

Workability Aids

Air-entraining agents, retardars or water-reducers may improve workability of concrete and eliminate bleeding, segregation and honeycombining, etc.

Accelerators

It is an additive used for quick setting of concrete. About 1-2% addition of calcium chloride to concrete causes acceleration in hardening and strength development. However, it has certain harmful side-effects, e.g. increased corrosion to reinforcement, dry shrinkage, or heat evolution. Some other accelerators like the triethonolamine may not have these side effects.

Set-retarders

These are used for hot-weather concreting where setting time is desirably delayed, and less heating evolved from the concrete mass. Some salts of lingosulphuric acids, some detergents, sugar and silicone have been used as retarders.

Water Reducers

Reducing the water-cement ratio increases the compression strength of concrete and improves workability while placing the concrete, but it may cause increased porosity and low durability to the concrete.

Water Proofing Compounds

Commonly used water proofing compounds are soaps, stearates, mineral oils and bitumen emulsion.

Corrosion Inhibiting Admixtures

These are sodium benzoate, stannous and ferric chlorides and sodium nitrite. They reduce the corrosion of reinforcing steel.

Bonding of New Concrete

Joining new concrete surface to old surfaces are done by using polyvinyl chlorides, acrylic, epoxy and styrene co-polymers.

Most of the admixtures are available as proprietary formulations and their use are subject to laboratory studies and field experience.

Floor Finisher

These are provided to protect the structural floor from erosion and chemical attack and also to provide a pleasing appearance. They can be either

(a) in-site floor finish, or

(b) jointed floor finishes.

In-site Floor Finishes

These are, for examples, cement concrete, bitumen mosaic, resin cement concrete, etc.

Jointed Floor Finishes

These are clay tiles and bricks, cast-iron and steel floors, rubber and PVC sheets, tiles, etc.

All jointed floor finishes must have an underlay to prevent water (or any liquid) to penetrate into the joints. Most of the underlays available are of bituminous materials or polyethylene films (1mm thick). In any case the floor should also have a proper slope of 1/80 to 1/60.

For further hardening of concrete floor surfaces, *concrete floor hardeners* are used. These are metallic silica fluorides, low alkali sodium silicate, aluminium and zinc sulphates and some drying oils. For the application of hardness, the floor surface must be properly prepared by cleaning and drying.

7.2.3 Timber Products

Timber is one of the oldest and most efficient building material. Its high strength-weight ratio has made it suitable for large as well as small structures. However, the sources of supply of timber is rapidly dwindling due to the thoughtless cutting down of trees and large-scale deforestation. The need for conservation has resulted in great deal of attention on alternative sources and materials replacing timber. Work has been done to improve seasoning and preservation of timber and on conversion of timber wastes into building boards, etc.

Seasoning

In addition to the traditional methods of seasoning, like air and kiln seasoning, some recent methods used are as follows :

High Temperature Seasoning Kilns

In this process, the temperature used is above 100°C. This may reduce the strength of the timber, to some extent, although seasoning time is much less.

Microwave Drying

It is done in large microwave ovens. The process is quite expensive and hence used only on special situations.

Solar Seasoning Kilns

These kilns use solar energy for air-drying. Solar energy collectors centered the heat and direct it inside a chamber producing a "Green House Effect". Forced circulation of air inside the chamber is needed to remove the moisture. In India, such kilns have been developed by Forest Research Institute, Dehradun and CBRI, Roorkee.

Wood Preservation

Wood is liable to attack by termites, borers, fungus and roots (dry and wet), etc. Therefore, chemical preservers, used to protect it from these pests, are mostly of the following types :

Oil Type

For example, cresols, which is very toxic and has an unpleasant "odour". It makes painting difficult and risky.

Organic Solvent Type

For example, copper and zinc naphthenetes, pentachlorophenol and DDT. These are clean and permanent.

Water Soluble Type

These are either leachable type (e.g., zinc chloride, boric acid, sodium fluoride, etc.) or fixed type (e.g., a mixture of copper sulphate, potassium dichloromate and arsenic pentoxide).

The application of preservatives may be done by (see IS : 401-1961) one of the following methods :

(a) Surface Application

(b) Soaking Treatment

(c) Hot and Cold Process

(d) Boucheric Process

(e) Pressure Process

Building Boards

The main types of building boards are :

Fibre Boards

In these boards, the wood is first reduced to fibre, and then turned into a rigid board by action of heat with or without bounding materials.

Fibre boards are of two types :

Insulation Boards

These boards mostly have density less than 0.4 g/cm^3 and are used for heat and sound insulation.

Hard Boards

These boards (density range 0.8-1.2 g/cm^3) are used for panelling, partitioning, furniture, etc.

Particle Boards

These boards have a density range from 0.4-0.8 g/cm^3. These are also known as chip boards as they are manufactured after chipping, drying and then mixing with resin to form a mat, which is finally pressed. Commonly used resins are urea formaldehyde and phenol formaldehyde. The later one is more durable and water resistant. Pressing may be done by flat pressing or extrusion. The latter is weaker of the two and has to be veneered to improve their strength properties.

Wood Wool Boards

These are made from wood fibre and cement slurry and have medium density (0.3 to 0.5 g/cm^3). These have good flexural properties and can be used in structured paneling, and for thermal and acoustic insulation. These are fire and termite resistant and plaster can be applied to them. These are used for ceiling in inclined and flat roofs. Corrugated roofing sheets are also made from wood-wool base.

7.2.4 Bituminous Compounds

Almost all the bitumens are obtained at present by the rapid distillation of crude petroleum. A small quantity is obtained from natural sources also. They are available in the following forms :

(a) Solid Bitumen

(b) Liquid Bitumen and Cutback

(c) Bitumen Emulsions

(d) Bitumen Felts

(e) Blown or Oxidized Bitumen

Their approximate consumption in various engineering applications are as follows :

(a) As paving materials – 70%

(b) As roofing materials – 20%

(c) As water-proofing and acid or chemical proofing material – 10%

However, their use in other fields is also gradually spreading. Some of the recent applications of bitumen are in the following :

Asphaltic Roofing Sheet

RRL, Jorhat and CBRI, Roorkee has developed a low cost and durable asphaltic roofing sheets by impregnating waste paper (or other cellulose materials) pulp board by bitumen solution and treating it with fire-resistant treatment.

Bitumen Based Damp Proof Course

This is used between parapet walls and main walls above these junction with the roof, where the joints have a tendency to open and to allow percolation of water. The method of application for various joints are shown in Figure 7.1.

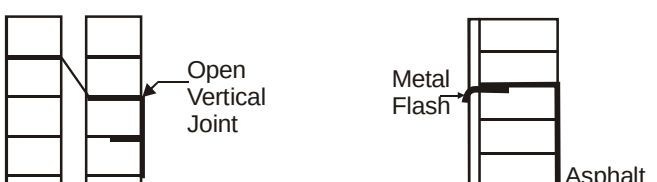


Figure 7.1

7.2.5 Polymers and Plastics

Polymers are giant chemical molecules formed by linking together smaller molecules called “monomers”. For example, the “Polymer Polyethylene” is made from the monomer “ethylene”. Most of the polymers are obtained at present from coal and petroleum and are based on carbon compounds. The four major applications are

(a) Plastics,

(b) Fibres,

(c) Rubber, and

(d) Paints.

