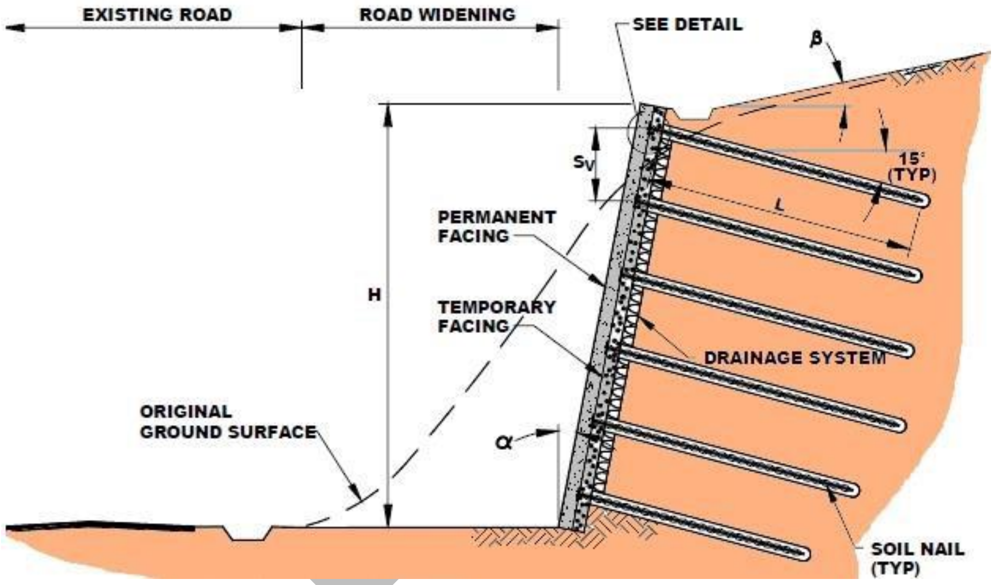
following: conformance of system components to material specification, conformance of construction methods to execution specifications, conformance to short-term performance specifications, and long-term monitoring. Short-term performance specifications are checked with loads tests, which utilize hydraulic jacks and pumps to perform several load applications. Three common load tests for short-term performance are verification or ultimate load tests, proof tests and creep tests. Verification or ultimate load tests are conducted to verify the compliance of the soil nails with pullout capacity and strengths resulting from the contractor's installation method. Proof tests are intended to verify that the contractor's construction procedure has been consistent and that the nails have not been drilled and grouted in a soil zone not tested in the verification stage. Creep tests are performed to ensure that the nail design loads can be safely carried throughout the structure's service life.

Long-term performance monitoring is used to collect data to ensure adequate performance and refine future design practices. Parameters to be measured include vertical and horizontal movement of the wall face, local movements or deterioration of facing elements, drainage to the ground, loads, load distribution and load changes in the nails, temperature and rainfall. These parameters are measured using several specific tools including inclinometers, load cells and strain gauges.



9.3.8.2 Advantages

Soil nail walls exhibit numerous advantages when compared to ground anchors and alternative topdown construction techniques. Some of these advantages are described below:

- Requires smaller right of way than ground anchors as soil nails are typically shorter;
- Less disruptive to traffic and causes less environmental impact compared to other construction methods.
- Provide a less congested work place, particularly when compared to braced excavations.

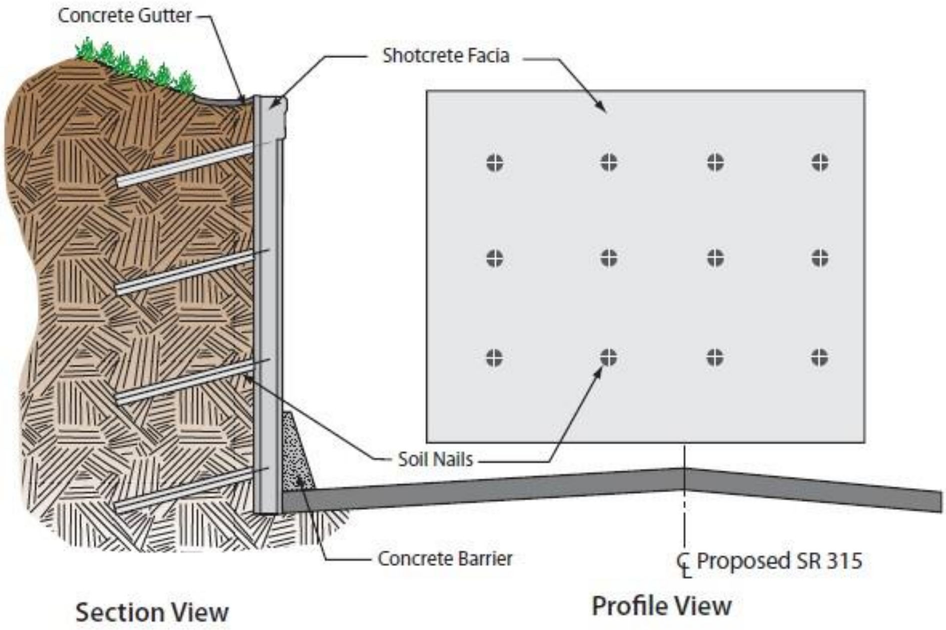
- There is no need to embed any structural element below the bottom of excavation as with soldier beams used in ground anchor walls.
- Soil nail installation is relatively rapid and uses typically less construction materials than ground anchor walls.
- Nail location, inclination, and lengths can be adjusted easily when obstructions (cobbles or boulders, piles or underground utilities) are encountered. On the other hand, the horizontal position of ground anchors is more difficult to modify almost making field adjustments costly.
- Since considerably more soil nails are used than ground anchors, adjustments to the design layout of the soil nails are more easily accomplished in the field without compromising the level of safety.
- Overhead construction requirements are smaller than those for ground anchor walls because soil nail walls do not require the installation of soldier beams (especially when construction occurs under a bridge).
- Soil nailing is advantageous at sites with remote access because smaller equipment is generally needed.
- Soil nail walls are relatively flexible and can accommodate relatively large total and differential settlements.
- Measured total deflections of soil nail walls are usually within tolerable limits.
- Soil nail walls have performed well during seismic events owing to overall system flexibility.
- Soil nail walls are more economical than conventional concrete gravity walls when conventional soil nailing construction procedures are used.
- Soil nail walls are typically equivalent in cost or more cost-effective than ground anchor walls when conventional soil nailing construction procedures are used.
- Shotcrete facing is typically less costly than the structural facing required for other wall systems.

9.3.8.3 Soil nail disadvantages

Some of the potential disadvantages of soil nail walls are:

- They may not be appropriate for applications where very strict deformation control is required for structures and utilities located behind the proposed wall, as the system requires some soil deformation to mobilize resistance. Deflections can be reduced by post tensioning but at an increased cost.
- Existing utilities may place restrictions on the location, inclination, and length of soil nails.
- They are not well-suited where large amounts of groundwater seeps into the excavation because of the requirement to maintain a temporary unsupported excavation face.
- Permanent soil nail walls require permanent, underground easements.

- Construction of soil nail walls requires specialized and experienced contractors.



9.3.9 Gabion walls

Gabions are cages, cylinders, or boxes filled with earth or sand that are used in civil engineering, road-building, and military application and many others. A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually battered (angled back towards the slope), or stepped back with the slope, rather than stacked vertically.

Gabion baskets have some advantages over loose riprap because of their modularity and ability to be stacked in various shapes; they are also resistant to being washed away by moving water. Gabions also have advantages over more rigid structures, because they can conform to subsidence, dissipate energy from flowing water, and drain freely. Their strength and effectiveness may increase with time in some cases, as silt and vegetation fill the interstitial voids and reinforce the structure. They are sometimes used to prevent falling stones from a cut or cliff endangering traffic on a thoroughfare.

The life expectancy of gabions depends on the lifespan of the wire, not on the contents of the basket. The structure will fail when the wire fails. Galvanized steel wire is most common, but PVC-coated and stainless steel wire are also used. PVC-coated galvanized gabions have been estimated to survive for 60 years. Some gabion manufacturers guarantee a structural consistency of 50 years. Gabion baskets are available in a variety of different sizes. They come in 1/2 or 1 meter high, and 2, 3, or 4 meters long. There are several types and colours of rock available from common river type round rock, to multi-coloured light and dark fractured rock.

Flexibility is an important benefit of any gabion structure. Since the baskets are constructed of galvanized mesh wire and filled with rock, the flexibility of a gabion structure allows it to withstand pressure without deforming, cracking or breaking as in the case of concrete and other materials. There are very few limits when it comes to the construction of a gabion wall. Walls can be constructed following grade along a road, tapered on top to follow changing elevation or terraced creating stunning flower gardens that can flow over the wall.

9.3.10 Anchored Walls

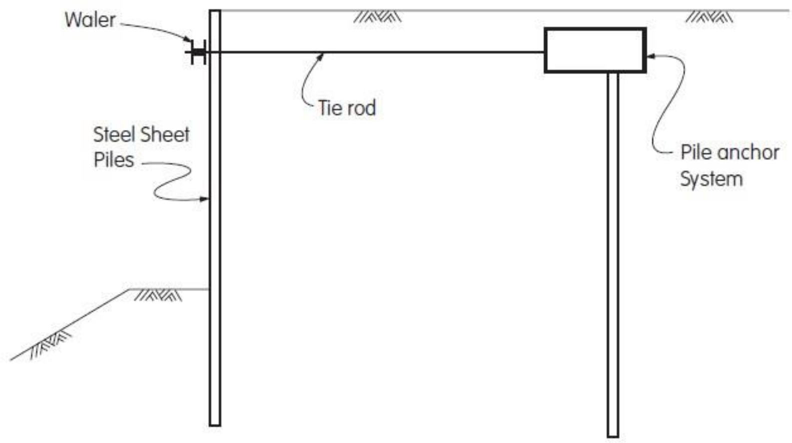
Anchored walls are typically composed of the same elements as non-gravity cantilevered walls, but derive additional lateral resistance from one or more levels of anchors. The anchors may be ground anchors (tiebacks) consisting of drilled holes with grouted in prestressing steel tendons extending from the wall face to an anchor zone

located behind potential failure planes in the retained soil or rock mass. The anchors may also be structural anchors consisting of reinforced concrete anchors, driven or drilled in vertical pile anchors or a group of driven piles consisting of battered compression piles and vertical tension piles connected with a reinforced concrete cap. These anchors are located behind potential failure planes in the retained soil and are connected to the wall by horizontal tie rods.

Ground anchors are suitable for situations requiring one or more levels of anchors whereas anchors utilizing tie rods are typically limited to situations requiring a single level of anchors. The ground anchor tendons and tie rods must be provided with corrosion protection.

The distribution of lateral earth pressure on anchored walls is influenced by the method and sequence of wall construction and the anchor prestressing. Ground anchors are generally prestressed to a high percentage of their design tension force whereas anchors with tie rods are secured to the wall with little or no prestress force.

Anchored walls are typically constructed in cut situations in which construction proceeds from the top down to the base of the wall. For situations where fill is placed behind the wall special consideration in the design and construction is required to protect the ground anchors or tie rods from construction damage due to fill placement and fill settlement. The vertical wall elements should extend below potential failure planes associated with the retained soil or rock mass. Where competent and stable foundation material is located at the base of the wall face, only minimal embedment of the wall may be required (soldier pileless design). The long-term creep characteristics of the anchors should be considered in design. Anchors should not be located in soft clay or silt.



Anchored walls may be used to stabilize unstable sites. Provided adequate foundation material exists at the site for the anchors, economical wall heights up to 24m are feasible. Mechanically stabilized earth (MSE) walls use either metallic (inextensible) or geosynthetic (extensible) soil reinforcement in the soil mass, and vertical or near vertical facing elements. MSE walls behave as a gravity wall, deriving their lateral resistance through the dead weight of the reinforced soil mass behind the facing.

MSE walls are typically used where conventional reinforced concrete retaining walls are considered, and are particularly well suited for sites where substantial total and differential settlements are anticipated. The allowable differential settlement is limited by the deformability of the wall facing elements within the plane of the wall face. In the case of precast concrete facing elements (panels), deformablitiy is dependent on the panel size and shape and the width of the joints between panels. This type wall can be used in both cut and fill applications. Because their base width is greater than that of conventional reinforced concrete walls they are most cost effective in fill applications. The practical height of MSE walls is limited by the competence of the foundation material at a given site.

9.5 CONSTRUCTION OF BRIDGES

9.5.1 General

Before starting the construction work, the procedure mentioned in section 2200 must be followed and care must be taken to ensure that the following documents are available at site.

- Sanction letter and technical note, if any
- Bill of Quantities
- Copy of contract document
- Copy of approved set of plans, estimates and detailed working drawings
- Standards, specifications, guidelines, codes of practices etc., according to which the work must be executed as per contract
- Survey, investigation and subsoil test reports, (if any)

9.5.2 Excavation

Before starting excavation, it is necessary that initial site levels are taken. Protective works, if any, shall be completed before monsoon so that foundations do not get undermined. Excavations for laying foundations shall be carried out in accordance with Section 300 of MoRTH Specification for Road and Bridge works. The last 300 mm of excavation shall be done just before laying of lean concrete below foundation.

Where there is any doubt regarding the bearing capacity or suitability of the foundation soil the matter shall be reported to the Executive Engineer. In the case of small works up to TS power of Executive Engineer, if any variation on the width, depth and type of foundation is found necessary the Assistant Executive Engineer himself may decide the matter after reporting to the authority sanctioning the estimate.

Load tests shall be conducted in the foundation soil if found necessary. If the contractor has over excavated the foundation, he shall not be allowed to refill this with earth but, the additional excavation shall be filled up by concrete. No extra cost is payable to the contractor on this account. In some cases, it may be possible to reduce the depth or width of foundation due to existence of harder type of soil or rock in particular localities but the Assistant Executive Engineer may decide on the alteration necessary and instruct the contractor accordingly. A report shall be sent to the Executive Engineer clearly indicating the change effected and the reasons therefore.

The useful materials obtained from excavation like moorum sand stone etc. shall be stacked separately and properly measured and accounted for. It shall be reused for backfilling of foundations and other useful works. All spaces excavated and not occupied by the foundation shall be refilled upto surrounding level in accordance with MoRD/ MoRTH Specification for Road and Bridge works. All safety measures shall be observed at site to avoid accidents. Unauthorized entries to site of work shall be prohibited. The contractor shall obtain proper license for explosives whenever these are to be stored.

The excavation for foundation shall be checked and got approved by the Executive Engineer

9.5.3 Concreting

All the materials used in concreting must be tested for relative properties before hand.

9.5.3.1 Key Points

i. The minimum cement content is based on 20 mm aggregate.

ii. For 40 mm and larger sized aggregates, cement content may be reduced suitably, but the reduction shall not be more than 10%

iii. For underwater concreting, the cement content shall be increased by 10 %.

iv. Prior to start of construction, the contractor shall design the mix and submit to the Executive Engineer for approval of the mix, proportions of materials, including admixtures used.

v. Trial mixes: Test cubes shall be taken, from trial mixes (if necessary).

vi. The average strength of the nine cubes at 28 days shall exceed the specified characteristic strength.

vii. Concrete shall be mixed either in a concrete mixer or in a batching and mixing plant approved by the Executive Engineer. Hand mixing shall not be permitted.

viii. Mixers, which have been out of use for more than 30 minutes, shall be thoroughly cleaned before putting in a new batch.

ix. The first batch of concrete from the mixer shall contain only two thirds of the normal quantity of coarse aggregate.

x. The compacted thickness of each layer shall not be more than 0.45 m when internal vibrators are used and shall not exceed 0.3 m in all other cases.

xi. Do not allow dropping of concrete from a height exceeding 2 m.

xii. When concreting is to be received on a surface, which has hardened, it shall be roughened, swept clean, wetted and covered with a 13 mm thick mortar layer composed of cement and sand in the same ratio as in the concrete mix.

xiii. Do not apply vibration through the reinforcement.

xiv. Keep the compacted concrete continuously wet for a period not less than 14 days

Transporting, placing and compaction of Concrete shall be as per clause of MoRD/ MoRTH Specification for Road and Bridge works. For formwork and staging clause of MoRD/ MoRTH Specification for Road and Bridge works shall be followed. The contractor shall furnish the design and drawings of complete formwork as well as their supports for approval of the Assistant Executive engineer before any erection is taken up. Metal/ laminated board formwork shall preferably be used for achieving good finish. The formwork shall be robust and strong and the joints shall be leak proof. The formwork shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete sides. The formwork shall be inspected and approved by Assistant Executive Engineer before concreting is done.

The requisite properties for structural steel shall be as per clause of MoRD/ MoRTH Specification for Road and Bridge works and its placement shall conform to clause of MoRD/ MoRTH Specification for Road and Bridge works. This includes protection of reinforcement, bar splicing and bending of reinforcement. The size (Maximum nominal) of coarse aggregates for concrete to be used shall be as given in Table

9.5.4 Foundations

a) Open Foundation:

The plan dimensions of the foundation shall be set out at the bottom of foundation trench and checked with respect to original reference line and axis. It shall be ensured that at no point the bearing surface is higher than the founding level shown on the drawing.

Open foundation shall be constructed in dry conditions and the contractor shall provide for adequate dewatering arrangements to the satisfaction of the Assistant Executive Engineer. Measures such as bailing out, pumping, constructing diversion channels etc. shall be taken to keep the foundation trenches dry and to protect the green concrete against damage. Where the bearing surface is earth, a layer of M15 concrete shall be provided below foundation concrete. The thickness of lean concrete layer shall be 100 mm minimum unless otherwise specified. All spaces excavated and not occupied by the foundation shall be refilled and compacted with earth up to the surface of surrounding ground. In case of excavation in rock, the annular space around foundation shall be filled with M 15 concrete up to the top of rock.

