CONTENTS

UNIT – I

ORGANIZATION OF MAINTENANCE DEPARTMENT - ROLE AND IMPORTANCE OF THE DEPARTMENT IN THE HOTEL INDUSTRY - ORGANIZATIONAL CHART - DUTIES AND RESPONSIBILITIES - TYPES OF MAINTENANCE - ITS ADVANTAGES AND DISADVANTAGES - TYPES OF CONTRACT - PRINCE RATE - LUMPSUM CONTRACT - RATE CONTRACT - TECHNICAL TERMS

OBJECTIVES:

- The meaning & scope of maintenance
- Issues & pre-requisites of maintenance
- Objectives of Maintenance
- Functions of Maintenance
- Types of Maintenance
- Types of Contract
- The Advantages & Disadvantages of Contract Maintenance
- The Technical Terms involved in Maintenance

STRUCTURE:

- what is maintenance
- scope of maintenance
- issues of maintenance
- causes of equipment failure
- objectives of maintenance
- improvement in functional reliability
- breakdown/corrective maintenance
- preventive maintenance
- which maintenance system should be adopted
- maintenance performance indices

Notes

WHAT IS MAINTENANCE:

Maintenance is a combination of actions carried out to retain an item/machine/equipment/system in order to restore it to an acceptable condition.

Maintenance ensures that the entire system is kept reliable, useful and efficient.

The purpose of maintenance is control of system availability.

The term maintenance covers the following aspects-

(a) Inspection of plant/equipment/machine/system

(b) Repair of defects

(c) Minor modification to reduce maintenance efforts

The basic function of maintenance is to keep plant, machinery, equipment, system in a condition that will meet normal operating requirements.

SCOPE OF MAINTENANCE:

In case of Hotel industry the maintenance of following can be done –

(a) Land

(b) Site development – boundary wall, septic tank, storage tank, etc.

(c) Buildings

(d) Plants, machinery, equipments and systems

(e) Water supply system

(f) Water heating system

(g) Gas distribution system

(h) Fuel line system

(i) Drainage system

(j) Waste disposal system

(k) Pollution control equipments

(l) Power supply system

(m) Ventilation, refrigeration and air conditioning system

(n) Fire fighting equipments

(o) Maintenance equipments and hand tools

(p) Laundry equipments

(q) Kitchen equipments or ranges

(r) Telephone system, Fax, Telex, E-mail

(s) TV cable system etc.

ISSUES OF MAINTENANCE:

(a) Scheduling of maintenance work – Timing and sequence of operation.

(b) Maintenance crew – size, remuneration, supervision and organization inspectors, mechanics, electricians, cleaners, plumbers, carpenters, paints, welders, masons, etc.

(c) Cost control of maintenance

(d) Records of maintenance

PRE REQUISITES OF EFFECTIVE MAINTENANCE SYSTEM :

These are as follows:

(a) Good information for analysis of equipment failure

(b) Planning of maintenance programme

(c) Ensuring availability of spares

(d) Keeping track of pending jobs

(e) Development of maintenance standards

(f) Evaluation and control of maintenance costs

Notes

CAUSES OF EQUIPMENT FAILURE:

The equipment may fail because of the following factors –

(a) Wrong design

(b) Wrong operation procedure

(c) The planning of equipment capacity

(d) Willful negligence on the part of operating personnel

(e) Nature's fury

OBJECTIVES OF MAINTENANCE:

They are:

(a) To increase safety of guests/employees of hotel

(b) To maximize the availability and reliability of all the assets

(c) To obtain the maximum possible return on investment

(d) To extend the useful life of assets

(e) To ensure operations readiness of all equipments required for emergency use at all times

(f) To ensure the safety of personnel using facilities

(g) To keep equipment down time minimum

(h) To decrease overall cost of operations

(i) To minimize cost of maintenance

(j) To increase operation stability

(k) To increase the operations efficiency of facilities

(l) To increase customer satisfaction

(m) To reduce energy expenditure

IMPROVEMENT IN FUNCTIONAL RELIABILITY:

(a) To employ sufficient maintenance staff

(b) To develop parallel paths/buffers

(c) To provide for the stand by equipments

(d) To adopt the preventive/predictive maintenance polity

(e) To keep maintenance time standards

PRODUCTIVITY IMPROVEMENT:

Productivity improvement is possible through

(a) Frequency of inspection

(b) Prevention checks and repairs

(c) Predictive maintenance policy

(d) Proper work allocation

(e) Improvement of work skills

(f) Control on cost of spares

(g) Use of proper materials

(h) Use of proper tools and techniques

(i) Standardization of parts and equipments

(j) Supervision, etc.

BENEFITS OF MAINTENANCE:

The benefits of maintenance are :

(a) Smooth and continuous operation

(b) Minimum chances of breakdown and accidents

(c) Minimize adverse effects on the workers/employees/guests

(d) Minimize equipment downtime

(e) Increase customer satisfaction

(f) Less overtime to be paid to employees

(g) Reduces large scale repairs

(h) Reduction in number of maintenance jobs waiting list

(i) Better quality services

(j) Lesser number of stand bys are needed

(k) Less destruction of equipments

(l) Less losses due to less failures

DIFFICULTIES IN MAINTENANCE:

Certain difficulties may be encountered during maintenance, these are:

(a) Inaccessible locations

(b) Hazards due to working at abnormal heights and depths

(c) In site welding

(d) On line maintenance

(e) Inflammable environments, fire hazards, chemical hazards, gaseous fumes, radiation exposure, etc.

(f) Presence of rust, grease, and coating

(g) Presence of water, oil, steam and chemicals etc.

Notes

FUNCTIONS OF MAINTENANCE PLANNING AND CONTROL:

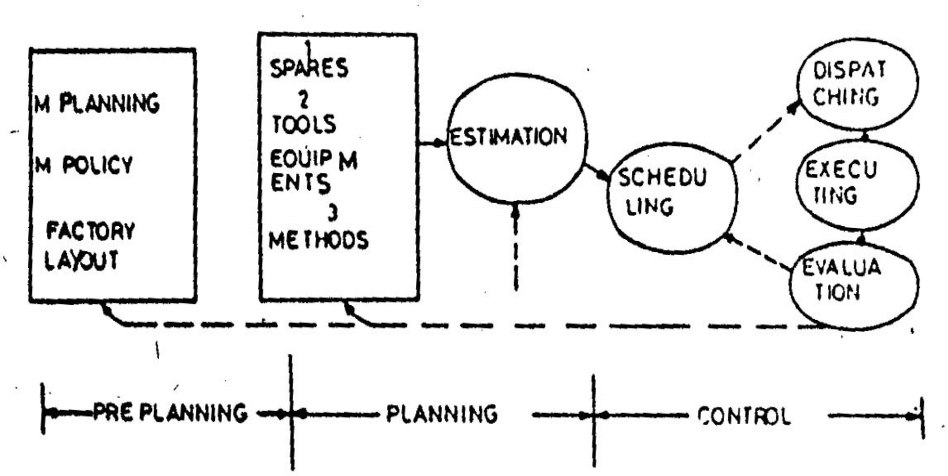


Figure Functions of Maintenance Planning and Control

The functions of maintenance department are as follows:

I. Preparation

(a) Maintenance request

(b) Assets/facilities register

(c) Maintenance Schedule

(d) Work/job specification

(e) Programming annual & weekly planned maintenance programme

(f) Inspection report

(g) History records

(h) Planned lubrication

(i) Work priority

(j) Facility priority

(k) Safety

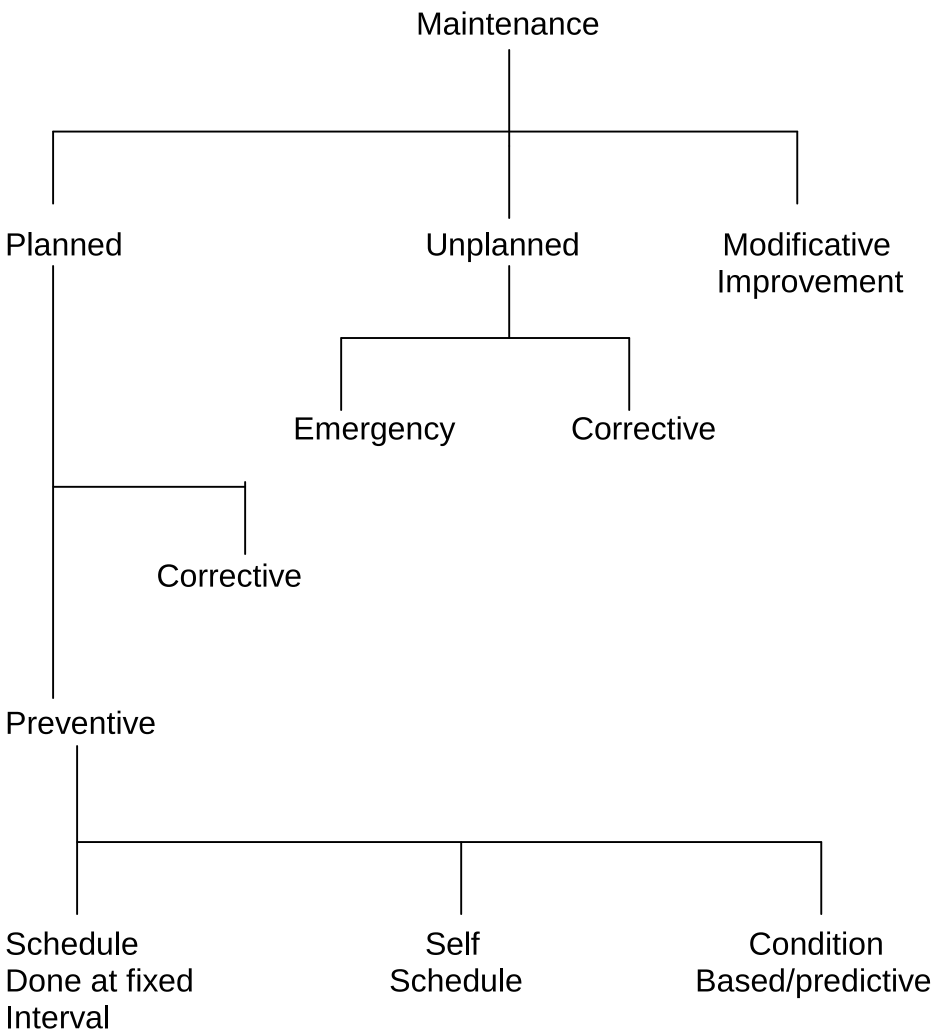
II. Operation

Routine analysis, Labour and cost, work measurement, managing work loading.

III. Progression

Critical analysis

CLASSIFICATION OF MAINTENANCE:



ROUTINE/CONTINUOUS MAINTENANCE:

Regular operation are done without thinking about economy – such as:

(a) Sweeping carpets, mats, etc.

(b) Washing floors, walls, etc.

(c) Cleaning readily accessible windows, doors, ventilators etc.

(d) Cutting grass, sizing trees, shrubs, etc.

(e) Cleaning guest room

(f) Showling snow

(g) Replacing burnt out light bulbs, tube lights etc.

(h) Lubrication of machines/equipments

(i) Adjustment of machines/equipments, etc.

SCHEDULED MAINTENANCE:

It is initiated at the property based on a formal work order which identifies a known problem.

Scheduled maintenance covers inspection, adjustments, repair, replacement, predetermined from past failure patterns.

REPAIR MAINTENANCE:

When any breakdown occurs, the repair maintenance staff endeavors to locate fault and correct it immediately.

The function involves the disassembling of the equipment, to locate the fault, to find out that part needed to replace it, to reassemble, then to check the equipment to ensure that it has restored its functional capacity.

ORGANIZED MAINTENANCE:

It is for sophisticated equipments and it requires higher skilled maintenance crew, these are available in limited number and they demand higher wages.

Notes

EMERGENCY MAINTENANCE:

It requires disruption of scheduled activities.

PLANNED MAINTENANCE:

Maintenance is planned in advance. Planned maintenance may be preventive and corrective/breakdown.

BREAKDOWN/CORRECTIVE MAINTENANCE:

The activity of repair after breakdown. A failed component or system is repaired and put back to operating condition. It consists of locating the trouble in parts, opening it, put back in use after repair/replacement.

The operation of certain equipment/system component is not functionally/economically critical. Therefore does not warrant the need for periodic inspection.

Break down may be minor, major, complete stoppage of equipment/do not causes work stoppage, repairable/irreparable once.

Methods of cleaning are:

Thermal method – with the aid of stove flame

Mechanical methods – with the help of brushes, rotor machine

Abrasive method – Hydraulic Sand blasters

Chemical methods – Solution unstacked lime chalk, caustic soda, fuel oil subjected to ultrasonic vibration.

Methods of Washing:

Kerosene

Gasoline

Alkali solution 3.5% solution of soda ash 0.5% aqueous solution of soda.

Activities during breakdown maintenance:

The activities during maintenance are:

Location of fault

Prepare to dismantle

Dismantle

Clean the component

Inspect wear, cracks, and dents

Repair, replace, and fit in components

Lubricate

Assemble

DESIGN OUT MAINTENANCE:

Here we try to eliminate the cause of maintenance

Poor design of equipment leads to frequent breakdown

An appropriate choice of tri-biological material might eliminate the needs for subsequent lubrication frequency.

PREVENTIVE MAINTENANCE:

It is a combination of those actions as a result of which equipment will be expected to continue performing the operation it is intended to do Preventive maintenance.

Regular type maintenance, oiling and cleaning. Periodic inspection – Identification of faults, further fault is required then first fault will be apparent, identification of degradation failure.

Preventive maintenance is carried to prevent sudden/catastrophic failure. It can be considered when corrective maintenance is not justified. It is safe against possible risk.

Features –

- It is simple and flexible.
- It can be adopted for any equipment.
- It is a corrective measure.

Policy:

- Regulation of activities
- Direction regarding when and how to start activities
- Procedures
- Resources

Objectives:

- To find any condition that may cause machine/equipment failure before such a breakdown occurs.
- To reduce expenditure in repairs
- To increase productivity through modification made during planned overhauls.

Activities:

- Inspection
- Dis-assemble the component
- Clean the component
- Replace the component/repair the component
- Lubricate the component
- Prepare to assemble
- Assemble the component

The based Preventive Maintenance:

The third stage of bath tub failure curve as shown in Figure.

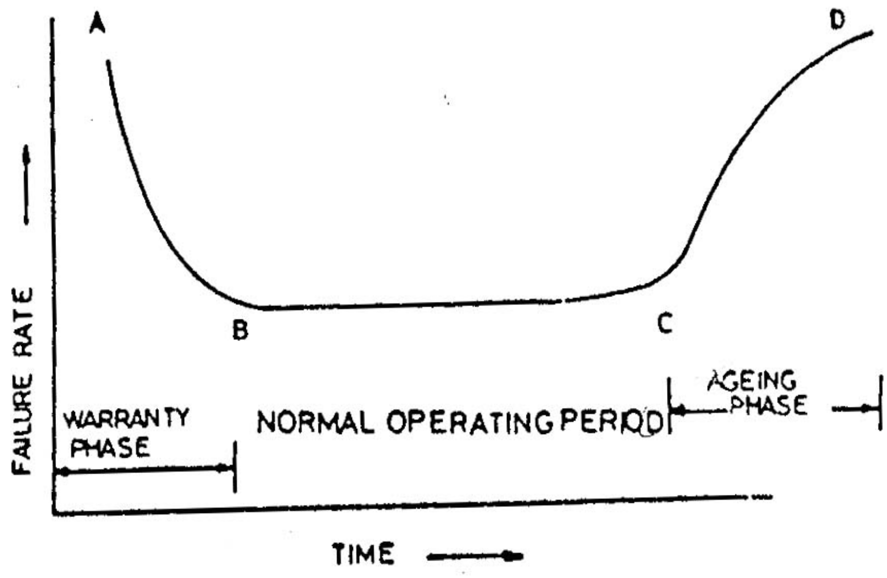


Figure Bath Tub Curve

Selective basis for preventive Maintenance:

It is not desirable to apply preventive maintenance to all the equipments of a plant.

For this purpose A, B, C analysis can be done and select equipments which are vital for operation (failure of which causes the whole unit to trip own) critical equipments-

(a) Failure of the unit would endanger health or safety of operating personnel.

(b) Failure would affect quality of product

(c) Capital invested is high

Preventive maintenance should be supplemented by

(a) Good paper work

(b) Good work planning and scheduling

(c) Sufficient trained manpower

(d) Good workshop and tools

(e) Good work measurement system

(f) Good controlling system

Pre-requisites for success of preventive maintenance-

(a) A sound personnel policy:

Maintenance personnel should have the necessary technical know how. Sound recruitment and promotion policies and facilities for retraining personnel is necessary.

(b) Proper equipment policy:

A proper policy on purchases of equipments, spares and other maintenance items in essential.

(c) Provision of auxiliary service:

Auxiliary service shops, internal transport facilities, supply of spare parts are necessary.

(d) Permissive Management Leadership:

Delegation, reporting and controlling is necessary.

Basic contents of preventive maintenance programme:

(a) Planning machines, materials and men

(b) Inspection

(c) Taking prompt action

(d) Routine maintenance

Advantage of preventive maintenance:

(a) Down time reduction

(b) Operation loss reduction

(c) Lower maintenance and operating cost

(d) Lower over time

(e) Minimum inventory of spare parts

(f) Lower operation pay

(g) Smooth operation

(h) Less manpower is needed

(i) Minimum danger to life and surrounding machines

(j) Better customer satisfaction

(k) Greater safety to workers

(l) Less damage to equipments

(m) Better life of parts

(n) Improved reliability and availability

(o) Increased percentage utilization

(p) Maximum return on capital investment

Draw backs:

(a) Certain amount of break down/catastrophic failures occurs even preventive maintenance is adopted.

(b) No prior warning can be obtained from equipment.

(c) Premature failures are there

(d) We do not know future life of equipment; even we go on repairing the equipment.

Factors:

(a) Previous breakdown

(b) Type and nature of repairs, periods

(c) Loss incurred due to shut down

(d) Time required for repair

Notes

(e) Cleaning and servicing time

Frequency cycle of inspection depending upon:

(a) Age

(b) Condition

(c) Value

(d) Severity of service

(e) Safety required

(f) Hours of operation

(g) Susceptibility of wear – exposure to dirt, friction, fatigue, stress concentration.

(h) Susceptibility to damage due to vibration, overload, mishandling.

(i) Complexity of machine.

(j) Susceptibility to losing adjustment.

Preventive maintenance Schedule:

(a) List of equipments

(b) Maintenance jobs to be done

(c) Methods of doing maintenance jobs

(d) Time, manpower, tools needed

(e) Time for which machine will be kept shut down

(f) Loss of operation due to shut down

(g) Periodicity of preventive maintenance

(h) Nature of repair

Preventive maintenance is based on the premises:

That continuing functioning of certain equipment is essential to the servicing and maintenance to prevent their functional failures.

Preventive maintenance is based on two themes:

- Prevention is better than cure.
- A stitch in time saves nine

Both aim to maintain equipment at its planned capacity by the most economically means.

Preventive maintenance is based on Techno economic measure, machinery erection, value analysis, cost effectiveness and defect analysis.

Strategies of preventive maintenance:

Perform preventive maintenance whenever the system completes a specified period of uninterrupted use. When the system has large number of components, this is not possible.

Perform preventive maintenance at time T, 2T, --- where T is a constant, when a unit fails, make replacement at that instant, block replacement policy.

Perform preventive maintenance at times T, 2T ------

If the unit fails between these time limits then postpone replacement, if residual time to less than a stipulated duration. The system is left idle till next planned preventive maintenance.

Make continuous inspection of the system and perform preventive maintenance whenever wear become constant.

The intervals for time based maintenance are determined primarily on the basis of failures statistics and associated cost. The optimum policy is to minimize overtime while providing the most effective use of system in order to secure desired results at the lowest possible costs.

Figure shows relationship between cost and amount of preventive maintenance.

Notes

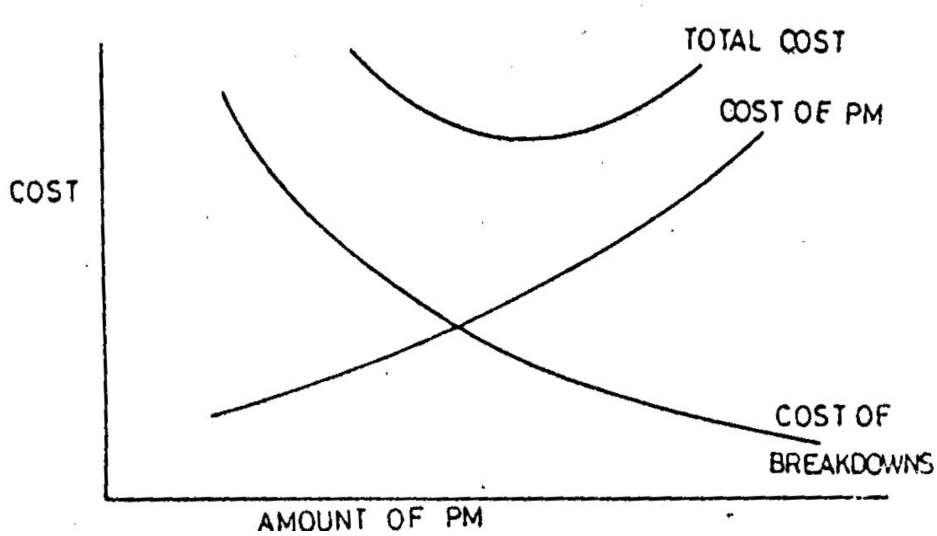


Figure Cost relationship of maintenance alternatives

PREDICTIVE/CONDITION BASED MAINTENANCE:

It diagnoses the condition of equipment during operation by identifying rate of deterioration or imminent failures with a view to determine when maintenance is required.

It is suitable for equipment that is expensive to repair or that causes serious losses if breakdown takes place.

One can make use of predictive maintenance by using a technique called signature analysis, which is intended to continually monitor the health of equipment by recording systematically signals derived from the form of vibration, noise, thermal emission, change in chemical composition, smell, pressure, relative displacement, etc.

Scientific collection of these signatures by a thorough analysis of the signatures based on the knowledge acquired in the field and judging the severity of the fault for decision making, all put together is called signature analysis.

Advantages:

(a) Prevents the breakdown/catastrophic/premature failure

(b) Safety, reliability and availability increases

(c) Cost of maintenance is less

(d) Proper planning to avoid failure

(e) Less down time

Disadvantages:

(a) Requires skilled personnel

(b) Requires costly monitoring equipments

WHICH MAINTENANCE SYSTEM SHOULD BE ADOPTED:

System adopted should be

(a) Which reduces the cost of maintenance?

(b) Which make the equipment available for operation uninterruptedly allowing for normal time required for periodical overhauls?

(c) Which give steady operation of equipment for producing quality production at minimum cost?

Criteria	Breakdown Maintenance	Preventive Maintenance	Predictive Maintenance
Breakdown	Highest	Small	Almost negligible
Product output	Low	High	High
Maintenance cost	High	Low	Low
Reliability/Availability	Low	High	Very High
Control of spares and inventory	No	Yes	Yes
Prior Warning before breakdown	No	No	Yes

Notes

MAINTENANCE PERFORMANCE INDICES:

1. Percentage Equipment availability

$$= \frac{\text{Eq. hours available for operation}}{\text{Total calendar hours during the period}} \times 100$$

2. Percentage maintenance cost index $= \frac{\text{Maintenance cost}}{\text{Capital cost}} \times 100$

3. Percentage fulfillment of schedule

$$= \frac{\text{Volume of scheduled work done during normal hours}}{\text{Total volume of work scheduled}} \times 100$$

4. Over time hours ratio $= \frac{\text{Overtime hours worked}}{\text{Total maintenance man hours}}$

5. Percentage inspection effectiveness

$$= \frac{\text{Standard minutes of work saved by improved inspection}}{\text{Total minutes of inspection carried out}}$$

6. Standardization effectiveness

$$= \frac{\text{Total saving affected by standardization}}{\text{Total maintenance cost}}$$

7. Inventory index

$$= \frac{\text{Cost of maintenance materials actually used}}{\text{Total maintenance stores in hand}}$$

Notes

8. Maintenance productivity index

$$= \frac{\text{Output of product}}{\text{Cost of maintenance effort}}$$

9. Downtime index

$$= \frac{\text{Downtime hours}}{\text{Production hours}} \times 100$$

10. Waste index

$$= \frac{\text{Quality of waste product}}{\text{Quality of total output}}$$

11. Breakdown maintenance index

$$= \frac{\text{Total hours spent on break down}}{\text{Total maintenance hours available}}$$

12. Level of maintenance

$$= \frac{\text{Total hours spent on maintenance}}{\text{Total man hours available}}$$

13. Technical competence ratio

$$= \frac{\text{Modification made during year}}{\text{Total annual maintenance cost}}$$

Notes

MAINTENANCE – A SYSTEM APPROACH:

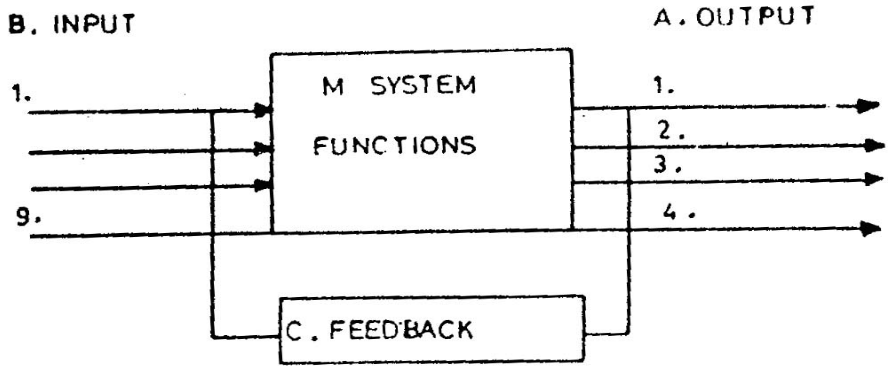


Figure Maintenance System

Objectives of the system are

(a) Reliability
(b) Availability
(c) Operational efficiency
(d) Safety

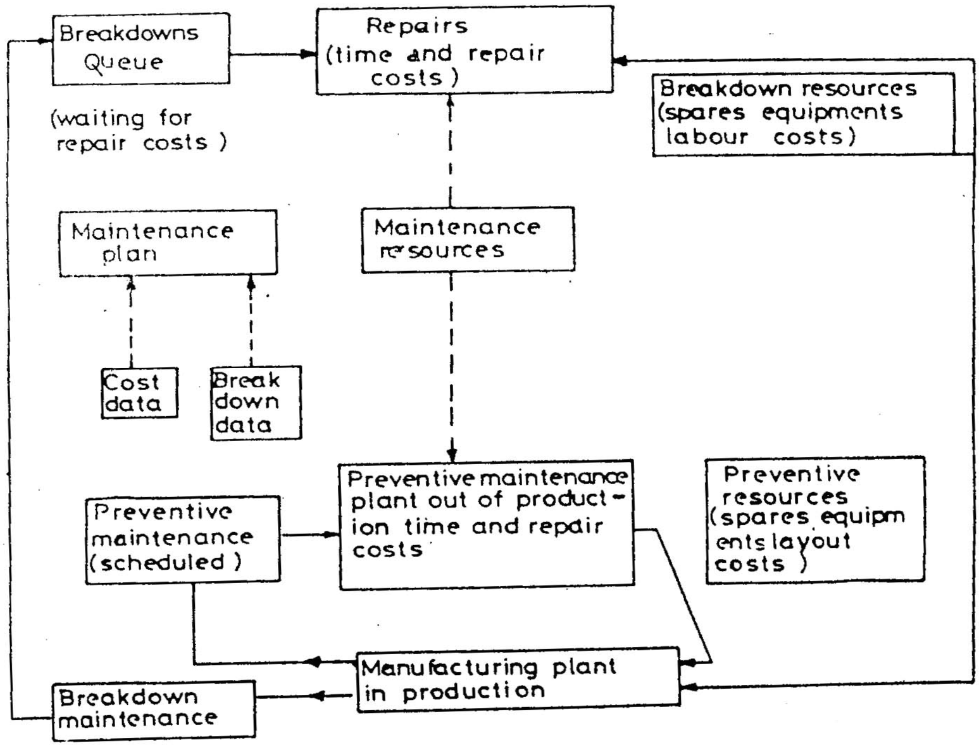


Figure A General model of a maintenance system

Notes

The purpose of the maintenance system is to secure reliable performance from the system.

Maintenance system outputs

(a) Schedule for the execution of selected policies.

(b) Reports prepared covering maintenance work done.

Total maintenance cost = cost of PM + cost of corrective maintenance + cost of downtime for desired degree of reliability.

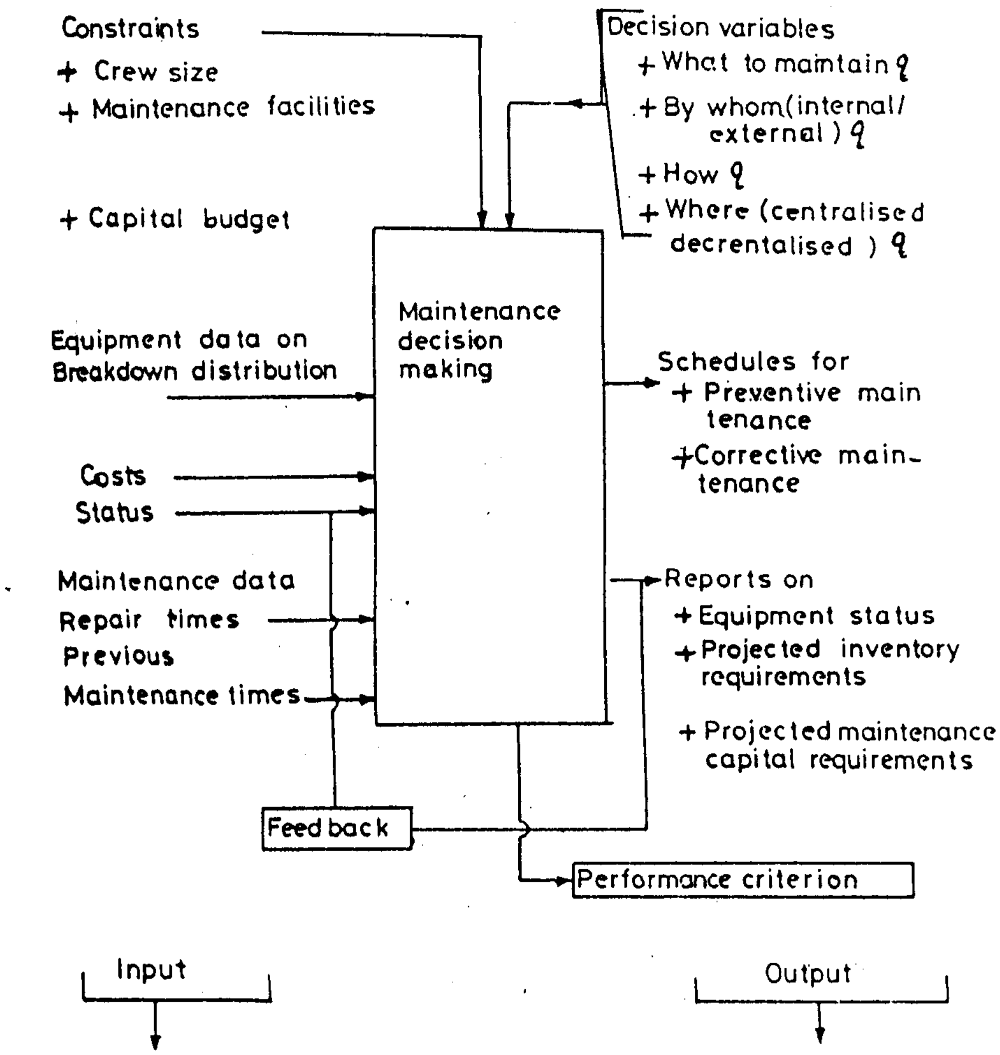


Figure Operation management of a maintenance system

Notes

MAINTENANCE/LOG BOOK:

(a) Records

(b) Ready reference for future

(c) Information to management

(d) Store

(e) Purchase

ENGINEERING/MAINTENANCE DEPARTMENT OF A HOTEL:

The personnel and the equipments under their control provide the comforts demanded by the guests.

The maintenance department affects the operation of the other departments of the lodging establishment.

The care and operation of the physical plant is largely the responsibility of maintenance department.

Objectives of maintenance department are:

(a) Protects the investment in the physical plant

(b) Controls the maintenance cost

(c) Minimizes the energy cost of the facilities

(d) Minimizes safety problems

(e) Supply and distribution of power, water, etc.

(f) Reduces down time

(g) Provides better services to customers

(h) Provides higher market value services

(i) Provides services at lower cost

(j) Provides timely services

(k) Makes longer life for equipments

(l) Provides higher safety and morale for employees

(m) Provides better environment for community

(n) Provides smoother and continuous running of hotel

(o) Provides efficient waste disposal system

(p) Ensures higher salvage value of equipments.

Function of maintenance department:

(a) To ensure repair of equipment under breakdown in shortest possible time.

(b) To introduce certain check lists etc. to prevent breakdown of equipment to maximum possible extent.

(c) Maintenance of existing equipments

(d) Equipment inspection, cleaning, lubrication, etc.

(e) Alteration of existing equipments

(f) Protects plant

(g) Looks after waste disposal system

(h) Increases salvage value of equipments

(i) Overhauls equipments

(j) Construction of equipments

Maintenance can be organized as:

(a) Centralized

(b) Decentralized – placed under shop/section superintendent

(c) A combination of two

In depends upon

(a) Physical location of facilities

(b) Type of equipment in use and its age

(c) Availability of skilled maintenance personnel

Notes

Maintenance Organization structure of a 200 rooms hotel is shown in Figure.

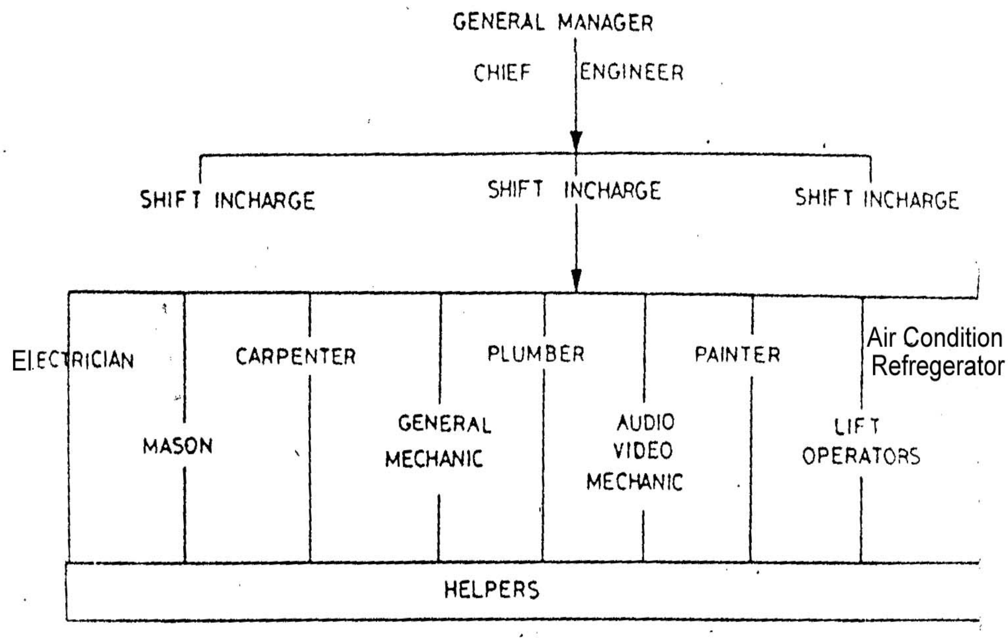


Figure 200 Rooms Hotel Maintenance Organization Structure

Maintenance of equipments need the coordinated efforts of all concerned with hotel because

(a) Maintenance is affected by the operational procedures.

(b) Maintenance is affected by the equipments and utilities.

(c) Maintenance is affected by the service plants.

(d) Equipment life is affected by the operational parameters.

(e) Hotels are affected by the use of substandard raw materials processing water, etc.

(f) Equipments getting affected and damaged due to scale forming, chocking of pipe lines, vessels, etc.

Traits of maintenance staff - are

(a) Patience

(b) Analytical mind

(c) Dignity of labour

Training of maintenance staff consists of

(a) General training

(b) Departmental training

(c) Job specific training

MAINTENANCE PROGRAMMES:

- Management maintenance policy – Objective types of programmes,
- Inventories and records of the system, system components, equipments and controls.
- Construction drawings and specifications
- Shop drawings and equipment catalogs.
- Equipment installation, service and maintenance instructions, trouble shooting check lists, spare parts list.
- Value charts, system diagrams, etc.
- Procedures and schedules
- Operation instructions
- Starting and stopping procedures
- Adjusting and regulation
- Logging and recording
- Inspection

Service& repair

- Frequency scheduled service
- Scheduled service procedure
- Repair procedure
- Recording and reporting

Notes

- System of records
- Inventory data
- Operating, inspecting, servicing instructions, procedures, schedule records and reports, works performed.
- Time spent and parts and supplies used
- Operating and maintenance manuals

MAINTENANCE STRATEGY:

A collection of methods and activities by which the operations availability aimed at by the maintenance policy can be achieved.

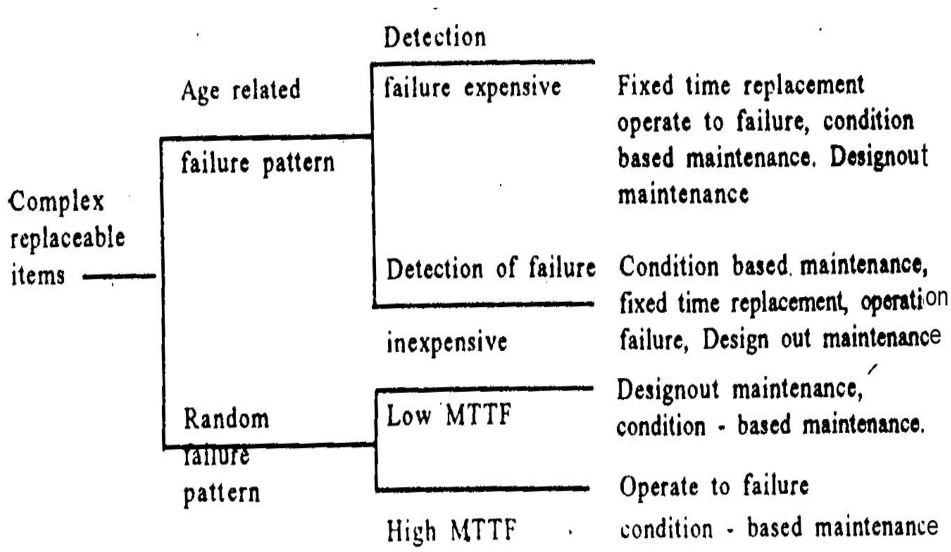


Figure Selection of maintenance strategy for complex plant items

MAINTENANCE COST

Consists of

(a) Repair and maintenance expenses

(b) Dismantling expenses

(c) Cost of producing and distributing utilities for maintenance work

(d) Experimental work cost

- Annuity form of expenses, equipments whose life expectancy is short.
- Cost of alteration, modernization, structural changes of building
- Down time cost
- Machine operation loss temporary, relocation of business. Tent Inconvenience
- Materials cost, spare parts
- Personnel cost
- External services cost – contractor
- Hiring of special equipments
- Maintenance overheads
- Cost of workshop, tools, storekeeper wages, sweeper, cleaner, etc.
- Maintenance labour cost 20%
- Maintenance materials 40%
- Fuel cost 25%
- Overheads 15%

MAINTENANCE POLICY:

Depends upon

(a) Choice of organization

(b) Motivation and Training of personnel, motivation, incentives, awards, counseling, medical facilities, etc.

(c) Formation of maintenance improvement group

(d) Contract maintenance or I house maintenance

(e) Provision of stand by equipment

(f) Preventive or breakdown maintenance or both

Notes

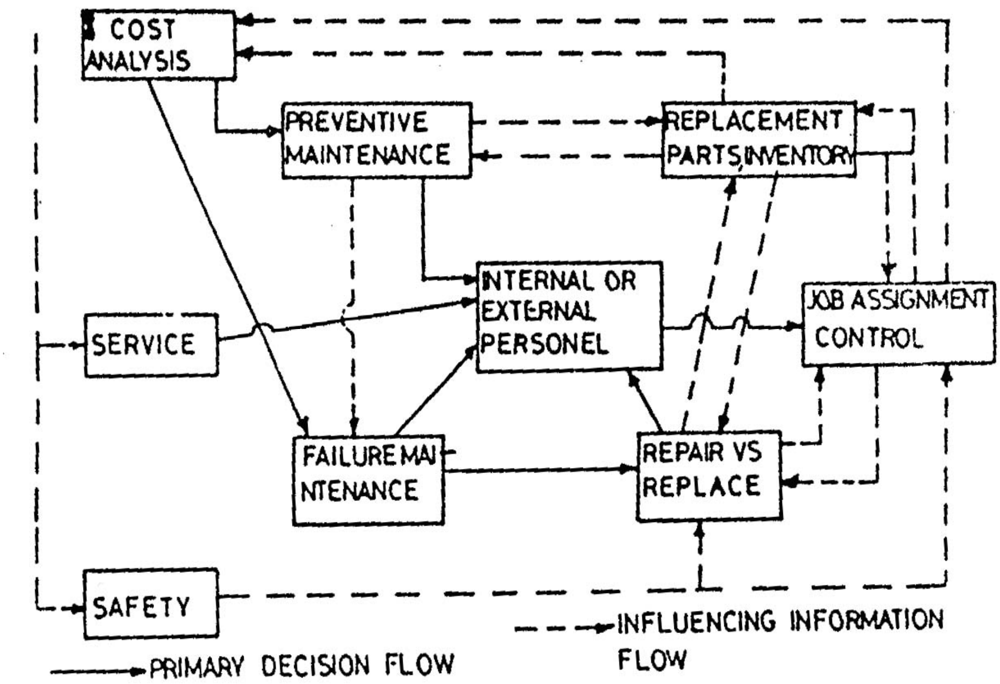


Figure Maintenance Decision Network

It is management's objective to determine when the breakeven failure costs and preventive maintenance costs occur.

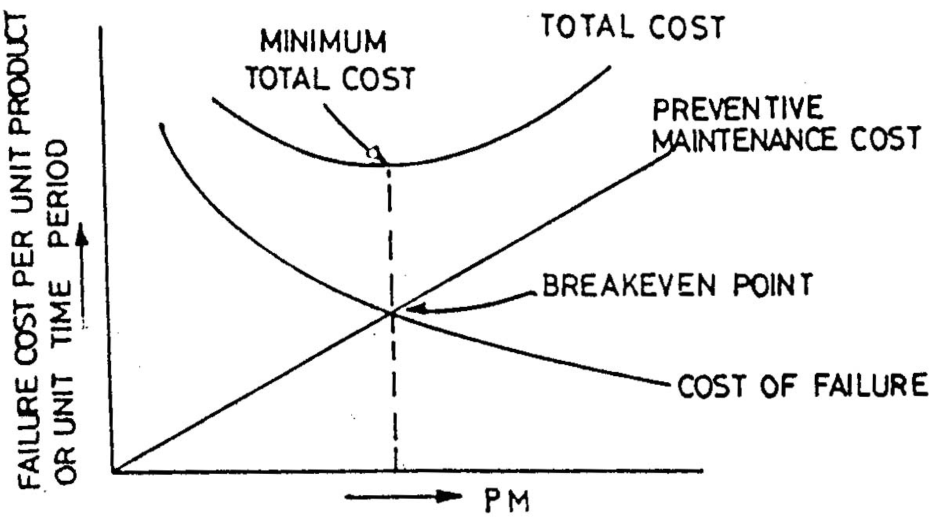


Figure Preventive maintenance cost per unit produced for unit time.

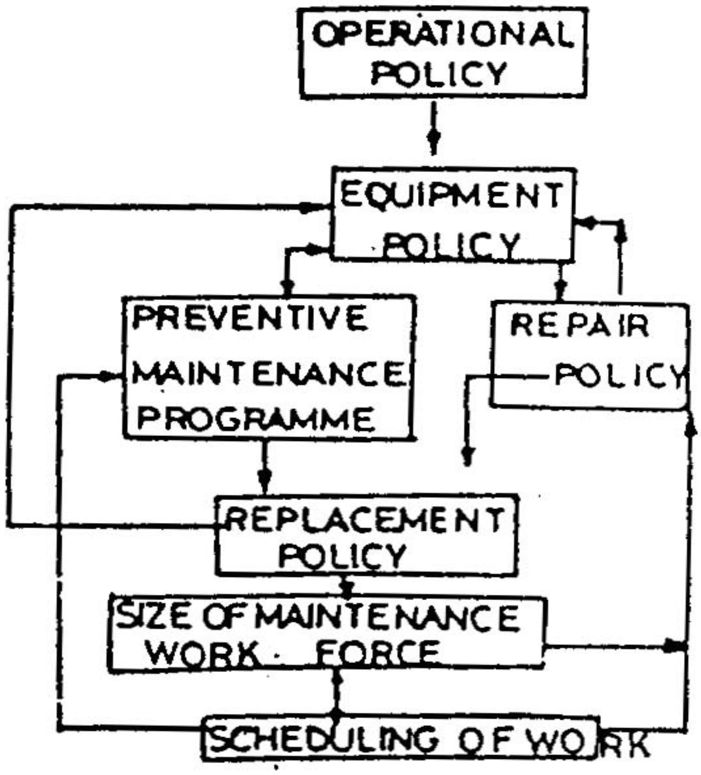
Notes

(g) Repair versus replacement

(h) Replacement parts inventory

(i) Maintenance job assignment control.

How different policies affect each other is shown in Figure.



For profitable maintenance policy

(a) Breakdown distribution frequency cost data.,

(b) Analysis

The information about the breakdown time distribution provides the basic data for the formulation of maintenance policies.

DIFFERENT POLICIES

Markov process for finding an optimal maintenance policy

The Markov process is quite useful in selecting an operating policy under conditions involving uncertainties of recurring nature. The particular situation considered fall under the broad category of Markov processes named after the Russian Mathematician.

RENOVATION, ADDITION AND RESTORATION:

It depends upon

(a) Wear and tear caused by use

(b) Changing need for space

(c) For supporting a new concept

Telephone system

Energy conservation equipment

Computerized office equipment

HVAC

Special floor covering

CONTRACT MAINTENANCE:

We should go for contract maintenance or in house maintenance depends upon equipment, maintenance facility available, cost of maintenance.

We have got The Indian contract Act 1872.

All agreements are contracts if they are made by the preconsent of parties competent to contract for a lawful consideration and with lawful object and are not hereby expressly declared to be void.

Advantage of contract maintenance:

(a) Reduction of labour cost

(b) Reduction of the cost of supplies-tools, spare parts, materials

(c) Reduction of the cost of equipments

(d) Use of latest techniques and methods

(e) Saving in administrative time

(f) Flexible to meet emergencies

(g) No need to negotiate with labour union

(h) No need to recruit and train employees

Disadvantages of contract maintenance:

(a) Management laziness – failures to negotiate the best price for the service.

(b) Loss of contact with the needs of the facility and staff contractor provides.

In hotel contract maintenance may be for

(a) Ground maintenance – Routine maintenance

(b) Preventive maintenance, water treatment plant, HVAC, etc.

(c) Building maintenance

(d) Changing of fire extinguisher chemicals

(e) Testing and adjusting fire alarm

(f) Kitchen duct work

(g) Dispose of grease

(h) Removal of snow from parking space etc.

Contract must have

(a) Insurance of employees

(b) Inspection facility of work done

(c) Safe practices should be used

(d) Local codes must be followed

Notes

Types of contract may be

(a) Lump-sum contract:

Offer by a contractor to furnish labour and materials and equipments necessary to complete a certain definite work.

Sometimes Lump Sum contract may not be advantageous.

For efficient working complete plans and specifications must be prepared and written in contract, otherwise dispute will be there.

(b) Unit price contract:

Nature of work is simple and clearly understood. Quality of work should be well defined otherwise dispute will be there.

This contract is done where plans and specifications may not be made, work quality is not known at present to remove all of the dirt from an excavation.

Work schedule rates are decided in different departments every year.

(c) Cost plus a fixed percentage contract:

Contractor agrees to furnish all labour and materials (including equipments) necessary to complete the entire work for cost plus an agreed percentage of the said cost.

It works well when plans and specifications are not complete and prices are not stable. In this case owner has full control. It is fair. Final cost may be less in this case because contractor has not to control the cost. Quality of the work will be good, work can be started immediately

(d) Cost plus fee

(e) Cost plus contract with upper limit

MAINTENANCE ACTION

The maintenance action may include the following:

(a) Inspection

(b) Measurement

(c) Testing

(d) Repair, Removal, replacement, adjustment, cleaning, lubrication, etc.

(e) Disassembly, assembly, checkout

(f) Securing material supply, storage spares

(g) Preparation of report

(h) Contingency items

(i) Administrative duties

Active repair time – disassembly, assembly, inspection, testing, measuring, removal, replacement, adjustment, checkout, cleaning, lubrication, etc.

Administrative time – Securing materials, preparation of report, administrative duties, contingency items, etc.

Diagnostic and localization (inspection measurement, testing) time is largest in active maintenance time.

Maintenance includes inspection, test, servicing, adjustment, alignment, removal replacement, reinstallation, repair, modification, overhaul, rebuilding and reclamation.

Early detection of equipment failure ensures quality maintenance and cost control.

The maintenance aspects may be studied under two branches as shown below:-

(1) Maintenance Engineering:

It covers the subjects and scientific principles. The basic principle is to keep the equipment in working order, free from breakdown and on safe conditions at reasonably minimum cost i.e. The equipment be capable of functioning with utmost reliability at its optimum efficiency.

(a) Friction, wear, lubrication

(b) Vibration, noise, shock and fatigue

Notes

(c) Diagnosis

(d) Reliability

(e) Maintainability

(f) Availability

(g) Failure analysis

(h) Maintenance information system

(i) Prognosis

(2) Maintenance Management:

It deals with effective and efficient use of resources such as men, money, material, time and space to achieve predetermined objectives.

(a) Policy

(b) Planning

(c) Techniques applied

- PERT/CPM
- Scheduling and sequencing
- Queuing
- Simulation
- Linear Programming
- Method Study
- Work Simplification
- Value analysis
- Quality Control
- Replacement

(d) Inventory management

- Spare parts

- Tools
- Equipments

TECHNICAL TERMS :

In normal functioning of the maintenance section/department it is very important that all the materials and spares are planned procured well in time. We may have

Stock items

Contingency, Non stock items

The requirement in the first year may be planned on the basis of others experiences. For the planning of the requirements for the subsequent years is very essential to take in to account the consumption of the previous year (s).

Standard raw materials/spare parts are:

(a) Bolts, screws, nuts washers

(b) Pipes & pipe fittings

(c) Belts

(d) Hoses

(e) Asbestos cord, sheet

(f) Araldite

(g) Steel wire netting

(h) Spirit

(a) Kerosene oil

(e) Waste cotton

(f) Old cloth

(g) Lubricants

(h) Grease, etc.

Notes

To reduce the repair time and to carry out the maintenance effectively. Parts needing replacement should be planned. Spare parts include.

(a) Fast wearing parts – whose service life do not exceed the period between two consecutive planned repairs.

(b) Parts whose life exceed the period between the two consecutive repairs.

(c) Large complicated and labour consuming parts.

(d) Replacement parts of specialized machine

(e) Standard spares, assemblies, apparatus

(f) Spares

(g) Complete equipments

(h) Major assemblies

(i) Minor assemblies

(j) Other parts

Notes

UNIT – II

EQUIPMENT REPLACEMENT POLICY - CIRCUMSTANCES UNDER WHICH EQUIPMENT IS REPLACED, INADEQUACY, OBSOLESCENCE - EXCESSIVE MAINTENANCE - DECLINING OF EFFICIENCY - REPLACEMENT POLICY OF EQUIPMENT WHICH GRADUALLY DETERIORATE - REPLACE WHEN CURRENT ANNUAL COST IS EQUAL TO AVERAGE ANNUAL COST TO DATE - ECONOMIC REPLACEMENT CYCLE FOR ABRUPTLY FALLING EQUIPMENT

OBJECTIVES :

- The Meaning of replacement
- Replacement Policies
- Different Replacement Methods

STRUCTURE :

- introduction
- replacement policies
- methods of replacement analysis
- system approach to replacement
- replacement of items which gradually deteriorate with time
- linen room equipment & accessories
- cleaning equipment
- laundry equipment

INTRODUCTION:

In replacement one is concerned with equipment and machinery that deteriorates with the passage of time. Since over time an equipment/machine ages, every piece of equipment/machine in a hotel is a candidate for replacement. However with increasing maintenance, the productive life of equipment/machine can be increased.

Replacement whereas reduces maintenance cost, it involves a high capital cost.

Equipment/machine must be constantly renewed and updated taking financial aspects into the consideration otherwise there is increasing risk that it will become obsolete.

Replacement of parts/equipments/machines/systems is necessary for better performance of equipments/machines/systems.

Replacement of an item/part is carried out due to following reasons –

(i) Technical

Replacement because of

(a) Inadequacy – The existing one may be incapable of meeting the increasing demand.

(b) Obsolescence – New equipment is continually being developed for better performance.

(c) Declining efficiency with time and use – This may require increase power consumption and more time.

(d) Deterioration – wear and tear of parts.

(e) Polluting or spoiling working conditions.

(f) Producing more noise and vibrations.

(g) Hard for workers.

(h) Increase in accidents.

(i) Increase in maintenance and repairs.

(j) Automation

(k) Line balancing

(l) Need for additional operations

(m) Less reliable

(ii) Financial

Presently owned equipment – defender

New equipment – challenger.

(a) Initial cost of challenger

(b) Operating expenses

Direct & indirect labour cost

Direct and indirect material cost

Power

Maintenance cost

Cost of replacing parts

Insurance

Interest on invested capital

(c) Expected salvage value at the end of the service life.

Requirements –

Better quality product

More output

Less labour cost

Less power consumption

Less fuel consumption

Less space requirement

Flexibility

More economic life of equipment

Less capital cost

There are two types of equipments

(i) Equipment may fail without notice – Electric lamps, circuit breakers, scaled refrigeration units, walk in coolers, freezers, furniture's, beddings, etc.

(ii) Gradual wearing of unit with time.

(iii) Gradual wearing of unit with time

Unit become less sufficient consumes more energy, cost of maintenance and repairs increases, and cost of operating equipment increases.

REPLACEMENT POLICIES:

(i) When a machine stop – maintenance man to go to m/c.

Failure of a component has taken place

(a) Replace all other similar components also

Replace all other similar components also

Replace certain of other similar components

(a) Total cost of replacement/year = single replacement cost x number of replacements/year.

(b) & (c) Total cost of replacement/year = number of components replaced at a time x number of times components replaced/year.

(ii) Operating cost increases

We have to collect information about Present/Defender & challenger.

Present/Defender

(a) Its life

(b) Its current and future sale value

(c) Revenue produced throughout the rest of its life

(d) Expenditure incurred throughout the rest of its life

Challenger

(a) Its-life

(b) Its present cost

(c) Its sale value at various times of its life

(d) Revenue produced at various time of its life

(e) Expenditure incurred throughout its life.

METHODS OF REPLACEMENT ANALYSIS:

(i) Total life average method

Steps

(a) Add the initial cost of the machine and its operating expenses.

(b) Divide this figure by the estimated life of the m/c to arrive at the average annual cost.

(ii) Annual cost method

Annual cost = capital recovery to operating cost

Capital recovery = $\{(C - sn)\}\left[\frac{(1+i)^N i}{(1+i)^N - i}\right] + s(n)i$

Where C – capital cost of equipment

N - life of equipment in years

S(n) – salvage/sale value at the end of n year

I – Interest discounted rate

The basis for decision is lowest annual operating and capital cost.

Capital cost, depreciation, interest.

Operating cost -

Wages to operators

Power consumption

Repairs & maintenance

Materials losses

(iii) Present work method. Discounted cash flow technique

Reducing all receipts and expenditure for each alternative to a present worth basis.

$$NPV = \sum_{n=1}^{n=N} \left(\frac{In - En}{(1+i)^n} \right) + \frac{sn}{(1+i)^n} \geq 0$$

Where NPV – Net present value

In - Income for years

En - Expenditure for years

i - Interest discounted rate

N - Life of equipment in years

Sn - Sale value at the end of n years

n - Years 1, 2, 3 … N

The discounted cash flow technique takes no account of the following –

(a) Risk uncertainty, operating life, repair cost, disposal value

(b) Inflation

(c) The timing of the cash flows in relation to opportunities for the use of the money elsewhere

(d) Difficulty of raising money for the outlays

(e) Policy after the period considered

(f) Possible future development of improved equipment

(iv) Rate of return method

Interest costs are not accounted and therefore the resulting figure is known as unadjusted rate of return

$$= \frac{100\,(\text{Net monetary operating advantage} - \text{Amortization})}{\text{Average investment}}$$

Net monetary operating advantage = operation cost + maintenance cost – Revenue

$$\text{Amortization} = \frac{\text{Incremental Investment}}{\text{Economic life}}$$

(v) Barnes formulae

This formula is used where the old and new equipment is having short life.

The number of years during which the equipment will pay for itself.

$$X = \frac{A + B}{(E + F)\,DG + H - C}$$

Where

A = the cost of the new equipment including installation charges

B = the depreciated value of the old equipment at the time of replacement as reduced by any realizable value of scrap

C = the interest charge on the new equipment

D = the number of units produced per day by new equipment

E = the labour cost per unit with old equipment

F = the estimated labour cost per unit with new equipment

G = the estimated number of working days per year for new equipment

H = Savings in fixed charges per year other than interest charges.

(vi) MAPI method

This method concentrates on the comparison of the rate of return on the proposed equipment and return with out the implementation of the proposed equipment in the immediate next years because distant forecasts are not reliable.

Net investment – The project cost of the proposed project less investment eliminated by its implementation.

Next year advantages from the project –

Operating advantages = Increase or decrease, in revenue + change in the operating costs.

Non operating advantages – fall in the salvage value for holding the existing asset one more year + the next year allocation of possible capital additions or renewals and the fall in the use values of the new project for the next year. Next year after tax advantages.

Next year operating advantages + Non operating advantages – Taxes MAPI urgency rating

$$= \frac{\text{After tax return from the project}}{\text{Net investment required by the project}} \times 100$$

Operating inferiority of the equipment

Amount by which it is operationally inferior to its best alternative

Adverse min

Time adjusted average of capital cost + operating inferiority

Replacement decision is taken on the basis of lowest obtainable capital cost and operative inferiority

(vii) Replacement of item that fall completely all of sudden

Individual replacement policy

An item is replaced immediately after its failure

Notes

(viii) Group replacement policy

Incandescent lamp average life 1000 hours.

Probability of a lamp operating 1000 hours is 50%

Group replacement is feasible when the cost of labour is very high in relation to the cost of item being replaced. The costs of labour include the preparation, removal, installation and clean up man hours for replacing items.

It assumes that item fail prematurely they will be replaced on a routine basis.

The cost of individual replacement is compared to the cost of per unit for group replacement.

In group replacement all items are removed at one time and majority of these items are discarded.

Some are retained for figure individual replacement.

SYSTEM APPROACH TO REPLACEMENT:

(I) Emergence of equipment replacement

(II) Classification of equipment replacement

(III) Assignment equipment replacement

(IV) Selection equipment

(V) Follow up reports

REPLACEMENT OF ITEMS WHICH GRADUALLY DETERIORATE WITH TIME:

Let

C = Capital cost of a certain item

S(n) = Selling or scrap value of the item after n years

f(n) = Operating (maintenance) cost of the item at n year

t = Optional replacement period of the item

Replacement of items whose maintenance cost increases with time and the value of money remain same during the period.

The average annual total cost incurred on the m/c per year during t years is given by

$$TA = \frac{1}{t}\left[C - S(n) + \int_0^t f(n)dn\right]$$

When TA is minimum, replace the item

Problem:

The following data are available for highly. Specialized precision m/c which has high rate of obsolescence. Quality of the output deteriorates fast.

Year	1	2	3	4	5
(A) Yearly gross earning from sales Rs.	20000	15000	5000	4000	3500
(B) Yearly expenses Rs.	1500	2000	2500	3000	3000
(C) Salvage value at the end of the year	10000	6000	3000	1000	-

If the installed cost of the m/c is Rs.25,000/- and expected rate of return for company investment is 10%.

Find the economic life of the m/c.

Solution – Net present value method is used.

Year	1	2	3	4	5
E(t) Net earning (A-B)	18500	13000	2500	1000	500
Discount factor $\frac{1}{(1+i)^n}$	$(0.909)^n$ 0.909	$(0.909)^2$ =0.826	0.751	0.683	0.621
Present Value of net earnings Rs.	16816	10738	1878	683	310
Present value of salvage	9090	4956	2252	683	-
Cumulative present value	25906	32510	31685	30798	30425
Net present value = Cumulative present Value = cost of m/c	906	7510	6685	5788	5425

The net present value starts decreasing from the third year, it is advisable to replace the m/c every two years.

Storage Tips for Linen

1. Restaurant and floor linen should be arranged by size and neatly stacked in shelves.

2. Heavier linen must be stacked in lower shelves while lighter ones on higher shelves.

3. Cotton items like sheets, pillow cases, table cloth, etc. should not be stored for a long time unless they are washed to remove starch. Starch or finishing chemicals attract insects which may have a tendency to make fabric dry and brittle

4. For long-term storage wrap items in plastic foils or pack in paper-lined cartons after washing. Dark paper is preferred to preserve colour. Wrap loosely to permit air to circulate.

Storage Tips for Uniforms

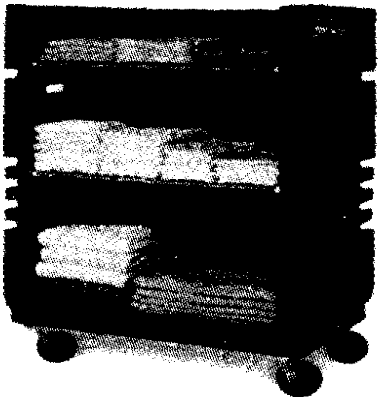
1. Uniforms of better quality materials should be preferably hung.

Notes

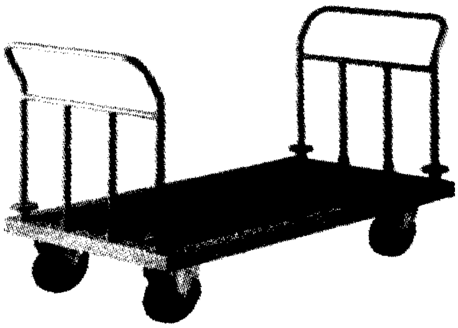
2. Uniforms made of cheaper materials (used by back house personnel) should be separated size-wise and stacked in racks.
3. Small items like gloves, caps, ties, bows, etc. should be kept in closed cupboards.
4. Soiled uniforms must be dumped into hampers.
5. Coloured or embroidered materials or those with indelible ink should be laundered before storing to prevent discolourization.

LINEN ROOM EQUIPMENT & ACCESSORIES

Trolleys: to transport fresh linen from the laundry. Modern trolleys are light with reliable wheels to reduce the fatigue of those pushing them.

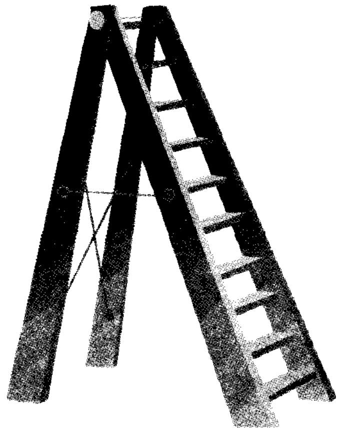


Multi-purpose trolley: to transport linen or other goods.

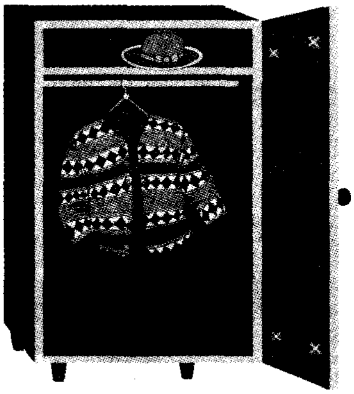


Notes

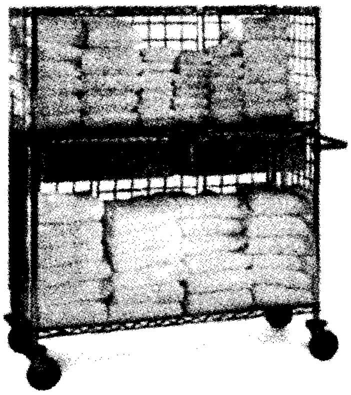
Ladders: to reach the higher shelves of racks



Cupboards: to store quality linen

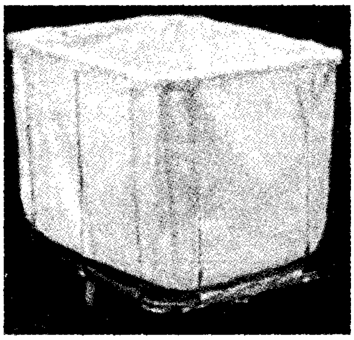


Racks: to store fresh linen in circulation. They can be fixed or mobile as shown in the picture.



Notes

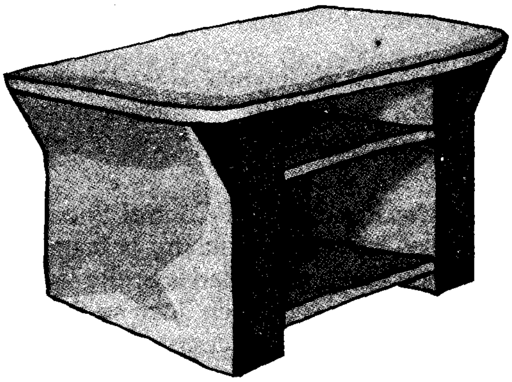
Hampers: to dump soiled linen



Linen bags: to segregate linen being sent to the laundry

Plastic bags: to pack linen when put in the linen store

Folding Table: to fold fresh linen



TYPES OF LINEN

Bathroom Linen

Bath rug	24” × 42”
Bath towel	25” × 45”
Hand towel	6” × 7 ½ “
Face towel	9 ½ “× 10 ½ “
Pillow slips	24” × 32”
Pool towel	36” × 80”
Staff towel	36” × 62”

Bedroom Linen

Blanket	72” × 108”
Bed spread	72” × 108”
Mattress protector	64” × 96” (single bed)
Bed sheet	72’ × 108”

Restaurant Linen

Moultan	72” × 104”			
Table napkins	21” × 21”			
Tea napkins	12” × 12”			
Table cloths	90” × 90”,	45” × 45”,	54” × 54”,	58” × 62”,
	62” × 64”,	72” × 78”,	72” × 104”,	72” × 240”
Tray cloth	16” × 27”			
Waiter Cloth	18” × 27”			
Dusters	22” × 22”			

EXCHANGE OF LINEN

The exchange process is very critical to the Linen Supervisor as it is here that linen counts can go wrong. Even one piece of linen a day lost or misplaced adds to quite a number in the month. It is for this reason that she must maintain a strict exchange process. She coordinates closely with the Laundry Manager or Supervisor. She keeps a track of movement of linen loads from floors and from the linen room. She must ensure that the exchange norm of one fresh item with the soiled one is meticulously followed. Given below are the processes used to fulfil an efficient exchange process:

Room Linen

1. Room linen is either directly received by the laundry or via the linen room.

2. In either case, The Floor Supervisor physically counts each soiled item on the floor and enters the figures into the Room Linen Control Sheet (Fig.) in triplicate. One copy is retained by the Floor Supervisor.

3. The second and third copies of the Room Linen Control Sheet are sent with the floor houseman with the hamper of soiled linen to the laundry or linen room. Alternatively, she will send the linen through the linen chute which lands at the laundry floor. The Laundry would give specific times for each floor to send their linen so that there is no mix-up with linen from other floors. In such a case, the Floor Supervisor will send her representative to the laundry floor first before she dispatches the linen from the chute.

CLEANING EQUIPMENT

Equipment Selection

Cleaning equipment are essential tools for housekeeping professionals. They help improve productivity and efficiency. As equipment is expensive, their selection is of utmost importance. The correct choice and quality of equipment could save the costs of breakdowns, labour and time. During the purchase of equipment the following points should be kept in mind:

1. Quality of equipment by ascertaining the history of their use in other organisations. It should be tested for its performance.

2. Reliability of the supplier to meet time deadlines.

3. Transportation on time to replenish stocks.

4. Weight of equipment—it should be light, well-balanced and easy to manipulate.

5. Availability of parts and accessories.

6. Sturdiness in terms of usage.

7. Cost factors.

8. Easy maintenance

9. Warranties

10. Productivity in terms of square feet it cleans in one hour.

Notes

11. Washing efficiency of extractors and wet vacuum cleaners in terms of the pressure with which they inject fluid. They come with pressures from 11 PSI to 1000 PSI. Similarly the solution recovery is equally important in terms of time taken to lift solutions as well as its completeness of task.

12. Appearance is important as the equipment will be in the view of guest.

13. Ease of handling of the equipments is an important factor as they should not physically overload the operators.

Rules for the Storage of Equipment

To give equipment a longer life, they have to be handled with care. One criterion for proper care is their storage. Given below are some storage tips:

1. The store should be dry and well-ventilated as dampness causes rust and mildew leading to degeneration of equipment.

2. The store should provide enough space for easy access to shelves and to facilitate proper cleaning.

3. The store should be properly locked to prevent pilferage.

4. The store should be accessible to all cleaning personnel without hindering other operations.

5. Buckets and pails must be cleaned dry before storing them.

6. Brushes should not rest on their bristles.

7. All detergents and polishes must be properly sealed before storage to prevent evaporation and drying.

8. Mops must be wrung and dried before storage.

9. There should be adequate racks and cupboards, properly labeled for easy identification.

10. Equipment must be cleaned thoroughly prior to storing them.

11. Equipment accessories must be labeled and kept preferably in cupboards.

12. Stock records should be maintained showing the following:

(a) Date of purchase

(b) Kind of stock and quality

(c) Name of supplier

(d) Cost per unit

(e) Date of issue into service

(f) Remarks on suitability and durability.

13. For the proper control of equipment their issues from the store must follow certain rules:

    (a) Equipment must be issued at definite times.

    (b) New issues must be made strictly against the worn out equipment.

    (c) Equipment must be labeled to show the information about the person to whom it has been issued e.g. his floor, public area etc.

14. The store must be subject to regular inspection and audit.

15. Expensive equipment must be covered in polythene to protect them from dust during storage.

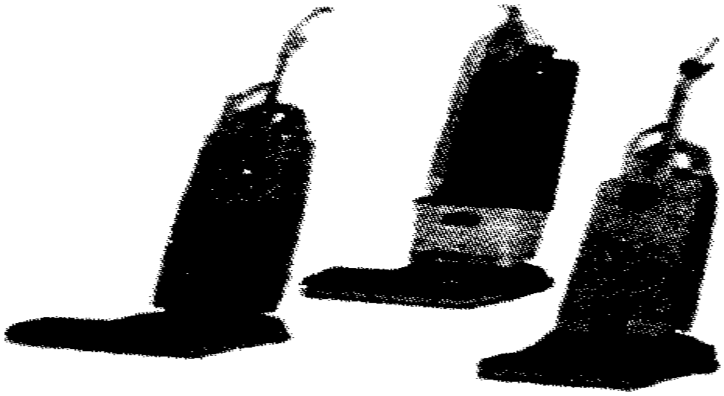
Cleaning Equipment

Cleaning equipment can be put into six broad categories:

I. Mechanical Equipment

Vacuum cleaners are the greatest friends of housekeeping cleaning staff. They come with nozzles and attachments for all types of surfaces. They are handy equipment for daily maintenance and find their way onto maid carts. Vacuum cleaners are recommended where there is a large amount of carpeted area in the hotel. There are many types of vacuum cleaners. The upright models work on a combined suction and beating process; and the floor models—cylindrical or spherical operate solely on suction. There are many kinds of upright vacuum cleaners.

Notes



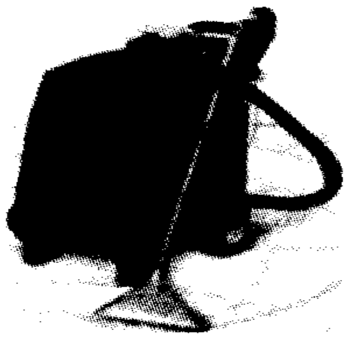
The beater-bars vacuums agitate carpet piles and loosen dirt; brush vacuums agitate carpets glued to the floor; pile lifter vacuums have a strong suction capacity and a separate brush motor that restores crushed carpet piles. There are canister models with tanks that are mounted on castors and some that are held on the operator's back. Canister models are preferred to reach difficult corners and edges. The value of the vacuum cleaner comes from the fact that it is quicker, requires less labour and raises no dust thus preventing dust from being deposited elsewhere in the room. When using the vacuum cleaner it must be checked for its functionality. When using it over carpets it should be done crossways over the carpet to ensure that suction has time to draw out the dust and the grit. A regular movement is most effective and can be judged by feeling the pull against the carpet. The wire connecting the power socket should be straight as the coiling of wire could lead to unmanageable knots which may even fall under the suction. Small objects such as pins and needles that are sharp should be picked by hand otherwise the nozzle or suction tube could get damaged and the effectiveness of the suction could reduce. The dust bags of the vacuum cleaner must be cleaned daily or more depending upon the frequency of its usage. A vacuum cleaner with an empty bag provides greater suction than the one whose bag is full of dust. The bag may be emptied out into a newspaper or paper sack and kept with the rubbish. All brush attachments should be kept free from dust, bits of cotton and hair that are picked up in the course of cleaning.

Notes

A dustette is a small, light vacuum cleaner used for cleaning curtains, upholstery and mattresses. It cleans by brush and suction and is very easy to handle.

Wet Vacuums:

This is a kind of vacuum that can suck water from floors or can have both suction and water sprayer to rinse the soiled area. Squeegee attachments on wet vacuums can make floor clean-up, stripping and scrubbing more efficient. Conventional vacuum cleaners must never be used to clean wet floors. Wet vacuums come in a variety of shapes and sizes. Some canister models can be dragged on castors while others can be strapped on the back of the cleaner. These vacuums have collection tanks that store the water that has been sucked up from the floors. This equipment can be used on wet carpets as well. Some wet vacuums may be pushed like a cart and are heavier for large water suction needs off floors.



Wet Extractors:

While wet vacuum cleaners have a suction feature, wet extractors have suction and water injection features. With this they simultaneously rinse and suck water from the surface. They are best for both carpets and floors. The basic principle of operation is that the extractor sprays water and detergent onto the surface and then uses suction to extract the water into tanks built into the wet extractor. Some machines have agitators to loosen the dirt from the carpet before spraying. They have other attachments for draperies and upholstery as well. Wet extractors come in various shapes and sizes. They come in lighter portable tank versions, as well as the heavy duty push-cart variety. They can be used for both floors and carpets. Some extractors can also have a feature for dry pick-up like normal vacuum cleaners.

Rotary Floor Machines:

Rotary machines have several applications: to shampoo, polish and scrub. They can be used for both carpets and floors just by the change of an attachment. For example, the machine can be used for carpets by changing the bonnet block to bonnet brush. Rotary machines can be fitted with pads for rotary spin pad cleaning, mist pad cleaning, bonnet pad shampoos, huffing, burnishing, scrubbing, stripping and refinish of a variety of floor finishes; or brushes to perform dry foam cleaning, or brush shampoos. Manufacturers provide a variety of pads for specific purposes. There are separate pads for stripping, scrubbing, polishing, burnishing and spray cleaning. Mechanical scrubbers are used on large uncarpeted floors after they have been washed with water and detergent. Scrubbers are used to clean any sticky grit on the floors. Mechanical polishers are used on large polished wood or vinyl floor surfaces. The floor must be swept clear of dust and mud marks. Polish is lightly rubbed onto the floor surface for the best results.

The machine has a feed-in tray for detergent solutions and tanks for water supply and water extraction. Rotary machines come at different speeds ranging from less than 175 rpm for carpets to 1500 rpm for burnishing and buffing of other surfaces.

Use and Maintenance

All machines especially rotary machines must be handled by trained and experienced people only. Improper use of the machines can cause such damage to carpets as seam separation, de-lamination of backing material, buckling, shrinking, premature face fibre wear. Such equipment comes with accessories and attachments like hoses and electrical cords. Hoses must be checked for perforation and leaks. They must be rinsed properly after use. Electrical cords must be checked for frayed insulation and naked wire. The plugs used must fit in the sockets well. Never put bare wire ends of cords into sockets as they involve hazards of electrocution and short circuits. Small objects like pins and needles must be removed with a brush and dustpan first before vacuum cleaning the carpet as these items tend to puncture the dust bag of the vacuum cleaner.

Notes

Any large object should also removed from the floor as it could damage the suction process. Suction nozzles should be facing downwards when vacuuming as other articles like jewellery, fine garments can be sucked in.

2. Containers

Containers are vital to cleaning. Following types of containers are primarily used in hotel industry—

- Buckets or pails for carrying water primarily. They come in plastic or galvanized metal.
- Basins and bowls that are used for removing spots and stains. They usually come in plastic.
- Dust pans for collecting dust by hand brushes. They come in plastic or galvanized metals.
- Housemaid box which is a plastic carry case for various cleaning solutions, brushes and dusters.
- Public refuse bins that come in chrome for internal use and galvanized metal for external use.
- Waste bins that are used in guest rooms and bathrooms, offices and restaurants. They come in plastic. They must be lined with garbage bags of appropriate size for easy disposal of trash.
- Mixing buckets for carrying detergent solutions.
- Mop buckets on castors with a ringer attached.
- Tanks for wet extractors and wet vacuum cleaners that collect water sucked up from floors by the machines.
- Vacuum cleaner bags that collect the dust from floors and carpets.

Use *and Maintenance*

Most containers are made of plastic these days for aesthetic appeal, lightness and easy maintenance. Containers must be cleaned everyday by gently rinsing them inside out. They must be dried before stacking. Buckets may be piled upside down. Tanks are of galvanized metal and must be cleaned thoroughly before and after use. Vacuum cleaner bags must be allowed to fill only to 2/ *3*^{r} of its capacity should be cleaned out at this point. Vacuum bags must be emptied before

Notes

storage. These equipments are wheel mounted. The wheels (or castors) must be well-oiled for easy carriage. The wheels must be free of dust, tangled strings and hair, etc. Broken wheels must be replaced immediately to give the equipment maneuverability.