Following are some of the main techniques in polymerisation process :

(a) Mass Polymerisation

(b) Solution Polymerisation

(c) Emulsion Polymerisation

(d) Suspension Polymerisation

The fundamental properties of plastics is its high plasticity, i.e. ability to change its shape under the action of a force and mouldability into any shape. When that force is removed, it behaves like ordinary solids. Plastics are getting greater applications in building industry, e.g. water-supply pipes, plumbing, overhead water storage tanks and composite panels. These are also being used as insulation, lightening fixtures, glazing, roof lightening, wall covering, and flooring materials. As fibre reinforced plastics they are used as roofing sheets, and decoration laminates.

These are generally transparent. Some are translucent or opaque also. Their bulk density is much lower than metals and their strength/density ratios are quite high to find favour in engineering use. The surface hardness, heat resistance properties, etc. varies largely and can be improved by proper treatment. They are susceptible to change in temperature and weathering actions. Thus, they have lower durability.

Growing uses of plastics are found in the field of paints and varnishes, sealants, crack-filling materials and for thermal and sound insulation as well. These are also used as film-making materials to act as a protective cover, corrosive

protection and as distempers. In fact, their uses are expanding at a very fast rate with growing research and applications.

SAQ 1

Explain various application of bituminous compounds in building construction?

7.3 MODERN TRENDS IN CONSTRUCTION TECHNIQUES

With the introduction of mechanization and mass production, there has been a vast improvement in construction techniques. New materials are being developed and new research is continuously in progress to effect economy and improve durability. Use of various forms of energies like electricity, gas, heating and cooling (refrigeration and air-conditioning), etc. have drastically changed the scenario. Availability of some of the conventional type of materials is getting reduced, while new and more efficient materials are being developed. In the previous section, we have described some of the most commonly used materials in recent times. In the present section, we shall see how these have affected construction techniques.

7.3.1 Foundations

In olden days, the foundations are a simple foundations like step foundations for wall construction, etc. Now-a-days, special structural requirements are demanding special types of foundations like pile foundations, casions, etc. Also various ground improvement techniques are used for problematic soils for better and economical foundation designs.

Foundations are mainly divided in two groups :

Shallow Foundation

When the width is greater than the depth of the foundation, e.g. wall and column footings, rafts, etc. the foundations are categorized as shallow foundations. These are generally used for soils with good bearing capacity.

Deep Foundations

Those foundations where the depth is much larger than the foundation width are termed as deep foundations, e.g. piles, cassions, etc.

7.3.2 Foundation in Problematic Soils

In design of foundations, the imposed load and soil characteristics, e.g. bearing capacity and settlement, etc. are the main criteria. Special foundation techniques are required where the soil is problematic. Such soils are loose cohesionless soil with high water table, saturated fine silt, saturated clays, expansive clays (also known as black-cotton soil), etc. New methods of geotechnical soil exploration and field investigation provide solutions to such difficult problems.

Methods of Ground Improvement

There are several methods of ground improvements, e.g. drains, stabilization, preloading, tamping, lime piles, etc. However, they are costly and require special equipment and skill to execute the work.

Sand Drains or Sand Piles

These are used for quicker consolidation, though these are costly and sometimes tend to fail.

Rope drains are made of coir fabric. It is driven in ground by enclosing in steel pipes, which are subsequently withdrawn leaving the rope of fabric in place. After installing the drains the ground is loaded by sand gravel, etc. to produce the desired loading intensity.

Granular Piles

These are made by making a boring holes in the soil by 200 mm diameter deep augur. These piles are shown in Figure 7.2. The bore hole is cleaned and filled with sodium bentonite solution after withdrawing the casing. These granular piles use made by filling of 15 mm to 70 mm stone chips and 20-25% of sand in a compacted form. Various construction stages of these piles are as shown in Figure 7.3.

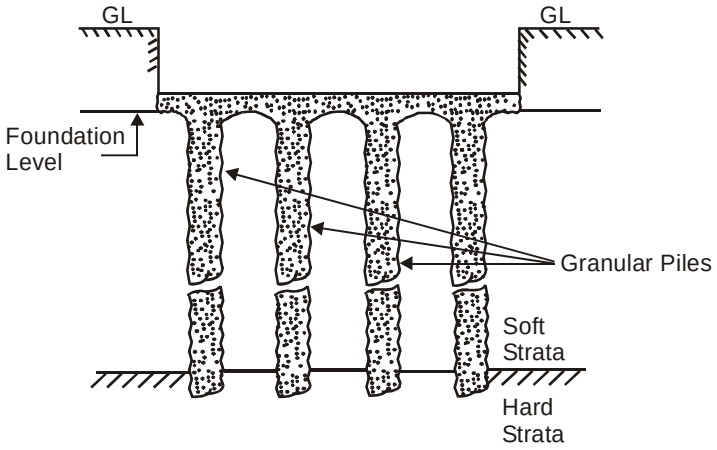


Figure 7.2 : Granular Piles

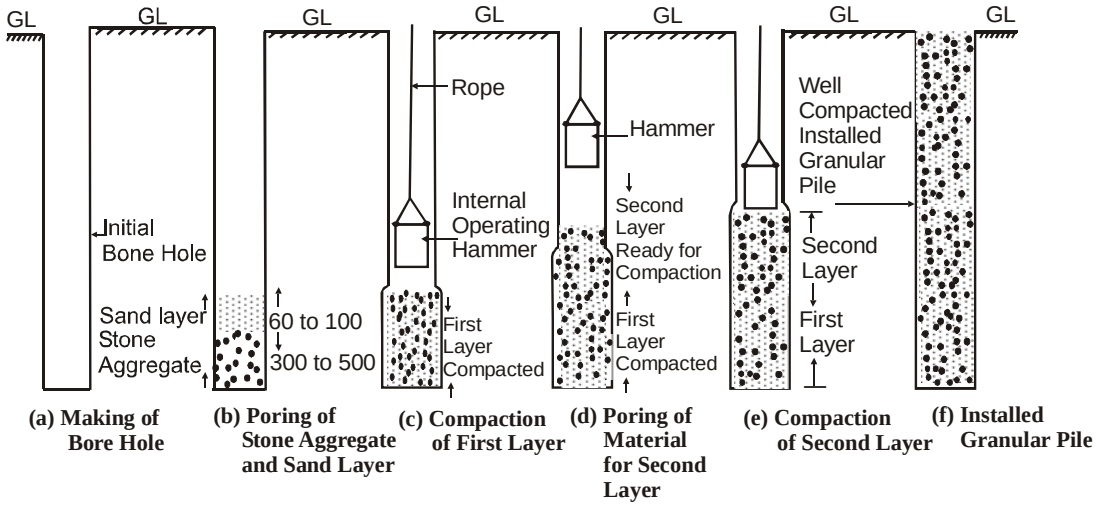


Figure 7.3 : Construction Stages of Granular Piles

Skirted Foundation

A rigid RCC skirt is provided around a footing foundation confining the soil below it. This is known as a “soil plug”. Rigid skirting increases the bearing capacity and reduces the settlement appreciably (Figure 7.4).

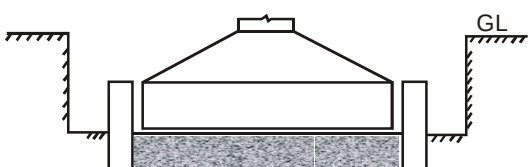


Figure 7.4 : Skirted Foundation

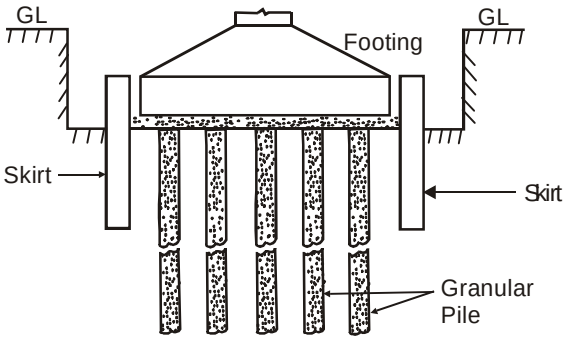


Figure 7.5 : Skirted Granular Pile Foundation

In some cases, skirting and granular piles both are provided as shown in Figure 7.5. These types of foundations are suitable and commercially viable, if soil-bearing capacity is less than 75 kPa (7.5 t/m^2).