The construction procedure shall conform to provisions contained in MoRD/ MoRTH Specification for Road and Bridge works.

b) Well Foundation:

This work consists of construction of well foundation, taking it down to the founding level through all kinds of sub-strata, plugging the bottom, filling the inside of the well, plugging the top and providing a well cap in accordance with the details shown on the drawing and as per the specifications ofMoRD/ MoRTH Specification for Road and Bridge works.

- Fix up reference points, away from the zone of blowups/ settlements resulting from well sinking and mark centre lines of the individual wells in longitudinal and transverse directions accurately.
- Benchmark and reference points shall be checked regularly from permanent points fixed at site.
- Cutting edge shall be laid on dry ground / Sand Island.
- Sand Island to be protected against scour until the sinking is done to a safe level.
- Floating caisson of steel can be adopted when construction of Sand Island is not feasible.
- Use steel formwork for well curb
- Concreting in the well curb shall be done in one continuous operation.

- Steining shall be cast only after sinking the curb to some extent so that it becomes stable.
- The steining shall be built in one straight line from bottom to top.
- The height of the steining shall be calibrated by marking on outer faces in longitudinal and transverse directions (4 sides) with every metre mark in paint. Zero shall start from bottom of the cutting edge.
- For sinking, material be excavated uniformly all round the dredge hole
- De-watering shall not be permitted as a means for sinking.
- A detailed statement with regard to the progress of well sinking shall be maintained at site as per Appendix 2200 F.
- If a tilt occurs, further steining has to be carried out, with the axis of the extended steining following the axis of the well already sunk. Tilts shall be corrected as soon as it occurs.
- Sinking history of well including tilt and shift, kentledge, dewatering, blasting done during sinking shall be maintained in the format given in Appendix-2200 G
- The depth of sump below the level of cutting edge shall be generally limited to one-sixth of the outer diameter/ least lateral dimensions of well in place. Normally, the depth of sump shall not exceed 3m unless otherwise specifically permitted by the Engineer.
- Bottom plugging shall be done with the help of tremie pipe. Additional 10 per cent cement shall be provided in the concrete for bottom plug.
- A record of the method of sinking adopted, bottlenecks encountered etc. may be kept as per proforma given in Appendix-2800 H

c) Pile Foundation

Sub-surface investigation shall be carried out by in-situ pile tests. At least one bore-hole for every foundation of the bridge shall be executed. Depth of boring shall not be less than,

- 1.5 times estimated length of pile in soil but not less than 15 m beyond the probable length of pile
- 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock
- 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock

Type of Piles

The piles may be of reinforced concrete, pre stressed concrete, steel or timber. The piles may be of solid or hollow sections or steel cased piles filled with concrete. Concrete piles may be driven cast-in-situ or pre-cast or bored cast- in-situ or pre-cast piles driven into preformed bores. The shape of piles may be circular, square, hexagonal, octagonal, "H" or "I" Section.

Construction of pile foundations shall be as per theMoRD/ MoRTH Specification for Road and Bridge works and IS: 2911. The construction of pile foundations requires a careful choice of the piling system depending upon sub-soil conditions and loading characteristics and type of structure. The method of installing the piles, including details of the equipment shall be submitted by the Contractor and got approved by the Executive Engineer

(i) Test piles

- Test piles that are to become a part of the completed structure shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.
- Test piles, which, are not to be incorporated in the completed structure, shall be removed to at least 600 mm below the proposed soffit level of pile cap and the remaining hole shall be backfilled with earth or other suitable material.

(ii) Pre-cast concrete piles

- For pre cast piles, concrete shall be placed continuously until the completion of each pile, the length of pile shall not normally exceed 25 metres.
- Pre-cast concrete piles shall be lifted by means of a suitable bridle or sling attached to the pile but normally at points not more than 3 metres from the ends of the piles
- Pre-cast concrete piles cured with water shall not be driven for at least 28 days after casting (10 days with rapid hardening cement)

Detailed procedure for construction and driving of pre-cast pile are given in the MoRD/ MoRTH Specification for Road and Bridge works.

(iii) Cast-in-situ concrete piles

- Cast-in-situ concrete piles may be either installed by making a bore into the ground by removal of material or by driving a metal casing with a shoe at the tip and displacing the material laterally.
- Cast- in-situ concrete piles may be cast in metal shells, which may remain permanently in place.
- The reinforcement cages must be prepared in advance and adjustment to the length done depending on site requirements.
- This cage shall be lowered just prior to concreting and completed without interruption.
- In case of liners being withdrawn, sufficient head of concrete has to be provided to prevent the entry of ground water or reduction of cross section (necking of the pile).
- A minimum of 2.0 m length of top of bore shall invariably be provided with casing to ensure against loose soil falling into the bore.
- If the concrete is placed inside pre-cast concrete tubes or consists of pre-cast sections, these shall be free from cracks or other damage before being installed.

Specific requirements of cast- in-situ driven piles shall be as per MoRD/ MoRTH Specification for Road and Bridge works. The equipments used for pile driving and the detailed procedures shall be as per MoRD/ MoRTH Specification for Road and Bridge works.

9.5.5 Sub Structure

The construction procedure shall conform to provisions contained in MoRD/ MoRTH Specifications for Road and Bridge Works.

9.5.6 Piers and Abutments

- In case of concrete piers, the number of horizontal construction joints shall be kept minimum.
- Construction joints shall be avoided in splash zones.
- No vertical construction joint shall be provided.
- In case of tall piers and abutments, use of slip form shall be preferred.
- The surface of foundation/well cap/pile cap shall be scrapped with wire brush and all loose materials removed.
- In case reinforcing bars projecting from foundations are coated with cement slurry, tapping, hammering or wire brushing shall remove the same.
- Before commencing masonry or concrete work, the surface shall be thoroughly wetted.
- In case of solid (non-spill through type) abutments, weep holes as shown on the drawings shall be provided.
- The surface finish shall be smooth, except the earth face of abutments, which shall be rough, finished.
- In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers to, the full height to allow for the anticipated movement during construction period before casting of superstructure.

Specific requirements of piers and abutments shall be as per MoRD/ MoRTH Specification for Road and Bridge works.

9.5.7 Pier Cap and Abutment Cap

- The locations and levels of pier cap/abutment cap/pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment in accordance with the drawings of the bridge.
- The surface of cap shall be finished smooth and shall have a slope for draining of water as shown on the drawings.
- For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal.
- The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

- The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane which shall not vary more than 1.5 mm from straight edge placed in any direction across the area.
- The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings and as indicated on the drawings.

Specific requirements of Pier Cap and Abutment Cap shall be as per MoRD/ MoRTH Specification for Road and Bridge works.

9.5.8 Dirt/ Ballast Wall, Return Wall and Wing Wall

- In case of cantilever return walls, no construction joint shall generally be permitted.
- Wherever feasible, the concreting in cantilever return walls shall be carried out in continuation of the ballast wall.
- For gravity type masonry and concrete return and wing wall, the surface of foundation shall be prepared in the same manner as prescribed for construction of abutment. No horizontal construction joint shall be provided.
- If shown on drawing or directed by the Assistant Executive Engineer, vertical construction joint may be provided.
- Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 metre intervals or as directed by the Assistant Executive Engineer.
- Weep holes shall be provided as prescribed for abutments or as shown on the drawings.
- The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.
- Architectural coping for wing wall/return wall in brick masonry shall conform to MoRD/ MoRTH Specifications.

Specific requirements of Dirt/ Ballast Wall, Return Wall and Wing Wall shall be as per MoRD/ MoRTH Specification for Road and Bridge works.

9.5.9 Bearings

Bearings are the part of the bridge structures, which bears directly all the forces from the structure above and transmits the same to the supporting structure. The different types of bearings currently in use are Steel bearings, Elastomeric Bearings, Pot Bearings and Special bearings. Bearings shall conform to the provisions contained under MoRD/ MoRTH Specifications for Road and Bridge Works.

9.5.10 Super Structure

a) Reinforced Concrete Construction

Construction of Solid Slabs and RCC T-Beam & Slab are carried out as per the clause set forth in MoRD/ MoRTH Specification.

b) Pre-stressed Concrete Construction

Construction of PSC Girder and Composite RCC Slab, Box Girder and Cantilever shall be carried out as per the clause set forth in MoRD/ MoRTH Specifications

c) Expansion Joint

Expansion Joints shall be provided as per Section of MoRD/ MORTH specification for Road and Bridge Works.

9.5.11 Wearing Coat and Appurtenances

a) Wearing Coat

A wearing coat over the deck slab with bituminous material or Cement concrete shall be provided as per Clause of MoRD/ MoRTH Specifications.

b) Approach Slab

Reinforced concrete approach slab covering the entire width of the roadway shall be provided ~~as per details given on the drawings or~~ as approved by the Assistant Executive Engineer. Minimum length of approach slab shall be 3.5 m and minimum thickness 300 mm. ~~The base for the approach slab shall be as shown on the drawings.~~

c) Drainage Spouts and Weep Holes

Drainage spouts and Weep holes shall be provided as per MoRD/ MoRTH respectively.

d) Illumination

Provision for lighting arrangements (if necessary) shall be done as per the drawings.

e) Railings

Bridge railing includes the portion of the structure erected on and above the kerb for the protection of pedestrians and traffic. Railings can be of Metal, Cast in situ and Pre-cast concrete. These shall be erected as per MoRD/ MoRTH Specification. Railings or closely spaced guard stones shall be extended to the approach slabs.

f) River Training and Protection Works

River training and protection work shall include construction of Guide bunds, Aprons, Stone pitching or Revetment on Slopes, Flooring, Curtain wall and Flexible Aprons as required for ensuring safety of the bridge structure and its approaches against damage by flood/flowing water. Constructions of the above components shall be carried out as per MoRD/ MoRTH Specifications.

9.6 CONSTRUCTION OF BUILDINGS

9.6.1 General

Before start of the construction work, care must be taken to ensure that the documents as specified in section 2200 are readily available. The site shall be handed over to the contractor within the stipulated time and acknowledgement in prescribed form forwarded to all concerned officials.

9.6.2 Professional Services and Responsibilities

The responsibility and competence of the team of professionals with regard to planning designing and supervision of building construction work shall be in accordance with Part 2 'Administration' of National Building Code 2005. The provisions in Part 2 'Administration' of National Building Code 2005 shall also govern all applications for permits and issuance of certificates, etc. Employment of trained workers shall be encouraged for building construction activity.

9.6.3 Storage, Stacking and Handling of Building Materials

Storage, Stacking and Handling of Building Materials shall be in accordance with the Part 7 section 2 of National Building Code.

9.6.4 Safety in Construction of a Building

The provisions of this Section shall apply to the erection/alteration of the various parts of a building or similar structure. In case of a doubt or dispute, the specific Rules, Regulations and Acts pertaining to the protection of the public or workmen from health and other hazards wherever specified by the Local/State Authority or in the Acts of the Government take precedence over whatever is herein specified. The safety management of the building site shall be in accordance with Part 7 Section 3 ofNational Building Code 2005.

9.6.5 Construction Activities Undertaken from Foundation to Roof:

i. The Contractor shall mark the Layout of Building on the ground in the form of centre lines of walls and columns. These centre lines shall be guided by brick pillars made along the centre line at a distance of 1.2 m from the outer walls and columns with the centre marked on these reference pillars with fresh plaster. Excavation is done to the prescribed basement floor level.

ii. Balance excavation to be done after remarking the position of columns on excavated ground and also making temporary markings of centre lines on excavated sides. Marking the foundation/ beams sizes and then doing the balance excavation giving shape to the raft foundation / column foundations as per the design.

i. In case external waterproofing is to be done, it is to be done on the PCC and if internal it shall be done after completing the RCC of the basement. Then the final Layout of walls, columns and beams on the PCC shall be made and got verified by the Assistant Executive Engineer.

ii. Contractor shall prepare and submit the bar bending schedule as per drawings and get it approved by the Assistant Executive Engineer. Cover blocks to be made by contractor in PCC at the time of laying PCC in the thicknesses stipulated and placed below or around reinforcement so as to provide proper cover. After laying of the Steel reinforcement it is to be checked and measured by the Assistant Executive Engineer for accuracy and cover to reinforcement. This shall be check measured by AEE

iii. Concrete for columns (or in walls) shall be as per design mix and vibrated properly. Cement additives can be added for generating proper flow and compaction of concrete as per clause 5.5 of IS 456: 2000. Single lift shall not be more than 1.2 m

iv. Contractor is to cast the balance height of column after proper shuttering up to beam bottom.

v. Contractor is to provide and do shuttering of the roof as per structural drawings and check its level. It shall be ensured that proper amount of supports are provided and also that the shuttering is not uneven or done with very old planks or bent plates. The shuttering of wareproof ply or of steel sections made to the size required shall be used. Steel shuttering of various column sizes and also steel plates for roof shuttering shall be used. Assistant Engineer shall check the shuttering for levels and design aspect he shall also check the supports for any loose ends.

vi. The primary responsibility of ensuring the correctness of the reinforcement details as per design isvested with the Assistant Engineer. But the contractor's Engineer shall certify that the reinforcementis provided as per structural drawings and bar bending schedule. The Overseer in charge shall reportthe matter to the Assistant Engineer.

vii. In normal course concreting shall be done at a stretch. In the case of emergency the work shall be stopped only at supports or at the point of contra flexure.

viii. Time shall be given to the electrical contractor and the plumbing contractor for laying the pipes, fan and light boxes properly. Thus a gap of one day shall be provided after the bending of steel reinforcement so that both the electrical and sanitary contractors can execute this work properly and also for the Assistant Executive Engineer to check the reinforcement, shuttering, electrical and sanitary work.

ix. Assistant Engineer shall depute one of his Overseers to keep a check at the point of mixing for volumes of cement, coarse sand, coarse aggregate. Additives for concrete available in the market for increasing the workability of concrete shall be used as per requirement.

9.6.6 Site Layout

The layout of the construction site shall be carefully planned keeping in view the various requirements to construction activities and the specific constraints in terms of its size, shape, topography, traffic and other restrictions, in public interest. A well-planned site layout would enable safe smooth and efficient construction operations. The site layout shall take into considerations the following factors:

a) Easy entry and exit, with proper parking of vehicle and equipments during construction.

b) Properly located material stores for easy handling and storage.

c) Adequate stack areas for bulk construction materials.
d) Optimum location of plants and equipments (batching plants, etc).
e) Layout of temporary services (water, power, power generation unit, hoists, cranes, elevators, etc).
f) Adequate yard lighting and lighting for night shifts.
g) Temporary buildings; site office and shelter for workforce with use of non-combustible materials as
h) far as possible including emergency medical aids.
i) Roads for vehicular movement with effective drainage plan.
j) Construction safety with emergency access and evacuations and security measures. j) Fabrication yards for reinforcement assembly, concrete pre-casting and shuttering k) Fencing, barricades and signage's.

9.6.7 Buildings Materials

For all Building materials, methods of use and specifications National Building Code 2005, part V- may be followed

9.6.8 Earthwork Excavation

Excavation wherever required shall be done to the prescribed building plan as per the clause 11, 12 and 13 of Section 3 Part 7 National Building Code 2005.

9.6.9 Foundation

Foundation shall be done as per the design drawings. The forms and materials of building foundations vary according to ground conditions, structural material, structural type, and other factors. Types of foundation and details shall be referred to in Part VI Section 2 of National Building Code 2005(Clause 6 to 13).

a) Plain Cement Concrete.

Plain Cement Concrete shall be done as per the thickness given in the drawing. The minimum thickness of PCC must be 100 mm. The bottom of the foundation shall be leveled both longitudinally and transversely or stepped as directed by the Assistant Engineer. Before footing is laid, the surface shall be slightly watered and rammed. In the event of excavation having been made deeper than that shown on the drawings or as otherwise ordered by the Assistant Engineer, the extra depth shall be made up with concrete of same grade as that of PCC of the foundation at the cost of the Contractor. Earth filling shall not be used for the purpose to bring the foundation to level. When rock or other hard strata is encountered, it shall be freed of all soft and loose material, cleaned and cut to a firm surface either level and stepped as directed by the Assistant Engineer. In the case of open foundation dewatering shall not be permitted from the time of placing of concrete up to 24 hours after placement.

b) Random Rubble Masonry for Foundation and Basement:

In this type rubble stones are carefully laid, hammered down in to position and solidly embedded in mortar, with mortar joints not exceeding 12.5 mm in thickness. The stones will be hammer dressed on the face and stones are so arranged as to break joint as much as possible and long vertical lines of joints are avoided. The mortar used in the rubble foundation shall be minimum 1:6 proportion. Bond stones must be used at staggered spacing of 1.5 m. The stones must be wetted before using.

c) Damp Proof Course

Damp proof courses are inserted in horizontal beds in masonry. In basements vertical damp-proof courses also are provided. Usually the damp proof course consists of a layer of cement mortar or cement concrete 25 mm to 40 mm. thick painted over with 2 coats of bitumen - 1st coat at 1.2 Kg./sq. meter and 2nd coat at 0.7 Kg. per sq. meter. This is covered with coarse sand @ 0.006 cum per sq. meter.

Another method of damp proofing consists of adding certain compounds to concrete or mortar, like chalk, talc etc. which have a mechanical action of pore filling or alkaline silicates, aluminum or zinc sulphates, calcium, aluminum or ammonium chloride, iron fillings etc. which react chemically and fill the pores.

A third method of damp proofing consists of incorporation of a layer of water-repellent material such as lead sheet, slates, mastic asphalt etc. between the source of moisture and part of the building adjacent to it. Alternately one of the specifications as per part 5 of National Building code shall be followed.

Damp-Proof Course above Ground Level: To prevent moisture rising above ground level by capillary action, the damp proof course is provided above ground level. To form an effective barrier, the course shall extend to the full thickness of masonry. Damp proof course when provided below flooring shall form a continuous layer with the damp-proof course in the masonry.