3. Brushes

Brushes are manufactured to fulfil a number of objectives. Brushes with soft fibre or nylon bristles are designed to brush carpets, cane, etc. without damaging the surfaces. Scrub brushes have short coarse bristles designed for use on surfaces which have become ingrained with dirt and stains. Following types of brusted are used for cleaning in hotel industry:

(a) Toilet brush for cleaning WC and bidet bowls.

(b) Sink brush that comes in wire for unclogging sink outlets.

(c) Scrub brush for cleaning hard, grime from floors.

(d) Carpet hand brush fro cleaning carpets as an alternative to vacuum cleaners.

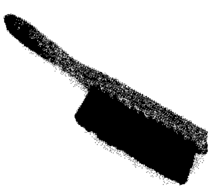
(e) Tapestry brush for cleaning delicate draperies.

(f) Cane chair brush which is a soft nylon brush that prevents damage to cane surfaces.

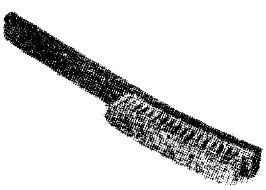
(g) Soft hand brush to gather dust from various surfaces. It goes with a dustpan.

(h) Wall brush has long handles to reach the upper corners and sides of walls. They are soft so as not to damage wall finishes,

(i) Feather brush that is soft as a feather to clean delicate surfaces like lampshades, televisions, etc.



Soft Hand Brush



Fabric Brush

Upholstery Brush

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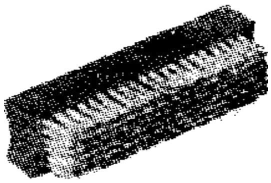
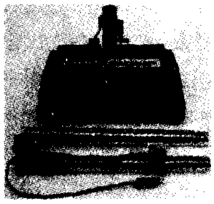
Carpet Brush



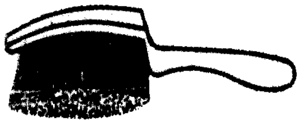
Spotting Brush



Electric brush

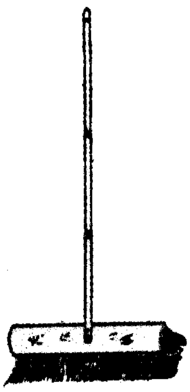
Nylon Scrub Brush

Nylon Chair Brush

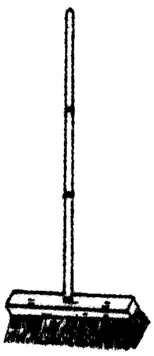


Nylon Tapestry Brush

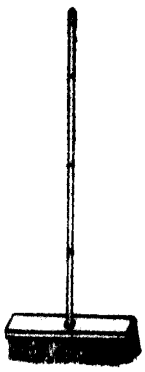
Soft Nylon Toilet Brush



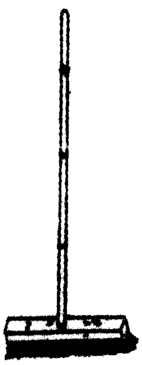
Yard Broom



Sweeping Broom



Firm Bristle Carpet Brush

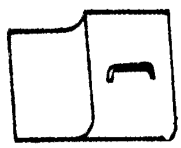


Cotton Wall Brush

Feather Duster

Hard Bristle Toilet Brush

Nylon Sink Brush



Dust Pan

Notes

(j) Nylon nap brush used to restore carpet pile after cleaning.

(k) Hand shampoo brush used on stairs and edges.

Use and Maintenance

Brushes must be free of fluff, hair and dust each day. Periodic washing is also recommended. Natural bristles tend to lose some of their stiffness if washed frequently but by giving the brushes a final rinse in salted cold water, the bristles regain their natural stiffness. Nylon brushes can be washed more easily and they dry quickly. In general, brushes must be washed with soap lather by working the bristles up and down in warm water and rinsed clean with cold water and dried in sun. Brushes that are worn by must be replaced 1/8 of an inch. They must be dry when stored and not placed on their bristles.

4. Mops and Brooms

Following types of different mops and brooms are required in hotels for cleaning floors.

(a) Yard brooms with coarse bristles to clean rough floors and garden areas. They come with long handles to reduce fatigue over large areas and are hand held shorter ones for small areas.

(b) Mops are used for dusting floors as well as cleaning the floors with water. They come in various sizes for different purposes.

(c) Soft sweeping broom for internal areas to remove dust from floors and carpets.

(d) Squeegee is a tool with a rubber blade, like a windshield wiper used for gathering and channelizing water. Squeegees are small hand held ones for window glazes and large ones for floors.

Notes


Floor Mop
Casacolour Floor Duster
Magnet Mop
Flex Neck Scrubber
Extendable Microfibre Cleaner
Micro Floor Squeeze Mop
Squeegee Set
Wring Leader Mop
Folds flat for storage

Use and maintenance

In principle, soft bristled brooms are used on smooth floors while coarse-bristled ones are used on coarse surfaces, especially outside. Brooms are maintained in the same manner as brushes. Mops must be washed in hot soapy water or detergent (never both together). The use of soapless detergent will prevent the formation of scum. The mop should be tightly squeezed out by hand, shaken well in the open air and left to dry. Coarse cotton mops are used for large stone or cement floors. It takes less time to clean than hand washing, but cannot ensure a good standard of cleanliness. New mops must be soaked in clean water for 30 minutes to allow for shrinkage.

5. *Cleaning Cloths*

Following types of cleaning clothes are a necessity in hotels:

(a) Cloth dusters

(b) Rags for applying polish

(c) Flannelette cloth for polishing

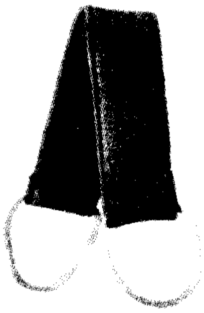
(d) Chamois leather

(e) Glass cloth

(f) Floor dusters

(g) Faucet Duster

(h) Sponges



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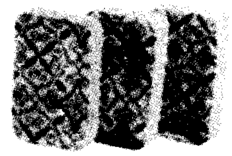
Scrubby Sponges-
Set of 9

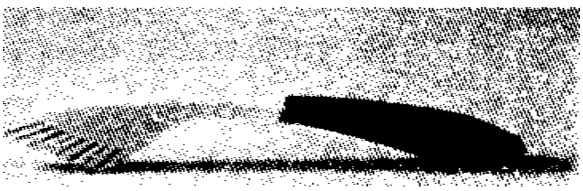


Gripple Fish Faucet
Sponges-Set of 9

6. *Sundry Equipment and Protective cloth*

Some other equipments and clothes, such as the following, also aid in cleaning exercise in hotels:

All-Purpose Gloves



(a) Step ladders or stool steps

(b) Cleaning rubber gloves

(c) Racks for holding brushes, dustpans etc.

(d) Airing rack for dry cleaning clothes

(e) Discarded linen for covering furniture and storing materials.

(f) Adjustable ladders for public areas

(g) Chandelier shampoo tent.

(h) Waterproof tarp used for mixing cleaning solutions

(i) Carpet rake used after cleaning of carpets or to restore vey long carpet pile that has become crushed.

(j) Stirring paddle used to mix cleaning solutions.

(k) Runners used to protect just cleaned carpets from foot traffic or to protect floor length draperies from wet carpets during shampooing.

(l) Clip-on floodlights operated on battery and used to light dark hallways and stairwells.

(m) Sprayers that are both manual and electric powered used to spray solutions and water onto carpets.

(n) Measuring cups ton measure cleaning solutions.

(o) Hand wringers used to squeeze excess moisture out of mop heads and bonnets.

(p) Pick-up pans to gather water collected by squeegees. They are like dustpans.

(q) Furniture guides that are kept under furniture to prevent them from making serious indentations when laying on a carpet for a long time.

(r) Pill shear which is a small shaver to crop pills from carpet surfaces.

LAUNDRY EQUIPMENT

Equipment for Laundry Operations

Laundry equipment is a major investment for owners. It is this that puts the owner in a dilemma of whether to have an on-premises laundry or outsource the operations. The decision he makes has already been discussed in the part. However, the main concerns in this regard are two:

1. The value of another large investment in linen and uniforms and their maintenace.

Notes

2. The reliability of supply of fresh linen to housekeeping to be able to make revenue areas like rooms and food and beverage operational.

These two considerations tilt the balance usually to having a captive laundry in the premises. Hotels with over 200 rooms may certainly decide to have their own laundry for the sheer size of operations. Smaller properties may decide to have part operations like only washing activity while outsourcing dry cleaning operations to a public laundry. Alternatively, the owner may decide to outsource guest laundry while retaining the house operations. Should the hotel decide to have their own laundry, the best allies are the laundry equipment manufacturers who are able to give reliable estimates of workloads and the kind of equipment required to meet them. The main equipment for laundry operations are as follows:

Washing Machines

Industrial washing machines are different from the conventional ones at home or those found at Laundromats. They have large capacities ranging from 25 to 1500 pounds and are bolted onto the floor on concrete pods. Heavier machines are more durable. Washing machines are sophisticated and come with many functions—washing, rinsing and drying. The washing machine has two perforated drums that rotate with a motor, mounted on a stationery casing. The inner drum carries the fabrics while the outer drum does the extraction function. The perforation helps in extracting the excess water from the clothes. Care must be taken that perforations are away to prevent damage to the fabrics. The perforations also feed water and detergent into the drum. The drum carries the fabrics and rotates at speed to enable detergents to agitate the fabrics and dislodge the soil from them. The amount of detergent added must be just right to have the best results. Today, there are automated washing machines that feed and control the water and detergents electronically. Water too has to be fed at temperatures suitable for the wash. Electronic equipment determines the right temperatures. The washer man then has many options of water flow, temperatures and detergent feed for different types of cleaning cycles. Automatic washing machines also have rinsing facility that rinses out excess water. They also have driers that prepare fabrics with the right moisture content for pressing. Industrial washing machines must be kept busy as idle time costs as well as reduces the life of the machine.

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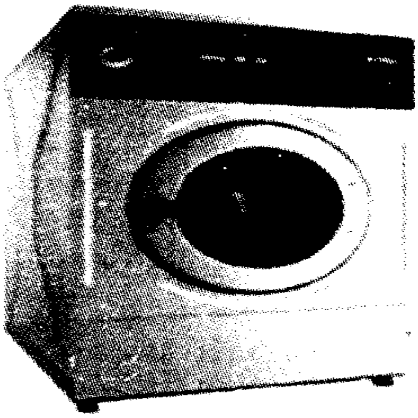
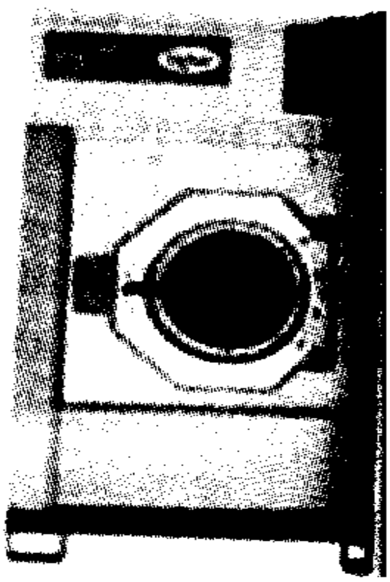


Tumbler Machines

Tumblers are dryers. They can be used as a supplement to washing machines that do not have drying facility or used for special fabrics like towel material. Tumblers fluff the fabric and give it the soft texture we experience in hotel bed and bath linen. Dryers remove moister from fabrics by tumbling them in a rotating cylinder through which hot air passes. Industrial laundries install tumblers with greater drying capacity than washing because it takes upto twice the time to dry laundry than wash it. Dryers must be maintained well as clogging of perforations in the dryer due to lint can cut off hot air supply and sometimes overheat the equipment.



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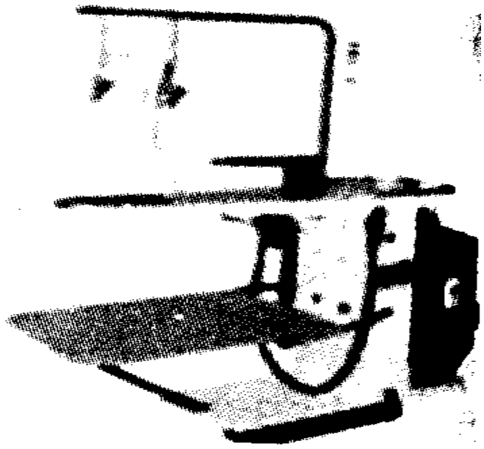
Dry Cleaning Machine

Dry cleaning is a process that removes dirt and stains from fabrics. Dry cleaning uses little or no water, but the process is not really dry. It involves the use of liquids called solvents. Dry cleaning machines are able to handle volume fabrics ofti same type. The fabrics must be of the same colour and type. Befoi clothes are dry cleaned they must be spotted to remove any sti that could become permanent during the dry cleaning process.' dry cleaning machine has a movable drum that is filled with lie solvent rather than water. A special dry cleaning detergent is addedj to the solvent to help remove soil. The drum rotates and the solvenlj circulates through the clothes. After the cleaning cycle the solventisj drained from the machine and the drum rotates rapidly to removej any residual solvent solution. The clothes are tumble dried andj rechecked for spots and stains before sending for pressing.

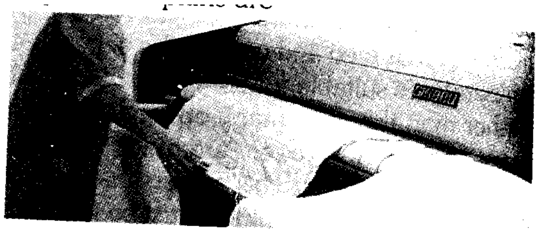
Spotting Machine

The spotting machine is a self-contained table that has all the stain removers and steam gun for treating spots. The spotter uses a nozzle called a steam gun that can spray a jet of water vapour to wet the stain. Special stain removing chemicals are used depending on the nature of the stain and fabric.



Flatwork Irons (Calendar Machines)

Flatwork irons are equipment with steam rollers that roll over large flat items of linen. Linen like bed sheets, towels, pillow slips and napkins are fed into the roller by conveyor belt. Those that do this activity are called feeders. The items come out from the other end and folded into desired sizes by folders. The material coming must be properly washed. The feeders inspect items before rolling them into the flatwork iron. Dirt on linen can shorten the iron's life; too much sour can make them catch in the roller; and too much alkali can turn the linen brown. Linen should be moist before ironing as dry linen causes static electricity. Alternatively, too wet linen can be difficult to feed in the roller and can overload the



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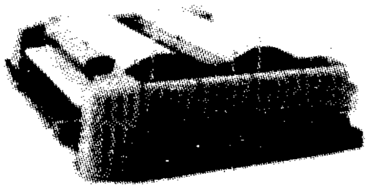
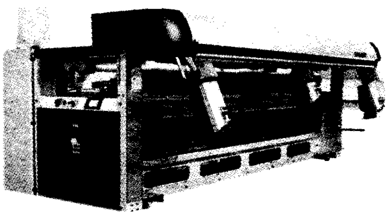


effect of the flatwork iron. There are machines that are of s^^le rollers and double rollers that may be selected according to the volume of work and efficiency required.

Folding Machines

This term is quite misleading as the machine does not fold linen but secures it well for a folder to fold the linen more easily. Earlier, the folder had the onerous task of spreading the linen on a folding table and folding them with proper creases and sizes. When one considers the tons of linen being churned out by washing machines the task seems challenging. The folding machine is a labour saving and productivity enhancing devise. However, nowadays there is good news for folders. There are folding machines that virtually eliminate tumble drying and hand folding. These machines dry, fold, cross fold and stack the linen.



Stackers

These are equipment that feed off from folding machines and stock the linen in appropriate sizes. It helps in determining the lot size for easy accounting of linen.

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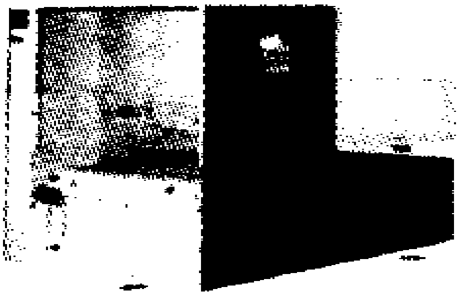
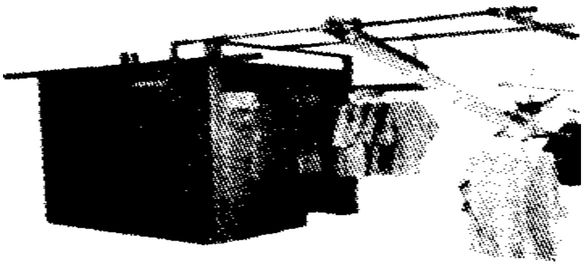


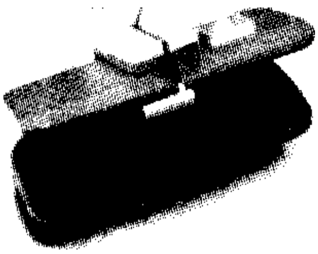
Steam Cabinets *and Tunnels*

Steam cabinets or tunnels effectively eliminate wrinkles from uniforms and linen. It is a chamber fed with hung uniforms or linen that moves through the chamber either manually fed or on a conveyor belt, steaming them and removing the wrinkles as they move through.



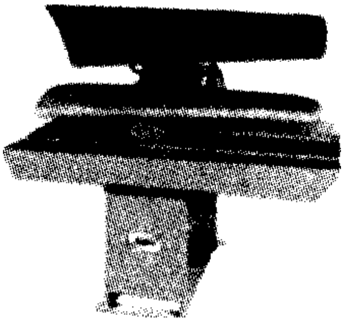
Steam Press

This device comes in a table top version that is operated by hand and a floor version that is operated with the foot. The press has two padded heads that press together. The top head opens and closes and feeds steam on the clothes while the lower head is static on which clothes are spread for ironing. The hand-leg equipment has a foot pedal that when pressed can lower the top head and open it when pressing. A busy laundry will have several of these machines. This press is ideal for clothes that are too wrinkled and need smoothening out.



Hot Head Press

This press is similar to the steam press in construction. The top movable head has a hot iron surface instead of a padded one and provides hot pressure on the lower padded head when clothes are spread for pressing. This is ideal for wrinkle free garments.



Uniform Press

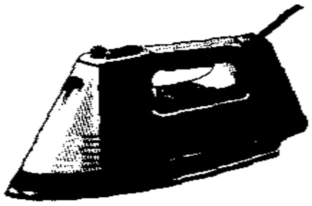
This is a press that mounts uniforms particularly tunics, jackets and coats to give its shape when pressing. It is efficient in giving consistency to the way uniforms look. It applies pressure uniformly to all corners of the uniform and is extremely time-saving.

Shirt & *jacket Press*

It is similar to the uniform press but specifically meant for shirts and jackets. It gives the shirt collars and cuffs the right contours for perfect pressing. It is useful for expensive material that may get burnt in hand held operations.

Steam Iron

This is the age old iron used at home. It is hand held and is good for delicate guest laundry and uniforms that can get damaged by larger press applications. The hand held iron is fed with steam through steam hoses.



Transporters

In addition to the standard heavy equipment given above, the laundry also has a number of mobile transporters to carry the volume of laundry from one machine to another or from the laundry to the linen and uniform rooms. They come in all shapes and sizes to meet the requirements in a daily operation.

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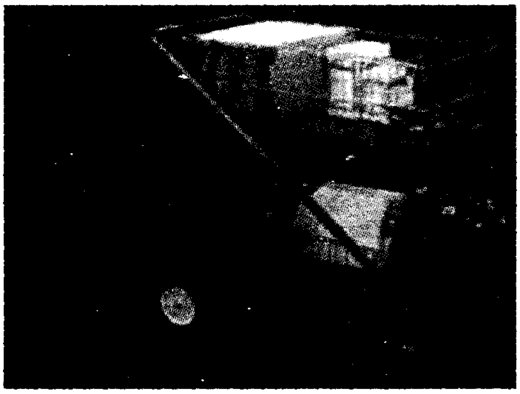
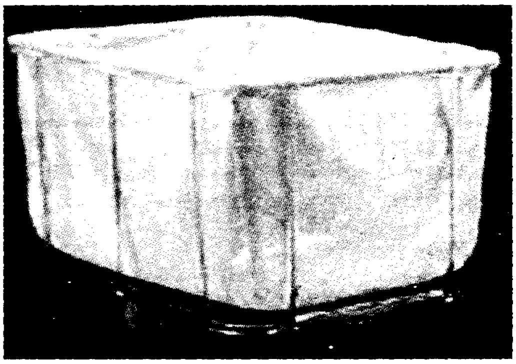


Utility Cart

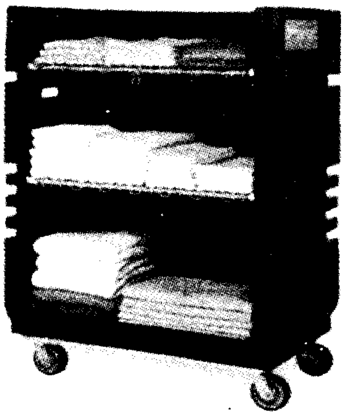


Soiled Linen Hamper

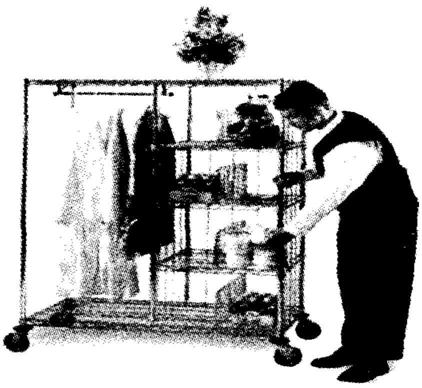
Mobile Fresh Linen Trolley

Notes

Mobile Soiled Linen Trolley



Mobile Fresh Small Linen Trolley



Valet Guest Laundry Trolley

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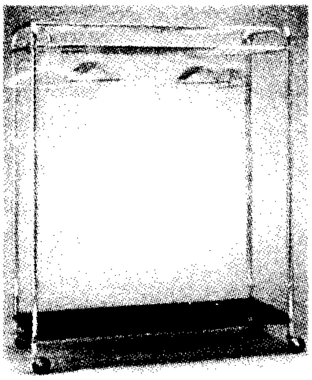
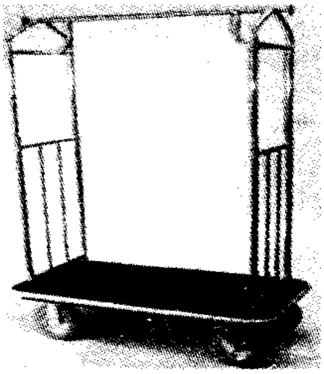
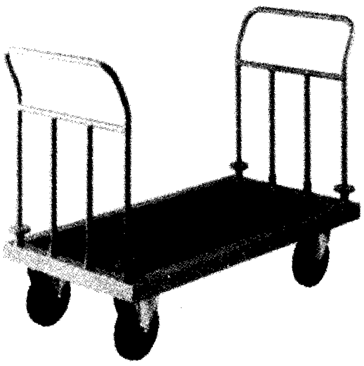


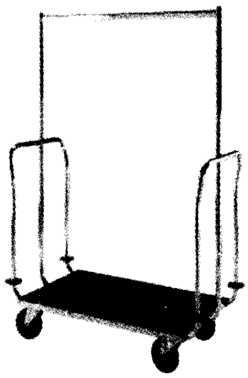
Mobile Uniform Trolley



Mobile Guest Laundry Trolley



All-Purpose Trolley



All-Purpose Trolley (Hanging)

Cleaning equipment

When purchasing housekeeping equipment, it should be remembered that there are many products that will seem *to* fulfil a requirement but will fall short of lasting needs. The challenge is to find the right piece of equipment, one that is of a quality that will with stand continuous use with limited maintenance, and that will be the most cost effective in use of resources. The decision as to what equipment best meets the needs of the department is usually made as job descriptions are being written. Quality, however, becomes another issue.

Some managements stress price of purchase rather than quality of product and do not consider the overall value of more substantial equipment. Other managements will demand a high quality of equipment for employees and will then expect the highest standards of cleanliness. The executive housekeeper should presume that management desires the highest level of cleanliness possible and expect that workers be supplied with the wherewithal to accomplish the task.

Many product suppliers also act as equipment representatives. When new hotels open, suppliers will seek an appointment to present their product and equipment lines. A manufacturer's representative who can be depended upon is an asset worth considering when purchasing equipment.

The executive housekeeper should have the final say regarding the type, quantity, and quality of equipment required for cleaning the guestrooms and public areas of the rooms department. Equipment purchases will be substantial and will therefore require the utmost care and consideration in selection. An analysis of the various items of equipment is appropriate for a hotel the size of our hypothetical model. General information about this equipment follows.

Housekeeper's cart

The housekeeper's cart is a most significant piece of equipment. There should be one cart for each section of rooms. This cart must be large enough to carry all of the supplies that tile GRA might readily be expected to use in the workday. (Repeated trips to the main or satellite linen room for two extra sheets or three more glasses is distracting and will decrease work efficiency.)

Since the cart is large and may be heavily loaded, it must be maneuverable and capable of being Pushed by someone weighing less than 100 pounds. Surprisingly, such carts do exist. Quality

Notes

housekeepers' carts are maneuverable with fixed wheels at one end and castered wheels at the opposite end. The solution lies in quality caster and ball-bearing wheels. Carts should have three deep shelves, facilities to handle soiled linen sacks and rubbish sacks that are detachable, storage for a maid's vacuum, and a top that is partitioned for small items. The neoprene bumper guard that surrounds the cart and protects corridor walls and door casings. These bumper guards should not leave unsightly marks if they come in contact with walls.

The partitioning of the top of the cart is best accomplished on a local basis when the specific items to be carried are available for sizing. The hotel carpenter should be able to make the appropriate partitions. Small service carriers are also available to support the work of lobby and public area housekeepers.

Housekeeper's vacuum

There are many ways to provide vacuums for cleaning guestrooms. Some hotels have tank-type vacuums for guestroom attendants. Others have tank-type vacuums installed on the housekeeper's carts with 24-foot vacuum hoses that will reach from the hotel corridor through the entire room. The main concern about tank vacuums being permanently installed on the, housekeeper's cart, however/ is the noise that permeates the hallway when one or more vacuums are in use. The vacuum most readily seen in hotel operations remains the upright vacuum with bag and belt-driven beater brush.

There are many commercial grade vacuums of varying degrees of quality ranging in price from just over $100 to in excess of $500. (1 have yet to find $400 worth of significant difference in vacuum cleaners and am thus disposed toward the less expensive.) The horsepower of the vacuum motor/ ease of emptying and changing of beater belts, and routine maintenance are either criteria upon which to judge vacuums.

Whether inexpensive or top line, housekeeper's vacuums will receive heavy use and at times abuse. If the less-expensive vacuum can withstand the heavy use (and it can) it is better to use it and have a higher replacement schedule when machines wear out than to pay a higher price and only be able to replace vacuums one-fifth as often. There should be one vacuum cleaner for each GRA, one for each public area housekeeper, and a 10 percent complement of spare vacuums.

Notes

Corridor vacuum

Housekeeping teams have section housekeeping aides whose responsibilities include vacuuming extensive sections of hotel corridors. .Such areas have open expanses of carpet that require an efficient form of vacuuming. The section housekeeping aide should have a vacuum that can do this heavy and time-consuming task.

All manufacturers of commercial equipment make models of this type and size and each should be investigated and compared before purchase.

Space vacuums

Space vacuums look like lawn mowers. Approximately 30 inches (76.2 centimeters) wide, motor driven/ and capable of picking up large items of debris, space vacuums are best suited for vacuuming the large expanses of carpet found in ballrooms, meeting rooms, and corridors. In a hotel the size of our model, both the banquet and housekeeping departments need space vacuums. On occasion, one space vacuum can substitute for the other if one is out of commission. There will be times when the catering department will need to use both space vacuums.

Pile lifter

Pile lifting, as the term implies, means lifting carpet pile that has become packed. This process usually occurs in conjunction with shampooing. The Regulator is an example of a machine that is capable of returning carpet pile to its vertical orientation. A pile lifter used before shampooing assists in cleaning the carpet and, if used after shampooing, assists in drying the carpet. Pile lifters are another form of vacuum cleaner, having a very heavy vacuum and large rotary brush that is operated by pulling the machine across the carpet. One pile lifter is usually found in the arsenal of equipment of every hotel with over 300 rooms.

Wet *vacuums*

Wet vacuums are an absolute necessity in hotel operations. Even though wet vacuums can be used for both wet and dry vacuuming, they are usually maintained in their wet configuration and are therefore ready for any spill emergency. There should be two wet vacuums on the property, one in the banquet department and one in housekeeping, both clean and ready for use. Wet vacuums are also required when large areas of noncarpeted floor are being stripped and

Notes

cleaned. They greatly aid in water removal/ making such operations more efficient.

Backpack vacuums

Backpack vacuums are very efficient for cleaning curtains, drapes/ ceiling corners, and other areas requiring high dusting. The vacuum unit straps to the user's back and has a hand-held wand with various attachments that provide flexible cleaning methods without having to configure the vacuum. Two backpack vacuums are sufficient in a housekeeping department that services 350 rooms.

Electric brooms

Electric brooms are very lightweight vacuums that have no motor-driven beater brush. 'Electric brooms are used primarily for very light vacuuming and are sometimes used in place of the housekeeper's vacuum. Electric .brooms are excellent for quick touch-ups on carpet and hard floors or for sand and spills when full vacuuming is not required. They should not be relied upon to replace the housekeeper's vacuum.

Single-disk floor machines

The single-disc floor machine, also known as the buffer or scrubber, is the most versatile item of equipment in the housekeeper's inventory. This machine can scrub floors, strip floor finishes, spray buff floors, sand wood floors, polish floors, and shampoo carpets. Machines are available in 17, 18, 19, 20, and 21-inch models. These machines will accommodate pads, brushes, and bonnets. Different pads are designed for different jobs from stripping to buffing.

Brushes are used to scrub floors and shampoo carpets and bonnets are used to "bonnet clean" carpets. When selecting a standard single-disc scrubber, do not select too small a scrubber. A larger machine will cover an area faster, thus reducing labour costs. Depending on the model, a single-disc floor machine will operate between 175 rpm and 350 rpm.

Burnishers

Burnishers or ultra-high-speed (UHS) buffers resemble single-disc floor machines, but they operate between 350 rpm and 2,500 rpm. They were developed to polish the new harder floor finishes that were introduced into the market. Unlike single-disc floor machines, the pad of a UHS buffer does not rest entirely upon the floor. Only the front part of the pad comes into contact with the floor; the rest of the weight is distributed to the wheels.

Many models have caster wheels in the front of the machine to distribute the weight. UHS buffers operate in a straight line, while traditional scrubbers operate from side-to-side. There are battery and propane models that enable the operator to cover vast areas without the need for troublesome electric cords. Propane models are noisy, they create noxious fumes, and they present 3 possible fire hazard.

Automatic scrubbers

The purpose of the automatic scrubber is to scrub or strip hard and resilient floors. The units apply a cleaning or stripping solution, scrub the floor, and vacuum up the dirty floor solution in one continuous operation. Most units are self-propelled. Some have attachments that turn them into a wet/dry vacuum, while others can also be used to buff dry floors. In addition to AC electric-cord models, there are battery-driven models.

The better battery-driven models are preferred because the constant plugging and unplugging of electric cords is an inconvenience and reduces employee productivity. Automatic scrubbers come in a wide variety of sizes, from a width of 17 inches to widths over 4 feet. When purchasing a machine to clean halls and aisles, consider the number of passes necessary to clean a hall. If a machine cleans aisles in the same number of passes as a smaller machine, then there is no benefit in paying the additional cost for the larger machine.

Wet-extraction systems

Wet extraction is sometimes referred to as a "steam" or hot water carpet machine. These terms are actually misnomers, for steam is never produced by these machines and hot water is often not used because of the shrinkage and fading risk. There are three varieties of extractors on the market today. The first type is the least expensive. It consists of two tanks—one holds the cleaning solution, a second tank holds the dirty pick-up water—and a wand that connects to the two tanks through two hoses.

As the wand is pulled across a carpet, the operator Sprays the clean detergent solution onto the carpet. On the same stroke, the solution is immediately vacuumed up into the waste tank. The second variety of extractor is virtually identical to the first, but it incorporates an invaluable attachment. A beater brush is attached to the wand that works the detergent solution into the carpet. and physically breaks

Notes

down the clinging soils before vacuuming. This option is definitely worth the higher price.

The third variety is unquestionably the best) for it reduces operator fatigue and effectively eliminates the extra effort required to periodically reposition the hose and tank unit. This variety is called a self-contained carpet extractor. These units eliminate the wand and. hoses, and battery models also eliminate the bothersome electric cord. The smaller self-contained units work quite well in guestrooms and the larger walk-behind models can clean up to a 3-foot swath of carpet in one pass. Some of these models have a hose and hand tools for cleaning stairs and upholstery. Dry foam carpet cleaners brush a low-moisture foam into the carpet that is vacuumed up after it has been allowed to briefly dry. It does leave a residual amount of foam in the carpet. Units come in a variety of width sizes, from 12 inches to over 28 inches. Many have attachments for upholstery.

Dry powder systems

Dry powder systems normally use three pieces of equipment. First, the dry powder is laid down on the carpet with an applicator. Then a brush unit works the powder into the carpet; this dislodges the soil from the carpet fibbers. The powder is then vacuumed up using a standard vacuum cleaner.

Convertible mobile shelving

Convertible mobile shelving is unique in its versatility and construction. A shelving unit in a satellite linen room, with shelves adjusted to receive soiled linen, acts as a storage hamper for used linen. At the end of the day the soiled linen is moved to the laundry in its own conveyor. In the meantime, another unit, with shelves adjusted to receive clean linen being processed in the laundry, may be moved to the satellite linen room so GRAs can load their housekeepers' carts for the next day's operation. Once emptied, the shelves are repositioned for a repeat of the cycle the next day.

Mobile convertible shelving not only removes the need for permanent shelving in the laundry and satellite linen rooms, it reduces the three-step task of moving linen from shelf to conveyor to shelf to a one-step loading process. There should be at least two units for each satellite linen room.

Trash-handling equipment

Another piece of equipment used by the section housekeeping aide is some form of conveyor whereby rubbish and other materials may be moved from various sections of the hotel to a disposal area. A conveyor similar to that produced by Rubber-maid, known as a hopper, is recommended. The hopper may be used to remove soiled linen several times each day from housekeepers' carts to the satellite linen room, or it may be used to carry rubbish sacks from maids' carts for emptying. A great deal of moving of material supplies and rubbish occurs each day in each section of the hotel. Each housekeeping team (section housekeeping aide) will therefore need a conveyor for moving material.

Sewing machines

A sewing machine of commercial quality is useful in the main linen room. This sewing machine will be used to repair drapes and bedspreads and may be used to make certain fabric items. The machine must be of commercial quality since one item requiring repair will be heavy blackout drapes. No automatic or multiple stitch machines are required.

G/ass *washers*

Depending on whether guestroom drinking glasses will be made of plastic or glass and depending upon the availability of the hotel dish room dishwasher, the housekeeping department may need its own glass washer. In hotels of major size (1000 rooms) a properly equipped linen room should have a glass washer to prevent using labour to move 15 or 20 cases of glasses to the kitchen each night. Glass washers are expensive and are major items of equipment. The use of real glasses as opposed to plastic ones is a matter of quality as well as economics, and the multiple uses of glasses justify the expense of a glass washer.

UNIT – III

WATER SYSTEM - HARDNESS OF WATER - WATER SOFTENING BY BASE EXCHANGE METHOD - COLD AND HOT WATER SYSTEM - FLUSHING CISTERN - WATER TAPS - TRAPS AND CLOSETS - TYPES OF JOINTS AND PLUMBING EQUIPMENT

OBJECTIVES:

- Water System
- Hardness & Softness of Water
- Water Softening
- Cold Water distribution
- Host Water distribution
- Flushing system
- Types of Taps
- Types of Joints

STURUCTURE:

- Importance of water
- Sources of water
- Maintenance of tube well
- Water supply and drainage
- Plumbing services
- Distribution system
- Estimation of water requirements
- Material for service pipes
- Service connection
- Size of service pipes
- Water meter
- Valves
- Storage tanks
- Quality of safe water
- Water softening

- Hot water appliances and installations
- Piping layouts
- Conveyance of water
- Pipes and traps
- Sanitary fittings
- Systems of plumbing
- Drainage plans

IMPORTANCE OF WATER:

Next of air, the other important requirement, for human life to exist is water. It is essential for life, health and sanitation. It is the principal raw material for food production. It is needed for drinking, bathing, washing of hand, face, floors, washing of cloth, flushing of W.C., gardening, vehicles & road washing, fountain, heating, air conditioning, swimming pool, air cooler, etc.

In hotels water requirement is 180 Lit/bed/day. In restaurant water requirement is 70 lit/day.

SOURCES OF WATER:

The chief source of all water supply is rainfall. This water after getting proper treatment is received from municipal corporation/water supply department i.e. public health engineering department.

Other source of water is underground water. Water that has percolated into the ground is brought on the surface.

The upper surface of free water, in the top soil is termed as ground water level/table. Infiltration wells are sunk in series on the bank of river.

Other source is spring, an outcrop of water. A ground well is defined as an artificial hole/pit made in the ground for the purpose of tapping of water.

Following are types are wells –

(a) Shallow wells

(b) Deep Wells

(c) Tube wells

(d) Artisan wells

Tube wells are of different types

(a) Strainer type

(b) Cavity type

(c) Slotted type

(d) Perforated type

Tube well is deep well having diameter of 50 to 200 mm.

A bore is drilled in the ground (Percussion, core, rotary drilling m/c). For testing the yield of a well recuperation and constant pumping test is done. The pipe for tube well is then inserted in the bore hole. It consists of strainers and blind sections. A strainer is a perforated pipe which is provided with an arrangement such as that only water will be admitted to inside of the pipe. Pumping is then started.

Maintenance of Tube Well:

(i) Cleaning of screen with Hydro-sulphuric acid, Hydrochloric acid.

(ii) Removal of lime particles – clogging of screen.

(iii) Replacement of parts

Failure of tube well is due to

(i) Corrosion

(ii) Incrustation – deposition of alkali salts on the inside walls of the tube well.

Types of well construction:

(a) Dug well – Shallow well

(b) Driven well – Deep well in unconsolidated solid

(c) Bored/drilled well

Sanitary protection of well:

(a) Water tight connection of pump

(b) Covered top

(c) Casing depth 3m below the ground water table

(d) Distance from the source of contamination, minimum 90 m

(e) No presence of trees

(f) Priming of pump by safe water

(g) Washing of cloth should be prohibited

WATER SUPPLY AND DRAINAGE:

PLUMBING SERVICES

Public water supply systems follow the sequence of water collection from source of supply, conveyance to treatment plants, treatment including disinfection and, finally, its distribution. Ultimately, water is distributed for various consumption purposes in a building through internal water distribution system. In every building, adequate quantity of water should be available at required locations, to meet various needs of the occupants. Before designing a building, water needs must be properly computed. The transmission of water within the building is carried through pipes which may run either underground or above ground. The water so supplied ultimately gets converted into waste water, which has to be properly drained. Various fittings used for use of water, and for drainage of used water are commonly known as sanitary fittings.

The services like water supply, drainage, sanitation etc. are sometimes known as plumbing services. Plumbing is a general term indicating the practice, materials and fixtures used in the installation or maintenance of all piping, fixtures, appliances and other appurtenances used in connection with water supply system as well as sanitary and storm water drainage system within a building and its connection with any point of public disposal. The plumbing system comprises the entire system of piping fixtures and appliances etc. used for water supply and drainage. Thus a plumbing water supply system comprises of water supply and distribution pipes, taps, valves, storage tanks etc., while plumbing drainage system consists of wash basins, water closets, urinals, traps, soil waste pipes, vent pipes, septic tanks etc. etc.

WATER

DISTRIBUTION SYSTEM

Water is collected from the water main through a service connection. The layout of water distribution piping may be basically a horizontal or vertical arrangement of limited height and in which underground mains under pressure supply water to the fixture inlets. Such a system is known as unfed system. Alternatively, water is first collected in underground tank (known as suction lank) and then it is pumped to elevated storage tanks, usually situated at the top of the building. From these elevated storage tanks, water can flow down and feed the fixtures.

General considerations While laying out the pipe lines, the following considerations should be kept in mind:

1. The lines should be so laid that there is no risk involved in the contaminating of water supply. For this, following three things are necessary:

(a) There is no cross-connection any where between a pipe carrying possible water and the pipe carrying used or waste water.

(b) There should be no back flow from any cistern or appliance towards the source of supply.

(c) Water supply pipes and waste water pipes (drainage pipes) should not be laid very close to each other.

2. The pipe line should be properly protected against any damage. To achieve this, underground pipe line should be enclosed in a cement mortar so that its rusting by soil bacteria is prevented, and also it should have earth cover of at least 60 cm. When pipe line is laid above ground, it should run clear of water. Also, when it crosses a wall, it should be contained in suitable sleeve for the entire length of the crossing.

3. In the unfed system, pipe should carry water under adequate pressure. For this, lay out of pipe should be simple and direct as far as possible. The pipes should be laid out as straight as possible.

Estimation of water requirements

For residential buildings, Indian Standard recommends that a water requirement of 135 litres per head per day may be assumed. Out of this, 90 litres may be taken for domestic purposes while the balance 45 litres are taken for flushing requirements.

The requirements of water for buildings other than residence may be found from Table.

WATER REQUIREMENTS FOR BUILDINGS OTHER THAN RESIDENCES

S.NO.	TYPE OF BUILDING	RATE PER HEAD PER DAY IN LITRES
1	Factories, where bath rooms are required to be provided	45
2	Factories where no bath rooms are required to be provided	30
3	Hospital (including laundry) per bed (i) Number of beds not exceeding 100 (ii) Number of beds exceeding 100	 340 450
4	Nurses homes and medical quarters	135
5	Hostels	135
6	Hostels (per bed)	180
7	Offices	45
8	Restaurants (per seat)	70
9	Schools (a) Day Schools (b) Boarding Schools	 45 135

MATERIAL FOR SERVICE PIPES

The pipe leading from the distribution main of the municipal water supply to the plumbing system of the house is known as the service main. The following materials are commonly used for service pipes:

(1) Copper pipe or brass pipe

(2) Galvanized iron, either lined or unlined

(3) Load pipe, either lined or unlined

(4) Polythene pipe.

1. Copper tubing:

Copper tubing is non-corrosive with most waters. It is used extensively in better grade houses and where ground water is highly corrosive to steel pipe. It has considerable strength, reasonable ductility, and is obtainable in long lengths. There are two types of copper water service pipes: heavy gauge and light gauge. The former can be threaded and is used for high pressure work in industrial layouts. For general purpose work where pressure does not exceed 1.5 kg/cm^2, and interval domestic work, light gauge tube is used. For underground work, as for the pipe from the main to the building, special copper tube is used having a heavier gauge. The copper tube can be attached to the main without the use of conventional goose neck, the flared end of the tubing being connected directly to the corporation cock without threading.

2. G.I. pipes:

These are used where water is suitable. In India, these are extensively used because of their low cost in comparison to copper tubes. Galvanized iron or steel tubes corrode more readily in soft and acid waters and are not so easily manipulated as copper, although they are stronger and can be used in hard water area where they withstand the hammering needed to remove the scale.

3. Lead pipe:

Lead pipe has the following advantages (i) highly resistant to corrosion (ii) highly flexible and (iii) high hydraulic coefficient of flow. However, lead has cumulative poisoning effect, especially when it goes into solution. Due to this, it is not preferred.

4. Polythene tube:

These are being increasingly used internally and externally for cold water service pipes only. Plastic pipe has the following advantages over metal piping. (i) it is lower in cost (ii) it is non corrosive (iii) it is light in weight (iv) it can be installed with ordinary tools, (v) it does not require threading (vi) it is more resistant to bacterial scale and (vii) it has some insulating value. However, these are not useful where temperature is high.

SERVICE CONNECTION

A service connection is primarily a connection from the distribution system to the consumer. A consumer may be a single house, an apartment house, a planned block development or a water district buying water "wholesale'. A connection for a single house will normally involve tapping the main while it is under pressure and installing a corporation cock.

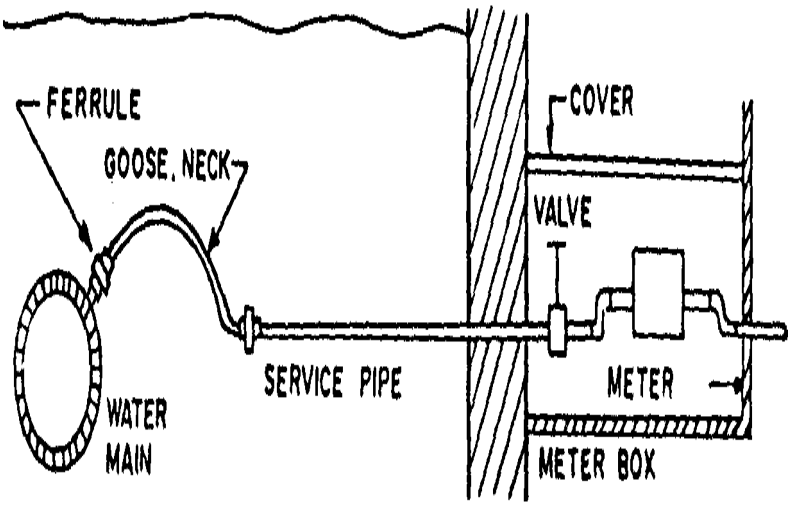


FIG. SERVICE CONNECTION

A domestic service connection includes the following components:

1. Brass or bronze ferrule:

Ferrule is a right angled sleeve made of brass or bronze. For a typical service connection to a house, a ferrule is inserted in the main, most usually an 'under pressure' connection which can be inserted without shutting down the main.

2. Goose neck:

This consists of a 40 to 50 cm long curved piece of flexible pipe made of brass, copper or lead. The goose neck prevents the breaking of the main service pipe due to movement that takes place between the water main and the service pipe, thus providing flexibility of the junction.

3. Stop cock or curb valve:

It is installed in a suitable chamber with cover, to close down the supply, for repairs of the plumbing system.

4. Main service pipe:

It may he of various materials. Its diameter may very from 12 mm to 40 mm.

5. Water meter:

It is also installed in a suitable chamber with cover. It measures the quantity of water used by the consumer.

SIZE OF SERVICE PIPES

The sizes of the service pipes are determined on the basis of the following:

(i) the minimum pressure in the distribution main at the proposed point of connection,

(ii) Length of service pipe required,

(iii) elevation of the highest point of delivery above the distribution mains,

(iv) number and types of plumbing fixtures in the building, and

(v) Maximum rate of flow required. The maximum rate of flow may be estimated by considering what the average householder expects at his plumbing fixtures. Guidance may be taken from Table.

TABLE

PLUMBING FIXTURE	FLOW REQUIRED (LITRES/MIN.)	
	GOOD	REASONABLE
Kitchen Tap	10	7
Bath Tap (cold)	25	15
W.C. Flushing Cistern	10	7

If it is assumed that one of each of these is in operation simultaneously, a maximum demand rate of 29 to 45 litres/min. is obtained. Knowing ihc rate of How and the desired velocity, pipe diameter can be found. Alternatively, the diameter of service pipe can also be fixed on the basis of occupants in the house, as given in Table.

TABLE

No. of Occupants	4	8	24	60
Diameter of service pipe (mm)	12.5	20	25	30

WATER METER

Water meter is normally used for measuring flows to domestic buildings. A water meter should possess the following characteristics:

1. It should accurately measure and register both small and large flows.

2. It should be easy to maintain and repair. Spare parts should be readily available.

3. It should have good capacity with reasonable head loss.

4. It should be capable of working, at all pressures efficiently.

5. It should be durable. Its parts should not be affected by chemicals used for purification and the impurities in water.

6. It should be rugged.

7. It should prevent back flow passing through it and should not be liable to clogging.

8. It should have low cost.

Meters used on water distribution systems may be of two types :

(a) Inferential or velocity meters, and

(b) Positive or displacement meters.

Inferential meter:

It measures the velocity of flow across a cross-section whose area is known. They are used only for high flows. Common examples of this type of meters are the rotary and the turbine meters.

Displacement meter:

These are primarily used for relatively low flows as for the residential buildings. In this meter, the quantity of water actually passing through it is measured by filling and emptying

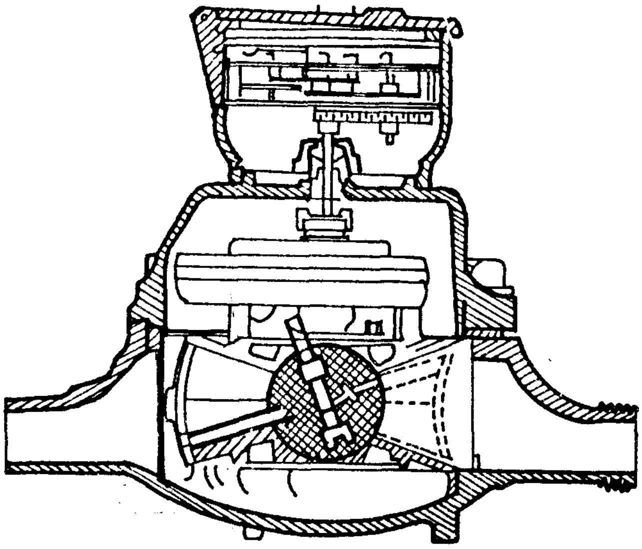


FIG. NUTATING-DISC METER

The chamber of known capacity. Types of displacement meters in use include reciprocating, rotary, oscillating and mutating disc meters, depending upon the motion of the moving part in the measuring device.

Disc meter, shown in Figure consists of a disc of hard rubber placed inside a chamber which is provided with inlets and outlets. The water entering the chamber oscillates the disc about its centre with a spiral motion. The oscillations implied by one complete filling and emptying are recorded by the disc meter in terms of volume of water.

VALVES

For domestic water supply, two types of valves are commonly used:

(a) Globe valve, and

(b) Gate valve.

Globe valve:

It is used in pipe lines for convenience in manually closing the pipes to control the flow of water. Figure shows the section of a globe valve. It should be installed with water pressure under the valve seat as shown. The globe valve has advantage of quicker opening and closing, of longer life and of being more easily repaired.

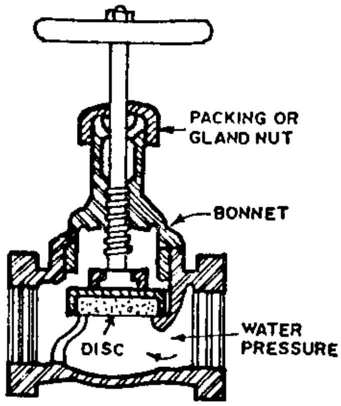


FIG. GLOBE VALVE.

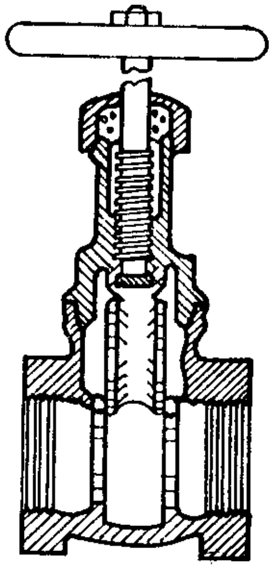


FIG. GATE VALVE.

Gate valve:

Gate valve is used in pipe lines for convenience in manually closing the pipes. The gate valve has an advantage over the globe valve in that it offers less resistance to flow. It is therefore used in preference to the globe valve where resistance to the flow of water is to be kept at a minimum. It also controls the flow equally well from either direction.

STORAGE TANKS

The water supply to a building may either be continuous or intermittam. Even in the case of continuous supply in the mains, the pressure of water may not be sufficient to rise to all the floors of the building. In either case, storage tanks are required. The storage tanks may be situated either at the ground level, or at the roof level or at both the levels. If the pressure of water is sufficient to rise to the roof level, storage tank is provided only at the roof level, so as to store water because of intermittant supplies. If the pressure of water is not sufficient, water is first stored at the ground tank from where it is pumped to the top storage tank.

A storage tank is made of the following materials: (i) mild steel pressed plates (ii) reinforced concrete, or (iii) stone or brick masonry. Figure shows a typical section of a storage tank cover.

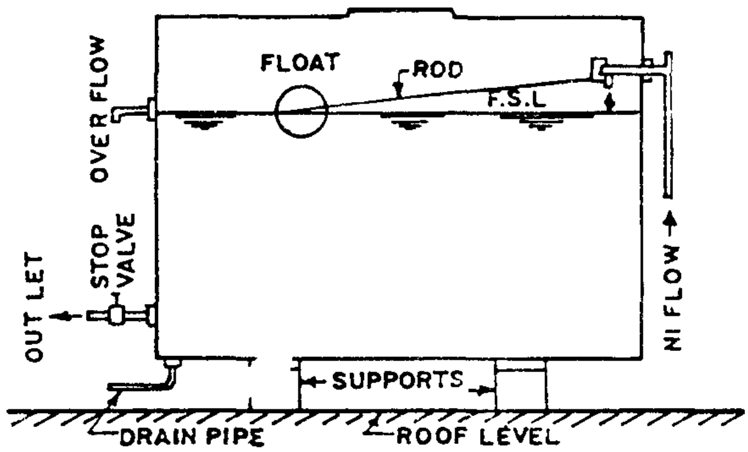


FIG. STORAGE TANK.

A storage tank consists of following accessories:

1. Top valve is made of mild steel, aluminum or other suitable material, light in weight and tight fitting so that mosquitoes do not enter. It may have locking arrangement.

2. Ball valve with float which is provided near the inlet to the tank, so as to control the inflow of water. The float assembly works automatically, thus maintaining a constant water level in the tank. When the water level falls down, the float moves down thus opening the inlet valve. When the level in tank reaches the desired full supply level (F.S.L.), the float rises up thus closing the inlet valve.

3. over flow pipe which is set about 2.5 cm above F.S.L. In case the float assembly fails, the inflow is not cutoff and the water entering the tank overflows through this pipe.

4. Supply pipe or inlet pipe, admitting water into the tank.

5. Outlet pipe with stop valve set about 2.5 to 5 cm above the bottom of the tank, for cutting off the supply to down tank pipes.

6. Drain pipe or scour pipe for cleaning the tank periodically.

Capacity of storage tank

The capacity of storage tank depends upon the following factors:

(a) Supply hours from the mains, with sufficient pressure.

(b) Frequency with which the tank can be refilled during 24 hours.

(c) Rate and regularity of supply.

In the case of multi storeyed building, the first two or three storey may be fed directly from the water mains while upper storeys are fed directly from the storage tanks. However, if the supply is either intermittent or irregular, storage may be provided for all the storey. Table gives Indian Standard Recommendations for domestic storage capacities.

TABLE DOMESTIC STORAGE CAPACITIES

(A) For premises occupied as tenements with common convenience (1) Ground floor (2) 1st, 2nd, 3rd, 4th and upper floors	No storage required, provided no down take fittings are installed 500 litres per tenement
(B) For premises occupied as flats or blocks; (1) Ground floor (2) 1st, 2nd, 3rd, 4th and upper floors	No storage required, provided no down take fittings are installed 800 litres per tenement

Flushing storage tank:

These tanks arc required to supply water to the various flushing cisterns through down tank pipes. The supply pipes of a building do not directly feed water to these cisterns. The storage capacities for flushing purposes depend upon the number of water closets (W.C.) and urinals in a building. Table gives I.S. code recommendations for flushing storage capacities for various types of buildings.

STORAGE CAPACITIES

S.No.	Classification building	Storage Capacity
1	For tenements having common conveniences	900 litres net per W.C. seat
2	For residential premises other than tenements having common conveniences	270 litres net for each W.C. seat and 180 litres for each additional seat in the same flat
3	For factories and workshops	900 litres per W.C. seat and 180 litres per urinal seat
4	For cinemas, public assembly hall etc.	900 litres per W.C. seat and 360 litres per urinal seat

QUALITY OF SAFE WATER :

Properties of safe water –

(a) Physical – colour 10 – 20 Platinum cobalt scale testing to Tint meter.

(b) Taste and odour – Threshold number $\leq$ 3, smell 0 to 4 pu value

(c) Temperature 10^{0}C to 15.6^{0}C

(d) Turbidity 5 to 10 ppm. Silica scale measured by Turbidity meter

(e) Chemical tests

Fluorides 0.5 to 1.5 ppm

Chlorides 200 ppm 200 mg lit

Dissolved gases, oxygen 5 to 10 ppm

Hardness 5-8 degrees = 75 to 115 ppm

Hydrogen ion concentration (pH value) 7 to 8.5, determined by electrometric method, calorimetric method.

Sulphate maximum up to 250 ppm

Carbonate alkalinity up to 100 ppm

Metals and other chemical substances

Iron and manganese up to 0.3 ppm

Nitrogen and its compound, Nitrates 45 mg/lit, total solids 500 mg/lit

(f) Bacteriological tests B coil No. B coil in 100 ml.

(g) Impurities of water suspended, silt causes turbidity

Bacteria causes diseases

Algae causes colour, odour, turbidity.

WATER SOFTENING:

Water which does not produce lather with soap solution is called hard water.

The hard water should not be used because –

(a) If it is drunk it helps in formation of stone or calcus.

(b) It causes corrosion and incrustation of pipes and plumbing fixtures.

(c) It causes more consumption of soap is laundry work, sticky precipitates, adheres on the cloth giving spots and scratch – straining of cloth.

(d) It increases the fuel cost. It takes more time, pulses, beans, peas do not cook.

(e) Tea and coffee are unpleasant in taste, with muddy looking.

(f) It makes food tasteless, tough rubbery.

(g) It provides scales on hot water system, over heating of utensils is needed.

(h) During bathing, lots of soap is wasted, skin become dry and dark.

The hardness is of two types:

(a) Temporary/Carbonate hardness – due to the presence to bio-carbonates of calcium and magnesium. It can be removed by boiling or by adding lime to the water.

(b) Permanent Hardness – due to the presence of sulphates, chlorides and nitrates of calcium and magnesium.

Advantages of Soft Water:

(a) Improves the taste of food

(b) Increases the life of textiles

(c) Personal washing and domestic cleaning becomes less laborious.

(d) Less loss of heat in hot water pipes.

Removal of permanent Hardness:

Water softening treatment is to be given to water for the removal of permanent hardness.

Storage of Water

Storage of water within the premises of a building is usually necessary, because the municipal supplies are usually not available round the clock. Such storage may also help in meeting static fire demand and to provide uninterrupted water supply in the building in case the main municipal or ground water supply is shut oft' for repairs, or if there is a power failure. Storage may also help to supplement the direct municipal supply in case of excess or peak demand.

Estimating Storage Capacity:

The water storage capacity for a building will depend on the following factors:

(i) Hours of supply;

(ii) Rate of supply, governed by the pressure in the mains;

(iii) Demand pattern in the given building; and

(iv) Fire storage required.

Overhead Storage:

When the city water supply is available at sufficient pressure round the clock, as to rise to the highest floor, then no overhead storage is required, and all the water supply fixtures can be connected with the direct supply line. However, in India most of the city water supplies are confined only to a few hours in the morning and evening. Due to this reason, it becomes imperative to store water in overhead tanks, particularly for its use in toilets and urinals. Most of the Indian municipalities require mandatory overhead water storage exclusively for flushing of toilets and urinals to ensure constant supply for flushing toilets. This requirement depends upon the number of sanitary fixtures in the building and may vary from city to city, depending upon the living standards of the occupants of the building. The required overhead storage capacity for flushing purposes per fixture for different types of buildings, stipulated by Bureau of Indian Standards, vide its code IS 1172, is given in table:

Table Water Storage required for Flushing purposes in Buildings

S.No.	Type of Building	Storage Capacity Required
1	For tenants having common conveniences	900 litres per W.C. (Water Closet)
2	For residential premises other than (1) above	270 litres for one W.C. seat, and 180 litres for each additional seat in the same flat
3	For factories and workshops	900 litres per W.C. and 180 litres per urinal seat
4	For cinema halls, public assembly halls, etc	900 litres per W.C. seat and 350 litres per urinal seat

In areas of chronic water shortage or intermittent supply, additional overhead storage is required for other domestic uses like' washing and bathing, as indicated in table.

Table Storage required for Domestic Uses

S.No.	Type of Building	Unit (Pet)	Unit storage in litres per unit
1	Dwelling units	Resident	70
2	Hostels	Resident	90
3	Hotels	Resident	135
4	Commercial building without canteens	Head	35
5	Commercial buildings with canteens	Head	45
6	Restaurants	Meal	7
7	Day schools	Head	25
8	Boarding schools	Resident	90
9	Nursing homes and medical quarters	Resident	135

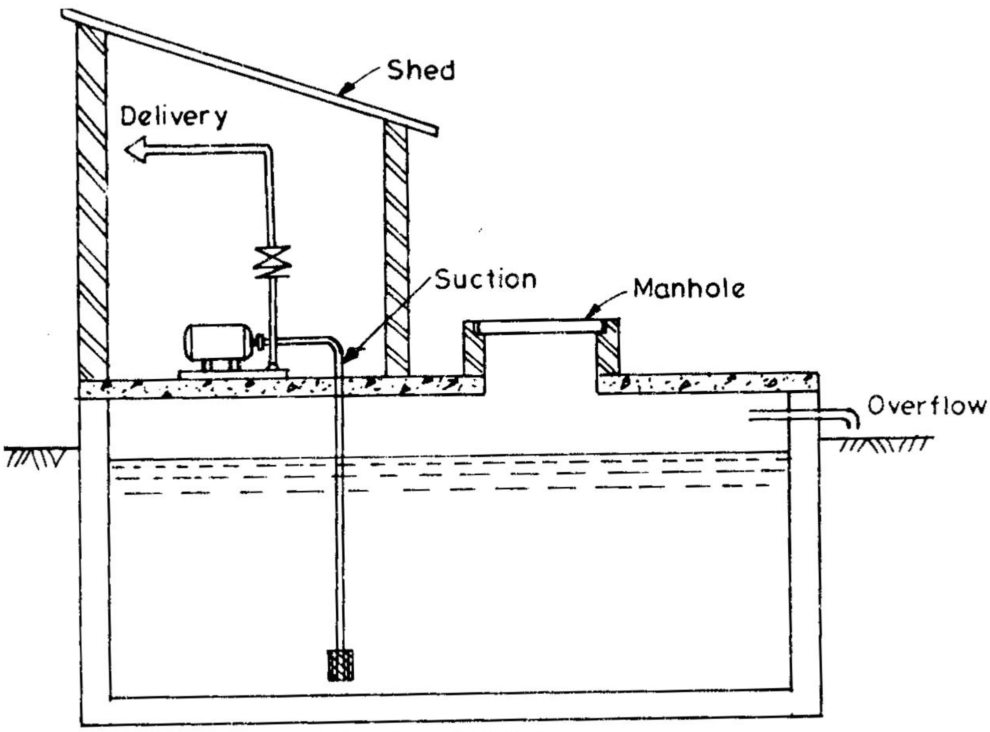
Underground Storage:

Underground storage tanks (or tanks at ground level) are necessarily required to collect water from municipal supply lines, if the water pressure in the main is insufficient to reach the overhead tanks. The water collected in the underground tank is then pumped up to the overhead tank. Direct use of pumps on the municipal mains is always prohibited by the municipal authorities, as it reduces the water pressure in the adjoining houses or buildings. Inspite of prohibition, many residential units do install their individual tullu pumps on the municipal mains, to avoid the con5truction of underground tanks.

The capacity of an underground storage tank should be the net difference between the daily peak demand and the flow during hours of supply. Provision should be added for non-supply due to power failures or other causes. For normal buildings with a dependable water supply, underground storage capacity is taken at 12—24 hours of average daily demand.

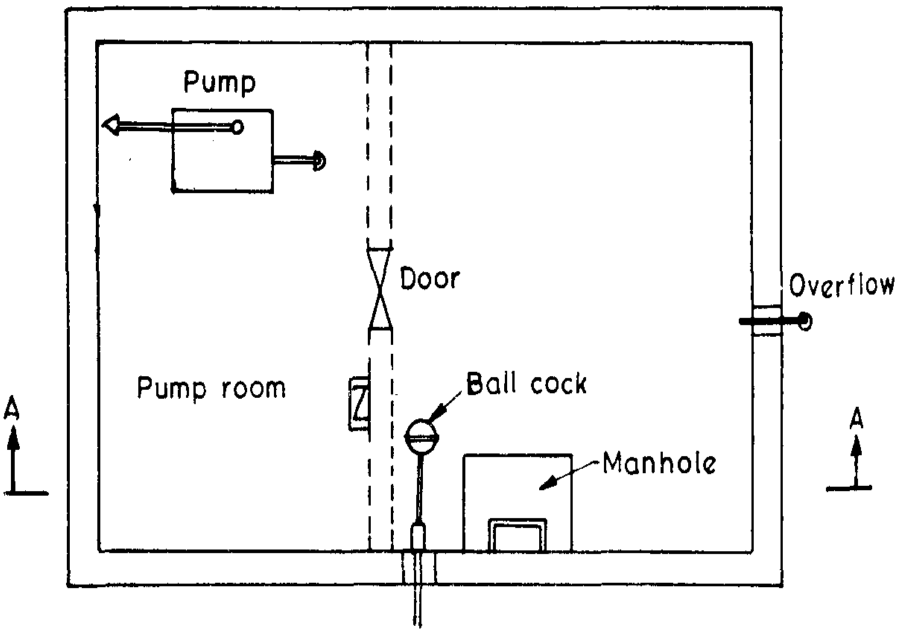
Domestic Under-ground Storage Tanks

Typical details of a rectangular under ground water tank are shown in Figure. Such a tank is made of R.C.C. or brick masonry, and has to be structurally designed safe to withstand earth pressure (When the tank is empty). The tank is to be filled from the municipal supply inlet, and is covered from the top to avoid any contamination. The top cover may be provided with a manhole for inspection and cleaning purposes. Suitable pump is installed to lift the water from this tank and up to the overhead tank. Care should be taken to construct an underground tank so that:



(a) SECTION A-A

(a) Section



Inlet

Fig. A typical underground water storage tank.

(i) It is water-tight and does not leak when empty or full;

(ii) It is not located in low-lying areas, which may permit entry of surface water from the top;

(iii) It should prevent ingress of subsoil water into the tank through leakage;

(iv) It should not be located near sewers, septic tanks, soak pits, oil tanks, or under-ground car parking areas, to avoid seepage of surface waters;

(v) The overflow water level in the tank should be above the surrounding ground level, to prevent the surface water from entering the tank through overflows;

(vi) The top slab is designed to carry the load for heavy traffic and fire tenders, which may be likely to move at the given site;

(vii) The masonry or R.C.C. retaining walls of the tank should be structurally safe to withstand the earth pressure from behind, when the tank is empty.

Domestic Overhead Storage Tanks:

Overhead tanks placed on the top of the buildings should be properly located as to safely transmit their loads to the beams and columns (or to the walls) in the building. Three types of tanks are usually being used:

(i) **R.C.C. tanks;**

(ii) **G.I. tanks; and**

(iii) **HDPE tanks.**

There three types tanks are briefly described below:

(i) R.C.C or Masonry Tanks:

Tanks made from R.C.C. or brick masonry have traditionally been used, since they can be easily constructed in any shape and size to suit the site dimensions. Brick masonry tanks are generally used for smaller sizes, while R.C.C tank are generally adopted in higher sizes. Such a tank has to be made water-tight by adding a water-proofing compound in the concrete and the plaster mix. All inlets, outlets etc. must be inserted at the time of construction. Precast R.C.C. tanks (Figure) have also been used, but are becoming obsolete with the advent of HDPE tanks.

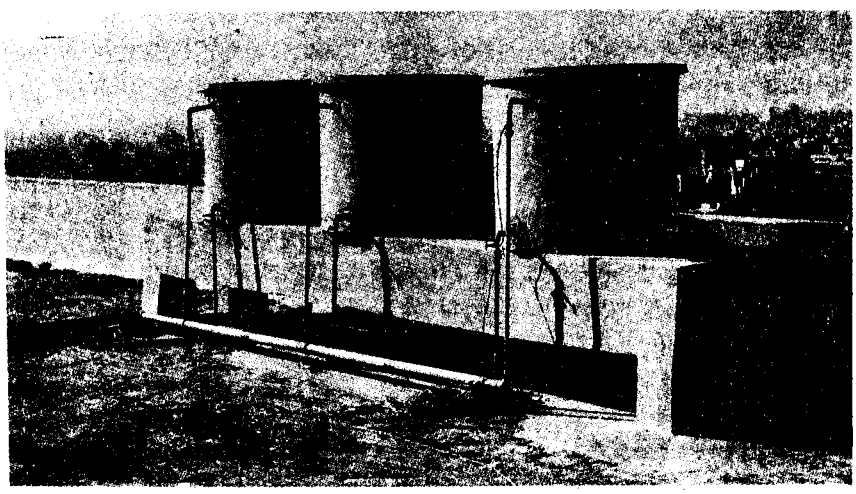


Fig. Precast concrete tanks.

Metal Tanks:

Metal tanks fabricated from mild steel or galvanized iron. Sheets have traditionally been used in our houses over the years, as they can be easily fabricated and are light, durable and easy to install.

Galvanized iron (G.I.) **tanks** are made from G.I. sheets, usually 16 or 18 gauge, and fabricated by using galvanized angle iron for corner supports and the sheets riveted with G.I. rivets. The non-corrosive natures of galvanized tanks make them ideal for domestic and drinking water. Use of ungalvanised materials in the fabrication of G.I. tanks may, however, corrode them faster. G.I. tanks can be made only in smaller sizes (up to 1800 litres or 1.8 m^3 capacity) due to limitation of sheet sizes. A typical G.I. tank installation is shown in Figure.

Metal tanks using **Mild** steel (M.S.) sheets can however be fabricated to any shape and size with suitable structural supports. The inside and outside surfaces of such tanks are protected against corrosion by suitable paints and coatings. When the tank water is used for drinking and domestic purposes, the paints used must be non-toxic.

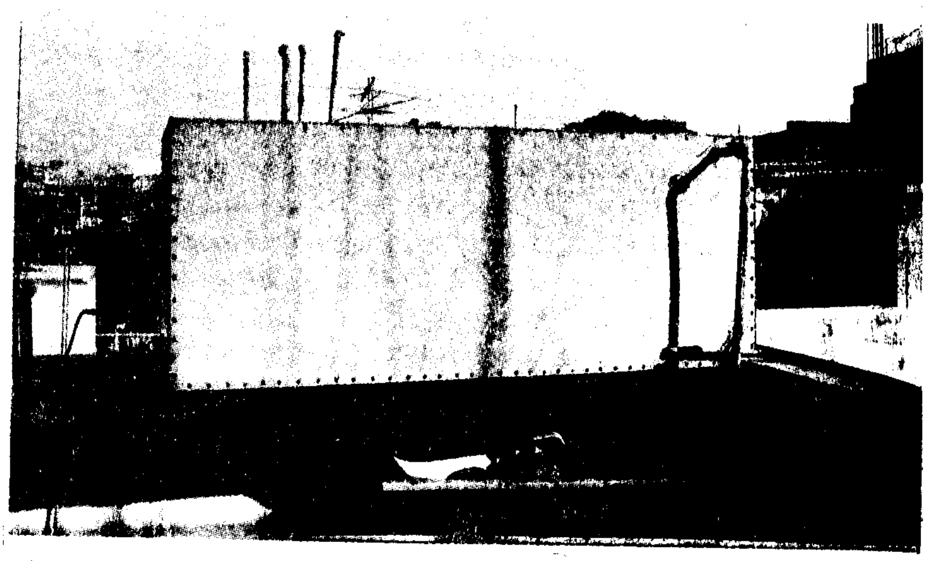


Fig. Galvanized iron tank

Plastic Tanks:

Plastic tanks are usually made of high density polyethylene (HDPE) or fibre glass reinforced plastic (FRP), or any such strong plastic material. They are usually available in a variety of shapes and sizes, and are light and corrosion resistant. Though they are not immune to ultra violet radiation from sunlight, yet they can be protected by using appropriate resin coverings. Sintex brand HDPE tanks (Figure) have nowadays become very popular in the country.

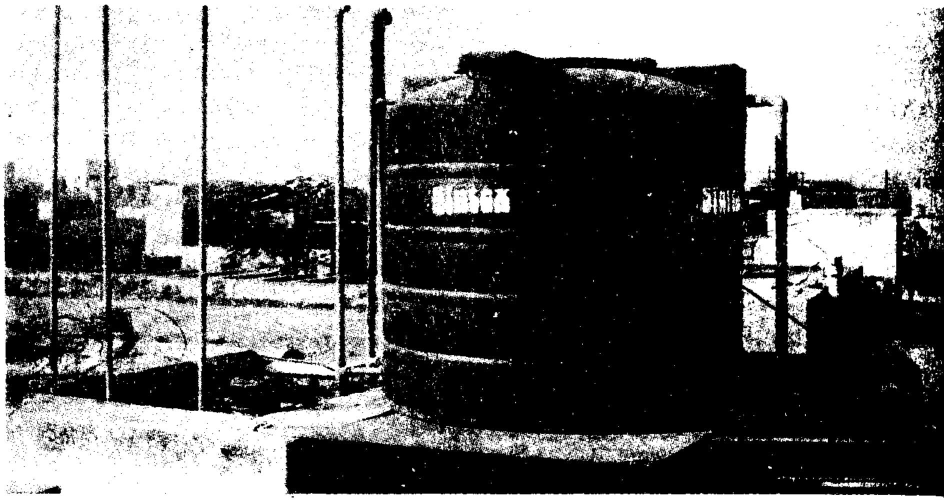


Fig. HDPE tank

General Requirements of Domestic Water Storage Tanks:

The domestic water storage tanks should fulfil the following general requirements:

(1) Water Tanks should be water-tight. They should be constructed with non-corrosive and non-toxic materials. They should have smooth surface inside. They should be provided with sufficient number of manholes or accesses for repairs with locking arrangement and corrosion resistant steps, catch rings or ladders to reach the manhole bottom for maintenance.

(2) Water tanks should be provided with a vent pipe for ventilation as well as for prevention of negative pressures when water is drawn from the tank. Such negative pressures, may other wise trigger a collapse if the tank is weak, and retard flow from the tank.

(3) Water tanks should have an overflow pipe. Overflow pipes may also act as a 'warning pipe' to indicate overflow of water in the tank.

(4) Water tanks should have a scour pipe with a plug at the bottom so that it can be emptied easily. In case of underground tanks, emptying has to be achieved by using the pumping sets provided for boosting.

(5) Under no circumstances should any overflow or scour be directly connected to any drain, gully trap or sewer. These connections should be discharged over properly designed drains with a minimum air gap of 75—100 mm.

(6) Vents and overflows must be protected by a suitable gauge or grating to prevent the entry of mosquitoes and insects. The top slab cover should be sloped away for proper drainage and to prevent stagnation of water on top.

Water Piping Systems in Buildings

The distribution of water within a building from the city mains or other sources such as ground water can be obtained by several piping systems. Each method has its own merits and demerits depending upon the local conditions. Such piping systems must, however, is designed to provide uniform flow and pressure in all floors and places within certain practical limitations, of course. The piping systems to be adopted will differ when the main supply is used, or when the overhead tank supply is used, or when the underground-overhead tanks supply is used, as discussed below :

Piping System Using Direct Supply:

In this system, water is supplied to all the fixtures at all floor \eve[s of a building directly from the city main, through the house connection, as shown in Figure. Such a system is, however, successful only when the water supply is available at adequate pressure round the clock. The minimum pressure available will, however, limit the number of floors (or storeyes) to which water can be supplied.

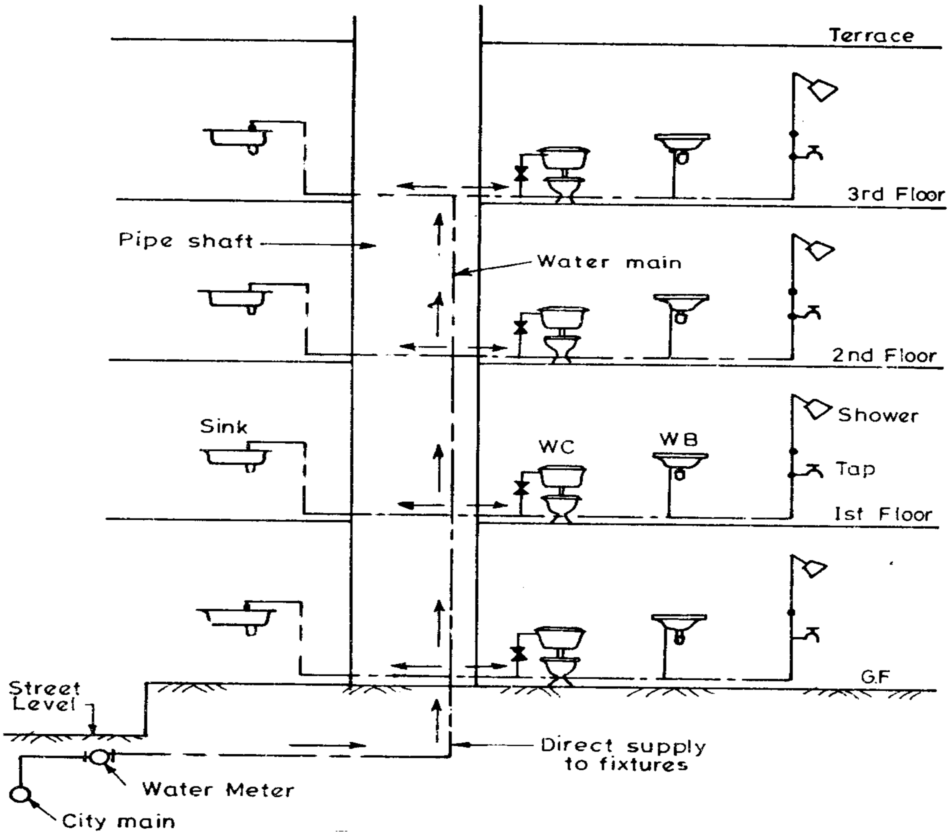


Fig. Direct supply

This system is suitable for countries that maintain high standards for water supply, as it eliminates the need for storage tanks, which may be a major source of contamination. This system is very convenient and economical to users, as it avoids the necessity of storage tanks, pumping sets, etc. Even in such a system, separate provision of supplying stored over-head water to closets and urinals is sometimes made to ensure supply to these fixtures in case of accidental low pressure or breakdown in the city mains.

Piping System Using Overhead Tank:

In many cities, the water pressure in the municipal mains is sufficient to make the water reach up to 3—4 storeyes or higher, but only for a limited period in the mornings and evenings. To meet the water requirement during non-supply hours, water is stored in overhead tanks placed on the terrace, which are filled with a direct connection from the mains. Supply to kitchens is taken from the direct main, while supply to taps for bathing and flushing etc. is taken from the overhead tank. Such a piping system is shown in Figure.