Under-reamed Piles

Under-reamed piles (Figure 7.6) are now commonly used in expansive soils (known as black cotton soils) and also for transmission towers to resists the uplift pressure due to wind. The expansive soils exhibit swelling and shrinking characteristics due to moisture movement. Under-reamed piles are bored cast-in-situ concrete piles having one or more bulbs as shown in Figure 7.6.

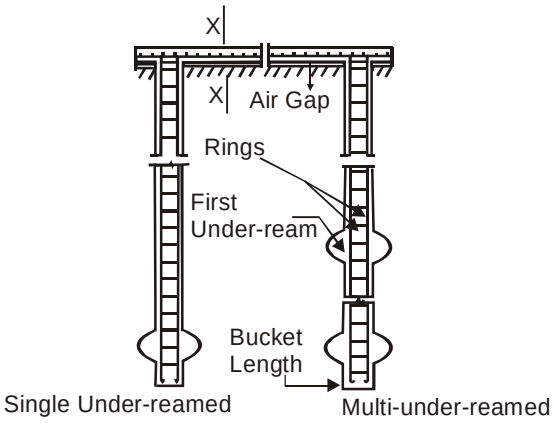


Figure 7.6 : Under-reamed Piles

Board compaction piles, pre-cast driven piles, and diaphragm walls are some of the techniques used to carry very heavy loads in poor soil conditions. Now-a-days heavy load structures like multi-storied apartment houses, fly-over and bridges becoming quite common. These foundation techniques are employed with excellent results in the above situations.

7.3.3 Walls

Some of the modern techniques in construction of masonry walls are discussed below :

Cavity Wall Construction

This type of construction is done where good heat insulation is required like AC buildings, etc. A 200 mm thick cavity wall consists of a 50 mm air gap between the 75 mm masonry leaves (Figure 7.7).

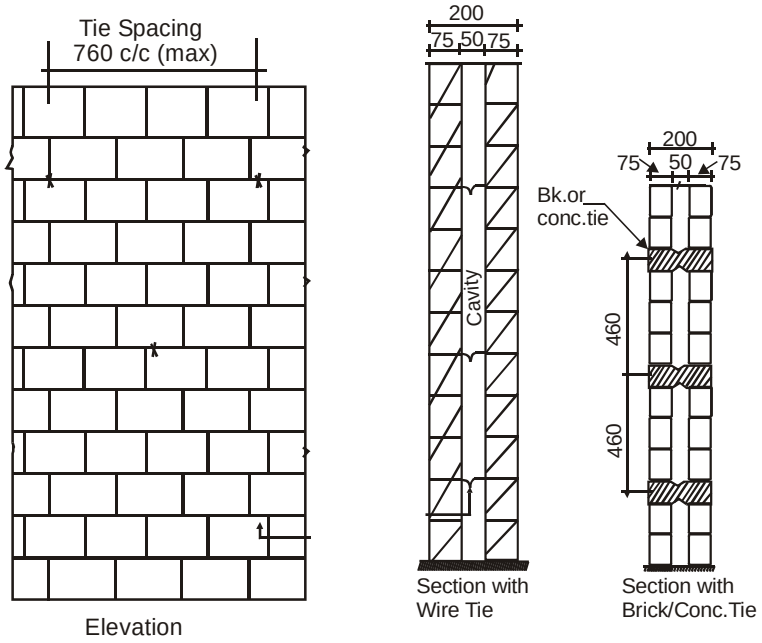
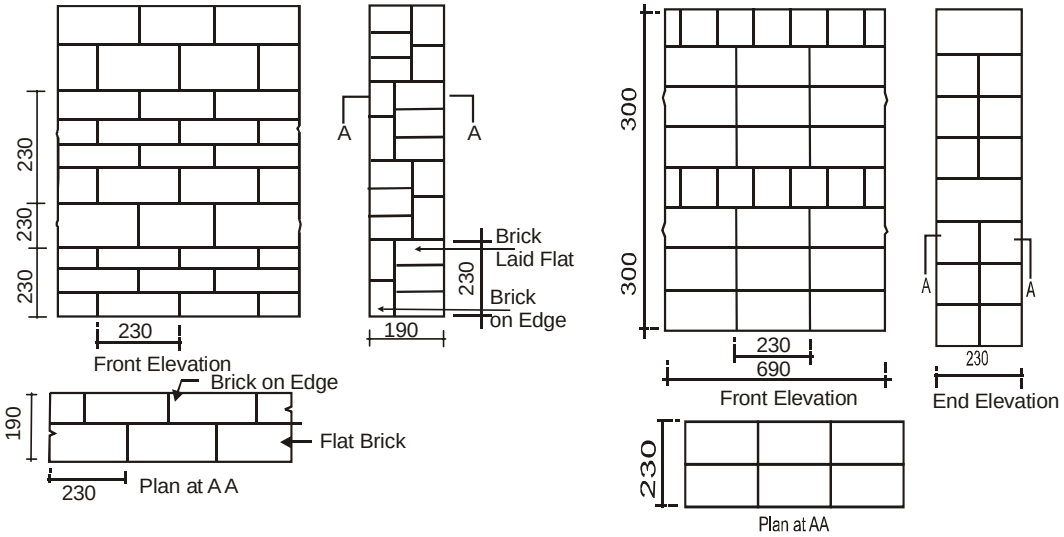


Figure 7.7 : Cavity Wall Construction

These two leaves are tied together by metal tiers, bricks or concrete blocks (maximum spacing 460 mm vertically and 750 mm horizontally). Besides heat insulation, it keeps the inner face of walls dry and can conceal.

Masonry with Non-conventional Bonds

You are already familiar with English and Flemish bonds in conventional brick masonry walls. However, some non-conventional types of bonds have been introduced to obtain economy in materials and cost and also to have better resistance against moisture penetration. Also it calls for better aesthetics and even surfaces. Two such bonds are shown in Figure 7.8.



(a) 190 mm Thick Wall **(b) 230 mm Thick Wall**

Figure 7.8 : Modified Bond

Hollow Concrete Block Masonry

This masonry is produced according to IS : 2185-1967. It is of 400 mm length and 200 mm height and the width of 300, 200 or 100 mm. Its advantages are reduced mortar consumption, lightweight and faster construction. A disadvantage is the appearance of shrinkage cracks in masonry if proper precautions are not taken while constructing it.

7.3.4 Doors, Windows, Lintels and Shelves

Doors and Window Frames

As timber has become costly, timber door frames are gradually being replaced by angle iron door-frames (Figure 7.9) and reinforced concrete door frames (Figure 7.10).