Damp Proof Course for Basement: This work shall be taken on hand only when the sub-soil water level is at its lowest. Further the site has to be kept dry by pumping till the work is completed and has set completely. Suitable structural support shall be provided for the damp - proof course to withstand the anticipated water pressure. The following methods can be adopted:

i. A base slab of weak cement concrete with a smooth surface finish is constructed on the floor of the excavation. This shall project at least 15 cm. beyond the outer walls. The damp proof course is laid over the entire slab.
ii. A protective flooring of flat brick or cement concrete 1:3:6 is constructed over the damp proofing course to protect it. The structural walls and floor are then constructed. They shall be suitably designed to withstand the anticipated water pressure. The outside faces are plastered and finished smooth.

iii. The damp proof course is then applied to the outside face of the wall, joining at the base to the projecting damp proof course originally laid over the base slab, taking care to ensure a perfect bond. A thin protective brick wall, half brick thick, is then constructed over the projecting base slab. The gap between the walls shall be grouted with cement.

Alternately, where sufficient working space is not available after the base concrete is laid, the outer protective wall is first constructed. The damp proof course is then laid over the floor and sides. A protective layer of brick is laid over the floor and a thin inner protective wall is constructed to protect the damp proof course laid over the sides. The structural walls are then constructed.

9.6.10 Plinth Beam

If the foundation is deep, that is, going more than half a storey in depth below the plinth, the Plinth shall be connected using beams. Plinth level shall be checked with respect to drawing level. Bottom of the peripheral plinth beam shall be kept 15cm below the existing ground level. Plinth beam shall be provided as per structural drawing.

9.6.11 Cement Mortar

Cement and sand shall be mixed intimately in a mechanical mixer in the specified proportions. Proportioning of cement shall be weighed while sand can be by volumes, after making due allowance for bulking. The mortar shall be used within 30 minutes of addition of water.

9.6.12 Brick Work for Structures

Bricks are to be immersed in water for a minimum period of one hour before use. All brickwork shall be laid in English bond, even and true to line, plumb and level. Bricks shall be laid with frogs up, on a full bed of mortar. All joints shall be properly flushed and packed with mortar so that no hollow space isleft. Thickness of joints shall not exceed 10mm. The masonry shall be kept constantly moist on all faces for a minimum period of 7 days.

9.6.13 Formwork

Most structural concrete is made by placing (also called CASTING) plastic concrete into_ spaces enclosed by previously constructed Forms. These forms are usually removed once the plastic concrete hardens into the shape outlined by the forms. Forms for concrete structures must be tight, rigid, and strong. The forms must be strong enough to resist the high pressure exerted by the concrete.

9.6.14 Form Materials

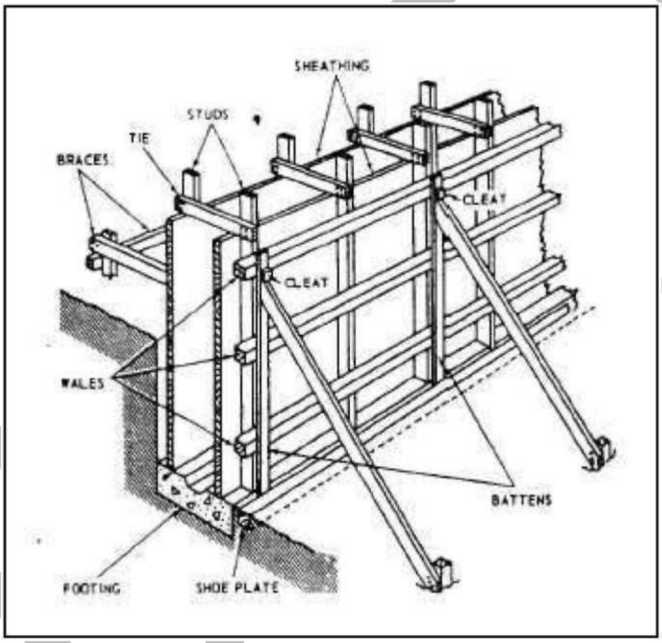
Wood, plywood, steel, fiberglass, and other approved materials are commonly used as form materials.

9.6.15 Foundation Forms

Foundation forms may include forms or parts of forms for column footings, pier footings, and wall footings. Whenever possible, the earth shall be excavated and the hole used to contain the foundation of footing forms. Footings are cast directly against the earth, and only the sides are molded in forms. Where there is a firm natural earth surface, which is capable of supporting and molding the concrete, there is no need of additional formwork.

Wall forms are made up of five basic parts. They are as follows:

i. Sheathing, to shape and retain the concrete until it sets;
ii. Studs, to form a framework and support the sheathing;
iii. Wales, to keep the form aligned and support the studs;
iv. Braces, to hold the forms erect under lateral pressure; and
v. Ties and spreaders or tie-spreader units, to hold the sides of the forms at the correct spacing.



Wall forms may be built in place or prefabricated, depending on the shape and the desirability for reuse. Wall forms are usually reinforced against displacement by the use of TIES. Small surface holes remain, which can be plugged with grout. The prefabricated panels for formwork can be used. The panels can be sized to suit any particular situation. Projects requiring mass concrete are often formed by the use of giant panels or ganged, prefabricated forms. Cranes usually raise and place these large sections, so only the available equipment limits their size. These large forms are built or assembled on the ground, and their only basic difference from regular forms is the extra bracing required withstanding handling. Special attention must be given to corners when forms are being erected. These are weak points because the continuity of sheathing and wales is broken. Forms must be pulled tightly together at these points to prevent leakage of concrete.

9.6.16 Column Forms

A typical concrete column form is securely braced to hold the sheathing together against the bursting pressure exerted on the form by the plastic concrete. Since the bursting pressure is greater at the bottom than the top, the bracings are placed closer together at the bottom. Boltholes are bored in projections, and bolts are inserted to backup the wedges that are driven to tighten.

9.6.17 Beam and Girder Forms

The type of construction to be used for beam forms depends upon whether the form is to be removed in one piece or whether the sides are to be stripped and the bottom left in place until such time as the concrete has developed enough strength to permit removal of the shoring. Beam forms are subjected to very little bursting pressure but must be shored up at frequent intervals to prevent sagging under the weight of the fresh concrete. The vertical side members are placed to assist in transmitting slab loads to the supporting shores.

9.7.18 Scaffoldings

Properly designed and constructed scaffolding built by competent workmen shall be provided during the construction in the building site to ensure the safety of workers. Joining the members of scaffolds only with nails shall be prohibited, as they are likely to get loose under normal weathering conditions. In the erection or maintenance of tall buildings, scaffoldings shall be of noncombustible material especially when the work is being done on any building in occupation. Frequent inspections of scaffolding shall be done after initial construction of the scaffolding.

9.7.19 Column

Concrete columns shall be executed as per approved structural drawings/ designs. For any change proposed at site, in the size of column section and reinforcement/or their orientation, etc., approval of Executive Engineer shall be obtained before execution.

9.7.20 Walls

Walls are differentiated into two types: load bearing and non-load bearing. Load-bearing walls not only separate spaces, but also provide structural support for whatever is above them. Non-load bearing walls function solely as partitions between spaces. Partition walls, curtain wall, panel wall and shear wall come under this category.

Common burnt clay bricks, Burnt clay fly ash bricks, pulverized fuel ash lime bricks, Stones, Sand lime bricks, Concrete blocks (Solid & Hollow), Lime based blocks, Burnt clay hollow blocks, Gypsum Partition blocks, Autoclaved cellular concrete blocks and Concrete stone masonry blocks are used with cement mortar for the construction. The materials used in masonry construction shall be in accordance with the Part 5 Building Materials and construction shall conform to the accepted standards of Part 6 Section 4 Masonry of NBC. Height and length of masonry walls shall be restricted as per clause 4.6 and clause 8 of Section 4 of part 6 of National Building Code.

Depending on the type of wall to be constructed height of the wall per day shall be restricted to ensure that the newly constructed wall does not come down due to lack of strength in lower layers. In long walls adequate expansion/crumple joints shall be provided to ensure safety. If an opening is necessary in the existing wall then adequate support against the collapse or cracking of the wall portion above or roof or adjoining walls shall be provided. Whenever projections cantilever out of the walls temporary form work shall be provided for such projections and the same shall not be removed till wall over the projecting slabs providing stability load against over turning are completely constructed.

9.7.21 Lintel, Bond Beams, and Sills

Bond beams are reinforced courses of block that bond and integrate a concrete masonry wall into a stronger unit. They increase the bending strength of the wall and are particularly needed to resist the high winds of hurricanes and earthquake forces. In addition, they exert restraint against wall movement, reducing the formation of cracks. Bond beams are constructed with special-shape masonry units (beam and lintel block) filled with concrete or grout and reinforced with embedded steel bars. These beams are usually located at the top of walls to stiffen them. Since bond beams have appreciable structural strength, they can be located to serve as lintels over doors and windows. Lintels shall have a minimum bearing at each end equal to depth or 15cms whichever is higher. Pre-cast concrete lintels can be used with an offset on the underside to suit the modular openings. Pre-cast concrete sills can be used.

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9.7.22 Sunshade

This is provided for protection of doors windows, ventilators and other openings from the effect of rain and sunlight. This may be provided as per the provisions of the code IS 456. It must be cast monolithically with the lintel and care must be given to ensure sufficient slope to aid runoff. Lintel must be raised above the sunshade to a minimum 5 cm so that water seepage is avoided.

9.7.23 Beam

Beams are the principal load-carrying horizontal members. They take the load directly from the floor above and carry it to the columns. The beams shall be constructed in accordance with the structural drawings.

9.7.24 Slabs

Slabs shall be constructed as per the structural drawings. Top surface of Roof slab shall have necessary slope to drain off rainwater. In case of sloping roof, the slabs shall rest on RCC beams over masonry walls, so that crack development can be avoided.

9.7.25 Pre-stressed Concrete

For this method of concreting Refer IS 1343: 1980

9.7.26 Ready Mixed Concrete

For this method of concreting Refer IS 4926: 2003

9.7.27 Doors

Wood, Metal and Plastic are used for fabrication of doors, windows and ventilators. All wood components are treated with a water-repellent preservative to provide protection against moisture. Doors in the traditional pattern are usually of the panel type. Flush doors consist of thin plywood faces over a framework of wood with a wood block or particleboard core. Exterior doors are usually 4cms thick and not less than 2mts high. The main entrance door is of minimum 100cms width, and the side or rear door is normally 90cms wide. Novelty doors, such as PVC door unit, are commonly used for water closets/bath rooms because they provide water resistance. Hinged doors shall open or swing in the direction of natural entry, against a blank wall, and shall not be obstructed by other swinging doors. Doors shall never be hinged to swing into a hallway. If there is no sufficient space for swing doors, sliding doors shall be provided. For the general requirements of the door refer Part 3 Clause D-3.3 of the NBC.

9.7.28 Windows

Windows shall be designed to avoid the glare which is a particular problem for people with impaired vision. Large glass areas close to circulation spaces shall be marked a little below eyelevel with a coloured band or frame. Normally, the sill shall not be more than 800 mm from the floor. Windows shall be easy to open and close. A window schedule on the construction drawings shall give the dimensions, type, such as casement, double-hung, and so forth, and the number of lights (panes of glass) for each window in the structure.

9.7.29 Ventilators

Windows and Ventilators are provided for the air circulation and daylight. But in case where window is not advisable ventilators are provided. Generally glazed ventilators with wooden or metal frames shall be provided in bathrooms, toilets, storerooms, dressing rooms etc.

9.7.30 Hardware & Fasteners

Hardware accessories of approved quality made of metal or plastic that includes locks, hinges, door pulls, cabinet hardware, window fastenings, door closers and checks, door holders, and automatic exit devices shall be used. The fastening devices like nails, glues, screws, and bolts shall be of approved quality.

9.7.31 Interior Finishes

Finishes for floors, walls and partitions, and ceilings is an important and make sure that each finishing job is properly done and gives a neat, attractive appearance Interior finishes are those materials installed to cover the surfaces of the floors, the walls, and the ceilings.

9.7.32 Flooring and Floor Finishes

Floor materials found in shore establishment buildings and structures for various occupancies include wood, concrete, terrazzo, and clay tile. Common floor coverings include asphalt, vinyl tile, and linoleum. Common tiles in use are ceramic tiles, stone tiles, granite tile, marble and slate etc

9.7.32.1 Laying of Tiles

Clean the surface. Roughen the concrete under-bed to provide a good bond for the new setting cement. Dampen the under-bed and place the setting mortar mixed in the proportion of 1 part cement to 3 parts sand. Set the tile, tamping it to the level of the required finished floor. Fill the joints with grout or pointing mortar, matching the color and finish of floor as closely as possible. Grout joints 3 mm or less in width with neat cement grout of the consistency of thick cream. Point joints one-3mm to 6mm in width with pointing mortar, consisting of one-part cement to one-part screened sand. Point joints wider than 6 mm with pointing mortar consisting of one-part cement to two-parts screened sand. I n locations, such as galleys and food-preparation areas, where the floor is directly exposed to the effects of corrosion agents, acid-resistant joint material is used to fill the joints. The acid-resistant mortars are proprietary products and shall be mixed according to the manufacturer's recommendations. **2263.3.**

9.7.32.2 Grinding and Polishing

When grinding of a floor/Tile is required, it shall be started after the surface has hardened sufficiently to prevent dislodgement of particles or till the tile is fixed. The machines used shall be of an approved type. The floor is kept wet during the grinding process, and the cuttings are removed by squeegee and flushing with water. After the surface is ground, air holes, pits, and other blemishes are filled with a thin grout. This grout is spread over the floor and worked into the pits with a straightedge and rubbed into the floor with the grinding machine. When the filings have hardened a final grinding removes the film and gives the finish a polish. All surplus material is then removed by washing thoroughly. A rubbed finish is required when a uniform and attractive surface must be obtained. The first rubbing shall be done with coarse carborandum stones curing must precede until final rubbing. Finer carborundum stones are used for the final rubbing.

9.7.33 Wall Finishes

Plastering is the common type of wall finish for walls and partitions. Other types shall be drywall and wall tile.

9.7.33.1 Plastering

Plastering using cement mortar as per specification shall be done for both interior and exterior walls.

9.7.33.2 Drywall

Drywall construction is an alternative to plastering for walls and ceilings. Essentially, it consists of panels of wallboard of various types with joints tight, true, and effectively concealed. All materials used shall strictly adhere to the specifications. Ensure that the wallboard is applied accurately.

9.7.33.3 Wall Tile

For wall finishes of baths, galleys, mess halls, hospital rooms, and other applications for which a highly sanitary, easily cleaned, impervious wall finish is required, glazed ceramic tile, glazed vitrified (waterproof) clay tile, and plastic tile shall be used. In the case of exterior walls, for better appearance, suitable tiles shall be used. Ensure that the tile furnished conforms to the specifications in kind, quality, size, colour, glaze, texture and grip.

9.7.33.4 Stucco

This shall be done on walls, for acoustical effects in interiors and for an ornamental finish for exterior walls. It has to be ensured that the masonry has an unglazed rough surface with joints struck flush and adequate key to assure a good bond.

9.7.34 Ceiling

Plastering is the common type of ceiling finish. Other types of finishes using tiles, boards etc. may be used. In case of large halls and auditoriums, for acoustics, special acoustical tiles and acoustical plaster of approved quality and specifications shall be used. Acoustical tiles are available in various materials, such as wood, vegetable or mineral fibre, perforated metal, or cemented shavings in different thicknesses, shapes, and dimensions and with varying textures, perforations, and joint treatment.

9.7.35 Painting

9.7.35.1 Surface Preparation

The most essential part of any painting job is proper surface preparation and repair. Each type of surface requires specific cleaning procedures. Before painting suitable priming coat shall be applied as per specifications and maximum possible time gap shall be allowed before painting is done. Paint will not adhere well, provide the protection necessary, or have the desired appearance unless the surface is in proper condition for painting. Exterior surface preparation is especially important because hostile environments can accelerate deterioration.

9.7.35.2 Application of Paint

Painting shall be done to different types of surfaces, such as metal, wood, and concrete/ masonry. The common methods of applying paint are brushing, rolling, and spraying. The choice of method is based on several factors, such as speed of application, environment, type and area of surface, type of coating to be applied, desired appearance of finish, and training and experience of painters. Brushing is ideal for small surfaces and odd shapes or for cutting in corners and edges. Rolling and spraying are efficient on large, flat surfaces. Spraying can also be used for round or irregular shapes. While spraying, adjacent areas not to be coated must be covered. Lacquer products, which dry rapidly, shall be sprayed.

9.7.35.3 Interior Painting

Paint for interior walls and ceilings are usually flat wall paint. Interior enamel may be specified where a semi gloss or gloss washable finish is desired on woodwork or walls. A standard undercoat for primer under enamel, or use of the enamel with thinner may be permitted. Paint and enamel may be obtained with color added, or color-in-oil may be added to the white paint on the job. Specifications may require the sanding of interior woodwork or rubbing with steel wool. Priming of plaster surfaces with a glue size may also be required. Make sure that finish coats are of uniform gloss and color and are free from suction spots, highlights, brush marks, and other imperfections.

9.7.35.4 White washing

The interior wall of ordinary buildings and all ceilings shall be whitewashed

9.7.35.5 Colour washing

The interior wall of residential buildings and office buildings shall also be colour washed.

9.7.35.6 Distemper washing

Interior walls of hospitals and other important buildings shall be given distemper coating. In the case of prestigious buildings, plastic emulsion shall be provided.

9.7.35.7 Exterior Painting

The exterior work includes steel structures, concrete masonry and woodwork. The exterior painting of steel structures, concrete, masonry and woodwork shall be done with special care for protection from environment.