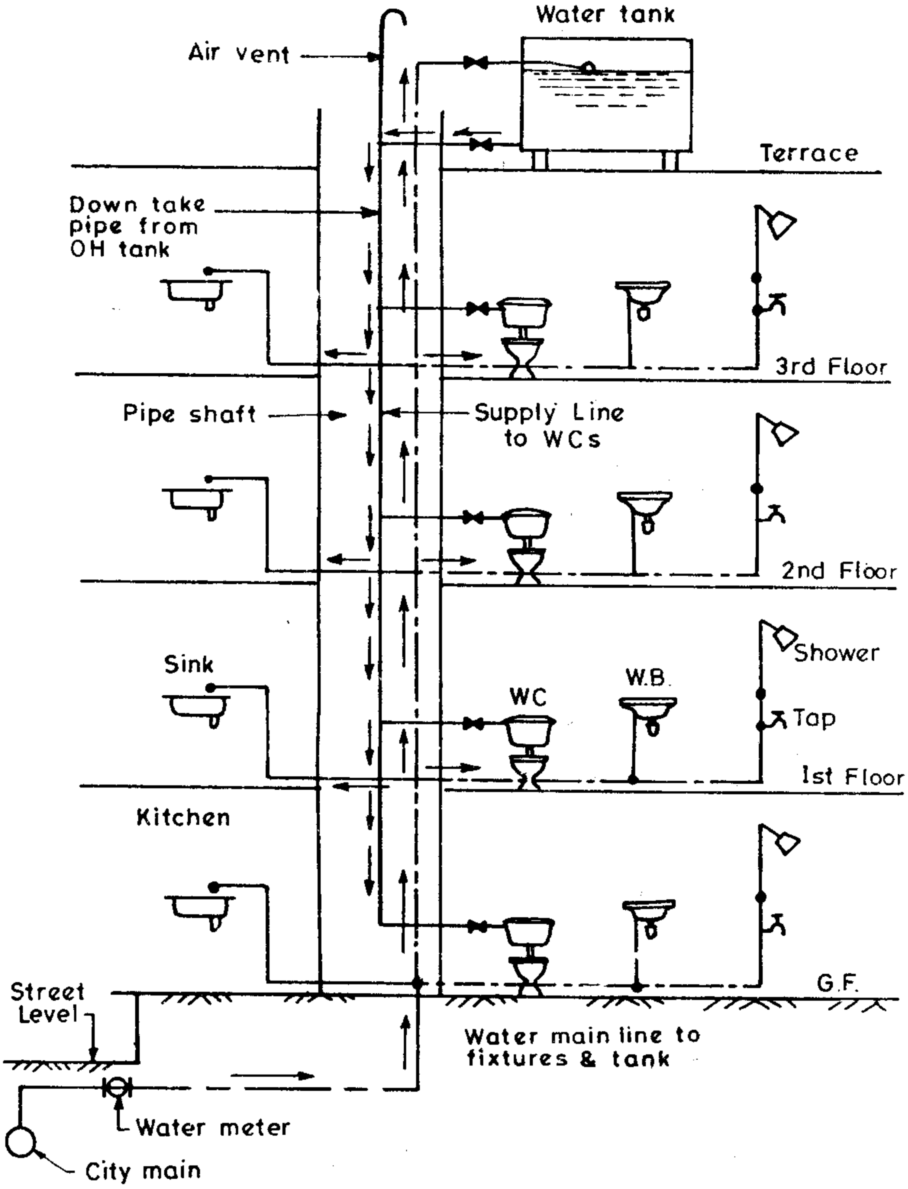


Fig. Direct supply supplemented with an overhead tank.

In such a system, drinking water has to be stored by the consumer in his vessels everyday during hours of direct supply. This system is very common in Indian houses and even in smaller hotels and restaurants.

Piping System Using Under-ground—Overhead

Tank Supply. When the municipal water supplies are at low

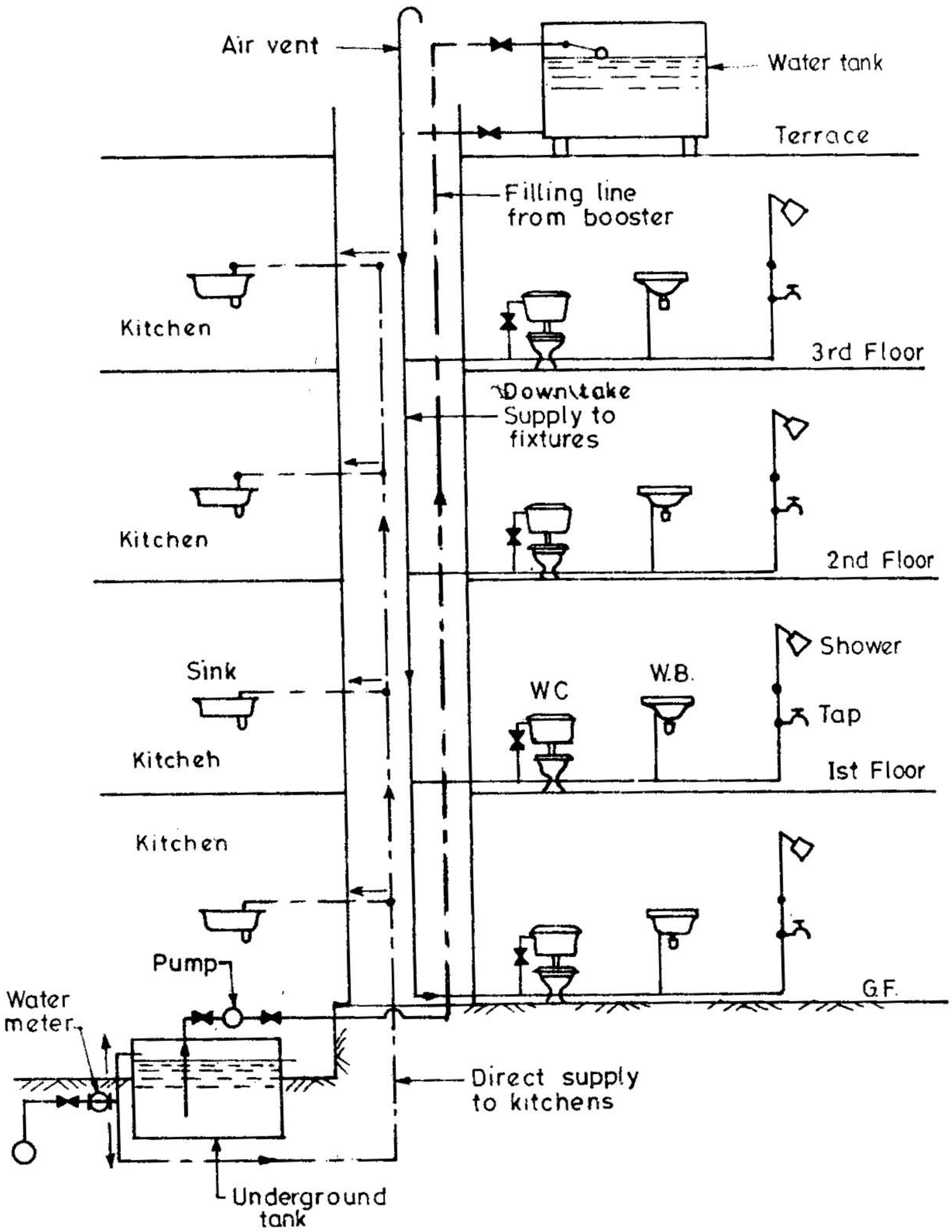


Figure showing the piping system when the overhead storage is made through the underground tank by using a pump set, while the direct supply is used in kitchens and for drinking purposes pressure, whether intermittent or continuous, then it becomes necessary to store water in under-ground tanks (since direct connection of pumps to the mains is prohibited). The water collected in the underground tank is finally lifted to the overhead tank, as mentioned earlier.

Direct supply connections may also be made to the lower storeyes, as to obtain at least some amount of direct supply for drinking purposes; otherwise in all higher floors, the stored water will have to be used even for drinking purposes. Ordinary 2-3 storeyed houses will therefore install a direct as well as an under-ground—overhead tank supply system, as shown in Figure.

Multi-storeyed tall buildings, which cannot use low-pressured municipal supplies, will of course have to pump up the entire requirement to the overhead tank by collecting it in the under-ground tank, and then providing all down-take connections from the overhead tank. Use of domestic filters and particularly of Aqua guards, etc. ; are quite essential in such cases to obtain safe drinking water. Such a piping system is shown in Figure.

Pumped Systems:

Water can be distributed by an automatic pumping system (such as a hydro pneumatic system) directly to the supply-point, similar to that shown for direct supply. The pressure in the system is boosted by pumping sets that pump water from under T ground/ground level tanks.

The main advantage of such a system lies in the fact that it eliminates the need for overhead tanks and is ideal for existing buildings when new overhead tanks cannot be constructed, and also for low buildings when the tanks placed on roof cannot generate enough pressure at upper floors. The system is able to supply water at much higher pressures than it is possible from local overhead tanks. In hot climatic regions, the water supplied from overhead tanks becomes too warm, while in cold regions, it may freeze. A pumped system in such situations is more reliable. Figure shows such a piping system.

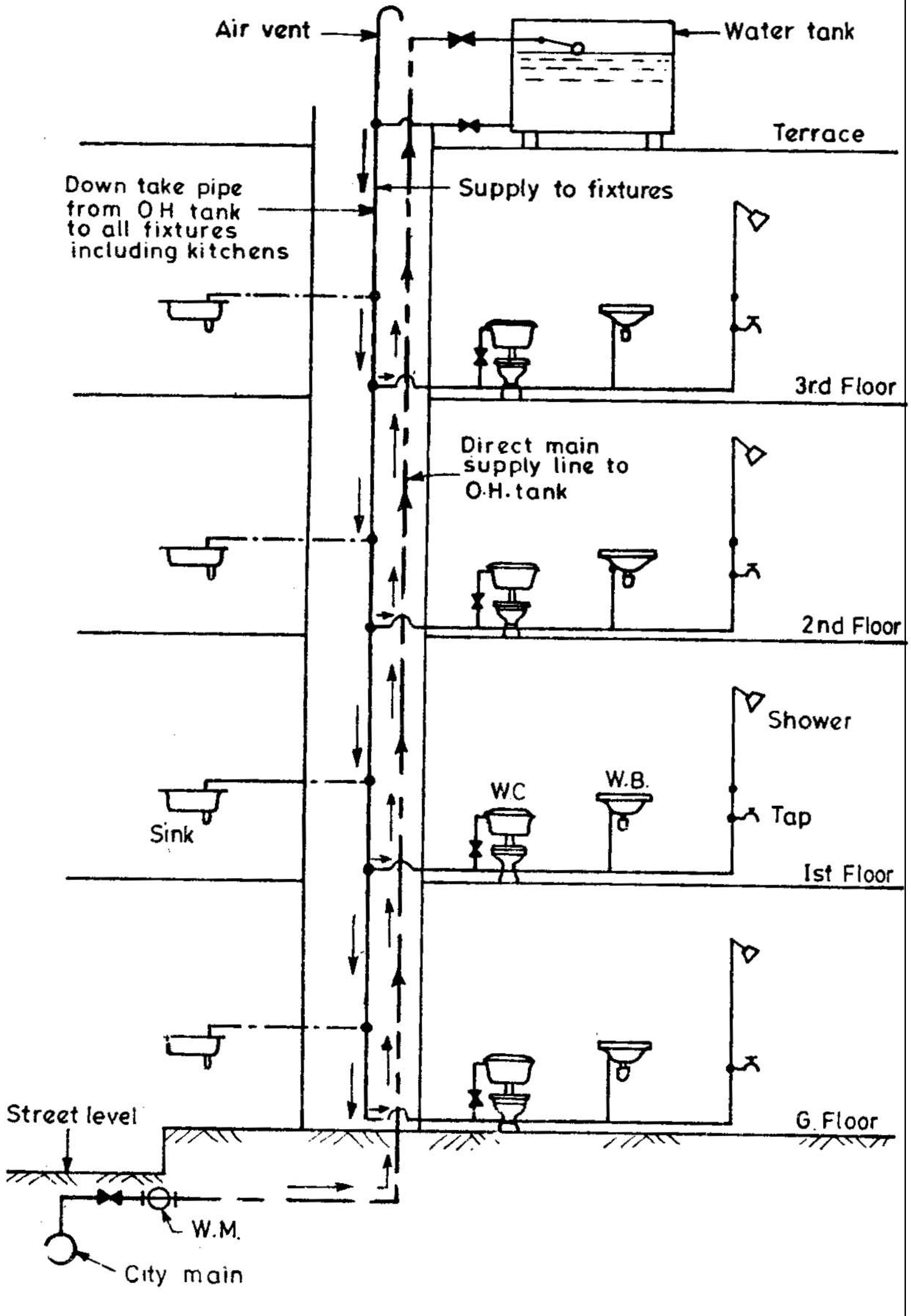


Fig. Total overhead tank supply through underground tank.

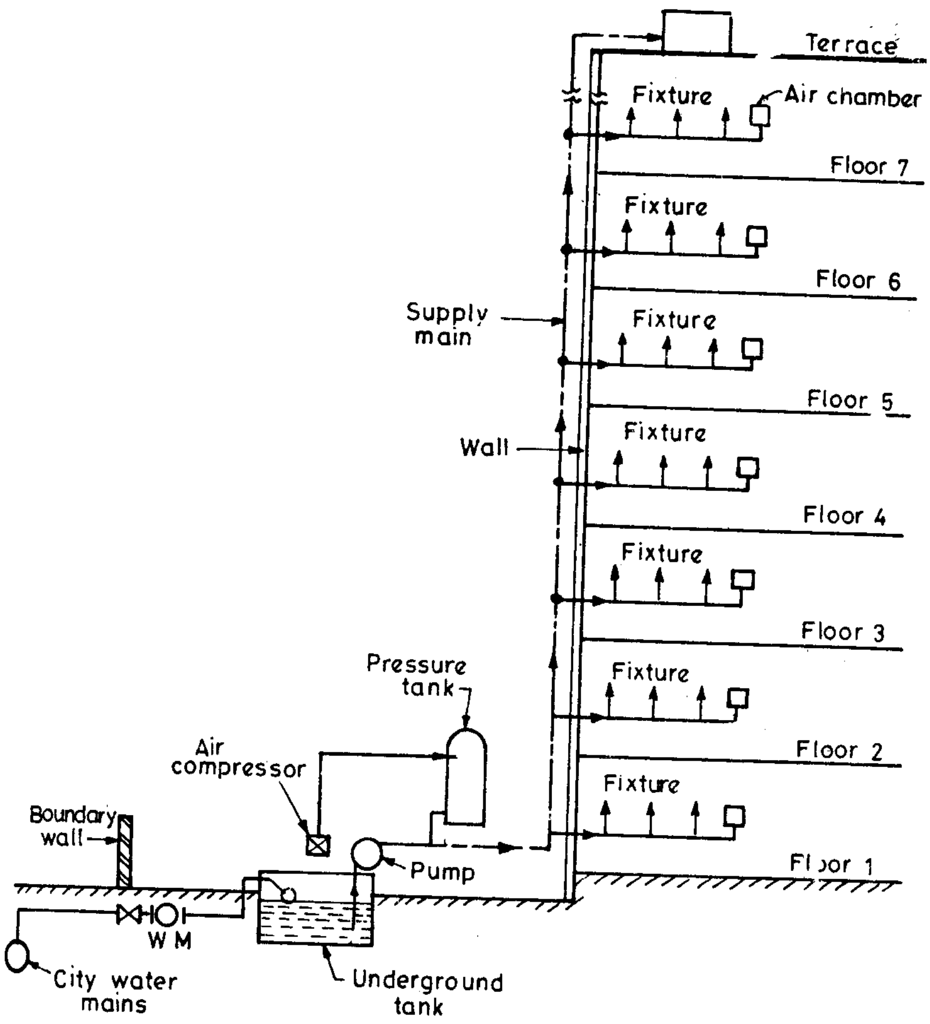


Fig. Hydro-Pneumatic piping system.

Other Systems:

Many new pumping systems have been developed for special applications arid usages.

Continuous running systems (Figure) supply directly to the point of use where the demand for water is constant and matches with the pump capacity. Typical examples are: air conditioning cooling towers; steam boilers, and industrial processes having a uniform water demand.

Modern systems include variable-speed pumping systems, high-pressure systems, etc.

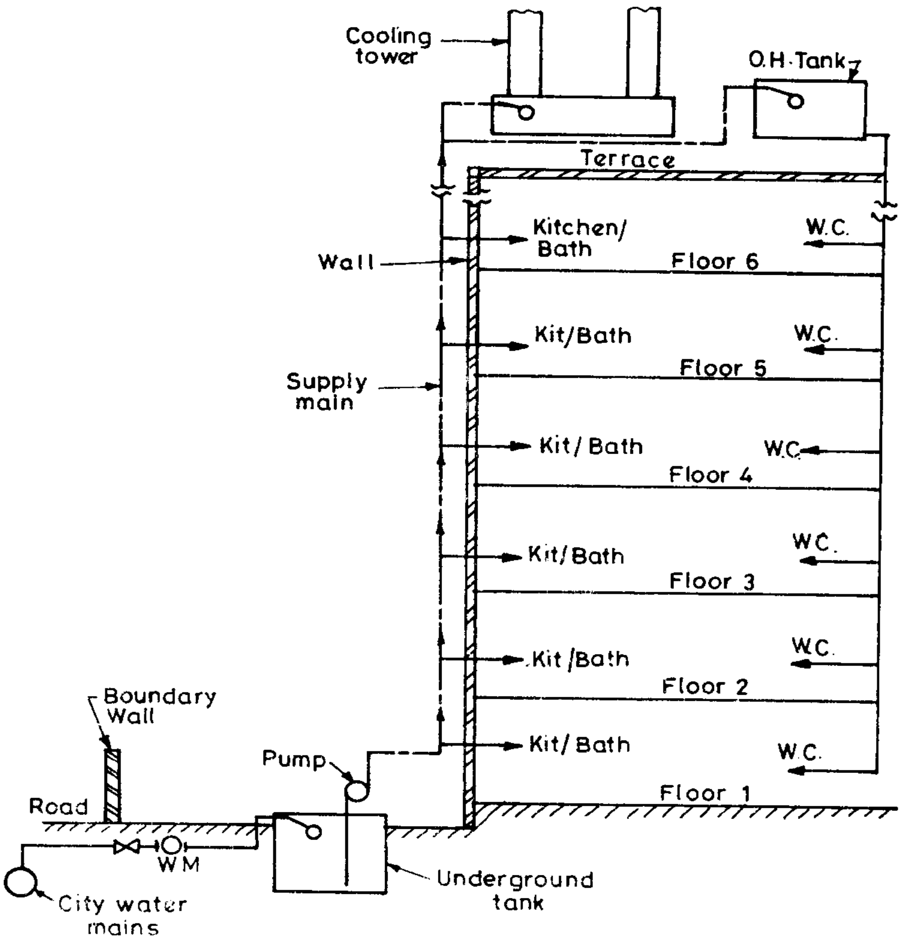


Fig. Direct pumping-Continuous running system.

Design Considerations for Water Piping Systems in Buildings

The water pipe network in a building will have to be designed as to be all to supply adequate quantity of water to all the floors of the building and with adequate pressure even in the remotest fixture. The knowing factors will affect this design are…

Water Demand for a Building:

The daily water demand of a building will have to be worked out by multiplying the per capita demand with the population. The population for each type of building i-u-v he estimated on the basis of information obtained from the stills alternatively, the population may be worked out on the follow in a basis for different types of buildings:

Table Projected Populations for Different Buildings

(*i*) Residence	5 persons per dwelling unit area
(*ii*) Offices	1 person per 10—15 m^2 of plinth area
(*iii*) Schools	Strength of the school plus teaching staff
(*iv*) Hostels	Number of beds + 4.5 × (warden's residence) + staff
(*v*) Hotels	Number of beds + staff + requirement of restaurant seats
(*vi*) Hospitals	Number of beds + staff (residential requirement, if any, should also be added.

Note. 5 to 15% additional population, depending on the usage of the building shall be added for visitors and floating population likely to use the building.

Required Flows for Various Water Supply Fixtures and Probable Simultaneous Demand:

The water supply pipe network in a building will have to be designed as to be able to supply adequate quantity of water to all the floors of the building and with adequate pressure even in the remotest fixture. However, all the fortunes of one compartment having a W.C., wash basin, bath tub ablution tap, etc., in a house or a hotel toilet will not be in operation simultaneously at the same time. As the various fixtures will require different flow rates to work optimally, it would be sufficient to design the gross supply rate as to fulfill the required flow rate of the fixture having the highest rate of flow, as only one fixture can be used at a fame in a one toilet or unit.

The required flow rates for different fixtures are given in col. (3) of table. These flow rates of various fixtures are further as signed a Fixture Unit (F.U.), as shown in col. (4) of table. These units do not have an exact direct mathematical relation with the rate of flow, but depend upon factors like: the average working time I of a fixture, etc.

For example, an ablution tap needs 0.12 litres/sec of flow and is assigned 1 fixture unit; whereas a bath tub needs about 0.20 litres/sec of flow but is assigned 4 fixture units, which only shows that the use of a bath tub in place of ablution tap for bathing purposes is likely to put 4 times load on the water supply of the building, although the rate of flow required is not exactly 4 times.

Table Flow Rates and Fixture Units of Various Types of Water Supply Fixtures

S. No.	Type of Fixture	Required flow rate in litres / sec	Fixture Units assigned to each fixture
(1)	(2)	(3)	(4)
1.	Ablution tap (occasionally used, *e.g.*, for W.C.s, baths, etc.	0.12	1
2.	Ablution tap in (public places of worship, common baths, etc.)	0.15	3
3.	Bath tubs (supply taps)	0.20	4
4.	Showers with spray heads, individual/common	0.15	2
5.	Showers with 125 mm diameter, individual/common	0.20—0.30	4
6.	Wash basins	0.12	1
7.	Surgeons wash basins	0.15	2
8.	Kitchen sinks (domestic)	0.15	2
9.	Kitchen sinks (canteens, etc.)	0.15—0.20	4
10.	Drinking fountains (connection to water cooler)	0.10	1
11.	Bidet	0.15	3
12.	Water-closet with flushing tank	0.12	1
13.	Water-closet with flush valve	1—1.5	8
14.	Urinals automatic/manual flush tank	0 12	1
15.	Urinals, flush valve operated	0.5—1	6

The gross demand of a building will therefore be worked out by multiplying the number of flats (each having one toilet and one kitchen) in the entire building with the required flow rate of the fixture having the highest flow rate. Thus, if a flat in a building is provided with a water closet (flushing tank), a bath tub, a kitchen sink, a wash basin and an ablution tap, gross demand of the flat will be taken as 0.20 1/s, since this flow rate corresponds to a bath tub, which is the maximum rate among the flow rates of the 5 types of fixtures (see table).

Just as there is no probability of use of all the fixtures of a flat at any given time, in the same manner the probability that even one fixture of all the flats of the same building or of a floor will be in use at the same moment is quite remote. If pipe diameters are calculated by assuming that all fixtures are open simultaneously, it would lead to prohibitively large sizes and unnecessary and uneconomical plumbing provisions. 100% simultaneous drew off in all the flat is however; feasible if the water supply hours are severely restricted in the building. It may also occur in buildings such as factories wash-rooms, hostels, toilets, showers in sports facilities, places of worship and the like. In all such cases, all the fixtures are likely to be open at the same time during entry, exit and recess, and hence pipe sizes must be determined for 100% demand.

In order to avoid the use of such methods, simple tables and graphs have been developed to calculate the probable flow rate for a given number of fixtures to calculate the probable demand of a building or a floor.

The different types of water supply fixtures are assigned different Fixture Units (Table), and by considering the total loading units, the probable water demand (1/s) can be read out by using the standard chart given in Figure.

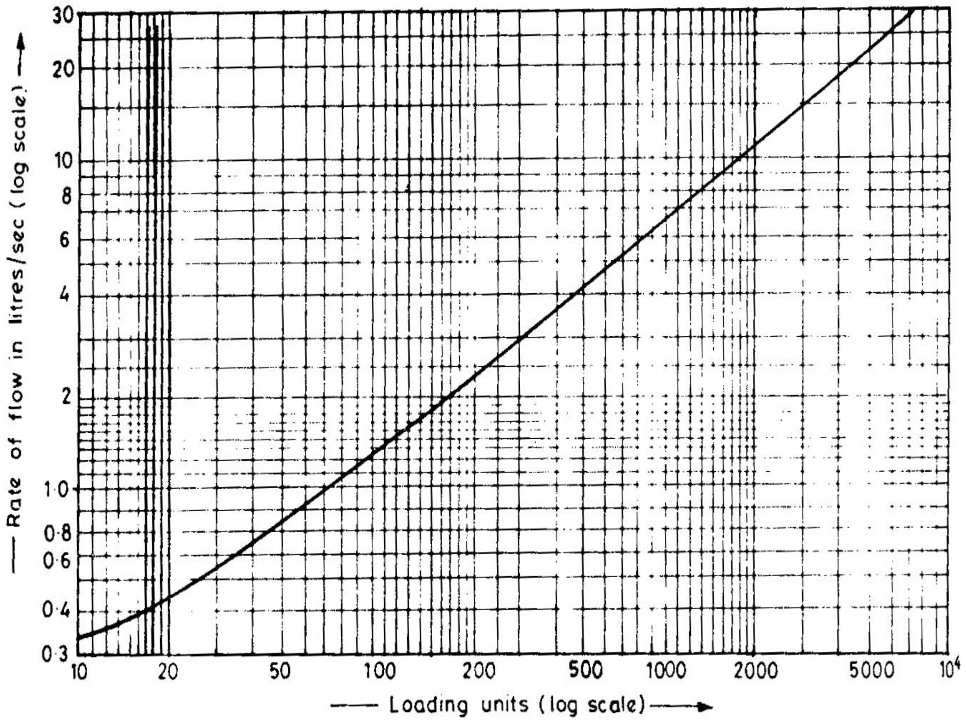


Fig. Probable simultaneous demand (log-log scale).

Principles of Distribution and Design Methods:

As discussed earlier, the water supply can be supplied either directly from the city main, or from an overhead tank, or from a hydro-pneumatic pumping system. The principles of calculating pipe sizes will however remain the same.

Pipe sizes must be calculated to permit flow at the most unfavorably placed fixture, i.e. the remotest fixture on the top most floor. A reasonably accurate estimate of the probable drew of demand can be made from table and Figure Pipe runs may be marked on a scale in plan. It is useful to draw an isometric drawing. The total developed length of the pipe line from its source to all supply points, and the number of fittings, e.g. bends, tees, and elbows in the line, should be worked out. Pressure required for the water to flow from a tap is its velocity head after overcoming the frictional losses in all fittings including the tap.

Actual pressure loss through taps and supply fixtures will vary considerably with their types and designs. In western countries having high pressure supplies, the water taps are usually made to have a high pressure loss within the taps. If the same tap is used in a low pressure system, i.e. from an overhead tank with a low head, flow through the tap may be very low or not at all. Taps for such low pressure water supply systems should therefore have a low pressure loss within it. If such a low-loss tap, on the other hand, is used in a high pressure system, it would result in a high rate of flow and wastage of water.

Design Principles:

Pipe sizes for any riser or vertical down take can be calculated by using data on rate of flow, loading units, simultaneous demand, frictional loss in pipes, taps and fittings.

When water is supplied from an overhead tank or hydro-pneumatic system, the taps on the top floors will have the least pressure, and are likely to be deficient in water supply when lower taps are open. This problem may be overcome by balancing the available pressure on all floors. For the upper floors this is achieved by adding the frictional loss of the branch lines to that of the main vertical line. The number of floors for which this resistance is to be added to the main line is the ratio between the probable simultaneous demand and the gross demand.

As the pressure is higher in lower floors, pipe diameters are reduced successively to increase the frictional loss to balance the flow. However, due to the limitation of availability of only a few sizes of pipes in the market, it may not always be possible to achieve balancing of the losses very accurately. In such cases, a combination of different pipe sizes may be used. Also, the higher residual pressures at lower floors can be reduced by using orifice flanges, or pressure reducing valves, or high-loss water taps. Balancing of pressures can also be achieved to a limited extent by using globe valves to throttle supply in high pressure areas or in high pressure zones.

In a water supply system, which has a very low pressure due to unfavorable location of overhead tanks, supply to the upper two or three floors may cease when taps on the lower floors are open. These floors should be isolated and supplied water by a separate down take.

In very tall buildings, it is always better to divide the building in vertical hydraulic zones, and restricting the maximum pressure to 25—30 m on the lowest floors. The supply to each zone may be given from a separate tank installed over each zone. Say for example, in a 16 storeyed building in Figure the lower eight storeyes are being supplied water from tank No. 1, installed on 8th floor ; while the supply to upper 8 storeyes, is being made from tank No. 2 installed on terrace of 16 storeyed building.

If however, the supply is made up to the lowest floor in such tall buildings from the overhead tank located on the top most terrace, then pressure reducing valves must be used for supply to the lower floors. The left out static head must be restricted to the limits of the working pressure of the pipes used, since excessive pressure in the water pipes causes not only heavy draw-off and wastage of water, but also leakage in fittings, noises due to water hammer, and wear corrosion by suitable paints and coatings. When the tank water is used for drinking and domestic purposes, the paints used must be non-toxic.

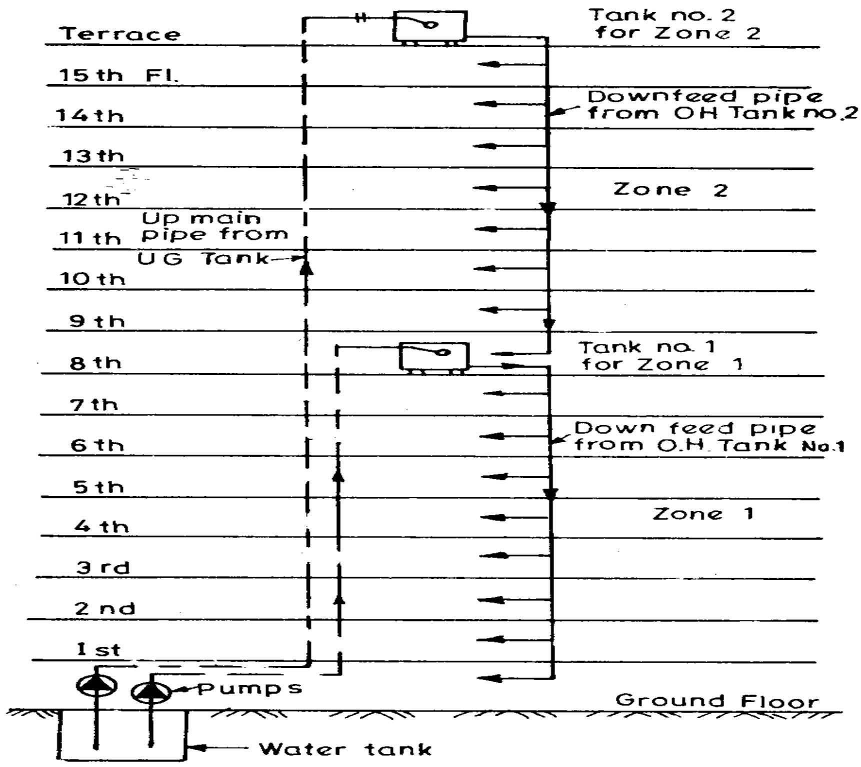


Fig. Hydraulic zones for a tall multi-storey.

Pressure inhibitors fixed on each water tap may help in permitting a predetermined rate of flow irrespective of the pressure at each tap.

Example: Water supply is being provided in a seven storey building through an overhead tank installed on the terrace at 1 m. height. The ht. of each storey is 3 m and water taps are installed at 1 m ht. at each floor. One down take pipe from the tank is serving tuio\ flats on each floor, and each flat is provided with the following water supply fixtures, @ mentioned distance from the down take:

1. Water closet (W.C.)—flushing tank type @ 7.5 m
2. Wash basin (W.B.) @6m
3. Bath taps with shower @ 4.5 m
4. Kitchen sink @ 1.5 m

Design the pipe diameters for the main (down take) as well as the branch lines. Suitable values of fixture units and discharge rates for the fixtures may be assumed. The probable simultaneous demand may be worked out by using the standard graph chart.

Solution Let us assume the following fixture loads of various fixtures:

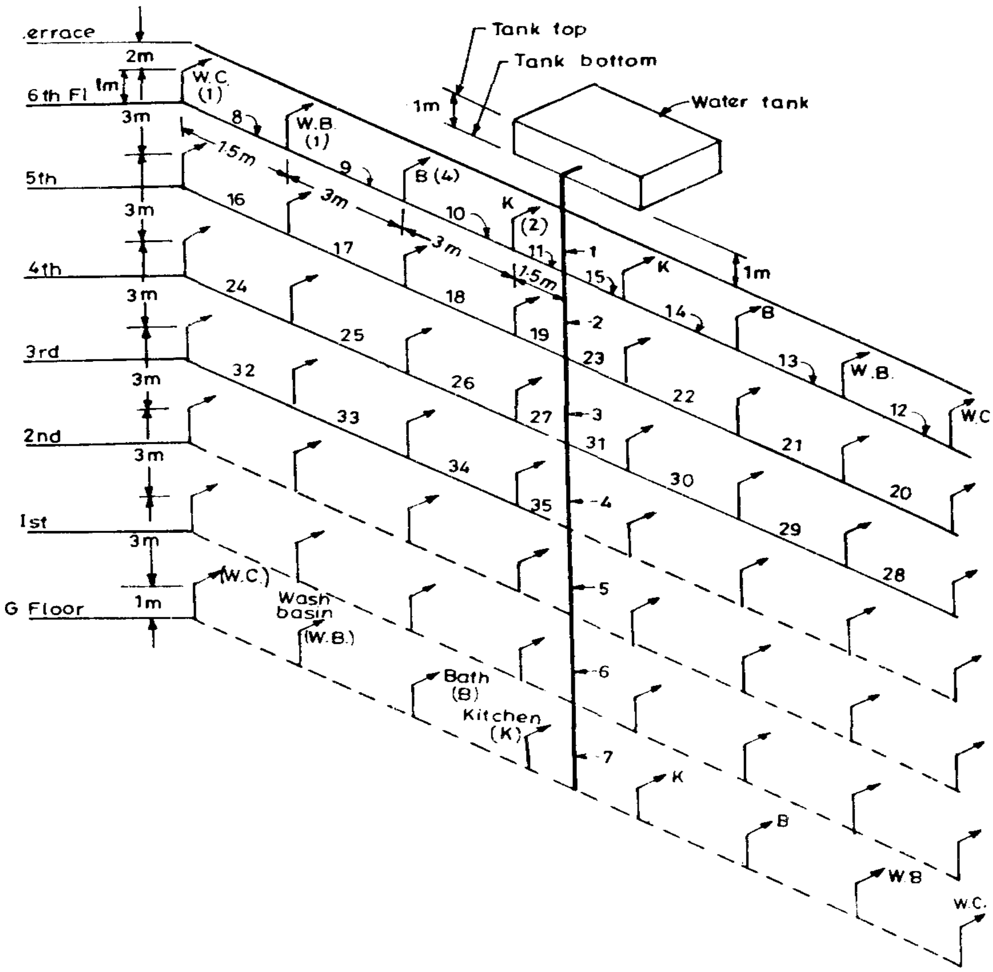
Fixture	*F.U.*
W.C.	= 1
Wash basin (W.B.)	= 1
Bath taps with showers (*B*)	= 4
Kitchen sink	= 2
Total for each flat	= 8

Gross demand of the building

= 2 Flats on each floor x No. of floors x U.2 1/s = 2 x 7 x 0.2 = 2.8 1/s.

An isometric diagrammatic sketch of the pipe network is now drawn in Figure, wherein the main down take pipe portions between various floors are marked from (1) to (7). The branch lines from top most floors are numbered starting from 8 onward. Left side branch is marked first starting from extreme end, and continuing the numbers on right side branch from extreme end, as shown. The pipes are thus, numbered from 8 to 11 on left side, and from 12 to 15 on right side on 6th floor. The pipes on lower floors are similarly numbered.

The probability of simultaneous use is worked out from Figure. Thus, for pipe No. 1, total load of 2x7x8 F.U. = 112 **F.U.** is used to read out the probable demand as **1.3** 1/s (From Figure). As the head on the lower floors is high, it will tend to draw all the water; and hence, larger sized pipes will have to be used in upper floors, and the design shall be done for upper floors to balance the available static head upto the remotest point in the branches by accounting their frictional resistance also. In other words, for upper floors, the frictional loss of the main shall be increased by adding the friction loss of the branch lines, and the available head shall not be loss than this total loss. The number of upper flats for which the frictional resistance of branch lines is to be added is given by the ratio of the probable demand and gross demand-



Pipe No.	Load in Fixture Units	Probable flow in l/s from Fig. 11.15
1	112	1.3
2	96	1.25
3	80	1.00
4	64	0.90
5	48	0.50
6	32	0.50
7	16	0.40
8	1	0.12
9	2	0.24
10	6	0.30
11	8	0.30

Figure Water piping scheme. Load (F.U.) on main pipes (1 to 7) and branches 8 to 10 are shown along with flow (l/s) read from Figure, in the above table

This ratio in this case is $= \frac{1.3}{2.8} = 46\%$

.-. Total No. of Hats for which the branch frictional losses are to be added

$= 14 \times 0.46$
$= 6.44$; say **7**.

Hence, the friction loss of branch lines of both sides on top three floors (6th to 4th floors) and of one side on the 3rd floor shall be computed. Friction loss of branch lines on lower floors can be ignored.

While designing the pipes, we will have to work out the head loss for each pipe as to work out the residual pressure at each of the off-take points. The head loss in pipes can be computed by multiply-ing the pipe length with the loss of head per metre run—a value to be calculated by Hazen William's formula, which is given by Eq. 6.12

a) As:

$$H_L = \frac{1}{0.094}\left(\frac{Q}{C_H}\right)^{1.85}\frac{L}{d^{4.87}} \text{ (i.e. Eq. 6.12a)}$$

When loss in m per m pipe length is calculated, we have L = 1 m

$$H_L/m = \frac{1}{0.094}\left(\frac{Q}{100}\right)^{1.85}\frac{1}{d^{4.87}} \text{ (Using } C_H = 100)$$

Here Q is in rr/sec, and d is in m. If however, Q is in 1/sec and d (pipe dia) is in cm, then the formula reduces to :

Loss **of head in m/m**

$$= \frac{1}{0.094}\left(\frac{Q \text{ in l/s}}{1000} \times \frac{1}{100}\right)^{1.85} \cdot \left(\frac{1}{d \text{ in cm}/100}\right)^{4.87}$$

$$\boxed{\text{Loss of head in m/m} = 32.875\,\frac{Q^{1.85}}{d^{4.87}}}$$

The various types of pipe fittings can be counted and converted into equivalent pipe lengths, by using the factors given in table.

Equivalent Pipe Lengths for Fittings

Pipe Fittings	Equivalent length of pipe in pipe diameter
90^0 Elbow	30
Tee	40
Gate Valve	20
Globe Valve, bib taps	300

When counting of fittings is difficult, certain adhoc percentages as given in table, may be adopted to add to the pipe length.

15 mm dia pipe	100%
20 mm dia pipe	100%
25 mm dia pipe	50%
50 mm dia pipe	25%

These percentages have been us head losses in pipe fittings, as shown in the calculation chart-table.

To work out the pipe diameters scientifically, it is easier to tabulate the data, assume pipe diameters, and work out the residual head. The figure or isometric view, as drawn in Figure, will help in completing the computation table (Table).

The computing procedure is a trial and error method. If any pipe diameter assumed is over-sized 3r under-sized, the same has to be revised, and the calculations redone. It will be noticed that in the table, the head loss in each sector or floor is nearly equal to the available static head at that point. The pressure in the lower floors is however; higher than the static head available. This is to some extent unavoidable due to limited pipe sizes available in the market, and limitation of velocity of flow in pipes (maximum: 1.5—2 m/s). The computation table is otherwise self explanatory, and the finally computed pipe sizes, are tabulated below :

Pipe	*Size*	
Main Down Take Pipe No. 1	50 mm dia	**Ans.**
Main Down Take Pipe No. 2	40 mm dia	
Main Down Take Pipe No. 3	40 mm dia	
Main Down Take Pipe No. 4	32 mm dia	
Main Down Take Pipe No. 5	25 mm dia	
Main Down Take Pipe No. 6	20 mm dia	
Main Down Take Pipe No. 7	20 mm dia	
Branch pipes—all branches	20 mm dia.	

Water is to be supplied in a seven storey Low Income Group housing building having 4 flats on each floor. Each flat is provided with a toilet and a kitchen, and average number of persons living per flat is 5. The municipal water supply in the area is intermittent and irregular with supply restricted to 3 hours in the morning and 3 hours in the evening. Separate water meters are not to be provided in flats. Design the sizes of the various units that are to be installed to ensure continuous tank supply. The living standards do require average per capita daily demand of 160 L . Solution. Av. daily water requirement

= Av. Daily per capita demand x population

= 160 x (7 x 4 x 5)

= 22400 L = 22.4 m^3

Since there is no separate ground water or effluent supply, and the municipal supply is to be used for domestic as well as hushing purposes, separate storage for domestic and flushing purposes are not required. An overhead tank is proposed to be installed for the building at the terrace.

However, due to municipal prohibitions, the pumps to lift water to the over-head tank shall not be attached to the municipal main rather an under-ground tank shall be provided to collect municipal supply in the morning as well as evening, during 3 hrs each. This water shall be lifted to the over-head tank, say by pumping for 2 hrs in the morning and evening each.

(i) Capacity of Under-ground Tank. Strictly speaking, the capacity of under-ground tank would depend on the rate of inflow (supply) and rate of outflow (i.e. lifted water). The rate of inflow may, however, vary. The pattern of consumption may also change with seasons. A good deal of accuracy in calculating the tank size is, therefore, not required. An under-ground tank of 24 hrs consumption or daily requirement is sometimes recommended to cater for the prolonged shut down in municipal supply. Normally, however, in shift supplies, an under-ground tank of 2nd of one day requirement, and an over-head tank of 2nd of one day requirement may suffice. So, let us provide an under-ground tank of 2nd of one day's

requirement of 22400 L.

∴ **Tank capacity**

$$= \frac{2}{3} \times 22400 \text{ L}$$

$$= 15000 \text{ L} = 15 \text{ m}^3$$

Provide a tank of4mx2.5mxl.5m (water depth) size with a free-board of 0.2 m.

Over-all tank size = 4 m x 2.5 m x 1.7 m. Ans**.**

(ii) Capacity of Over head Tank. Let us provide over head tank storage equal to 3rd of one day’s requirement.

∴ Capacity of O.H. Tank

$$= \frac{1}{3} \text{ rd of one days requirement}$$

$$= \frac{1}{3} \times 224000 \text{ L}$$

$$= \mathbf{7500 \text{ L. Ans.}}$$

The size of the overhead tank may be decided as per availability.

(iii) Size of Rising Main. Average daily water requirement to be pumped

= 22,400 L

Pumping hours allowing power failures = 4 hours.

= 4 hours.

$$\therefore \text{ Pumping rate} = \frac{22400}{4} \text{ L/h}$$

$$= 5{,}600 \text{ L/h}$$

$$= 1.56 \text{ L/s}$$

Now, assume that the length of the rising main from the underground tank to the over-head tank is measured from the building plan to be 30 m.

Let us use 50 mm diameter rising main.

Let the equivalent length of all the pipe fittings like elbows, gate valve, etc.

be 22 m (6 elbows x 3 m + 1 gate valve x 4 m = 22 m) .-. Total pipe length causing head loss

$= 30 + 22 \text{ m} = 52 \text{ m}$

Let us use 40 mm diameter pipe for the rising main, to carry 1.56 L/s. The velocity in the pipe shall be 1.56

$$= \frac{1.56}{1000 \times \frac{\pi}{4} \times (0.04)^2} = 1.24 \text{ m/s.}$$

Now, Head loss H_L/m

$$= 32.875 \frac{(Q \text{ in L/s})^{1.85}}{(d \text{ in cm})^{4.87}} \quad (i.e. \text{ Eq. } 11.2)$$

$$= 32.875 \frac{(1.56)^{1.85}}{(4)^{4.87}} = 0.0875 \text{ m/m}$$

Total head loss in 52 m length of pipe

$= 0.0875 \times 52 \text{ m} = \mathbf{4.6 \text{ m.}}$

Note. Use of smaller sized rising main will increase the velocity and head loss, causing water hammer noises, and additional burden on pump.

(*iv*) *Design of Pump Capacity* :

Rate of pumping = 1.56 L/s

Head on the Pump.

Suction head = 1.7 m (depth of under ground tank)

Static head = 23 m

assuming the O.H. tank to be placed on roof with its W.L. 2 m above roof level, which is 21 m above the ground level

Frictional loss = 4.6 m (calculated)

Minimum Residual head required at inlet

= 3 m (assumed)

Total, delivery head = **32.3 m**

$$\text{H.P. of pump} = \frac{\gamma_w \cdot QH}{0.735 \cdot \eta}$$

Assume η = efficiency of pump and motor = 0.6

r_w = 9.81 kN/m^3

Q = 1.56 L/s = $\frac{1.56}{1000}$ m^3/s

H = 32.3 m

$$\text{H.P.} = \frac{9.81 \times \frac{1.56}{1000} \times 32.3}{0.735 \times 0.6}$$

= **1.13** ; say 1.5 H.P.

Let us use 1.5 H.P. Centrifugal Pump Set. **Ans.**

HOT WATER APPLIANCES AND INSTALLATIONS

Hot water is required in houses and buildings for bathing and washing of clothes and utensils, etc. Higher temperatures melt oil and grease from human body, pot and panes, making the cleaning work easier, Bathing with hot water opens the body pores, washing dirt and sweat easily, and giving a sense of freshness. Evidently, in winter season, the requirement of hot water becomes all the more necessary.

In order to meet the hot water requirement of houses, hostels, hotels, etc., hot water systems are designed and installed in accordance with the requirement of a particular building.

In its rudimentary form, water in Indian houses, particularly in rural areas, is heated in pots on local stoves and chulahas. Where electricity is available, water may be heated on electric heaters. Such appliances may, however, provide us with small quantity of hot water only, and are risky and dangerous as the hot water may | spill during transit, causing burns to elders or children. Open flame chulahas and stoves may also cause burn injuries and harmful gases. Hamams and electrical geysers have however now been invented and are being largely used to fulfill domestic demand of hot water.

Hot Water Requirement

Hot water is used in kitchens and bathrooms in residential areas. The quantum of consumption of hot water widely depends upon the weather conditions of the area, as well as the habits and living standards of the people. In India, natural climatic temperature widely varies from near Arctic conditions in Leh (J & K State)—where temperatures may get as low as (-) 20°C in winter, to as high as 40—45°C in southern India. Hot water requirement therefore varies widely, and will be much high in areas of cold climates as compared to the hotter regions.

In addition to its requirement for domestic uses, large quantity hot water may be required for laundries and industrial kitchens and in buildings like hotels, hospitals, schools, hostels, industrial canteens, etc. Hot water may also sometimes be required as a heating medium for space heating and air-conditioning. Although the water is not consumed in such room heating uses, yet the boiler capacity has to be increased to provide for the heat load. Average daily hot water requirement in residences and other types of buildings in cold climates are given in table.

Table Average Daily Hot Water Requirements in Buildings in Cold Climates

S. No.	*Type of Building / Use*	*Average daily hot water demand in L / d / head*
(1)	(2)	(3)
1.	*Residences*	
	(*a*) Residential (with showers/taps)	45
	(*b*) Residential (with bath tubs)	135
2.	*Factories*	
	(*a*) Factories (with showers)	90
	(*b*) Factories (ablution taps only	30—45
3.	*Hospitals*	
	(*a*) Beds (patients, clean-up nurses station, etc.)	180
	(*b*) Staff, doctors and nurses	90
	(*c*) Visitors	10

(1)	(2)	(3)
4.	*Hostels* (*a*) Colleges, schools, nurses' hostels, etc. (*b*) Offices, schools, colleges (day-use where required)	 135 145
5.	*Hostels* (*a*) Rooms with showers (*b*) Rooms with tubs (*c*) Hotel staff (*d*) Visitors (Av. 2/room daily) (*e*) Swimming pools, changing rooms (*f*) Kitchens/restaurants (3 times the number of bed plus 2 times the number of seat covers in all restaurants)	 70—90 135 25—45 15 45 5/meal served (many types of modern laundry equipment may require less water)
6.	*Laundries* (3—5 kg of linen per room (includes staff uniforms, restaurant linen)	20/kg of laundry

Domestic Hot Water Appliances

The various appliances, which are usually used for generating hot waters for domestic uses, are:

(i) Hamam; and

(ii) Electrical geysers

These appliances are discussed below:

Hamam:

Hamam is an old displacement type hot-water heater, using solid fuels like coal, wood, etc. It is found not only in India, but also in other countries. This appliance (Figure) had been in use for many centuries, and still serves its purpose safely, if installed in a proper manner.

Electrical Geysers or Hot water Heaters.

The natural hot water springs found in many parts of the world (such as the one in Tatapani near shimla, one near Sohna, one near Manali— all in India) are known as 'Geysers'. Modern appliances generating hot water artificially have also acquired the same name. Electrical Geysers generate hot water using electrical heating elements. LPG may be used in gas water heaters.

Electrical geysers have now a days become a very common appliance of our modern life, and even in our developing country, geysers are now-a-days being used in houses even in smaller towns and advanced villages, where electricity is available.

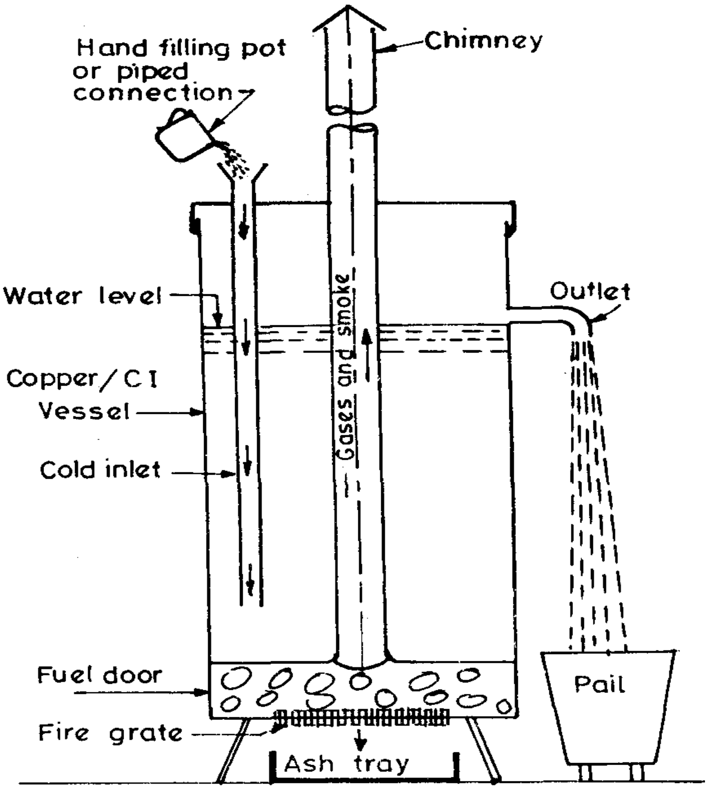


Fig. Traditional Hamam. Types of Electrical Geysers

Instantaneous and Storage type of geysers are usually available in the market these days, and are discussed below

Instantaneous electrical geysers:

These geysers are designed for direct connection to the water-taps, and the electric heating element is switched on after the flow of water is established. Such an appliance requires a heating element bound round a pipe, which heats the water to a specified temperature matching the rate of flow. The heating element has to be of a much higher capacity (wattage) as compared to the one required in a storage heater. An electrical load of 6 kW is found to give water for showering at 3 litres/ minute, while an electrical load of 3 kW will give warm water at a rate of about 1.4 litres/min. These heaters not only require heavy wiring switch board connections but also require very efficient earthing to avoid shocks. Sub-standard instantaneous heaters can lead to fatal electrical shocks. It would therefore be advisable to install a storage type of a geyser rather than using an instantaneous geyser. Storage geyser shall even be preferred to an

electrical immersion **rod—**which is sometimes used to heat up a bucket of water, by direct immersion in water.

Storage geysers:

These geysers are usually of **pressure type** (Figure), which are connected with an assured water

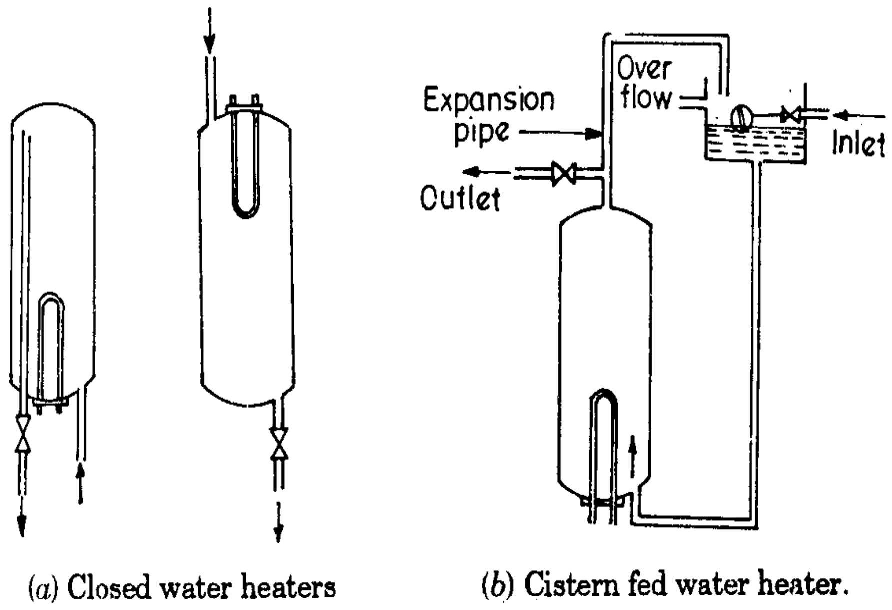
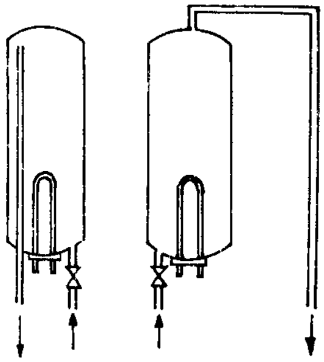


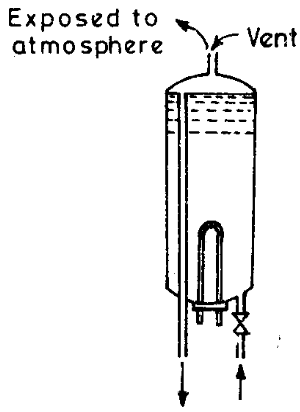
Fig. Pressure geysers.

supply from a cold overhead storage tank. Such geysers should under no circumstances be connected to the direct main water supply, which may stop and suck back the water from the geyser (inlet may become the outlet) if the check valve fails to function, which is quite a normal occurrence.

Direct main water supply can however, be connected to the sparsely used non pressure type or open outlet type of a geyser Vented open outlet type of geyser the geyser is open to atmosphere so that. under no conditions of use (a) closed unvented open outlet can the pressure at the surface of type water heaters, water be other than atmospheric.



(a) Closed unvented open outlet type water heaters.



(b) Vented open outlet type of geyser (the geyser is open to atmosphere so that under no conditions of use can the pressure at the surface of water be other than atmospheric.

Fig. Non-pressure geysers (open outlet type water heaters).

[Note. There is no bib cock or stop cock at the outlet.]

(Figure), in which the outlet is kept open and not provided with any bib cock or stop cock. In such a geyser the inlet stop cock is opened to draw water from the open outlet.

Thus, when hot water is not being drawn, the supply 10 such a geyser (either direct or from over-head tank) will be closed by closing the inlet stop cock, and hence there will act no water pressure on the geyser. When supply is open, equal amount of hot water will get out of the geyser. There will, thus, be no water pressure ever acting on the geyser; and hence such a geyser is called a non-pressure type of a geyser. Such geysers are manufactured in smaller capacities, and are rarely used in modern day life, since it gives only hot water in a bucket and won't allow automatic mixing of cold and hot water.

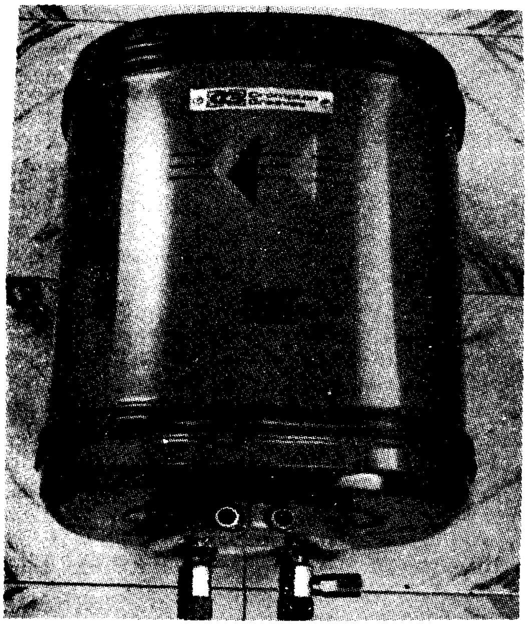
In the pressure type of storage geyser, however, the inlet is not blocked and its stop cock even if provided for convenience of connec-tions, is kept always open. The outlet is connected to a bib cock (water tap) through a stop cock. The outlet stop cock is usually kept open, and hot water can be drawn by just opening the hot water tap. In such a geyser, therefore, the over-head tank supply is always open, which keeps the geyser always under the pressure of water. This pressure allows hot water to be distributed to a number of points, and permits mixing of hot and cold supply through a mixing fitting (mixer). The non-pressure type of geyser though provided with a thermostat, does not, however, require any expansion pipe or vacuum breaker, as are required by the pressure type of geysers, as shall be discussed a little later. The difference between pressure and non-pressure types of geysers is illustrated in Figures.

Table

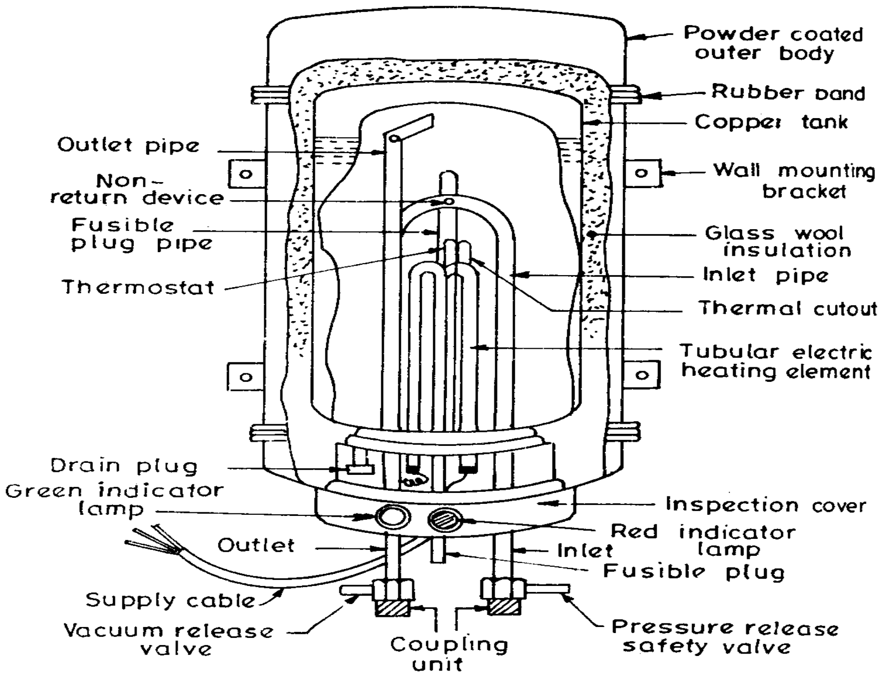
Rated Capacity in litres	6	15	25	35	50	70	100	140	200
Recommended input in kW	1	1	1	1.5	2	2	3	4	5

Two electrical heating elements are usually provided in dual heater type water reptter having two heating units-one towards the top container and the other near the bottom, the unit being independently controlled. The shape of this geyser is generally cylindrical.

An operating continuously under thermostatic control, a 2 kW ' is adequate for small dwellings, requiring 90 litres of hot storage. Smaller sized geysers of 1 kW (15 to 25 litres) can help the purpose in small households, but there would have to time gap between the use of hot water by one person for and the next bather view and section of a closed automatic geyser (pressure of course) provided with a pressure release safety value near et is shown in Fig. (a) and (b) storage geysers, the cold water enters at the bottom of the tank, while the hot water from the top is withdrawn. The awn hot water is intact displaced by the equivalent cold feed through the inlet. This keeps the geyser always filled up later, thereby eliminating the danger of the geyser becoming and burning of the heating element. we will discuss the dangers posed by the pressure geysers remedial measures.



(a) Photoview.



(b) Section view.

Fig. A closed automatic pressure geyser.

Geyser Implosions. All pressure type automatic geysers are con-j trolled by an automatic thermostatic switch, which cuts on and off.1 the electric supply to the geyser at a pre-set temperature. They operate at a differential temperature of about 10—12°C and cutout say at 70°C (The temperature setting is adjustable).

If the water supply in such a geyser is from an over-head tank installed at a height of 20 m, the pressure in the heater will 196.2J kN/m^2, and the boiling point of water corresponding to this pressure will be 132.6°C (Appendix Table A-1)*. If the thermostat of that geyser fails to cut off at set temperature of 65—70° C, the geyser continue to heat the water up to its boiling point at the given pressure (132.6°C in the case of 20 m high storage tank). During such a Water boils at 100°C at atmospheric pressure, i.e. when the pressure is about 9ti. 1 kN/m^2 or 10 m head of water. If the pressure is more atmospheric then than the boiling temperature increases.

Many a times, when hot water taps are opened, the over-heated water coming out from the tap, immediately changes into steam (flash steam) within a few seconds, sometimes with explosive violence, like a bomb blast, causing heavy damage to life and property. To avoid such accidents, all pressure type automatic geysers must be constructed from enameled metal sheets capable of sustaining high pressures, and each geyser must be provided with a good quality temperature-pressure relief valve, set to release at preset settings. This should be in addition to installing fusible link, similar to the one provided in domestic pressure cookers.

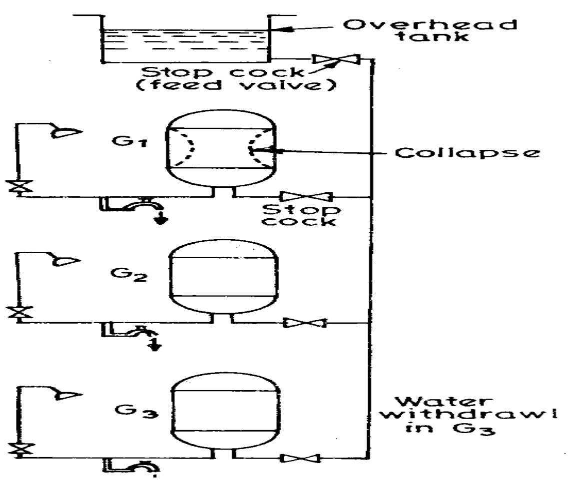
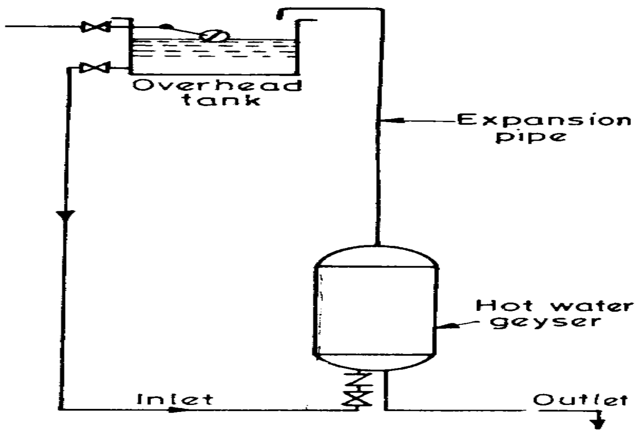


Fig. Collapse of geysers due to negative pressure.

Vacuum Formation in Geysers. Sometimes hot water geysers are installed on different floors of a building on a common down-take pipe, as shown in Figure. In such installations, if the outlet from the over-head tank (i.e. the feed valve or stop cock is closed and no check valves are provided on the inlets of the geysers, then the water from the geysers of upper floors will be drawn, if the hot water is drawn from a geyser in the lower floor, and if all the taps on the upper floor are shut. This will generate a negative pressure in the upper level geysers and the created vacuum will cause inward collapse of the geysers if they are not constructed strongly.

Such possibilities can be avoided by installing an **expansion pipe** from the top of the geyser, extending above the water level in the over head tank, as shown in Figure. This pipe will also serve the function of a vent pipe to help remove air-locks from the line. During initial filling of the geyser, it expels the air from within the system; and also acts as an expansion pipe for the heated water. This pipe also pl-lows the exit of any steam formed due to over-heating. The cold feed pipe of the geyser and the vent pipe act as a 'U' tube, providing hydraulic balance in the system. The expansion pipe has to be separate and independent for each geyser. It should only rise up, without dipping below the level of its origin and should not have any kind of valve on it.



Provision of Expansion pipe in automatic geysers to avoid negative pressures and collapse of geysers of upper floors when installed on a common down-take pipe.

A check valve or a vacuum breaker installed on the geyser inlet also eliminates the problem of negative pressures and collapse of upper floor geysers.

Independent expansion pipes are difficult to be installed in tall buildings and one has to depend on other safety devices like pressure relief valves, vacuum breakers, check valves, etc.

Standing Energy Loss in Automatic Geysers. The automatic geysers are usually kept switched on in modern days, as to ensure availability of hot water round the clock. In such a case, a geyser will go on loosing heat inspite of thermal insulation provided on its body. The loss of heat will eventually depend on the cut off temperature of the geyser (i.e. the maximum-temperature at which the thermostat will automatically switch off the electric current—kept at about 70—75°C) and the ambient air temperature. All the geysers manufactured in India are required to ensure some maximum energy loss, when tested over 24 hrs at a temperature difference of 45°C between the ambient air temperature and thermostat cut out temperature. BIS Code IS 2082 : 1993 has specified the maximum energy loss over 24 hours to be as shown in table.

Table Limiting Values of Standing Loss in Automatic Geysers

Rate capacity of geyser in litres	*Max. Permissible Energy Loss in kilowatt hour per day for 45°C difference*
6	0.880
10	1.100
15	1.265
25	1.540
35	1.760
50	2.035
70	2.310
100	2.640
140	2.970
200	3.300

Solar Water Heaters

Introduction:

Solar water heating, now a days, has become quite cost effective and saves on fossil fuels or electricity, which are usually scarce. Solar water heaters have therefore, gained popularity in countries notably Japan, Israel, Australia, and U.S.A., where commercial solar water heaters are readily available. Solar water heaters have also been designed in India to suit the indigenous raw materials, tropical climate, portability and ease of manufacture etc., so as to produce efficient and economical solar water heaters. National Physical Laboratory (NPL) New Delhi, and C.B.R.I. (Central Building Research Institute) Roorkee have remained associated with the design work of solar water heaters favorable to Indian conditions.

Solar Water Energy:

The design of a solar water heater and particularly that of the area of the absorber unit, is primarily governed by the solar energy available at the place of installation of the solar heater. In order to help designers, the solar energy available during different months of the year at four widely separated cities of India; i.e. Poona, Delhi, Calcutta and Madras, are given in table.

Table Daily Total Solar Radiation on a Horizontal Surface in Calories/cm day

Months → *Cities ↓*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Poona	460	562	598	617	664	589	395	402	496	518	474	447
Delhi	350	447	556	606	630	614	485	452	491	501	413	345
Calcutta	339	394	489	506	542	472	454	481	427	396	393	363
Madras	472	559	591	595	546	523	423	422	503	369	373	397

Construction and Design Details of a Solar Water Heater. A solar water heater is a coupled unit of:

(1) A solar energy collector; and

(2) A storage tank with a suitable device to minimize heat lost. These units of a solar water heater are discussed below

(1) **The Collector Unit.** The main function of the collector unit is to absorb solar radiation and to transfer this heat energy to the sold water for heating the same. It usually is a blackened plate, constructed in such a way that channels are formed, through which water can circulate. Copper in the form of tubes and sheets proves) to be the best material

for this unit due to its high thermal conductivity, long life, and high corrosion resistant. This metal is however, quite costly in India, and hence G.I. (galvanized iron) sheets are generally used to make this unit. The closed or covered channels are formed by welding inverted corrugated G.I. sheet over a plane G.I sheet. The side water channels are fabricated from plane G.I. sheets,

Heat loss from the absorber is reduced by providing insulation at the back and sides. The convection heat losses from the blackened surface of the plate are reduced by covering it with a glass plate which acts as a heat trap. The insulation is protected with cover boxes, and the whole assembly is made air tight.

Area of the heat absorber depends on the available solar radiation, mean dry bulb temperature, the quantity of hot water, required. In India, owing to large variation in the living standards, no definite figure for daily demand of hot water can be given, but the consumption by a middle class family of 5 persons, is estimated to be about 140 litres/day. For solar heating of 140 litres of water up to a temperature of about 50°C on a winter day, the required collector area is estimated to be 2.1 m^2 for Delhi, 1.8 m^2 for Madras, 1.5 m^2 for Poona, and 2.8 m^2 for Calcutta. Thus, a unit of 2.1 m^2 area, described here after, will serve for many places in India.

An absorber unit of a solar heater is made of smaller typical units, each of 1.05 m^2 area. Each smaller unit can, thus, heat up 70 litres of water per day Two or three such typical units can be coupled together to produce larger capacity heater.

A typical absorber unit, shown in Fig., consists of a corrugated and a plane G.I. sheet 122 cm x 79 cm of 24 and 20 gauges respectively, which arts welded together. Five rivets are fixed, four at equal distance from the sides, and one at the centre in the depressions in the G.I. sheet. To this unit is welded a top and a bottom water channel made out of 20 gauge G.I. sheet. The water channels are in the shape of rectangular boxes of size 40 mm x 25 mm (ht), as shown. These are closed at one end ; while at the other end, a 10 cm long 25 mm diameter G.I. pipe nipples are welded, as shown.

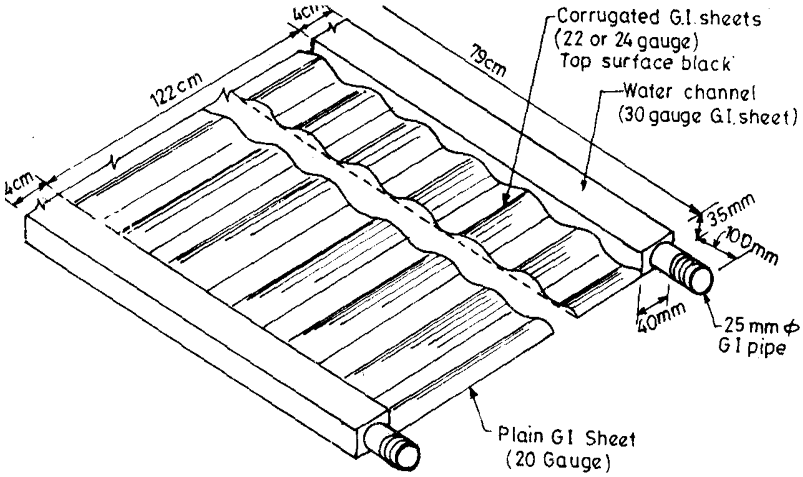


Fig. A typical isolated absorber unit of 1.05 m^2 area (122 cm x 79 cm).

A cover box of size 137 cm x 90 cm x 11.5 cm is made of 24 gauge G.I. sheet. A wooden frame of size 137 cm x 90 cm x 4 cm made of 2 cm thick deodar wood is fixed inside this cover box, flush with top edges. 5 cm thick glass fibre or mineral wood mattress with one side covered with craft paper is placed inside this cover box, and the absorber unit is finally placed over the wool mattress in the cover box. The side pipes of the absorber unit are brought out through holes at the side of the cover box. Insulation is pushed around the absorber. 2 to 3 coats of a dull black paint (lamp block dispersed in shellac-spirit solution) are applied over the corrugated surface and nearby sides. 3 mm thick transparent window glass sheet of size 137 cm x 90 cm, with rubber beading all around, is placed over the wooden frame in the cover box. The ends are pressed by folded G.I. strips, as shown in Fig.

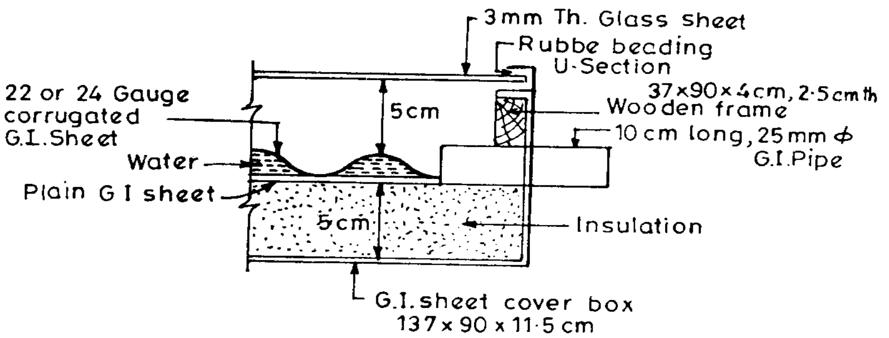


Fig. Details of encased collector unit, i.e. the absorber unit placed in the cover box etc. complete.

Orientation of the Collector Unit. In order to absorb maximum solar energy all the year round, the collector should be placed with its face towards the equator; i.e. facing towards the south at a place located in the northern hemisphere, and facing towards the north when placed in the southern hemisphere, and is tilted so that its angle with the horizontal is 15° in excess of the latitude of the place. [Please see photo Fig.].

(2) **The Water Storage Tank with Stand.** the hot water may have to be stored over night for use in the next morning, the tank must be well insulated and weather proof. It should have double walls, having a sandwich of at least 10 cm of fibre glass or mineral wool or similar insulation. The hot water from the collector unit is usually allowed to enter the tank at a depth of about 30 cm below the water level in the tank. The cold water to the collector unit comes from the bottom of the tank.

Fig. shows a typical 140 litres storage tank for a family of 5 persons. It is a two walled box filled with glass fibre insulation in between the walls. The inner tank is rectangular 40 cm x 40 cm at the base and 91.5 cm high. It is fabricated of a 18 or 16 gauge G.I. sheet. G.I. sheet nipples and sockets are welded at places as shown. The outer tank is made of 24 gauge G.I. sheets with bottom made of 16 or 18 gauge sheet. Its dimensions are 60 cm x 60 cm x 112 cm.

Cold water is allowed to enter the inner tank through a float system. Beneath the float outlet, is fitted a G.I. tray having a 25 mm diameter G.I. pipe welded at its centre. The pipe runs to the bottom of the tank. By this arrangement, cold water from the float does not mix with the hot water at the top, but is directed by the G.I. pipe to the bottom of the tank.

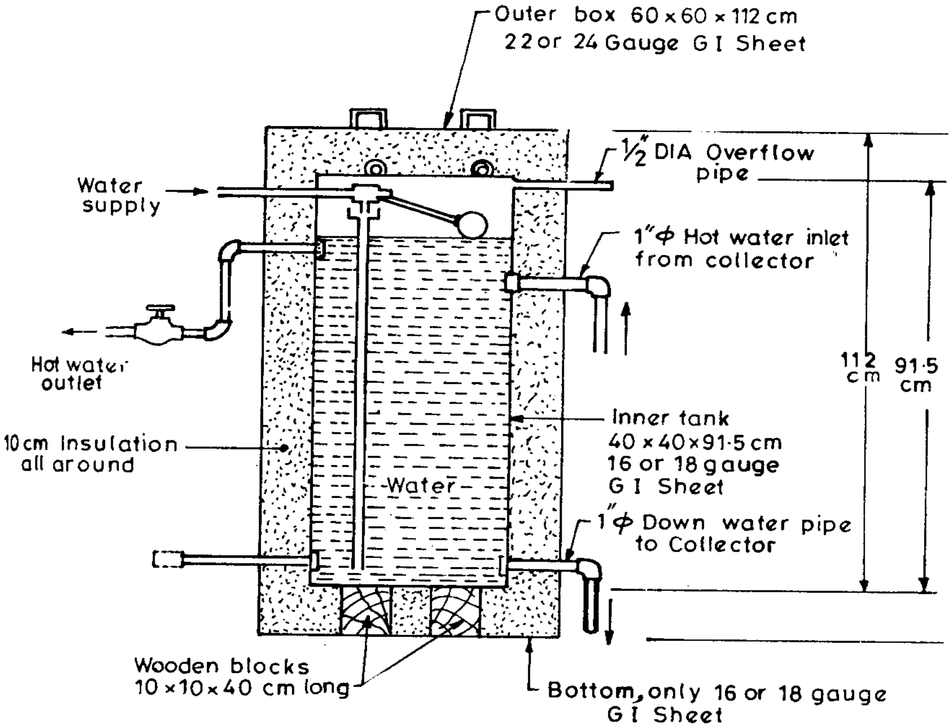


Fig. Typical 140 litres water storage tank.

The tank is placed on a stand as shown in the photo Fig. The stand is made of 25 mm x 25 mm x 3 mm angle iron frame. At the top, it is 61 cm x 61 cm; and at the bottom, its size is 91.5 cm x 91.5 cm. Cross ties are provided to reinforce the frame. The height of the stand is 140 cm. The stand can also be made of masonry.

The storage tank is finally connected with the collector unit through G.I. pipes and bend of approximate 120° angle. The connection pipes are insulated with 4 cm thick glass fibre or mineral wool for weather proofing, alkathene or polyethylene sheets are wrapped over the insulation. The collector is finally oriented as indicated earlier. Cold water connection to the tank is made through a float and hot water is taken out of the tank through a ' (12.5 mm) insulated G.I. pipe, as shown in Fig.