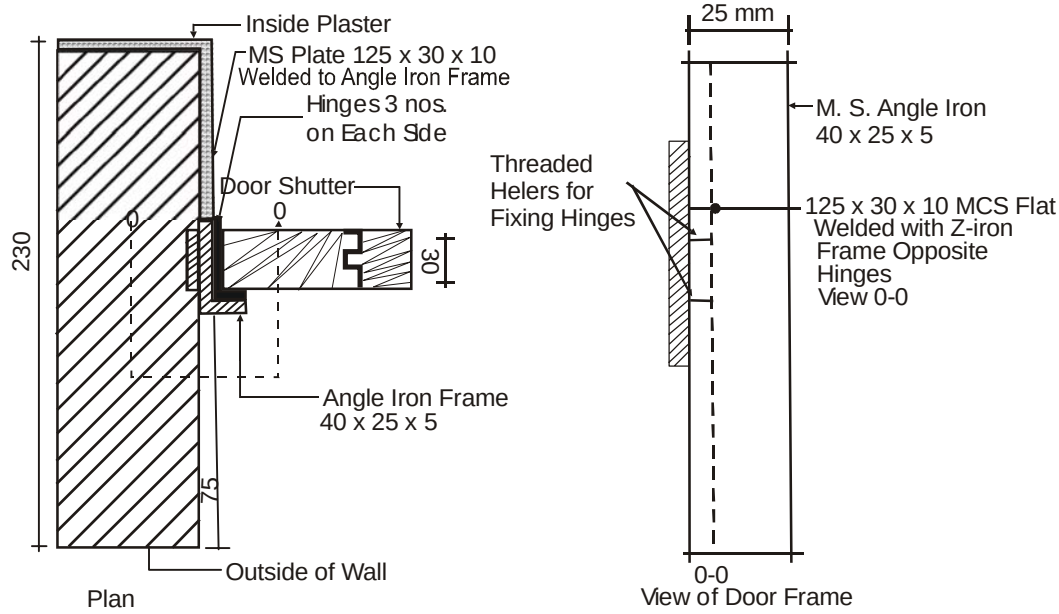


Figure 7.9 : Details of Fixing Door Shutter to Angle Iron Door Frame

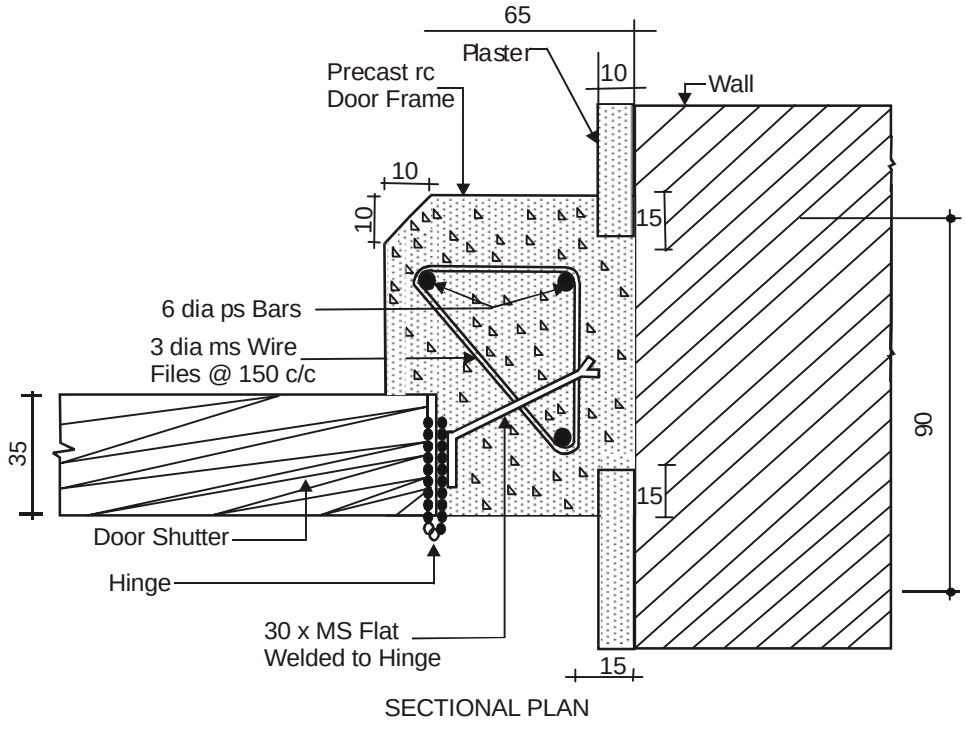
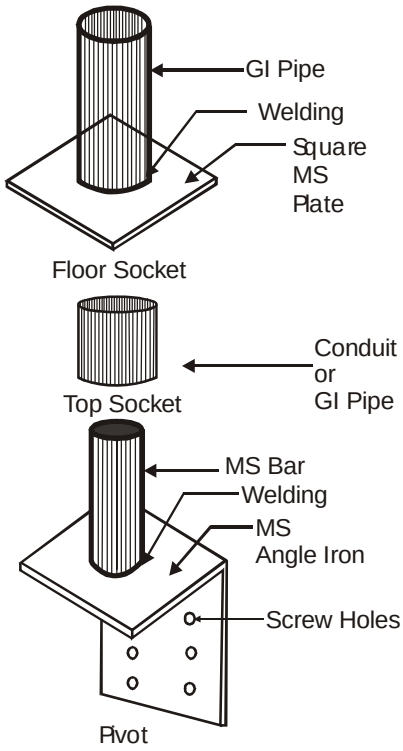


Figure 7.10 : Detail of Fixing Shutter to RC Door Frame

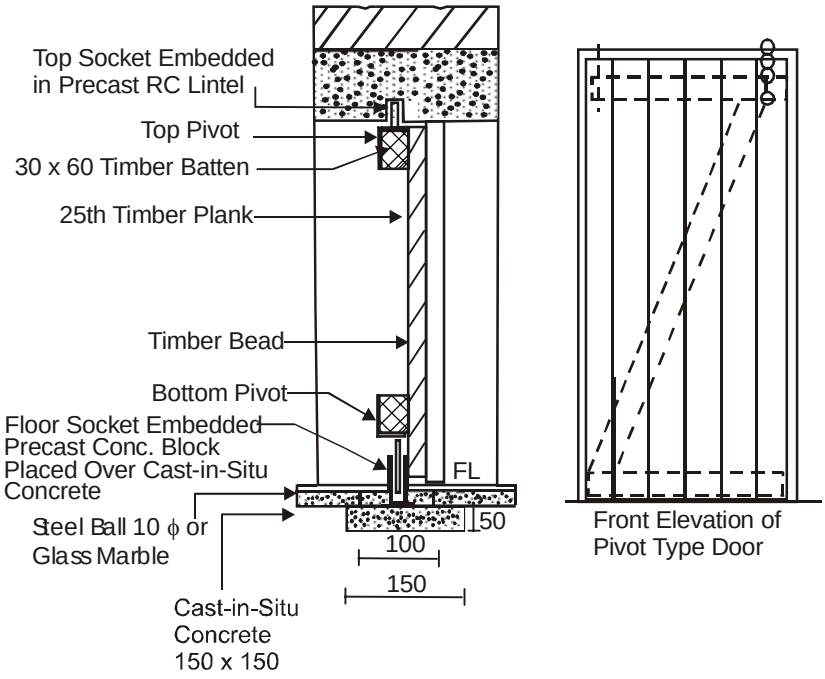
In the termite-infested areas these types of window frames are very useful. The anti-termite is an added feature to the cost of timber windows and doors. The only difficulty is to fix them into place a skilled manpower is needed. Details of function of these doors and windows are given in Figure 7.9.

Frameless Shuttering

CBRI has developed frameless shutters working on pivot and fork system. These look simple and are easy to install and economical in its construction. The details of these shutter doors are given in Figure 7.11. They have been widely used in buildings, thus reducing the overall cost of doors.