9.7.36 Metal and Steel Structures

Metal and Steel surfaces shall be cleaned by wire brushing, sandblasting, grit blasting, flame cleaning, cleaning with solvent, or air blasting, as may be specified; All surface rust, dirt, grease, oil, and loose scale shall be removed and if specified tight scale shall also be removed. Suitable priming coat shall be applied after cleaning the surface. The paint is worked thoroughly into all joints, cracks, and crevices. Each coat is allowed to dry thoroughly before the next coat is applied and the prescribed number of coats, each conforming to the requirements of the specifications, is applied. Nonferrous metal is usually not painted.

9.7.37 Masonry walls

Painting of concrete, stucco, masonry walls and similar surfaces is done primarily for decorative purposes or for damp proofing walls. Paints usually are of white Portland cement base with color but may be of an oil base. Make sure that the materials conform to the standard specifications. Also determine whether surfaces are clean and free from dust, efflorescence, and other contamination and whether they are adequately cured. When Portland cement paint is used, be certain that the surface is thoroughly wetted. If oil-based paints are used, ensure that the surface is thoroughly cured, pretreated as specified, and thoroughly dry. In the case of prestigious buildings, good quality anti fungal paints shall be provided

9.7.38 Woodwork

Make sure that surfaces are thoroughly dry and clean and are otherwise suitably prepared for painting before permitting work to proceed. Ensure that the priming coat is intact and is of suitable consistency to protect the wood, but not so tight that moisture in the wood is prevented from evaporating. Make sure that the wood is smooth enough to assure the continuity and adherence of the paint film; that holes and cracks are puttied or filled with wood filler; and that knots and pitch streaks are sealed with shellac, varnish, or other sealer, as prescribed. Make certain that the paints are of approved quality and color; and are applied by brushing, using high-quality brushes, until the coat is smooth, even, free from brush marks, and of uniform thickness, texture, and color. Also be sure that the paint is not brushed too thin to assure satisfactory hiding power; that each coat is allowed to dry thoroughly to a firm film before permitting application of the next coat; and that the specified number of coats is applied.

9.7.39 List of relevant codes for painting

Document	Standard Title Number
IS 144: 1950	Ready mixed paint, brushing, petrol resisting, air-drying, for interior painting of tanksand container, red oxide (colour unspecified)
IS 145: 1950	Ready mixed paint, slushing, petrol resisting, air-drying for interior painting of tanks andcontainers, red oxide (colour unspecified)

IS 146: 1950 Specification for ready mixed paint, brushing, petrol resisting, stoving, or interiorpainting of tanks and containers, red oxide

IS 147: 1950 Specification for ready mixed paint, slushing, petrol resisting, stoving, for interiorpainting of tanks and containers, red oxide

IS 1200: Part 13: Method of measurement of building and civil engineering works: Part 13 Whitewashing,1994 colour washing, distampering and painting of building surfaces

IS 1200: Part 15: Method of measurement of building and civil engineering works: Part 15 painting,1987 polishing, varnishing etc

IS 1477: Part I: Code of Practice for Painting of Ferrous Metals in Buildings - Part I : Pretreatment2000

IS 1477: Part 2: Code of practice for painting of ferrous metals in buildings: Part2 Painting1971

IS 2395: Part 2: Code of practice for painting concrete, masonry and plaster surfaces: Part 2 Schedule1994

IS 2524: Part 1: Code of practice for painting of nonferrous metals in buildings: Part 1 Pretreatment1968

IS 2524: Part 2: Code of practice for painting of non-ferrous metals in buildings: Part 2 Painting1968

IS 3140: 1965 Code of practice for painting asbestos cement building products

IS 9954: 1981 Pictorial Surface Preparation Standards for Painting of Steel Surfaces

IS 14177: 1994 Guidelines for painting system for hydraulic gates and hoists

IS 14428: 1997 Guidelines for painting of structures in aggressive chemical environment

Lighting and Ventilation Refer National Building Code 2005, Part 8 Sec 215

Electrical and Allied Installations Refer National Building Code 2005 Part 8 Section 2

Heating Ventilation and Air conditioning (HVAC) Refer National Building Code 2005 Part 8 Section 3

Acoustics sound Insulation and Noise control Refer National Building Code 2005 Part 8 Section 4

Lift and Escalators Refer National Building Code 2005 Part 8 Section 5

Stairs, passages This shall be constructed as per the architectural and structural drawings.

Water supply Refer National Building Code 2005 Part 9 Section 1 clause 4

Rain Water Harvesting Refer National Building Code 2005 Part 9 Section 1 clause 5.5.12

Drainage and Sanitation Refer National Building Code 2005 Part 9 Section 1 clause 5

Gas Supply Refer National Building Code 2005 Part 9 Section 2

Fire fighting Refer National Building Code 2005 Part 4

Landscaping, Signs and Outdoor Display Structures Refer National Building Code 2005 Part 10 Section 2

9.7 CONSTRUCTION OF MINOR IRRIGATION STRUCTURES

9.7.1 Weir

A weir is a barrier across a river designed to alter the flow characteristics. In most cases weirs take the form of a horizontal barrier across the width of a river that pools water behind it whilst still allowing it to flow steadily over the top. Weir is a structure in a river, stream, canal or drain over which free-surface flow occurs. It may be used variously for control of upstream water levels, diversion of flow, and/or measurement of discharge.

Weirs can vary in size both horizontally and vertically, with the smallest being only a few inches in height whilst the largest may be hundreds of metres long and many metres tall. Unlike a dam, which specifically impounds water, a weir's purpose can be less obvious. They most commonly exist to alter or control river flow characteristics. A particular distinction between dams and weirs is that water flows over the top (crest) of a weir at least some of its length.

9.7.1.1 Flood Control & Altering River Conditions

Weirs are commonly used to control the flow rates of rivers during periods of high discharge. Sluice gates can be altered to increase or decrease the volume of water flowing downstream. Weirs of this purpose are commonly found upstream of towns and villages and can either be automated or manually operated. By slowing the rate at which water moves downstream even slightly a disproportionate effect can be had on the likelihood of flooding. On larger rivers a weir can also alter the flow characteristics of a river to the point that vessels are able to navigate areas previously inaccessible.

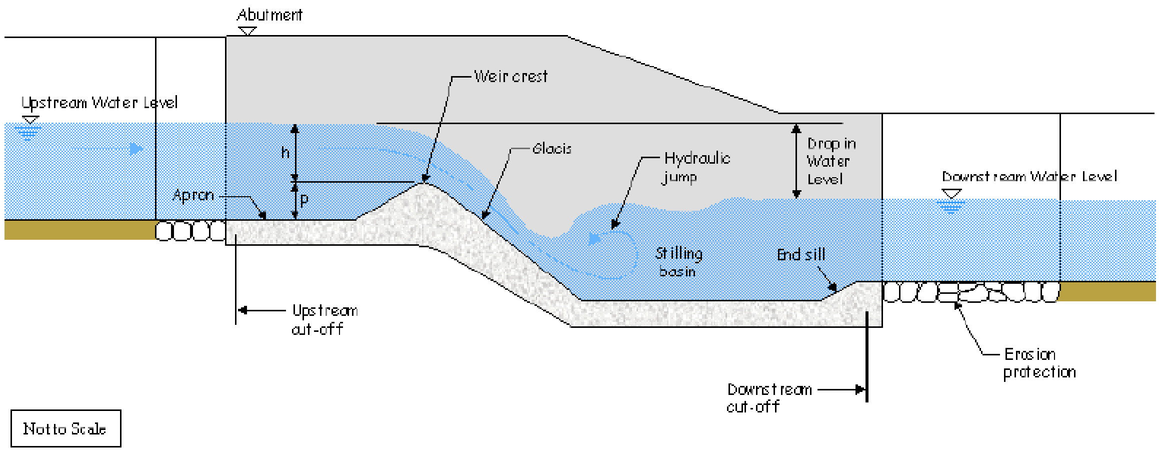
Most of the weir structure remains unseen throughout theirlife. Furthermore, the unseen portion is largely inaccessible and therefore must beengineered to remain durable with little maintenance. Weirs constructed to low designstandards or skimped on safety factors, run the risk of premature damage or collapse,and may end up costing more in the long run. Weirs formed from dumped rock areoften seen as an inexpensive answer. It is true that such weirs can offer a rapid, cheapand attractive structure in small rivers, but unless properly engineered, they can bedemolished in the first significant flood.

9.7.1.2 Basic Components of a Weir Structure

Weirs are often provided for purposes other than simply raising water levels; whether this is for navigation, flood defence or habitat improvement. The increase in water level will, for the same flow rate, reduce the average velocity in the upstream reach, which may in turn have an impact on the sediment transporting capacity of the channel. The slower velocities will have knock-on effects in terms of water quality and habitat type. There are downstream issues as well, namely that there is likely to be a localised increase in turbulence and flow velocity immediately downstream of the weir. This has the potential to cause erosion of the river bed and banks, and may result in the creation of a deep pool downstream of the weir, and deposition in the form of a shoal further downstream.

The four cornerstones of good engineering for weirs are:

1. Hydraulics
2. Foundations (including river channel stability upstream and downstream)
3. Materials
4. Construction (method/approach)



A weir must be designed to operate satisfactorily in all flow conditions. It is therefore important that all available flow data for a river are obtained when planning the construction, rehabilitation or demolition of a weir. A weir, by definition, raises the upstream water level in a river for most, if not all flow conditions. In doing so it creates a sudden drop in the water level in the river, the nature of which changes with changing flow conditions.

9.7.1.3 Foundation

Apart from destruction by hydraulic forces, the most common cause of weir failure is loss of foundation support. This can be caused by construction on weak foundations but is more often the result of loss of foundation material through seepage, or undermining of the apron due to erosion downstream.

9.7.1.4 Seepage

Seepage under or round a weir can destabilise the structure by removing finer soil particles and eventually creating voids. In extreme cases, seepage flow returning to the river downstream of the weir can cause a piping failure, in which the riverbed loses all strength. This can undermine the weir apron and lead to complete collapse.

This problem is generally avoided by providing cut-offs in the riverbed at the upstream and downstream ends, most commonly in the form of sheet piling (steel, concrete, timber). The cut-offs extend the seepage path and reduce the hydraulic gradient that causes piping. It should be remembered that this is a three dimensional problem and that the cut-offs should extend into the banks of the river under the wing walls to increase the length of the seepage path round the sides of the structure.

Seepage through the weir structure is common in many old masonry weirs and, in many instances, this is of no great consequence and can be ignored. Over a long period of time, this type of seepage can become problematic, with risk of structural failure (e.g. risk of un-bonded masonry blocks being washed away in a flood). In this case, it will probably be necessary to repair the structure by grouting (risk of pollution) or by dismantling and reassembling the structure.

9.7.1.5 Uplift

Hydrostatic pressure under the weir structure will lead to uplift forces that can cause failure of the weir if not adequately resisted by the weight and strength of the structure. In general, the provision of an upstream cut-off wall will decrease uplift, whereas a downstream cut-off will increase uplift. The bigger the difference in water level across the weir, the more serious the uplift problem is likely to be.

Uplift forces can be resisted by increasing the weight of the structure (by increasing the thickness of the concrete floor, for example), or they can be reduced by the provision of suitable drainage (for example, pressure relief valves in the weir apron).

9.7.1.6 Materials

There is no doubt that good quality concrete is one of the most durable materials available for the construction of weirs. However, there is a wide range of materials to choose from, and the choice should be made on environmental and economic grounds as well as engineering need. Locally sourced materials are often used for small weirs, whilst reinforced concrete is normally the material of choice for larger projects.

Materials for the construction of weirs

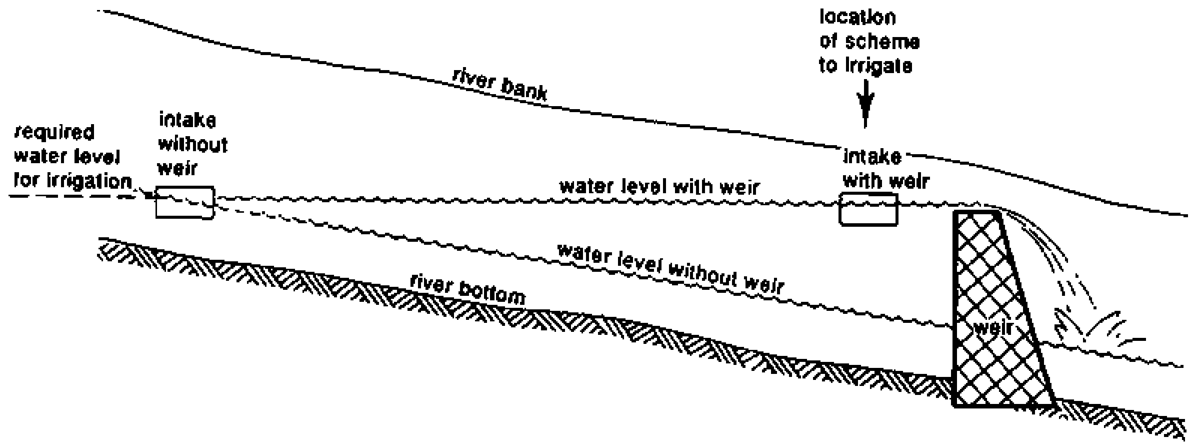
Material	Uses	Limitations
Brick	Small structures in an urban setting. The right choice of brick can create an attractive weir. Engineering bricks should be selected where durability and frost resistance is required.	Long-term durability, including loss of mortar and frost damage. Avoid brick on the weir crest and glacis as it can become very slippery with time
Concrete	A good engineering material, durable and suited to many applications. Frequently used for discharge measuring structures.	Can be unattractive. Exposed areas can be improved by the addition of a brick or masonry facing, exposed aggregate finish, or patterned formwork to create micro-habitats.
Masonry	Commonly used in the early days of weir construction. Can be very attractive. Can be used to	Old weirs may exhibit loss of mortar leading to seepage through the structure.

	disguise a concrete structure.	
Steel sheet piling	Often a component of modern weirs because of ease of construction, use as a cut-off, and use in temporary works	Unattractive if not faced in masonry or brickwork. Corrosion may be a long-term problem. Less hydraulically efficient than amore even surface such as concrete or brick.
Rock	Ideal for forming a "natural" structure with least impact on the environment. The size of the stones is important. Too small and they may be washed away; too large and the water will flow round rather than over them	Must be properly engineered to ensure that it does not get washed away in the first flood. Good quality durable stone is required to ensure long-term integrity. For a significant drop in water level, a sheet pile cut-off may be required. Flow can "disappear" into the rock in low flow conditions.
Gabions (wire baskets filled with stone)	Can be a cheaper alternative to concrete or masonry, with a more natural appearance when colonised by vegetation. Inherent permeability can aid drainage through retaining walls. Can be used in mattress form for erosion protection, or box form for retaining walls. However, not universally liked – see limitations opposite.	Need to be properly constructed with due attention paid to filling the gabions, limiting or preventing seepage, and durability of the wires. Corrosion rates can be unacceptably high in acidic waters - the use ofplastic coated wires will reduce corrosion. Can be hazardous to swimmers, canoeists, and other river users if wires deteriorate with time. Can be prone to vandalism – avoid in places where the level of access by children is likely to be high.
Timber	Ideal for small temporary structures	Durability and stability
Fibreglass	Has been used for the crests of weirs used for electronic fish counters	Durability in high flows – vulnerable to vibration damage and impact from floating debris.
Earth	Earth weirs are commonly used as side weirs to evacuate flood flows from the river. Often these are un-reinforced earth structures, with a grassed	Un-reinforced earth can be used for low intensity flow. For high intensity flow the surface of the earth weir will need to be reinforced with geotextile, concrete revetment or gabion

	surface.	mattress.

9.7.1.7 Drawbacks

- Because a weir typically increases oxygen content of the water as it passes over the crest, a weir can harm the local ecology of a river system. A weir artificially reduces the upstream water velocity, which can increase siltation (deposition of fine particles of silt and clay on the river bottom).
- Weirs can have a significant effect on fish migration. Any weir that exceeds either the maximum vertical height a species can jump or creates flow conditions that cannot be bypassed (e.g., due to excessive water velocity) effectively limits the maximum point upstream that fish can migrate. In some cases this can mean that huge lengths of breeding habitat are lost and over time this can have a significant impact of fish populations. In many countries it is now a requirement by law to build fish ladders into the design of a weir that ensures that fish can bypass the barrier.
- Even though the water around weirs can often appear relatively calm, they can be extremely dangerous places to boat, swim, or wade, as the circulation patterns on the downstream side—typically called a hydraulic jump— can submerge a person indefinitely.



9.7.2 Check dams

Check dams are often used in natural or constructed channels or swales. They should never be placed in live streams unless approved by appropriate local and/or state authorities.

9.7.2.1 Guidelines for Exploitation of Surface Water by construction of Check Dams

- Irrigation use of water flowing down drainage channels.
- To divert water from perennial / semi-perennial streams in hilly areas for irrigation purpose.

9.7.2.2 Materials

Check dams are made of a variety of materials. Because they are typically used as temporary structures, they are often made of cheap and accessible materials such as rocks, gravel, logs, hay bales, and sandbags. Of these, logs and rock check dams are usually permanent or semi-permanent; and the sandbag check dam is implemented primarily for temporary purposes. Also, there are check dams that are constructed with rockfill or wooden boards.

9.7.2.3 Size

A check dam should not be more than 2 ft (0.61 m) to 3 ft (0.91 m) high and the center of the dam should be at least 6 in (0.15 m) lower than its edges. They may kill grass linings in channels if water stays high or sediment load is great. This criteria induces a weir effect, resulting in increased water surface level upstream for some, if not all flow conditions.