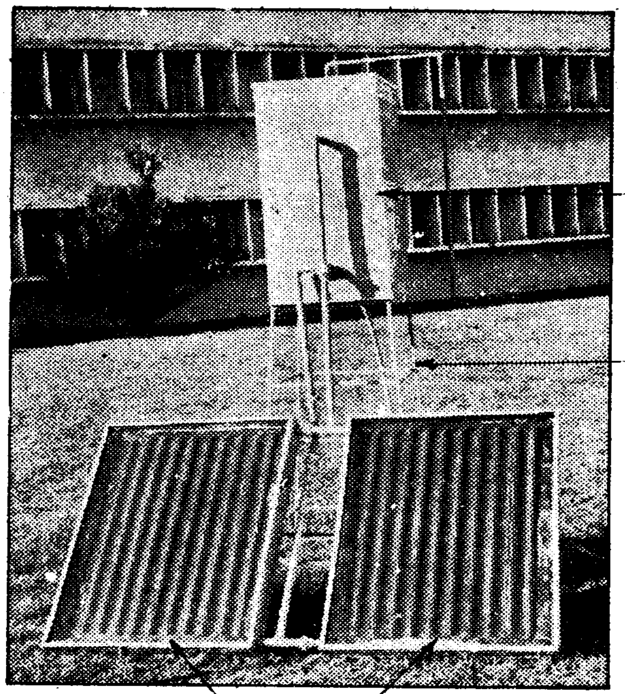


Fig. Photo view of an installed solar water heater.

Centralized Hot Water Systems

Individual geysers, described in the previous article, prove useful in small installations, such as houses, hostels, etc. However, in large installations like hotels, the demand of hot water is usually large involving—large number of supply points and hence installing individual geysers in such buildings may prove to be uneconomical and troublesome, involving heavy consumption of electricity and maintenance problems. In such buildings, therefore, it is usually advantageous to provide a central hot water system, in which the water is heated at one particular place in a boiler (of course water is heated and not boiled), and then circulated in the entire building through a properly designed network of hot water piping system, as to make the hot water reach at each distribution point. The boiler to be used in such a system can use either electricity or any other fossil fuel like coal, wood, kerosene, diesel, furnace oil, natural gas, L.P.G. (liquefied petroleum gas), gobar gas, solar energy or a combination of these fuels.

The various factors which are considered in its design are discussed below

Ambient Temperatures:

The temperature of the hot water to be supplied is usually kept between 55°C to 80°C, depending upon the required uses and climatic conditions of the place. The heat required in the boiler to achieve this desired temperature will of course depend upon the temperature of the incoming cold water, and may usually vary between 10 to 25°C, although of course it may be lower in sub-zero ambient conditions. The furnace or boiler requirements should be designed for the lowest temperature conditions, if the same is sustained over long periods, one weak or more, lowest ambient temperature to be considered in design should be established after a study of the area's temperature conditions. Air temperatures determine the viscosity of liquid fuels, furnace oil and light diesel oils, and may need pre-heating in very cold climates.

Pressure in the System:

Pressure in hot water taps should be the same as that in the cold water taps. Unequal pressure may result in back flow of water from one system to another, when hot and cold mixers are used and may cause scalding.

Hot Water Storage and Generation:

If a boiler is able to generate hot water at the same rate as the peak demand in the system, then evidently no storage of hot water is required. However, by providing a storage tank for hot water, the boiler capacity can be reduced. Large storage tanks for hot water are, however, usually avoided due to availability of limited space. But some storage may become necessary in certain specific cases, to take care of emergent requirements. The system to be adopted will finally depend on the capital and operational costs and the availability of space.

Hot Water Piping Systems:

The hot water generated in the central boiler should be supplied to the various points efficiently, without excessive loss of temperature and pressure. If the length of me supply pipes from the boiler to the supply point is long, a lot of heat from the water will dissipate, even if the pipes are insulated.

Secondly, if there is no recirculation of hot water in the distribution system, then hot water from a tap will come out only after initial delivery of cold water for 1 to 5 minutes (since the stagnant water in the pipe length from boiler to the off take point will loose heat by convection and become cold). If the rate of flow at the tap is about 8—10 1/min, then the user will be wasting about 8 to 50 1 of water before getting the hot water. In such a non-circulating system, the energy used in heating the water initially, also gets wasted. To avoid this wastage of heat, a return pipe is installed from the remotest section of the hot water main, which is connected back to the vessel supplying hot water to the building, as shown in Fig. In case, there are a number of risers, each one is provided with a return line, connected to a common return header to the boiler. The recirculation is automatically achieved due to thermo-symphonic action (Fig.);

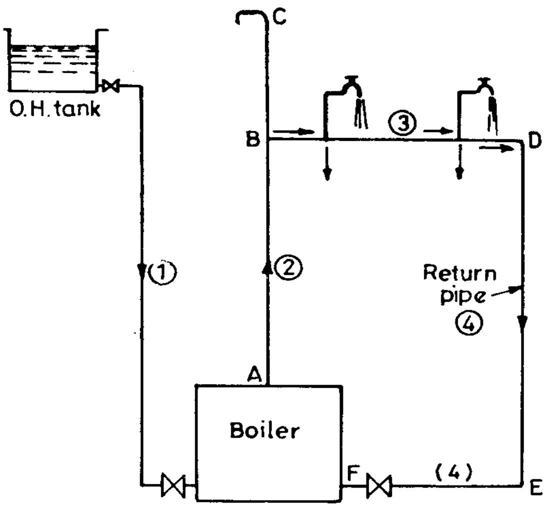


Fig. typical hot water distribution network supporting recirculation by thermo-symphonic action. or is sometimes forced by using a recirculation pump (Fig), as explained below:

Piping System using Natural Thermo-symphonic action:

A simple typical installation of hot water system, using an overhead cold storage tank, a centralized boiler at ground level, one hot water main (2) rising vertically up from the boiler, one distribution main (3) is shown in Fig.. The remotest point D of the distribution main is connected back to the boiler by a return pipe DEF (4).

The circulating pressure developed in the system is calculated by the equation:

$$H = \frac{h}{\rho_w} (\rho_{w_2} - \rho_{w_1})$$

where H = Circulating pressure in metre head of water

h = mean height in m between the boiler and the supply point

ρ_{w_1} = density of hot water at flow temperature t_1 in pipe AB

ρ_{w_2} = density of less hot water at return temperature in pipe DEF

ρ_w = density of water at 0°C = 1000 kg/m^3

For example, let us assume that:

h = 12 m

t_1 = flow temperature at boiler = 70°C

t_2 = return temperature = 45°C

∴ ρ_{w_1} at 70°C = 978 kg/m^3

ρ_{w_2} at 45°C = 990 kg/m^3 [See Appendix Table A-2]

∴ H = Circulating pressure in the system

$$= 12 \text{ m} \times \frac{990 - 978}{1000}$$

= 0.14 m of water head

≈ 1.4 kN/m^2.

The pipe diameter is calculated from pressure loss formula or chart after calculating the probable flow and length of the line to the remotest point. The size of the return pipe is calculated by estimating the heat loss in the line from a designed temperature drop.

Circulation by natural thermo-symphonic action usually succeeds only in smaller installations, where the boiler is installed in the basement below the lowest supply-line level, and the usage of hot water is uniform. When the required flows are larger, the limited circulating pressure makes the pipe sizes very large and uneconomical.

Piping System with Forced Circulation:

Since the natural thermo-symphonic circulating pressure is usually low, it becomes necessary in larger installations to generate additional pressure within the system to force the circulation by means of a pump. This helps in using reduced pipe sizes and allows hot water to circulate in all parts of the distribution system for quick draw off of the hot water.

The circulating pumps should however, never be used as booster pumps for increasing the pressure in the hot water lines, which infact is provided by the cold water over-head tank. When the source of cold water as well as hot water remains the same, the pressure in the cold water taps as well as in the hot water taps will remain almost the same, which is very much desirable.

Piping Layouts:

The hot water piping network can be arranged in different ways depending upon the architectural and structural considerations of a building. The most common systems are:

(i) Down feed system;

(ii) Up feed system; and

(iii) Reverse circulation system.

These systems are discussed below :

Down feed System:

In this system (Fig.), the main vertical hot water line AB (pipe marked as 1) is lifted up to the top floor or to terrace level, where the distribution main BC (i.e. pipe 2) will run over the floor. Single down take pipes (3) are dropped in each

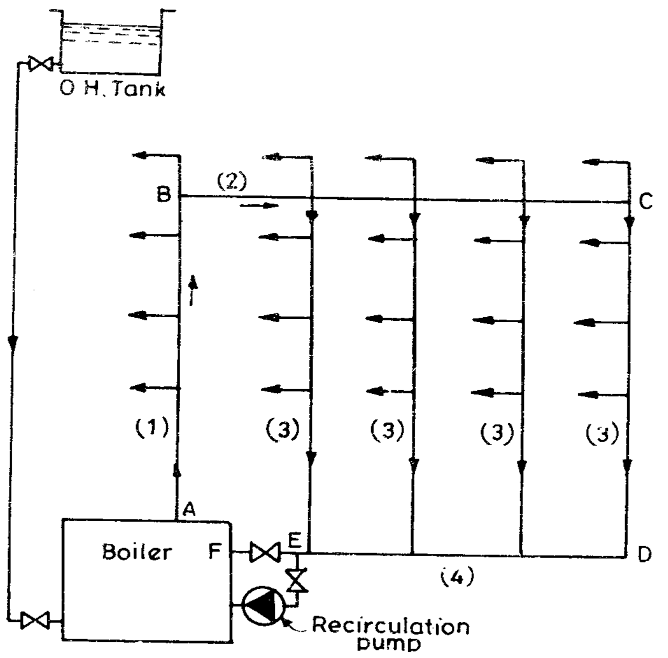


Fig. Down feed piping system. Shaft to join a common return line DE (4) at the lowest level, which is connected to the boiler. A recirculation pump may be attached as shown, to improve circulation pressure, as discussed earlier.

For efficient operation, the flow pipe on the top floor must run horizontally at the same level. Any change in its direction in vertical plane should be avoided to prevent air-traps. Accessible space is therefore necessary to lay this main pipe (2) on the top floor. When such space on the top floor is not available, this pipe may be laid on the terrace.

This system is simple, efficient and economical.

Upfeed System. In this system (Fig.), the main flow line (1) and the return pipe (4) are both laid at the ceiling of the lowest floor like basement roof or on ground floor. Vertical up flow pipes (2) and their corresponding return pipes (3) supply the water to the rooms above. Circulation may occur either under natural thermo-symphonic action or by forced circulation, as discussed earlier.

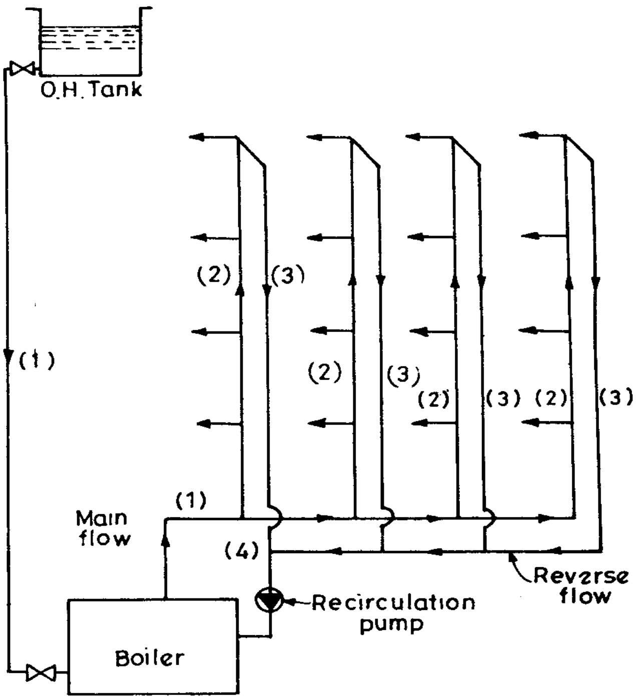


Fig. Upfeed piping system.

Reverse Circulation System:

This system (Fig.) is similar to the up feed system except that the return flow occurs in the same direction as that of the main flow pipe (1) till the end of the remotest circuit, from where it returns to the boiler through a separate reverse return line (2). This system is suitable where the circuits are long and where there is a possibility of the least favorably placed fixtures not getting adequate flow or pressure. A reverse return line enables closer balancing of pressure in the system.

CONVEYANCE OF WATER:

Water is conveyed through water pipe line containing water pipe, pipe joints.

Water pipe materials may be

(a) Asbestos cement

(b) Cast iron

(c) Cement concrete

(d) Copper

(e) Galvanized iron either lined or unlined

(f) Lead pipe either lined or unlined

(g) Plastic polyethylene

(h) Steel

(i) Wood

(j) Wrought Iron

(k) Brass, etc.

The pipe material is selected for specific applications.

When water flows through these pipes water line get corroded.

Prevention of pipe corrosion is possible by following methods

(a) Cathodic protection

(b) Proper pipe material. The alloys of iron or steel with chromium, copper nickel are found to be more resistant to corrosion.

(c) Treatment of water

Aeration reduction free carbon dioxide

Addition of lime or soda after filtration

Vexanta phosphate for iron pipe.

Distribution pipe appurtenances

(a) Air valve

(b) Bibcock/tap

These are water taps which are attached at the end of water pipe and from which the consumer obtains water.

(c) Fire hydrant

(d) Reflex valve

(e) Relief valve

(f) Scour valve

(g) Sluice valve

(h) Stock coke

(i) Water meter

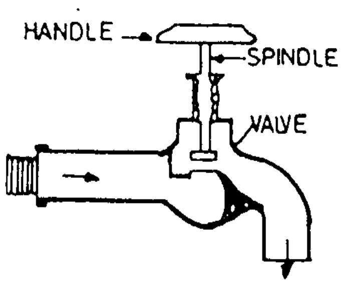


Figure Bibcock / Tap

It is used for measuring the quality of water. It is of

(a) Positive displacement – Rotary, oscillating, Reciprocating or rotating disc types.

(b) Velocity type, Turbine meter, Venturi meter.

HOUSE DRAINAGE: GENERAL PRINCIPLES

The arrangement provided in a house or building, for collecting and conveying waste water through drain pipes, by gravity, to join either a public sewer or a domestic septic tank, is termed as house drainage or building drainage. Aims of house drainage

House drainage is provided

(i) To maintain healthy conditions in the building

(ii) To dispose off waste water as early and quickly as possible

(iii) To avoid the entry of foul gases from the sewer or the septic tank

(iv) To facilitate quick removal of foul matter (e.g. human excreta)

(v) To collect and remove waste matters systematically

Principles of house drainage

The following principles are adopted for the efficient drainage system

1. The lavatory blocks should be so located that the length of drainage line is minimum. In the case of multi-storeyed building they should be located one above the other. At least one wall of the lavatory block should be an outside wall, to facilitate the fixing of soil and vent pipes.

2. The drainage pipes should be laid by the side of the building rather than below the building.

3. All the drains should be aligned straight between successive inspection chambers. All sharp bends and junctions should be avoided except through chambers.

4. The slope of the drains should be sufficient to develop self cleansing velocity.

5. The size of drain should be sufficient, so that flooding of the drain does not take place while handling i.e. maximum discharge.

6. The drainage system should contain enough number of t.c.ps at suitable locations.

7. The house drain should be disconnected to the public sewer by the provision of an intercepting trap. This will avoid the entry of foul gases from entering the house drainage system. It should be seen that the public sewer is deeper than the house drain.

8. Rain water pipes should drain out rain water directly into the street gutters from where it is carried to the storm water drain.

9. All the connections should be water tight.

10. The entire drainage system should be properly ventilated from the starting point to the final point of disposal. It should permit free circulation of air.

11. All the materials and fittings of the drainage system should he hard, strong and resistant to corrosive action. They should be non-absorbent type.

12. The entire system should be so designed that the possibilities of formation of air locks, siphonage, under deposits etc. are minimize.

PIPES AND TRAPS

Pipes:

In a house drainage system, a pipe may have the following designations, depending upon the function it carries

1. Soil pipe. A soil pipe is a pipe through which human excel flows.

2. Waste pipe. It is a pipe which carries only the liquid waste. It docs not carry human excreta.

3. Vent pipe. It is a pipe which is provided for the purpose of the ventilation of the system. A vent pipe is open at top and bottom, to facilitate exit of foul gases. It is carried at least 1 m higher than the roof level.

4. Rain water pipe. It is a pipe which carries only the rain water.

5. Anti-siphonage pipe. It is pipe which is installed in the house drainage to preserve the water seal of traps.

The following sizes of pipes are commonly used in house drainage

Soil pipe	: 100 mm
Waste pipe - horizontal	: 30 to 50 mm
Waste pipe - vertical	: 75 mm
Rain water pipe	: 75 mm

Vent pipe : 50 mm

Anti-siphonage pipe

(/) Connecting soil pipe : 50 mm

(ii) Connecting waste pipe : 40 mm

Traps

A trap is a depressed or bent fitting which, when provided in a drainage system, always remains full of water, thus maintaining water seal. It prevents the passage of foul air or gas through it, though it allows the sewage or waste water to flow through it. The depth of water seal is the vertical distance between the crown and dip of a trap (Figure). The depth of water seal represents its strength or effectiveness. Greater the depth of water seal, more effective is the trap. The depth of water seal varies from 25 mm to 75 mm.

Causes of breaking of seal. Water seal may break due to the following reasons

(i) Faulty joints

(ii) Crack in the bottom of seal

(iii) Creation of partial vacuum in the sewer fittings

(iv) Increase in the pressure of sewer gases, and

(v) Non-use for a prolonged period.

The breaking of the water seal can be prevented by (i) connecting the portion between the soil pipe and trap by a vent pipe, and (ii) use of anti-siphonage pipe in this building.

Characteristics of traps.

A trap should possess the following characteristics

1. It should possess adequate water seal at all times, to fulfill the purpose of its installation. However, it should retain minimum quantity of water for this purpose.

2. It should be of non-absorbent material.

3. It should be free from any inside projections, angles or contractions, so that flow is not obstructed or retarded.

4. It should be simple in construction, cheap and readily available.

5. It should be self cleansing.

6. It should be provided with suitable access for cleaning.

7. Its internal and external surfaces should have smooth finish so that dirt etc. does not stick to it.

Classification of traps

Traps are classified as follows

(a) Classification according to shape (Fig.) (i) P-Trap (Fig. a). This resembles the shape of letter P, in which the legs are at right angles to each other.

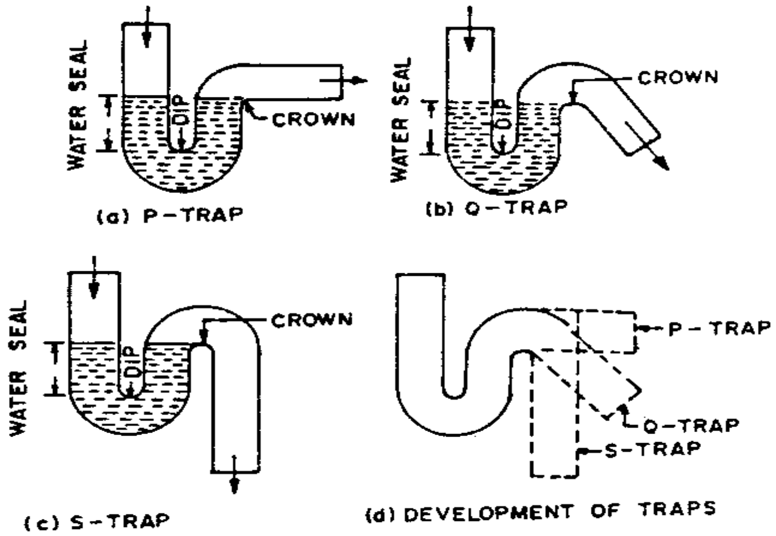


FIG TRAPS ACCORDING TO SHAPES.

(ii) Q-trap or half-S-trap (Fig. b). This resembles the shape of letter Q, in which the two legs meet at an angle other than a right angle.

(iii) S-trap (Fig. c). This resembles letter-5, in which both the legs are parallel to each other, discharging in the same direction. Fig (d) shows the development of all the three types of traps.

(b) Classification according to use

(i) Floor trap or nahni trap

(ii) Gully trap

(iii) Intercepting trap.

Floor trap or Nahni trap

A floor trap, commonly known as a nahni trap is used to collect wash water from floors, kitchens and bath rooms. It forms the starting point of waste water floor. It is made of cast iron, with gravity at top, to exclude entry of solid matter of big size. This cover can be removed to do frequent cleaning of the trap. These traps have small water seal.

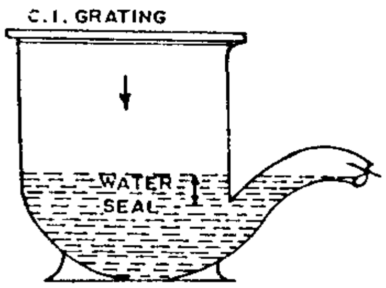


Figure FLOOR TRAP.

Gully traps (Fig.)

These are special types of traps which disconnect sullage drain (collected from baths, kitchen etc.) from the main drainage system.

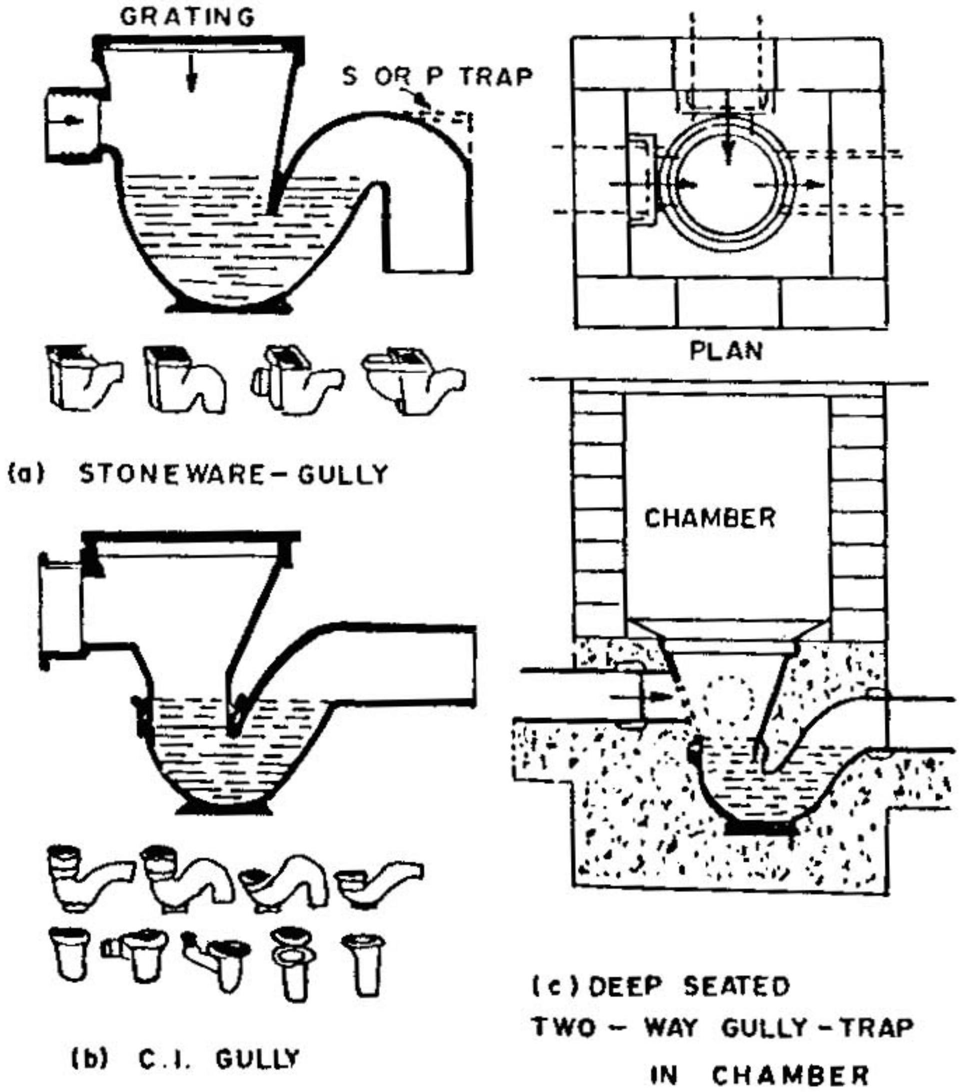


FIG VARIOUS FORMS OF GULLY TRAPS.

It is either made of stone-ware or of cast iron. Stone ware gully trap is of square section at the top on which C.I. grating is fitted. Fig. (a) shows such a gully along with its variations. A C.I. gully is circular in section, as shown in Fig. (b), along with its variations. It can also be fitted in a masonry chamber as shown in Fig. (c). A water seal of 60 to 70 mm is usually provided. It may have either a S trap and TM trap. A gully trap is provided at the external face of a wall. It thus receives waste water from baths kitchens etc. and pass it on to the house drain carrying excremental discharge from water closets etc. A well designed gully trap may serve two or three connections from nahni traps.

Intercepting traps

This is a special type of trap provided at the junction of house drain with the public sewer or septic tank. It is thus provided in the last manhole of the house drainage system. It has a deep water seal of 100 mm, so as to effectively prevent the entry of sewer gases from public sewer line into the

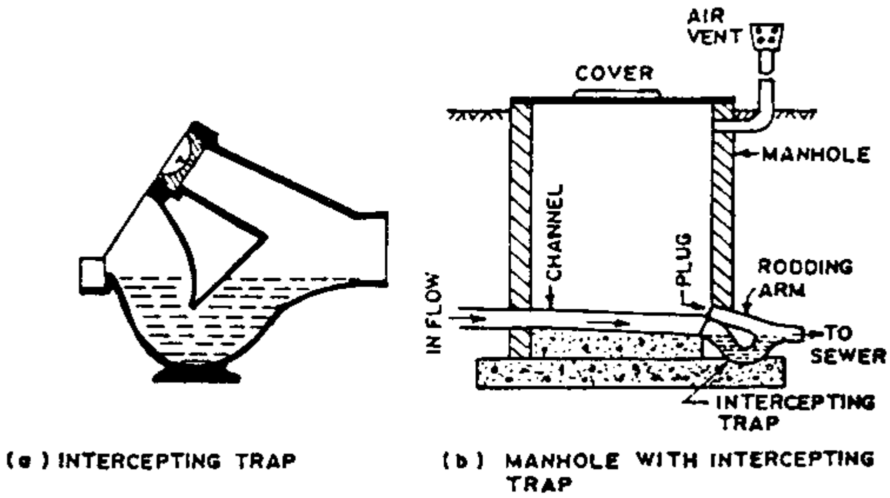
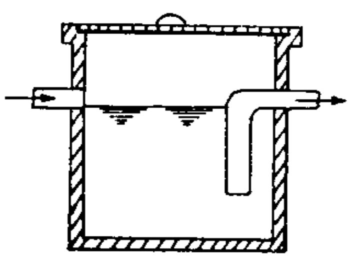


FIG INTERCEPTING TRAPS

The trap has an opening at the top, called the cleaning eye or rodding arm, having a tight fitting plug, for frequent cleaning of the trap.



Grease traps

Such traps are used only in large hotels, restaurants or industries where large quantities of oily wastes are expected to enter the water flow. If the oily or greasy matter is not separated, it will stick to the building drainage system resulting in the formation of ugly scum and consequent obstruction to a grease trap is either a masonry or cast iron chamber, with a bent pipe or Tee-pipe at the outlet end. Because of sudden increase in the area of flow at entry, the velocity of flow is reduced, resulting in the separation of oily and greasy matter from the waste water. This greasy matter, floating on the top can be removed later.

Silt traps

If the water carries a lot of coarse particles of silt, sand etc., it is better to remove these before entering into the building drain. The silt particles normally enter the drain because of its use in washing the utensils. A silt trap is just similar to a grit chamber. Fig. shows a combined silt and grease trap.

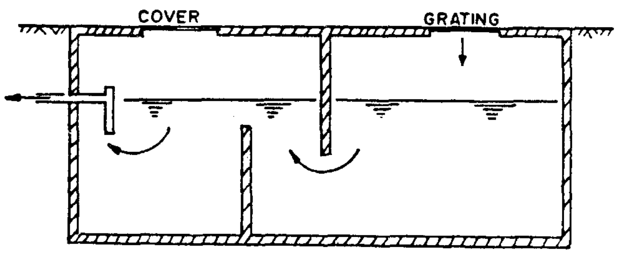


FIG COMBINED SILT AND GREASE TRAP

SANITARY FITTINGS

The following fittings are commonly used in buildings, for efficient collection and removal of waste water to the house drain:

(i) Wash basins

(ii) Sinks

(iii) Bath tubs

(iv) Water closets

(v) Urinals

(vi) Flushing cisterns.

1. Wash Basin

Wash basins are usually made of pottery or porcelain ware. Sometimes, they are also made of porcelain enamelled cast iron, pressed steel or plastic, especially where number of users are more. An ordinary wash basin is mounted on brackets fixed on wall, while a pedestal type basin is mounted on pedestal rising from wall. They are available in different shapes and sizes. Normally, a wash basin is provided with two taps- one for hot water and the other for cold water mounted at its top. It has an oval shaped bowl, with an overflow slot at the top. The waste pipe with a metallic strainer is provided at the bottom of the bowl. The waste pipe has a trap at its bottom. Fig. shows a flat bottom wash basin.

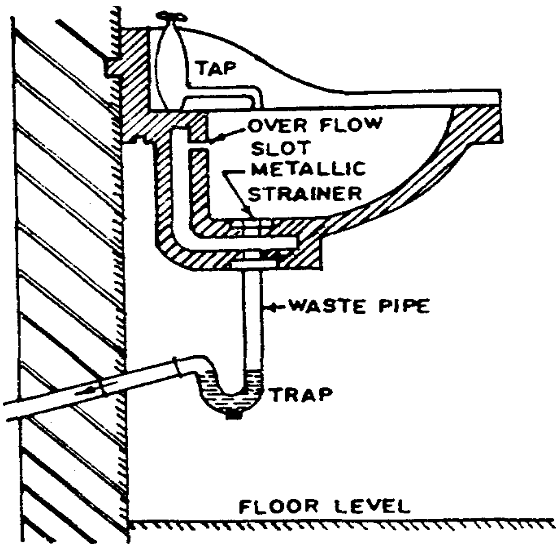


FIG. WASH BASIN

2. Sink.

While a wash basin is used for washing hands, face etc. a sink is used in kitchen or laboratory. These may be made of glazed fire clay, stainless steel, metal porcelain or enamelled pressed steel. They are manufactured in various sizes and shapes, though rectangular shape is quite common in kitchens. It may also have a drain board attached to it. A sink may also be constructed of cast-in-situ concrete, with suitable finishing surface such as marble, terrazzo etc. The outlet pipe, provided with a grating of brass or nickel, may discharge over a floor trap or nahni trap.

3. Bath tub

Bath tubs, are usually made of iron or steel coated with enamel, enamelled porcelain or of plastic material. They may also be made of cast-in-situ concrete finished with marble chips or terrazzo, or else may be made of marble slabs properly jointed at the side. It has a length varying from 1.7 to 1.85 m, width between 0.7 m to 0.75 m and depth near waste pipe varying from 0.43 m to 0.45 m. The overall height may vary between 0.58 to 0.6 m. It is provided with outlet and overflow pipes, usually of 40 mm diameter. A trap with proper water seal is used at the outlet.

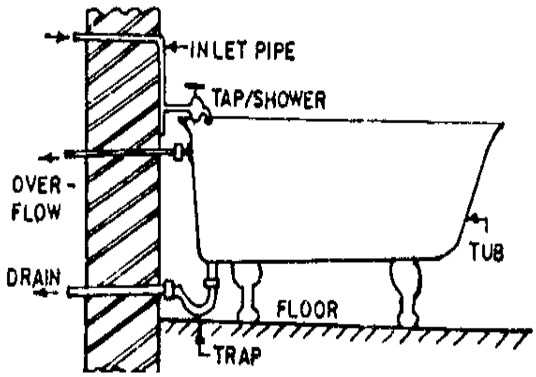


FIG BATH TUB.

4. Water closets

Water closets are designed to receive and discharge human excreta directly from the person using it. The appliance is connected to the soil pipe by means of a suitable trap. It is usually connected to a flushing cistern to flush the closet and discharge the human excreta to the soil pipe. Water closets are of three types.

(1) Indian-type

(2) European type

(3) Anglo-Indian type.

1. Indian type W.C.

The Indian style water closet (W.C.), shown in Fig. is simple in construction and working, but is used in squatting position. It is usually made of porcelain. The pan and trap arc available in two different pieces. The trap has an opening for anti-siphonage pipe. The W.C. is fixed in squatting (or sitting) position just at floor level. Since the excreta does not directly fall into the trap, therefore, there are chances for excreta to become foul. The excreta may stick to the surface of the pan if the flushing is not proper. The flush water enters the rim of the pan through the opening provided in the front of the pan. The flushing cistern is normally kept 2 m above the closet. Indian type closet requires greater quantity of water (at least 10 litres) for flushing.

2. European type W.C.

Fig. shows a typical European type water closet. It is usually made of porcelain. It is a wash down water closet, provide with a seat and a cover. The pan has flushing rim to spread the flush water. The excreta directly fall in the trap, and therefore there are fewer chances of excreta becoming foul. The pedestal type European W.C. also known as commode is commonly used. The closet is fitted with either a P-trap or 5-trap. It can also be used at upper floors, while in case of Indian type W.C., the upper floor has to be depressed to receive the pan fixed at floor level. Generally, a low level flushing cistern is used with the European type W.C.

3. Anglo-Indian W.C.

The main advantage of Indian type W.C. is that it can be used in squatting position since it is fixed at floor level, while an

Notes

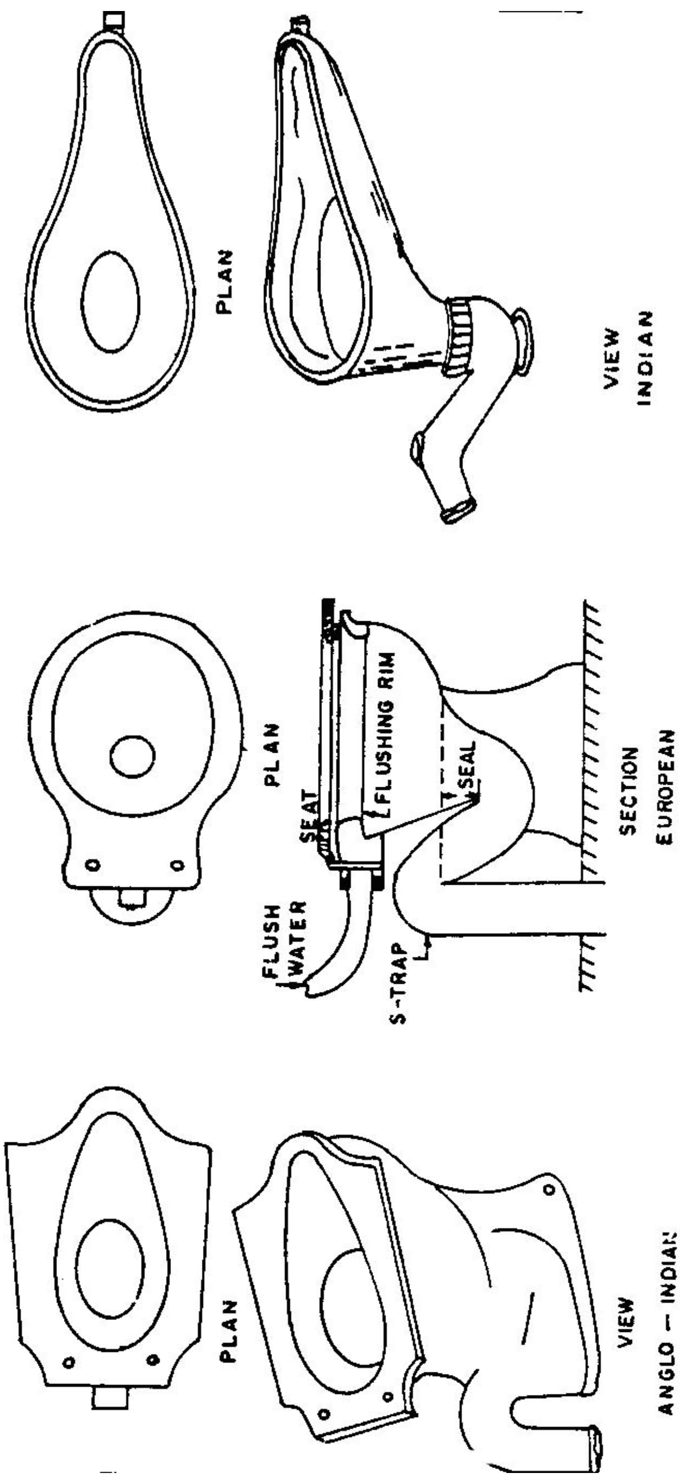


FIGURE WATER CLOSETS

European type W.C., which is fixed at about 40 cm higher than the floor level, cannot be conveniently used in squalling position since the legs of the user cannot rest on thin rim conveniently. However, the defect with Indian W.C. is that the excreta does not fall directly in the trap. An Anglo-Indian W.C. removes both these defects. As shown in Fig. the closet is fixed about 40 cm above the floor level. However, the upper rim of the pan is properly enlarged so that legs can rest on it while using in squatting position. The inner shape of the pan is intermediate between the two types, with wider top area of the trap. The excreta directly falls in the water contained by the trap.

Requirements of a water closet

The following are the requirements of a good water closet:

1. It should be convenient in use by persons of all both old as well as children.
2. The size of the pan should be such that the urine as well as the fecal material docs not falls outside the pan.
3. The trap should be such that water docs not splash when the excreta falls in water.
4. Urine should not splash outside the pan.
5. Fecal matter should flow easily in the trap without sticking to the pan. For that the, surface of the pan should be smooth.
6. Flushing should be achieved effectively with the use of small quantity of water.
7. Fecal material should not be too plainly visible before flushing.
8. The water in the trap should provide an effective and air tight seal.
9. The pan should be of durable material, so that it does not crack with the passage of time.

5. Urinals

Urinals are usually of two types

(i) how type and

(ii) slab or stall type

The former type in used in residential buildings while the later type is used in public buildings. A stall urinal normally has more than one unit, with a centre to centre spacing of 0.6 to 0.7 m. Fig. shows the two types of urinals. The best types of urinals are made of enamelled fireclay, others of salt glazed stoneware, marble, stale and in cement. The contents of urinals are collected and discharged into the soil pipe through floor trap (nahni trap). Automatic flushing cisterns arc generally provided for stall type urinals, which operates, at regular interval of 10 to 15 minutes.

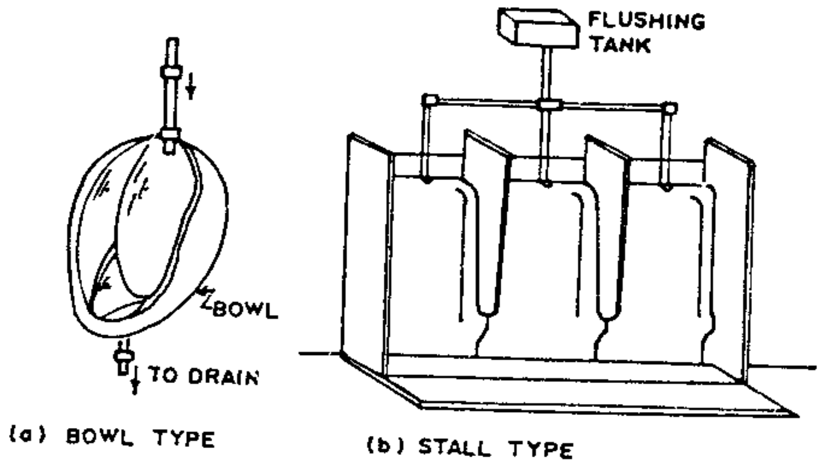


FIG. URINALS.

6. Flushing cisterns

Flushing cisterns are used for flushing out water closets and urinals. These are made of either cast iron or of porcelain. For Indian type W.C., cast iron flushing cistern is normally used, fixed at about 2 m above the floor level. For European type and Anglo-Indian type closets, porcelain cisterns are normally used, fixed at about 60 cm above floor levels. The low levels flushing cisterns, made of porcelain, are decent in look, and operate very easily by simply turning a handle.

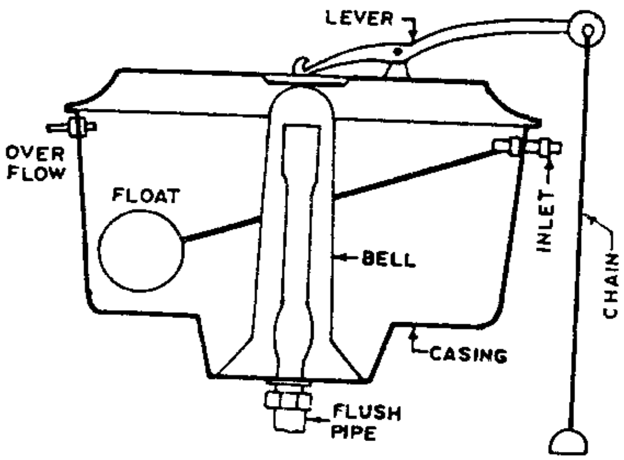


FIG. BELL TYPE FLUSHING CISTERN

Flushing cisterns are of two types

(i) Valve less siphonic type and

(ii) Valve fitted siphonic type. Bell type flushing cistern, commonly used with Indian type closets, is the typical example of valueless siphonic cistern, shown in Fig.

A bell type flushing cistern consists of the following parts:

1. A bell or dome

2. A float

3. A lever with a chain

4. Inlet, outlet and overflow pipes and

5. Cast iron casing.

The bell is connected to flushing chain through a lever. The float is so set that when the discharge level is reached; the float rod slightly closes the inlet cock. When the chain is pulled, the bell is lifted up, thus splashing the water. The splashing of water takes away some air with it, causing partial vacuum in the top of the bell. Siphonic action thus starts, and water in the cistern enters the bell through holes provided at its bottom. When the tank is emptied, air enters from the bottom and siphonic action is broken. The lowering of the float results in the opening of the inlet cock, and water thus enters the cistern. It should be noted that the chain should be released immediately after the pull, otherwise the partial vacuum caused by splashing water may be destroyed by the entry of air from the flush pipe. The capacity of a bell type flushing cistern may vary between 5 to 15 litres.

SYSTEMS OF PLUMBING

There are four principal systems of plumbing for drainage of buildings

(1) Single stack system

(2) One pipe system

(3) Partially ventilated single stack system and

(4) Two pipe system.

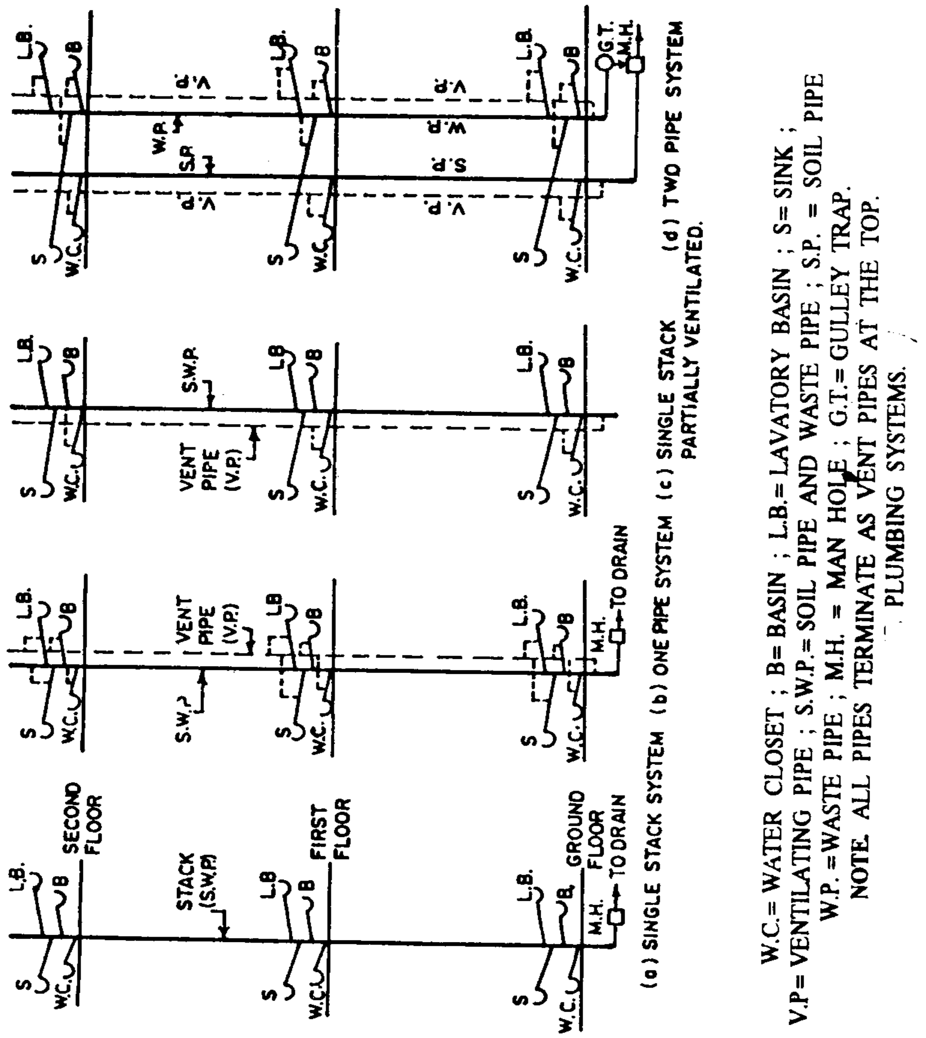
All the four systems are shown diagrammatically in Fig.

1. Single stack system (Fig. a)

This is the simplest system, in which the waste matter from baths sinks, etc., as well as foul matter from the W.C. is discharged in one single pipe, called the soil and waste pipe (S.W.P.). This pipe terminates as the vent pipe at its top, and no separate vent pipe is provided. The single stack system is effective only if the traps are filled with water seal of depth not less than 75 mm. Gulley traps and waste pipes are completely dispensed with. The system is simple and economical since only one pipe is used.

2. One pipe system (Fig. b)

In this system, a separate vent pipe is provided, and the traps of all water closets, basins etc. are completely ventilated. In a multi-storeyed building, the lavatory blocks of different floors are situated one above the other, so that the waste water discharged from various units at different floors can be carried through common soil and waste pipe (S.W.P.). The system is costlier than the single stack system.



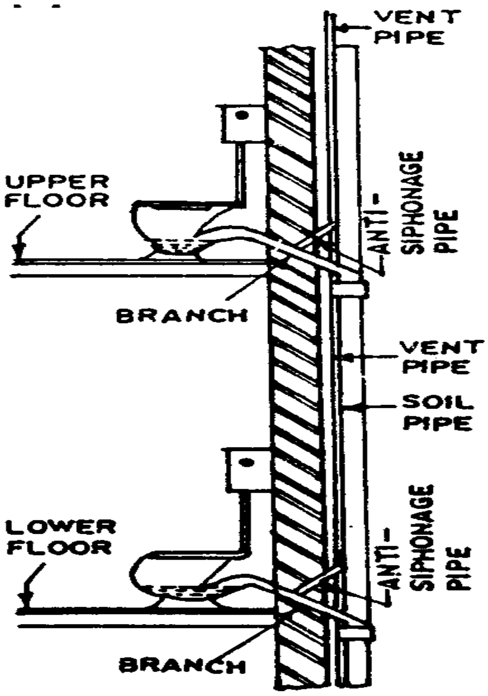
3. Single stack system partially ventilated (Fig. c)

This is modified form of the single stack system and one pipe system. In this system, the waste from W.C., basins, sinks etc. is discharged into one common soil and waste pipe (S.W.P.) However, in addition, a relief vent pipe is also provided which provides ventilation to the traps of water closets. The traps of basins etc. are not directly connected to the vent pipe.

4. Two pipe system (Fig d)

In this system, separate soil pipe (S.P.) and waste pipe (W.P.) are provided. The discharge from W.C. is connected to the soil pipe

(S.P.) while the discharges from baths, sinks, lavatory basin etc. are connected to the waste pipe (W.P.). All the traps are completely ventilated by providing separate ventilating pipes. Thus, four pipes are required. The discharge from waste pipe is disconnected from the drain by means of a gully trap.

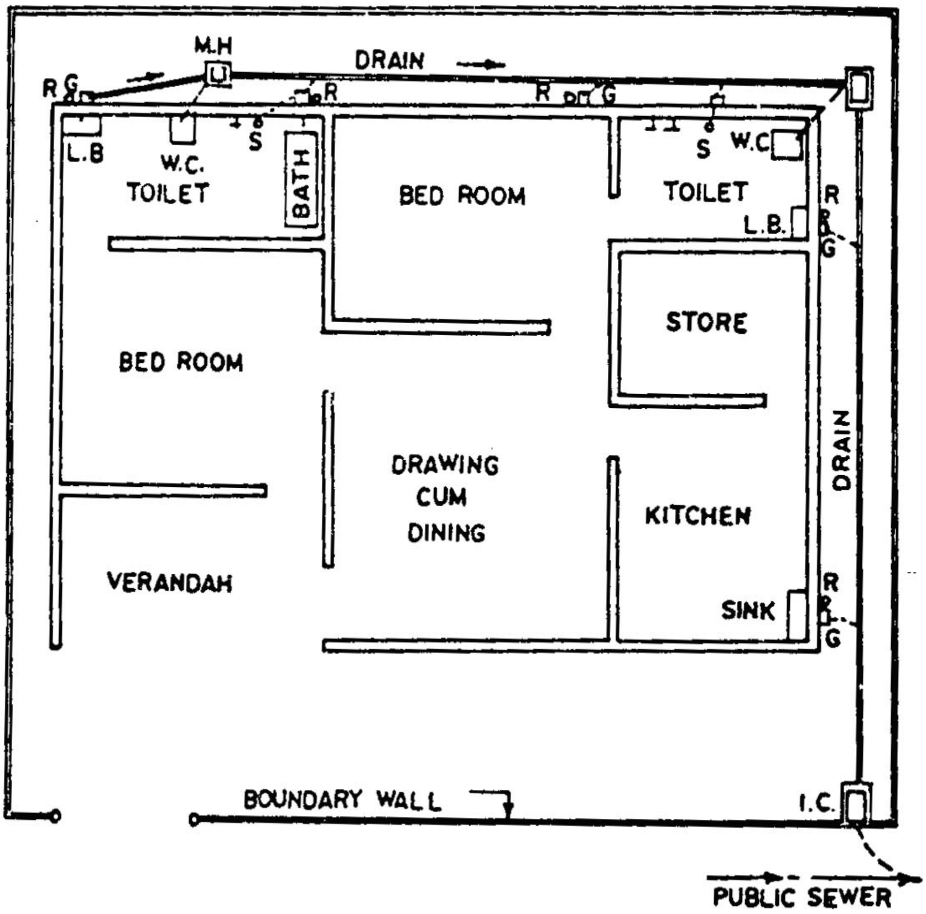


ANTI-SIPHONAGE PIPE.

It is a pipe provided to preserve the water seal of traps. It maintains proper ventilation and does not allow the water seal to get broken due to siphonic action. In the case of a multi- storeyed building, the sudden flush of water in the upper storey results in the sucking of air from the short branch of the pipe connecting the W.C. to the soil pipe of lower storey. This sucking of air causes partial vacuum on the downstream side of the water seal of the lower W.C. The pressure at the upstream side of the water seal is more (atmospheric), which forces the water up the trap and siphons it out in the branch.

DRAINAGE PLANS

For efficient drainage, it is always better to prepare house drainage plan. In some cities, it is statutory to submit such plans.



R= RAINWATER PIPE; G= GULLEY TRAP; L.B.= LAVATORY BASIN W.C.= WATER CLOSET ; S= SINK M,H.= MANHOLE; I.C.= INTERCEPTING CHAMBER. FIG.DRAINAGE PLAN OF A BUILDING.

The site plan is drawn to a suitable scale, showing onto it the position of baths, W.C, urinals, wash basins and other units, along with the position of gully traps and floor traps. The longitudinal section of the drain is also drawn, showing distances, invert levels, size and levels of inspection chambers and man holes, gradient of pipes and the position and level of the public sewer.

SEPTIC TANK

A septic tank is used to treat sewage from isolated group of country houses, where a piped sewage system (i.e., a public sewer) is not available. It is a horizontal continuous flow sedimentation tank in which sewage moves very slowly.

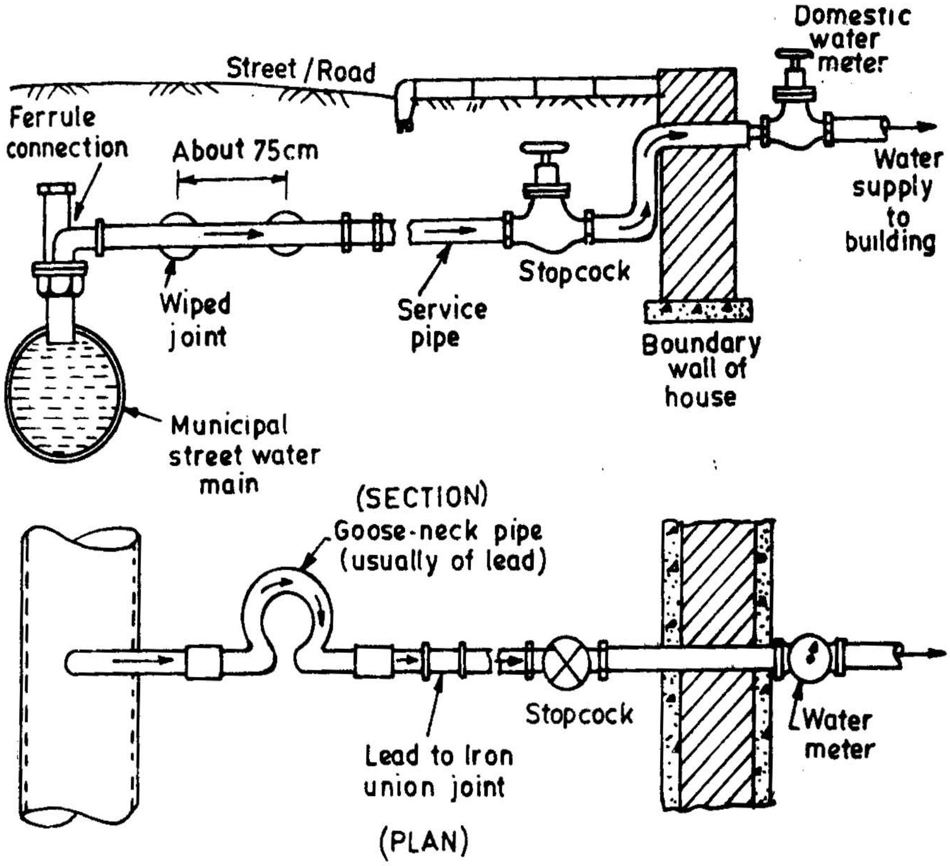


Fig The Water Connection.

(i) **Ferrule.** A ferrule is a right angled sleeve made of brass or metal, and is joined to a hole drilled in the water main, to which t is screwed down with a plug. Its size usually varies between 10 to i0 mm diameter. For all other connections of more than 50 mm diameter, a tee a-anch connection, off the water main, is used.

(ii) **Goose neck.** Goose neck is a small sized curved pipe made of i flexible material (usually lead) and is about 75 cm in length brining a flexible connection between the water main and the lervice pipe.

(iii) **Service pipe**. Service pipe is a galvanized iron pipe of size less than 50 mm diameter. It should be laid underground in a trench in which no sewer or drainage pipe is laid. The service pipe which tupplies water to the building through the municipal main is thus connected to the main through the goose neck and ferrule.

(iv) **Stop cock.** The stop cock is provided before the water enters he water meter in the house. It is housed in a suitable masonry hammer with a removable cover, and is fixed in the street close to he boundary wall in an accessible position. Sometimes, it is irovidedjust before the water meter inside the house, keeping both of them in one chamber. The details of stop cocks are given in the next article.

(v) **Water meter.** Water meter measures and records the quantity of water consumed in the house. The domestic type water meter generally employed for houses is fitted into the service pipe with unions, which enables the meter to be changed where necessary. The water meter is generally fixed in an iron box fitted in an opening or cavity made in the boundary wall of the house, and is covered with a movable iron cover. The details of the domestic water meters are given in the previous chapter in article 10.17.

Stop Cocks

A stop cock is a screw down type of sluice valve which is used in smaller sized pipes in service connections for stopping or opening the supply. They are generally provided at the water entrance of each building and also within the building. When provided just prior to the water meter in each house connection, they should be enclosed in a proper cast iron box having a hinged cover.

A typical stop cock is shown in Fig. The body of the valve is so cast that the water passes through an orifice when the valve stem is raised. When the valve is closed, it rests against the seat, and thereby closing the orifice. They are extensively used in pipes upto 50 mm sizes.

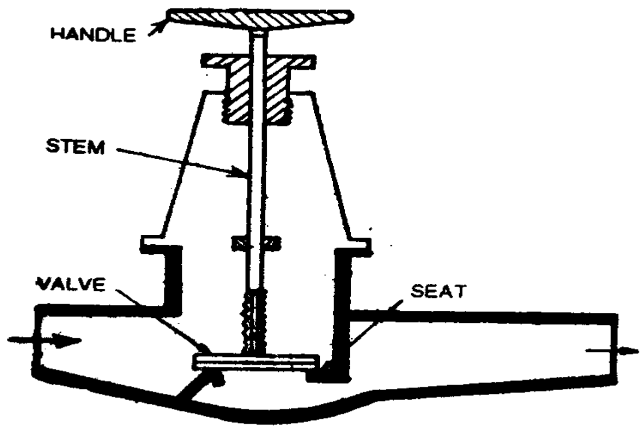


Fig. A typical stop cock.

Water Taps and Bib Cocks

Water taps are the types of valves provided at the end of service pipes for withdrawing water at the consumers' houses. Sever varieties of water a tap are available, and the most common of then is a bib cock. A typical bib cock is shown in Fig. By rotating the

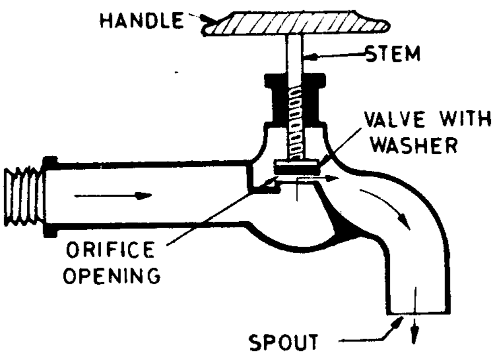


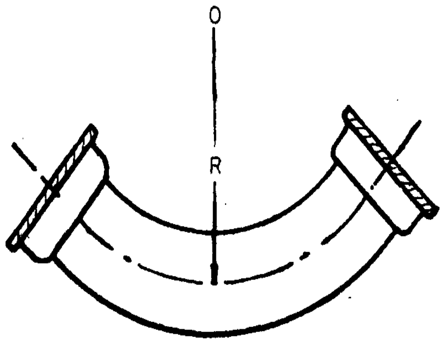
Fig A typical bib cock handle of the bib cock, the orifice opening, through which the water passes, can be increased or decreased, thereby controlling the outflow through the spout. They are available to be fitted in different pipe sizes from 10 to 50 mm diameter.

The bib cocks may also be of the push type which opens from a slight push given vertically upward, and closes down automatically due to self-weight when the push is removed. Such valves are used in public taps in order to avoid wastage of water from handle type bib cocks, which may be left open by the irresponsible people.

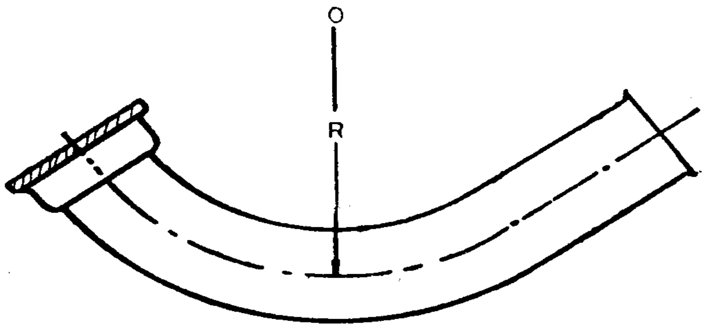
The bib cocks should be water-tight and should not leak, as it may lead to considerable wastage of water. The rubber or leather washers used in them may get damaged and lead to leakage, and hence should be replaced as and when needed.

Pipe Fittings

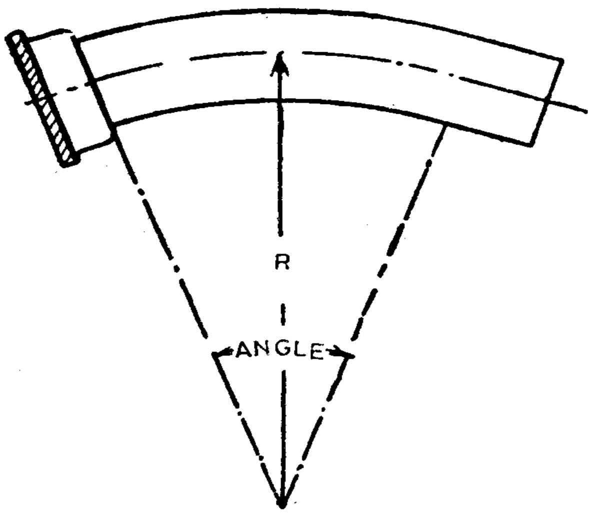
The various pipe fittings, such as bends, crosses, tees, elbows, unions, caps, plugs, flanges, nipples, etc. are frequently used in making service connections and also sometimes in bigger sized mains or sub-mains. Various types of bends and other important pipe fittings are shown in Fig.



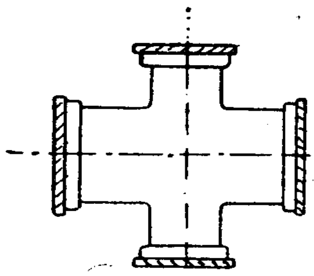
(a) 1/4 **Bend with double hub.**



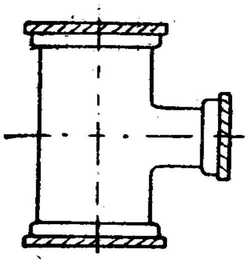
(*b*) 1/4 Bend with single hub.



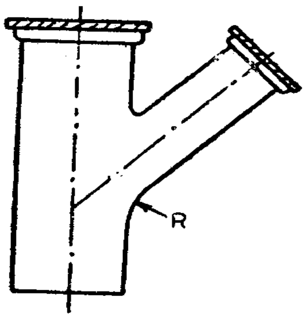
(*c*) 1.8 Bend (45°)
1/16 Bend (22°)
1/32 Bend (11.25°)



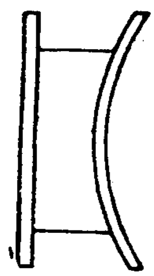
(*d*) Cross



(*e*) Tee



(*f*) Wye



(*g*) Saddle flange

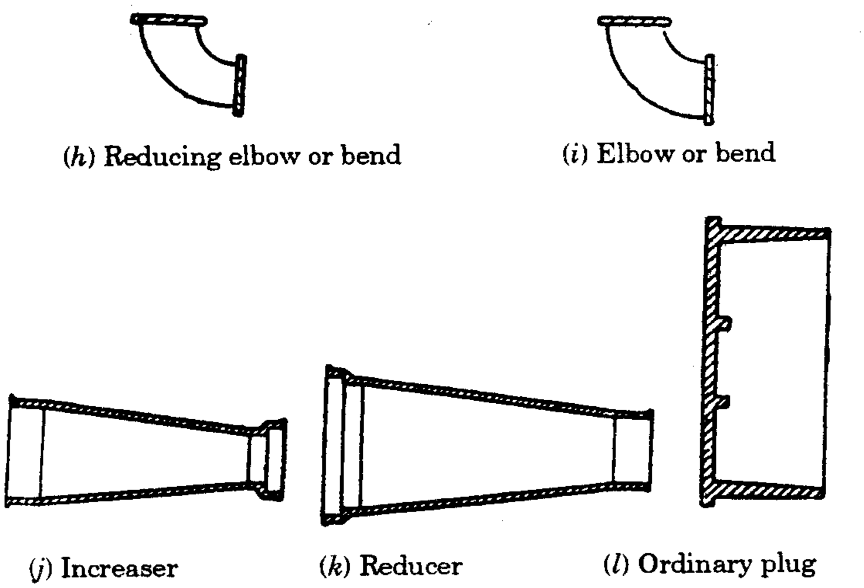


Fig Various Pipe fittings.

UNIT – IV

CONSTRUCTION OF CEILING - WALL AND FLOORING - MATERIAL USED - PREVENTION OF DAMPNESS - LEAKAGE - REASONS AND PREVENTION

OBJECTIVES

- Importance of roofs & ceilings
- Types of Roofs
- Roof Coverings
- Types of Walls
- Materials for Walls
- Types of Floors

STRUCTURE

- Roofs and ceilings
- Types of roofs
- Pitched roofs : basic elements
- Types of pitched roofs
- Single roofs
- Double roofs
- Trussed roofs
- Steel roof trusses
- Roof coverings for pitched roofs
- Types of walls
- Partition walls
- Floors
- Types of floors
- Damp proofing
- Causes of dampness
- Effects of dampness
- Methods of damp proofing
- Materials used for damp proofing

ROOFS AND CEILINGS

A roof may be defined as the uppermost part of the building, provided as a structural covering, to protect the building from weather (i.e.. from rain, sun, wind, etc.). Structurally, a roof is constructed in the same way as an upper floor, though the shape of its upper surface may be different. Basically, a roof consists of structural elements which support roof coverings. The structural element may be trusses, portals, beams, slabs (with or without beams), shells or domes. The roof coverings may be AC. sheets, G.I. sheets, wooden shingle, tiles, and slates or slab

Roof and roof coverings receive rain and snow more directly and in much greater quantity than do the walls. It must, therefore, provide a positive barrier to the entry of rain, and vigorous weather proofing is most important. At the same time, the roof structure, which supports the roof coverings, must have adequate strength and stability. Apart from these, a roof must have thermal insulation, fire resistance and sound insulation.

Requirements of a roof

The requirements of a good roof are summarized below

1. It should have adequate strength and stability to carry the super-imposed dead and live loads.
2. It should effectively protect the building against rain, sun, wind, etc., and it should be durable against the adverse effects of these agencies.
3. It should be water-proof, and should have efficient drainage arrangements.
4. It should provide adequate thermal insulation.
5. It should be fire resistant.
6. It should provide adequate insulation against sound. Most forms of roof construction provide for majority of buildings an adequate insulation against sound from external sources.

TYPES OF ROOFS

Roofs may be divided into three categories

1. Pitched or sloping roofs,

2. Flat roofs or terraced roofs, and

3. Curved roofs.

The selection of the type of roof depends upon the shape or plan of the building, climatic conditions of the area and type of constructional materials available. Pitched roofs have/sloping top surface piece are suitable in those areas where rainfall/snowfall is very heavy. Broadly Buildings with limited width and simple shape can generally be covered satisfactorily by pitched roofs. Buildings irregular in plan, or with long spans, present awkward problems in the design of a pitched roof, involving numerous valleys, gutters and hips. fielding of large area, such as factories, when covered by a series of parallel pitched roofs; require' internal guttering in the valleys. Flat roofs are considered suitable for buildings in plains or in hot regions, where rainfall is moderate, and where snowfall is not there. Flat roofs are equally applicable to buildings of any shape and size.

Curved roofs have their top surface curved. Such roofs are provided to give architectural effects. Such roofs include cylindrical and parabolic shells and shell domes, doubly curved shells such as hyperbolic paraboloids and hyperboloids of revolution, and folded slabs and prismatic shells. Such roofs are more suitable for public buildings like libraries, theatres, recreation centres etc.

PITCHED ROOFS

BASIC ELEMENTS

A roof with sloping surface is known as a pitched roof. Pitched roofs are basically of the following forms
1. Lean-to-roof
2. Gable roof
3. Hip roof
4. Gambrel roof
5. Mansard roof
6. Deck roof.

Lean-to-roof: This is the simplest type of sloping roof, provided either for a room of small span, or for the verandah. It has slope only one side (Fig. a).

Gable roof: This is the common type of sloping roof which slopes in two directions. The two slopes meet at the ridge. At the end face, a vertical triangle if formed

Hip roof: This roof is formed by four sloping surfaces in four directions (Fig. c). At the end faces, sloped triangles are formed.

Gambrel roof: This roof, like gable roof, slopes in two directions, but there is a break in each slope, as shown in Fig. (d). at each end, vertical face is formed.

Mansard roof Mansard roof, like a hip roof, slopes in the four directions, but each slope has a break, as shown in Fig. (e). Thus, sloping ends are obtained.

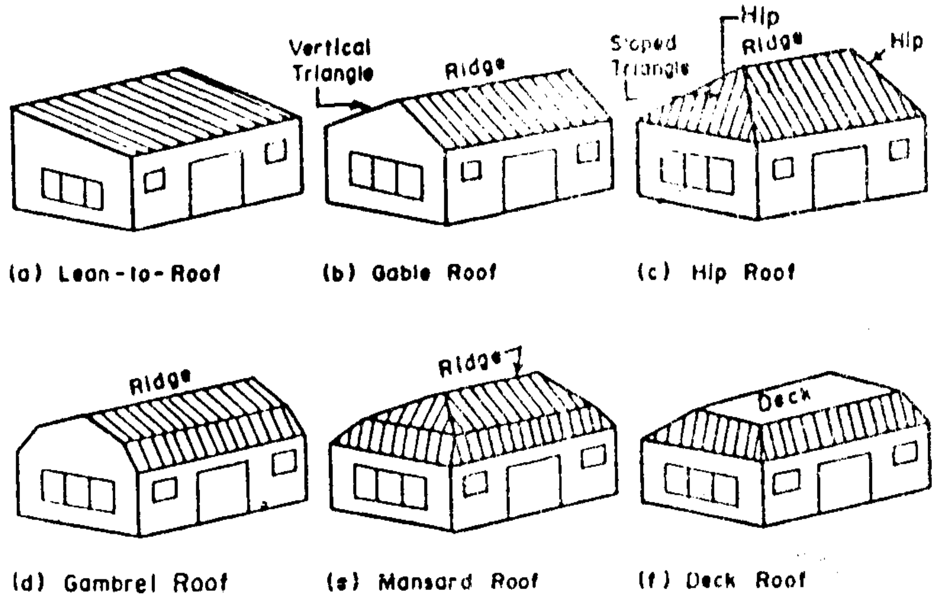


FIG. VARIOUS FORMS OF SLOPING ROOFS

Deck roof

A deck roof has slopes in all the four directions, like a hip roof, but a deck or plane surface is formed at the top

Fig. shows various elements of pitched roof. These clemers are defined below

1. Span. It is the clear distance between the supports of an arch, beam or roof truss.

2. Rise. It is the vertical distance between the top of the ridge and the wall plate.

3. Pitch. It is the inclination of Miles of u roof to the horizontal plane. It is expressed either in terms degrees (angle) or as a ratio of rise to span.

4. Ridge. It is defined as the apex line of the sloping root. It is thus the apex of the angle formed by the inclination of the inclined surfaces at the top of a slope.

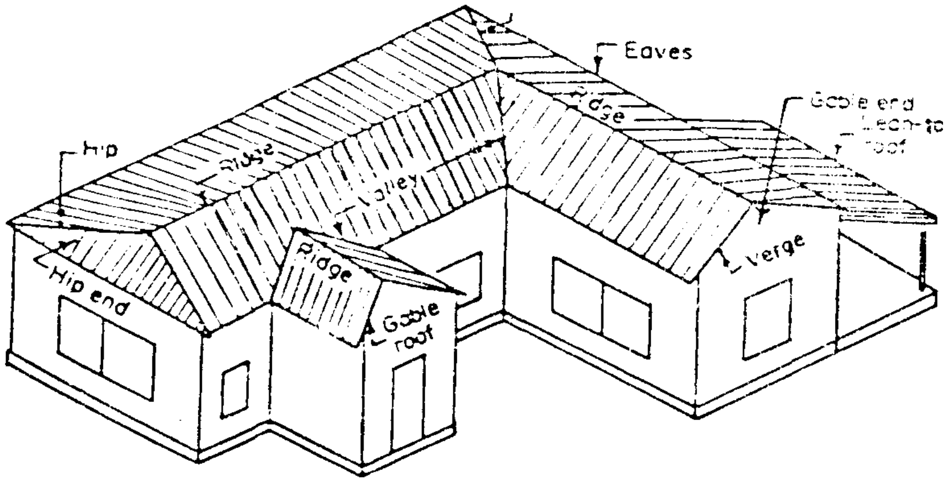
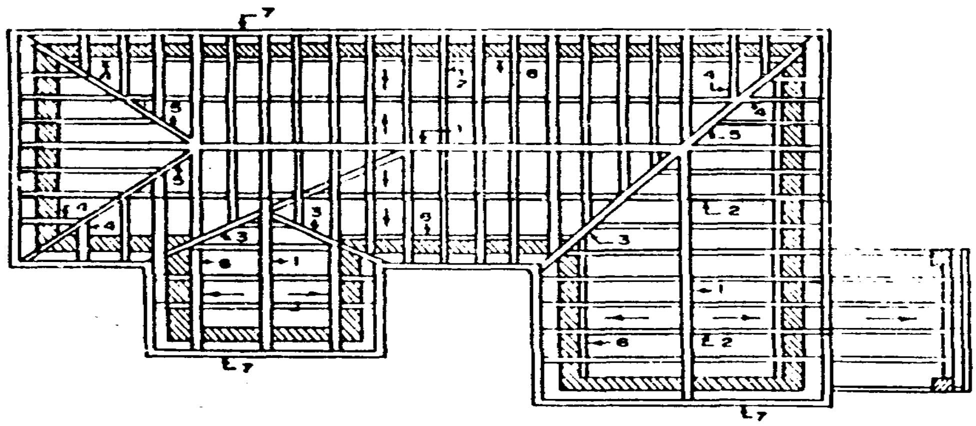
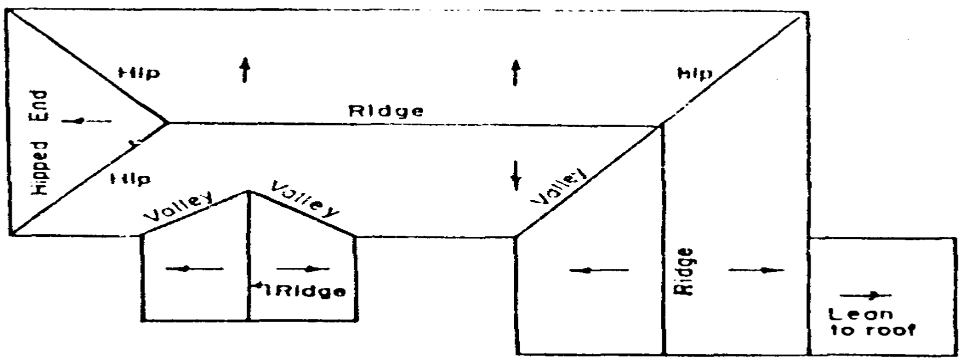


FIG VIEW OF A BUILDING WITH BASIC SLOPING ROOFS



(a) Plan Showing Rafters etc



(b) Plan Showing Slope

FIG PLAN OF THE BUILDING HAVING SLOPING ROOFS

1. RIDOE.
2. COMMON RAFTERS.
3. VALLEY RAFTERS.
4. JACK RAFTERS.
5. HIP RAFTERS.
6. WALL PLATE.
7. EAVES BOARD.

5. Eaves. The lower edge of the inclined roof surface is called eaves. From the

lower edge (eaves), the rain water from the roof surface drops down.

6. Hip. It is the ridge formed by the intersection of two sloping surfaces, where the exterior angle is greater than 180°.

7. Valley. It is a reverse of a hip It is formed by the intersection of two roof surfaces, making an external angle less than 180°. -

8. Hipped end. It is the sloped triangular surface formed at the end of a roof.

9. Verge. The edge of a gable, running between the eaves and ridge, is known as a verge.

10. Ridge piece, ridge beam or ridge board. It is the horizontal wooden member, in the form of a beam or board, which is provided at the apex of a roof truss. It supports the common rafters fixed to.

11. Common rafters or spars These are inclined wooden members running from the ridge to the eaves. They are bevelled against the ridge beam at the head, and are fixed to purlins at intermediate point. They support the battens or. boarding to support the roof coverings. Depending upon the roof covering material, the rafters are spaced 30 to 45 cm centre to centre.

12. Purlins. These are horizontal wooden or steel members, used to support common rafters of a roof when span is large. Purlins are supported on trusses or walls.

13. Hip rafters. These are the sloping rafters which form the hip of a sloped roof. They run diagonally from the ridge to the corners of the walls to support roof coverings. They receive the ends of the purlins and ends of jack rafters.

14. Valley rafters. These are the sloping rafters which run diagonally from the ridge to the eaves for supporting valley gutters. They receive the ends of the purlins and ends of jack rafters on both sides,

15. Jack rafters These are the rafters shorter in length, which run from hip or valley to the eaves.

16. Eaves board or facia board. It is a wooden plank or board fixed to the feet of the common rafters at the eaves. It is usually 25 mm thick and 25 mm wide. The ends of lower most roof covering material rest upon it. The eaves gutter, if any, can also be secured against it.

17. Barge board. It is a timber board used to hold the common rafter forming verge.

18. Wall plates. These are long wooden **members,** which are provided on the top of stone or brick wall, for **the purpose** of fixing the feet of the common rafters. These are embedded from sides and bottom in masonry of the walls, almost at the centre of their thickness. Wall plates actually connect the walls to the roof.

19. Post plate. This is similar to a wall plate except that they run continuous, parallel to the face of wall, over the lops of the posts, and support rafters at their feet.

20. Battens. These are thin strips of wood, called scantlings, which are nailed to the rafters for lying roof materials above.

21. Boarding. They act similar to battens and are nailed to common rafter to support the roofing material.

22. **Template.** This is a square or rectangular block of stone or concrete placed under a beam or truss, to spread the load over a larger area of the wall.

23. **Cleats.** These are short sections of wood or steal (angle I iron), which are fixed on the principal rafters of trusses to support the purlins.

24. Truss. A roof truss is a frame work, usually of triangles, designed to support the roof covering or ceiling over rooms.

TYPES OF PITCHED ROOFS

Pitched roofs may be broadly classified into the following

(a) Single roofs

1. Lean-to-roof (verandah roof).

2. Couple roof.

3. Couple-close roof.

4. Collar beam roof or collar tie roof.

(b) Double or purlin roofs

(c) Triple-member or framed or trussed roofs

1. King-post roof truss.

2. Queen-post roof truss.

3. Combination of king-post and queen-post trusses,

4. Mansard roof truss.

5. Truncated roof truss.

6. Bel-fast roof truss or latticed roof truss.

7. Composite roof trusses.

8. Steel sloping roof trusses.

Single roofs consist of only common rafters which are secured at the ridge (to ridge beam) and wall plate. These are used when span is less so that no intermediate support is required for the rafters. A double roof is the one in which purlins are introduced to support the common rafters at intermediate point. Such roofs are used when the span exceeds 5 metres. The function of a purlin is to tie the rafters together, and to act as an intermediate support to the rafters. A triple member or trussed roof consists of three sets of members : (i) common rafters, (ii) purlins, and (iii) trusses. The purlins, which give an intermediate support to the rafters, are themselves supported on trusses which are suitably spaced along the length of a room. A trussed roof is provided when the span of the room is greater than 5 metres, and when the length of the room is large, i.e. where there are no internal walls or partitions to support the purlins.