(a) Pivot System Component for Frameless Doors, Windows



(b) Typical Frameless Doors' Details

Figure 7.11 : Frameless Doors' Details

Pre-cast RC Lintels

Pre-cast lintel, 20 mm thick × 90 mm wide, is shown in Figure 7.12. The concrete used in the construction is M-15. Pre-cast lintel makes construction faster by eliminating shuttering, centering, etc. at lintel level. It, therefore, provides an overall saving in materials and labour for correcting it. In case of changes over external windows both lintel and chajja may be pre-cast together.

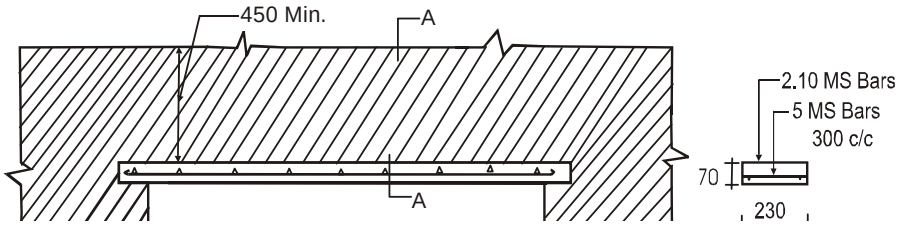
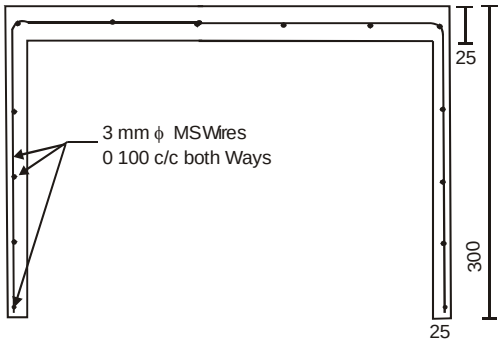


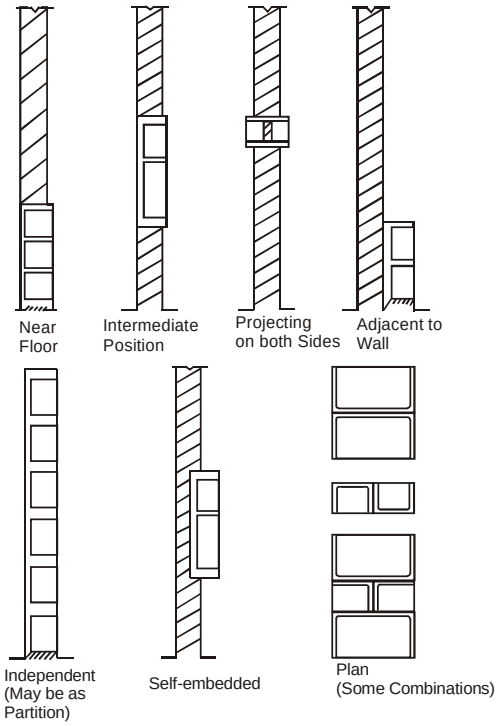
Figure 7.12 : Details of Pre-cast RC Lintel

Pre-cast Shelving Units

Similarly, we can have pre-cast shelving units of different modular construction schedule (Figure 7.13). These shelves look good and require less time to construct.



(a) Detail of Shelving Unit



(b) Some Suggested Shelve Position

Figure 7.13 : Shelving Units

7.3.5 Damp-proofing and Water-proofing

Dampness is one of the most common and serious defects in buildings. It may be due to capillary rise of water from foundation, direct penetration of moisture through joints of walls, roof, etc. or lay leaking pipes and water mains. The common constructional defects causing leakage are :

- absence of DPC or a defective damp proof course (DPC),
- defective floors,
- porous masonry work,
- defective water supply and sanitary pipes,
- insufficient water proofing of roofs, parapets and their joints, and
- defective construction at chajja and lintel joining with walls.

Damp Proof Course Insertion in Existing Walls

In walls constructed without DPC, an insertion of bituminous felt is made by making a semi-cut in the wall at horizontal bed joint. Another method is by injecting latex silicate after making holes at suitable intervals.

Damp-proofing with Silicone Compounds

Where dampness is caused by large exposed surfaces on walls the treatment consists of an under coat of bentonite clay and water-proof chemical compounds dissolved in water. The finishing coat is alone of sodium silicate with some water-soluble chemicals.

Application of Sediments to Joints and Cracks

In case of leakage caused through joints and cracks, bituminous sealant is applied under pressure after cleaning and opening it. Figure 7.14 shows a typical sealant application under pressure.

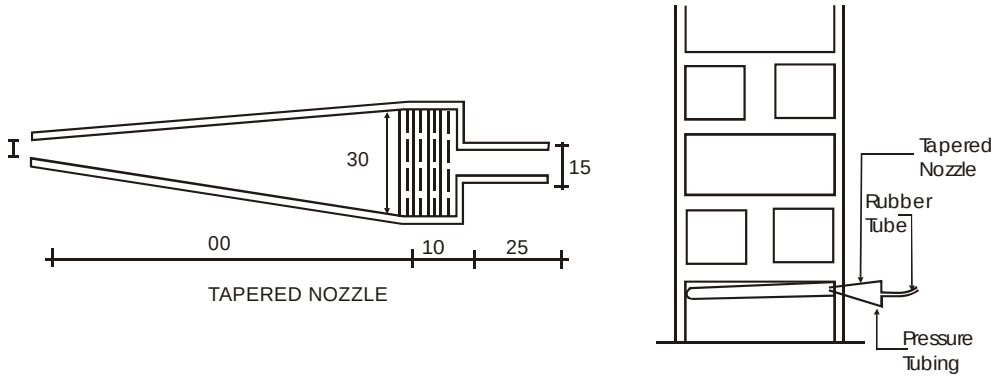


Figure 7.14 : Injecting Damp Proofing Compound

Flat RCC Roofs

Water proofing is done by mud phuska with brick bites. Initially, a coat of hot bitumen @ 1.7 kg/m^2 of roof area or polyethylene sheet is laid. Over this 100 mm average mud phuska rendered by cowdung plastring is laid, over which one-time layers of brick tiles is laid and pointed with 1:3 cement water. This is a traditional method along with lime terracing.

Ferrocements

It is a latest type of construction being highly crack resistant, impervious and resistant to thermal change. It can be used with advantage as an ideal light weight construction. Some of these construction treatments can be seen in Figure 7.15.

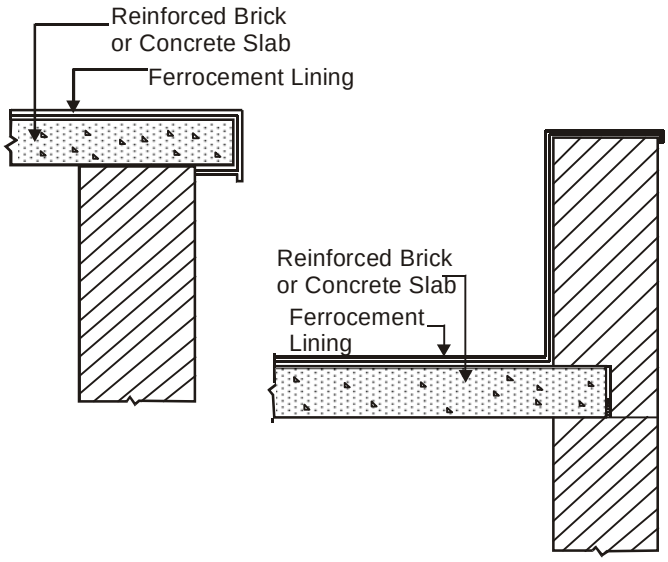


Figure 7.15 : Roof Treatment with Ferrocement

It is produced by providing a layer of galvanised square or hexagonal mesh with 20/24 gauge wire. The 5 mm thick cover blocks are inserted to maintain cover above roof surface. Cement slurry is spread over the roof surface before laying the 1 : 3 cement sand mortar of 20 mm thick. Water-proofing compounds (2-4%) are added to the dry mix. Water-cement ratio is kept at 0.4. The usual curing is started after 12 hours of laying the mortar.