9.7.2.4. Spacing

In order to effectively slow down water velocity to counter the effects of erosion and protect the channel between dams in a larger system, the spacing must be designed properly. The check dams should be spaced such that the toe of the upstream check dam is equal to the elevation of the downstream check dam's crest. By doing so, the water can pond between check dams and thus slow the flow's velocity down substantially as the water progresses down slope.

9.7.2.5 Control Water Level

The water level in the drain ponded by the check dam should be kept as high as possible to prevent the plants from drying out and turn into a highly combustible material. Some general requirements in the desired water level to be maintained by the check dam are as follows:-

a. The ground water table in the land adjacent to the check dam structure should not be more than 400 mm below the average ground level
b. The risk of submergence of any cropped lands or local residential population during flash floods should be minimized
c. Check dams should never be placed in active and high flows waterways unless they are designed to convey the required flows.
d. Freeboard for channel shall be site specific and take into consideration the effects of any submergence to facilities such as roads, residential areas and crops lands

9.7.2.6 Durability of Check Dam

Check dams can be built using various type of materials such as earth, sand (loose or in bags), timber (sawn or log), stones/rocks (loose or stacked), or concrete (cast-in-situ or precast form). In selection of the most appropriate materials to be used as the main components of the check dam structure, designer should take into consideration the following factors:

- Size and dimensions of check dam
- Site conditions (e.g. waterlogged, depth of peats)
- Accessibility of site
- Availability of local materials
- Designed service life of the structure (short-term, medium term or long-term)
- Cost of construction

9.7.2.7 General Layout

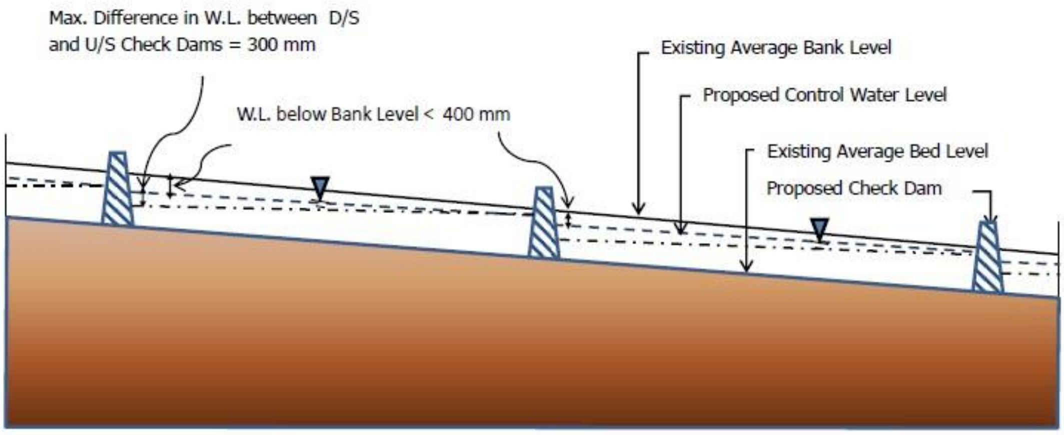
Some of the general layout requirements of check dam structures are:-

- The centre of the dam should be at least 150 mm lower than either edge, so as to form an outfall weir for any active flows. However, the actual freeboard to be incorporated should be based on the risk and hazard of flooding to the surrounding areas.
- Stabilization works with channel lining or protection works (such as riprap orgabion mattresses) should be provided immediately downstream of the checkdam to prevent any possible toe erosion and undercutting.
- The embankment/barrier of check dam should be extended adequately into the existing bank to prevent any excessive seepage and potential breaching of the banks
- If a series of check dams are required, the dams should be spaced so that the difference in the water levels between any two dams do not fall below 300 mm

9.7.2.8 Seepage Control

Seepage is to be anticipated in check dam structure either through its embankment, bank or foundation. To control the desired water level in the waterway, excessive loss of impounded water must be minimised. For this purpose, the design of checkdam structures should incorporate the following features,

a. Use of low permeability materials such as clayey soil for embankment and foundation.
b. Incorporate an impermeable layer such as HDPE sheet in the embankment and foundation
c. Remove highly porous peat soil under the foundation for the check dam structures and replace with more impermeable materials
d. Install vertical cut-off such as interlocking sheet piles, if necessary



Proposed Location of Series of Check Dam Structures along Waterway

9.7.2.9 Type of Check Dam Structures

There are many different types of check dam structures that can be used to control and maintain the water level in the waterway in lands, depending on factors such as the local site conditions and budget available. This section presented details of some typical check dam structures together with some general design and construction requirements. User should apply appropriate design procedures and assessment of the various types of check dam structures to suit the particular circumstances under consideration.

9.7.2.10 Sand/Local Earth Filled Bags Check Dam

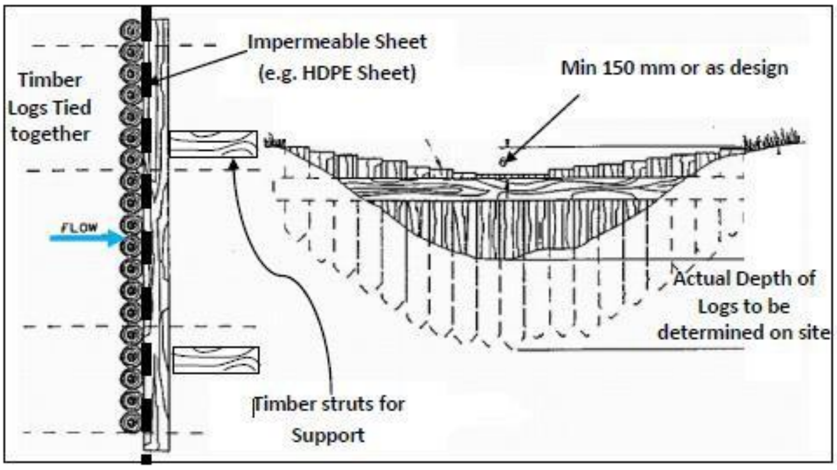
Sand /Local Earth Filled Bags check dam is a series of earth-filled bags placed on a level contour to intercept flows. It provides a relatively quick and effective way in holding the water flow to create a pond. Some of the general requirements of earth filled bags are:-

1. Bags should be made from durable, weather resistant fabric e.g. geotextile(unless for short-term). The fabric pores must be tight enough to retain the filler material. The bags usually measure about the standard size of 1 m x 2 m x 0.15m or other size as required. Low quality polypropylene (PP) woven sugar bags or sacks, commonly used in check dams construction, are found to be not durable as they are easily damaged by the flows and have low UV resistance. As such, these materials are not recommended as they normally do not last longer than a years and required regular maintenance, and as such are only suitable for short-term check dam structure.
2. On both side of the check dam structure, earth filled bags must be extended and tightly abutted into the banks to prevent excessive seepage or breaching at the banks of the check structure.
3. The center of the check dam must be lower by at least 150mm (min) to allow normal flows spilling to occur within the mid portion of the structure.
4. The earth-filled bags should be placed as deep as possible into the peat to minimize any seepage through the foundation. Alternatively, the peat could be removed and replaced with well compacted clayey soils.

Typical Sand-Fill Bag Check Dam

9.7.2.11 Timber Check Dam

This type of check dam is constructed using timber logs piled (or in combination with timber boards) and tied together across a waterway to serve as a barrier to back up the water level. It is more suitable for site where timber logs are available readily (such as in Sarawak where timber logs are commonly used for this purpose). The logs should be embedded sufficiently into the ground so as to withstand the hydraulic forces of the flowing water. Normally the barrier has to be strengthened and supported by strutting. The top of the logs at the center portion of the barrier should be at least 150mm lower to cater for daily overflow. To prevent scouring downstream, stacked rocks can also be placed on the downstream side of the dam to prevent scour during high flows.



Typical Timber Logs Check Dam

Timber Log Check Dam

9.7.2.12 Stones/Rocks Check Dam

Stones or rocks placed on top of a blanket of engineering fabric either in loose form or stacked tightly can also be used to block the water flows in the waterways to create check dam structure in land. Hand or mechanical placement of stones or rocks can be used depending on the accessibility of the site. Some general requirements of stones/rocks check dams are discussed below.

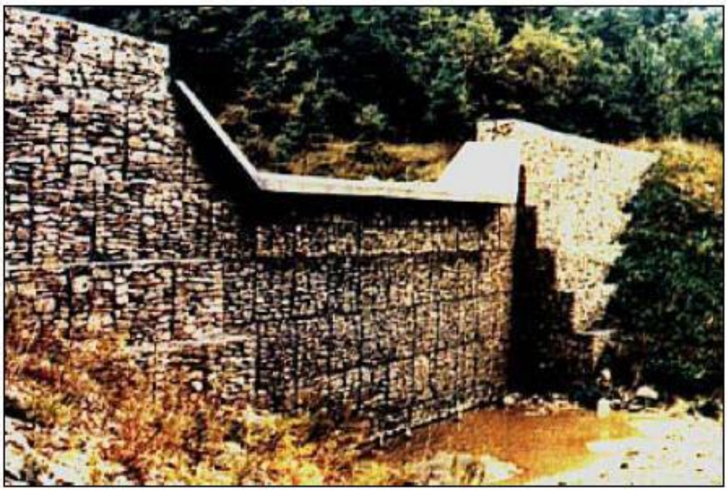
a. Maximum side slopes 1.5H : 1V
b. Center portion of the crest of the check dam should at least 150 mm lower than the sides to prevent normal flows from going around the dam, and eroding the sides of the channel.
c. Adequate freeboard to be provided for annual flood flows
d. Adequate scour protection downstream of check dam is to be provided for a length at least 1.5 times the height of the check dam
e. Rocks or stones armouring layer of at least 400mm thick should be extended into the banks of the waterway sides to prevent erosion and breaching of the sides of the check dam
f. To reduce the loss of water through foundation seepage, the underlying soil below the check structure should be removed and replaced with highly impermeable soils.

9.7.2.13 Gabion Check Dam

Stacked stones in wire cages (gabions or gabion mattresses) are also commonly used to construct check dams. Gabions check dams are essentially the same as stacked stones/rocks check dam structure, except that the former is wrapped in wire fence meshes for added stability and strength. A typical drawing of a gabion checkdam structure with flow regulating gate. Some of the general requirements for gabion check dam structures are:-

a. The gabions formed check dams are highly porous and as such a layer of impermeable sheet such as HDPE need to be provided within the gabions to reduce the seepage of water. Alternatively, highly impervious clayey soil can be placed upstream of the gabions (together with a layer of geotextiles filter layer)to retain the water in the channel
b. A layer of gabion flexi-mattress is usually placed on the channel bed and banks before the required gabions are placed. The mattresses would provide a better sitting on the uneven ground of the channel bank/bed besides providing a more stable support for the gabions block.
c. A layer of geotextile fabric filter is placed on the soil in contact with the gabions mattresses to prevent ingress of soil into the gabions and washing away by the water flows.
d. Proper foundation seepage cut-off needs to be provided to enable effective control of water level upstream. This could be done by removing the peat soils and replacing with less permeable soil (clayey) or embedding appropriate cut-off barriers.
e. Opening in the check dam structure may also be provided for passing flood flows and can be gated (e.g. using timber drop boards) to raise the water level during the dry weather.

Gabion check dams can provide a very cost-efficient alternative to those constructed using concrete and are more resilient than concrete. They are also more durable than sand/earth filled bags, timber logs or loose stacked stones / rocks check dams.



Gabion Type Check Dam

9.7.2.14 Precast Concrete Stacked Blocks Check Dam

Stacked precast concrete blocks can also be used for the construction of check dam structures. Some requirements for precast concrete block check dams are:-

a. Proper foundation has to be provided to prevent excessive deformation and bearing capacity failure. If necessary the layer of soft and peat soils should be replaced.

b. The stacked precast concrete blocks should be stable and designed as mass gravity wall that is able to resist both hydraulic and earth pressures.
c. The dimensions of each individual precast block are to be decided based on handling as well as stability requirements
d. The precast blocks should be able to be removed swiftly in case of overtopping and flooding problems

Precast Concrete Block-Section Check Dam

9.7.2.15 Cast-in-situ Concrete Check Dam Structures

In waterway where long-term (permanent) check dam structures are required, cast-in-situ reinforced concrete structures are preferred. Flows regulating gates and sides spillway are normally provided to control the water level upstream as well as discharging designed flood flows. Some features of these drainage control check dam structures are:-

a. Consist of an inlet box structures with a upstream gated opening and two side spillways
b. The length and elevation of the two side spillways are designed for the necessary flood flows, thus minimizing the need for frequent operation of the gate. Timber drop board are used to adjust the height of the side spillways.
c. The gate itself can be opened in case of flood flows
d. The foundation of the structure need to be designed for bearing capacity and settlement as well as potential seepage/piping problems. If necessary, the highly permeable and soft peat layer is to be removed and replaced with better soil or strengthened with bearing piles
e. These structures are usually located upstream of a bund or road culvert. Proper access platform from the bund/road to the gate control device is also provided for ease of operation and maintenance.
f. The reinforced concrete structure should be designed to the latest code of practices for structural concrete

9.7.2.16 Advantages

Check dams are a highly effective practice to reduce flow velocities in channels and waterways. Contrasting big dams, check dams have a faster implementation timeline, are cost effective, and are smaller in scope. Because of this, their implementation will not typically displace people or communities nor will they destroy natural resources if careful design considerations are undertaken. Moreover, the dams themselves are simple to construct and do not rely on advanced technologies – thereby they can be applied in more rural and less advanced communities, as they have been in India's drylands for some time now.

9.7.2.17 Limitations

Check dams still require maintenance and sediment removal practices. They become more difficult to implement on steep slopes, as velocity is higher and thereby the distance between dams must be shortened Check dams, depending on the material used, can have a limited life span but if implemented correctly can be considered permanent though not encouraged.

9.8 CONSTRUCTION OF MINI WATER SUPPLY SYSTEMS

9.8.1 Introduction

Water is called the life stream of a community. The supply of safe water to the community in adequate quantity and quality is one of the important responsibilities of a civic body. For a small scale public water supply system, the source for water supply shall be either from ground water or surface source. Depending upon the availability of potable water in the region the source of water supply is selected as surface or ground water. A correct assessment of the capacity of the source investigated is necessary to decide on its dependability for the water supply project in view. The capacity of flowing streams and natural lakes is decided by the area and nature of the catchment, the amount of rainfall and allied factors. The safe yield of subsurface sources is decided by the hydrological and hydro-geological features relevant to each case.

9.8.2 Sources of water

Water, as source of drinking water, occurs as surface water and ground water. Three aspects should be considered in appraising water resources e.g. the quantity, the quality, and the reliability of available water.

9.8.2.1 Ground water

The water as it seeps down, comes in contact with organic and inorganic substances during its passage through the ground and acquires chemical characteristics representative of the strata it passes through. Generally, groundwaters are clear and colorless but are harder than the surface waters of the region in which they occur. In limestone formations, groundwaters are very hard, tend to form deposits in pipes and are relatively non-corrosive. In granite formations they are soft, low in dissolved minerals, relatively high in free carbon dioxide and are actively corrosive. Bacterially, groundwaters are much better than surface waters except where subsurface pollution exists. Groundwaters are generally of uniform quality although changes may occur in the quality because of water logging, over-draft from areas adjoining saline water sources and recycling of water applied for irrigation and pollution.

9.8.2.1.1 Open Wells

The bottom of the well should be at a level sufficiently below the lowest probable summer water table allowing also for an optimum drawdown when water is drawn from the well. Adequate provision should also be made to take care of interference by other pumping wells. To facilitate infiltration into the well, either the steining is constructed in dry masonry or, weepholes are left in the steining at suitable intervals. It is usual to insert cut lengths of pipes in the steining with the outer end covered with a wire gauze and shrouded with gravel to arrest ingress of fine material. Depending on the location and nature of soil, suitable method of construction shall be selected.

The following points shall be taken care of during construction of open wells.

1. Only after constructing the well kerb, well ring shall be constructed.
2. Minimum thickness of concrete ring shall be 20 cm.
3. The reinforcement used for concrete ring shall be of maximum diameter 10 mm and is to be placed alternately in 2 layers of 20 cm spacing
4. Sufficient weep holes with pvc pipes shall be provided.
5. To prevent the entry of soil through weep holes, the pvc pipes shall be sloped such that the edge in the inner side is raised upwards.
6. The cement, sand and aggregate proportion for concrete well shall be 1:11/2:3.
7. The minimum cover for reinforcement in concrete wells shall be 2.50 cm
8. The height of construction of concrete ring shall be limited to 1 m per day.
9. The bottom of the well kerb shall be extended upto the rock as far as possible.
10. When open well is constructed in rivers or streams, construction shall be done based on structural design. In such cases, side walls shall be constructed to protect the well.

11. If at any instance it is required to place the foundation in loose soil, DR or concrete block packing shall be given under the kerb.
12. Laterite stones shall be used after polishing.
13. While constructing well walls with laterite/rubble, it is to be strengthened by wedging stone spalls wherever necessary.
14. In case of laterite/rubble wells done in loose soils, intermediate concrete belts ata na interval of 1.5m shall be constructed based on the thickness of the wall to avoid earth pressure.
15. The thickness of rubble wells shall be fixed based on the depth of the well to be constructed.
16. The wells shall be constructed at a minimum distance of 7.5 m from soak/waste pits
17. Drain shall be constructed if there is chance of flow of waste water near the well.
18. The wall shall have atleast 1m height from ground level and it shall be raised accordingly in case of water logged areas.
19. The platform shall have a minimum width of 60cm.
20. In case, motor is to be installed within the well, baby well with concrete ring must be constructed.
21. The well shall be properly covered.
22. The inside of the wall shall be plastered upto 3m depth from the top.
23. Steps shall be provided inside the well.