SINGLE ROOFS

Single roofs are those which consist of only the rafters which are supported at the ridge and at the eaves. Such roofs are used only when the span is limited to 5 metres otherwise the size of the rafters will be uneconomical. The-maximum span of the rafters is taken as 2.5 m. Single roofs are of four types

(i) lean-to- roof, verandah-roof or shed roof,

(ii) couple roof,

(iii) couple close roof, and

(iv) collar beam roof.

1. Lean-to-roof

This is the simplest type of sloping roof, in which rafters slope to one side only. It is also known as Pent roof or Aisle roof. The wall to one side of the room (or verandah) is taken higher than the wall (or pillars) to the other side. A wooden wall plate is supported either on a steel corbel or a stone corbel, which are provided at I m centre to centre. The wall plate (or post plate) is embedded on the other side, to the wall or pillars. The difference in elevation between the two wall plates is so kept that the desired slope is obtained. Usual slope is 30°. The common rafters are nailed to wooden wall plate at their upper end, and notched and nailed to the wooden post plate at their lower end. Sometimes, iron knee straps and bolts are used to connect the rafters to the post plate. Eaves boards, battens and roof coverings are provided as shown in Fig. This type of roof is suitable for maximum span of 2.5 m. These are provided for sheds, out-houses attached to main building, verandahs, etc.

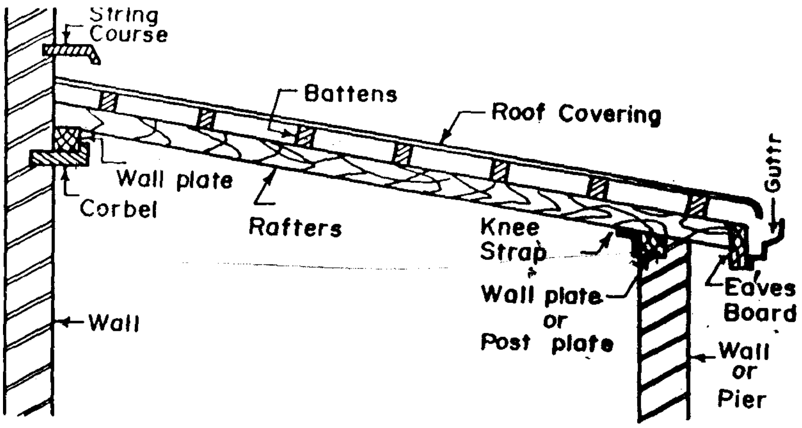


FIG. LEAN-TO-ROOF.

2. Couple roof

This type of roof is formed by couple or pair of rafters which slope to both the sides of the ridge of the roof. The upper ends of each pair of rafter is nailed to a common ridge piece and their lower ends are notched and nailed to the wooden wall plates embedded in the masonry on the top of the outer walls. Such a roof is not very much favored because it has the tendency to spread out at the feet (Wall plate level) and thrust out the walls supporting the "wall plates. Due to this, the couple roof is used when the span is limited to 3.6 metres.

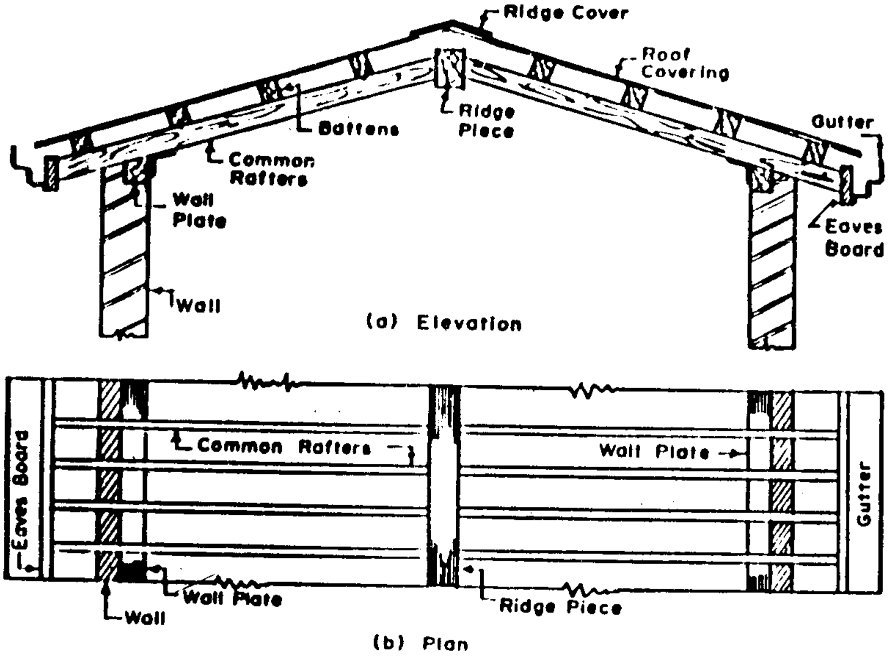


FIG COUPLE ROOF

3. Couple close roof

A couple close roof is similar to the couple roof, except that the ends of the couple of common rafters is connected by horizontal member, called tie beam, to prevent the rafters from spreading and thrusting out of the wall. The tie beam may be a wooden member or a steel rod. The connection between wooden tie and feet of rafters is obtained by dove tail halved joint. For inferior work, the ties may just be spiked to the rafters. There is one tie beam for each pair of rafters. These tie beams can also be used as ceiling joists when required. A couple-close roof is economically suitable for spans upto 4.20 m. For increased span or for greater loads, the rafters may have tendency to sag in the middle. This can be checked by providing a central vertical rod, called king rod or king bolt which connects the filly; piece and the tic beam as shown in Fig.

Notes

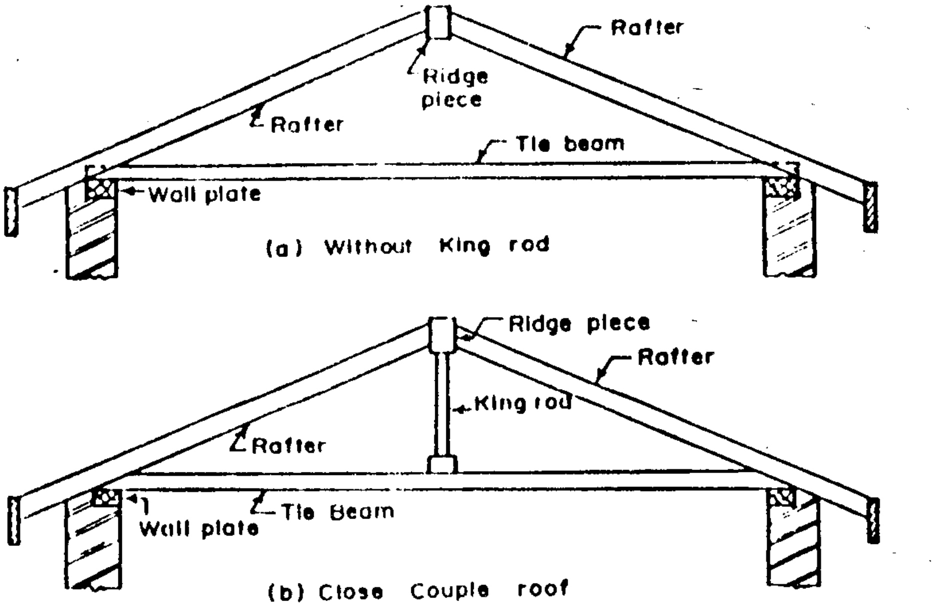


FIG. CLOSE COUPLE ROOF.

4. Collar and scissors roof

It is similar to collar roof, except that two collar beams, crossing each other to have an appearance of scissors is provided as shown in Fig.

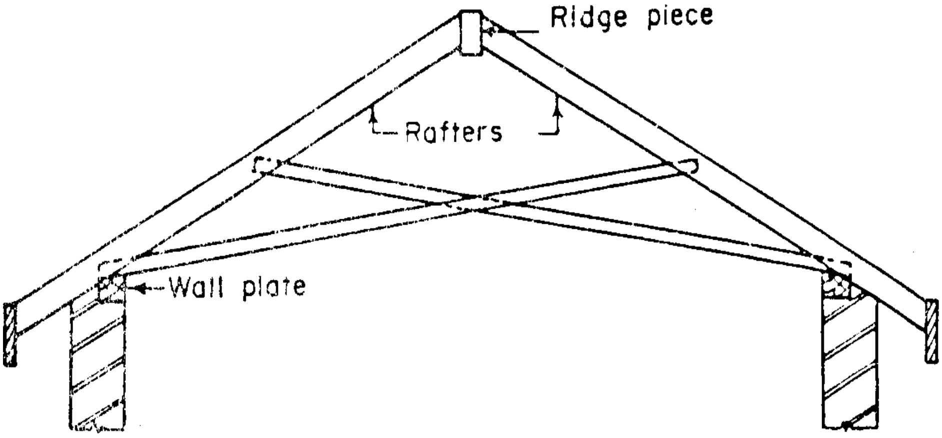


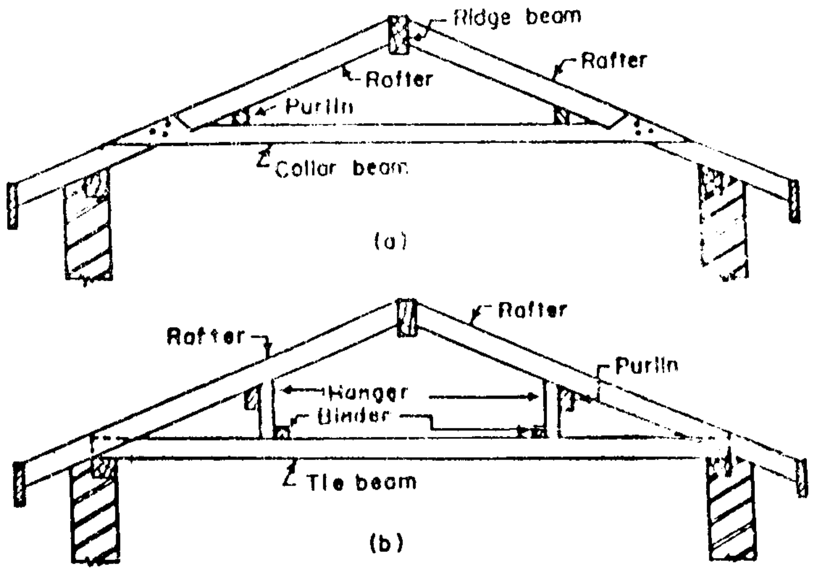
FIG. COLLAR /\ND SCISSORS ROOF.

DOUBLE OR PUKLSN ROOFS

These roof's have two basic elements

(i) rafters, and

(ii) purlins. Such a roof is also known as rafter and purlin roof. The rafters are provided fairly close (40 to 60 cm c/c). Each rafter is thus supported at three points : (1) as the bottom ; on the wall through wall plate,



(2) at the top, by the ridge, and (3) at the centre by a purlin. By supporting the rafter at Hs mid-point in this manner with a purlin, the span is halved, thus enabling the rafter to be made considerably lighter than it would need to be if it spanned the whole distance from eaves to the ridge. For larger roofs, two or more purlins may be provided to support each rafter.

TRUSSED ROOFS

When the span of the roof exceeds 5 m and where there are no inside walls to support the purlins, framed structures, known as trusses are provided at suitable interval along the length of the room. Spacing is generally limited to 3 metres for wooden trusses. In this system, the roof consists of three elements

(i) Rafters to support the roofing material (i.e.. tiles etc.),

(ii) purlins to provide intermediate support to rafters, and

(iii) Trusses to provide support to the ends of purlins. The trusses span in the same direction in which the couple of rafters run. The trusses also support the ridge piece or ridge beam. The various types of trusses in use are:

A. King-post truss,

B. Queen-post truss.

C. Combination of king-post and queen-post trusses.

D. Mansard truss,

E. Truncated truss.

F. Bel-fast truss.

G. Steel trusses.

H. Composite trusses. The first six types are essentially wooden trusses.

1. King-post truss

A king-post truss, shown in Fig. consists of the following components

(i) Lower laid beam,

(ii) Two inclined principal rafters.

(iii)two struts, and

(iv) a king post. The principal rafters support the purlins. The purlins support the closely-spaced common rafters which have the same slope as the principal rafters. The common rafters support the roof covering as usual.

The spacing of the king-post truss is limited to 3 m centre to centre. The truss is suitable for spans varying from 5 to 8 metres. The lower, horizontal, tie beam receives the ends of the principal rafters, and prevents the wall from spreading out due to thrust. The king-post prevents the tie-beam from sagging at its centre of span. The struts connected to the tie beams and the principal rafters in inclined direction; prevent the sagging of principal rafters. Rise beam is provided at the apex of the roof to provide end support to the common rafters. The trusses are supported on the bed blocks of stone or concrete, embedded in the supporting walls so that load is distributed to a greater area.

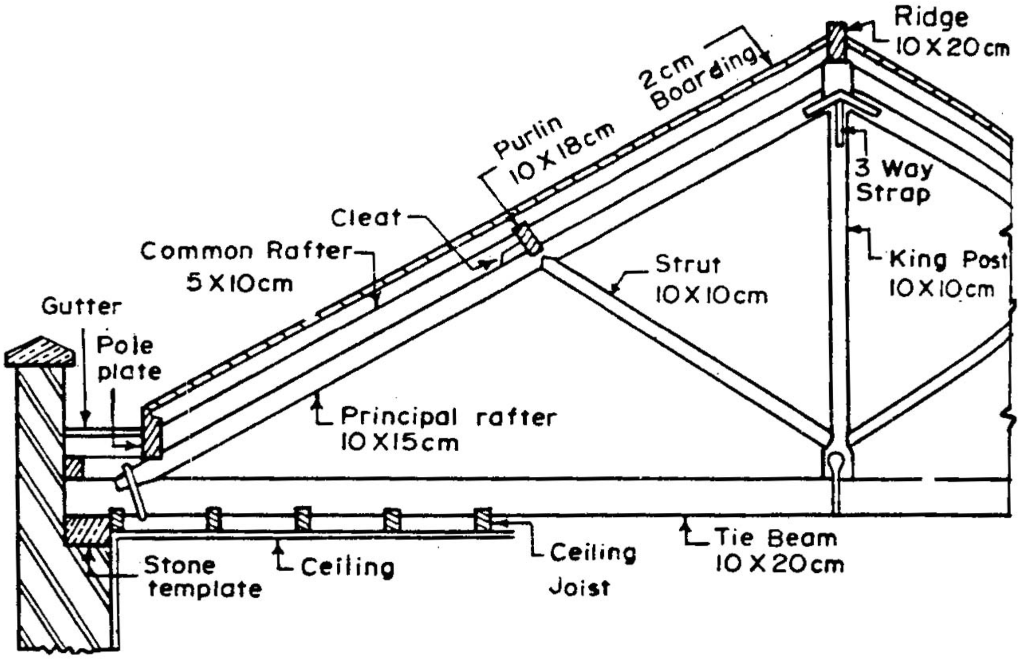
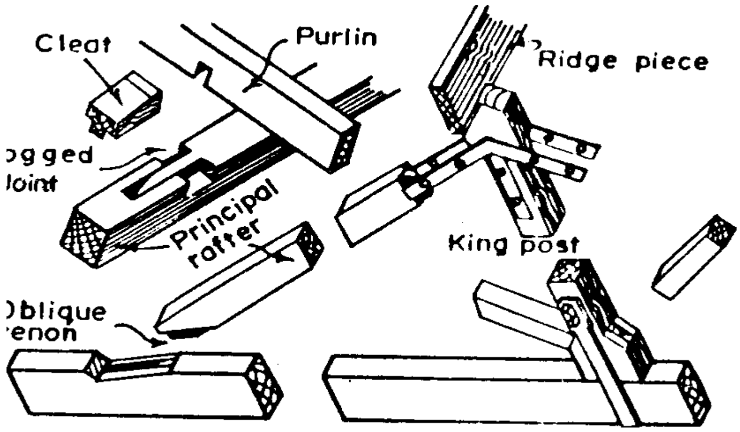


FIG KING-POST TRUSS (SPAN 7 M.)

The principal rafter is jointed to the tie beam by a 'single abutment and tenon joint' or by a 'bridle joint'. The joint is further strengthened by a wrought iron heel strap, would round the joint.



Tie Beam Stirrup Shop

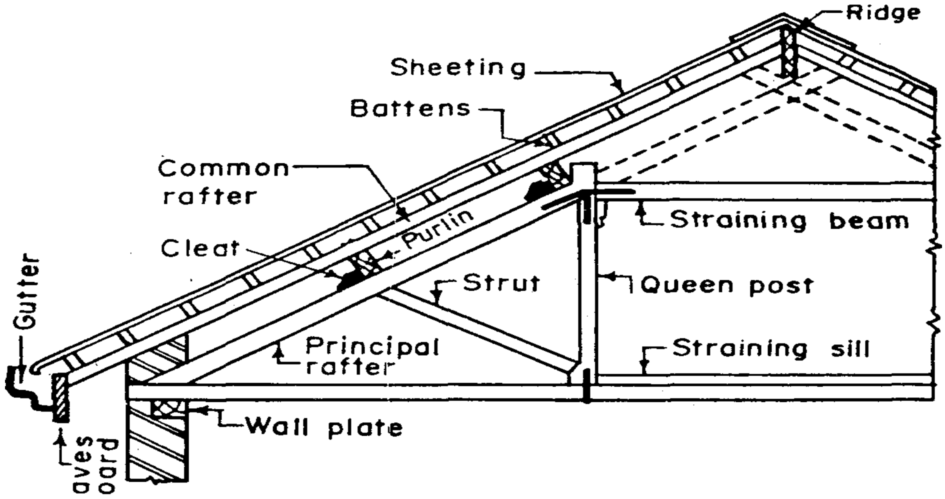
FIG DETAILS OF JOINTS IN KING-POST TRUSS

The head of each strut is fixed to the principal rafter by an 'oblique' mortise and tenon joint. The king-post is provided with splayed shoulders and feet, into the upper edge of the tie beam for a sufficient distance. It is further strengthened by mild steel or wrought iron strap. At its head, the king-post is jointed to the ends of principal rafters by 'tenon and joint. The joint is secured by means of a three-way wrought iron or mild steel strap on each side. Purlins, made of stout timber, are placed at right angles to the sloping principal rafters, and are secured to them through cogged joints and cleats. Cleats, fixed on principal rafter, prevent the purlins from tilting. Fig. shows the details of the joint. The common rafters may be connected to eaves board or to pole plate at the other end. Pole plates are horizontal timber sections which run across the tops of the tie beams at their ends, or on principal rafters near their feet. They thus run parallel to purlins.

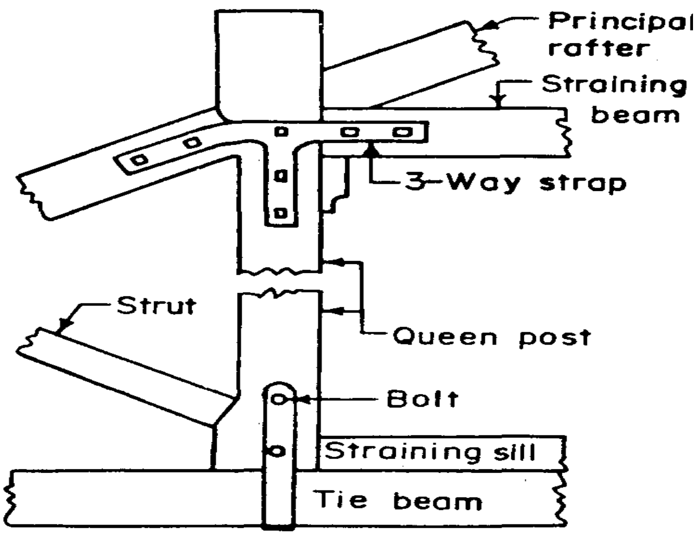
2. Queen-post truss

A queen-post truss differs from a king-post truss in having two vertical posts, rather than one. The vertical posts are known as queen-posts, the tops of which are connected by a horizontal piece, known as straining beam. Two struts are provided to join the feet of each queen-post to the principal rafter, as shown in Fig. (a). The queen-posts are the tension members. The straining beams receive the thrust from the principal rafters, and keep the junction in stable position. A straining sill is introduced on the tie beam between the queen-posts to counteract the thrust from inclined struts which are in compression. In absence of the straining sill, the thrust from the strut would tend to force the foot of the queen-post inwards. Purlins, with cleats, are provided as in the king-post truss. These trusses are suitable for spans between 8 to 12 metres.

The joint at the head of queen-post is formed due to the junction of two compression members (principal rafter and straining beam) and a tension member (queen-post). The head of the queen-post is made wider, and the head of the principal rafter and the end of straining beam are tenoned into it. The joint is further strengthened by fixing a 3-way strap of wrought-iron or steel on each face as shown in Fig. Similarly, the feet of queen-post are widened to receive the tenon of the inclined strut, forming a 'single abutment and tenon joint'. The queen-post then tenons into the tie beam. The joint is further strengthened by stirrup straps and bolts.



(a) Queen Post Truss



(b) Joint Details

FIG QUEEN-POST TRUSS.

3. Combination of king-post and queen-post trusses

Queen-post trusses are suitable for spans upto 12 metres. For greater spans, the queen-post truss can strengthened by one more upright member, called princess-post to each side. Fig. show the resulting combination of king-post and queen-post trusses, which are suitable upto 18 m span.

Notes

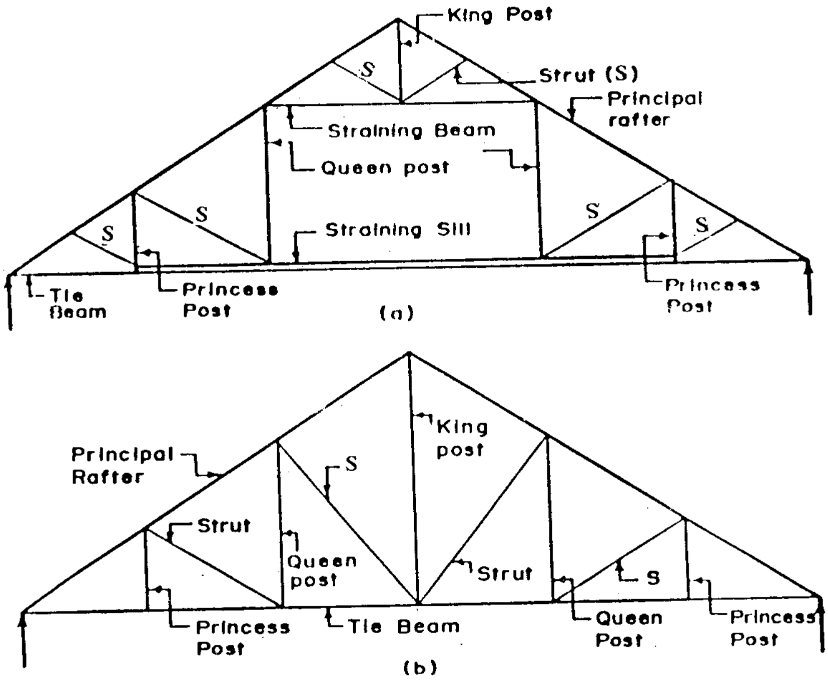


FIG COMBINATION OF KING-POST AND QUEEN-POST TRUSSES

4. Mansard roof truss

This roof truss, named after its designer Francois Mansard, a French architect, is a combination of king-post and queen-post trusses. It is a two-storey truss, with upper portion consisting of king-post truss and the lower portion of queen-post truss. The entire truss has two pitches. The upper pitch (king-post truss) varies from 30° to 40° while two lower pitches (queen-truss) varies from 60° to 70°. The use of this truss results in economy in space, since a room may be provided between the two queen-posts. However, it has become obsolete because of odd shape.

5. Truncated truss

A truncated truss is similar to Mansard truss, except that its top is formed flat, with a gentle slope to one side. This type of truss is used when it is required to provide a room in the roof, between the two queen-posts of the truss.

6. Bel-fast roof truss (Bow string truss)

This truss, in the form of a bow, consists of thin sections of timber, with its top chord curved. If the roof covering is light, this roof truss can be used upto 30 m span. The roof truss is also known as latticed roof truss.

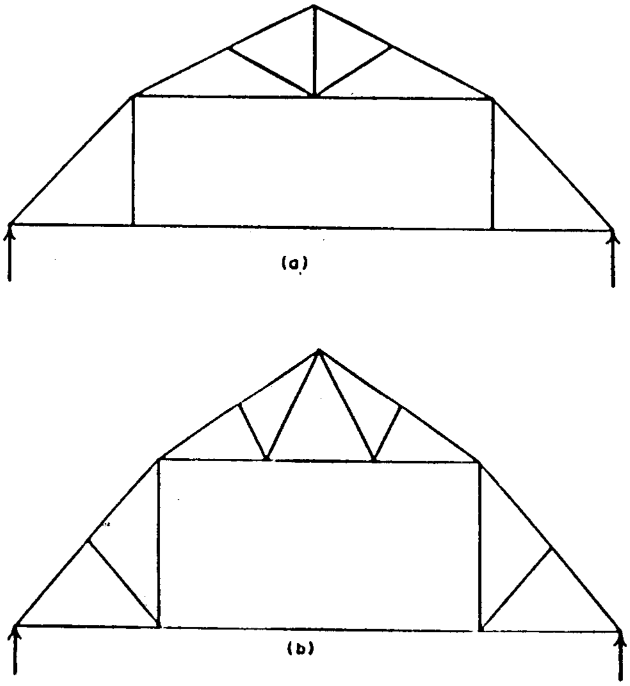


FIG ALTERNATIVE FORMS OF MANSARD TRUSSES

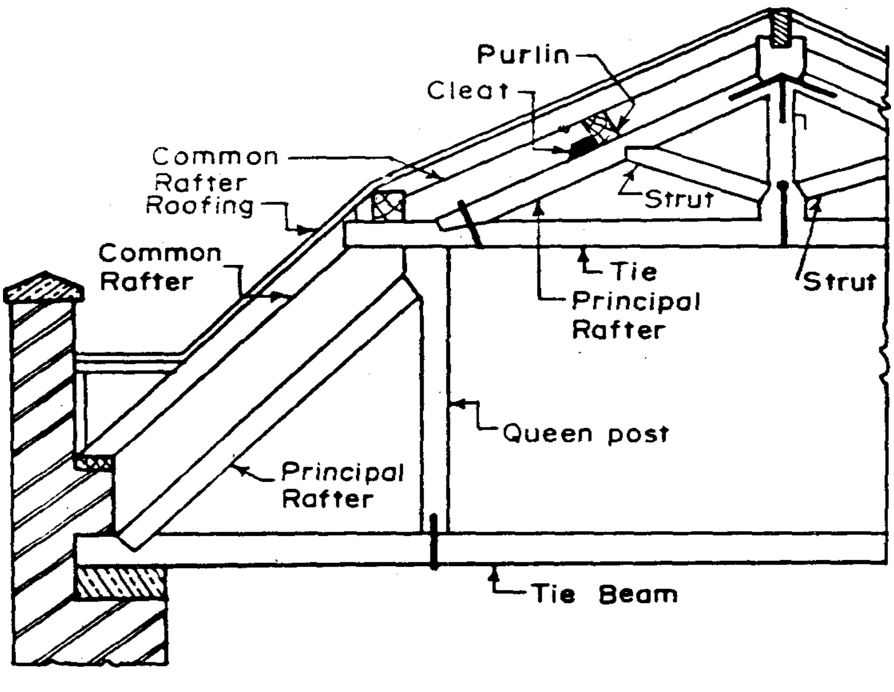


FIG DETAILS OF MANSARD TRUSS.

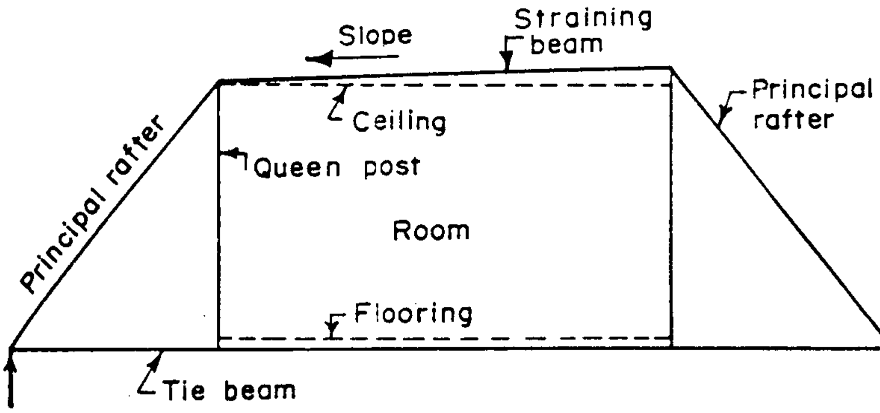


FIG TRUNCATED TRUSS.

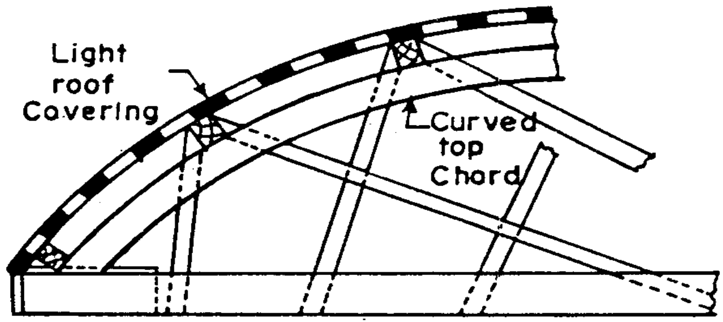


FIG BET-FAST TRUSS

7. Composite roof trusses

Roof trusses made of two materials, such as timber and steel, are known as composite roof trusses. In a composite truss, the tension members are made of steel, while compression members are made of timber. If tension members are made of timber, their section becomes very heavy because of reduction of section at the joints. Special fittings are required at the junction of steel and timber members. The joints in composite trusses should be such that cast or forged fittings can be easily used. Fig. shows some common types of composite roof trusses, using fittings such as C.I. head, CI. shoe, steel angle bolts and straps etc.

STEEL ROOF TRUSSES

When the span exceeds 10 m, timber trusses become heavy and uneconomical. Steel trusses are more economical for larger spans. However, steel trusses are more commonly used these days, for all spans-small or large, since they are (i) more economical, (ii) easy to construct or fabricate, (iii) fire-proof, (iv) more rigid, and (v) permanent.

Steel trusses are fabricated from rolled steel structural

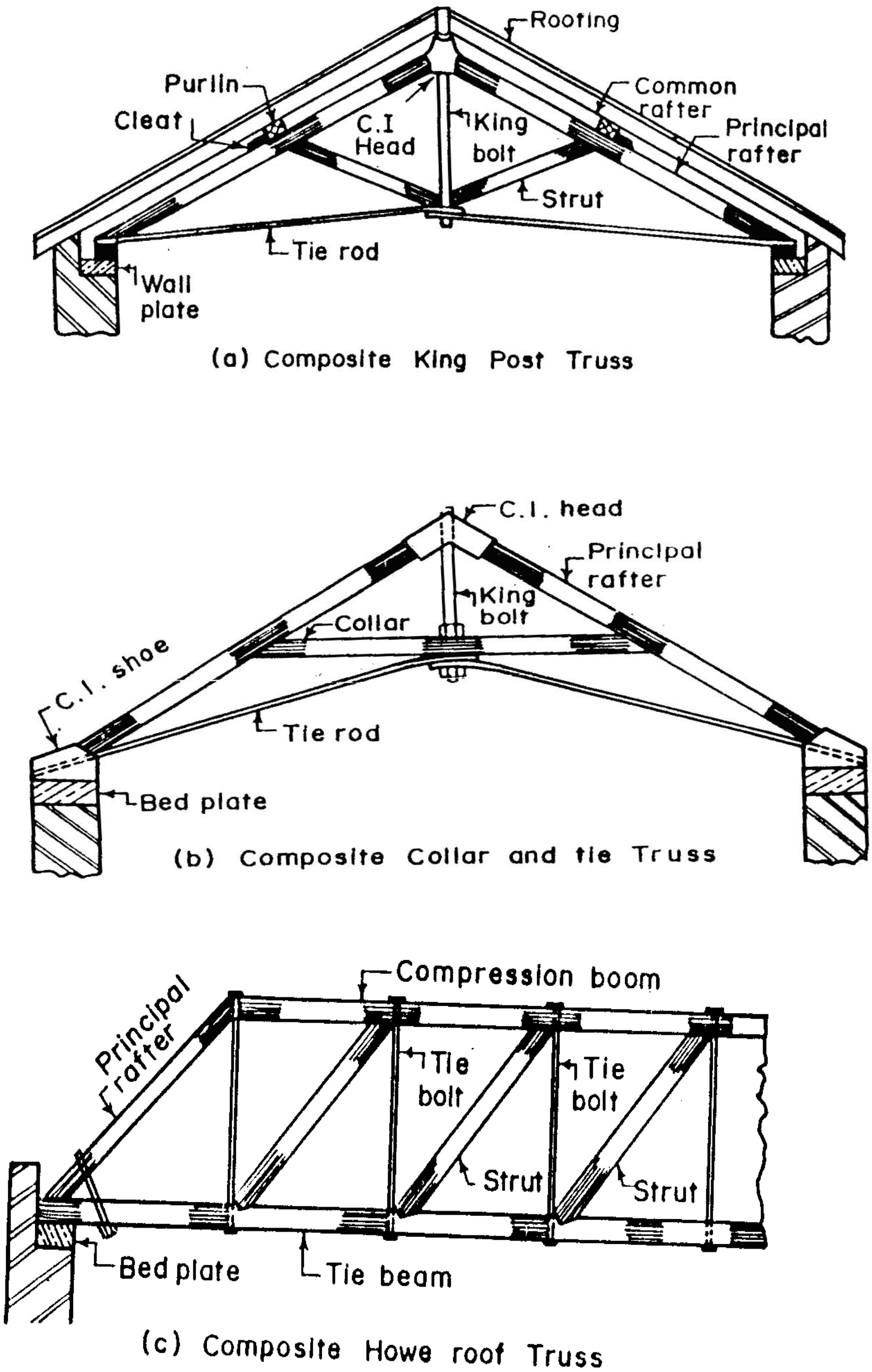


FIG COMPOSITE ROOF TRUSS

Members such as channels, angles, T-sections and plates. Most of the roof trusses are fabricated from angle-sections because they can resist effectively both tension as well as compression, and their jointing is easy. In India, where timber has become very costly (except in hilly regions), steel trusses have practically superseded timber trusses.

Steel trusses may be grouped in the following categories

(a) Open trusses

(b) North light trusses

(c) Bow string trusses

(d) Arched rib trusses and solid arched ribs.

The various shapes of these, along with their suitability for different span ranges, are shown in Figs. (a), (b) and (c).

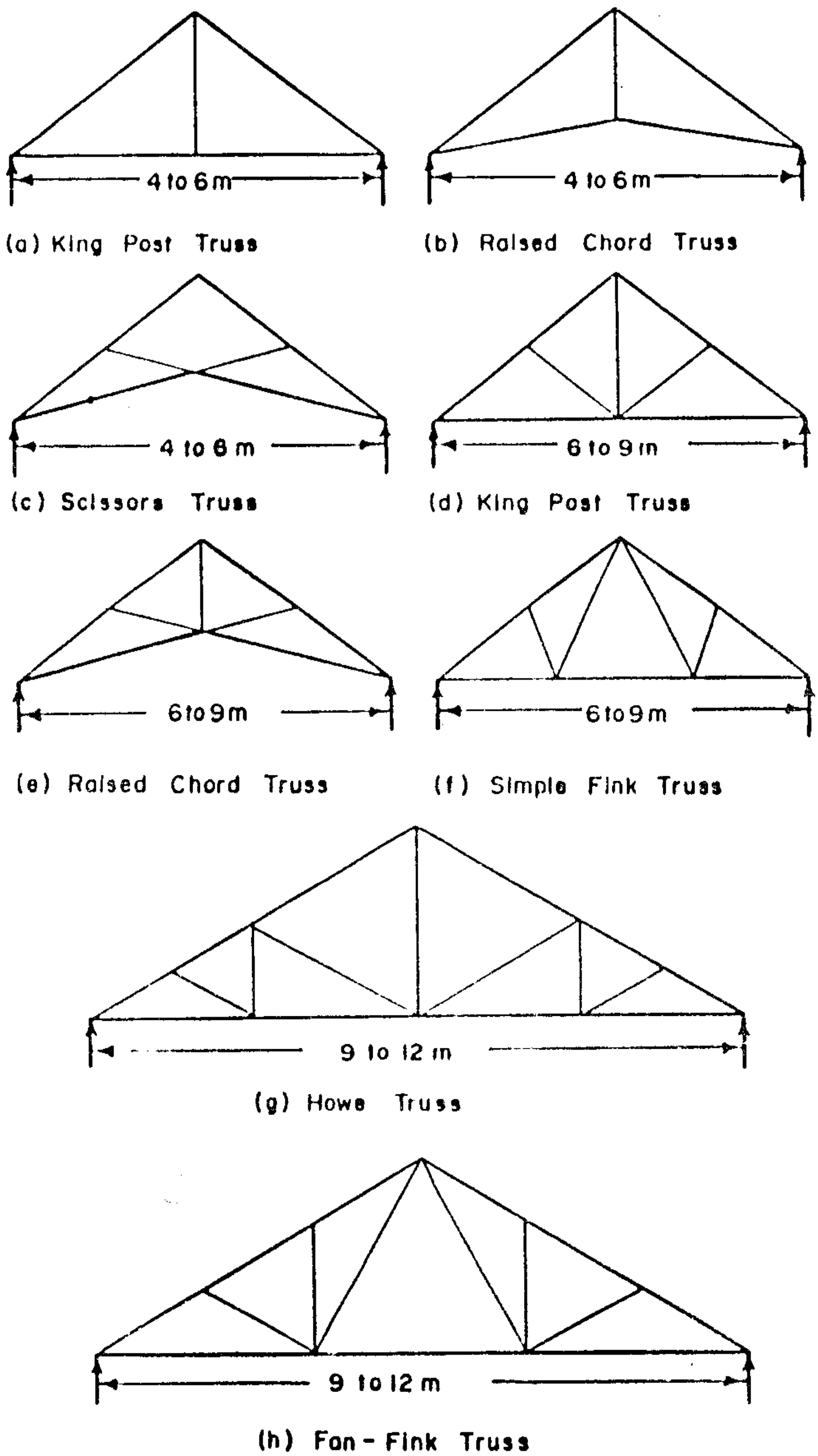


FIG (a) STEEL TRUSSES.

Notes

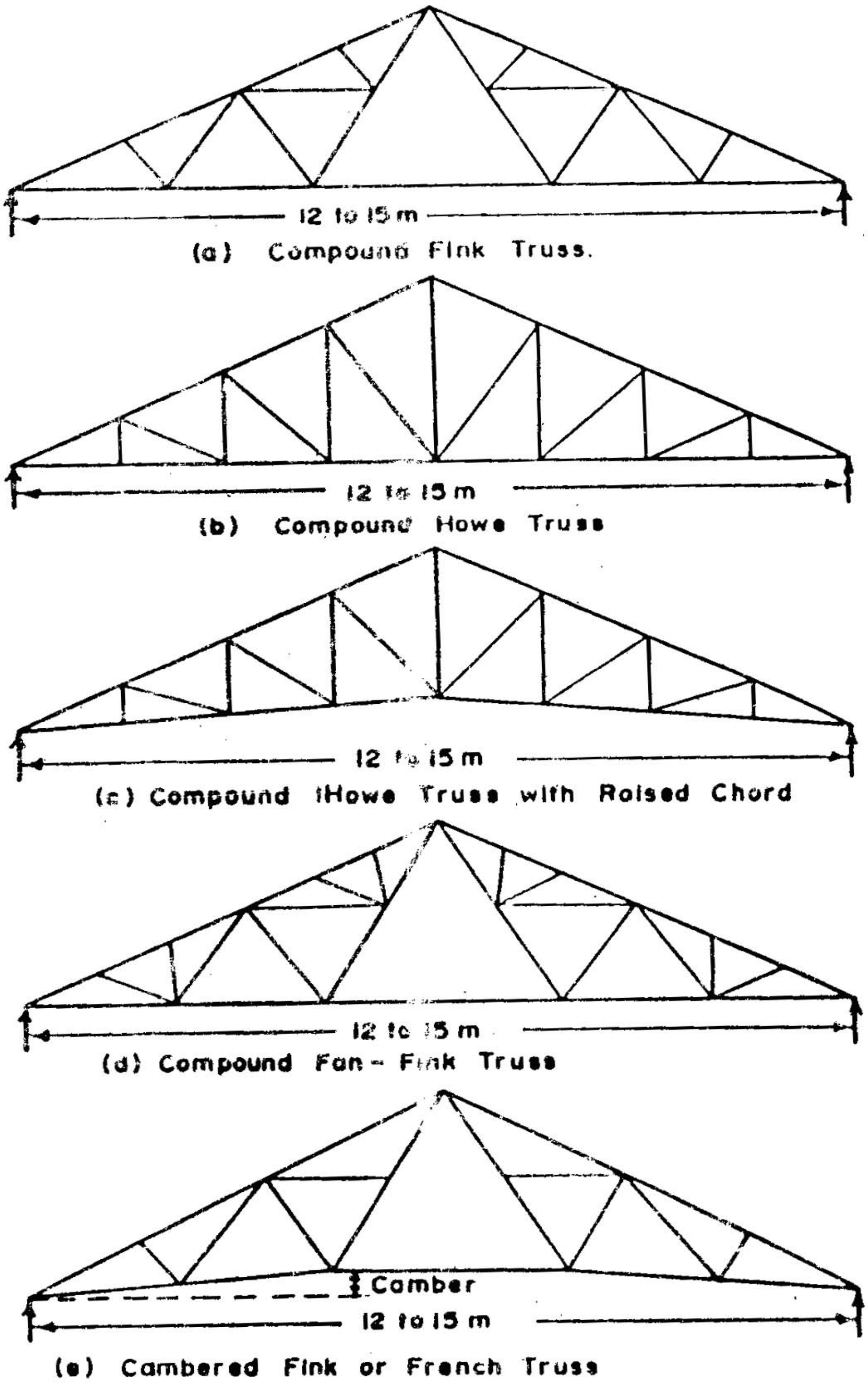


Fig (b) STEEL TRUSSES.

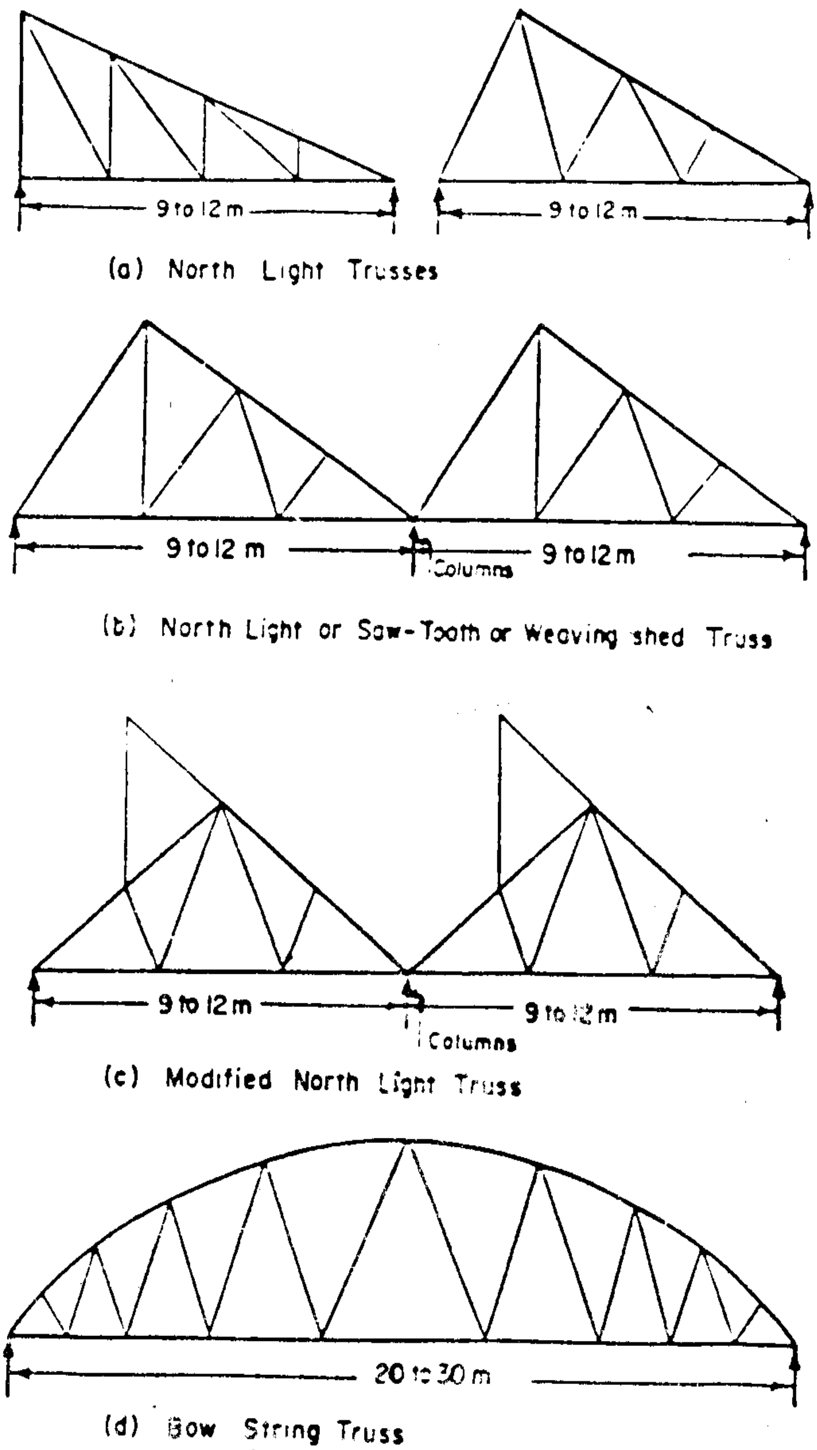


FIG. (c) STEEL TRUSSES.

Industrial Building Bents

This building bent, employed in big factories or mills, consists of a roof truss supported on stanchions. These bents arc transversely braced. The roof trusses supported on columns provide structural roof system for the industrial buildings. The type of roof coverings, its insulating value, acoustical properties, the appearance from inner side, the weight and the maintenance requirements are the various factors which are given consideration while designing the roof system. The asbestos corrugated and cement sheets, and the galvanized corrugated sheets are commonly used as the roof covering materials.

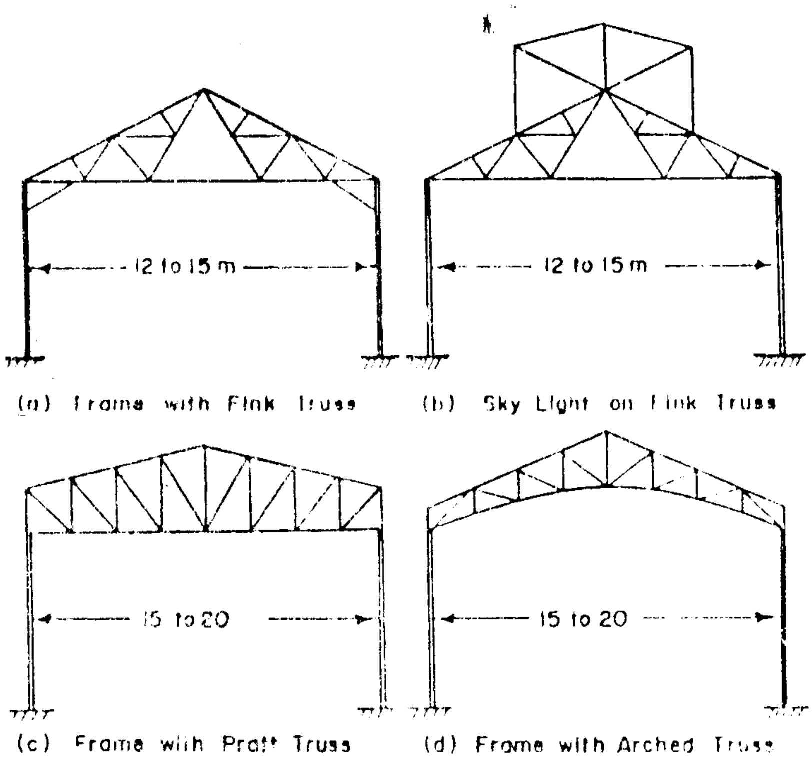


FIG INDUSTRIAL BUILDING BKN'IS

Details of Steel Truss

Steel trusses have the following advantages over timber trusses:

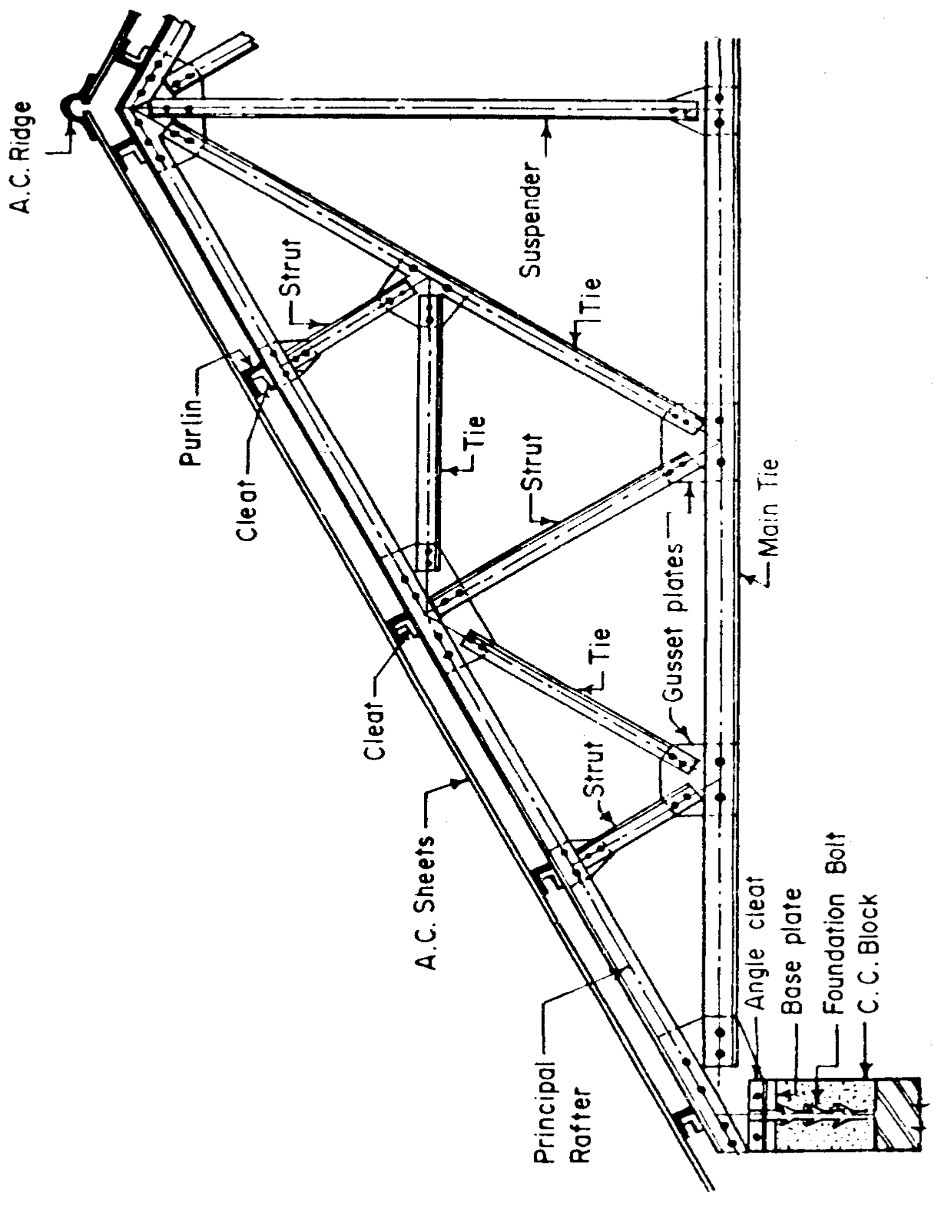
1. The sections comprising of a steel truss are readily available in the required dimensions, resulting in minimum wastage of material.

2. Steel trusses are light in weight, and can be fabricated in any shape depending upon structural and architectural requirements.

3. Steel trusses are stronger and more rigid in comparison to timber

trusses. The members are equally strong in tension ah well as compression.

4. Steel trusses can be used over any span, while timber trusses are suitable only upto 15 m span.



Details of steel roof truss

5. Steel trusses are fire-proof.

6. Steel trusses are termite proof.

7. Steel trusses are most resistant to other environmental agencies, and have longer life.

8. The fabrication of steel trusses is easier and quicker, since the sections can be machined and shaped in the workshop, and then transported to the construction site for erection.

ROOF COVERINGS FOR PITCHED ROOFS

Roof covering is an essential component of pitched roof, to he placed over the roof frame work, to protect it from rain, snow, sun, wind and other atmospheric agencies. Various types of roofing materials are available, and their selection depends upon (i) type of building, (ii) type of roof framework, (iii initial cost, (iv) maintenance requirements, (v) fabrication facilities, (iv) appearance and special features of the locality, (vii) durability, (viii) availability of the material itself, and (ix) climate of the locality.

The following are the roof-covering materials commonly used for pitched roofs

1. Thatch covering
2. Wood shinnies
3. Tiles
4. Asbestos cement sheets
5. Galvanized corrugated iron sheets
6. Eternit slates.
7. Light weight roofing.

(a) Thatch covering

This is the cheapest roof-covering, commonly used in villages. It is very light, but is highly combustible. It is unstable against high winds. It absorbs moisture and is liable to decay. It harbors rats; and other burrowing animals, and gives bad smell in rainy season. Thatch roof-covering consists of bundles of reeds or straw. The frame work to support thatch consists of round bamboo rafters spaced 20 to 30 cm apart and tied with split bamboos laid at right angles. to the rafters. The reed or straw must be well-soaked in water or ire-resisting solution to facilitate packing, and the bundles arc laid with their butt ends pointing towards the eaves. The thatch is tightly. Soured to the frame work with the .help of ropes or twines dipped in tar. In order to drain the roof effectively, a minimum slope of 45° is kept. The thickness of thatch covering should at least' be 15 cm ; normal thickness varies from 20 to 30 cm according to its quality and pitch of roof. It is claimed that reed thatch can last about 60 years and straw that can last for 20 years, if properly attended to.

(b) Wood shingle roofing

Shingles are thin slabs of wood used to cover roofs. The use of shingles is restricted to hilly areas where local timber is easily available at low cost. Though shingle roofing is light weight, it is not fire and termite resistant. Wood shingles are obtained from well seasoned timber, by either sawing or splitting. Sawn shingles arc used chiefly. They are obtained varying from 30 to 40 cm and widths varying from 6 cm. They are approximately 10 mm thick at the tail or butt end and taper to 3 mm or less at the head. They are laid in a similar fashion as tiles and slates.

(c) Tile roofing

Use of tiles for roofing is one of the oldest, and is still preferred for residential buildings and country houses. This is because country tiles are manufactured from locally available earth. Tiles are named according to their shape and pattern, and they arc manufactured by a process similar to the one used for the manufacture of bricks. The various types of tiles generally used are

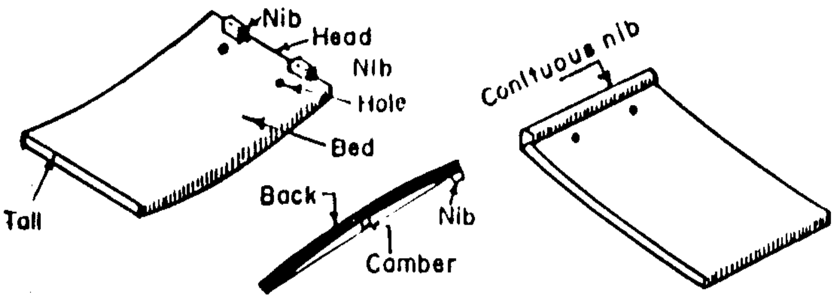
1. Plain or flat files.
2. Curved or pan-tiles.
3. Pot tiles or half-round country tiles.
4. Spanish tiles.
5. Italian or Allahabad tiles.
6. Inter-locking tiles.

Plain or Flat tiles

Plain tiles are made of clay or concrete, though clay tiles are more common in this country. Plain or flat tiles are manufactured in rectangular shapes, of sizes varying form 25 cmxl5 cm to 2<S cmxl8 cm, with thickness from 9 mm to 15 mm. The tiles are not perfectly flat, but have slight camber of 5 to 10 mm in their length which ensures that the tails will bed and not ride on the backs of those in course below. Plain tiles have stubs which project on the bed or under side at the head in

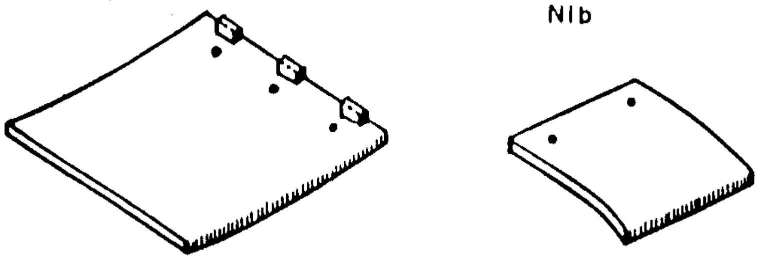
order that they may be hung from the battens. Sometimes, continuous nib is provided at the head. Each tile has two holes formed at about 25 mm from the head and 38 mm from the edges. The tiles can be nailed through these holes, using copper or composition nails of 38 mm length. It is not necessary to nail every tile.

Before laying the tiles, common rafters are laid at 20 to 30 cm spacing. Battens or repers are then fixed across the rafters at a spacing of 4 to 6 cm. The tiles are then laid over it with sufficient overlap on sides and edges. Plain tiles are laid in regular bond. For normal exposures, it is usual to nail every fourth or fifth course.



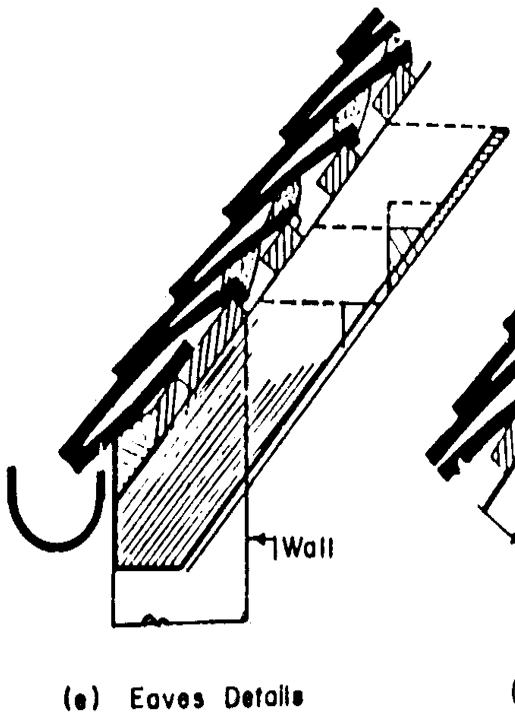
(a) Plain Tile with two Nibs

(a) Tile with Continuous Nib



(c) Tile and a Half Tile

(d) Eaves Under-Tile



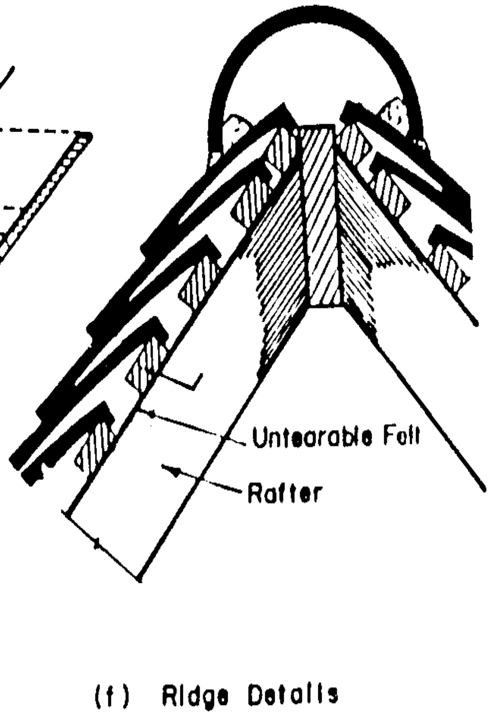
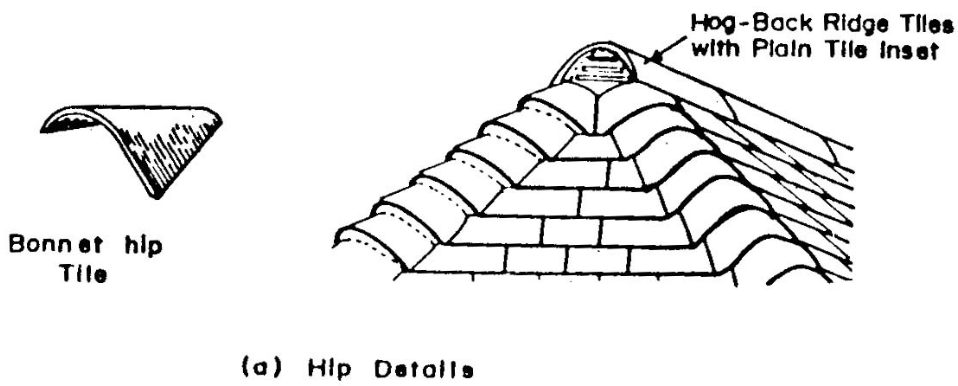


FIG. ROOFING WITH PLAIN TILES.

However, in very exposed positions, especially if the roofs are steeply pitched, it may be necessary to nail every tile.

1. Hip and Valley details

Special tiles for the under course at eaves, top course at the ridges, and for hips and valley are used. At hip, special granny bonnet hip tiles are used. These hip tiles are bonded with the general plain tiles. Each hip tile is well-bedded with mortar on the back of the tile below and is secured with a long nail to the hip rafter.



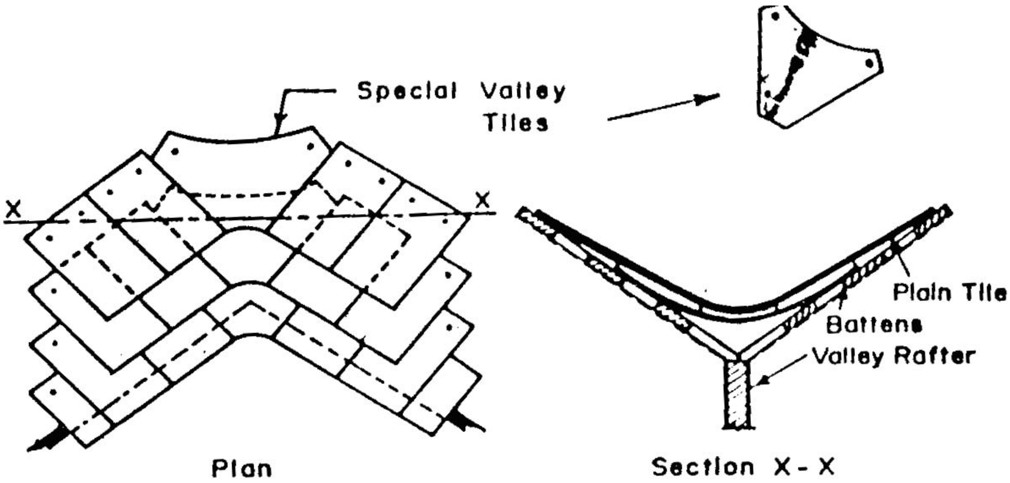


FIG. HIP AND VALLEY DETAILLS.

2. Curved or pan-tiles

Pan-tiles are 33 to 36 cm long, 22.5 to 25 cm wide and 12 to 19 mm thick. They are flat longitudinally, but are curved transversely to a flat wave or S-curve. One nib is provided at the head on the underside of the trough of the wave, a nail hole is formed below the nib and two of the opposite diagonals corners are splayed or rounded. Pan-tiles are laid with overlapping side joints with two thicknesses only at the head joints and a single thickness at the unlapped portions. Pan-tiles are unbounded, having continuous side joints from eaves to the ridge. Thus, pan-tiles are single lapped in contrast to the plain tiles which are double lapped. Side lap in pan-tiles varies from 38 to 50 mm. The head or longitudinal lap varies from 7.5 to 10 cm, according to the pitch of the roof. Plain tiles are also nailed. As stated above, two diagonally opposite corners or shoulders are splayed off to the depth of the lap, to permit a reasonably close fit between the tiles. If this is not done, four thicknesses would occur at the corners, resulting in open joints due to tilting or over-riding of tiles.

3. Half-round country tiles

Spanish tiles

Half-round country tiles are commonly used in villages. These

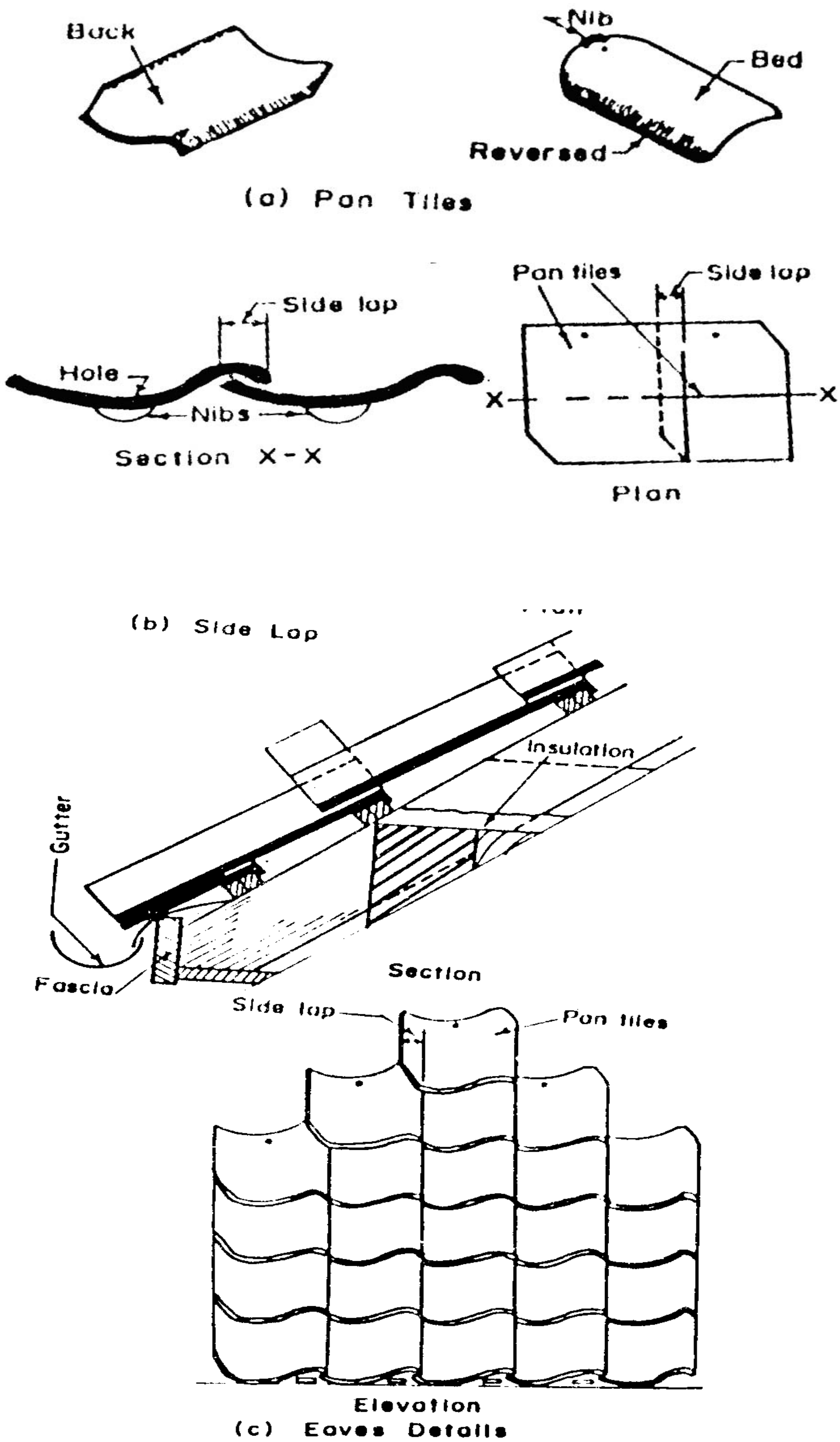
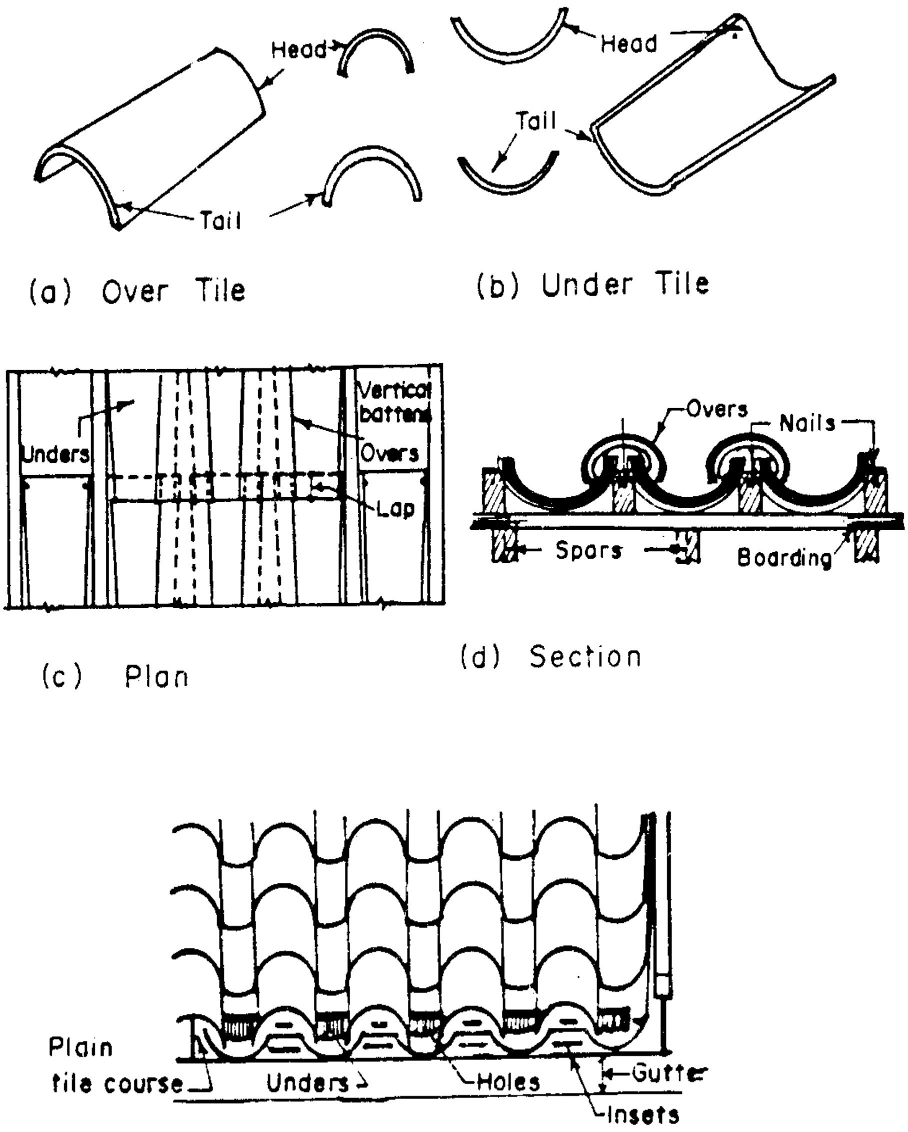


FIG. ROOFING WITH PAN-TILES

Notes

Tiles are laid in pairs of under-tiles and over-tiles. The under-tiles are laid with concave surface upwards, while the over-tiles are laid with convex surface upwards. These tiles are semi-circular in section at each end, but the diameter tapers longitudinally. In one variety of tiles, the under-tiles are flat with broader head tapering towards the tail, while the over-tile is segmental in section, with wider tail and narrower head. In another variety, both the under-tiles as well as over-tiles are semi-circular, and taper from head to tail.



(e) Elevation at Eaves

ROOFING HALF-ROUND COUNTRY TILES OR SPANISH TILES.

The country tiles are similar to the Spanish tiles. The over tiles taper down from tail to head while the under-tiles taper down from head to tail.

4. Italian or Allahabad tiles

These tiles are also used in pairs-flat broad bottom under-tile which alternate with convex curved over-tile. The under-tile is flat, tapered, with upturned edges or flanges at the sides. It measures 23 cm at the interior end (tail), 26 cm at the wide end (head) with a length of 37 cm and flange height of 4 cm. Italian tiles have the under-tile with flanges tapered, with a slight increase in depth towards the head. The over-tile is half-round in section and tapered in plan. The diameter tapers from 16 cm at tail to 12 cm at the head. The tile may be slightly shouldered to allow it clear the under-tile in the course above at the head lap. The head lap varies from 6.5 to 7.5 cm, depending upon the pitch while the side lap is 5 cm. The taper in over-tile allows the tile in the next course to fit in. The ground work consists of rafters to which 5 cm x 2.5 cm batiens are fixed at the apart. Alternatively, 2.5 cm hoarding, covered with felt may he used. The equals the length of tile-lap. Vertical battens of si/.c 2.2cm x 7.5 cm are fixed between sides of adjacent under-tiles and to these the half-round over-tiles or boarding with 38 mm long copper nails, while the over-tiles are fixed to vertical battens with 75 mm nails.