7.3.6 Floors and Roofs

Here some of the recent techniques introduced in roof slab construction are reported.

Thin RC Ribbed Slab

It consists of pre-cast RCC ribs 110 mm × 2200 mm up to 1.2 m c/c with 50 mm thick cast-in-situ RC flange above.

The flange portion is cast using plane simple plywood shuttering panels covered with GI sheets. Compared to conventional in situ RC slab, this method results in saving of 20-35% in overall costs.

Waffel Unit Flooring System

Due to usage of pre-cast moulding materials this type of flooring system is faster in construction and saves time. Further details and components of the system are shown in Figure 7.16.

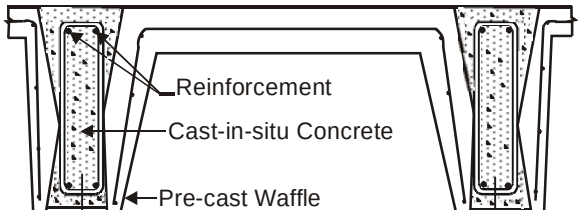


Figure 7.16 : Waffle unit Slab

Lift Slab Construction

In this construction system, several slabs are cast one over another as shown in Figure 7.17. After completing the casting and attaining strength they are lifted up using the hydraulic jacks of the order of 70 tons capacity. If the

height is more than 4 storeys, the columns are also extended in a staged manner. The slabs are fixed to the column by means of collars, which are embedded in the slab, and shear plates, which are welded to the column reinforcement at the correct floor level.

It is convenient to cast floors one on the top of other, without having to erect and dismantle shuttering, which cost 30 percent of the total cost of slab. Productivity is increased as all the slabs are cast at the ground level. However, in India, so far the lift slab construction has been done only at experimental stage.

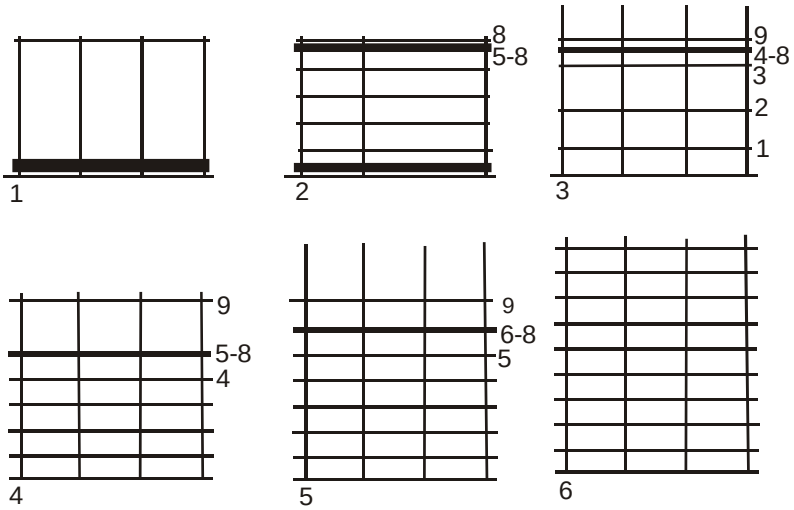


Figure 7.17 : Principles of Lift Slab Construction

In lift slab construction, all the slabs of multistoried building are cast at the ground level one above the other with a separating medium in between. They are then lifted to their final position by means of jacks and are permanently "connected" to the columns. The walls are filled in later on. The foundations and columns are built in the traditional RCC or steel construction. The slabs can be cast every alternate day. After the slabs have attained sufficient strength, they are lifted by using hydraulic jacks (of 70 t capacity). The slabs are connected to the jacks by high tensile wires. All jacks are simultaneously controlled from a single consol. The lift rate may be 1.2 to 4 m/hr. The slabs are fixed to the columns by means of collars (embedded in the slab) and shear plates, which are welded to the columns (Figure 7.17). This type of constructional shuttering costs about 1/3rd of the total costs of the slab and also the rate of erection is faster.

Ferrocement Flooring/Roofing

Ferro-cement is a highly versatile form of reinforcement work and it is a crack proof material. It has more life because quality rich cement concrete mortar is used in this type of construction. These are used in many forms depending on the requirement. These may be pre-cast units or cast-in-situ.

SAQ 2

(a) What are the common defects causing leakage in buildings?

(b) Discuss various ground improvement techniques for foundation.

7.4 PREFABRICATION

Large panel system of prefabrication has been prevalent in mass construction of buildings in US and Europe. The panels consisting of room size units of roofs and walls are produced in mass scale in factories and then transported to the building site, where they are assembled with the help of building cranes and mass construction equipment. These are assembled and joined together by using the large varieties of plastic and epoxy resins. It takes only a few days to complete a multistoried building, which would have taken several months if traditional methods of construction are used. Introduction of modular system in building planning makes the problem of mass production much easier. Some of the most common methods are described in this section.

It is possible to build houses of different plans and sizes with the combination of these two types of panels.

7.4.1 Prefabricated Wall Panel

A low cost construction for walls and roofs developed by the CBRI, Roorkee is described below. Figure 7.18 shows prefabricated brick panels of size 515 mm × 1050 mm or 500 mm × 865 mm.

The panels are pre-cast in moulds and 1 : 4 cement mortar is filled in the joints. It is soaked in water for about 3 weeks, to make them ready for transporting and assembling at site. Hooks are provided for lifting and carrying. The wall panels are assembled over the foundation leaving a 50 mm gap. One 6 mm dia steel bar is provided vertically in the joint, which is then filled with 1 : 2 : 4 concrete with 10 mm down aggregates.

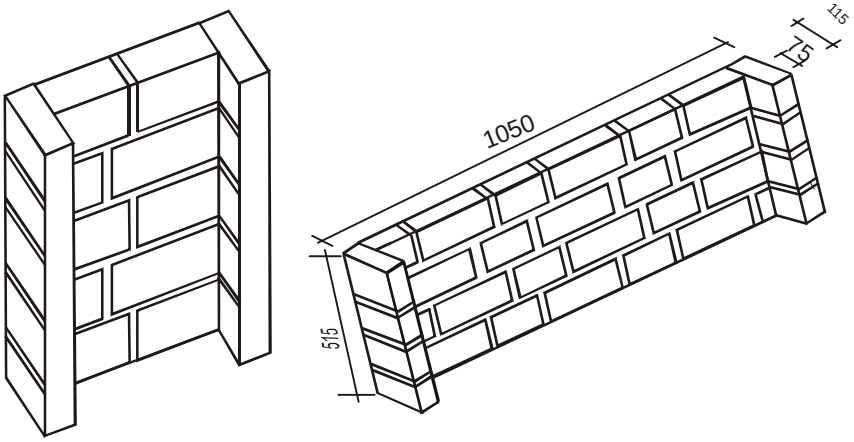


Figure 7.18 : Prefabricated Brick Panels

Universal Concrete Panel System (UCOPAN)

This system of pre-cast RC construction has been developed by the Calcutta metropolitan planning organisation, where 50mm size units for door window and solid wall panels. The 900 mm × 2700 mm × 40 mm thick units weigh 300 to 350 kg (Figure 7.19) similar panels of 350 to 400 kg are cast for floors or roofs. The casting is done manually or by semi-mechanical process on a horizontal platform. The panels are created by the help of a manually operated plant. The grouting is done at site to join the units. Any building plan conforming to 0.90 m × 3.00 m planning grid can be built by using this method.