9.8.2.1.2 Bore Well

A bore well is a well of 4 1/2", to 12" in diameter drilled into the earth for retrieving water. A bore well is cased in the region of loose subsoil strata and open in hard rock or in crystalline rock. High grade PVC pipes are used for Casing in bore wells. The depth of a bore well can vary from 150 feet to 1500 feet. A bore well is drilled with casing pipe put only up to the soil-rock boundary and this is done normally for shallow depths in hard rock or in crystalline rock. But in a tube well, the casing pipes are put up to the bottom of the bore wells, with perforation in the pipes in some level. Normally the Tube wells are drilled in sand and gravel where the availability of water is much below the ground level. Most commonly used are Compressor Drilling, Manual Drilling and Rotary Drilling. Compressor Drilling is done with the vehicle fitted with High Power Hydraulic Air Compressor Machine. It is commonly used to drill on soil surface and hard rock. Another method is by Manual Drilling or Hand Bore. This is most suited for lands with Clay or Sand. The rates for drilling a bore well depend on the location, nature of soil and availability of water.

While drilling a bore well we have to insert pipes called Casing pipes. It can be PVC/GI. This is done to prevent the Surface water with Sand from entering inside the bore well. These pipes are fixed inside the hard rock under the soil. Filtering can also be done to prevent muddy water and for getting surface yield. Bore wells must be kept closed using metal or PVC caps to prevent something to fall inside it and block the bore. Pumps must be installed as soon as possible to avoid bore silting and damage. Periodical cleaning must be done to retain yield and quality of water. High quality ISI mark casing pipes with correct measurement & thickness are recommended to use for long life of bore wells.

The casing pipe shall be retained atleast 1m above the ground level. After fixing the pipe in the hard strata, the outer side of the pipe should be sealed with cement grout. After construction, the bore well shall be flushed for atleast 2 hours.

9.8.2.1.3 Tubewells

The shallow tube well, also called a driven well, is sunk in various ways depending upon its size, depth of well and nature of material encountered. The closed end of a driven well comprises a tube of 40 to 100 mm in diameter, closed and pointed at one end and perforated for some distance therefrom. The tube thus prepared is driven into the ground by a wooden block until it penetrates the water bearing stratum. The upper end is then connected to a pump and the well is complete. Where the material penetrated is sand, the perforated portion is covered with wire gauze of suitable size depending upon the fineness of the sand. To prevent injury to the gauze and closing of the perforations, the head of the shoe is usually made larger than the tube or the gauze may be covered by a perforated jacket.

Such a driven well is adopted for use in soft ground or sand upto a depth of about 25 m and in places where the water is thinly distributed. On account of the ease with which it can be driven, pulled up and redriven, it is especially useful in prospecting at shallow depths and for temporary supplies. It is useful as a community water standpost in rural area.

Special care is necessary during construction to avoid surface pollution reaching the sub-soil water level directly, through any passage between the pipe and the soil. The usual precaution is to have the perforations confined to the lower depths of the aquifer with the plain tubing extending over the top few metres of the soil. In addition, a water-tight concrete platform with a drain should be provided above ground level, in order to deflect any surface pollution away from the pipe.

Tubewells collect the ground water infiltrated to deeper layers in the soil strata compared to dug wells and hence the quality of water will be good and can be supplied after disinfections (using bleaching powder). With the advent of modern drilling rigs it is possible to drill as much as 300, m below ground level even penetrating hard rock formations. Tube Wells shall be drilled in accordance with Indian Standard IS:2800 (Part- I)-1979 with latest amendments, developed in accordance with IS:11189-1985 with latest amendments and tested in accordance with IS:2800 (Part-II)-1979 with latest amendments.

9.8.2.1.3.1 General Requirements:

- Size of Tube well - M.S housing pipes confirming to IS:4270- 1983 with latest amendments of nominal bore dia. 200 mm to 250 mm shall generally be provided. Length of Housing pipe shall depend on depth of water table, draw down and submergence requirements of pump.
- Strainer - Steel strainer, Screens and slotted pipes shall be as per IS:8110 – 2000 with latest amendments of nominal bore dia. 200 mm shall generally be provided. Slot size of the strainer shall be arrived at from grain size analysis of aquifer to be tapped.
- Depth - Depth of Tube well shall depend on availability of potable water.
- Pump Chamber -Pump chamber to house machinery and other equipment shall be constructed as per standard departmental design

8.9.2.2 Surface Sources

Surface water supplies may be divided into river, lake, and reservoir supplies. Dams are constructed to create artificial storage. Surface water can be conveyed from Canals/ open channels to the schemes through intake structure/ flow regulator and transmission pipes by gravity / pumping. Managing lakes and reservoir used for domestic supplies vary widely depending on local condition.

The probability of contamination of surface water is very high. The factor affecting water qualities are waste water, agriculture waste, domestic and Industrial discharge, grazing of livestock, drainage from mining area. The method of treatment of water depends upon row water quality and range from disinfection only to complete treatment.

Waters in lakes and ponds would be more uniform in quality than water from flowing streams. Long storage permits sedimentation of suspended matter, bleaching of colour and the removal of bacteria. Self-purification which is an inherent property of water to purify itself is usually less complete in smaller lakes than in larger ones. Deep lakes are also subject to periodic overturns which bring about a temporary stirring up of bottom sediment. The microscopic organisms may be heavy in such waters on occasions. If the catchment is protected and unerodible, the stored water may not require any treatment other than disinfection.

Waters from rivers, streams and canals are generally more variable in quality and less satisfactory than those from lakes and impounded reservoirs. The quality of the water depends upon the character and area of the watershed, its geology and topography, the extent and nature of development by man, seasonal variations and weather conditions. Streams from relatively sparsely inhabited watersheds would carry suspended impurities from eroded catchments, organic debris and mineral salts. Substantial variations in the quality of the water may also occur between the maximum and minimum flows. In populated regions, pollution by sewage and industrial wastes will be direct. The natural and man-made pollution results in producing colour, turbidity, tastes and odours, hardness, bacterial and other micro-organisms in the water supplies.

9.8.3 Transmission and distribution system

9.8.3.1 Pipe Materials:

Out of the several of pipe materials available in the market, the most commonly used pipes in rural water supply schemes is PVC pipes.These are most economically suited for rural water supply schemes. These have certain advantages over metal pipes, such as resistance to corrosion, light weight and easy jointing.

For reasons of economy and ease of construction, many public water systems use plastic pipes and fittings. Other types of pipes used are cast iron, asbestos-cement, concrete, galvanised iron and steel. Under certain conditionas and in certain areas, it may be necessary to use protective coatings, galvanizing or hve the pipes dipped or wrapped.

9.8.3.1.1 Cast iron pipes

Though the cast iron pipe is heavy in weight, low in tensile strength, and liable to defects of inner surface, it is widely used because of its good lasting qualities. Due to its strength and corrosion resistance, C. l. pipes can be used in corrosive soils and for waters of slightly aggressive character. They are well suited for pressure mains and laterals where tapings are made for house connections. It is preferable to have coating inside and outside of the pipe. Vertically cast iron pipes shall conform to T.S. 1537-1976. The metal used for the manufacture of this pipe is not less than grade 15. The pipes shall be stripped with all precautions necessary to avoid wrapping or shrinking defects. The pipes shall be such that they could be cut, drilled or machined. Pipes are laid underground with a minimum cover of 1 metre on the top of the pipe.

The pipes have been classified as LA, A and B according to their thicknesses. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10°/ci increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA.

Excavation may be done by hand or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under a roadway a minimum cover of 1.0 m is recommended. The width of the trench at bottom shall provide not less than 200mm clearance on both sides of the pipe. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit finishing of joints.

While unloading, pipes shall not be thrown down but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes.

After laying and jointing, the pipeline must be pressure tested to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

Testing Of Pressure Pipes: The field test pressure to be imposed should be not less than the maximum of

(a) 1 1/2 times the maximum sustained operating pressure.

(b) 1 1 /2 times the maximum pipeline static pressure.

(c) Sum of the maximum sustained operating pressure and the maximum surge pressure.

(d))Sum of the maximum pipeline static pressure and the maximum surg,~ pressure, subject to a maximum equal to the work test pressure for any pipe fittings incorporated.The field test pressure should wherever possible be not less than 2/3 work test pressure appropriate to the class of pipe except i11 the case of spun iron pipes and should be applied and maintained for atleast four hours. If the visual inspection satisfies that there is no leakage, the test can be passed.

Where the field test pressure is less than 2/3 the work test pressure, the period of test should be increased to atleast 24 hours. The test pressure shall be gradually raised at the rate of 1 kg/cm2/mi.n. Jf the pressure measurements are not made at the lowest point of the section, an allowance should be made for the difference in static head between the lowest point and the point. of measurement to ensure that the maximum pressure is not exceeded at the lowest point. lf a drop in pressure occurs, the quantity of water added in order to re-establish the test pressure should be carefully measured. This should not exceed 0.1 litre per mm of pipe diameter per KM of pipeline per day for each 30 metre head of pressure applied.
In case of gravity pipes, maximum working pressure shall be 2/3 work test pressure.

Testing Of Non-Pressure Conduits :In case of testing of non-pressure conduits, the pipeline shall be subject to a test for of 2.5 meters head of water at the highest point of the section under test for 10 minutes. The leakage or quantity of water to be supplied to maintain the test pressure during the period of 10 minutes shall not exceed 0.2 litres/mm dia of pipes per kilometer length per day.

9.8.3.1.2 Steel pipes

Steel pipes of smaller diameter can be made from solid bar sections by hot or cold drawing processes and these tubes are referred to as seamless. But the larger sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press(IS:3589). The thickness of a steel pipe is however always considerably less than the thickness of the corresponding vertically cast or spun iron pipe. Owing to the higher tensile strength of the steel, it is possible to make steel pipe of lower wall thickness and lower weight. Specials of all kinds can be fabricated without difficulty to suit the different site conditions. Due to their elasticity, steel pipes adopt themselves to changes in relative ground level without failure and hence are very suitable for laying in ground liable to subsidence. If the pipes are joined by a form of flexible joint, it provides an additional safeguard against failure. Steel pipes being flexible are best suited for . high dynamic loading.

I t must be borne in mind, however, that steel mains need protection from corrosion internally and externally. Against internal corrosion, steel pipes are given epoxy lining or hot applied coal tar/ asphalt lining or rich cement mortar lining at works or in the field by the centrifugal process. The outer coating for under ground pipeline may be in cement-sand guiniting or hot applied coal-tar asphaltic enamel reinforced with fibreglass fabric yarn.

Laying and jointing : Small size mild steel pipes have got threaded ends with one socket. They are lowered down in the trenches and laid to alignment and gradient. The jointing materials for this type of pipes are white lead and spun yarn. The white lead is applied on the threaded end with spun yarn and inserted into socket of another pipe. The pipe is then turned to tighten it. When these pipes are used in the construction of tube wells, the socketed ends after positioning without any jointing material are welded and lowered down. Lining and out• coating is done by different methods to protect steel pipes. While laying, the pipes already stocked along the trenches are lowered down into the trenches with the help of chain pulley block. The formation of bed should be uniform. The pipes are laid true to the alignment and gradient before jointing. The ends of these pipes are butted against each other, welded and acoat of rich cement mortar is applied after welding.

9.8.3.1.3 Ductile iron pipes

Ductile iron pipes are normally prepared using the centrifugal cast process. The ductile iron pipes are usually provided with cement mortar lining at the factory by centrifugal process to ensure a uniform thickness throughout its length. Cement mortar lining is superior to bituminous lining as the former provides a smooth surface and prevents tuberculation by creating a high pH at the pipe wall and ultimately by providing a physical and chemical barrier to the water.

The Indian standard IS 8329-1994 provides specifications for the centrifugally cast ductile iron pipes(Similar to IS0:2531-1998 and EN:545-1994). These pipes are available in the range of 80 mm to 1000 mm diameter; in lengths of 5.5 to 6 m. These pipes are being manufactured in the country with ISO 9002 accreditation.

Ductile iron pipes have excellent properties of machinability, impact resistance, high wear and tear resistance, high tensile strength, ductility and corrosion resistance.. DI pipes having same composition of CI pipe, it will have same expected life as that of CI pipes. The ductile iron pipes are strong, both inner and outer surfaces are smooth, free from lumps, cracks blisters and scars. Ductile Iron pipes stand up to hydraulic pressure tests as required by service regulations. These pipes are approximately 30% lighter than conventional cast iron pipes.

9.8.3.1.4 Concrete pipes

Reinforced concrete pipes used in water supplies are classified as P1, P2 anci P3 with test pressures of 2.0, 4.0, and 6.0 Kg/cm2 respectively. For use as gravity mains, the working pressure should not exceed 2/3 of the test pressure. For use as pumping mains, the working pressure should not exceed half of the test pressure.

Generally concrete pipes have corrosion resistant properties similar to those of prestressed concrete pipes although they have their own features which significantly affect corrosion performance. Concrete pipes are made by centrifugal spinning of vibratory process. Centrifugally spun pipes are subjected to high rotational forces during manufacture with improved corrosion resistance properties. The line of development most likely to bring concrete pressure pipes into more general acceptance is the use of P.S.C. pipes which are widely used to replace reinforced concrete pipes.

The concrete pipes should be carefully loaded, transported and unloaded avoiding impact. The use of inclined planes or chain pulley block is recommended. Free working space on either side of the pipe shall be provided in the trench which shall not be greater than 1/3 the dia of the pipe but not less than 15 cm on either side.

Laying of pipes shall proceed upgrade of a slope. If the pipes have spigot and socket joints the socket ends shall face upstream. The pipes shall be joined in such a way to provide as little unevenness as possible along the inside of the pipe. Where the natural foundation is inadequate, the pipes shall be laid in a concrete cradle supported on proper foundation or any other suitably designed structure. If a concrete cradle is used, the depth of concrete below the bottom of the pipes shall be at least 1 / 4 the internal diameter of pipe with the range of 10-30cm. It shall extend upto the sides of the pipe atleast to a distance of 1/4 the dia for larger than 300mm. The pipe shall be laid in the concrete bedding before the concrete has set.

Trenches shall be back filled immediately after the pipe has been laid to a depth of 300mm above the pipe subject to the condition that the jointing material has hardened (say 12 hours at the most). The backfill material shall be free from boulders, roots of trees etc. The tamping shall be by hand or by other hand operated mechanical means. The water content of the soil shall be as near the optimum moisture content as possible. Filling of trench shall be carried on simultaneously on both sides of the pipe to avoid development of unequal pressures. The back fill shall be rammed in 1 5Omm layers upto 900mm above the top of the pipe.

In all pressure pipelines, the recesses at the ends of the pipe shall be filled with jute braiding dipped in hot bitumen. The quantity of jute and bitumen in the ring shall be just sufficient to fill the recess in the pipe when pressed hard by jacking or any other suitable method.

Pressure test: When testing the pipeline hydraulically, the line shall be kept filled completely with water for a week. The pressure shall then be increased gradually to full test pressure and maintained at this pressure during the period of test with the permissible allowance indicated therein. For further details, reference may be made to LS. 458-1971.

9.8.3.1.5 Prestressed concrete pipes

While RCC pipes can cater to the needs where pressures are upto 6.0 kg/cm2 and Cl and steel pipes cater to the needs of higher pressures around 24 kg/cm2, the Prestressed Concrete (PSC) pipes cater to intermediate pressure range, while RCC pipes would not be suitable.

The strength of a PSC pipe is achieved by helically binding high tensile steel wire under tension around a concrete core thereby putting the core into compression. When the pipe is pressurized the stresses induced relieve the compressive stress but they are not sufficient to subject the core to tensile stresses. The prestressing wire is protected against corrosion by a surround of cernentatious cover coat giving atleast 25mm thick cover.

The PSC pipes are suited for water supply mains where pressures in the range of 6 kg/ cm2 to 20 kg/ cm2 are encountered.

9.8.3.1.6 Plastic pipes

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes generally come in lengths of 6 meters. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adapters for pipe sizes upto 200mm are available.

9.8.3.1.6.1 PVC Pipes

The chief advantages of PVC pipes are

- Resistance to corrosion
- Light weight
- Toughness
- Rigidity
- Economical in laying, jointing and maintenance
- Ease of fabrication

The PVC pipes are much lighter than conventional pipe materials. Because of their lightweight, PVC pipes are easy to handle, transport, and install. Solvent cementing technique for jointing PVC pipe lengths is cheaper, more efficient and far simpler. PVC pipes do not become pitted or tuberculated and are unaffected by fungi and bacteria and are resistant to a wide range of chemicals. They are immune to galvanic and electrolytic attack, a problem frequently encountered in metal pipes, especially when burried in corrosive soils or near brackish waters. PVC pipes have elastic properties and their resistance to deformation resulting from earth movements is superior compared to conventional pipe materials specially AC. Thermal conductivity of PVC is verylow compared to metals. Consequently water transported in these pipes remain at a more uniform temperature.

Rigid PVC pipes weigh only 1 /5th of conventional steel pipes of comparable sizes. PVC pipes are available in sizes of outer dia, 20, 25, 32, 50, 63, 75, 90, 110, 140, 160, 250, 290, and 315mm at working pressures of 2,5,4,6, 10 Kg/cm2 as per IS 4985 - 1988.

Since deterioration and decomposition of plastics are accelerated by ultraviolet light and frequent changes in temperature which are particularly severe in India, it is not advisable to use PVC pipes above ground. The deterioration starts with discolouration, surface cracking and ultimately ends with brittleness, and the life of the pipe may be reduced to 15-20 years.

Precautions in handling and storage : Because of their lightweight, there may be a tendency for the PVC pipes to be thrown much more than their metal counterparts. This should be discouraged and reasonable care should be taken in handling and storage to prevent damage to the pipes. On no account should pipes be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stacked in large piles, specially under warm temperature conditions, as the bottom pipes may be distorted thus giving rise to difficulty in pipe alignment and jointing. For temporary storage in the field, where racks are not provided, care should be taken that the ground is level, and free from loose stones. Pipes stored thus should not exceed three layers and should be so stacked as to prevent movement. It is also recommended not to store one pipe inside another. It is advisable to follow the practices mentioned as per IS 7634 - Part I.