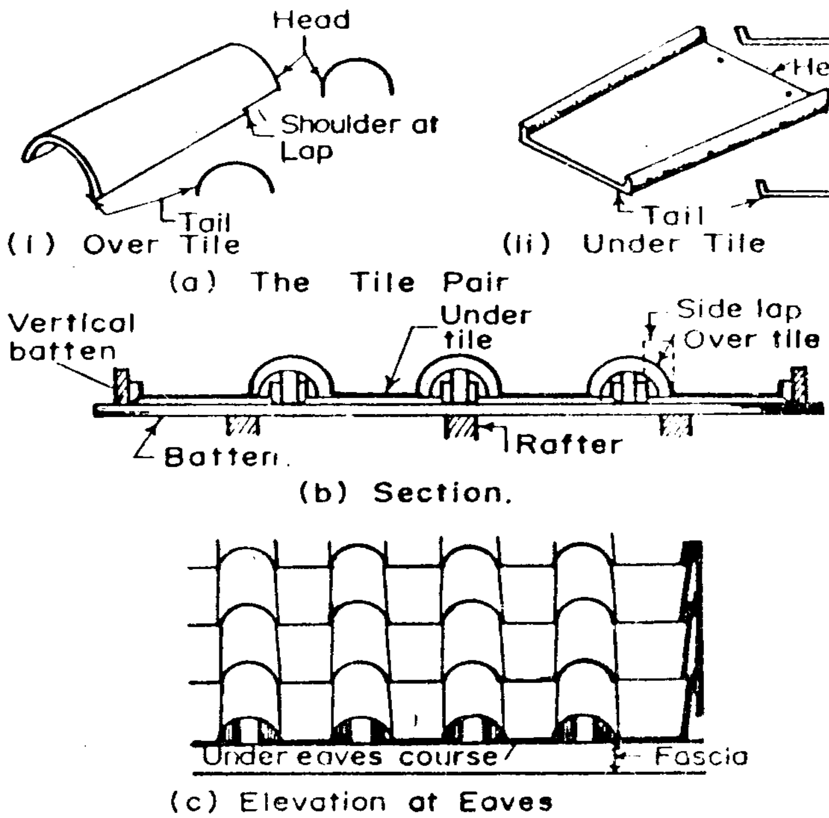


FIG ROOFING ITALIAN TILES

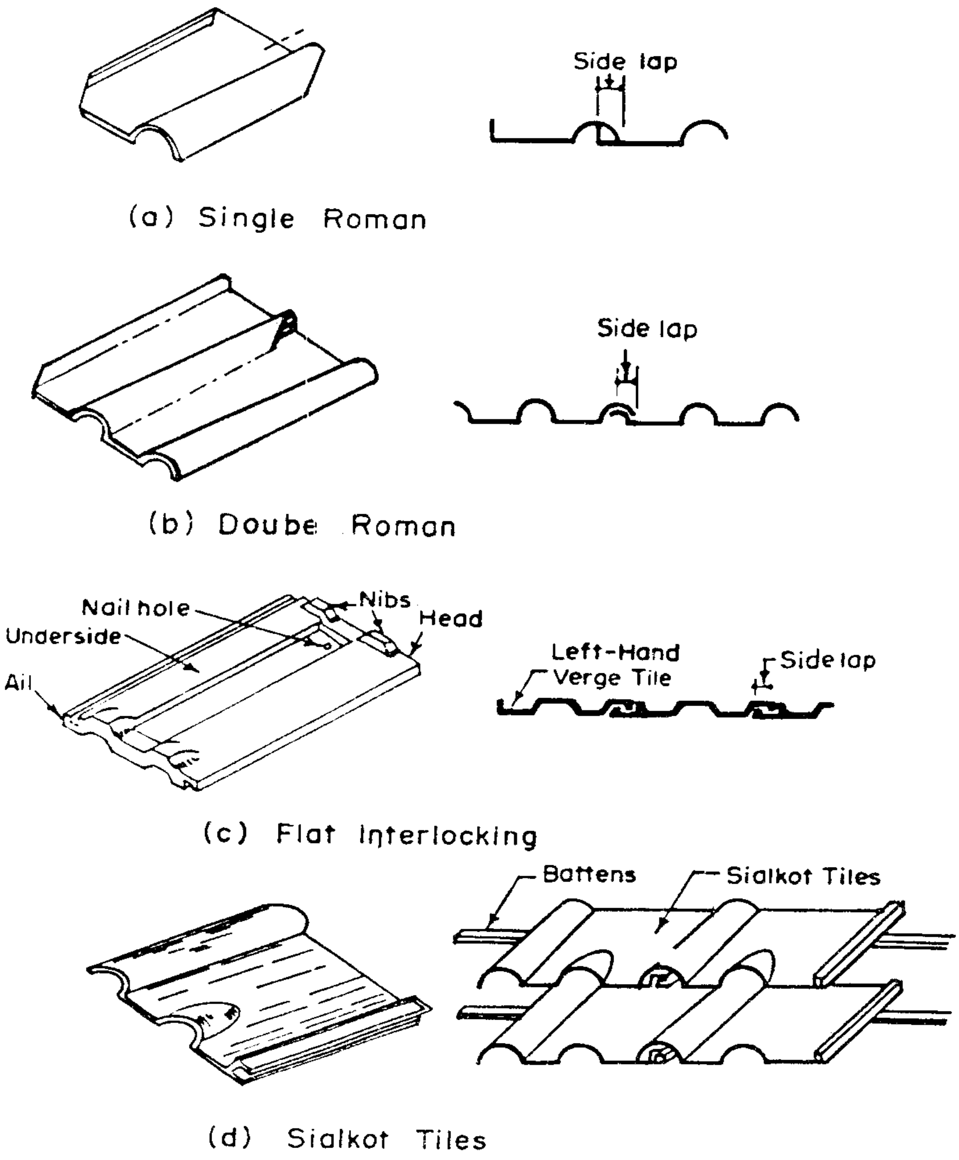


FIG VARIOUS FORMS OF 1NTER-LOCKING TILES

5. Inter-locking tiles

Asbestos cement sheets are now increasingly becoming popular for industrial buildings, factories, sheds, cinema houses, auditorium and even residential buildings, since they arc cheap, light weight, tough, durable, water tight, fire-resisting and vermin resistant. The biggest advantage is that they arc available in bigger units unlike tiles, and hence supporting frame work (ground work) is also cheaper, easier and lighter. These sheets do nut require any protective paint, and no elaborate maintenance is required. Also, the construction with A.C. sheets is very fast. A.C. sheets are manufactured from asbestos, fibre (about 15%) and Portland cement. Asbestos is a silky fibrous mineral existing in veins of meta-morphized volcanic rocks. It is found in several varieties but white asbestos, which is a compound of magnesia and silica, is principally used. Asbestos cement is now used for the manufacture of roofing slates, tiles and corrugated sheets. In India, asbestos cement roof coverings are available in the following three forms :

1. Everest big-six corrugated A.C. sheets.
2. Everest standard corrugated A.C. sheets.
3. Everest Trafford A.C. tiles (or sheets)

These sheets have length of 1.25 to 3 metres in increments of 15 cm. The details of these sheets (Fig.) are given in Table

PARTICULARS OF ASBESTOS CEMENT SHEETS

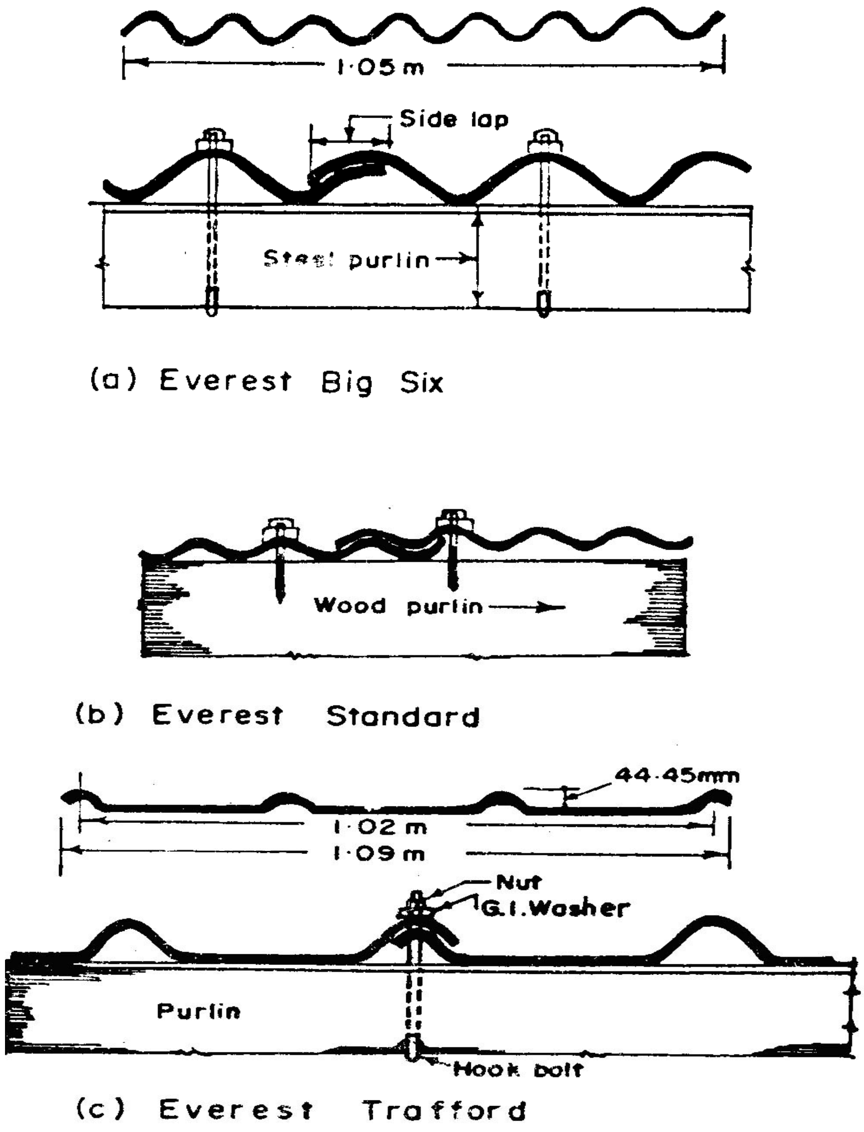
Type of A.C. sheet	*Standard length (m)*	*Laid width (m)*	*Thick-ness (mm)*	*Side lap (mm)*	*No. of corru-gations*	*Pitch (mm)*	*Depth (mm)*
1. Everest big six	1 to 3 m in 25 cm increments	1.05	6	50 mm or $\frac{1}{2}$ corru-gation	$7\frac{1}{2}$	130	55
2. Everest standard	1 to 3	1.05	6	100 mm or $1\frac{1}{2}$ cor-rugations	$10\frac{1}{2}$	55	25
3. Trafford tiles	1.2 to 3 m	1.09	6	74 mm or 1 corru-gation	4	340	50

The big-six type A.C. sheets have 1 corrugation per sheet and their overall depth is 55 mm. These sheets are fixed direct with smooth surface uppermost, to either steel purlins or wood purlins. The standard corrugated sheet is a smaller version of big-six, with over all Depth of corrugation of 25 mm. There are \0\ corrugations per sheet. The end or head lap is 150 mm and the side lap is equal to approximately 1' corrugations or 100 mm.

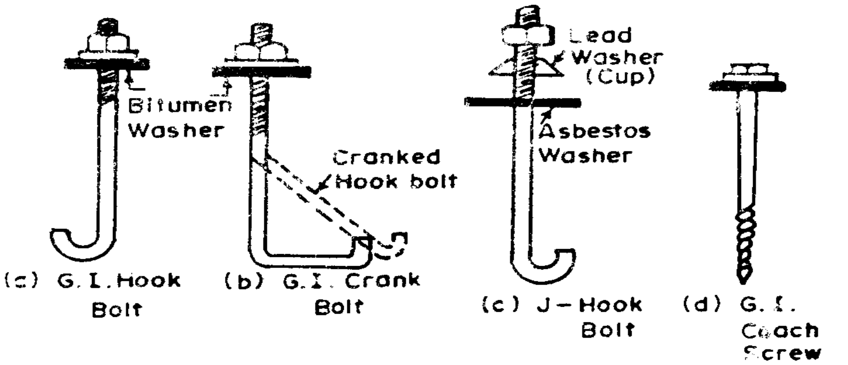
Notes

Trafford tiles are large tiles of 1.09 m standard width. Each sheet has four 50 mm deep corrugations alternating with portions. They are fixed to steel purlins by 8 mm diameter hook bolts, or straight bolts, and to wood purlins by 115 mm long driving screws. The head lap is 150 mm and the side lap is approximately one corrugation of 74 mm.

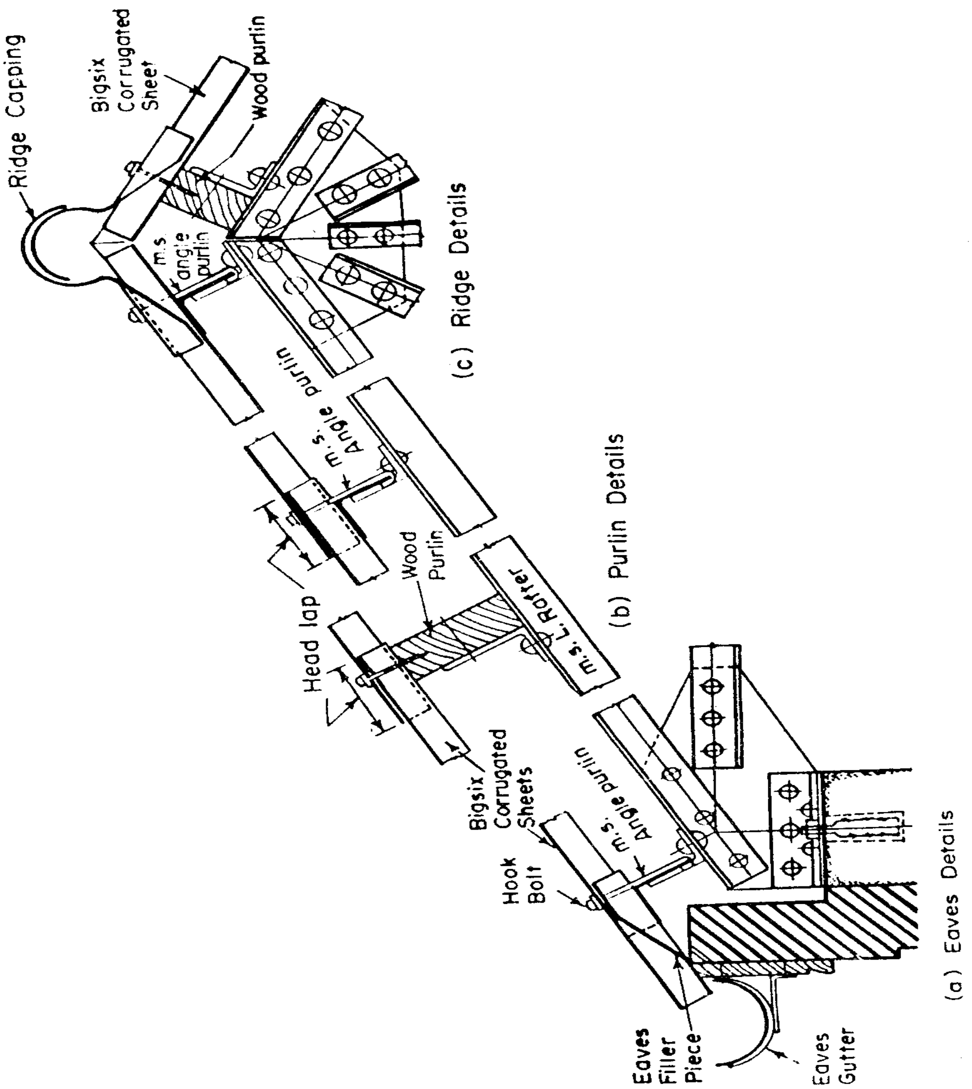
Fig. shows the details of fixing big-six A.C. sheet at eaves, ridge and intermediate locations.



A.C. SHEETS



FIXING BOLTS AND SCREWS



FIXING DETAILS OF BIG-SIX-SHEETS

Notes

Procedure for laying A.C. sheets

A.C. sheets are laid either from left to right, or from right to left. These should be laid at the end opposite to the direction of prevailing wind and rain. The purlin spacing are adjusted to provide specified overlap at intermediate point and specified overhang at the eaves. The sheets are fixed to the purlins, from top of corrugations, through holes which are made 3 mm greater than of bolts. Coach screws are generally used with wooden purlins and crank bolts are used with steel purlins.

The laying is always commenced from eaves. The eaves course is, therefore, laid first. When lying is done from left to right, the first sheet is laid uncut while the subsequent sheets in the bottom row should have the top left hand corners cut or mitred. After laying the first tow (eaves row), the second row is laid. The sheets in second row or intermediate rows should have both the left hand top corner and right hand bottom corners mitred, except the first sheet which should have only the top left corner mitred. In the top row (last row), every sheet should have bottom right corner mitred, except the last sheet which is not mitred. The process is reversed when the sheets are laid from right to left.

The following points should be noted while fixing A.C**.**
sheets.

1. The A.C. sheets should be laid with smooth side upward, and the end marked Top pointing toward the ridge.
2. End lap and side lap should be properly maintained. General end lap is 15 cm, but this can be varied to suit purlin spacing.
3. Purlin spacing and length of sheets should properly checked, before laying

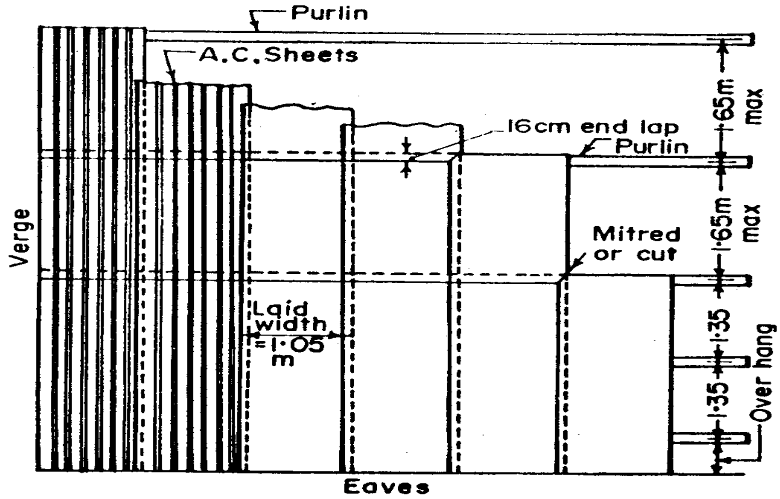


FIG LAYING OF AC. SHEETS (LEFT TO RIGHT)

4. The holes for fixing accessories should be drilled (and not punched) in the crown of the corrugations. The diameter of the holes should be 3 mm greater than the diameter of the fixing bolt or screw. Thus 8 mm . drilled holes, and screwed lightly.

5. Bitumen washers should be provided under G.I. flat washer. The nuts of the screws or bolts are moderately tightened when 10 to 12 sheets have been laid. They should not be screwed very tight.

6. Ridge cappings should be secured to the ridge purlin.

7. The sheets should be 'mitred' properly as required.

8. The unsupported overhang of A.C. sheets should not exceed 30 cm. (e)

Galvanized Iron corrugated sheets (G.I. sheets)

G.I. sheets are also widely used. They are stronger than A.C. sheets. However, because of their higher cost, they are now gradually replaced by A.C. sheets. They are not used for slopes flatter than 1 in 4. G.I. sheets are manufactured with corrugations running from one end to the other. The corrugations impart additional strength to the sheets. G.I. sheets are made of iron sheets which are galvanized with zinc to protect them from rusting action of water and wet weather. These sheets are fixed in a manner similar to the A.C. sheets. End lap should not be less than 15 cm and the side lap varies from li to 2 corrugations. The holes are either drilled or punched in the sheet crowns. The sheets are secured to purlins by means of G.I. hook bolts, screws and nails etc., with curved washers.

The sheets should be fixed to eaves by means of flat iron wind ties.

(i) Slate roofing

Slate is a hard, fine-grained sedimentary argillaceous stone. Slate is obtained from either open quarries or mines, in the form of blocks. A diamond or circular saw is used to divide each block into sections which are 450 to 600 mm wide and upto 360 mm thick. The saw blocks are then reduced to slabs which are about 15 to 30 mm thick. Each slab is then divided into thin laminae or slates, by hand labour, using a splitter. The thickness of slate, used for roofing may vary from 4 to 8 mm in thickness. The sizes of slates vary from 600 mm x 300 mm to 400 mm x 200 mm. A good slate should be hard, tough and durable, of rough texture, ring bell-like when struck, not split when holed or dressed, practically non- absorbant and of a satisfactory colour. Slates are not commonly used in our country. However, in hilly areas, where slate roofing has been used, the roofing consists of bituminous slates known as Etemit. They are generally available in three colours-grey, black and red.

Slates are laid so that each slate overlaps a slate in the next course but below it, the amount is known as lap. The amount of lap depends upon the pitch and the exposure. For fixing slates, two holes are made at the centre or the head. The holes are made from the bed of the slab so that the spalling forms a countersinking for the head of nail. Slates are fixed to the battens by means of copper or zinc nails. The spacing of the battens, known as gauge is determined from the following expression. Gauge length of slate-lap

Ridges and hips are generally covered with blue or grey ridge tiles—matching the colour of slate.

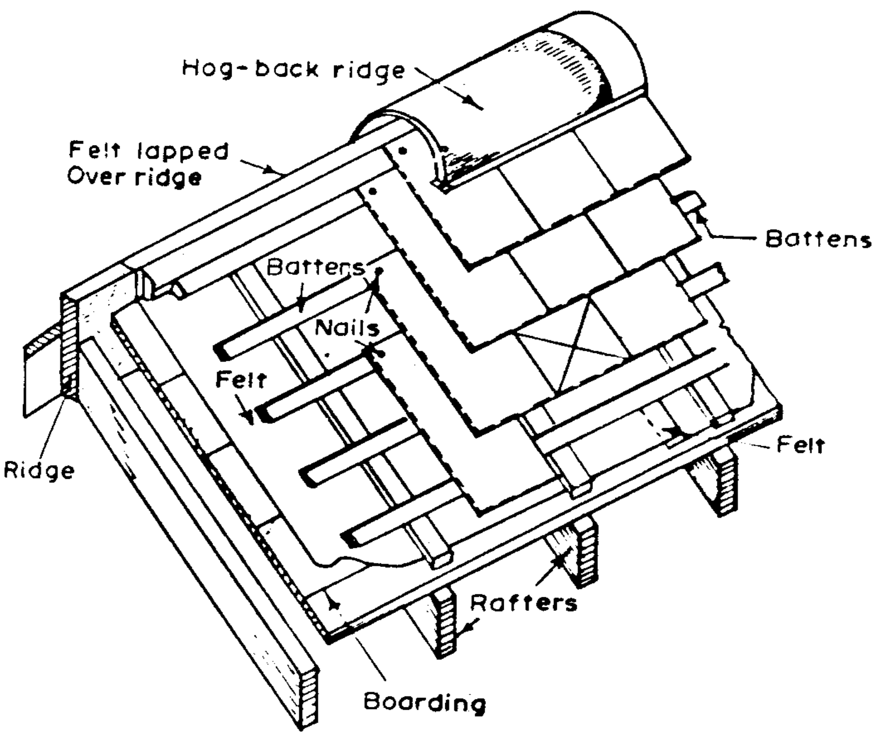


FIG DETAILS OF SLATE ROOFING

In order to exclude rain water and moisture, a layer of felt is used below slates. (g) Light Weight roofing

For wide-span industrial structures, it is desirable to reduce the weight of roof, so that structural framing can be economized. Intentional roofing materials (such as tiles, slates etc.) are heavy and require heavy framing to support them. The light weight roofing materials are of two types

(a) Sheeting

(i) Aluminum sheets

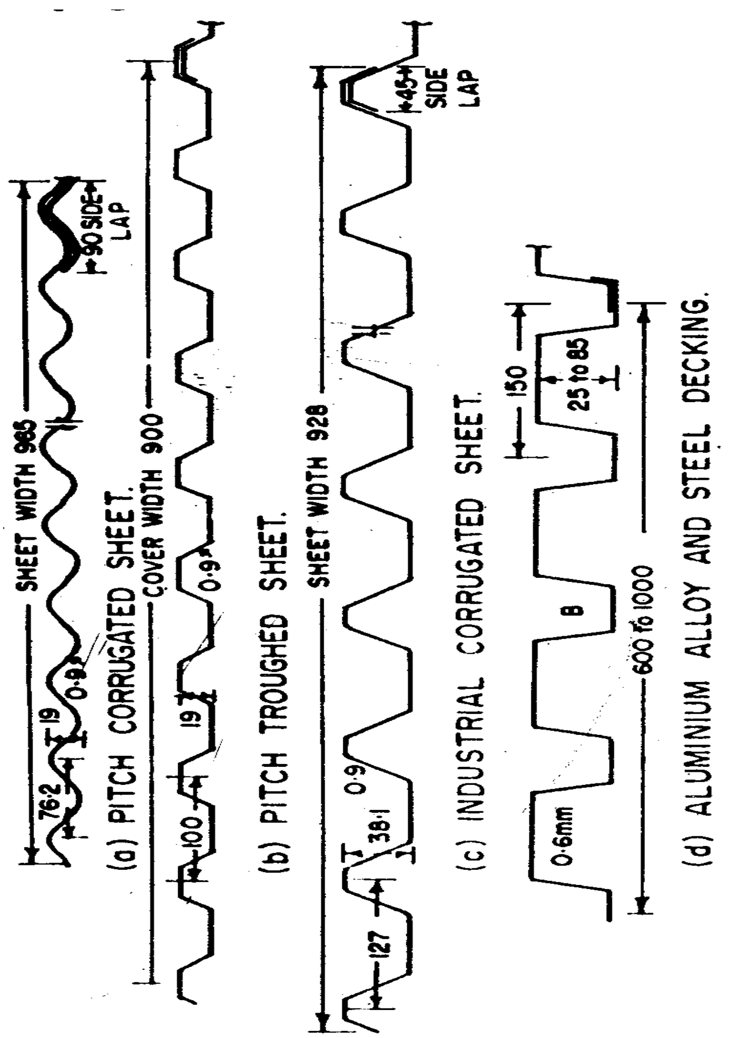
(ii) Asbestos cements sheets.

(b) Decking

(i) Wood wool

(ii) Straw board

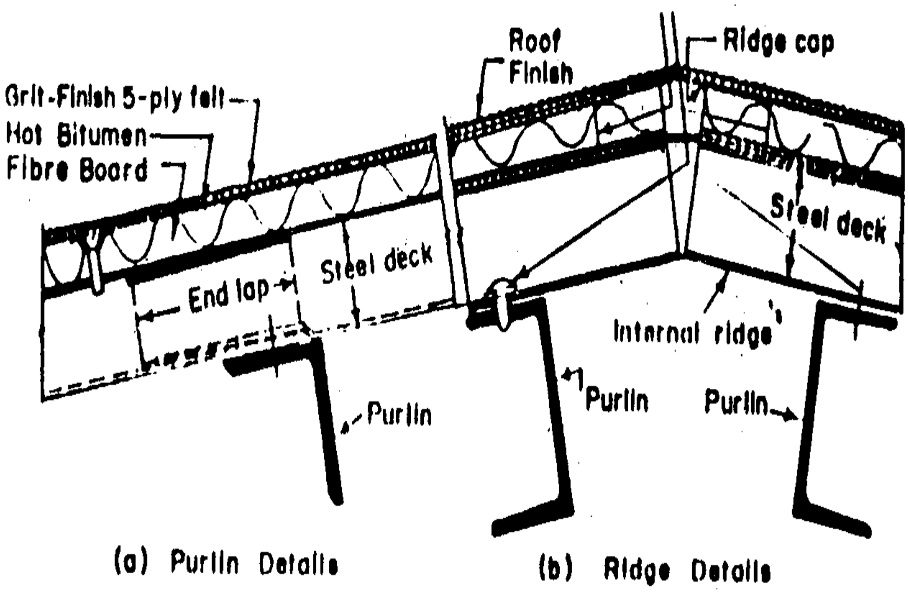
(iii) Aluminum alloy and steel decking. All these require a water proof layer of asphalt or roofing felt. Sheeting is used for sloping roofs while decking is used both for sloping as well as flat roofs.



Aluminum roof sheeting consists of aluminum alloyed with a small percentage of manganese for strength. It is the tightest of all roofing.

Wood wool is made from wood fibre interwoven together and cement bonded under pressure in a mould. They are available in the form of slabs, varying in thickness from 12 mm to 100 mm, and in size of 0.6 m width and upto 3.9 m length. Wood wool has good sound absorbing and thermal insulation properties. For roofing, the slabs are generally of 50 to 75 mm thickness. They are nailed to timber joists at 600 to 900 mm centres, with the help of 102 to 125 mm long clout nails. These slabs, when unreinforced, can take load upto 75 kg/m^2 (0.75 kN/m$^{2)}$

Straw board decking is made of compressed straw with thick water proof paper covering. The thickness is 50 mm, width 1.2 m and length from 1.8 to 3.6 m. For roof decking, the board is supported at 600 mm centres, all along all edges. Aluminum alloy and steel can be pressed to form roof decking with thicknesses varying from 0.7 mm 1.2 mm, depth of corrugations varying from 25 to 85 mm, widths varying from 450 to 900 mm, and lengths upto 10 m. These are suitable upto a super-imposed load of 75 kg/m^2 (0.75 kN/m^2). The deck is fixed to the roof supports by hook bolts, or bolts and cleats, or by hammer drive screws. A felt vapour barrier is bonded with bitumen to the top of the top of the deck on which an insulating media like fibre board or expanded poly is bonded to be covered with two or three layers of felt roofing. The top surface is finished with a layer of white stone chipplings spread on bitumen 10 provide for solar reflectivity and reduce heat absorption in summer. The purlin and ridge details are shown in Fig.



ALUMINIUM ALLOY AND STEEL DECKING

FLAT TERRACED ROOFING

Flat roof is the one which is either horizontal, or practically horizontal with slope less than 10°. Even a perfectly horizontal roof has to have some slope at top so that rain water can be drained off easily and rapidly. Similar to the upper floor, the flat roofs can be constructed of flag stones, R.S.J. and flag stones, reinforced cement concrete, reinforced brick work, jack arch roof or pre-cast cement concrete units. However, the flat roof differ from the upper floor only from the point of view of top finish, commonly called terracing, to protect it from adverse effects of rain, snow, heat etc.

Advantages of flat roofs

1. The roof can be used as terrace for playing, gardening sleeping and for celebrating functions.

2. Construction and maintenance is easier.

3. They can be easily made fire proof, in comparison to pitched roof.

4. They avoid the enclosure of the triangular space. Due to this, the architectural appearance of the building is very much improved.

5. Flat roofs have better insulating properties.

6. They require lesser area of roofing material than pitched roof.

7. They are more stable against high winds.

8. They do not require false ceiling, which is essential in pitched roofs.

9. Flat roofs are proved to be overall economical.

10. In multi-storeyed buildings, flat roof is the only choice, since overhead water tanks and other services arc located on the terrace.

11. The construction of upper floors can be easily done over flat roofs, if so required in future.

Disadvantages of flat roofs

1. The span of flat roof is restricted, unless intermediate columns are introduced. Pitched roofs can be used over large spans without any intermediate columns.

2. The self weight of flat roof is very high. Due to this, the sizes of beams, columns, foundations and other structural members are heavy.

3. They are unsuitable at places of heavy rainfall.

4. They are highly unsuitable to hilly areas or other areas where there is heavy snow fall.

5. They are vulnerable to heavy temperature variations, especially in tropics, due to which cracks are developed on the surface. These cracks may lead to water penetration later, if not repaired in time

6. It is difficult to locate and rectify leak in flat roof.

7. The speed of flat roof construction is much slower than the pitched roof.

8. The initial cost of flat roof is more than pitched roof.

9. The flat roof exposes the entire building to the weather agencies, while the projecting elements (such as eaves etc.) of pitched roof provide some protection to the building.

Types of flat terraced roofing:

Following are the commonly used terraced roofing

1. Mud-terrace roofing.

2. Brick-jelly or Madras terrace roofing.

3. Mud-phaska terracing with tile paving.

4. Lime concrete terracing.

5. Lime concrete terracing with tile paving.

6. Bengal terrace roofing.

7. Light weight flat roofing.

1. Mud-terrace roofing

This type of terracing is suitable where rainfall is less. It can be provided either on tiles (Punjab type terracing) or on wood boards (Maharastra and Madhya Pradesh practice). In both the cases, is made with white earth mud containing large percentage of sodium salt.

The mud-terracing in Punjab is provided over roof which consists of 50mm x 50 mmx 6 mm T-sections spaced at 32 cm centre to centre over R.S.J. Well-burnt tiles of size 30 cm x 30 cm x 5 cm or 30 cm x 15cm x 5 cm are placed between the flanges of the T-sections ; using lime mortar. Over the tiles, a 15 cm thick layer of sliff mud, white in colour and containing sodium salts, is spread and beaten with sticks till the surface becomes hard and the beater rebounds. The surface is then plastered with mud and cow-dung mix plaster. Finally, the surface is finished with 1 : 4 cement-cow-dung plaster.

In the Maharastra and Madhya Pradesh practice, mud terracing is done on teak wood boards (4 to 5 cm thick) nailed to the wooden joists. On the boards, a 2.5 cm thick layer of wood shaving is spread, over which bricks are laid on edge, in lime or mud mortar. On the bricks, a 8 to 10 cm thick layer of mud is spread and beaten hard. Finally, a 2.5 cm thick layer of white earth containing high percentage of sodium salts is applied. This top layer has to be reviewed once in a year. Such roofs do not leak, provide insulation against heat and thus keep the building cool and comfortable.

2. Brick jelly roofing or Madras terrace roofing

(i) Wooden joists are placed on R.S.J. with a furring piece in-between. The furring piece height at the centre is so adjusted that the required slope of the roof is obtained.

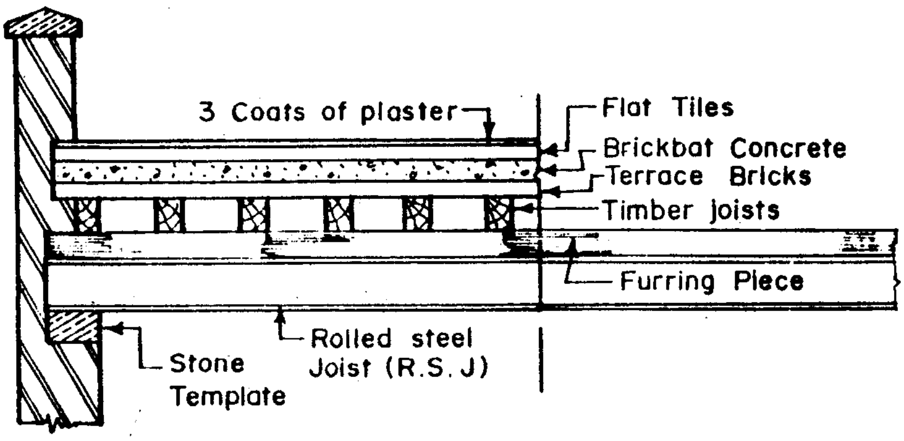


FIG MADRAS TERRACE ROOF

(ii) A course of specially prepared bricks of size 15 cm x 5 cmxl2 mm is placed on edge in lime mortar (1:1.5) laid diagonally across the joists.

(iii) After the brick course is set, a 10 cm thick layer of brick-bat concrete is laid, consisting of 3 parts of brick-bats, 1 part of gravel and sand, and 50 percent of lime mortar by volume. The concrete is well-rammed for 3 days, so that the thickness reduces to 7.5 cm, by wooden hand beaters. The surface is cured for 3 days, by sprinkling lime water.

(iv) When the brick-bat concrete has set, three courses of Madras flat tiles (15 cm x 10 cm x 12 mm) are laid in lime mortar (1: U), making a total thickness of 50 mm. The vertical joints of the tiles in successive layers should be broken. The joints of tiles in top layer are left open to provide key for top plaster. Alternatively, China mosaic tiles may be used.

(v) Finally, the top surface is plastered with three coats of j lime mortar. The surface is rubbed and polished.

3. Mud-phuska terracing with tile paving

This method of terracing is equally suitable to hot as well as arid regions, and is commonly used over R.C.C. roofing.

1. The R.C.C. slab is cleaned off dust and loose material, S A layer of hot bitumen is spread over it at the rate of 1.70 kg of bitumen per square metre of roof surface.

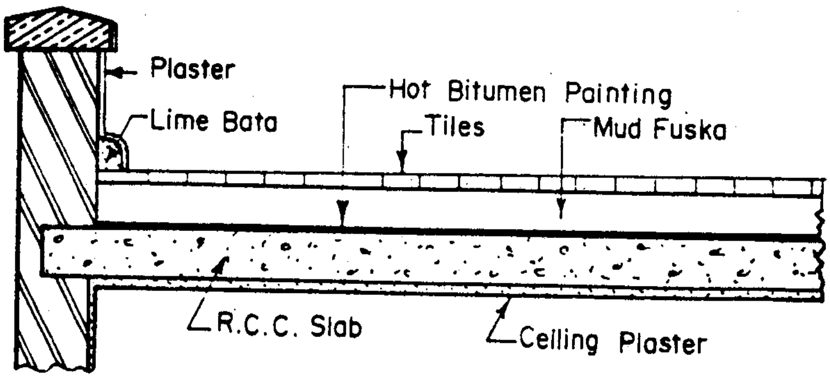


FIG. MUD-PHUSKA AND TILE TERRACING

2. A layer of coarse sand is immediately spread over the hot coat of bitumen, at the rate of 0.6 m^3 of sand per 100 m^3 of roof surface.

3. Mud-phuska is prepared from puddle clay mixed with bhusa at the rate of about 8 kg of bhusa per m^3 of clay. A 10 cm thick layer of this mud-phuska is applied over the sand-bitumen layer. Proper slope (usually 1 in 40) is given in mud-phuska layer. Alternatively, slope may be given in R.C.C. slab itself.

4. The mud-phuska layer is consolidated properly. It is then plastered with 13 mm coat of mud-cow-dung mortar (3:1).

5. Tile bricks are laid flat on plastered surface. The joints are grouted in 1:3 cement mortars.

4. Lime concrete terracing

Jodhpur type roofing

This type of terracing is commonly used over flag stone roofing, though it can also be used over R.C.C. slab. The procedure of lime terracing varies from place- to place. The one adopted for Jodhpur stone slab roofing is described below, in steps:

1. The longitudinal joints between the stone slabs are first pointed in cement mortar. The joints should be V-shaped, not exceeding 25 mm at the top and 10 mm at the bottom. This joint is filled with cement mortar (mix 1:2 to 1:4) and picked with stone chips of wedge shape and top finish rounded with cement mortar so as to project little above the slabs. Before filling mortar in the joints, flat strips of timber (or 3 inch bamboos) should be kept along the joint on the other face of the stone slabs so that mortar does not fall down. Similarly, the space left over the walls at the ends of the slabs, and also the space on walls between the slabs where roof is continuous should be filled with 1:2:4 cement concrete. These joints should properly cure, at least for 7 days.

2. In order to provide proper slope to the roof is laid. This is done by laying stone spawls in 1:2 lime mortar over the surface of the slabs in the required thickness. Hydraulic lime (kankar lime) should be used. Ralthal so laid should be cured for 7 days.

3. laying of the lime chat is done in four consecutive days. On the first day, unslaked kankar lime (hydraulic lime) 10 cm in thickness is spread over the roof slabs. The lime is then slaked in situ, by adding water. It is then beaten with conical stones by hand, so that no particles of lime remain unslaked to cause blisters.

4. On the second day, the lime is watered, raked up and again the process of first day is repeated.

5. On the third day, 250 gm of hemp (finely choped) and methi 750 gm finely powdered per 10 sq. metre is evenly and thoroughly mixed with the lime. Then coarse stone aggregate duly washed should be spread over this lime in a thickness not less than The coarse aggregate is thoroughly beaten with conical stones if by hand so that this stone aggregate gets well-embedded in lime mass.

6. On the fourth day, stone grit or screening is spread in a layer of 40 mm and beaten with stone beaters till they are well set. This process of beating should continue with wooden and by sprinkling water till the whole mass becomes stiff and offers resistance to penetration. Thickness of lime chat should not bless than 15 cm at any place.

7. The above work should be cured at least for 7 days.

8. After seven days, sandal coat consisting of cream of lime is laid over the lime chat in thin layers and rubbed for full four hours or more, using rounded pebbles for rubbing and polishing. During the process of rubbing, solution of 65 gm of Gur and 250 gm of Gugal per 10 square metres is sprinkled every now and then.

9. The surface thus prepared is cured with water at least for 15 days using damp sand or moist gunny bags so as to keep the surface constantly wet.

5. Lime concrete terracing with tiles

This type of terracing is commonly adopted over R.C.C. roofing.

1. The R.C. slab is cleaned off dust etc., land layer of hot bitumen is applied at the rate of 1.7 kg per sq. m. of roof surface.

2. A layer of coarse sand is immediately spread over the hot layer of bitumen, at the rate of 0.6 cubic metre of sand per 100 sq. m. of roof surface.

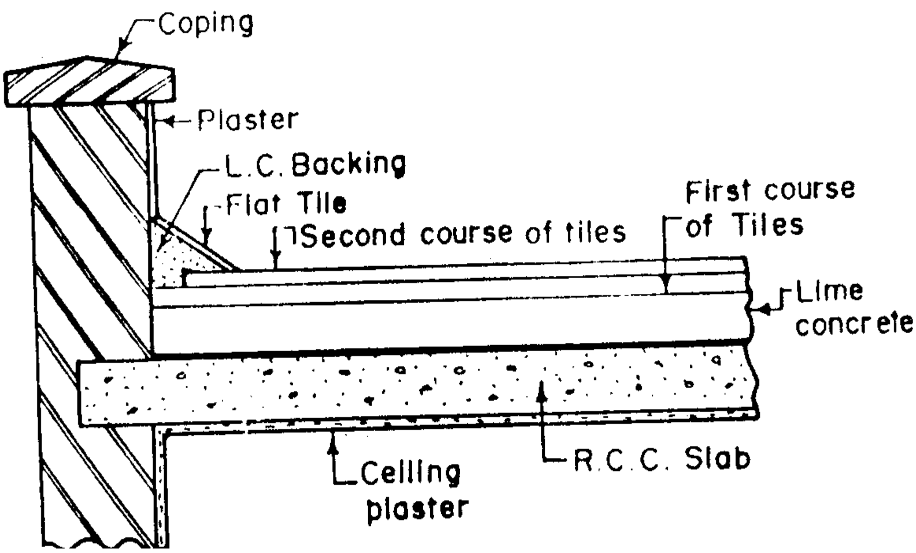


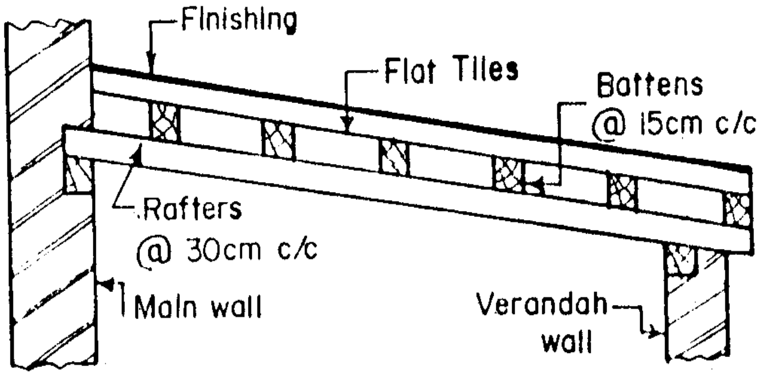
FIG LIME CONCRETE AND TILES ROOFING

3. A 10 cm thick (average) layer of lime concrete is laid, in proper slope. The entire slope is given in lime concrete itself. The lime concrete may consist of 2 parts of lime, 2 parts of surkhi and 7 parts of brick ballast of 25 mm gauge. The concrete is well beaten.

4. Two courses of flat brick tiles are laid in 1 : 3 cement mortars. The joints of top course are pointed with 1 :3 cement mortars. The vertical joints in the two courses are broken.

6. Bengal terrace roofing

This type of roofing is adopted for timber roots of verandah etc.



(i) Wooden rafters are placed at 30 to 50 cm c/c, on some slope.

(ii) Wooden battens (5x1 cm) are placed across the rafters, at 15 c/c.

(iii) A course of flat tiles (15cm x 8cm x 2 cm), well-soaked in white wash, is laid in lime or cement mortar, over the battens.

(iv) The roof is then finished with one of the following two methods

Method

(a). Two or more courses of flat tiles are laid in mortar. Two to three coats of lime plaster are applied. The final course of lime plaster is rubbed smooth and polished.

Method

(b). A 4 to 5 thick layer of fine jelly concrete is laid over the tiles. Over this concrete, a course of flat tiles is laid. The surface is then finally finished with two or three coats of lime plaster, the final coat being rubbed smooth and polished.

7. Light weight flat roof

This consists of aluminium alloy and steel decking, described earlier under pitched roofing. The decking has an additional soft sheet. The decking sheet is suitably supported on steel beams. The Table gives the maximum span over which these can be used, for an imposed load of 75kg/m^2 (0.75kN/m^2).

TABLE METAL DECKING

Depth of corrugation (mm)	*Thickness of metal (mm)*	*Maximum span (m)*			
		Aluminium		*Steel*	
		Single span	Double span	Single span	Double span
25	0.7			1.42	1.71
45	0.7			2.1	2.54
25	0.9	0.99	1.19	1.95	2.31
45	0.9	1.99	2.38	2.82	3.34
25	1.2	1.54	1.85		
45	1.2	2.25	2.67		
85	1.2	3.60	3.98		

TYPES OF WALLS

Wall is one of the most essential components of a building. The primary function of a wall is to enclose or divide space of the building to make it more functional and useful. Walls provide privacy, afford security and give protection against heat, cold, sun and rain. Walls provide support to floors and roofs. Walls should therefore be so designed as to have provision of adequate

(i) strength and stability

(ii) weather resistance

(iii) durability

(iv) fire resistance

(v) thermal insulation and

(vi) sound insulation.

A wall may be defined as a vertical load-bearing member, the width (i.e.., length) of which exceeds four times the thickness. In contrast to this a column is an isolated load-bearing member, the width of which does not exceed four times the thickness.

Walls may be basically divided into two types

(a) Load-bearing, and

(b) Non-load bearing. Each type may further be divided into external (or enclosing) walls and internal or divide walls.

Load-bearing walls are those which are designed to carry super-imposed loads (transferred through roofs etc.), in addition to their own weight (self weight). Non-load-bearing walls carry their own-load only. They generally serve as divide walls or partition wall The external non-load-bearing wall, commonly related to framed structures is termed as panel wall.

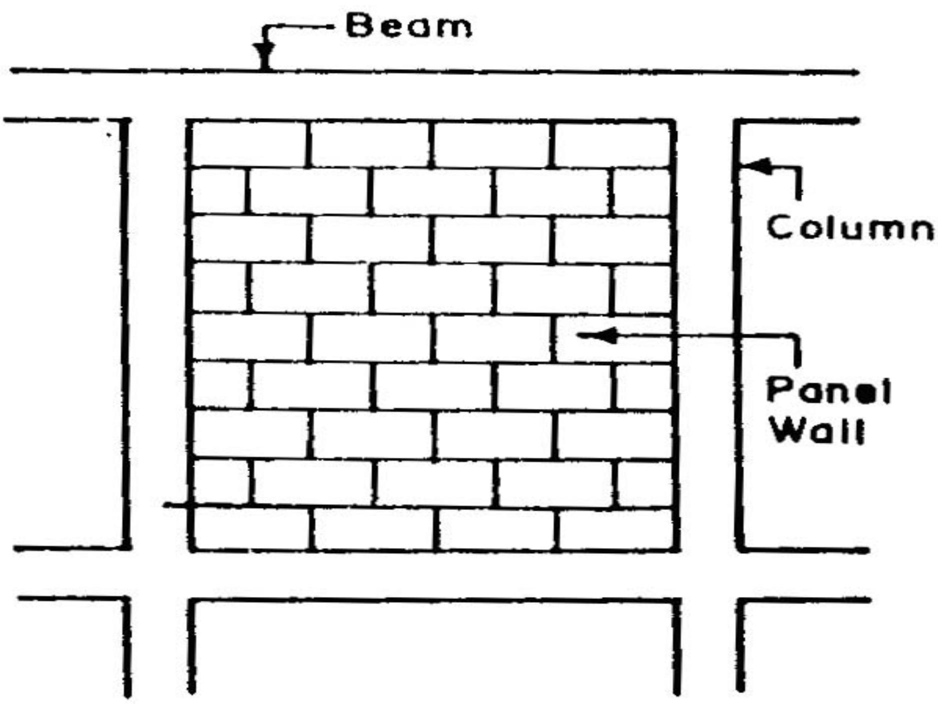


FIG PANEL WALL

A partition wall is a thin internal wall which is constructed to divide the space within the building into rooms or areas. It may either be non-load-bearing or load bearing. A load-bearing partition wall is called an internal wall.

A party wall is a wall separating adjoining buildings belonging to different owners or occupied by different persons. It may, or may not, be load-bearing.

A separating wall is a wall separating different occupancies within the same building.

A curtain wall is a self-supporting wall carrying no other vertical loads but subject to lateral loads. It may be laterally supported by vertical or horizontal structural members where necessary.

Cross-wall construction is a particular form of load-bearing wall construction in which all the loads are carried by internal walls, running at right angles to the length of the building. Load bearing walls may further be divided into the following types

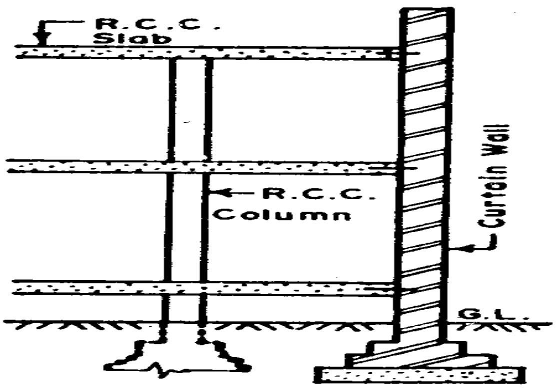


FIG CURTAIN WALL.

(a) Solid masonry wall

(b) Cavity wall

(c) Faced wall

(d) Veneered wall.

Solid masonry walls are the one most commonly used. These walls are built of individual blocks of material, such as bricks, clay or concrete blocks, or stone, usually in horizontal courses, cemented together with suitable mortar. A solid wall is constructed of the same type of building units throughout its thickness. However, it may have openings for doors, windows etc.

A cavity wall is a wall comprising two leaves, each leaf being built of structural units and separated by a cavity and tied together with metal ties or bonding units to ensure that the two leaves act as one structural unit. The space between the leaves is either left as a continuous cavity or is filled with non-load-bearing insulating and water proofing material

A faced wall is a wall in which the facing and backing are of two different materials which are bonded together to ensure common action under load.

A veneered wall is a wall in which the facing is attached to the backing but not so bonded as to result in a common action under load.

DESIGN CONSIDERATIONS

Load-bearing walls may be subjected to a variety of loads, viz., live loads (super-imposed loads), dead loads, wind pressure, earthquake forces etc. Live loads and dead loads act in vertical direction. When the floor slabs transferring the loads to the wall are not supported through the full width of the wall, the loads act eccentrically, causing moments in the wall.

Load-bearing walls are structurally efficient when the load is uniformly distributed and when the structure is so planned that eccentricity of loading on the wall is as small as possible. The strength of a wall is measured in terms of its resistance to the stresses set up in it by its own weight, by super-imposed loads and by lateral pressure such as wind, etc.; its stability by its resistance to overturning by lateral forces and bucking caused by excessive slenderness.

In order to ensure uniformity of loading, openings in walls should not be too large and these should be, as far as possible, of 'hole in wall' type; bearings for lintels and bed blocks under beams should be liberal in size ; heavy concentration of loads should be avoided by judicious planning and sections of load-bearing members should be varied with the loadings so as to obtain more or less uniform stresses in adjoining parts of members. One of the commonly occurring causes of cracks in masonry is wide variation in stress in masonry in adjoining parts. Eccentricity of loading on walls should be reduced by providing adequate bearing of floors/roofs on the walls and making than as rigid as possible consistent with economy and other considerations.

The strength of a masonry wall depends primarily upon the strength of the masonry .units and the strength of the mortar. In addition, the quality of workmanship and the method of bonding is also important.

Mortar strength shall be in general not greater, than that of the masonry unit. An un-necessarily strong mortar concentrates the effect of any differential movement of masonry in fewer and wider cracks while a weak mortar (mortar having more of lime and less of cement) will accommodate movements, and cracking will be distributed as thin hair cracks which are less noticeable. Also, stresses due to expansion of masonry units are reduced, it a week mortar is used. Lean cement mortars of cement alone, are harsh, pervious and less workable. Hence, when strong mortars are not required from strength considerations, it is preferable to use composite mortars of cement, lime and sand in appropriate proportions.

However, rich cement mortar is needed : (a) When masonry units of high strength are used so as to get strong masonry, (b) when early strength is necessary for working under frosty conditions, and (c) when masonry is in wet location as in foundation below plinth, where a dense mortar being less pervious can better resist the effect of soluble salts.

The thickness of a load-bearing wall should be sufficient at all points to ensure that the stresses due to the worst conditions of loading for which the structure is designed are within the limits prescribed for that particular type of wall. The thickness used for design calculations should be the actual thickness of the masonry and not the nominal thickness. In the case of modular bricks, thickness of one brick wall will be 19 cm actual and 20 cm nominal. Similarly, the thickness of I^1 brick wall will be 29 cm actual and 30 cm nominal

Thus, the actual thickness is computed as the sum of the average dimensions of masonry units together with the specified joint thickness. If joints are raked to provide key for subsequent plastering, the thickness should be reduced by the depth of the raking out. Thus, in the joints in one side is raked to a depth of 1 cm, and hence the effective thickness of wall =19-1=18 cm.

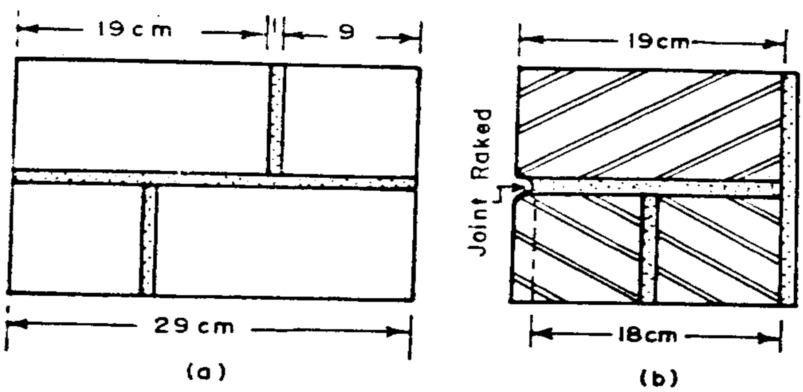


FIG THICKNESS OF WALL

When vertical loads act on the wall, either axially or at small eccentricity, the wall behaves like a column. Its strength, of the same vertical load intensity, depends upon the slendemess ratio which is a function of (i) height of the wall, and (ii) length of the wall, and (iii) thickness of wall, and (iv) support conditions. The slendemess ratio of a wall is the ratio of its effective height divided by the effective thickness or the effective length divided by the effective thickness, whichever is less. The effective height and effective length of the wall depend upon the lateral support to the wall.

LATERAL SUPPORT

A wall may be considered to be provided with adequate lateral support if the construction providing the support is capable of resisting the sum of following lateral forces

(a) The simple static reactions to the total applied horizontal forces at the point of lateral support, and

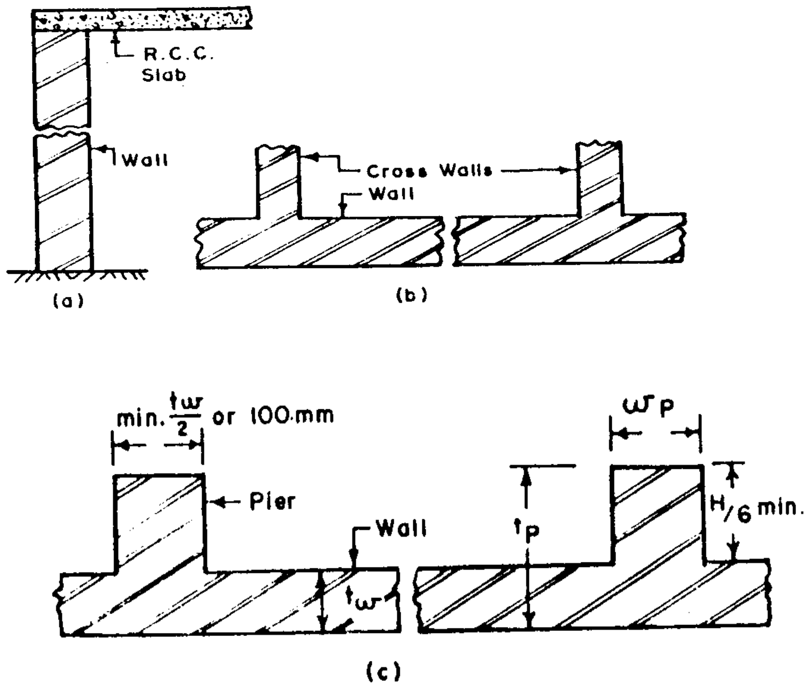
(b) Two and a half percent of the total vertical load that the wall is designed to carry at the point of lateral support. Lateral support to a wall has to perform two important functions, i.e.,

(i) to limit the slenderness so as to prevent buckling and (ii) to provide stability to the structure against over-turning on account of horizontal forces.

A wall can be laterally supported either at vertical intervals by floor roof transmitting horizontal forces to cross-walls and then to the foundation or at horizontal interval by cross-walls, piers or buttresses transmitting horizontal forces to foundation.

The load-bearing capacity of a wall depends upon the spacing and effectiveness of lateral supports.

If the slenderness ratio is based on height, a horizontal lateral support (i.e., floor/roof) may be deemed to be adequate if the R.C.C. floor/roof bears on wall to the extent of at least 10 cm. In case slenderness ratio is based on effective length, a vertical support will be deemed to be adequate if cross-wall, pier or buttress extends to the extent of one-sixth of the height of the wall, has a minimum thickness of half the thickness of supported wall or 100 mm whichever is more, and is bonded to the supported wall.



(a) R.C.C. SLAB GIVING LATERAL SUPPORT TO THE WALL
(b) CROSS-WALLS GIVING LATERAL SUPPORT TO THE WALL
(c) PIERS GIVING LATLRAI-SUPPORT TO THE WALL

LATERAL SUPPORT TO WALL.

S.No.	*Condition of Support*	*Effective Height (H)*
1.	Adequate lateral support and partial rotational restraint at top and bottom. For example, where the floor (or roof) has a direction of span at right angles to the wall, so that the reaction to the load of the floor or roof is provided by the walls ; or where the concrete floors have a bearing on walls irrespective of the direction of span.	0.75 H
2.	Adequate lateral support and partial rotational restraint at either top or bottom and lateral restraint at other end. For example, fully braced construction which is itself adequately supported and incorporates: (*a*) timber floors immediately below or above a reinforced concrete floor, and (*b*) roof trusses above a reinforced concreted floor or the like.	0.85 H
3.	Adequate lateral support at top and bottom where the floors (or roofs) have a direction of span parallel with the wall, top and bottom, and do not bear on it, or fully braced construction which is itself adequately supported and which incorporates roof trusses and timber upper storey floors.	1.00 H
4.	Adequate lateral support and partial rotational restraint at bottom and no lateral support or rotational restraint at the top (where the wall has no lateral support at top construction not fully anchored or not fully braced).	1.50 H
5.	Free standing non load bearing members.	2.00 H

National Building Code of India specifies that when the concrete slabs do not bear on a wall, as specified above, non-corrodible metal anchorages shall be provided at intervals of not more than 2 m and built into concrete slabs to a minimum distance of 40 cm. Timber floors and roofs shall be anchored by non-corrodible metal anchors having a minimum cross-section of 30 mm wide and 6 mm thick securely fastened to the joist and provided with split and upset ends or other approved means for building into the walls. The anchors shall be provided at intervals of not more than 2 m in buildings upto two storeys and 1.25 m for all storeys in other buildings.

EFFECTIVE HEIGHT OF WALL

The effective height (h) of the wall, to be used for the computation of the slenderness ratio, is the function of the actual height (/•/) of the wall and the conditions of lateral support.

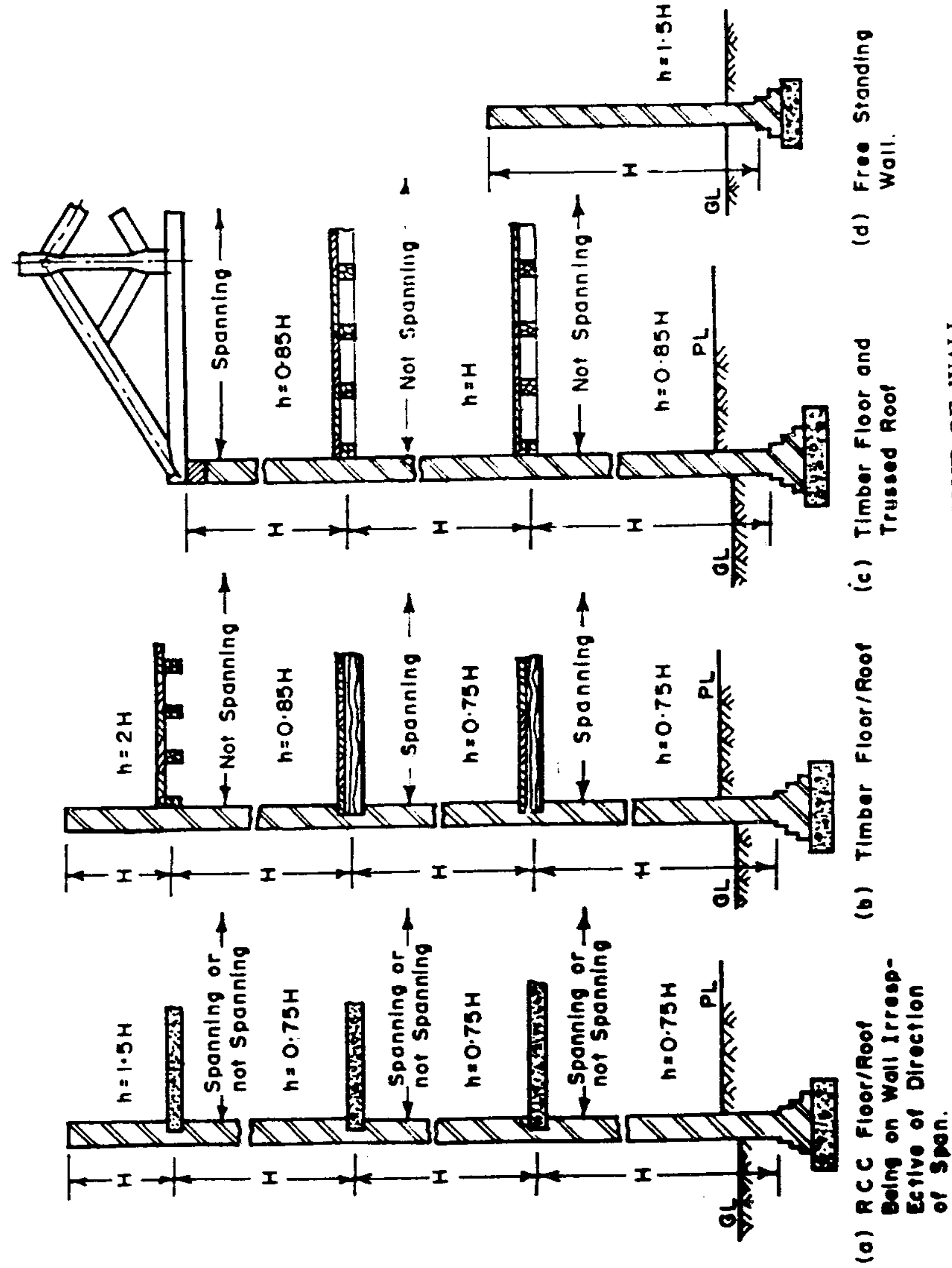
FFECTIVE HEIGHT OF WALL (NATIONAL BUILDING CODE OF INDIA, SP-7 : 1970)

Note 1. H is the height- of a wall between centres of support or the centre of support to the point near the footing, where the thickness of the wall is minimum.

Note 2. Where there is discontinuity in bond, due to damp-proof course or other materials, H should be measured from the discontinuity and the condition of end restraint at the discontinuity shall be taken as one of the lateral supports only.

Note 3. A suitable concrete element, such as a footing or

Notes



EFFECTIVE HEIGHT OF WALL.

Floor (irrespective of the direction of span) having bearing on or supporting a wall may be considered to provide partial restraint. In the case of roofs, the partial rotational restraint shall be assumed to be provided only when the direction of span is at right angles to the direction of wall.

Note 4. In the case of column, the effective height for both of its sides shall be considered taking into account the conditions of support at the ends.

Note 5. When assessing the effective height, floors not adequately anchored to walls shall not be considered as providing lateral support to such walls.

Note 6. Where a load-bearing pier is bonded to a wall whose thickness is at least two-thirds of the horizontal dimension of that pier, measured at right angles to the length of the wall and so as to include the thickness of that wall (thickness of wall thickness of pier), that pier and the portion of the wall to which it is bonded may be treated as a wall.

Openings in walls.

When openings occur in a wall such that the brick work between any two/consecutive openings is by definition a column, effective height of this brick work shall be taken as 1.5 times the height of taller opening subject to a minimum of effective of the wall, and maximum of effective height of column.

EFFECTIVE LENGTH OF WALL

S. No.	*Condition of Support*	*Effective length (l)*
1.	Where a wall is continuous and supported by cross walls or buttresses and there is no opening within one eighth of the wall height, *h* or *H* (which ever is less) from the face of the supporting wall or buttress	0.8 L
2.	Where a wall is supported by a buttress or cross wall at one end and continuous with buttress or cross wall supports at the other end.	1.0 L
3.	Where a wall is supported at each end by a buttress or a cross wall	1.0 L
4.	Where the wall is free at one end and supported by a buttress or cross wall at the other end.	1.5 L

1. Wall is continuous at both ends and is supported by cross-walls of thickness tw/1 or 100 mm, whichever is more; length of cross-wall is not less than H/6 ; opening in wall not closer than H/S from cross-wall.

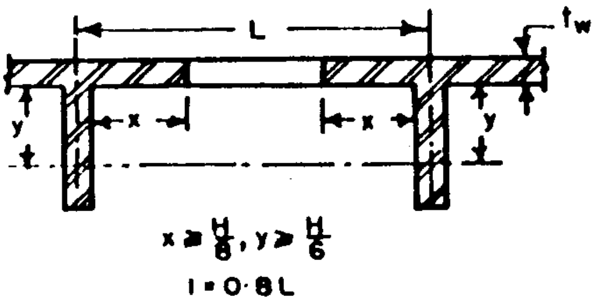


FIG EFFFECTIVE LENGTH OF WALL

Case I

2. Same as case 1 except that one end of wall is discontinuous.

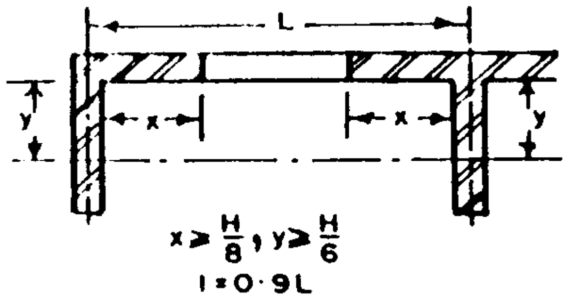


FIG EFFECTIVE LENGTH OF WALL

CASE 2

3. Same as case 1 except that the wall is discontinuous on both ends.

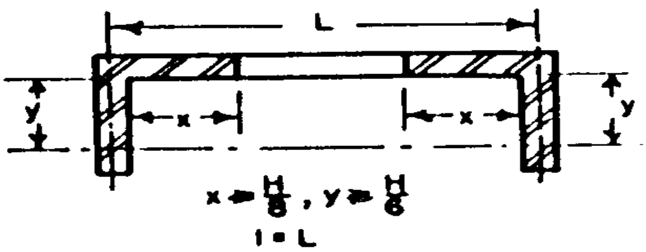


FIG EFFECTIVE LENGTH OF WALL

CASE 3

4. One end of the wall is free, other is supported by a cross- wall and is continuous, there being no opening within H/S from cross-wall.

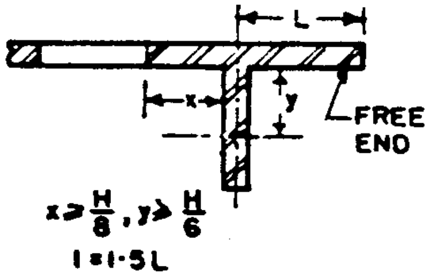


FIG EFFECTIVE LENGTH OF WALL

CASE 4.

5. Same as case 4, but opening is within H/S from crossT-wall and thus that end is taken as discontinuous.

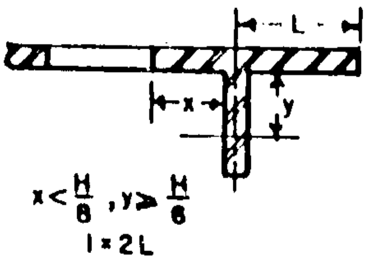


FIG. EFFECTIVE LENGTH OF WALL : CASE 5.

6. This illustration is with an opening which is within H/S from cross-wall.

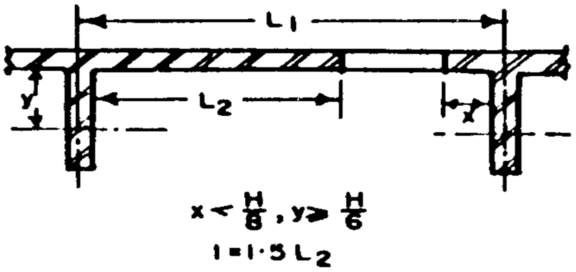


FIG. EFFECTIVE LENGTH OF WALL :

CASE

7. Wall length is between two openings which are closer than H/S from cross-walls. Slenderness ratio is determined by height.

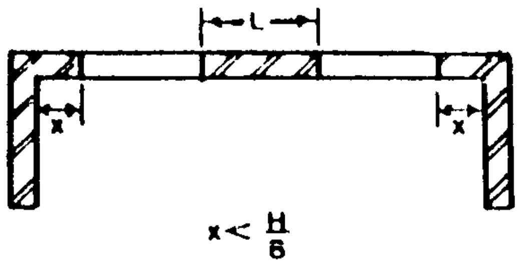


FIG. EFFECTIVE LENGTH OF WALL : CASE 7.

EFFECTIVE THICKNESS

The effective thickness used for calculating the slenderness ratio of a wall in compression is obtained as given below :

1. For solid walls or faced walls, the effective thickness shall be the actual thickness.

2. For solid walls adequately bonded into piers or buttresses, and provided the slenderness ratio is based on height, the effective thickness shall be taken as equal to the actual thickness multiplied by appropriate stiffening co-efficient as given in Table 8.3. No modification is, however, necessary if the slenderness ratio is based on the effective length of the wall.

TABLE STIFFENING CO.EFFICIENT (Kn) FOR WALLS STIFFENED BY PIERS, BUTTRESSES OR INTERSECTING (CROSS) WALLS.

S.No.	Ratio $\frac{sp}{wp}$	Stiffening co-efficient (K_n)		
		$\frac{tp}{tw} = 1$	$\frac{tp}{tw} = 2$	$\frac{tp}{tw} = 3$ or more
1.	6	1.0	1.4	2.0
2.	8	1.0	1.3	1.7
3.	10	1.0	1.2	1.4
4.	15	1.0	1.1	1.2
5.	20 or more	1.0	1.0	1.0

where Sp = centre to centre spacing of the intersecting wall. tp = thickness of pier. tw = actual thickness of wall proper. wp = pier width in the direction of wall or the actual thickness of intersecting wall

3. For solid walls or faced walls stiffened by intersecting wall, the appropriate stiffening co-efficient may be obtained on the assumption that the intersecting walls are equivalent to piers of width equal to the thickness of the intersecting wall and of thickness equal to three times the thickness of stiffened wall.

4. For cavity walls with both leaves of uniform thickness throughout, the effective thickness shall be two-thirds of the sum of the actual thickness of the two leaves.

5. For cavity walls with one or both leaves adequately bonded into piers, buttresses or intersecting walls at intervals, the effective thickness of the cavity wall shall be two-thirds of the sum of the effective thickness of each of the two leaves ; the effective thickness of each leaf shall be calculated in accordance with (1) and (3) above, as appropriate.

SLENDERNESS RATIO (5s)

For a wall, the slenderness ratio shall be the effective height divided by the effective thickness and stiffening co-efficient (Kn) or the effective length divided by the effective thickness, whichever is h whichever is less. When a vertical load is applied to a wall, it would tend to buckle around a horizontal axis parallel to the length of the wall. This buckling is resisted both by the horizontal supports (such as floors etc.)

as well as vertical supports (i.e., cross-walls, piers etc.). The load carrying capacity of wall very much depends upon its slenderness ratio (SR). As this ratio increases, crippling stress of the wall gets reduced because of the limitations of workmanship and elastic instability. When SR is less than 30, the load-capacity of wall is a stress problem, while if SR is more than 30, it becomes a stability problem.

From considerations of structural soundness and economy of design, most Codes control the maximum Sp so that failure is due to excessive stress rather than buckling. This limiting value of SR is less for masonry built in time mortar as compared to that built in cement mortar. Similarly, limiting Sp is less for taller buildings than that for short height buildings. The Table gives the limiting values of SR, based on British Standard C.P. 111-1970 (Revision November 1971) :

TABLE LIMITING VALUES OF SLENDERNESS RATIO

No. of storeys	*Thickness of wall*	*Maximum Values of S_R*	
		Mortar containing cement	*Mortar not containing cement*
Not exceeding 2	Any	27	20
Exceeding 2	(*i*) Walls of 90 mm thick-ness or more	27	13
	(*ii*) Wall less than 90 mm thickness	20	13

BASIC COMPRESSIVE STRESS (fb)

The basic compressive stress (fb) of masonry depends upon the crushing strength of masonry units (brick) and type of mortar used. It should be noted that basic compressive stresses, also depends upon surface characteristics, water absorption property of units, uniformity of shape and size of units, thickness of joints etc. Thus, strictly speaking, the basic stresses would not hold good for concrete blocks, sand lime bricks and stone. In absence of any other specific provisions in the Code, the basic stresses may be adopted for ashlars stone and coursed stone masonry with co-efficient of 1.25 and 0.75 respectively. This is so because ashlars masonry, requiring thin mortar joints would give high basic stress while coursed stone masonry with irregular stones and thicker joints would give lesser values of basic stresses.

STRUCTURAL DESIGN OF WALLS

British Code C.P. Ill divides the walls into two categories

Non-calculated walls and calculated walls. Non-calculated walls are those which are used as thin panel walls in framed structures and which do not carry roof load. The design of such walls is based on certain rules and not on the basis of calculations. On the other hand, calculated walls are the load-bearing walls of high rise buildings, which support floors and roof, and the design of which is based on calculations and not on rules. The method of design of such walls is commonly known as calculated masonry method. The calculated masonry method can be applied in two ways:

1. Design by use of nomograms

2. Design by structural analysis.

DESIGN BY USE OF NOMOGRAMS

Results of structural analysis, based on 'calculated masonry method', for certain loadings and span, have been presented in the form of nomograms, by the National Building Code of India (SP : 7-1920). Though the nomograms presented in the Code cover buildings upto 6 storeys, it is viewed that there is risk of some portion of the structure getting overstressed, on account of unfavorable location and shape of openings and occurrence of concentrated loads thus endangering the structural safety of tall buildings. It is desirable, therefore, to use the nomograms to design buildings upto 3 storey height. Buildings exceeding 3 storeys in height should be designed by detailed structural analysis.

The nomograms for determining thickness of brick wall contain nine vertical lines. From left to right, the vertical lines represent as follows

Line 1 : Basic stress

Line 2 : Storeys

Line 3 : Reference line 1

Line 4 : Span point

Line 5 : Reference line 2

Line 6 : Percentage of opening

Line 7 : Thickness of wall for span of 3.0 m

Line 8 : Thickness of wall for span of 3.6 m

Line 9 : Thickness of wall for span of 4.2 m.

Line 1 : Basic stress.

Basic stress is for the type of masonry.

Line 2: Storeys. Though the nomograms can be used for buildings upto 6 storeys height, it is preferable to use it only upto 3 storey height. For use of nomograms in the case of multi-storeyed buildings, the wall thickness at each floor is found by passing the line through the number of storeys above that section.

Line 3 : Reference line 1. This line fixes a point on the line for any combination of basic stress and storeys.

Line 4 : Span point. The fourth line has a span point through which all lines shall pass through for arriving at the wall thickness.

Line 5 : Reference line 2. This reference line also fixes a point on the line for any combination of values for basic stress and storeys.

Line 6 : Percentage of openings. This line takes care of openings provided on the wall, for windows, doors, ventilators etc. For example, if a wall, 6 m long, has a door of 1 m width and window of 1.5 m width, the gross horizontal area of wall, at a plane where there is no opening, will be 6tw m^2, where tw is the thickness of wall in metres. The area of opening at the window level will be =(l+1.5)fn, =2.5/1,- m^2.

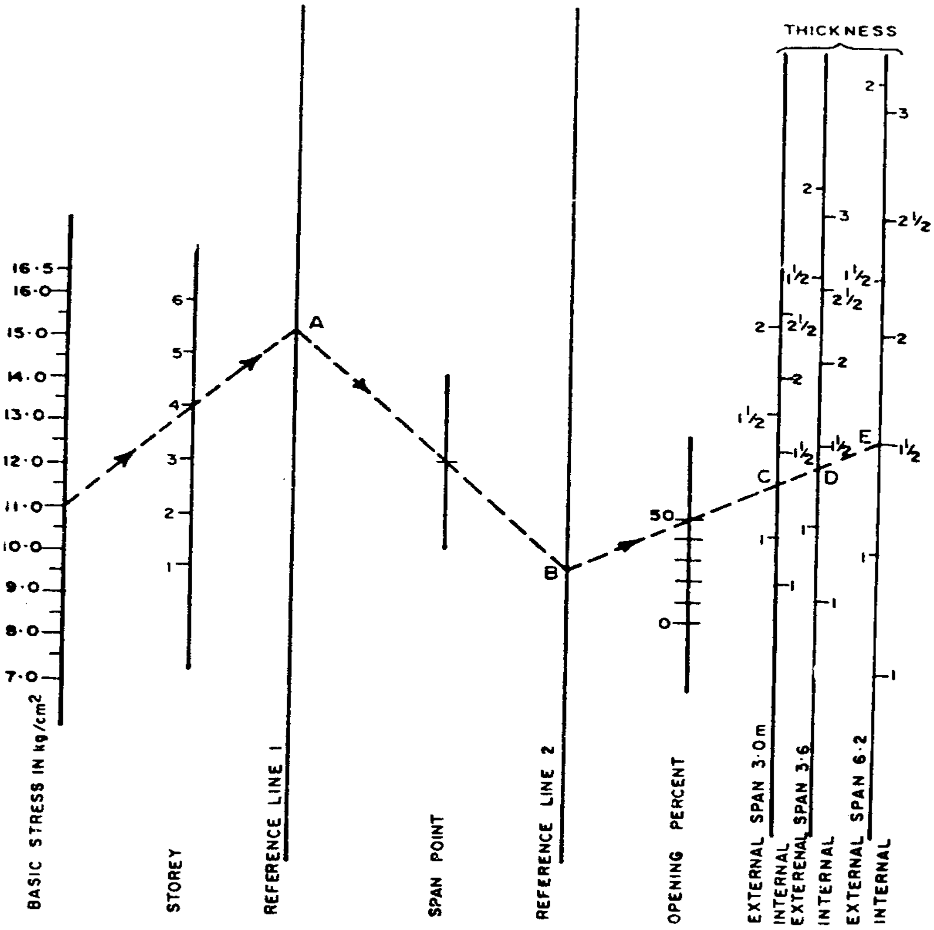


FIG. NOMOORAM FOR WALL THICKNESS: RESIDENTIAL BUILDING: CLASS 200 LOADING,(LIVE LOAD) DEAD LOAD : 415 kg/m^2 (4.15 kN/m^2) STOREY HEIGHT : 2:5 m

Lines 7, 8, 9 : **Thickness of wall.** The last three lines give the thickness of wall for three spans of the rooms (Le. 3.0 m, 3.6 m and 4.2 m). Thicknesses are indicated on both the sides of these lines. The bold markings on the left hand side of the lines give the thickness of the external walls and the dotted markings on the right side of the lines give the thickness for internal walls. Internal walls are analyzed as walls having spans on either side. The numbers 1, 1- 2 etc. on these lines indicate the (number of) brick thickness.

Method of use of nomograms

The method of use of nomogram for determining the thickness of brick wall has been illustrated in Figs. by a dotted line. The following procedure may be adopted

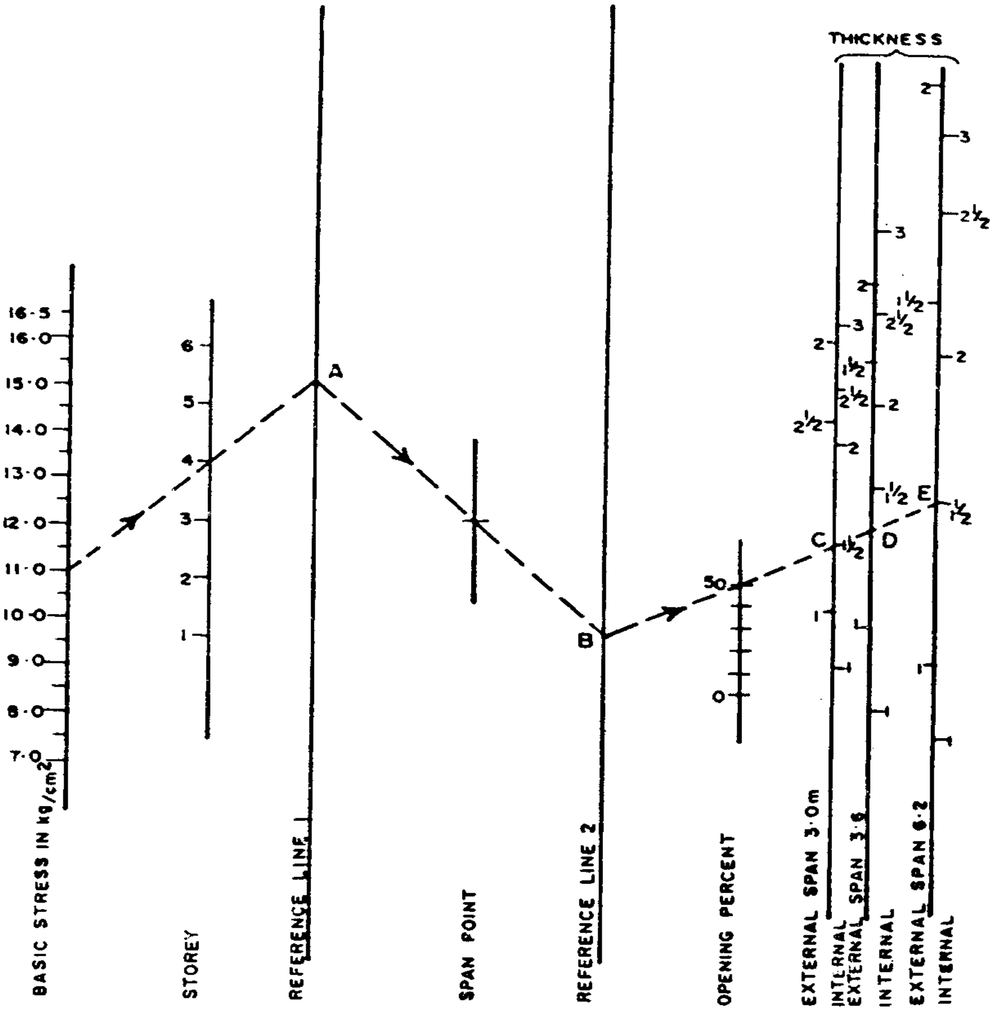


FIG. NOMOGRAM FOR WALL THICKNESS RESIDENTIAL BUILDING :CLASS 200 LOADING. DEAD LOAD 415 kg/m^2 (4.15 kN/m^2) STOREY HEIGHT : 3.2 m

1. Choose the basic stress corresponding to the properties of masonry units and type of mortar to be used. For example, if we use bricks having crushing strength of 140 kg/cm^2 (14 N/mm^2) and 1:1:6 cement-lime mortar, the basic compressive stress, found from Table, will be 11 kg/cm^2 (1.1 N/mm^2). This stress of 11 kg/cm^2 is marked on the first line of the nomograms.