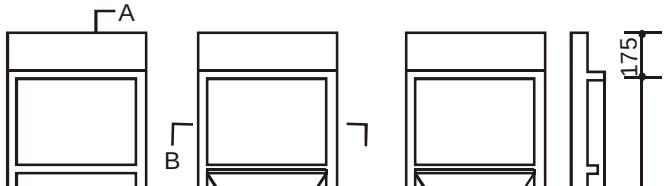


Figure 7.19 : UCOPAN System

CELCON System

This system is developed by the Tamil Nadu Housing Board for construction of single-storeyed house. In this system, 1 m wide × 3 m high × 120 mm deep channel shaped reinforced cellular concrete pre-cast panels are used for walls. For roof, 0.60 m × 3 m × 120 mm thick doubly reinforced cellular concrete units are used. The panels weigh 300-350 kg. Figure 7.20 gives the plan of such houses.

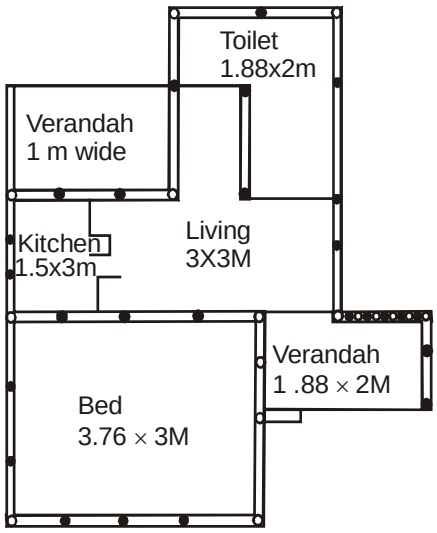


Figure 7.20 : Plan of House with CELCON System

7.4.2 Large Panel System

This system is widely used in Europe where various system types are developed. They are used for 5 to 16 storied high buildings and are factory-produced units to be transported and assembled at site. The wall panels are lightweight RC elements. They are either single leaf unit or composite or sandwich panels (Figure 7.21).

External panels may be 250 mm thick while internal ones are 150 mm thick. The weights vary from 2 to 7 tons. Doors and window frames, conduits and pipes for plumbing and electrical wiring are all fitted and fixed. The concrete used is M-25 or M-30. Joints are filled with M-20 concrete.

Mechanized methods of construction are used at site. The fast rate of completion of work which is 13 hours/m^2 as against 26 hours/m^2 for the traditional construction more than offset the entire costs involved.

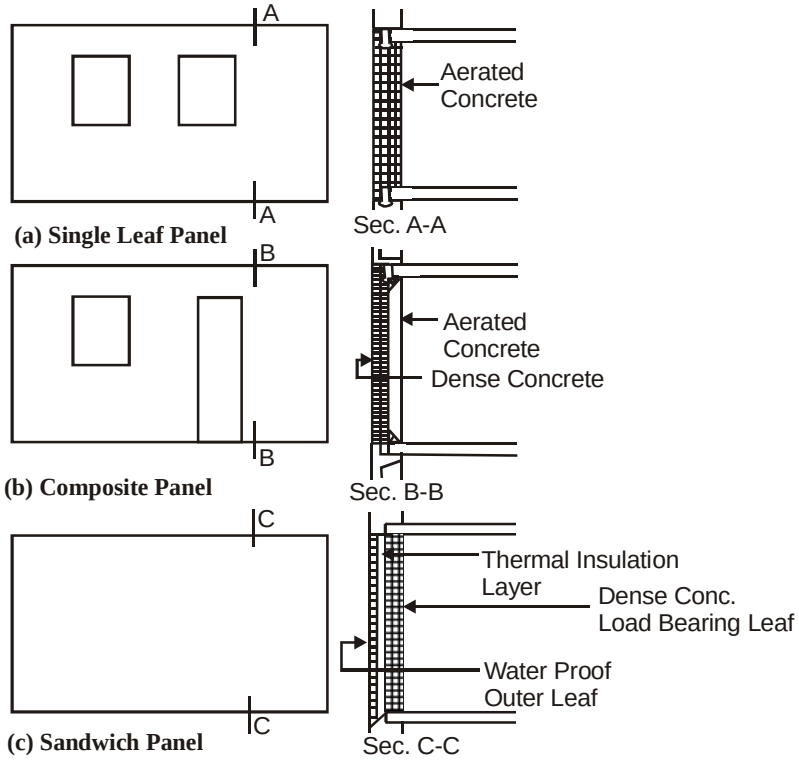


Figure 7.21 : Large Wall Panels

7.4.3 Box Type Construction

In this method of construction, single or multi-room size boxes houses 4 walls, doors, window, etc. and top floor all completely prefabricated in factories and transported and erected at site (Figure 7.22). These are especially suited in very cold countries of North and Eastern Europe, where at site construction is difficult because of extreme cold conditions.

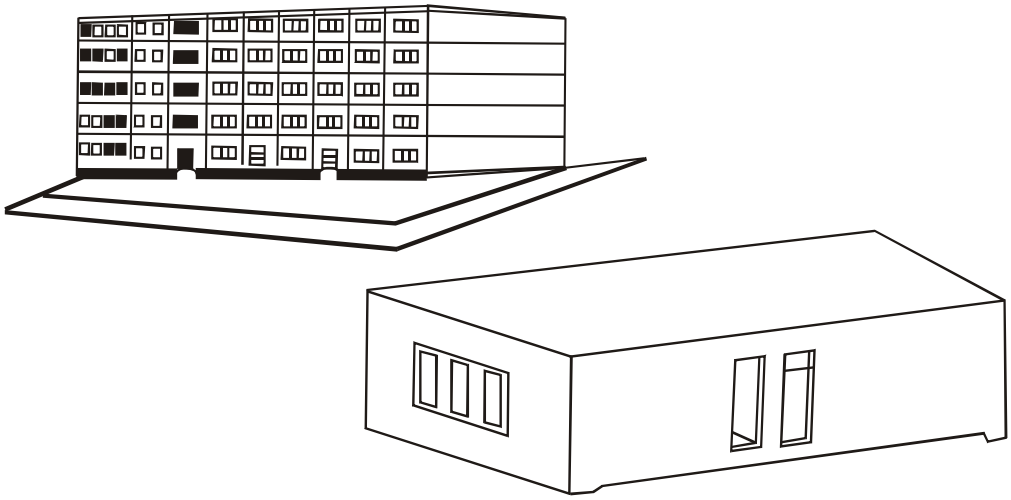


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Figure 7.22 : Box Type Construction

7.4.4 Pre-cast Framed Construction

The different components of the structure of a building, like columns, beams, floor, roof units are pre-cast elements used in this construction. The infill walls of a building can also be pre-cast elements. This type of construction is quick in

nature and also maintains the material quality because of controlled supervision of casting in manufacturing unit. But it needs specialized skill manpower for construction or errection on the site.

Skelton System

In this system, columns and beams are pre-cast with a special arrangements like groves and notches, etc. The details are shown in Figure 7.23. These will be assembled systematically to construct the required structure. The construction is fast and economical.