Trench Preparation: The trench bed must be free from any rock projections. The trench bottom where it is rocky and uneven a layer of sand or alluvial earth equal to 1 /3 dia of pipe or 100mm whichever is less should be provided under the pipes.

The trench bottom should be carefully examined for the presence of hard objects such as flints, rock, projections or tree roots. In uniform, relatively soft fine grained soils found to be free of such objects and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their lengths, the pipes may normally be laid directly on the trench bottom. In other cases, the trench should be cut correspondingly deeper and the pipes laid on a prepared under-bedding, which may be drawn from the excavated material if suitable.

Laying And Jointing: As a rule, trenching should not be carried out too far ahead of pipe laying. The trench should be as narrow as practicable. This may be kept from 0.30m over the outside diameter of pipe and depth may be kept at 0.60 -1.0m depending upon traffic conditions. Pipe lengths are placed end to end along the trench. The glued spigot and socket jointing technique as mentioned later is adopted. The jointed lengths are then lowered in the trench and when sufficient length has been laid, the trench is filled.

If trucks, lorries, or other heavy traffic will pass across the pipeline, concrete tiles 600 x600mm of suitable thickness and reinforcement should be laid about 2m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2m below bed level to protect the pipe.

For bending, the cleaned pipe is filled with sand and compacted by tapping with wooden stick and pipe ends plugged. The pipe section is heated with flame and the portion bent as required. The bend is then cooled with water, the plug removed, the sand poured out and the pipe (bend) cooled again. For further details on laying & jointing of PVC pipes, reference can be made to IS 4985 - 1988, IS 7634 - Part 1-3.

Normally PVC pipes should not be threaded. For the connections of PVC pipes to metal pipes, a piece of a special thick wall PVC connecting tube threaded at one end is used. The other end is connected to the normal PVC pipe by means of a glued spigot and socket joint. Before installation, the condition of the threads should be carefully examined for cracks and impurities.

Glue can be used for making joints leak proof. Yarn and other materials generally used with metal pipe and fittings should not be used. Generally, it is advisable to use PVC as the spigot portion of the joint.

Pressure testing: The method which is commonly in use is filing the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. After the specified test time has elapsed, usually one hour, a measured quantity of water is pumped into the line to bring it to the original test pressure, if there has been loss of pressure during the test. The pipe shall be judged to have passed the test satisfactorily if the quantity of water required to restore the test pressure of 30m for 24 hours does not exceed 1.5 litres per 10 mm of nominal bore for a length of 1 Km.

9.8.3.1.6.2 polyethylene pipes

Rigid PVC and ,high-density polyethylene pipes have been used for water distribution systems mostly ranging from 15 -150mm dia and occasionally upto 350mm.

Among the recent developments is the use of High-Density Polyethylene pipes. These pipes are not brittle and as such a hard fall at the time of loading and unloading etc. may not do any harm to it. HDPE pipes as per IS 4984 - 1987 can be joined with detachable joints and can be detached at the time of shifting the pipeline from one place to another. Though for all practical purposes HDPE pipes are rigid and tough, at the same time they are resilient and conform to the topography of land when laid over ground or in trenches. They are coilable, easily be bent in installation, eliminating the use of specials like bends, elbows etc., there by reducing fitting and installation costs. HDPE pipes are easy to carry and install. They are lighter in weight and can be carried to heights as on hills. They can withstand movement of heavy traffic. This would not cause damage to the pipes because of their flexural strength. HDPE has excellent free flowing properties. They have non-adherent surface which reject (not attract) any foreign materials which would impede the flow. HOPE pipes are anti-corrosive, have smooth inner surface so that there is less friction and pressure loss is comparatively less. HDPE pipes can be jointed by welding.

For further details of PVC and HDPE pipes refer to:
IS 7834 - 1975 Parts 1- 8
IS 8008 - 1976 Parts 1-7
IS 7634 - 1975 Parts 1-3
IS 3076 - 1985
IS 4984 - 1987

9.8.3.1.6.3 Medium density polyethylene (MDPE) pipes

The medium density Polyethylene Pipes (MDPE) are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730 - 1986) for carrying potable water. However no BIS is available for these pipes. The MDPE pipes are being used for consumer connection pipes as an alternative to Gl pipes. The Polyethylene material used for making the MDPE pipes conforms to PE 80 grade and the MDPE pipes when used for conveying potable water does not constitute toxic hazard and does not support any microbial growth Further, it does not impart any taste, odour or colour to the water.

The Polyethylene material conforms to PE 80 grade. The MDPE pipes are colour coded black with blue strips in sizes ranging from 20 mm to 110 mm dia for pressure class of PN3.2, PN4, PN6, PN 10 and PN 16. The maximum admissible working pressures an: worked out for temperature of 20 degrees centigrade as per 1SO 4427. The pipes arc supplied in coils and minimum coil diameter is about 18 times diameter of the pipe.

MDPE compression fittings made of PP, AABS, UPVC are also available in India for use with MDPE pipes. The materials used for the fittings are also suitable for conveying potable water like MDPE pipes. The jointing materials of fittings consists of thermoplastic resins of Polyethylene type, NBR 'O' ring of Nitrile and clamp of Polypropylene, copolymer body, Zinc plated steel reinforcing ring, nuts and balls of special NBR gasket.

The MDPE pipes are lightweight, robust and non-corrodible and hence can be used as alternative material for consumer connections. Since the pipes are supplied in coils, there will be no joints under the roads and bends are avoided resulting in fast, simple and efficient jointing.

Strength of pipes : The stresses in a pipe are normally induced by internal pressure, external loading, surge forces and change of temperature, although torsional stresses can also arise. Internal pressure induces circumferential and longitudina1 stresses, the latter developing where the line changes in size or direction, or has a dosed end. A pipe is usually chosen so as to carry the circumferential stress without extra strengthening or support but if the joints cannot safely transmit the longitudinal stress, anchorages or some other means of taking the load must be provided. Longitudinal stress is absorbed by friction between the outside surface of the pipe and the material in which the line is buried.

A pipe must withstand the highest internal pressure it is likely to be subjected. External loads generally arise from the weight of the pipe and its contents and that of the trench filling from superimposed loads, including impact from traffic, from subsidence and from wind loads in the case of pipes laid above ground. J fa pipe is laid on good and uniform continuous bed and the cover does not greatly exceed the normal, no special strengthening to resist external loading is generally necessary. Loading likely to arise from subsidence is best dealt with by the use of flexible joints and steel pipes. External loading becomes important usually when a line is laid on a foundation providing uneven support (e.g. across a sewer, trench or in rock under deep cover) or is subjected to heavy superimposed surface loads at less than normal cover. The necessity of stronger pipes can often be avoided by careful bedding and trench filling to give additional support. The importance of good bedding under and around the pipe upto at least the horizontal diameter cannot be overemphasized and in some cases concreting may be required.

Excessive distortion of a steel pipe may cause failure of its protective coating but can be limited by the use of strengthening rings. This problem is only likely to arise in very large mains. Distortions at flexible joints can cause leakage.

When a pipeline has to be laid above ground over some obstruction, such as waterway or railway, it may either be carried on a pipe-bridge or be supported on pillars. In the latter case, the pipe ends must be properly designed to resist shear, if the full strength of the pipe as a beam is to be realized. A small diameter pipe is usually thick enough to span short lengths with its ends simply supported, but as diameter and lengths of span increase, the problem becomes more complex and the ends must be supported in saddles or restrained by ring girders. For pipes of more than 900mm in dia the ring girder method will probably provide the most economical design. Structural design of buried pipes is discussed in detail in the companion volume "Manual on Sewerage and Sewage Treatment".

The temperature of the water in a transmission main varies during the year. If the water is derived from underground sources the variation is relatively small, but if it is obtained from surface sources and is filtered through slow sand filters, the variation may be as much as 20°C during the year. Furthermore, the temperature changes may take place fairly quickly and for these and other reasons, long lengths of rigid mains are to be avoided. Provision of expansion joints to take care of these stresses is necessary. Thrust and anchor blocks are provided to keep the pipe curve in position. In small mains, i.e, the mains with spigot and socket lead joints, the joints themselves allow sufficient movement, although some recaulking may be occasionally necessary. On large steel pipelines with welded joints expansion can be allowed to give a longitudinal stress in the pipes, when first laid. In about four years or so, the ground normally consolidates sufficiently around the pipe so that the stress is transferred to the ground. Valves require to be bridged by steel or reinforced concrete blocks so that the valve bodies are not stressed, as this could affect their water tightness.

In case of PVC pipelines, it should be noted that the coefficient of expansion of PVC is eight times greater than steel and considerable movement can take place in long lengths of rigidly jointed pipelines.

Depth of cover : One metre cover on pipeline is normal and generally sufficient to protect the lines from external damage. The pipeline shall be protected against damages due to external influence. Hence, the pipeline shall not be laid at surface, they shall be laid at sufficient depths to avoid damages. A minimum cover of 1.0m above the pipeline is to be laid to avoid damage by superimposed load. When heavy traffic is anticipated, depth of cover has to be worked out after taking into consideration the structural and other aspects. However in narrow streets 1-1.5 mt wide where no vehicular traffic is expected and digging deep may cause danger to the stability of adjoining structures it may be reduced to 60 cm. Distribution mains and pumping mains can be laid along the road berm to avoid load due to vehicular traffic on the pavement of road. When road is to be crossed, GI/CI pipes are preferred to PVC pipes.

Hydraulic testing of the pipe line : After a new pipeline is laid, hydrostatic test shall be done to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions. The completed pipeline may be tested either in one length or in sections. Each section should be properly sealed off with special stop ends and secured by adequate temporary anchors.

All permanent anchors should be in position and concrete should develop adequate strength before the commencement of test. The section under test should be filled with water, taking care that all the air is displaced either through vents at the high points or by using a peg or a sphere.

In a pumping main the total head for which the pump to be designed is the maximum working pressure. However, in the case of submersible pumps, by the time water comes out of the pump up to the ground level near the bore well the total head will be reduced by the depth of water in the bore well. Hence, PVC pipes at the bore well location, shall withstand a resulting static head above ground level plus the head due to water hammer effect. In gravity main the maximum static head is equal to the hydraulic gradient line minus the lowest ground level along the alignment of the pipeline.

The test pressure for pipe lines shall be as per following :
Pumping Mains = 50% of Pipe test pressure class or working pressure whichever is higher
Gravity Lines = 2/3 rd of the Pipe test pressure or working pressure whichever is higher

After filling, the pipeline should be pressurized to the specified operating pressure and left for a period of time to achieve stable conditions. The pipeline is pressurized upto the full test pressure gradually and the section under test completely closed. The test should be mentioned for a period not less than 10 minutes to reveal any defects in the pipes, joints or anchorage. The test pressure should be measured at the lowest point of the section under test or alternatively, an allowance should be made for the static head between lowest point and the point of measurement, to ensure that the required test pressure is not exceeded at the lowest point. The leakages/ burst if any should be identified and rectified there after the test is again carried out.

9.8.4 Appurtenances

Appurtenances are valves, which are installed in a pipeline to isolate and drain pipeline sections for test, inspection, cleaning and repairs, and for expulsion of air. A few of the commonly adopted appurtenances are discussed herein.

9.8.4.1 Sluice Valves

Sluice valves on main line are provided to stop and regulate the flow of water in the course of ordinary operations and in an emergency. The principle considerations in location of the valves are accessibility and proximity to special points such as branches, stream crossings, major summit points etc.

Sluice valves of the same size as per diameter of the main line pipe are normally used for isolating sections of pipe. Sluice valves are sometimes used for continuous throttling which may cause erosion of seats and lead to body cavitations. Wherever small flows are required, the bypass valve is more suitable for this purpose as compared to throttling the mainline valve.

9.8.4.2 Scour Valve

Scour Valves are located in valley portions in the alignment of pipe lines, so as to facilitate emptying of the pipe line whenever required for maintenance of the pipeline. The outlet of the scour valve has to be connected to a natural drain. However, precautions must be taken to ensure that the wastewater from the drains does not enter the water supply pipelines. During installation of the valve, it should be ensured that it is always accessible for operation. A proper valve chamber with locking ar5rangement is required to protect the valve and prevent misuse. The size of scour valve shall be normally equal to half the diameter of the main line.

9.8.4.3 Air Valves

Air release valves are designed to expel air automatically from the pipe lines, which tends to accumulate at the high points in the pipeline. Normally in gravity flow pipelines, when the pressure in the pipe falls below the atmospheric pressure, air has to be drawn in to prevent collapsing of the pipes to prevent the pipe from such collapse (vacuum).

Additionally Air Valve have also to release any entrained air which might accumulate at high points in the pipe line during normal operations . For most cases in water works and pumping practice , two types of air valves are required . These are known as

A) Large Orifice Air Valve : The purpose of this type of valve is to discharge air during filling or charging of mains and to admit air to mains while they are being emptied . They pass air at high rates of flow with small pressure difference either in to or out of the pipes on which the valve is fixed . The ball which forms the valve element although buoyant is rigid being covered with vulcanite . During normal service condition this ball is maintained in contact with its seating usually of leather backed rubber by the pressure in the main and cannot leave this seating except when the pressure falls practically to that of atmosphere .

This occurs at various sections of a main when it is either being charged or emptied . when the pipes carrying a large orifice air valve are empty, the valve is open and remains in that position until the ball is carried on to its seating by the arrival of water . once on this eating and under pressure the valve cannot open and remains in that position even if the pipe is full of air until the pressure drops . It will be seen there fore that this valve will not release air accumulations under conditions of normal working pressure . when such a valve is discharging at a high rate , as during the filling of main of a main there is a risk that the ball although lying in a fully open position in the absence of water may nevertheless suddenly be caught in the escaping air stream and closed when it may refuse to open again until the pressure has been reduced . The ball of the valve in such a case would have to be held down during filling operation . This defect has been over come in a large orifice air valve of the advanced design known as kinetic air valve . In this air valve water or air enters from the ottom side of the ball and the air rushing around the ball exerts the pressure and loosens the contact with the top opening and allows he ball to drop down . When the solid water reaches the ball , however it is at once displaced and instantly closed .

B) Small Orifice Air Valve : The purpose of this valve is to discharge air which may accumulate in sections of a main under working conditions , that is under the running pressure in the main . The orifice is relatively quite small and is sealed by a floating rubber covered ball at all pressures above atmospheric pressure except when air accumulates in this valve chamber . When air has accumulated to depress the water level sufficiently the ball falls away from out let orifice and the air escapes through this orifice until the water level rises again causing the ball to re seal the orifice . The diameter of the ball in a small orifice air valve is related to maximum working pressure and for a given size of orifice increase with this pressure . The orifice is not less than 2.5 mm in diameter

C) Double Air Valves : In many instances both large and small orifice air valves are required at the same point on a main and it is usual in such casaes to fit a combined air valve in a single fitting .

Air inlet valves are used at peaks. A manually operated sluice valve is introduced between the air valve and the main pipe to isolate the air valve for the repairs. Normally, air valves are used with size equal to D/4 where D is the diameter of the main pipe on which the air valve is placed.

9.8.4.4 Reflux Valves

Reflux valves are also called check valves or non-return valves, which automatically prevent reversal of flow in a pipe line. They are useful in pumping mains when positioned near pumping stations to prevent back flow when the pump is shutdown. The reflux valve is normally provided on delivery side of each pump to prevent back flow into pump impeller and to avoid rotation of impeller in reverse back flow into pump impeller and to avoid rotation of impeller in reverse direction. The size of the valve is equal to the same size as the pipeline on which it is installed. Reflux valves shall have by pass valves, which can be used for priming of the suction line before starting of the pumps.

9.8.5 Anchor Blocks

Internal pressure including water hammer creates transverse stress or hoop tension. Bends and closures at dead ends or gates produce unbalanced pressure and longitudinal stress. When pipes are not permitted to change length, variations in temperature like-wise create longitudinal stress. External loads and foundation reactions (manners of support) including the weight of the full conduit, and atmospheric pressure produce flexural stress. Bends end closures at dead produce unbalanced pressure and longitudinal stress in the pipeline. Further when pipes are not permitted to change length due to variations in temperature, pipes also expand and create longitudinal stress. Anchorages are necessary to resist the tendency of the pipes to pull apart at bends and restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes.

9.8.6 Water Hammer

The pump set is shut off only after the delivery valve at the outlet of the pump is closed gradually so as to prevent the velocity rise in the pumping main. However, sudden power failure causes the sudden stoppage of pump set. Such sudden stoppage of pumps prevents the forward flow of water, which creates a separation of water column. Hence the water column ahead of the pump set rushes towards the pump set (with a reversal of the direction) and velocity increases by several times causing water hammer. This pressure rise or water hammer results in a series of shocks, sounding like hammer blows, which may be of sufficient magnitude to rupture the pipe. The pressure due to water hammer depends on the elastic properties of the pipe material.

9.8.7 Control measures

The actual water hammer head can be calculated and added to the working pressure to arrive at the class of the pipe which shall be able to withstand the total head on account of water hammer plus the working head. Water hammer is contained in small size pipe lines by operating them at lower velocities (not more than 1 m /sec.) Since water hammer head is a function of velocity, choosing a higher diameter pipeline reduces the velocity and hence reduces the water hammer head. However, cost effect has to be studied for choosing higher diameter pipe to minimize water hammer head or chargining the pipe material or increasing the pressure class of pipe to withstand the water hammer head.