2. If the building has 4 storeys, and the wall is to be designed at the ground level, the point of 11 kg/cm^2 is joined to storey 4 of the second line (story line), and extended to cut reference line No. 1 at point A.

3. Join A to the span point and prolong further to cut the reference line No. 2 in point B.

4. Suppose the percent openings in the wall are 50. Join the Point B to 50 mark on the 6th line (opening line), and extend it further to cut the thickness lines in C, D and E.

5. The thickness of wall shall be the value of the dividing line which appears above the point of intersection on the thickness line. For example, the points of intersection C, D, E represent the following thicknesses

Table Basic stress of

Point	*Span*	*Thickness (External Wall)*	*(in Brick Thicknesses) (Internal wall)*
C	3.0	$1\frac{1}{2}$	$1\frac{1}{2}$
D	3.6	$1\frac{1}{2}$	$1\frac{1}{2}$
E	4.2	$1\frac{1}{2}$	2

DESIGN OF STRUCTURAL ANALYSIS

The design by the use of nomograms have certain limitations, i.e., the nomograms are limited in number and therefore do not cover all cases of loading and all combinations of live and dead loads, and also it is difficult to incorporate other variables such as slenderness ratio greater than 6, eccentricity of loading, shape factor etc. The design is therefore usually done by direct analysis. It should however be noted that both the nomographic method as well as the analytical method are based on the 'calculated masonry method' which is essentially a method of two dimensional analysis.

The permissible compressive stress in masonry depends upon the following factors

1. Strength of masonry units
2. Mix of mortar
3. Eccentricity of loading.
4. Slenderness ratio of masonry.
5. Shape factor.

Basic stresses (fb). For ashlar and coursed rubble masonry, factors of 1.25 and 0.75 respectively may be used.

Area Reduction factor. The Code has given in an expression of the reduction factor (Ka) due to small area of wall, which is based on the consideration that there is statically greater chance of failure of a small section, from weak individual units or variability of workmanship. The National Building Code recommends that where the cross-sectional area of the wall does not exceed 3000 cm^2, the basic stress (fb) should be multiplied by a reduction factor given by

$$K_a = 0.75 + \frac{A}{12000}$$

where A= Area (in cm^2) of the horizontal cross section of the wall.

Eccentricity of Loading

When the floor slabs (or roof slabs) transferring load to the wall do not bear on it for the full width of the wall, the vertical load transferred to will act eccentrically. Eccentric vertical loads or axial loads plus lateral loads on wall cause bending stresses in addition to axial stresses.

The resultant load W will have an eccentricity f which can be found by taking moments around the centroid of the section AB:

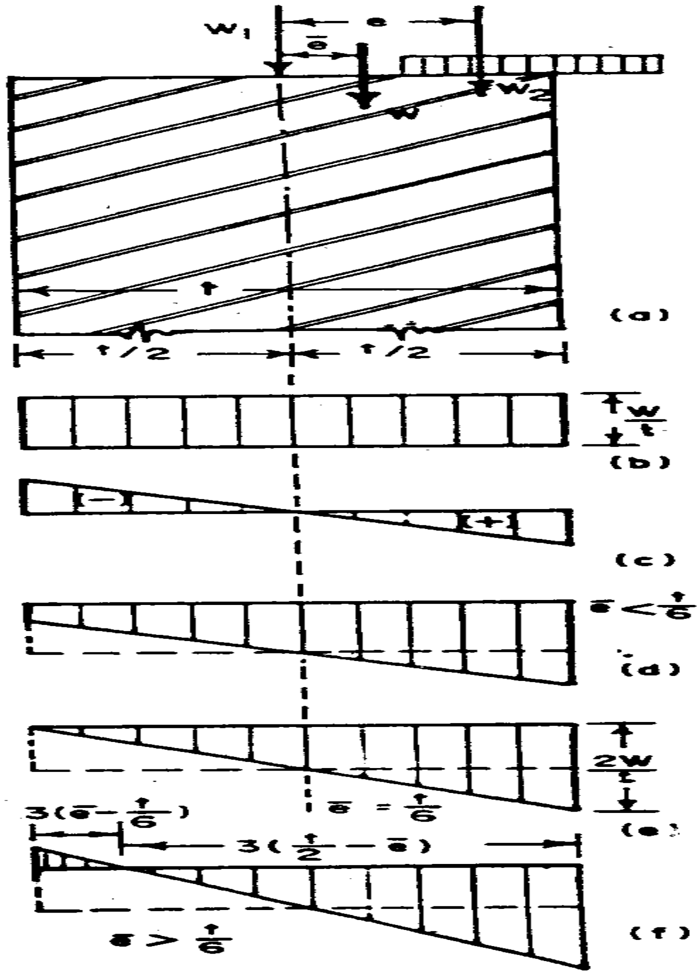
$$W . \bar{e} = W_1 \times 0 + W_2 \times e$$

(Where $W = W_1 + W_2$)

$$\therefore \quad \bar{e} = \frac{W_2 . e}{W_1 + W_2}$$

Code designates as the equivalent eccentricity.

The eccentric load will cause both axial stress (= W/t), and bending stress



Thus, the stress f at extreme fibres is given by

$\left(= \frac{W.\bar{e} \times 6}{t^2} \right).$

$$f = \frac{W}{t} \pm \frac{6\,W\bar{e}}{t^2}$$

or $$f = \frac{W}{t}\left(1 \pm \frac{6\,\bar{e}}{t}\right)$$

The total compressive stress fc at the extreme fibres of section AB is

$$f_c = \frac{W}{t} + \frac{W.\bar{e} \times 6}{t} = \frac{W}{t}\left(1 + \frac{6\,\bar{e}}{t}\right)$$

According to the code, additional stress due to bending could exceed the permissible compressive stress (axial) by 25 percent, provided stress due to axial loading does not exceed the permissible compressive stress. The provision leads us to :

$$\frac{W}{t} \times \frac{6\bar{e}}{t} \leq \frac{1}{4}\frac{W}{t}$$

which gives $$\frac{\bar{e}}{t} \leq \frac{1}{24}$$

This means that up to an eccentricity ratio of 1/24, bending stress need not be worked out. The permissible compressive stress will be basic stress multiplied by appropriate stress factor with zero eccentricity ratio.

Shape Factor

The shape factor takes into account the effect of the shape of the masonry unit (Le.., brick). The basic stresses (fb) are suitable when the units are of common brick shape, but may be unnecessarily low for some units whose ratio of height to thickness is greater than that of the common brick. For units of crushing strength not greater than 55 kg/cm^2 and with ratio of height to thickness as laid greater than 0.75 but not greater than 3, the basic stresses (fb) may be modified.

STRESS FACTORS (Ks) FOR SLENDERNESS RATIO AND ECCENTRICITY OF LOADING

S.No.	*Slenderness Ratio*	*Stress factors for equivalent eccentricity of loading divided by the thickness of members (i.e., $\bar{e}$ /t)*						
		0	0.04	0.1	0.2	0.3	0.33	0.50
1.	6	1.000	1.000	1.000	0.996	0.984	0.980	0.970
2.	8	0.920	0.920	0.920	0.910	0.880	0.870	0.850
3.	10	0.840	0.835	0.830	0.810	0.770	0.760	0.730
4.	12	0.760	0.750	0.740	0.706	0.664	0.650	0.600
5.	14	0.670	0.660	0.640	0.604	0.556	0.540	0.480
6.	16	0.580	0.565	0.545	0.500	0.440	0.420	0.350
7.	18	0.500	0.480	0.450	0.396	0.324	0.300	0.230
8.	21	0.470	0.448	0.420	0.354	0.276	0.250	0.170
9.	24	0.440	0.415	0.380	0.310	0.220	0.190	0.110

TABLE MODIFICATION FACTORS FOR SHAPE OF UNIT

Ratio of Height to width of brick or block	Factor
0.75	1.0
1.0	1.2
1.5	1.6
2.0 to 3.0	2.0

In the Draft British Standard for Masonry, concept of shape in modification factor has been changed and separate tables of basic stress have been given for varying values of height-to-width ratios. It is seen that for units of a particular strength, shape modification factor is more or less the same for various grades of mortar and this factor is very close to unity for units exceeding 150 kg/cm^2 (15 kN/mm^2) crushing strength.

TABLE REVISED SHAPE MODIFICATION FACTORS

Height to width ratio of units	Shape modification factors for units of crushing strength (kg/cm^2)			
	55	70	105	140
upto 0.75	1.0	1.0	1.0	1.0
1.0	1.2	1.1	1.1	1.0
1.5	1.5	1.3	1.2	1.1
2.0 to 4.0	1.8	1.5	1.3	1.2

Note 10 kg cm 1 N/mm^2

It is concluded that for units of strength greater than 140 kg/cm^2, effect of shape on stress is negligible and

Tensile Stress in masonry

For mortar not weaker than a 1:1:6 cement: lime sand mix or equivalent, the permissible tensile stress in bending shall not exceed 1 kg/cm^2. For weaker mortars, the designer should assume that, that part or section (upto which tensile stress is caused) will be inactive and the remainder will carry the compressive stress, Permissible shear stress.

In case of walls built in mortar not weaker than 1:1:6 cement : lime: sand mix and resisting horizontal forces in the plane of the wall, the permissible shear stress, calculated on the area of the horizontal mortar bed joint, shall be taken as 1.5 kg/cm^2.

CONCENTRATED LOAD

A wall has to support concentrated loads of girders, beams etc. supported on it. If the bearing area under a load does not exceed J of the total cross-sectional area of the member supporting the load, it may be termed as concentrated load. The above definition given in the of the Australian Code does not mention as to how to deal with a case when bearing is more than but less than 1. The City of New York Building Code gives some guidance in this regard and stipulates that allowable compressive stress provided the area of bearing does not exceed 1 of the area of member supporting the load and the least distance between the edges of the loaded and unloaded area is a minimum of the parallel side dimension of the loaded area. For bearing on the full area, the allowable bearing stress shall be taken as equal to the allowable compressive stress.

For reasonably concentric bearing areas greater than but less than full area, the allowable bearing stress shall be interpolated between 1.5 and 1.0 times the allowable compressive stress.

If the bearing stress in masonry wall is not within permissible limits, concrete bed block should be introduced below the load. to bring down the stress in masonry to safe limit. Width of the bed block is kept the same as thickness of wall and length is calculated such that stress in wall equals permissible stress. Maximum effective length of a bed block can be either centre to centre distance of concentrated loads or b + 41, whichever is less. Depth of bed block should be equal to its lengthwise projections from the bearing of load, which is, assuming 45° angle of dispersal of load within the bed block. Dispersion of Concentrated Load National Building Code of India (1970) puts no limit on the extent of dispersal of a concentrated load. However, it recommends that angle of dispersion shall not be taken greater than 45°. The City of New York Building Code stipulates that the length of a wall to be considered effective in resisting a concentrated load shall not exceed the centre to centre distance between the loads, nor shall it exceed the width of the bearing plus four times the wall thickness. It is further clarified by Amrhein that even when a bearing plate is provided under the concentrated load, maximum length of wall for distribution of concentrated load cannot exceed bearing plus 4 times the thickness of wall.

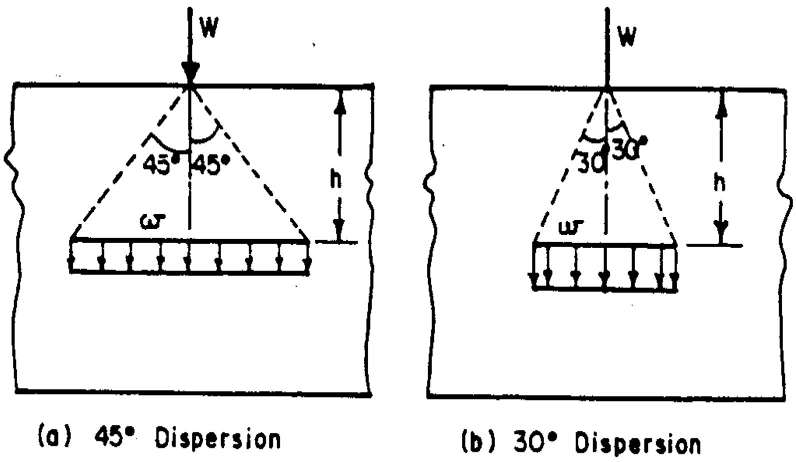


FIG. DISPERSION OF CONCENTRATED LOAD IN MASONRY.

Brick Institute of America recommends dispersal angle of 30° based on results of research in USA which is in agreement with German and Swiss thinking on this subject. For our Code, dispersal angle of 30° would be more appropriate since strength of bricks in India is rather low, resulting in less arching ad load on lintels.

MORTAR SELECTION

Requirements of a good mortar for masonry are strength, workability, water and low drying shrinkage. A strong mortar will have adequate crushing strength as well as adequate tensile and shear strength. It is necessary that mortar should attain initial set early enough to enable work to proceed at a reasonable pace. At the same time it should gain strength within reasonable period so that masonry is in a position to take load early. A workable mortar will hang from the trowel and will spread easily. A mortar with good water not readily loose water and stiffen on coming in contact with masonry units, and will remain plastic long enough to be easily adjusted in line and level. This property of good water will enable the mortar to develop good bond with masonry units, so that masonry has adequate resistance against rain penetration.

Mortars could be broadly classified as cement mortars, lime mortars and cement-lime mortars. Cement mortars set early and gain strength quickly. Rich cement mortars, though having good strength have high shrinkage and are more liable to cracking. Lime mortars gain strength slowly and have low ultimate strength. The main advantage of lime mortar lies in its good workability, good water and low shrinkage. Cement-lime mortars have the good qualities of cement as well as lime mortars, that is, medium strength along with good workability, good water freedom from cracks and good resistance against rain penetration.

Mix proportions and compressive strength of some of the commonly used mortars. In this table, letter H stands for high strength, M for medium strength and L for low strength mortars.

It has been stated earlier that mortar strength shall in general not be greater than that of the masonry unit. A unnecessarily strong mortar concentrates the effect of any differential movement of masonry in fewer and wider cracks while a weak mortar (mortar having more of lime and less of cement will accommodate movements and cracking will be distributed as thin hair cracks which are less noticeable. Also, stresses due to expansion of masonry units are reduced, if a weak mortar is used.

S.No.	Mix			Minimum compressive strength		Mortar Type
	Cement	Lime	Sand	Kg/cm^2	N/mm^2	
1.	1	$0-\frac{1}{4}$C	3	100	10	H 1
2 (a).	1	0	4	75	7.5	H 2
2 (b).	1	$\frac{1}{2}$C	$4\frac{1}{2}$	60	6	
3 (a).	1	0	5	50	5	M 1
3 (b).	1	1C	6	30	3	
4 (a).	1	0	6	30	3	M 1
4 (b).	1	2C	9	20	2	
4 (c).	0	1A	2 – 3	20	2	
5 (a).	1	0	8	7	0.7	L 1
5 (b).	1	3C	12	7	0.7	
6.	0	1 B or C	2 – 3	5	0.5	L 2

Note : A,B,C denote eminently hydraulic lime, semi-hydraulic lime and fat lime respectively, as stipulated in Indian Standards.

It is preferable to use composite mortars of cement, lime and sand, in appropriate proportions. Fig. based on BSR Digest 61 (second series), illustrates the relation between strength of mortar and brick-work for a number of mortar mixes when bricks of medium strength are used. As the proportion of lime in mortar is increased, though mortar looses strength, reduction in strength of brick work is not much. The strengths are relative to the strength of a 1:3 cement-sand mortar and the brickwork built with it.

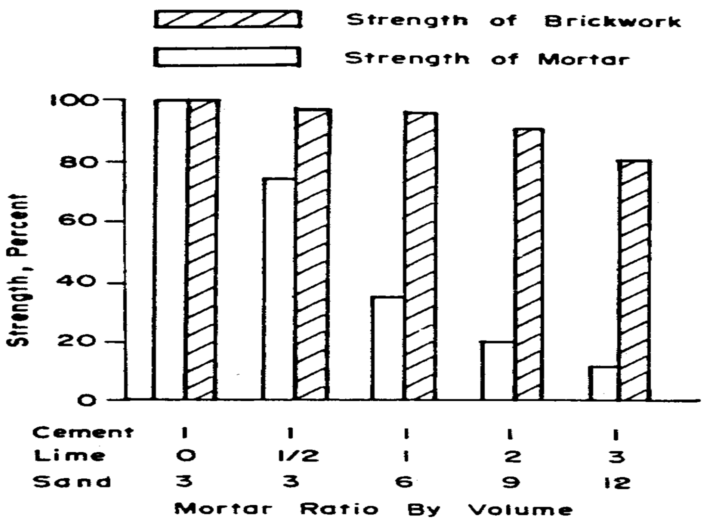


FIG. EFFECTS OF MORTAR MIX PROPORTIONS (MORTAR RATIO BY VOLUME)

OPTIMUM MORTAR MIXES FOR MAXIMUM STRENGTH WITH BRICKS OF VARIOUS STRENGTHS

	Brick Strength (kg/cm^2)	Mortar Mix (By Volume) Cement : Lime : Sand	Mortar Type
1.	Below 50	1 : 0 : 6 1 : 2 C : 9 0 : 1 A : 2–3	M2
2.	50 – 149	1 : 0 : 5 1 : 1 C : 6	M1
3.	150 – 249	1 : 0 : 4 1 : $\frac{1}{2}$ C : $4\frac{1}{2}$	H2
4.	250 or above	1 : 0 – $\frac{1}{4}$C : 3	H1

PARTITION WALLS

A partition wall is a thin internal wall which is constructed to divide the space within the building into rooms or areas. A partition wall may be either non-load-bearing or load-bearing. Generally, partition walls are non-load bearing. A load-bearing partition wall is called an internal wall. For a load-bearing internal wall, strength is an important factor of design; a partition, on the other hand, need only be strong enough to support itself under normal conditions of service. Weather exclusion and thermal insulation do not arise as criteria in the design of internal walls. However, sound insulation is an important requirement. A partition wall, separating two adjoining rooms must often provide a barrier to the passage of sound from one to another. An additional requirement in all partition walls is their capacity to support a surface suitable for decoration and which is able to withstand the casual damage by impact to which the occupation of the building is likely to subject them. On ground floors, partitions rest either on flooring concrete or on beams spanning between the main walls. In multi-storeyed buildings, partitions are supported on concrete beams spanning between columns. The total self weight of partitions may considerably affect the total load carried on the frame work and on the foundations. The lighter the partitions, the lighter and smaller will become the structural elements, and the building as a whole will become more economical. The thickness of partitions will affect the amount of usable floor space available in the building. However, light and thin partitions often raise problems of sound insulation and fire resistance.

Requirements to be fulfilled

To summaries, a partition wall should fulfill the following requirements

1. The partition wall should be strong enough to carry its own load.
2. The partition wall should be strong enough to resist impact to which the occupation of the building is likely to subject them.
3. The partition wall should have the capacity to support suitable decorative surface.
4. A partition wall should be stable and strong enough to support some wall fixtures, wash-basins etc.
5. A partition wall should be as light as possible.
6. A partition wall should be as thin as possible.
7. A partition wall should act as a sound barrier, specially when it divides two rooms.
8. A partition wall should be fire resistant.

Types of partition walls

Partition walls are of the following types :

1. Brick partitions.
2. Clay blocks partitions.
3. Concrete partitions.

4. Glass partitions.
5. Metal lath partitions.
6. Asbestos sheet or G.I. sheet partitions.
7. Plaster slab partition.
8. Wood-wood slab partition.
9. Timber partitions

BRICK PARTITIONS

Brick partitions are quite common since they are the cheapest. Brick partitions are of three types

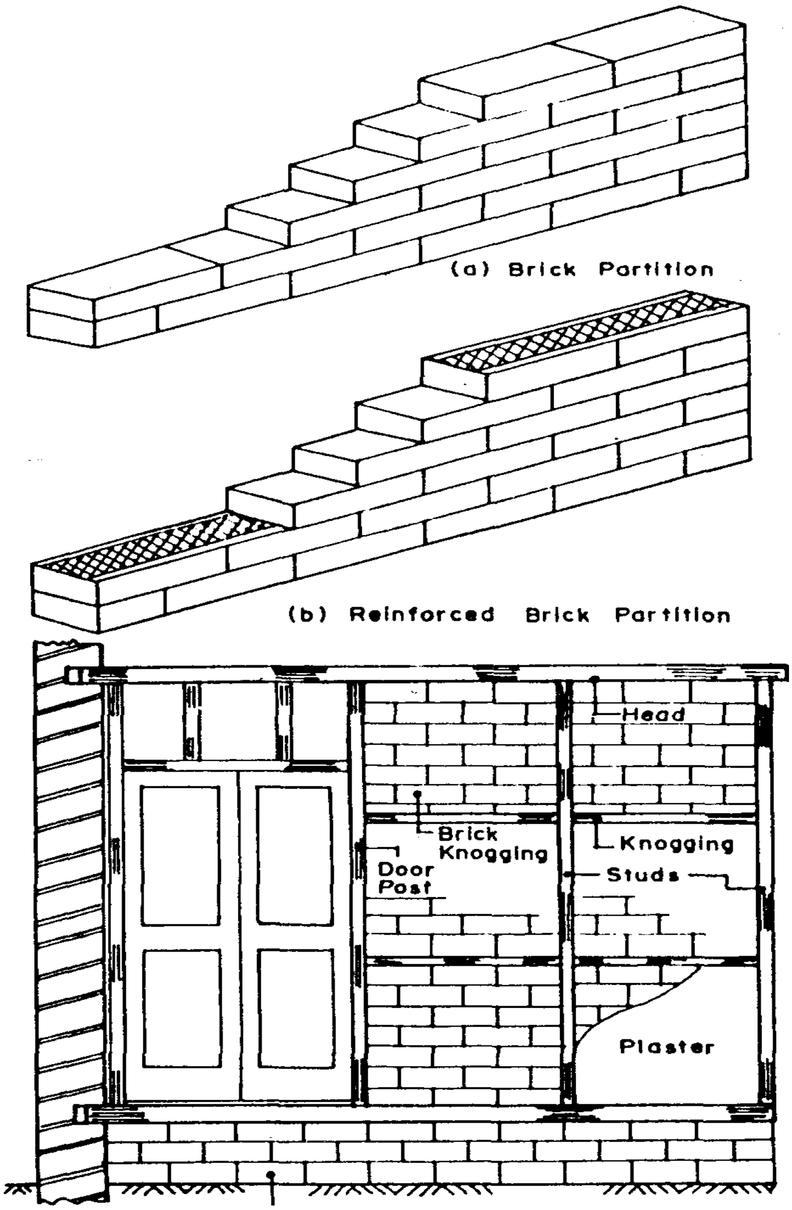
1. Plain brick partitions
2. Reinforced brick partitions.
3. Brick nogging partitions.

Plain Brick Partitions

Plain brick partitions are usually half brick thick. The bricks arc laid as stretchers, in cement mortar. Vertical joints are staggered alternate blocks. The wall is plastered on both the sides. The wall is considerably strong and fire resistant.

Reinforced Brick Partitions

These are stronger than the ordinary brick partitions, and is used when better longitudinal bond is required, and when the partition wall has to carry other super-imposed loads. The thickness of the wall is kept equal to half brick (10 cm). The reinforcement consists of steel meshed strips, called Exmet, made from thin rolled steel plates which are cut and stretched (or expanded) by a machine to a diamond network. Such a strip is known as expanded metal and is provided at every third course. Another form of meshed reinforcement, called Bricktor is made of a number of straight tension wires with binding wires Figure.



(C) Brick knogging Partition

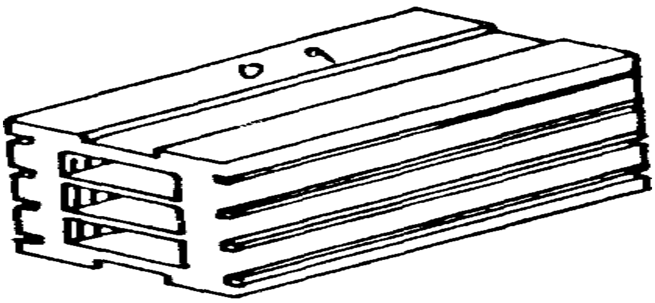
FIG BRICK PARTITION WALLS.

Brick Knogging Partitions

Brick knogging partition wall consists of brick work (half brick thickness) built up within the frame work of wooden members. The timber frame work consists of (i) sill, (ii) head, (iii) vertical members, called studs, and (iv) horizontal members called nogging pieces. The vertical members or studs are spaced at 4 to 6 times the brick length. The nogging pieces are housed into the studs at vertical interval of 60 to 90 cm. The framework provided stability to the partition against lateral loads and vibrations caused due to opening the adjoining door. The brick work is plastered on both the sides. The bricks are usually laid flat, but they may be laid on edge also. Cement mortar, 1 :3 is used. The surface of the timber frame work coming into contact with brick work is coated with coal tar.

CLAY BLOCK PARTITION WALLS

The blocks used for such partition wall are prepared from clay or terra-cotta, and they be either solid or hollow. For light partitions, hollow clay blocks are commonly used. They are good insulators for heat and sound. They are also fire resistant. The hollow clay blocks are usually 30 cm long, 20 cm high and 5 to 15 cm wide. The blocks are provided with grooves on top, bottom and sides. Grooves provide rigid joints, and serves as key to plaster. The blocks are laid in cement mortar.



HOLLOW CLAY BLOCK.

CONCRETE PARTITIONS

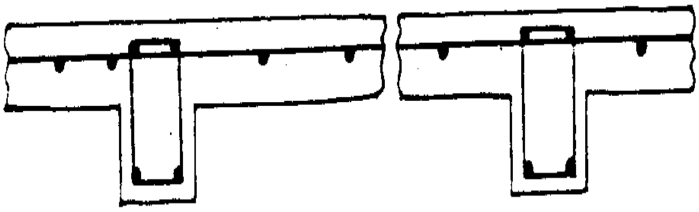
A concrete partition consists of concrete slabs, plain or reinforced, supported laterally between vertical members. These slabs may be either precast or cast-in-situ.

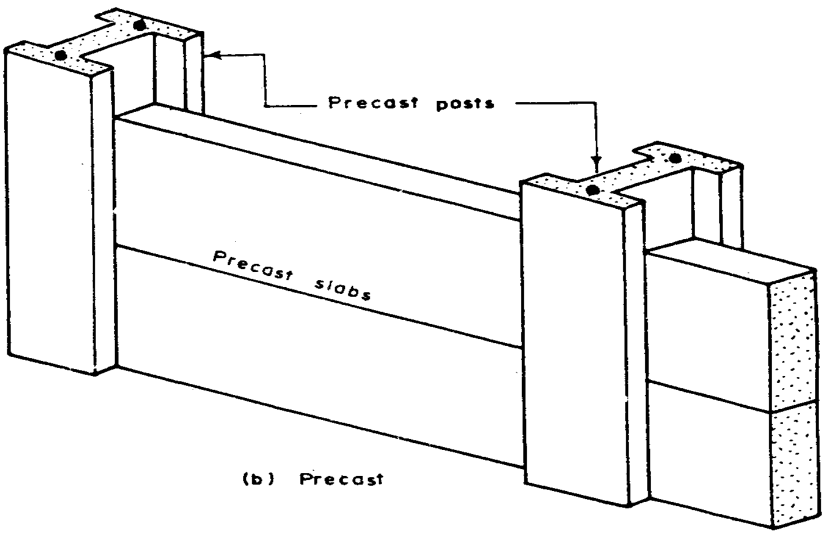
Cast-in-situ concrete partitions are usually 80 to 100 mm thick, cast monolithically with the intermediate columns. Such partitions are rigid and stable along both vertical and horizontal directions. However, such partitions require costlier form work.

Pre-cast slab units are commonly used for partitions. These slabs may be quite thin (25 mm to 40 mm) and are secured to precast posts. Concrete mix usually adopted is M 150 (1:2:4). The joints are filled with cement mortar.

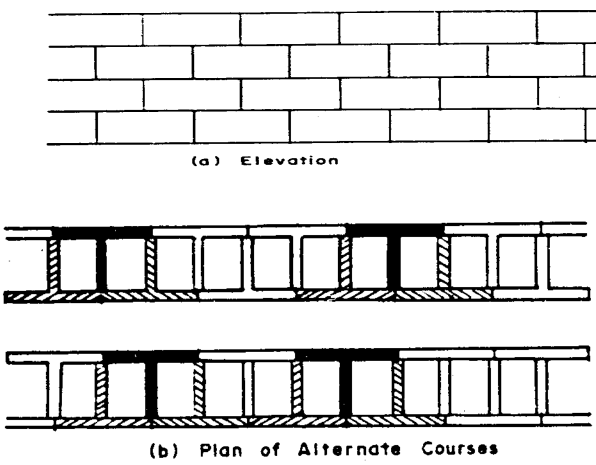
Another form of concrete partition is made from precast T-shaped or L-shaped units. A light weight, hollow partition is obtained, without any necessity of vertical post etc. Cement mortar (1:3) is used for jointing.

Notes





CONCRETE PARTITION WALL



PRECAST CONCRETE UNITS

GLASS PARTITIONS

Glass partition walls are constructed using either glass sheets or hollow blocks.

(a) Glass sheet partition

In this, a wooden frame work is used in which glass sheets are fixed. The wooden frame work consists of a number of horizontal and vertical posts, suitably spaced, to divide the entire area into a number of panels. The glass sheets are kept in position in the panels either by using timber headings or by putty which is made of linseed oil and whiting chalk. Such partitions are light weight, vermin-proof, sound-proof and damp-proof. However, ordinary glass is quite weak, and require frequent replacement. Nowadays, strong varieties of glass, such as wired glass, bullet-proof glass and three-ply glass are also available.

(b) Hollow Blocks

Hollow glass blocks are translucent units of glass, which arc light in weight and are available in different sizes and shapes and

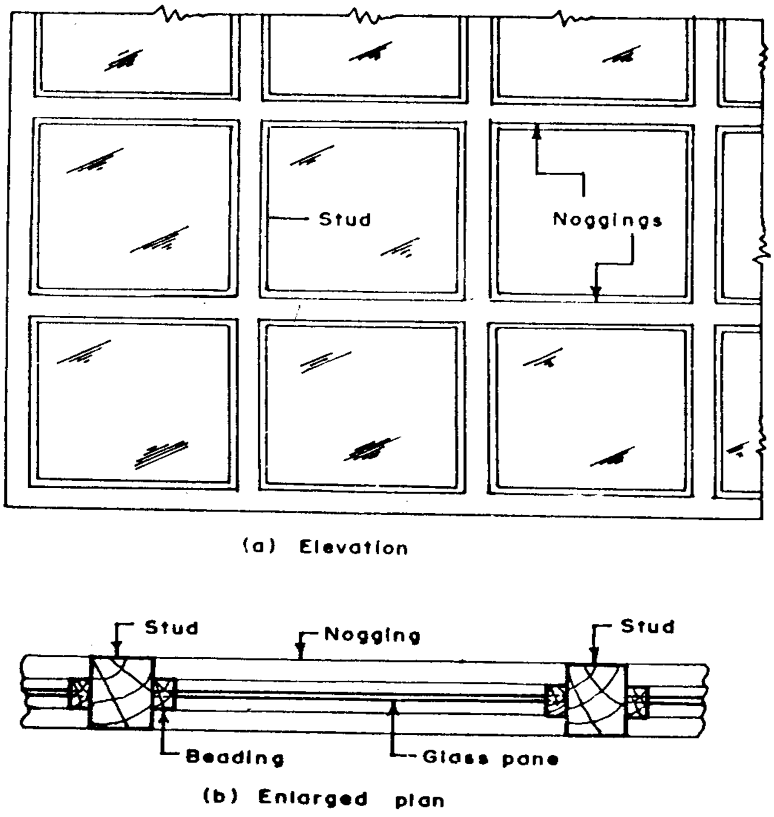
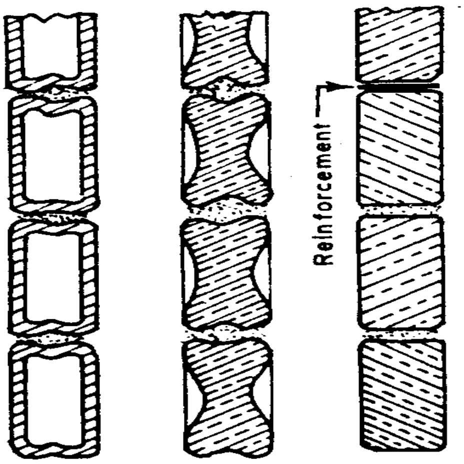
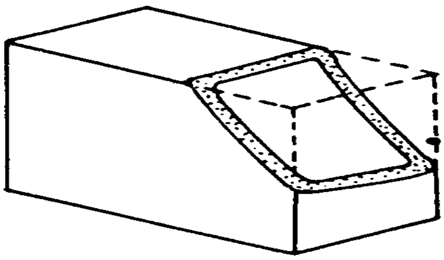


FIG GLASS PARTITION.

thicknesses. They are usually square (14 xl4 cm or 19x19 cm), with a normal thickness of 10 cm. The jointing edges are painted internally and sanded externally to form a key for mortar. The front and back faces may be either decorative or plain. The front and back faces are sometimes fluted. The glass blocks are usually laid in cement-lime mortar (1:1:4), using fine sand. All joints should be filled carefully. For blocks upto 15 cm in height, expanded metal strip reinforcement is placed in every third or fourth course. If the



(a) Glass Block Walls



(b) Hollow Glass Block

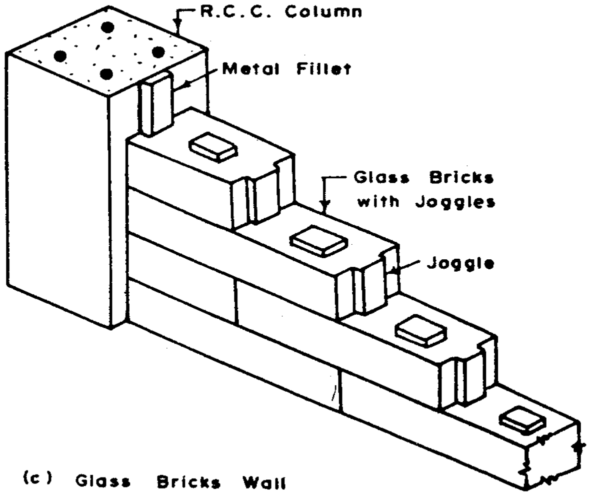


FIG. GLASS BLOCK AND GLASS BRICKS WALLS.

height of the block is more than 25 cm, the reinforcement is placed in every course. Provision for expansion should be suitably made along the jambs and head of each panel.

Another type of glass blocks are in the form of glass bricks with joggles and end grooves.

Glass blocks or glass bricks walls provide good architectural effect and also admit light. They are sound-proof, fire-proof and heat-proof to some extent.

METAL LATH PARTITIONS

Metal lath partition walls are constructed by placing 2 cm or 2.5 cm channels vertically (called studs) and fixing metal lath to it on one side. Plaster is then applied to both the sides. The channels are spaced 15 to 30 cm apart. Metal lath is tied to channels by galvanized iron wire. The channels are fixed to the floor and roof by driving holes. The thickness of such partition may vary between 5 and 7.5 cm.

If hollow partition wall is required, metal lath is fixed to the channels on both the sides and then plastering them. For thicker hollow walls, built-up channels, consisting of channels braced by flat iron strips are used. Metal lath partitions are thin, strong, durable and considerably fire resistant.

Notes

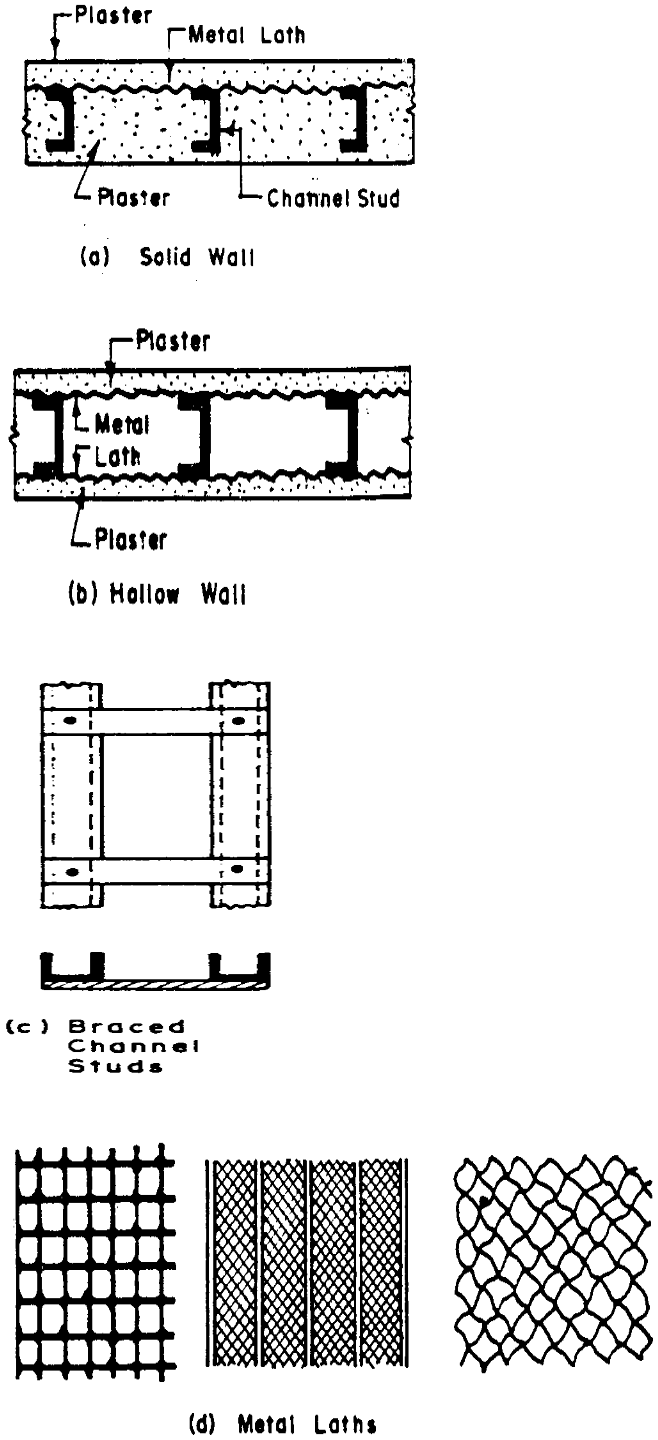


FIG. METAL LATH PARTITIONS

FIG. ASBESTOS SHEET OR G.I. SHEET PARTITIONS

Asbestos sheet or G.I. sheets can be fixed to suitable frame of wood, to act as partition wall. The sheets can be fixed either to one side of the frame, or to both the sides. Such partitions are economical, light weight and fairly strong.

A better form of partition is made from patented slabs of asbestos cement. One such form has two plain sheets (10 mm) are attached to an inner corrugated sheet (5 mm). The sheets are jointed by cement mortar. Such partitions are more fire resistant, and provides insulation against heat and sound. Galvanized corrugated sheets can also be used in place of asbestos corrugated sheets.

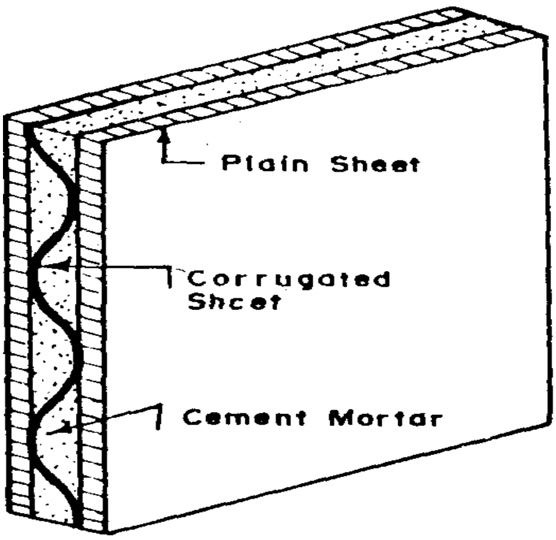


FIG. ASBESTOS CEMENT SLABS.

PLASTER SLAB PARTITIONS

Plaster slabs or plaster boards are made from burnt gypsum or plaster of Paris, mixed with sawdust or other fibrous material to reduce its weight. They are cast in moulds, of size 1 to 2 m long, 30 cm high and 50 to 100 mm thick. Hollow slabs of greater thickness are also cast. Such slabs are light weight and have insulating properties against heat and sound. The surfaces of these slabs may be smooth or rough. Rough surfaces serve as key for plaster. Smooth surfaces are not plastered.

WOOD WOOL SLAB PARTITIONS

Wood wool consist of long, tangled, wood fibres, uncompacted, coated and bound together with cement or plaster, and with a rough open surface which provides an excellent key for plaster. Such partitions have sufficient heat and sound insulating properties. They are available in different trade names. The unit weight of such slabs is only 480 kg/m^2; thus such partitions are extremely light weight. Slabs can be sawn and nailed. Vertical mortar joints between the slabs should be staggered. However, wood-wool slabs have a large movement due to changes in moisture content. Such movement must be properly restrained. Care must be taken at the heads of openings to preserve a crack-free plaster finish.

TIMBER PARTITIONS

Timber partitions consist of wooden frame work, properly supported on floor and fixed to the side walls. This frame work, made of horizontal and vertical members, can either be plastered or covered with boarding etc. from both the sides. Wooden partitions are light weight, but are costlier. It is likely to decay, or eaten away by termites. Also, it is not fire resistant. It's use is reducing day by day.

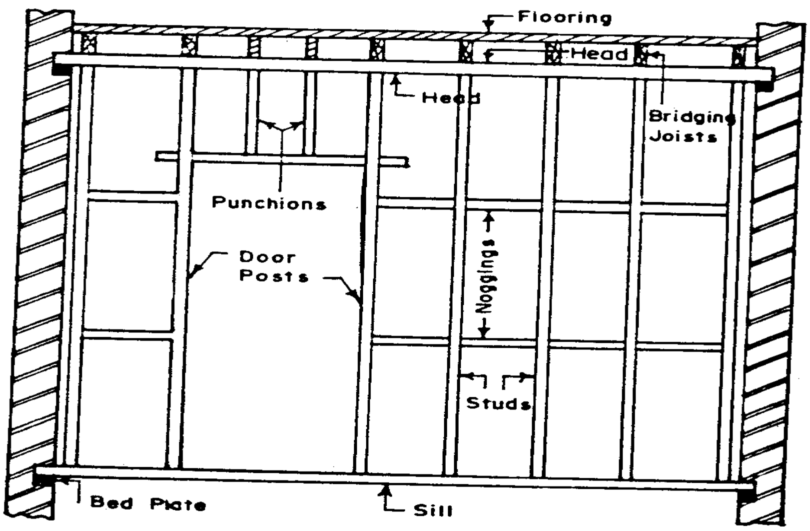
Two types of wooden partitions may be used :

(i) Common or stud partition.

(ii) Trussed or braced partition.

1. Common or stud partition

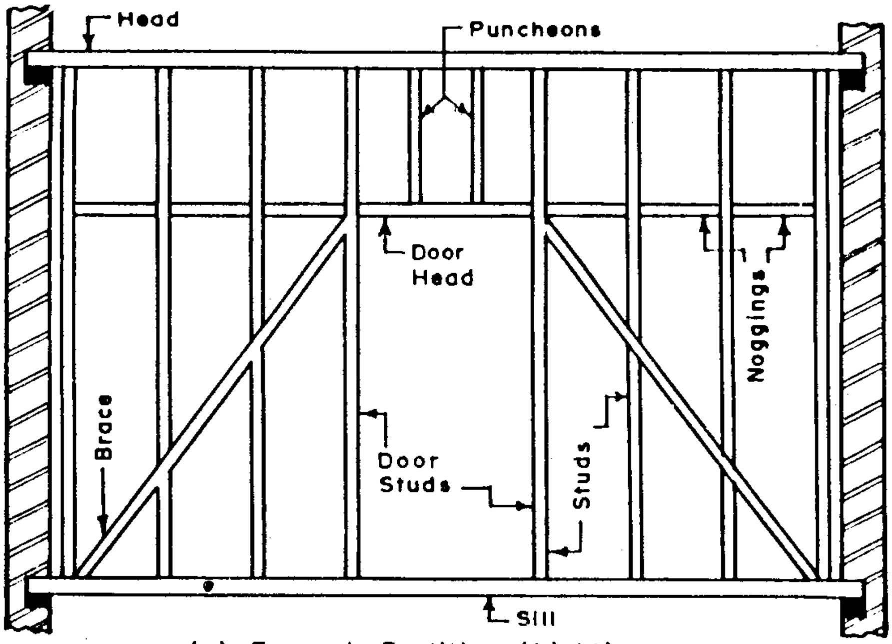
It consists of a framework of vertical members(called studs),and short horizontal pieces, called naggings. Horizontal pieces impart rigidity to studs. A stud of short length, such as the one provided on an opening, is called, puncheon. The upper and lower horizontal members of the frame are known as head and sill respectively. The studs, 10 cm x 5 cm in section, are spaced 30 to 45 cm apart. Nogging pieces are cut tightly and fixed between the studs and nailed. The head and sill are 10 cm x 75 mm in section.



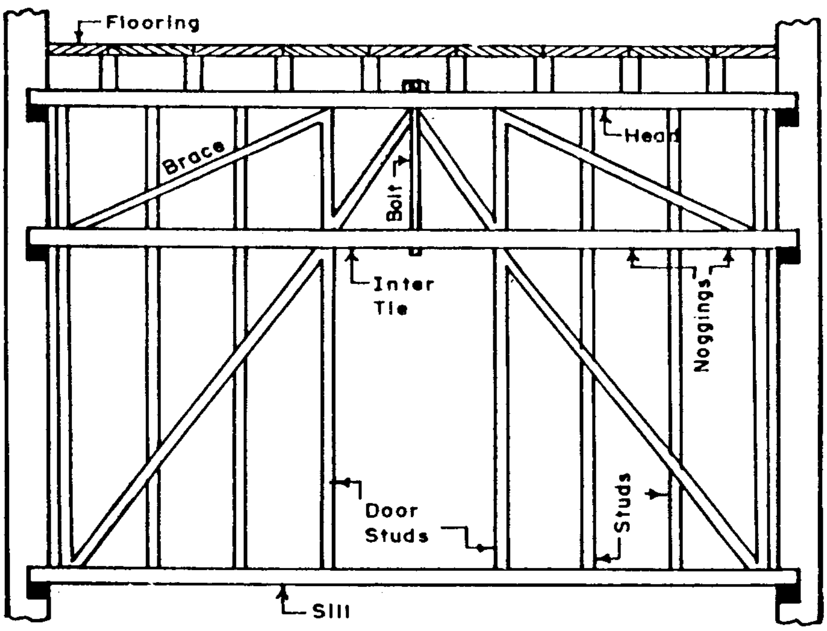
COMMON OR STUD PARTITION

2. Trussed or braced partitions

Such partitions are provided where there is no means of supporting the partition except at their ends. The frame work is similar



(a) Trussed Partition (Light)



(b) Trussed Partition (Heavy)

TRUSSED PARTTION

to the stud partition, but inclined members called braces, and steel straps and bolts are additionally used. Sometimes, such partitions carry floor load also, in addition to its own weight. For more rigidity and strength, an additional horizontal member, known as inter-tie is provided between head and sill. The ends of head and sill are made to rest on stone template embedded in the wall. Because of trussed action, tension may be developed at some joints. Hence steel straps or steel bolts are provided at all joints.

FLOORS

GROUND FLOORS :

The purpose of a floor is to provide a level surface capable of supporting the occupants of a building, furniture, equipment and sometimes, internal partitions. To perform this function, and in addition, others which may vary according to the situation of the floor in the building and the nature of the building itself, a floor must satisfy the following requirements :

(1) Adequate strength and stability

(2) Adequate fire resistance.

(3) Sound insulation

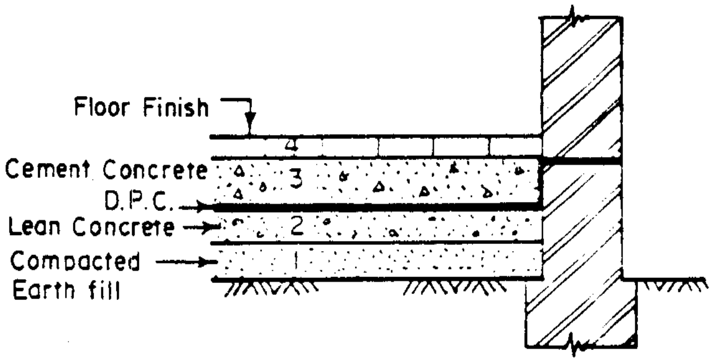
(4) Damp resistance and

(5) Thermal insulation.

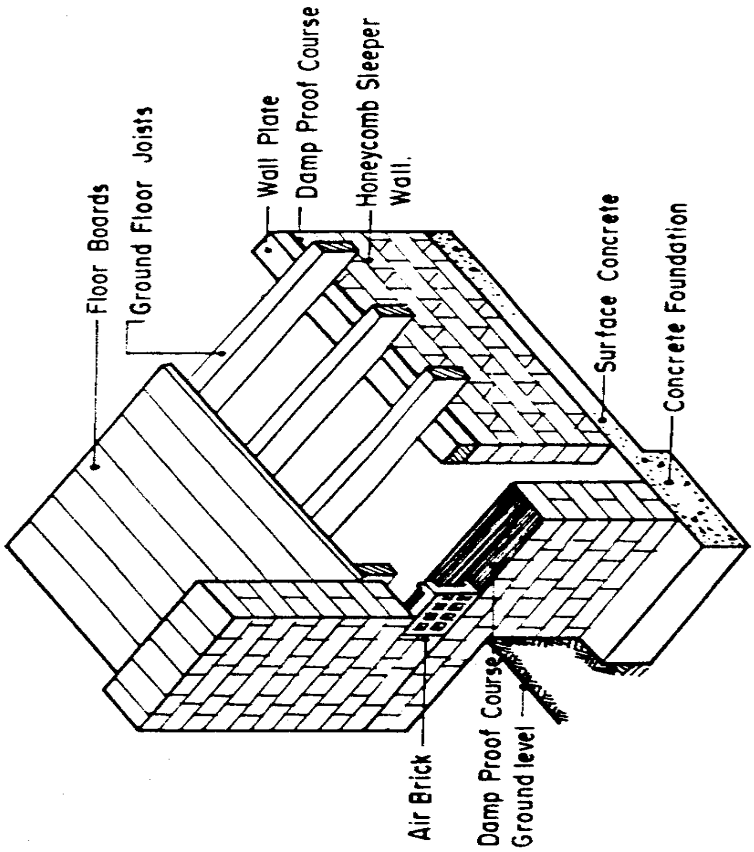
The floors resting directly on the ground surface are known as ground floors, while the other floors of each storey, situated above the ground level are known - as upper floors.

The problems of strength and stability are usually minor ones at ground and basement levels since full support from the ground is available at all points. However, major problem of ground floors is damp exclusion and thermal insulation. Moisture is generally present in the ground, which may pass into the building through the floor unless measures are taken to check it.

The upper floors have the major problems of strength and stability since they are supported only at their ends, on walls, beams etc. The structural design of a floor has to be such as to support the loads set up by the use of the building, in addition to the self weight and the weight of partitions etc. Upper floors do not have problems of damp resistance, though sound insulation is generally an important factor in the design. The problem of fire resistance does not arise for the lowest floor of a building, but is often important for upper floors.



SOLID GROUND FLOOR



SUSPENDD TIMBER GROUND FLOOR

COMPONENTS OF A FLOOR

A floor is composed of two essential components :

(i) Sub-floor, base course or floor base

(ii) Floor covering, or simply, flooring.

The floor base is a structural component, which supports the floor covering. For the ground floors, the object of floor base is to give proper support to the covering so that it does not settle, and to provide damp resistance and thermal insulation.

Ground floors may either rest directly on the ground, or may be supported a little distance above the ground. The floors supported directly on the ground are known as solid floors while the floors supported above the ground level are called suspended floors. Suspended floors are generally made of timber.

MATERIALS FOR CONSTRUCTION

Materials used for construction of ground floor base are :

(1) Cement concrete

(2) Lime concrete

(3) Stones

(4) Bricks

(5) Wooden blocks (for wooden flooring only).

The floor base for a solid ground floor. The lowest layer, just above ground surface is that of compacted earth fill. The second layer may either of lean cement concrete or lime concrete or sometimes broken brick bats or stones rammed properly. The third course may be either of cement concrete or of bricks or stones arranged and packed properly. The third layer of cement concrete is more common since it gives proper rigidity to the floor base. Over the third layer of floor base, floor finish or flooring is laid.

The materials used for floor finish or floor covering or flooring are :

1. Mud and Muram
2. Bricks
3. Flag stones

9. Granolithic finish
10. Wood or timber
11. Asphalt

4. Concrete
5. Terrazzo
6. Mosaic
7. Tiles
8. Marble
12. Rubber
13. Linoleum flooring
14. Cork
15. Glass ,
16. Plastic or P.V.C.

SELECTION OF FLOORING MATERIAL

Following are the factors that affect the choice of a flooring materials :

1. Initial Cost. The cost of the material should be in conformity with the type of building, and its likely use. Floor coverings of marble etc. are very costly and may be used only for residential buildings.

2. Appearance. Covering should give pleasing appearance, i.e.., it should produce a desired colour effect and architectural beauty. Floorings of terrazzo, mosaic, tiles and marble give good appearance.

3. Cleanliness. The flooring should be capable of being cleaned easily, and it should be non-absorbent. It should have effective resistance against absorption of oil, grease etc.

4. Durability. The flooring should have sufficient resistance to wear, temperature changes, disintegration with time and decay, so that long life is obtained. From this point of view, flooring of marble, terrazzo, tiles, concrete, mosaic etc. are considered to be of best type.

5. Damp resistance. Flooring should offer sufficient resistance against dampness, so that healthy environment is obtained in the building. Flooring of concrete, terrazzo, mosaic etc. are preferred for this purpose, while flooring of cork, wood, rubber, linoleum,, brick etc. are not suitable for damp conditions.

6. Sound Insulation. Flooring should insulate the noise. Also, it should not be such that noise is produced when users walk on it. Cork flooring, rubber flooring and timber flooring are good from this point of view.

7. Thermal Insulation. The flooring should offer reasonably good thermal insulation so that ccwnfort is imparted to the residents of the building. Floor covering of wood, rubber, cork, P.V.C. tiles are better for this purpose.

8. Fire resistance. This is more important for upper floors. Flooring material should offer sufficient fire resistance so that fire barriers are obtained between different levels of a building. Concrete, tiles, terrazzo, mosaic, marble have good fire resistance. Cork, asphalt, rubber and P.V.C. coverings, if used, should be laid on fire resistance base only.

9. Smoothness. The flooring material should be smooth, and should have even surface. However, it should not be slippery.

10. Hardness. It should be sufficiently hard so as to have resistance to indentation marks, imprints etc. likely to be caused by shifting of furniture, equipment etc.

11. Maintenance. The flooring material should require least maintenance. However, whenever repairs are required, it should be such that repairs can be done easily, with least possible expenditure. Hard coverings like tiles, marble, terrazzo, concrete etc. require less maintenance in comparison to materials like cork, wood etc.

MUD FLOORING AND MURAM FLOORING

Mud and Muram floorings are used only in low cost housing, specially in villages.

Mud flooring. Such flooring is cheap, hard, fairly impervious, easy to construct and easy to maintain. It has good thermal insulation property due to which it remains cool in summer and fairly warm in winter. The method of construction is very easy. Over a well-prepared ground, a 25 cm thick selected moist earth (mostly impervious) is spread and is then rammed well to get a compacted thickness of 15 cm. In order to prevent cracks due to drying, small quantity of chopped straw is mixed in the moist earth, before ramming. Sometimes, cow-dung is mixed with earth and a thin layer of this mix is spread over the compacted layer. Sometimes, a thin paint of cement-cow-dung (1:2 to 1:3) is applied.

Muram flooring. Muram is a form of disintegrated rock with binding material. This flooring has practically the same properties as that of mud flooring. To construct such a floor, a 15 cm thick layer of muram is laid over prepared subgrade. Over it, a 2.5 cm thick layer of powder muram (fine muram) is spread and water is sprinkled over it. The surface is then rammed well. After ramming, the surface is saturated with a 6 mm thin film of water. The surface is well-trampled under the feet of workmen till the cream of muram rises to the top. The surface is levelled and then kept in that state for a day, and then rammed again with wooden rammers called thapies for 3 days, so that dry hard surface is formed. This surface is then smeared or rubbed with thin paste of cow-dung and rammed again for two days, during morning hours. Finally, a coating of mud-cow-dung mix or cement-cow-dung mix is applied over the surface.

BRICK FLOORING

Such flooring is used in cheap construction, specially where good bricks are available. This flooring is specially suited to ware-

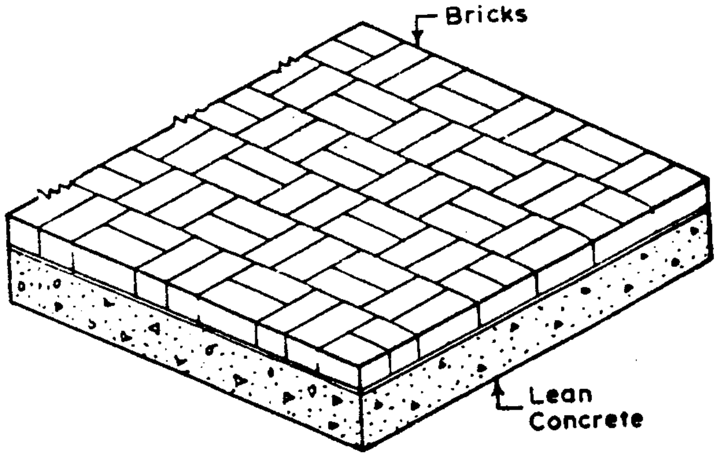


FIG BRICK FLOORING

houses, stores, godowns etc. Well-burnt bricks of good colour and uniform shapes arc used. Bricks are laid cither flat or on edge, arranged in herring bone fashion or set at right angles to the walls, or set any other good looking pattern.

The method of preparing the base course for brick flooring varies from place to place. In one method, the sub-grade is compacted properly, to the desired level, and a 7.5 cm thick layer of sand is spread. Over this, a course of bricks laid flat in mortar is built. This forms the base course, over which the brick flooring is laid in 12 mm thick bed of cement or lime mortar, in the desired pattern. In the second method, 10 to 15 cm thick layer of lean cement concrete (1 : X: 16) or lime concrete is laid over the prepared sub-grade. This forms the base course, over which bricks are laid on edge (or flat) on 12 mm thick mortar bed in such a way that all the joints arc full with mortar. In both the cases, the joints are rendered flush and finished. The work is then properly cured.

FLAG STONE FLOORING

Flag stone is any laminated sand stone available in 2 cm to 4 cm thickness, in the form of stone slabs of square (30 cm x 30 cm, 45 cm x 45 cm or 60 cm x 60 cm) or rectangular size (45 x 60 cm). This type of work is also called paving. The stone slabs are laid on concrete base. The sub-soil is properly compacted, over which 10 to 15 cm thick lime concrete or lean cement concrete is laid. This forms the base course of the floor. The flag stones (stone slabs) are then laid over 20 to 25 mm thick layer of bed mortar. In laying the slabs, work is started from two diagonally opposite corners and brought up from both sides. A string is stretched between two corner slabs laid first to correct level. Other slabs are then so laid that their tops touch the string. If any particular slab

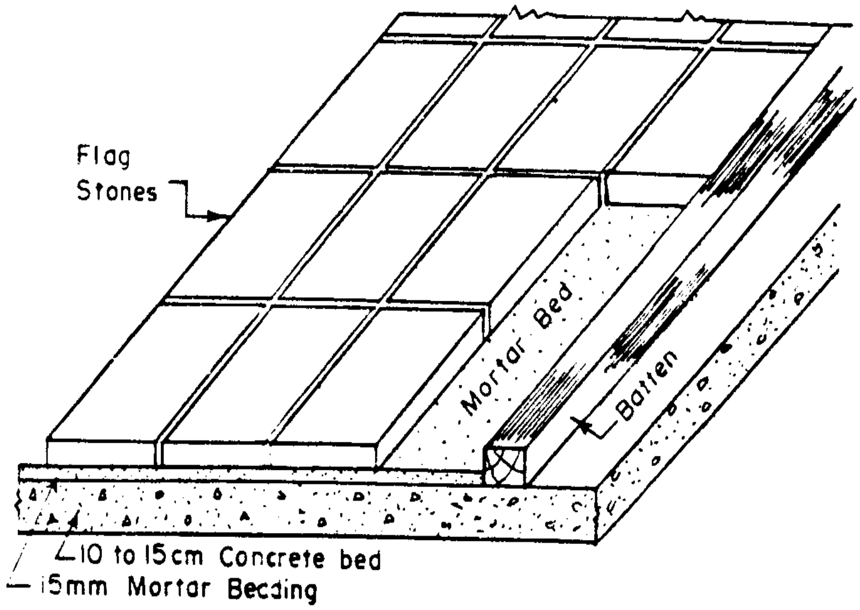


FIG FLAG STONE FLOORING

falls lower than the string level, it is re-laid by putting fresh layer of stiff mortar. When the stone slabs are properly set, mortar in the joints is raked out to a depth of about 15 to 20 mm and then flush pointed with 1:3 cement mortar. Proper slope is given to the surface for drainage. The work is properly cured.

CEMENT CONCRETE FLOORING

This is commonly used for residential, commercial and even industrial building, since it is moderately cheap, quite durable and easy to construct. The floor consists of two components: (i) base concrete, and (ii) lopping or wearing surface. The two components of the floor can be constructed cither monolithically (i.e. topping lay immediately after the base course is laid) or non-monolithicaily. When the floor is laid monolithically, good bond between the two components is obtained resulting in smaller over all thickness. However such a construction has three disadvantages: (iii) the topping is damaged during subsequent operations, (iv) hair cracks arc developed because of the settlement of freshly laid base course which has not set, and (v) work progress is slow because the workman has to wait at least till the initial setting of the base course. Hence in most of the cases, non-monolithic construction is preferred.

The base course may be 7.5 to 10 cm thick, cither in lean cement concrete (1:3:6 to 1:5:10) or lime concrete 40% mortar of 1 : 2 lime-sand (or 1 lime : 1 surkhi: 1 sand) and 60% coarse aggregate of 40 mm nominal size. The base course is laid over well-compacted soil, compacted properly and levelled to rough surface. It is properly cured.

When the base concrete has hardened, its surface is brushed with stiff broom and cleaned thoroughly. It is welled the previous night and excess water is grained. The topping is then laid in square or rectangular panels, by use of either glass or plain asbestos strips or by use of wooden battens set on mortar bed. The panels be 1x1 m, 2 x 2 m or 1x2 rn in size. The topping coiisis;s of 1:2:4 cement concrete, laid to the desired thickness (usually 4 cm) in one single operation in ti.c panel. Alternate panel's arc laid first. Prior to laying the concrete in the panel, a coat of neat cement slurry is applied. This cement slurry laid on rough-finished base course ensures proper bond of topping with the base course. Glass strips or battens should hive depth equal to thickness of topping. Tapping concrete is spread evenly with the help of a straight edge, and its surface is thoroughly tamped and floated with wooden floats till the cream of concrete comes at the top. Steel trowel is used for something and finishing the top surface. Further troweling is done when the mix has stiffened of the surface with neat cement and then toweling results in smooth the top. Other alternate layers are then laid after 72 hours, so that initial shrinkage of already laid panels take place, thus eliminating the cracks. The prepared surface is protected from sunlight, rain, other damages for 12 to 20 hours. The surface is then properly cured for a period of 7 to 14 days. When monolithic construction is laid, the topping is laid 1 hour to 4 hours after placing the base concrete.

Granolithic finish In industrial building, hard wearing surface is sometimes required. This can be achieved by applying granolithic finish over the concrete topping described above. Granolithic finish consists of rich concrete made with very hard and tough quality coarse aggregate (such as granite, basalt, quartzite etc.) graded from 13 mm to 240 no. I.S. sieve. The concrete mix proportion varies from 1 : 1 : 2 to 1 :1:3 for heavy duty floors to 1 : 2 :3 for public buildings. The thickness of finish may be minimum 25 mm when laid monolithically with the top concrete, and 35 mm when laid over hardened surface. However, for public buildings such as schools hospitals etc. the thickness of the finish may be 13 mm to 20 mm. using small size aggregate. If exceptionally hard surface is required, sand may be replaced by fine aggregate of crushed granite, and/or abrasive grit may be sprinkled uniformly over the surface (@ 1.5 to 2.5 kg/m^2), during floating operation.

TERRAZZO FLOORING

Terrazzo flooring is another type of floor finish that is laid in thin layer over concrete topping. It is very decorative and has good wearing properties. Due to this, it is widely used in residential buildings, hospitals, offices, schools and other public buildings. Terrazzo is a specially prepared concrete surface containing cement (white or grey) and marble chips (of different colours), in proportion to 1:1 to 1:2. When the surface has set, the chips are exposed by grinding operation. Marble chips may vary from 3 mm to 6 mm size. Colour can be mixed to white cement to set desired tint. The flooring is, however, more expensive.

The sub-base preparation and concrete base laying is done in a similar manner, as explained for cement concrete flooring. The top layer may have about 40 mm thickness, consisting of (/) 34 mm thick cement concrete layer (1:2:4) laid over the base concrete, and (ii) about 6 mm thick terrazzo topping.

Before laying the flooring, the entire area is divided into suitable panels of predetermined size and shape. For this, aluminum or glass strips are used. The strips have the same height as the thickness of the flooring (Le. 40 mm). The strips are jointed to the base concrete, with the help of cement mortar, and their tops are perfectly set to level and line. Alternate panels are filled. The width of the strips may be 1.5 to 2.0 mm.

The surface of base concrete is cleaned of dirt etc. and thoroughly wetted. The wet surface of the base concrete is smeared with cement slurry. Concrete of grade 1:2:4 is then laid in alternate panels leveled and finished to rough surface. When the surface is hardened, the terrazzo mix (containing cement, marble chips and water) is laid and finished to the level surface. Additional marble chips may be added during tamping and rolling operation, so that at least 80% of the finished surface show exposed marble chips. The surface is then floated and trowelled, and left to dry for 12 to 20 hours. After that, the surface is cured properly for 2-3 days.

The first grinding is done, preferably by machine, using coarse grade (No. 60) carborundum stones, using plenty of water. The ground surface is then scrabbed and cleaned. Cement grout of cream-like consistency, of the same colour, is then applied on the surface so that pores and holes etc. are filled. The surface is cured for 7 days and then second grinding is done with carborundum stones of fine grade (NO. 120). The surface is scabbed and cleaned thoroughly, and cement grout is again applied. The surface is cured for 4 to 6 days and final grinding is done with carborundum stones of 320 grit size. The surface is thoroughly scrabbed and cleaned, using plenty of water. The floor is then washed with dilute oxalic acid solution. Finally, the floor is polished, with polishing machines the wheels of which are fitted with felt or hessian bobs, to get fine shine. Wax polish is also applied with the help of the polishing machine, to get final glossy surface.

MOSAIC FLOORING

Mosaic flooring is made of small pieces of broken tiles of china glazed or of cement, or of marble, arranged in different pattern. These pieces are cut to desired shapes and sizes. A concrete base is prepared as in the case of concrete flooring, and over it 5 to 8 cm thick lime-surkhi mortar is spread and leveled, over an area which can be completed conveniently within working period so that the mortar may not get dried before the floor is finished. On this, a 3 mm thick cementing material, in the form of paste of two parts of slaked lime, one part of powdered marble and one part of puzzling material, is spread and is left to dry for about 4 hours. Thereafter, small pieces of broken tiles or marble pieces of different colours are arranged in definite patterns and hammered into the cementing layer. The surface is gently rolled by a stone roller of 30 cm dia. and 40 to 60 cm long, sprinkling water over the surface, so that cementing material comes up through the joints, and an even surface is obtained. The surface is allowed to dry for 1 day, and is, thereafter, rubbed v.ith a pumice stone fitted with a long wooden handle, to get smooth and polish surface. The floor is allowed to dry for two weeks before use.

TILED FLOORING

Tiled flooring is constructed from square, hexagonal or other shapes, made of clay (pottery), cement concrete or terrazzo. These are available in different sizes and thicknesses. These are commonly used in residential houses, offices, schools, hospitals and other public buildings, as an alternative to terrazzo flooring, specially where the floor is to be laid quickly. The method of laying tiled flooring is similar to that for flag stone flooring except that greater care is required. Over the concrete base, a 25 to 30 mm thick layer of lime mortar 1:3 (1 lime and 3 sand or surkhi) is spread to serve as bedding. This bedding mortar is allowed to harden for 12 to 24 hours. Before laying the tiles, neat cement slurry is spread over the bedding mortar and the tiles are laid flat over it, gently pressing them into the bedding mortar with the. help of wooden mallet, till leveled surface is obtained. Before laying the tiles, thin paste of cement is applied on their sides, so that the tiles have a thin coat of cement mortar over the entire perimeter surface. Next day, the joints between adjacent tiles are cleaned of loose mortar etc. to a depth of 5 mm, using wire brush, and then grouted with cement slurry of the same colour shade as that of the tiles. The slurry is also applied over the flooring in thin coat. The flooring is then cured for 7 days, and then grinding and polishing is done in the same manner as that for terrazzo flooring.

MARBLE FLOORING

It is a superior type of flooring, used in bath-rooms and kitchens of residential buildings, and in hospitals, sanitariums, temples etc. where extra cleanliness is an essential requirement. Marble slabs may be laid in different sizes, usually in rectangular or square shapes. The base concrete is prepared in the same manner as that for concrete flooring. Over the base concrete, 20 mm thick bedding mortar of either 1:4 cement: sand mix or 1 (lime putty) : 1 (surkhi) : 1 coarse sand mix is spread under the area of each individual slab. The marble slab is then laid over it, gently pressed with wooden 'mallet and leveled. The marble slab is then again lifted up, and fresh mortar is added to the hollows of the bedding mortar. The mortar is allowed to harden slightly, cement slurry is spread over it, edges of already laid slabs are smeared with cement slurry paste, and then the marble slab in question is placed in position. It is gently pushed with wooden mallet so that cement pastes oozes out from the joint which should be as thin as possible (paper thick). The oozed out cement is cleaned with cloth. The paved area is properly cured for about a week.

TIMBER FLOORING

Timber flooring is used for carpentry halls, dancing halls, auditoriums, etc. They are not commonly used in residential buildings in India, because timber flooring is also quite costlier. However, in hilly areas, where timber is cheaply and readily available, and where temperature drop very low, timber flooring is quite common. One the major problems in timber flooring is the damp prevention. This can be done by introducing D.P.C. layer below the flooring.

Timber floors can either be of 'suspended type' (i.e.. supported above the ground) or 'solid type' (fully supported on the ground). The suspended type timber flooring. An alternative sketch of 'suspended' or 'supported' timber flooring. The hollow space between the flooring and over site concrete is kept dry and well-ventilated by providing air bricks in the outer walls, and voids in the sleeper wall. The flooring consists of hoarding supported on bridging or floor joists of timber, which are nailed to the wall plates at their ends. Sleeper walls are not spaced more than 1.8 to 2 m.

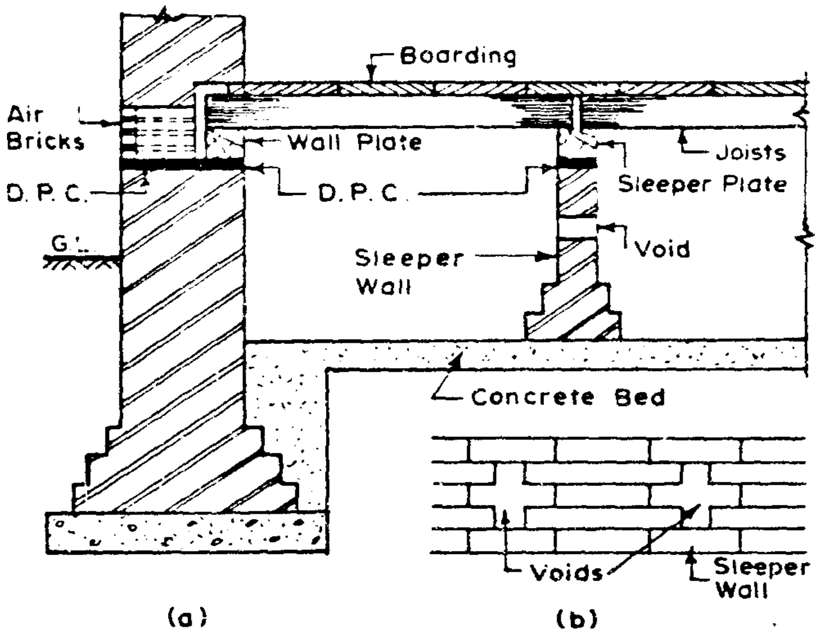


FIG. SUPPORTED TYPE TIMBER FLOOR.

Where the problems of dampness is not acute, timber floors may be supported on the ground all along. For this type of construction, base concrete is first laid in 15 to 20 cm thickness. Over it, a layer of mastic asphalt is applied. Wooden block flooring is then laid over it. Wooden blocks are short but thick (with sizes 20 x 8 cm to 30 x 8 cm and thickness 2 to 4 cm) and are laid in suitable designs. In order to fix the wooden floor on concrete slabs, longitudinal nailing strips, with bevelled section, are embedded in concrete at suitable interval. Sometimes, special concrete, called nailing concrete may be used as an alternative to the nailing strips. Special flooring nails are used for nailing down the flooring.

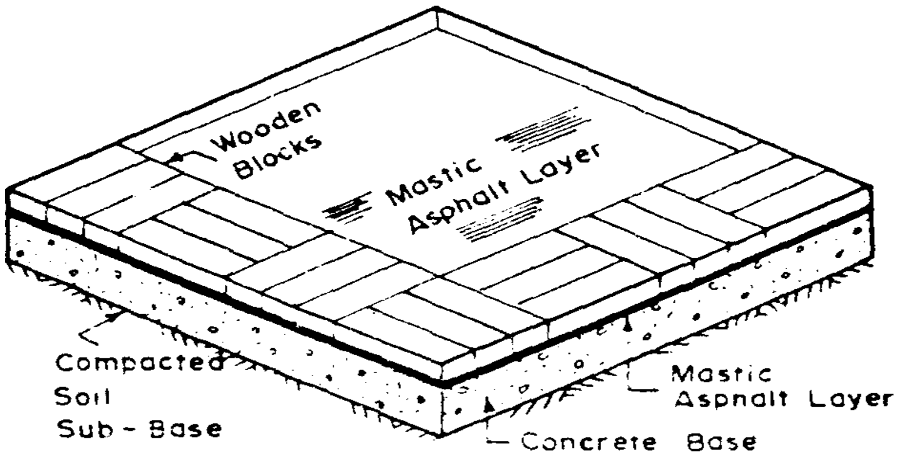


FIG. WOODEN BLOCK FLOORING

ASPHALT FLOORING

Asphalt flooring are of many types

(i) asphalt mastic flooring (ii) asphalt tiles flooring, (iii) asphaltic mosaic and (iv) Acid proof mastic flooring.

1. Asphalt mastic Hoofing. Asphalt mastic is a mixture of sand (or grit) and asphalt in the ratio of 2: 1, mixed hot and then laid in continuous sheets. It can also be applied cold, by mixing with mineral oil and asbestos. The thickness of the asphalt mastic may be 2.5 cm for ordinary construction. It is laid on cement concrete base course. The mix is poured on the concrete base, and is spread by means of trowel to get leveled surface. On the top of the surface, a thin layer of sand is spread, which is then rubbed with a trowel. The joints of mastic asphalt laid on successive days are properly lapped.

2. Asphaltic tiles. These are prepared from asphalt, asbestos fibres, inert materials and mineral pigments, by pressing the mix in different sizes (20 cm square to 45 cm square), with thickness varying from 3 to 6 mm. These tiles are cither directly cemented to concrete base or are fixed to wooden floors by using an intervening layer of mastic asphalt or asphalt saturated felt. Asphaltic tiles are cheap, resilient, sound proof, non-absorbant and moisture proof.

3. Asphaltic mosaic. This is prepared similar to mastic asphalt, except that marble chips are used in the place of sand/gril. Asphalt may be either in black or other suitable colour, and is laid in hot condition.

4. Acid proof mastic flooring. Acid proof blocks of asphalt are available, which arc manufactured from moulding acid proof asphalt and inert crushed rock aggregate under high pressure. The asphalt blocks are first laid on concrete base then acid proof asphalt is uniformly spread over the surface of the blocks. Find sand is spread over the liquid asphalt before it hardens.

RUBBER FLOORING

It consists of sheets or tiles of rubber, in variety of patterns and colours with thickness varying from 3 to 10 mm. The sheet or tile is manufactured by mixing pure rubber with fillers such as cotton fibre, granulated cork or asbestos fibre. The sheets or tiles are fixed to concrete base or wood by means of appropriate adhesives. rubber floorings are resilient and noise proof. However, they are costly. They are used only in office or public buildings.