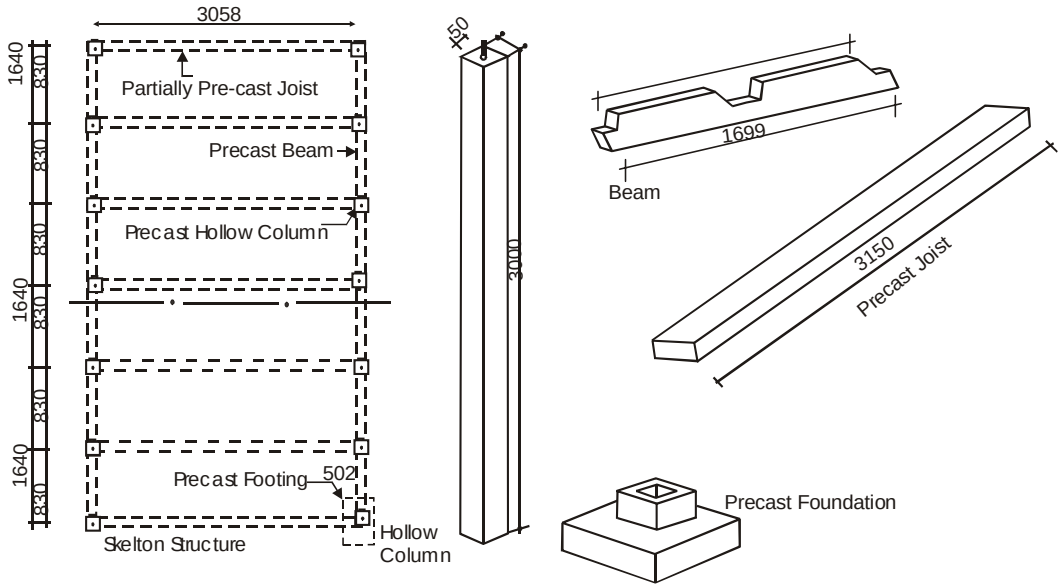

Figure 7.23 : Concrete Skeleton System

Prefab Brick Panels for Roofs

It consists of pre-cast RB Panels 560 mm × 1200 mm × 75 mm thick placed over pre-cast RC Joints 100 mm × 1300 mm section and up to 4.2 m long spaced at 1.2 m center to centre. 35 mm thick structural deck concrete with nominal reinforcement is provided over the panels. The panels are cast manually in timber forms and weigh 75-90 kg (Figure 7.24).

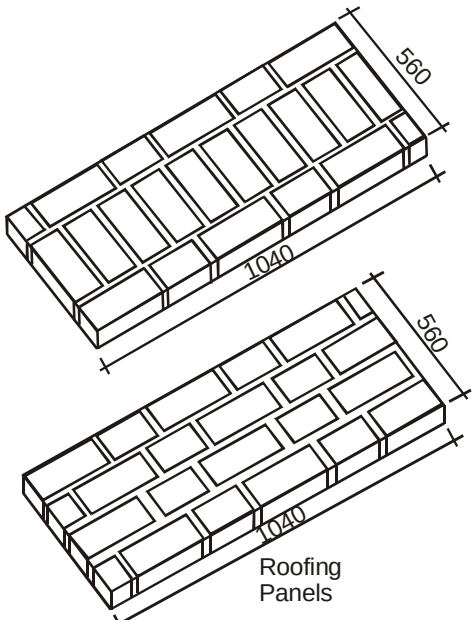

Figure 7.24 : Prefab Brick Panels for Roofs

They are lifted and placed over the pre-cast beams, which is supported on pipes till the curing is completed. This involves a saving of about 15% over the traditional methods of constructions.

SAQ 3

Explain various pre-cast framed construction with their advantages.

7.5 SUMMARY

During the last few decades, there have been significant developments in the field of new construction materials as well as new construction techniques. This has been possible mainly due to the technological and scientific progress as witnessed in all other fields of human activities. But the main causative factor has been to fulfill the basic housing needs of a fast growing world population, as well as the necessity of conserving energy and fuel in buildings and also in manufacturing and production of materials. With the greater awareness of prevention of pollution the various environmental factors have to be taken into account. This can be seen in the gradual replacement of timber and forest products by synthetic products like polymers and plastics.

Bricks and tiles are now being machine manufactured and mass-produced, thus lowering the fuel and energy requirements. Same can be said of cement and concrete. Now various types of admixtures are available that can increase the quality, strength and durability of concrete.

However, the most remarkable developments have taken place in the field of construction methods. The modern trend is again towards machanisation and mass production. To fulfill the requirements of multi-rise and energy-conserving buildings, new methods of construction of foundations, walls, roof and floor construction have been devised. Doors, windows, water-supply, drainage, etc. have all improved by the emergence of new techniques that have developed during the last 30 years.

Special attention has been given to prefabrication techniques of manufacture of wall and roof panels, and box type construction. Lastly, pre-cast framed construction has been described.

7.6 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the section ‘Further Reading’ given at the end to get the answers of SAQs.

FURTHER READING

Rangawala, S. C., *Engineering Material*, Charotar Publishing House, Anand.

Rangawala, S. C., *Building Construction*, Charotar Publishing House, Anand.

Merritt, F. S., *Building Construction Handbook*, McGraw Hill Book Company, New York (USA).

Arora, S. P. and Bindra, S. P., *A Text Book of Building Construction*, Dhanpat Rai & Sons, New Delhi.

Arya, A. S. and Ajmani, J., *Design of Steel Structures*, Nem Chand & Bros., Roorkee.

ASHRAE Handbooks.

CONSTRUCTION TECHNOLOGY-II

The infrastructure development in construction industry demands latest technologies and advanced building materials in effective construction project implementation. This course gives an insight to the latest techniques and technologies as well as building materials used in construction of civil structures. For imparting the knowledge of real life situation, a case example of Military Engineering Services (MES), construction wing of Indian Army, has been taken.

The course has been divided into seven units.

Unit 1 introduces you to some important functional and design aspects of building along with their aims and essential requirements. It also gives an exposure to concepts of planning and site organisation of construction project. As a real life case example of an organisation, it also discusses the mechanism of supervision of a work execution, testing of materials particularly practiced in Military Engineering Services (MES).

Unit 2 gives an idea as how the maintenance work is being carried out in MES. This unit explains overall concepts like repair and their execution, planning of maintenance works and also procedures of preventive maintenance of buildings.

Unit 3 deals with causes and effects of fire damaging the buildings along with the description of fire protection and prevention techniques. It also discusses how to maintain the fire safety in the buildings.

Unit 4 explains the usages of different steel sections, built-up sections commonly used in civil structures. It also gives an understanding to different types of connections like bolted, riveted and welded connections.

Unit 5 describes the basic principles and requirements of good acoustical, ventilation and insulation systems in a building. It gives an understanding of good acoustical design of a building along with various ventilation system commonly used in buildings. It also gives an exposure to thermal insulation in terms of principles and methods of application to buildings.

Unit 6 deals with construction plants, like road rollers, concrete mixers, stone crushers, asphalt plants, etc. in terms of their operations and maintenance along with their applications.

Unit 7 deals with the latest construction techniques along with modern building materials and their applications in construction. Towards the end, the unit discusses prefabrication and also describes some of the techniques of prefabricated construction.

The Self-Assessment Questions (SAQs), given in each unit, are intended to help you to self-monitor the progress while reading the study material. After studying each section, try to solve the SAQ independently and check your progress. This will definitely develop your confidence.

At the end, we wish you all the best for your all future educational endeavours.