LINOLEUM FLOORING (COVERING)

Strictly speaking, it is covering which is available in rolls, and which is spread directly on concrete or wooden flooring. Linoleum sheet is manufactured by mixing oxidized linseed oil in gum, resins, pigments, wood flour, corkdust and other filler materials. The sheets are either plain or printed, and are available in 2 to 6 mm thickness, and 2 to 4 m wide rolls. Linoleum tiles are also available , which can be fixed (or glued) to concrete base or wood floor, in different patterns. Linoleum sheet is cither spread as such, or also may be glued to the base by inserting a layer of saturated felt. Linoleum covering are attractive, resilient, durable and cheap, and can be cleaned very easily. However, it is subjected to rotting when kept wet or moist for some time. It cannot, therefore, be used for bath-rooms, kitchens etc.

CORK FLOORING

Such type of flooring is perfectly noiseless, and is used in libraries, theatres, art galleries, broadcasting stations etc. Cork, which is the outer bark of cork oak tree, is available in the form of cork carpet and cork tiles. It is fixed to concrete base by inserting a layer of saturated felt. Cork carpet is manufactured by heating granules of cork with linseed oil and compressing it by rolling on canvass. Cork tiles are manufactured from high grade cork bar or shearings compressed in moulds to a thickness of 12 mm and baked subsequently. They are available in various sizes (10 cm x 10 cm to 30 cm x 90 cm), various thicknesses (5 to 15 mm) and various shades.

GLASS FLOORING

This is a special purpose flooring, used in circumstances where it is desired to transmit light from upper floor to lower floor, and specially to admit light at the basement from the upper floor. Structural glass is available in the form of tiles or slabs, in thicknesses varying from 12 to 30 mm. These are fixed in closely spaced frames so that glass and the frame can sustain anticipated loads. Glass flooring is very costly, and is not commonly used.

PLASTIC OR P.V.C.

FLOORING

It is made of plastic material, called Poly-Vinyl-Chloride(P.V.Q), fabricated in the form of tiles of different six's and different colour shades. These tiles are now widely used in all residential as well as non-residential buildings. The tiles are laid on concrete base. Adhesive of specified make is applied on the base as well as on the back of P.V.C.

tile with the help of a notched trowel. The tile is laid when the adhesive has set sufficiently (say within 30 minutes of its application); it is gently pressed with the help of a 5 kg weight wooden roller and the oozing out adhesive is wiped off. The floor is washed with warm soap water before use. P.V.C. tile flooring is resilient, smooth, good hiking and can be easily cleaned. However, it is costly and slippery, and can he damaged very easily when in contact with burning objects.

FLOORS

UPPER FLOORS

An upper floor is basically a principal structural element, and the general structural design of a building will greatly influence the choice of the type of floor. Upper floors are supported either on the walls or on columns; they have, therefore, the major problems of strength and stability. The structural design of upper floors has to be such as to support the loads set up by the use of the building, in addition to the self weight and the weight of partitions etc. However, the flooring materials are practically the same as used for ground floors.

Depending upon the materials used for construction, and upon the arrangement of beams, girders etc. for supporting the flooring, upper floors may be classified into the following types

1. Steel joist and stone or precast concrete floors.
2. Jack arch floors.
3. Reinforced cement concrete floors.
4. Ribbed or hollow tiled flooring.
5. Filler joists floors.
6. Precast concrete floors.
7. Timber floors.

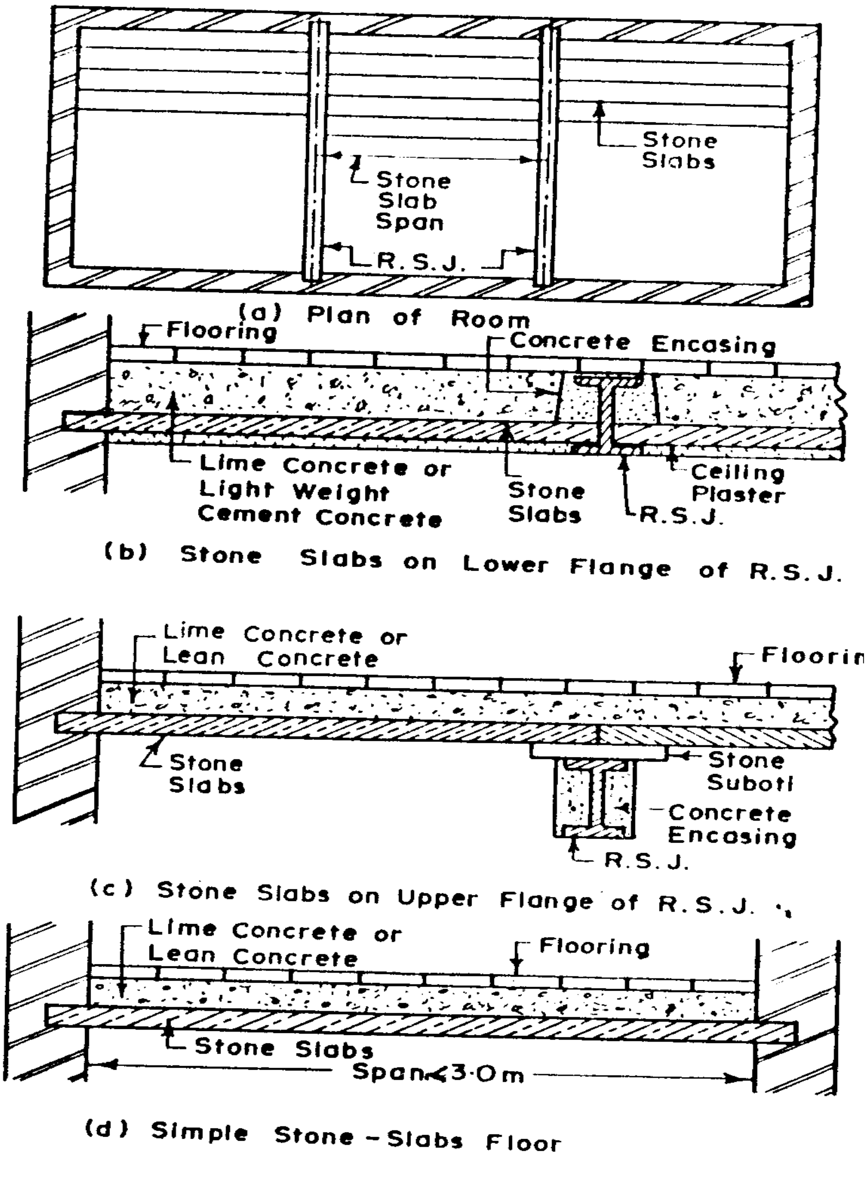
STEEL JOIST AND STONE OR PRECAST CONCRETE

SLAB FLOORS.

This type of floor is quite common in locations where flag-stones or stone-slabs are readily available in spans of 1 to 3 metres and widths

30 to 60 cm. Where stone slabs are not available, precast concrete slabs can be used. The slabs are placed at the lower flange of rolled steel joists (R.S.J.), especially where plain ceiling is required, though in this case the bearing to the slabs is small. Otherwise, the slabs can be supported on the upper flange of R.S.J. by inserting wide stone bedding plate, called suboti between the flange and the slab. When the slabs are placed on the lower flange of joists, the space between the top of the slab and top of R.S.J. is filled with lime concrete or light weight cement concrete, after encasing the steel joists completely in cement concrete so that they do not get rusted. On the top of it, regular flooring is laid.

The spacing of the rolled steel joists depend upon the length



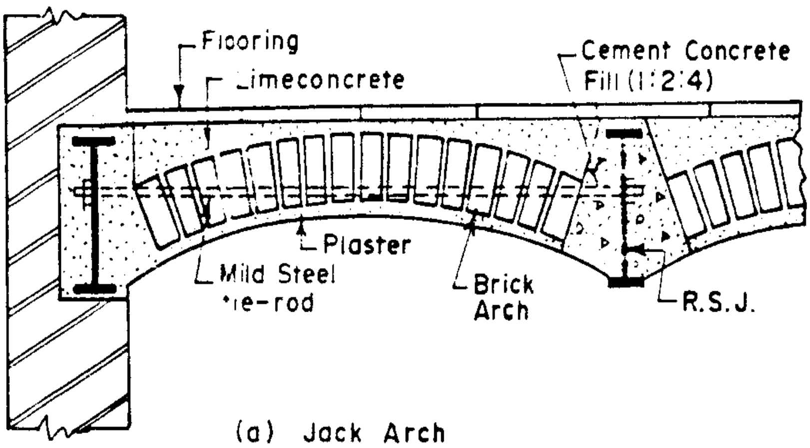
STONESLAB FLOOR WITH OR WITHOUT JOISTS

of available stone slabs. The joists have the clear span equal to the width of the room. The bearing of joists on the wall should at least be equal to depth of the joist, but in no case less than half the width of the wall. It is better if bearing is kept just equal to the width of the wall so that eccentric load of the wall is eliminated. A bed plate is provided below each end of the joist, to suitably distribute the load to the wall.

Sometimes stone slabs are available in lengths of 2.5 to 3.5 m, such as those at Jodhpur. If the width of the room is slightly less than this value, stone slabs can be directly supported on the walls, without using steel joists. Such a construction is quite cheap.

JACK ARCH FLOORS

Jack arch is an arch of either brick or concrete, supported on lower flange of mild steel joists (R.S.J.). The joists are spaced 1 to 1.5 m centre to centre, and are supported at their ends either on the walls or on longitudinal girders. The rise of the arch is kept equal to the of the span. The minimum depth of concrete at the crown is kept equal to 15 cm. Since the super-imposed load is being borne by arch action, tension is developed on the supporting walls, specially at the end span. Due to this, steel tie rods are provided at the end span, at suitable spacing, usually 1.8 to 2.4 m c/c. The



(a) Jack Arch

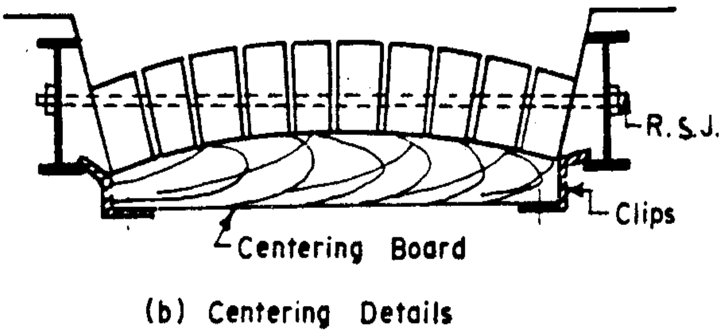


FIG. BRICK JACK ARCH FLOORING.

tie rods are 2 to 2.5 cm diameter, and are properly anchored into the wall. The end arch is supported on wall by either providing rolled steel joist into the wall or simply fixing an angle iron or mild steel in the wall. The bottom of the floor is not plane; this is the only disadvantage of this floor.

Brick Jack Arch Flooring

Figure shows the details of brick jack arch flooring. The construction on jack requires centering of 30 to 40 mm thick segmental piece of timber, with chord length equal to the span of the arch and conforming to the soffit. Then centering board is cut slightly at the ends and is made to rest on the lower flange of R.S.J., with the curved surface upwards. Alternatively, a bend iron strap is attached to its ends to form a hook through which the centering board is suspended from R.J.S., as shown in Figure. After the centering is ready, bricks are laid on edge from both the joists. The end bricks are cut suitably to fit firmly with the joists. Only well-burnt bricks are used for the construction, and they are saturated with water, before use. Joists arc encased in cement mortar, so as to prevent their rusting from lime mortar. The bricks are laid in such a way that necessary bond is developed between different rings or layers of bricks. In the first ring, the bricks are laid in lengths of 20 cm and 10 cm alternatively, to secure good bond between this ring and the next ring along the length of arch (perpendicular to the span). The key brick at the crown is laid in rich mortar, and is pushed as tight as possible. After the first ring is complete, the centering board is advanced or pushed 20 cm further, by light blows of hammer, to construct the second ring. The second and successive rings are constructed 20 cm long bricks. The last ring, however, is constructed with alternate bricks of half and full lengths. The entire brick work is watered or cured for 15 days. The top flooring is then provided on a bedding of lime concrete or light weight cement concrete put on spandrel.

Precautions

(i) Before starting the work, the R.S.J. should be properly secured in position.

(ii) Only first class bricks should be used.

(iii) Successive rings should be properly interlocked.

(iv) Key brick should be properly and tightly secured in rich mortar.

(v) If lime mortar is used, R.S.J. should be encased in cement mortar. (vi) Top concrete and flooring should not be laid unless the brickwork is properly cured,

Cement Concrete Jack Arch Flooring

Figure (a) 'shows a cement concrete jack arch flooring in which the arches are made of 1 : 2 : 4 cement concrete, supported on the lower flanges of M.S. joints. The construction of concrete jack arches is relatively simple. The centering consists of a 3 mm thick mild steel plate, bent to the shape of arch soffit, and having pair of holes at ends, spaced at 75 cm c/c. The centering plate is supported on the lower flange of joists through a pair of 12 mm dia. rods, each having an eye hook at its end (Fig. b). Each rod passes through the end eye of the other (Fig. c), and their total length is adjusted to the span of the arch. The ends of the rods pass through symmetrical holes of the centering plate (Fig. d) and finally rest on she lower flange of R.S.J., thus providing the support to the M.S. plate, as shown in Fig. (a). In order to check the deflection of the centering plate, a wooden packing block is tightly inserted between the M.S. plate and the rods. When the centering is ready, cement concrete of 1 : 2 : 4 mix is laid on the top of the M.S. plate, to the required depth and is properly compacted either manually or with the help of a vibrator. The flooring is then completed with the desired type of flooring material. The entire work is then well watered for 10 days, for efficient curing. After that, the centering is removed by first removing the wooden packing and then hammering the eyes of the rods toward each other. The under side of the arches can be plastered to give good appearance.

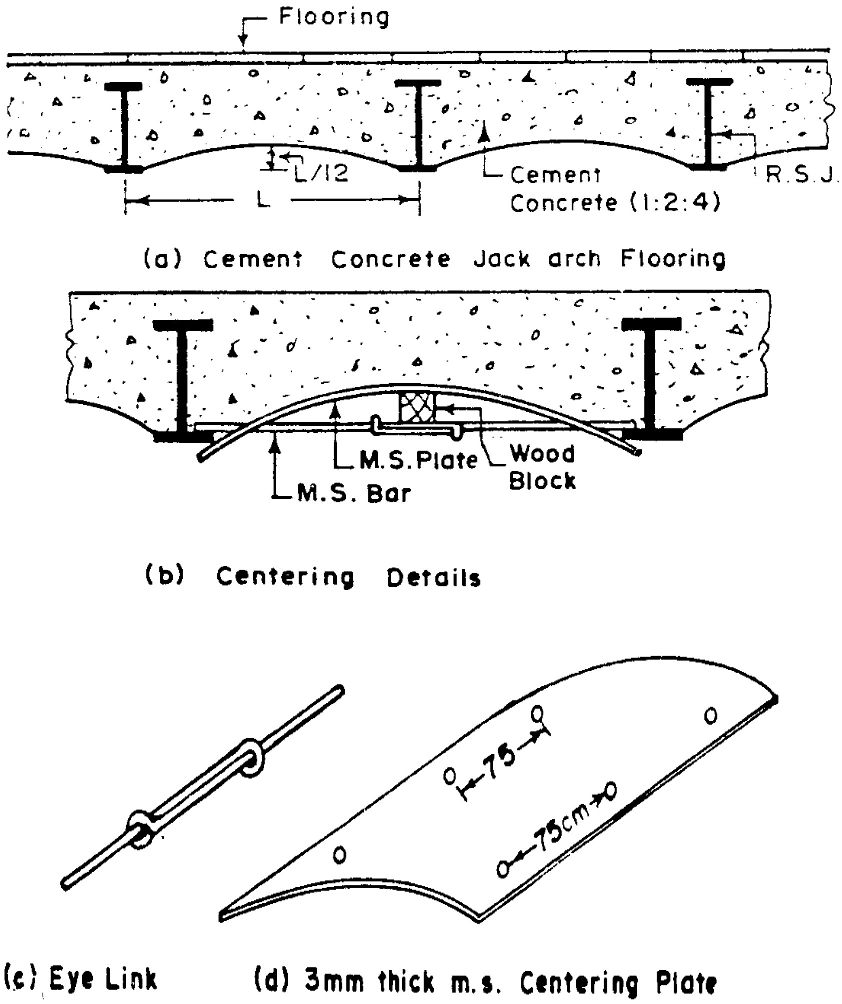


FIG. CEMENT CONCRETE JACK ARCH FLOORING.

REINFORCED CEMENT CONCRETE FLOORS

Floors of modern buildings are invariably made of reinforced cement concrete (R.C.C.), because of the inherent advantages of this type of construction. Concrete, though strong in compression, is weak in tension. However, it is suitably reinforced with the help of mild steel bars which take the entire bending tension. Due to this, the overall thickness of R.C.C. floors is comparatively small, thereby reducing the self weight of floor itself. R.C.C. floors are also comparatively fire proof and damp proof. The method of construction is also easy except that centering is required. These floors can also be used on large spans, and therefore, more suitable for big size rooms, halls etc.

R.C.C. floors can be classified into the following types :

(i) Simple slab flooring

(ii) Reinforced brick flooring

(iii) Beam-slab flooring

(iv) Flat slab flooring.

(v) Ribbed flooring or hollow tiled flooring.

1. Simple R.C.C. slab Flooring

In simple R.C.C. flooring, the R.C.C. slab bends downwards, causing tension at the bottom fibres. Due to this mild steel bars reinforcement is placed at the bottom of the slab, keeping a minimum clear cover of 15 mm. Half these bars are bent up near ends to take up negative bending moment caused due to partial frigidity at the ends. This main reinforcement is placed in the direction of the span of the slab, which is equal to the width of the room, especially when the length of the room is more than 1.5 times the width of the room. Such a slab is known as one way reinforced slab. Nominal reinforcement (known as temperature/distribution reinforcement) is placed in the perpendicular direction. Hooks are placed at the end of each plain bar, though these are not required in ribbed bars (tor-reinforcement). The bearing of the slab in the wall should neither be less than its thickness, nor less than half the width of the wall. Fig. (a) shows one way reinforced slab. Such slabs are quite suitable and economical for spans upto 5 m. The slab is cast on timber or steel shuttering. After erecting the centering, properly bent reinforcement is placed in position. Distance pieces of stone or concrete are placed between the reinforcement and the shuttering plate so that proper cover is maintained. Cement concrete of appropriate mix (usually 1 : 2 : 4) is then poured and well-compacted. The slab is then properly cured. Shuttering is removed only when the concrete has fully set.

When the length of the room is less than 1.5 times the width of the room, the slab spans/bends in both the directions. It is essential

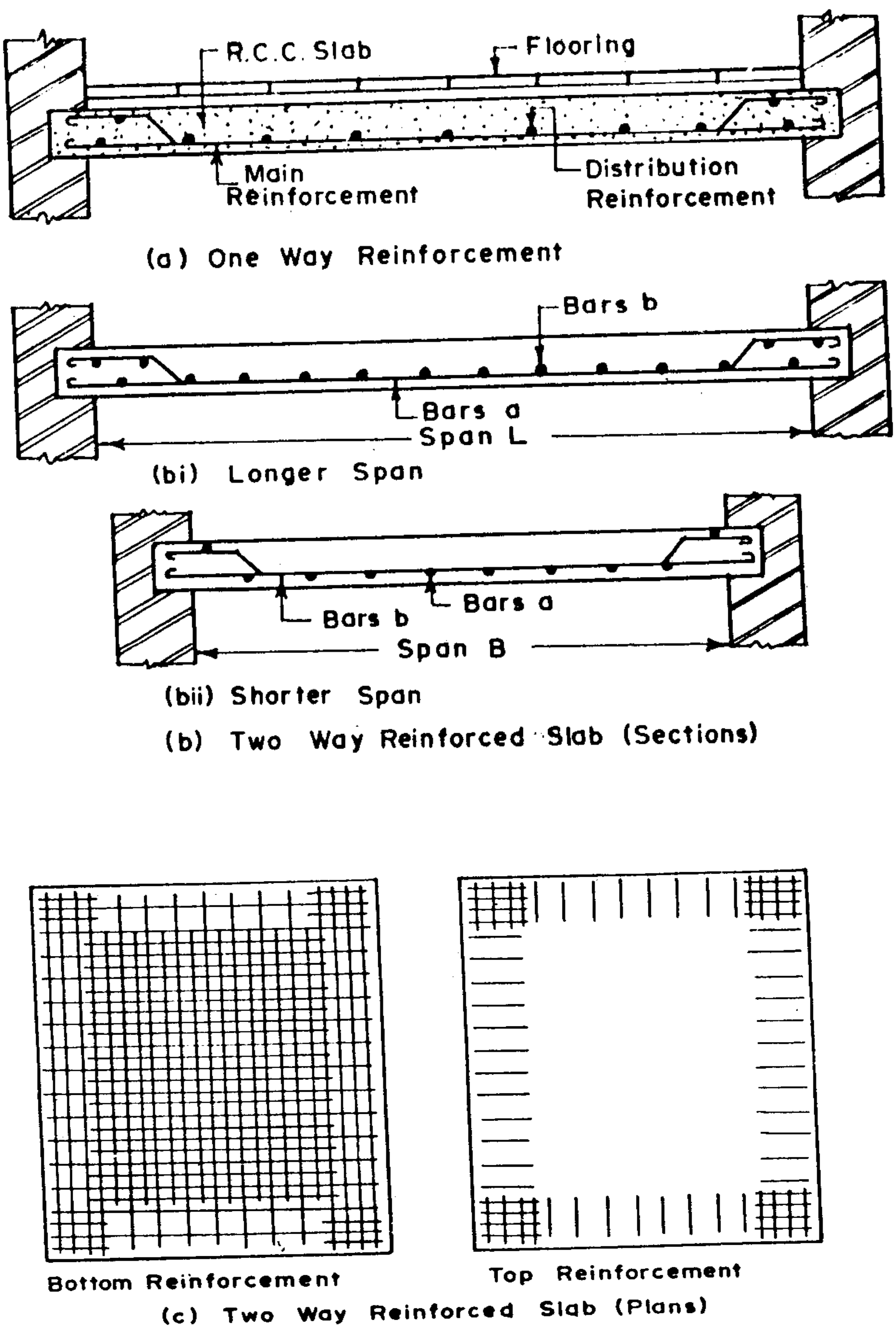


FIG REINFORCED CONCRETE SLABS

to provide reinforcement in both the directions. Such a slab is known as a two-way reinforced slab, such as the one shown in Fig. (b). At the comer, suitable mesh reinforcement is provided at the top and bottom their lifting. The plan of the reinforcement of a two-way slab, at its top and bottom is shown in Fig. (c).

2. Reinforced Brick Flooring

Reinforced brick work is a typical type of construction in which the compressive strength of bricks is utilized to bear the compressive stress and steel bars are used to bear the tensile stresses in a slab. In other words, the usual cement concrete is replaced by the bricks. However, since the size of a brick is limited, continuity in the slab is obtained by filling the joints between the bricks by cement mortar. The reinforcing bars are embedded in the gap between the bricks, which is filled with cement mortar. Such type of construction is quite suitable and cheap for small span floor slabs carrying comparatively lighter loads. Fig. 12.5 shows typical sections of reinforced brick slab.

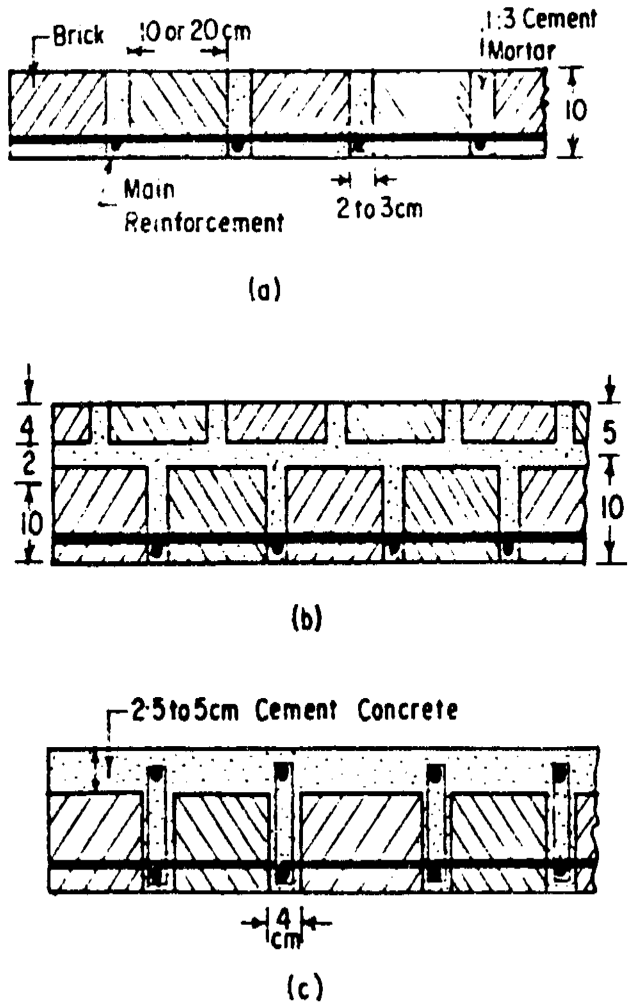


FIG REINFORCED BRICK SLAB

The depth of reinforced brick slab is governed by the thickness of the bricks available. Modular bricks are 10 cm thick (nominal). Hence thickness of slab may be kept as 10 cm or 20 cm. If 15 cm thickness is required from design point of view, 5 cm thick tiles are used on the 10 cm thick bricks to make a total thickness of 15 cm. The joint between the two layers of tile and brick is filled with cement mortar. Before use, the bricks should be thoroughly soaked in water. The reinforcing bars put in the joints should not come in contact with bricks.

When two layers of bricks are used, vertical joints in the bricks should be broken (staggered) so that slab does not shear along the joint. The bricks near the edge should rest half on the bearing wall so that vertical joint above the edge of the is avoided. First class bricks should be used for such a work. Cement mortar used to fill the joints etc. should he of 1 : 3 ratio, with proper water-cement ratio to make the mortar workable. The width of the joint between adjacent bricks is generally kept equal to 2 cm. The compressive strength of reinforced brick work is sometimes increased by providing wider gap (say about 4 cm) between the bricks, and providing 2.5 to 5 cm thick layer of cement concrete on the top of the bricks.

3. Beam-Slab Flooring

When the width of room becomes more, the span of slab increases, and simple R.C.C. slab becomes uneconomical. In that case, the floor structure consists of R.C.C. beams and slabs cast monolithically. The beams, known as T-beams, act as intermediate supports to the slab which is continuous over these beams. When the size of the room (t.c'.. hall) is very large, these floor beams are supported on longitudinal beams which, in turn, are either supported on R.C.C. columns or end walls Figure shows typical details.

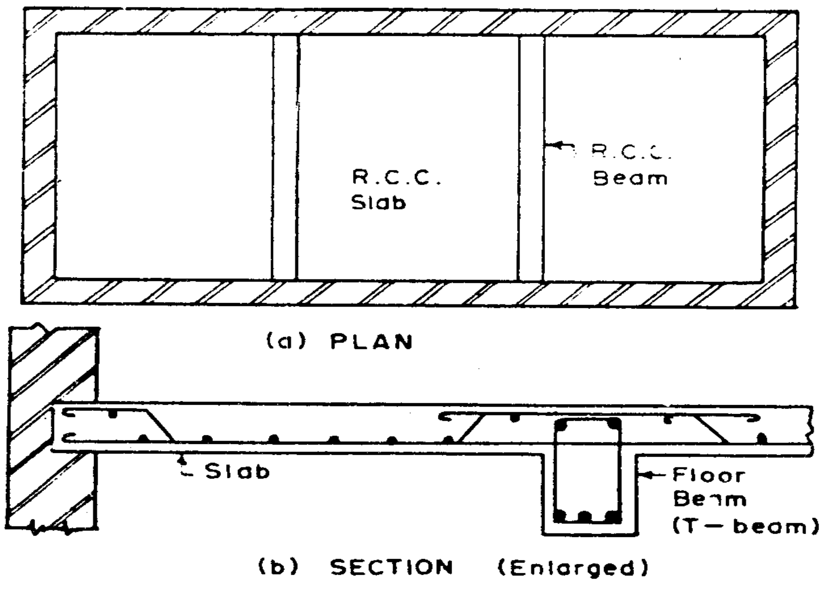


FIG. BEAM-SLAB FLOORING.

4. Flat Slab Flooring

A flat slab is a typical type of construction in which a reinforced slab is built monolithically with the supporting columns and is reinforced in two or more directions, without any provision of beams. The flat slab thus transfers the load directly to the supporting columns suitably spaced below the slab (Figure-a). Because of exclusion of beam system in this type of construction, a plain ceiling is obtained, thus giving attractive appearance from architectural point of view. The plain ceiling diffuses the light better and is considered less vulnerable in case of fire than the usual beam slab construction. Concrete is more logically used in this type of construction, and hence in case of large spans and heavy load, the total cost is considerably less.

The slab in a flat slab construction may be either with drop or without drop. Drop is that part of the slab around the column

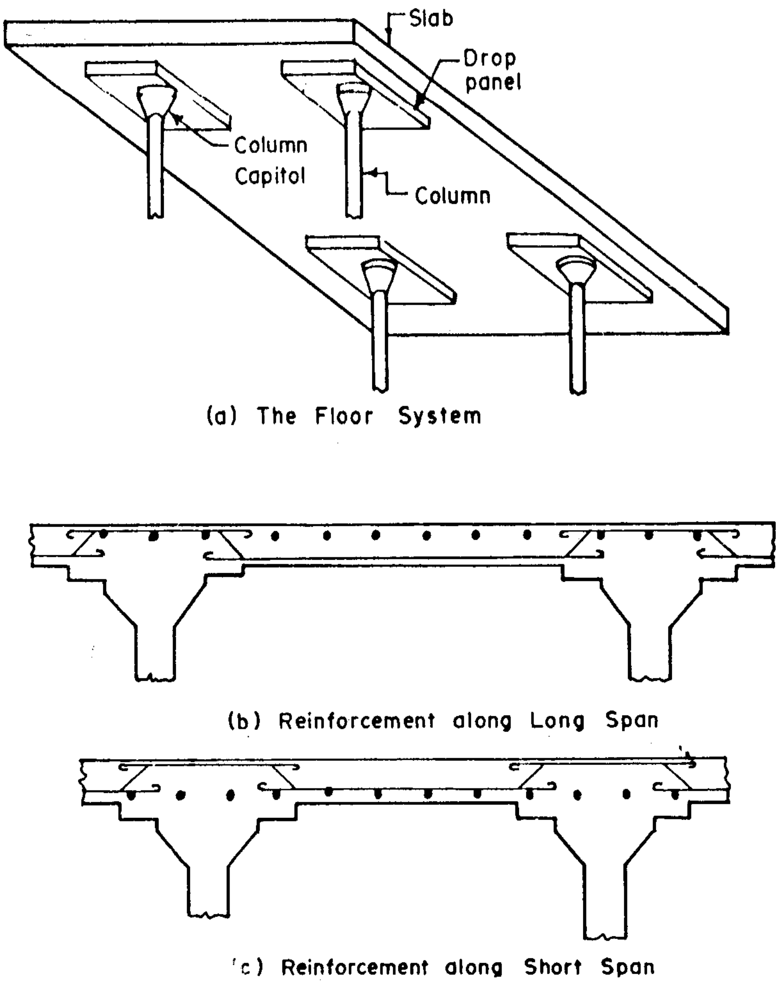


FIG FLAT SLAB CONSTRUCTION

which is of greater thickness than the rest of the slab. Reinforcement in the slab can be arranged either in two-way system or in four-way system. Two-way system of reinforcement is commonly adopted for slab subjected to ordinary loading conditions. Fig. (b) and (c) shows details of reinforcement in the slab along two directions, in the two-ways system.

RIBBED OR HOLLOW TILED FLOORING

Concrete is incapable of resisting tension which is caused in the lower part of the thickness of the slab. This lower part does not partake in load bearing, and hence part of it can be replaced by hollow tiles so that weight of the slab is reduced. This results in a ribbed floor system, as shown in Figure. Unlike T-beam construction, the ribs of hollow tile construction are closely spaced. The clear spacing of ribs depends upon the size of hollow blocks available, but it should normally not exceed 50 cm. The width of ribs may vary between 6 to 10 cm. The span of ribs may be as much as 7 m. However, when the span exceeds 3 m, lateral ribs of the same width as the main longitudinal ones are provided at intervals between 1 to 3 metres. In that case, longitudinal ribs are designed as continuous beams. Main reinforcement is provided at the bottom of the rib. To resist the support moment (negative) an additional bar is placed at the top of rib section. A minimum cover of 2.5 cm is provided. The depth of rib is calculated on the

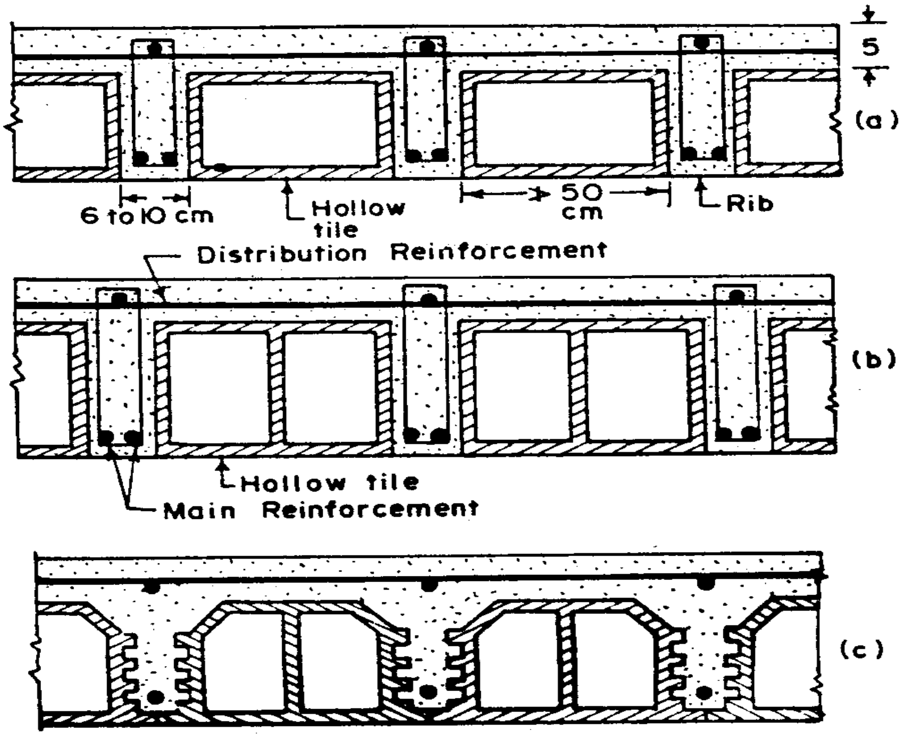


FIG. HOLLOW TILE AND CLOSE-RIBBED FLOOR

basis of bending moment as well as the cost ratio of steel and concrete. Depth of rib is usually kept as at least L/20 with free support and at least Z./25 with fixed support, where L is the span of the ribs.

Due to small span, the slab is normally not analyzed. Slab thickness of 4 to 5 cm is generally provided. To check its cracking and to distribute the load properly, shrinkage and temperature reinforcement is provided in The slab, in both the directions. Sometimes, a welded fabric is arranged approximately along the middle of the thick of the slab.

Hollow tiles arc available in different widths and different depths. Sometimes, to suit (he requirements of the depth of rib, hollow tiles of required depth may be manufactured at the she. Various forms and types of hollow tiles are available, so suit the clear distance between the ribs.

Ribbed or hollow-tiled floors have the following advantages

(i) They arc light in weight, and hence the supporting system has to be designed for comparatively lighter loads.

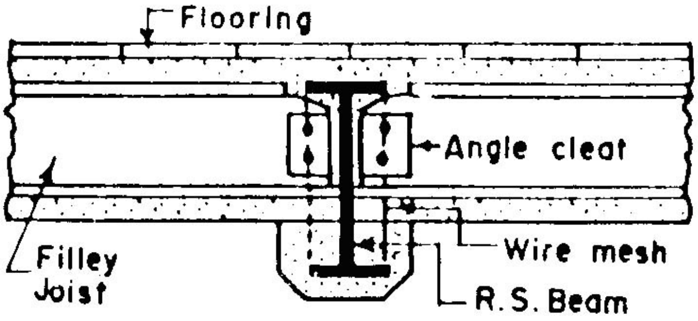
(ii) They provide better thermal insulation, keeping the building cool in summer.

(iii) They have sound-proofing qualities.

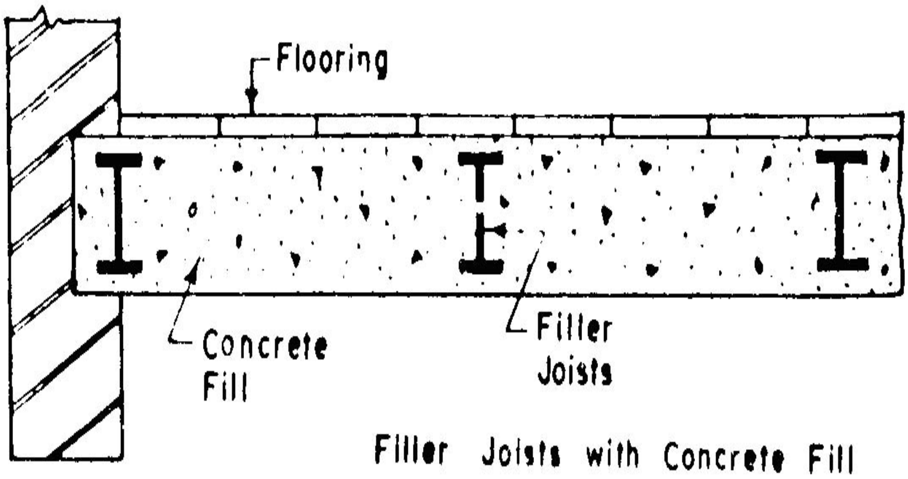
(iv) They have better fire resistance.

(v) Electrical, plumbing and other service installations can be conveniently installed through it, without affecting its appearance.

FILLER JOISTS FLOORS



Connection with R.S. Beam



FILLER JOIISTS FLOOR

This is a typical type of composite construction in which R-SJ. of small sections are placed in concrete, as shown in Figure. The spacing of the joists may vary between 40 to 90 cm. The filter joists may either rest on walls (if the span is less) or on longitudinal steel beams. The joists act as reinforcement, and no separate reinforcement is provided in the concrete filled in between the joists. Concrete should completely surround the filler joists and steel beams, with a minimum cover of 2.5 cm over filler joists.

PRE-CAST CONCRETE FLOORS

With the modem developments in construction technology, precast beam-slab units are now available with the help of which the floors can be constructed easily and expeditiously, without the aid of any form work. These precast units (Figure) are available in about 25 cm width, various depths, and various spans, and can be supported either on walls or on rolled steel joists. The sides of each unit are provided with grooves to form connecting joggles for adjacent units. The joints are grouted with cement mortar, using concrete guns. Such floors are economical, light weight, sound proof, fire proof, and economical.

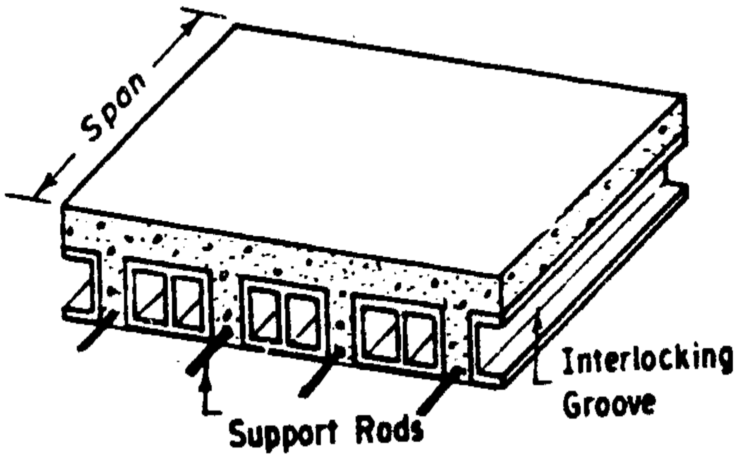


FIG HOLLOW PRECAST FLOOR UNITS

TIMBER FLOORS

Timber floors, though quite light in weight, have poor fire resistance and sound insulation properties. They arc quite costly, except at those locations where local timber is cheaply available. It is also highly vulnerable to termite attack.

Timber floors are basically of three types :

1. Single joist timber floor's.
2. Double joists timber floors.
3. Framed or triple joists timber floors.

1. Single joist timber floors:

This is the simplest type of timber floor used for residential buildings, where spans are short or moderate (say upto 4 m) and loads are comparatively lighter. The floor consists of wooden joists (also called bridging joists) spaced 30 to 40 cm apart and supported on end walls, over which timber planking or boarding is fixed. The width of joists are kept 5 to 8 cm wide. The depth of the joists is determined from the thumb rule

Depth (cm) = (4 x span in metres) + 5 cm.

The joists are supported on wall plates 10 x 7 cm tol2x7 cm in size, at the end walls. A space of about 5 cm is kept at the ends for air circulation. When the span exceeds 2.5 m, it becomes essential to strengthen the timber joists by providing herring bone strutting at the mid-span, by means of inclined pieces of timber of size 5x3 cm to 5x5 cm. End wedges are provided between the wall and joist.

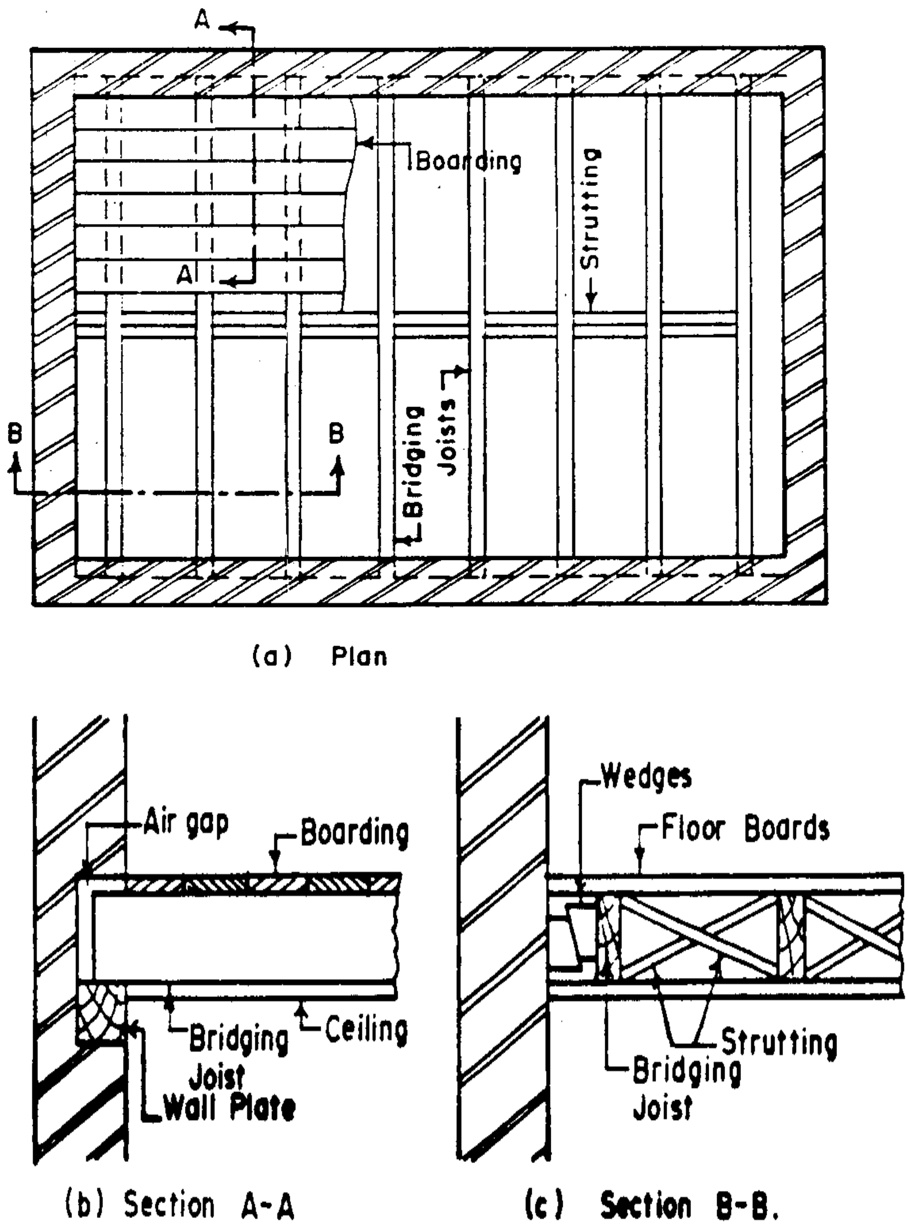


FIG. SINGLE JOISTS TIMBER FLOORING

The end of the joists are nailed, cogged or notched to the wall plates. If the joists of adjacent room run in the same direction, they may be overlapped and nailed to each other. Planking consists of wooden boards of 4 cm thick and 10 to 15 cm width, which are fixed to the bridging joists.

2. Double joists timber flooring:

This type of flooring is stronger, and is used for spans between 3.5 to 7.5 metres. The bridging joists are supported on intermediate

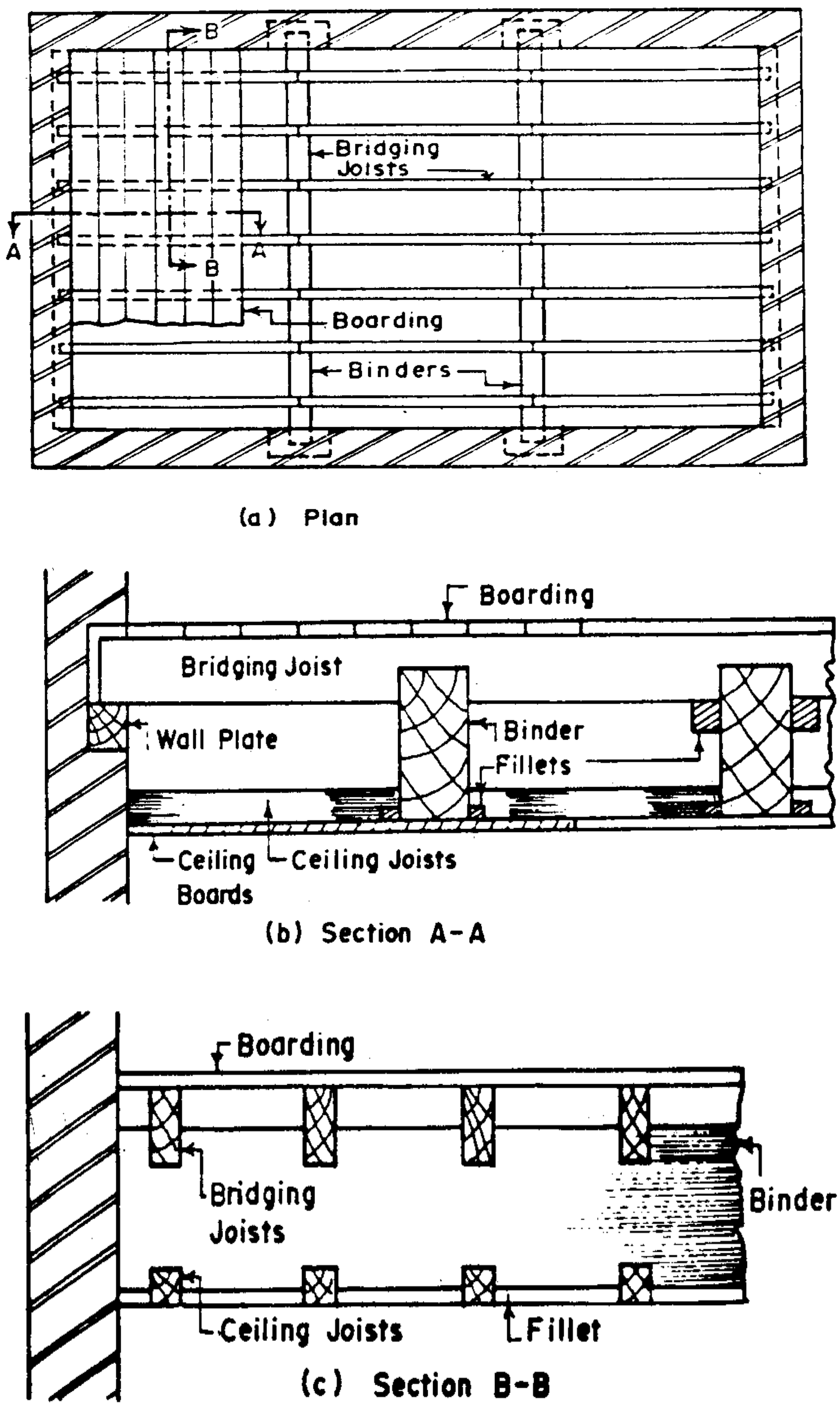


FIG DOUBLE JOISTS TIMBER FLOORING

wooden supports, called binders. Thus, the loads of bridging joists are first transferred to the binders and through them to the end

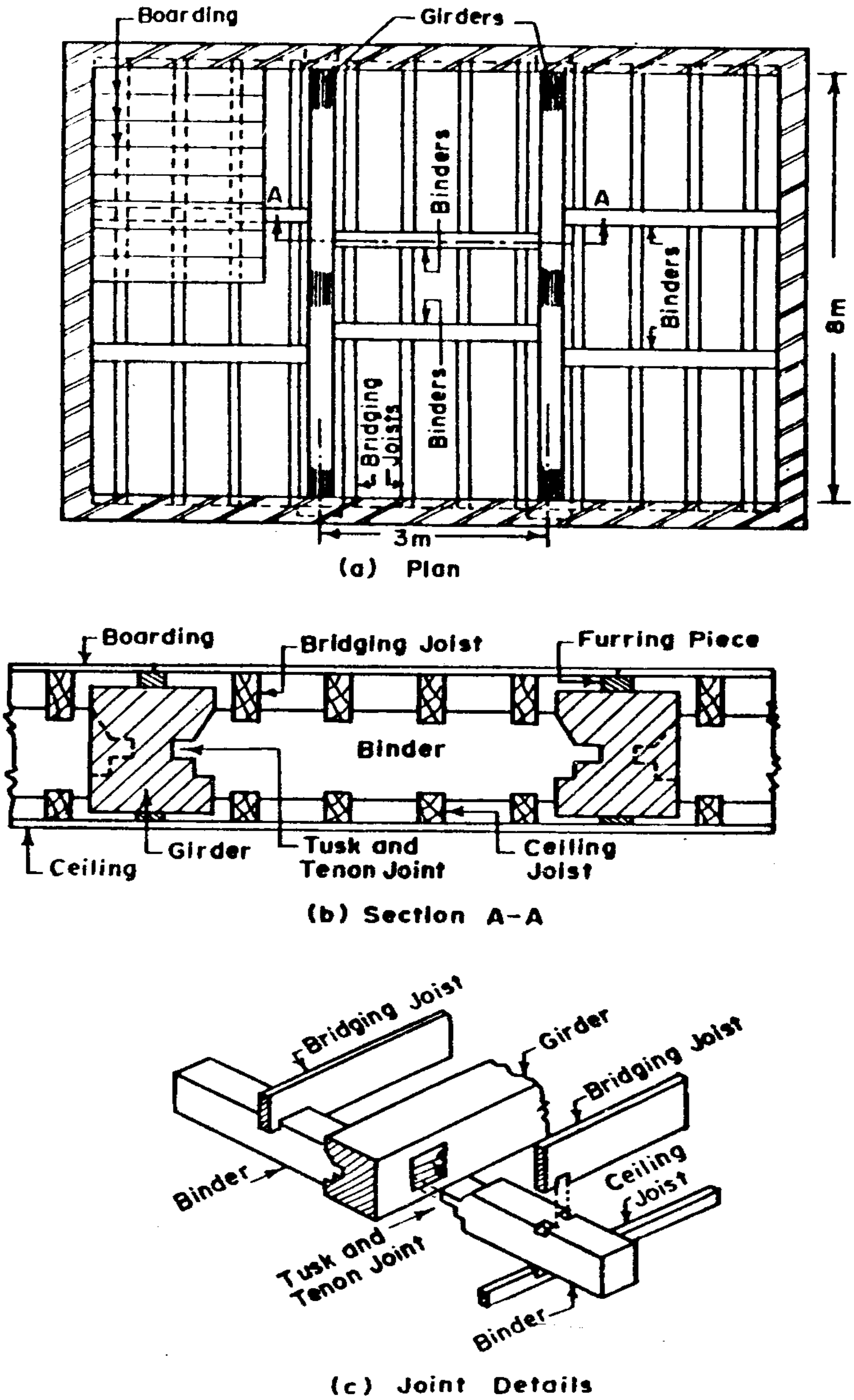


FIG FRAMED OR TRIPLE JOISTS TIMBER FLOORING

DAMP PROOFING

CAUSES OF DAMPNESS

One of the basic requirement of a building is that it should remain dry or free from moisture travelling through walls, roofs or floors. Dampness is the presence of hygroscopic or gravitational moisture. Dampness gives rise to unhygienic conditions, apart from reduction in strength of structural components of the building. Damp prevention is therefore one of the important items of building design. Every building should be damp proof. Provisions of damp proof courses prevent the entry of moisture in the building.

Following are various causes of dampness in buildings

1. Moisture rising up the walls from ground

All the structures are founded on soils, and the sub-structure is embedded into it. If the soil is pervious, moisture constantly travels through it. Even in the case if impervious soils, lot of soil moisture may be present. This moisture may rise up into the wall and the floor through capillary action. Ground water rise will also result in moisture entry into the building through walls and floor.

2. Rain travel from wall lops

If the wall tops are not properly protected from rain penetration, rain will enter the wall and will travel down. Leaking roofs will also permit water to enter.

3. Rain healing against external walls

Heavy showers of rain may beat against the external faces of walls and if the walls are not properly treated, moisture will enter the wall, causing dampness in the interior. If balconies and chat projections do not have proper outward slope, water will accumulate on these and could ultimately enter the walls through their junction. This moisture travel would completely deface interior decoration of the wall.

4. Condensation

Due to condensation of atmospheric moisture, water is deposited on the walls, floors and ceilings. This moisture may cause dampness.

5. Miscellaneous causes

Moisture may also enter due to the following miscellaneous causes

(i) Poor drainage at the building site.

(ii Imperfect orientation, Walls getting less sunlight and heavy showers may remain damp.

(iii) Imperfect roof slope, especially in the case of flat roofs.

(iv) Defective construction Imperfect wall jointing, joints in roofs, defective throating etc.

(v) Absorption of water from defective rain water pipes.

EFFECTS OF DAMPNESS

The following are the ill effects of entry of dampness

1. Dampness gives rise to breeding of mosquitoes and creates unhealthy living conditions.

2. Travel of moisture through walls and ceiling may cause unsightly patches.

3. Moisture travel may cause softening and crumbling of plaster, specially lime plaster.

4. The wall decoration (i.e.. painting etc.) is damaged, which is very difficult and costly to repair.

5. Continuous presence of moisture in the walls may cause efflorescence resulting in disintegration of bricks, stones, tiles, etc., and consequent reduction in strength.

6. The flooring gets loosened because of reduction in the adhesion when moisture enters through the floor.

7. Timber fittings, such as doors, windows, almirahs, wardrobes etc., coming in contact with damp walls, damp floors etc., get deteriorated because of warping, buckling, dry-rotting etc. of timber.

8. Electrical fittings get deteriorated, giving rise to leakage of electricity and consequent danger of short circuiting.

9. Floor coverings are damaged. On damp floors, one can not use floor coverings.

10. Dampness promotes and accelerates growth of termites.

11. Dampness along with warmth and darkness breeds germs of dangerous diseases such as tuberculosis, neuralgia, rheumatism etc.

Occupants may even be asthmatic.

12. Moisture causes rusting and corrosion of metal fittings attached to walls, floors and ceilings.

METHODS OF DAMP PROOFING

Following methods are adopted to make a building damp proof :

(1) Use of damp proofing course (D.P.C.)

Proofing.

(2) Integral damp proofing.

(3) Surface treatment.

(4) Cavity wall construction.

(5) Grunting.

(6) Pressure grouting.

1. Membrane damp proofing

Use of D.P.C.

This consists of introducing a water repellent membrane or damp proof course (D.P.C.) between the source of dampness and the part of building adjacent to it. Damp proofing course may consist of flexible materials such as bitumen, mastic asphalt, bituminous felts, plastic or polythene sheets, metal sheets, cement concrete etc. Damp proofing course may be provided either horizontally or vertically in floors, walls etc. The following general principles should be kept in mind while providing D.P.C. :

(i) The damp proofing course should cover the full thickness of walls, excluding rendering.

(ii) The mortar bed supporting D.P.C. should be levelled and even, and should be free from projections, so that D.P.C. is not damaged.

(iii) D.P.C. should be so laid that of a continuous projection is provided.

(iv) At junctions and corners of walls, the horizontal D.P.C. should be laid continuous.

(v) When a horizontal D.P.C. (i.e.. that of a floor) is continued to a vertical face, a cement concrete fillet of 7.5 cm radius should be provided at the junction.

(vi) D.P.C. should not be kept exposed on the wall surface otherwise it may get damaged during finishing work.

2. Integral damp proofing

This consists of adding certain water proofing compounds of materials to the concrete mix, so that it becomes impermeable. These water proofing compounds may be in three forms

(I) Compounds made from chalk, talc, fullers earth, which

may fill the voids of concrete under the mechanical action principle.

(ii) Compounds like alkaline silicates, aluminium sulphate, calcium chlorides, etc. which react chemically with concrete to produce water proof concrete.

(iii) Compounds, like soap, petroleum, oils, fatty acid compounds such as of calcium, sodium, ammonia etc. work on water repulsion principle. When these are mixed with concrete, the concrete becomes water repellent.

(iv) Commercially available compounds like Publo, Permo, and Silka etc.

3. Surface treatment

The surface treatment consists of application of layer of water repellent substances or compounds on these surfaces through which moisture enters. The use of water repellent metallic soaps such as calcium and aluminium and stearates are much effective against rain water penetration. Pointing and plastering of the exposed surfaces must be done carefully, using water proofing agents like sodium or potassium silicates, aluminium or zinc sulphates, barium hydroxide and magnesium sulphates etc. It should be noted that surface treatment is effective only when the moisture is superficial and is not under pressure. Sometimes, exposed stone or brick wall face may be sprayed with water repellent solutions.

4. Cavity wall construction

This is an effective method of damp prevention, in which , the main wall of a building is shielded by an outer skin wall, leaving a cavity between the two.

5. Guniting

This consists of depositing under pressure, an impervious layer of rich cement mortar over the exposed surfaces for water proofing or over pipes, cisterns etc. for resisting the water pressure. Cement mortar consists of 1 :3 cement sand mix, which is shot on the cleaned surface with the help of a cement gun, under a pressure of 2 to 3 kg/cm^2. The nozzle of the machine is kept at a distance about 75 to 90 cm from the surface to be gunited. The mortar mix of desired consistency and thickness can be deposited to get an impervious layer. The layer should be properly cured at least for 10 days.

6. Pressure grouting

This consists of forcing cement grout, under pressure, into cracks, voids, fissures etc. present in the structural components of the building, or in the ground. Thus the structural components and the foundations which are liable to moisture penetration are consolidated and are thus made water-penetration-resistant. This method is quite effective in checking the seepage of raised ground water through foundations and sub-structure of a building.

MATERIALS USED FOR DAMP PROOFING

An ideal damp proofing material should have the following characteristics:

(1) The material should be perfectly impervious and it should not permit any moisture penetration or travel through it.

(2) The material should be durable, and should have the same life as that of the building.

(3) The material should be strong, capable of resisting superimposed loads/pressure on it.

(4) Material should be flexible, so that it can accommodate the structural movements without any fracture.

(5) The material should not be costly.

(6) The material should be such that leak-proof jointing is possible.

(7) The material should remain steady in its position when once applied. It should not allow any movement in itself. Following materials are commonly used for damp-proofing course.

1. Hot bitumen

This is highly flexible material, which can be applied with a minimum thickness of 3 mm. It is placed on the bedding of concrete or mortar, while in hot condition.

2. Mastic asphalt

Mastic asphalt is semi-rigid material which is quite durable and completely impervious. It is obtained by heating asphalt with sand and mineral fillers. However, it should be laid very carefully, by experienced persons. It can withstand only very slight distortion. It is also liable to squeeze out in very hot climate or under heavy pressure.

3. Bituminous or asphaltic felts

This is a flexible material which is available in rolls of various wall thicknesses. It is laid on a leveled flat layer of cement mortar. An overlap of 10 cm is provided at joints and full width overlap is provided at angles, junctions and crossings. The laps should be sealed with bitumen. Bituminous felts cannot withstand heavy loads; through they can accommodate slight movements.

4. Metal sheets

Sheets of lead, copper aluminium can be used as D.P.C. These sheets are of flexible type. Lead sheets are quite flexible. Their thickness should be such that its weight is not less than 7Okg/nr they are laid similar to the bituminous felts. Lead sheets have the advantages of being completely impervious to moisture, resistant to ordinary atmospheric corrosion, and capability of taking complex shapes without fracture and resistant to sliding action. It does not squcc/.c out under ordinary pressure. However, it may be corroded when in contact with lime or cement. It should, therefore, he protected by a coating of bitumen. Copper sheets, of minimum 3 mm thickness, are embedded in lime or cement mortar It has high durability, high resistance to dampness, high resistance to sliding and reasonable resistance to ordinary pressure. Aluminium sheets, if used, should be protected with a layer of bitumen. It is not as good as lead or copper sheets.

5. Combination of sheets and bituminous felts

Lead foil sand wished between asphaltic or bituminous fells can be effectively used as D.P.C. The combination, known as lead core possesses characteristics of easy laying, durability, efficiency, economy and resistance to cracking.

6. Bricks

Special bricks, having water absorption not less than 4% of their weight may be used as D.P.C. in locations where damp is not excessive. These bricks are laid in two to four courses in cement mortar. The joints of bricks are kept open.

7. Stones

Dense and sound stones, such as granite, trap, slates, etc. are laid in cement mortar (1:3) in two courses or layers to form effective D.P.C. The stones should extend to the full width of the wall.

8. Mortar

Cement mortar (1:3) is used as bedding layer for housing other D.P.C. materials. A small quantity of lime may be added to increase workability of the mortar. In water used for mixing, 75 gm of soft soap is dissolved per litre of water. This mortar may also be used for plaster work on external walls.

9. Cement concrete

Cement concrete of 1 :2:4 mix or 1 : i ; : 3 mix is generally provided at plinth level to work as D.P.C. The thickness may vary from 4 cm to 15 cm. Such a layer can effectively check the water rise due to capillary action. Where dampness is more, two coats of hot bitumen paint may be applied on it.

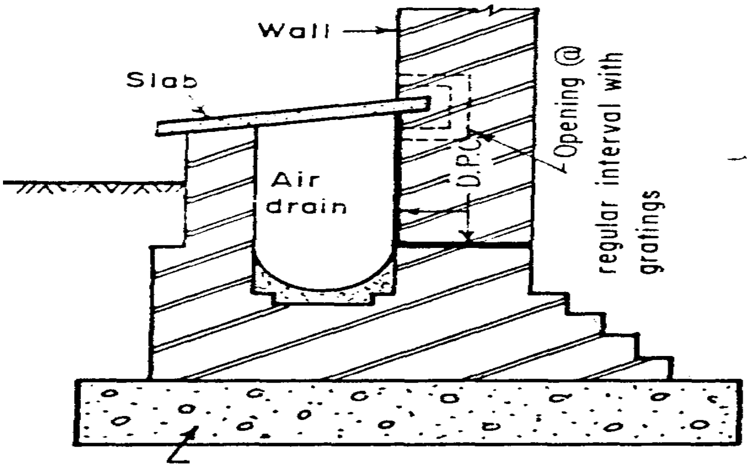
10. Plastic sheets

This is relatively a new type D.P.C. material, made of black polythene, 0.5 to 1 mm thick in the usual walling width and roll lengths of 30 m. C.B.R.I. Roorkee has recently suggested a new D.P.C. which comprises a 400 gauge thick alkaline laid over 12 mm thick 1:4 cement mortar. The treatment is cheaper but is not permanent.

D.P.C. TREATMENT IN BUILDINGS

1. Treatment to foundations against gravitational water

Foundation may receive water percolating from adjacent ground, and this moisture may rise in the wall. This can be checked by providing air drain parallel to the external wall. The width of air drain may be about 20 to 30 cm. The outer wall of the drain is kept above the ground to check the entry of surface water. A R.C.C. roof slab is provided. Openings with gratings are provided at regular interval, for the passage of air. Usual D.P.C. are also provided horizontally and vertically, as shown in Figure.



Foundation concrete

AIR DRAIN

2. Treatment to basements

When basements in damp soils are constructed, three methods may be adopted :

(i) Provision of foundation drains and D.P.C.

(ii) Provision of R.C.C. raft and wall slab.

(iii) Asphalt tanking.

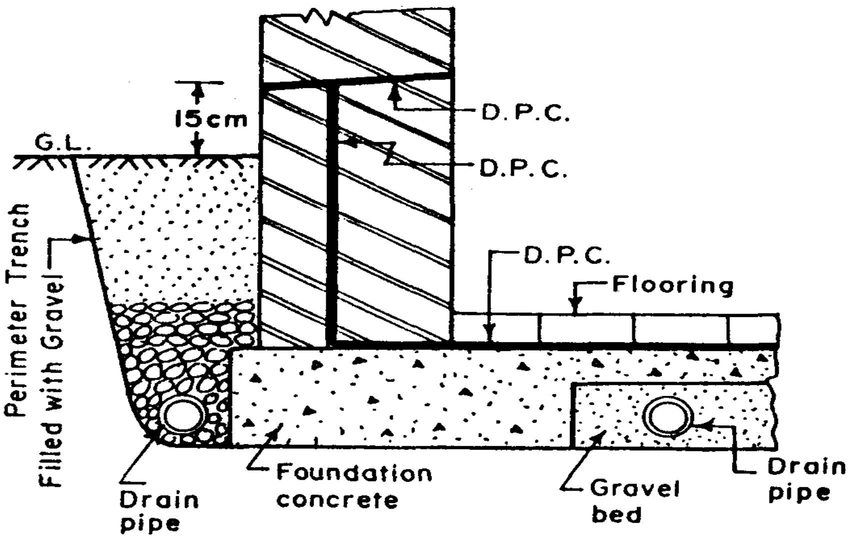


FIG D.P.C. TREATMENT FOR BASEMENT ON UNDRAINED SOIL

(a) Provision foundation drains and D.P.C.

When basement rests on soils which are not properly drained, (such as peat soil etc.) great hydrostatic pressure is exerted and

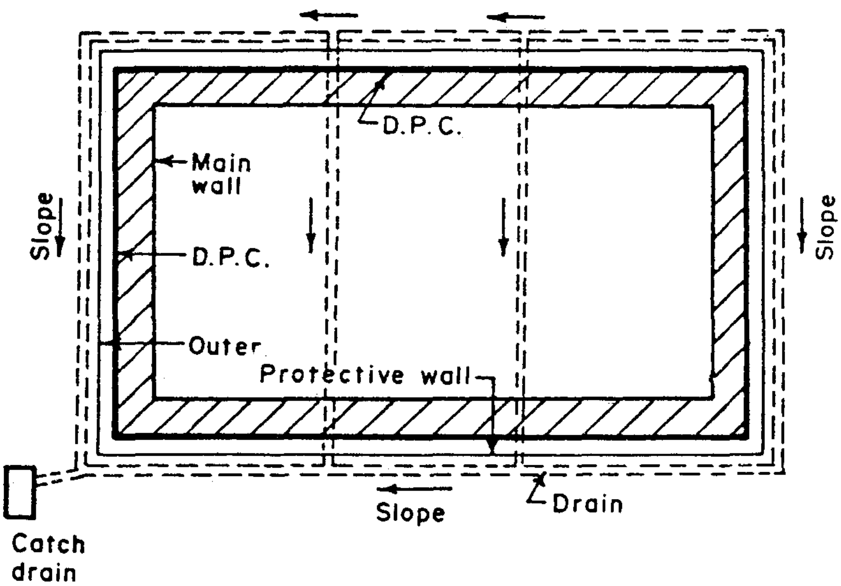


FIG PLAN SHOWING LAYOUT OF DRAINS

the floor as well as wall receive water continuously oozing out. In such a case it becomes necessary to make a trench all round, upto foundation level and fill it with gravel, coke and other pervious materials. Open jointed drains may be provided to collect the underground water. Drainage pipes, embedded in gravel bed, may also be provided before foundation concrete. Horizontal and vertical D.P.C. are provided in wall as well as foundation concrete.

The drain may have suitable longitudinal slope, ultimately draining the water into a catch drain. Drain pipes under the basement slab may be provided at some suitable interval.

(b) Provision of R.C.C. raft and wall slab

Where underground water pressure is severe, the drainage system may not solve the problem effectively. Also, constant pumping out water may be costly. In such a case, floor slab as well as walls may be constructed in rigid R.C.C. structure. Horizontal and vertical D.P.C. treatment is also provided. Atleast 3 layers of bituminous felts are used as D.P.C. Half- brick thick outer protecting wall is provided at the outer face of R.C.C. wall slab.

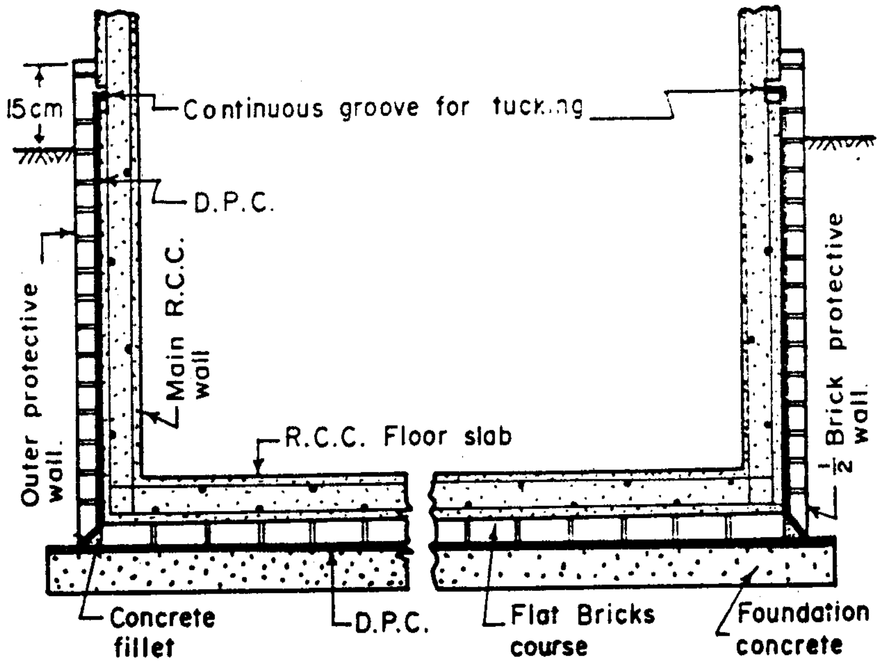


FIG D.P.C. TREATMENT FOR BASEMENT IN DAMP SOIL

(c) Asphalt tanking

This is adopted when the subsoil water table is not very high.

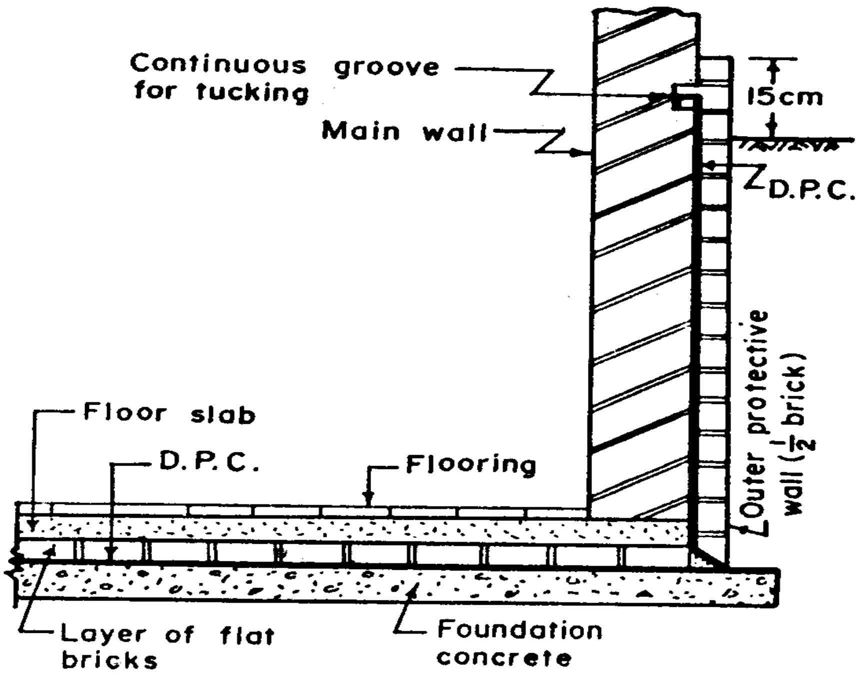


FIG ASPHALT TANKING FOR BASEMENT

The treatment consists of horizontal D.P.C. in the form of asphaltic layer of 30 mm thick in three coats over the entire area of basement floor and then extending it in the form of vertical D.P.C. on the external faces of the basement walls. The thickness of vertical asphaltic layer may be 20 mm, applied in three coats. The D.P.C. thus functions like a water proof tank on the external faces of the basement, thus keeping it dry. All brick thick outer protective wall is constructed.

The vertical D.P.C. is taken at least 15 cm above ground level. A protective flooring of flat bricks on foundation concrete (1:3:6) is provided to protect the D.P.C. from damage during the construction of floor slab.

3. Treatment to floors

For locations where ground moisture is not present, subsoil is rammed well and a 7.5 to 10 cm thick layer of coarse sand is spread over the entire area under flooring. Alternatively, stone soling may first be provided and then 7.5 cm to 10 cm thick layer of lean cement concrete (1:3:6 or 1:4:8) may be provided under it. Over this base, flooring may be laid. However, in damp soils, where water table is near ground surface, it is essential to provide membrane D.P.C. over the entire area, as shown in Figure. The membrane may be in the form of mastic asphalt or fibrous asphalt felt. A layer of flat bricks is laid on a cushion of find sand over D.P.C. to protect it from damage during the construction of floor slab.

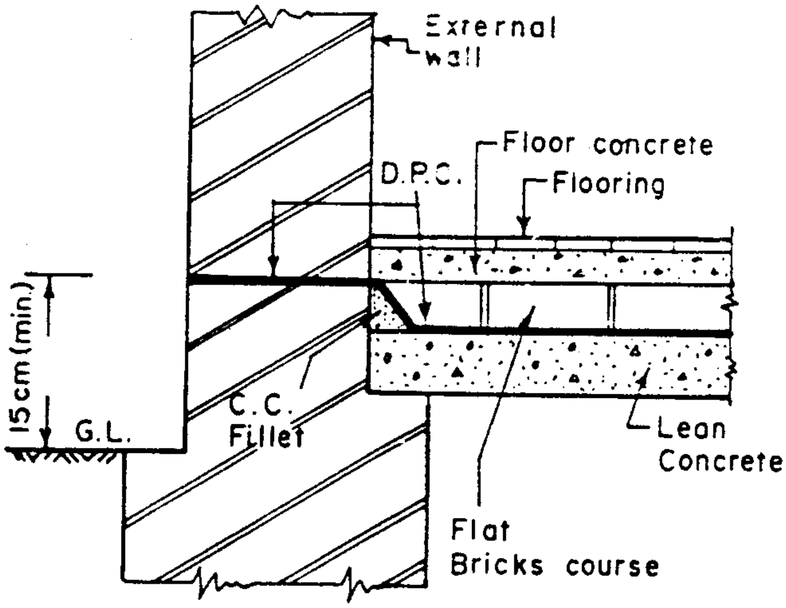


FIG D.P.C. FOR FLOORING

Before laying bituminous felt, a coat of hot bitumen, at the rate of 1.5 kg/m^2 is applied over the foundation concrete, to serve as primer coat. After laying bituminous felt over it, a finishing coat of hot bitumen is applied at the rate of 1.5 kg/m^2 over the felt.

4. Treatment to walls

For basement walls, a vertical D.P.C. is laid over the external

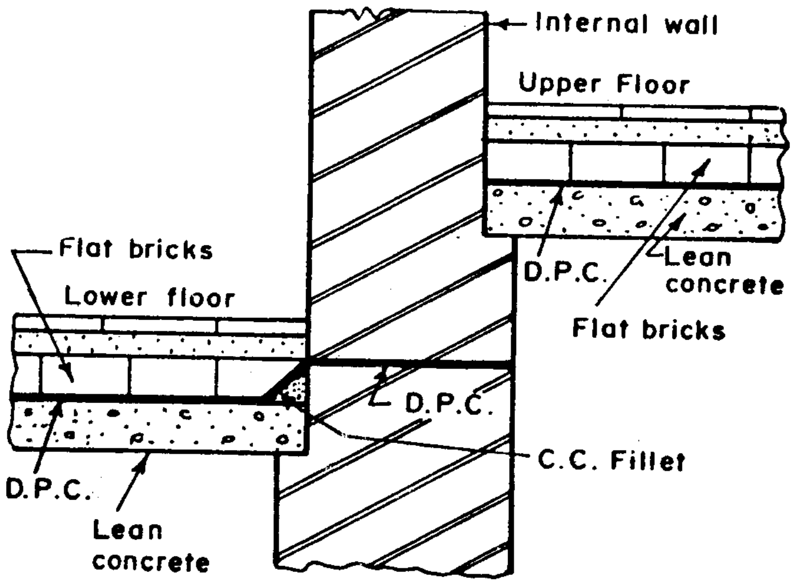


FIG D.P.C. FOR INTERNAL WALL

face of wall. This vertical layer of D.P.C. is laid over the base of water-cement plaster grounted on the external face of the wall. This vertical D.P.C. is further protected by external protective wall of half-brick thickness. The vertical D.P.C, should be carried at least upto a level 15 cm above G.L. Similarly, horizontal D.P.C. in external wall, extending from the floor, is provided at least 15 cm above G.L. In the internal walls, D.P.C. is provided in level with the upper surface of concrete floor. If two ground floors are at different levels and are connected by an internal wall, the D.P.C. is provided.