9.8.8 Storage reservoirs

Overhead tanks are generally used to store water in water supply schemes. They can be concrete or PVC. All tanks are designed as crack free structures to eliminate any leakage. In case of concrete tanks, a dense impermeable concrete is required. Therefore, proportion of fine and coarse aggregates to cement should be such as to give high quality concrete. The minimum quantity of cement in the concrete mix shall be not less than 30 kN/m3. The design of the concrete mix shall be such that the resultant concrete is sufficiently impervious. Efficient compaction preferably by vibration is essential. The permeability of the thoroughly compacted concrete is dependent on water cement ratio. Increase in water cement ratio increases permeability, while concrete with low water cement ratio is difficult to compact. Other causes of leakage in concrete are defects such as segregation and honey combing. All joints should be made water-tight as these are potential sources of leakage.

Elevated R.C.C. storage tank shall be constructed to supply water to the consumers at water works site. In a multi village water supply scheme OHSR can be constructed at individual villages and a transmission line shall be laid from central water works to storage tank to fill the water in the individual water storage tanks. The capacity of water tank shall be calculated by using the mass curve. The height of tank shall be so adjusted as to keep a minimum residual pressure of 12 m (water column) at consumer end. Tank shall be designed as per IS:3370 (part 1 to 2)-1965, IS:3370 (part 3 to 4)-1967. The staging of tank will be as guided by IS:11682-1985. Foundation design shall depend on bearing capacity of soil.

The outlet/inlet/scour/overflow pipes shall be of appropriate diameter and quality and are to be fixed at proper position during concreting. During construction of cover slab, two vent pipes of dia 50 mm shall be fixed.

A manhole of dimension 75 x 75 cm shall be provided for cleaning and inspection of the tank. The manhole cover shall have proper locking arrangement. Arrangements shall be made during construction for fixing water level indicator. The bottom slab of the water tank shall be extended so that it can be used as a foot path for inspection of the tank.

9.8.9 Pumping machinery

9.8.9.1 Submersible Pumps:

Submersible pumps shall be installed in a bore well such that the motor assembly is always submerged in water. Hence, normally they are installed at 1.5- 2.0 m below the lowest safe yield level during summer under continuous operation. Hence it is necessary to install Electronic water level indicators to read the water level in the bore well ensuring the required minimum submergence (1.5m) also to avoid drawing of the sit/stand from bottom it is preferable that lowest part of the pump is 3.0m above bottom of the well. The motor assembly is suspended through the riser pipe, which in turn is clamped at the top of the casing pipe. The insulated cable is tied to the riser pipe at regular intervals. The casing pipe is taken to height of about 0.45 m above the ground level and is covered in order to prevent misuse.

Indoor control panels where pump chamber are provided or out door type control panel for bore well pump sets will have provision for energy meter, main switch, starter, single phase preventer, capacitor, etc.

a) Switches: A main switch of adequate capacity to disconnect power supply shall be provided after the meter. This will enable to disconnect the service immediately in case of any emergency or for maintenance purpose.

b) Starter: Starter with over load relay is provided to start and stop the motor and to protect it against any over load. Over load may be either electrical or mechanical.

c) Capacitor:- Installation of capacitor of suitable rating in the motor circuit will improve the power factor and reduce energy consumption. The running cost of the motor will also be reduced. The recommended capacitor ratings are given below. It is essential to provide capacitor to avoid penal action from the PSEB. Typical components for starter and power capacitor rating for different range of motors are presented below.

d) Single phase preventer:- In three phase circuit, three fuses are provided (1 for each phase). If in any one phase fuses were to blow or any one phase is disconnected form service during running of the motor, the motor keeps running drawing excess current from the two lines and hence causing damage to the motor. If a single phase preventer is provided in the circuit, it will sense the operating coil and trips the starter and protects the motor from burning.

e) Voltmeter and three phase ammeters: - These meters will indicate whether system voltage is within permissible range for the motor or to know whether motor is drawing current equally on all three phases. The functioning of Voltmeter is very important, voltage being low in villages damaging the motors.

(f) Selector Switch:- Selector switches of adequate capacity shall be used wherever more than one pump is installed. The selector switches will enable to operate any one of the pump or both the pumps from a single switch board.

Components for starter and power capacitor for different range of motors.
TABLE

9.8.9.2 Safety Procedures

a) After installation, it shall be tested to ensure that the wires / cables used are sufficiently insulated to avoid leakage of current.

b) For safety, all the metallic casing of enclosure of switches etc. must be solidly connected to earth. The body of the out door kiosks shall have a separate and efficient earth connection.

9.8.9.3 Pump Operation:

1. Trial Operation:

The operation of centrifugal pumps is quite simple and safe. There are relatively few valves to operate and the pump will not be damaged even if the discharge valve is closed for short periods of time.

2. Starting:

The pump must be primed before it will deliver any water. Failure to prime the pump may cause the wearing of rings rub and seize or the shaft may be scoured at the packing boxes. During starting it is desirable to have the vent
cock in the casing open slightly to remove any dissolved air in the water.

It is necessary to have the discharge valve closed so that the least load is thrown on the driver when the pump is started. The valve should be opened gradually to avoid over load on the motor and to prevent a sudden surge in the discharge line.

3. Shutting Down

When shutting down, the discharge-valve should be in the same position as when starting up by closing the discharge valve gradually so that less power is dropped from the line and any sudden pressure surges in the pipe system are avoided.

4. Inspection and Maintenance

Manufacturers supply instruction books that give directions for the operation and maintenance of each pump.

If the base is not too rigid the shaft alignment should be checked occasionally.

9.8.10 Water treatment

The aim of water treatment is lo produce and maintain water that is hygienically safe, aesthetically attractive and palatable, in an economical manner, Though the treatment of water would achieve the desired quality, the evaluation of its quality should not be confined to the end of the treatment facilities but should be extended to the point of consumer use.

The method of treatment to be employed depends on the nature of raw water constituents and the desired standards of water quality. The unit operations in water treatment include aeration, flocculation (rapid and slow mixing) and clarification, filtration, disinfection, softening, deferrization, defluoridation and water conditioning and many different combinations of these to suit these requirements. The choice of any particular sequence of treatment units will depend not only on the qualities of the raw water available and treated water desired but also on the comparative economic, of alternative treatment steps applicable.

In the case of ground waters and surface waters with storage which arc well protected, where the water has turbidity below 10 NTU and they are free from odour and colour, plain disinfection by chlorination is adopted before supply .

Where ground water contains excessive iron, dissolved carbon dioxide and odorous gases, aeration followed by flocculation (rapid and slow mixing) and sedimentation, rapid gravity or pressure filtration and disinfection may be necessary. In case it contains only carbon dioxide or odorous gases, aeration followed by disinfection may be sufficient. In surface waters with turbidities not exceeding 50 NTU and where sufficient area is available, plain sedimentation followed by slow sand filtration and disinfection are practised.

Conventional treatment including prechlorination, aeration, flocculation (rapid and slow mixing) and sedimentation, rapid gravity filtration and post chlorination are adopted for highly polluted surface waters laden with algae or other microorganisms. Sometimes, unconventional flow sheets may be adopted for waters of low turbidity (below 10 to 15 NTU) and containing low concentration of suspended matter (less than50 mg/l) . Such raw waters are applied to the rapid sand filters with alum addition which may or may not be accompanied by slow mixing for a short period (10 minutes). Slow sand filters can also be used to polish the filtrate from rapid sand filtration plant. Water with excessive hardness needs softening. For removal of dissolved solids, demineralisation by ion-exchange may form a part of the domestic or industrial water treatment units.

9.8.10.1 Aeration

Aeration is necessary to promote the exchange of gases between the water and the atmosphere. In water treatment, aeration is practised for three purposes:

a) To add oxygen to water for imparting freshness e.g:- water from underground sources devoid of or deficient in oxygen.

b) Expulsion of carbon dioxide, hydrogen sulphide and other volatile substances causing taste and odour e.g. water from deeper layers of an impounding reservoir; and

c) To precipitate impurities like iron and manganese in certain forms e.g. water from some underground sources.

Limitations of aeration : The unit operation of aeration requires significant head of water. The water is rendered more corrosive after aeration when the dissolved oxygen content is increased though in certain circumstances it may be otherwise due to removal of aggressive carbon dioxide. The designer should carefully consider the merits of other alternatives because of the additional cost of lifting which may be involved in aeration. For taste and odour removal, aeration is not highly effective but can be used in combination with chlorine or activated carbon to reduce their doses.

Aeration process: Gases are dissolved in or liberated from water until the concentration of the gas in the water has reached its saturation value, The concentration of gases in a liquid generally obeys Henry's law which states that the concentration of each gas in water is directly proportional to the partial pressure (product of the volume per cent of the gas and the total pressure of the atmosphere) or concentration of gas in the atmosphere in contact with water. The saturation concentration of a gas decreases with temperature and dissolved salts in water. Aeration tends to accelerate the gas exchange.

The rate of exchange of a gas is governed by the area of interface between the gas and the liquid, the thickness of the interlayers, time of contact, the partial pressure of the gas in the overlaying atmosphere and the degree of under-saturation or oversaturation of the gas in the liquid.

Types of aerators : There are two main types of aerators depending upon the mechanics of aeration:

a) those forming drops or thin sheets of water exposed to the atmosphere i.e. water is exposed to come in contact with the ambient air; and

b) those forming small bubbles of air which rise in the water i.e, air is brought in contact with the water.

9.8.10.2 Coagulation and Flocculation

The terms 'Coagulation' and 'Flocculation' arc often used indiscriminately to describe the prc,cess of removal of turbidity caused by fine suspensions, colloids and organic colour. 'Coagulation' describes the effect produced by the addition of a chemical to a colloidal dispersion, resulting in particle destabilization. Operationally, this is achieved by the addition of appropriate chemical and rapid intense mixing for obtaining uniform dispersion of the chemical. 'Flocculation' is the second stage of the formation of settleable particles (or floes) from destabilised colloidal sized particles and is achieved by gentle and prolonged mixing.

In modem terminology, this combination of mixing (rapid) and stirring or agitation(slow mixing) that produces aggregation of particles is designated by the single term 'flocculation'. It is a common practice to provide an initial rapid or flash mixing for dispersal of the coagulant or other chemicals into the water followed by slow mixing where growth of floc takes place.

Influencing factors: Both these states in flocculation are greatly influenced by physical and chemical forces such as electrical charges on particles, exchange capacity, particle size and concentration, pH water temperature, electrolyte concentrations and mixing.

Coagulant Dosage : Although there is some relation between turbidity of the raw water and the propet coagulant dosage, the exact quantity can be determined only by trial. Even thus determined, the amount will vary with other factors such as time of mixing and water temperature. The use of the minimum quantity of coagulant determined to be effective in producing good flocculation in any given water, will usually require a fairly long stirring periods varying from 15 to 30 minutes in summer and 30 to 60 minutes in the colder months, as water temperatures approach the freezing point.

Addition of coagulants in excess of the determined minimum quantity may increase bactericidal efficiency. It is, however, usually more economical to use the minimum quantity of coagulant and to depend on disinfectant for bacterial safety. Very finely divided suspended matter is more difficult to coagulate than coarse particles, necessitating a larger quantity of coagulant for a given turbidity. The cation-exchange capacity of the particles of turbidity bears a significant relationship to the success of flocculation.

Characteristics of Water: The characteristics of water especially pH have considerable influence on the satisfactory formation of floes. Some natural waters need certain adjustments in acidity or alkalinity of water.

Optimum pH Zone : There is at least one pH zone for any given water in which good flocculation occurs in the shortest time with a given dose of coagulant, or in a given time with the required minimum dose of coagulant. Coagulation should be carried out within this optimum zone using alkalis and acids for correction of pH wherever necessary. For many waters, usually those which are low in colours and well buffered and having pH in the optimum zone, no adjustment of pH is necessary. However, in waters of low mineral content, or in the presence of interfering organic matter, constant attention is needed for pH adjustment. Failure to operate within the optimum zone, may be a waste of chemicals and may be reflected in the lowered quality of the plant effluent. As a result of studies of the effect of pH on coagulation, it has been found that "the more dilute the water in total dissolved solid and the less the alum added, the narrower becomes the pH zone".

In the case of coagulation with alum, the control over the alkalinity is very important. Not only should the water contain sufficient alkalinity to completely react with the aluminium sulphate but there should be a sufficient residual to ensure that the treated water is not corrosive. A consideration of the reaction involved shows that one molecule of "filter alum"

Coagulant Aids: Coagulant aid is a chemical, which when used along with main coagulant, improves or accelerates the process of coagulation and flocculation by producing quick-forming, dense and rapid-settling flocs. Finely divided clay, fuller's earth, bentonites and activated carbon arc the most commonly used materials as nuclei to floe formation. The particles may become negatively charged making them subject to attraction by the positively charged aluminium ion.

Activated silica, i.e. sodium silicate activated with aluminium sulphate, sulphuric acid, carbon dioxide or chlorine, when applied to water, produces a stable solution having a high negative charge which unites with the positively charged alum or other floe to make it denser and tougher. lt is especially useful for clear water that do not coagulate well with the usual processes. It has a wider range of use in water softening.

9.8.10.2.1 Rapid mixing

Rapid mixing is an operation by which the coagulant is rapidly and uniformly disperse; throughout the volume of water, to create a more or less homogeneous single or multiphaser system. This helps in the formation of microflocs (Perikinetic flocculation) and results u proper utilisation of chemical coagulant preventing localisation of concentration and premature formation of hydroxides which lead to less effective utilisation of the coagulant The chemical coagulant is normally introduced at some point of high turbulence in the water The source of power for rapid mixing to create the desired intense turbulence are gravitational, mechanical and pneumatic.

9.8.10.2.2 Slow Mixing or Stirring

Slow mixing is the hydrodynamic process which results in the formation of large and readily settleable flocs (orthokinetic flocculation) by bringing the finely divided matter into contact with the microflocs formed during rapid mixing. These can be subsequently removed in settling tanks and filters.

Design Parameters : The rate at which flocculation proceeds depends on physical and chemical parameters such as charges on particles, exchange capacity, particle size and concentration, pl-l, water temperature, electrolyte concentration, time of flocculation, size of mixing basin and nature of mixing device. The influence of these and other unknown factors which vary widely for different waters, is not yet fully understood. Information on the behaviour of the water to be treated can be had by examination of nearby plants treating similar water and by laboratory testing using Jar Test.

The physical forces of slow mixing of the coagulant fed water and adhesion, controlled by chemical and electrical forces are responsible to a large extent in influencing the flocculation processes. Slow mixing is meant to bring the particles to collide and then agglomerate. The rate of collision among the particles is dependent upon the number and size of particles in suspension and the intensity of mixing in the mixing chamber.

9.8.10.3 Sedimentation

Sedimentation is the separation from water by gravitational settling of suspended particles that are heavier than water. It is one of the most commonly used unit operation in the flow sheet of conventional water treatment. Sedimentation (settling or clarification) is used to remove readily settling sediments such as sand and silt, coagulated impurities such as colour and turbidity and precipitated impurities such as hardness and iron. When suspended solids are separated from the water by the action of natural forces alone i.e. by gravitation with or without natural aggregation, the operation is called plain sedimentation. Plain sedimentation is usually employed as a preliminary process to reduce heavy sediment loads from highly turbid raw waters prior to subsequent treatment processes such as coagulation/filtration. Finely divided solids and colloidal particles, which cannot be removed by plain

sedimentation within commonly used detention periods of few hours, are converted into settleable flocs by coagulation and subsequently settled in sedimentation tanks.
The factors that influence sedimentation are:

a) Size, shape, density and nature of the particles
b) Viscosity, dcensity and temperature of water;
c) Surface over flow rate;
d) Velocity of flow;
e) Inlet and outlet arrangements,
f) Detention period; and
g) Effective depth of settling zone

9.8.10.3.1 Types of suspended solids

In water treatment practice, three main types of suspended particles are to be separated from water. The first type of suspended particles are finely divided silt, silica and clay having specific gratvities ranging from 2.65 for sand and 1.03 for flocculated mud particles containing 95 percent water. The grain size may be 0.002 mm or more. Alum and iron flocs constitute the second type of suspended solids. These absorb and entrain water and specific gravities for alum and iron floes may range from and 1.34 respectively to as little as 1.002. Floc particles range in size from submicroscopic to 1 mm or more. The third type is the precipitated crystals of calcium carbonate obtained from lime soda softening operations. Their specific gravity is, 2.7 with particle size of 15 to 20 µm. However, due to absorption of water upto 75, the specific gravity reduce to 1.2 and formation of cluster of crystals increases the size to a typical value of 0. 1 mm. Suspended particles may settle either as discrete or flocculant particles. Discrete particles do not change their size, shape or weight during settling.

9.8.10.4 Clariflocculators

Clariflocculators are widely used in the country in water and wastewater treatment. The coagulation and sedimentation processes are effectively incorporated in a single unit in the clariflocculator. All these units consist of 2 or 4 flocculating paddles placed equidistantly. These paddles rotate on their vertical axis. The flocculating paddles may be of rotor-stator type rotating in opposite direction around this vertical axis. The clarification unit outside the flocculation compartment is served by inwardly raking rotating blades. The water mixed with chemicals is fed in the flocculation compartment fitted with paddles rotating at slow speeds.

The flocculated water passes out from the bottom of the flocculation tank to the clarifying zone through a wide opening, the area of the opening being large enough to maintain a very low velocity. Under quiescent conditions in the annular settling zone the floe embedding the suspended particles settle to the bottom and the dear effluent overflows into the peripheral launder.

9.8.10.5 Sludge Removal

Sludge is normally removed under hydrostatic pressure through pipes. The size of the pipe will depend upon the flow and the quantity of suspended matter. It is advisable to provide telescopic sludge discharge arrangement for easy operation and for minimising the wastage of water. For non-mechanised units, pipe diameters of 200 mm or more are recommended. Pipe diameters of 100 to 200 mm are preferred for mechanised units with continuous removal of sludge with hydrostatic head. In circular tanks, where mechanical scrapers are provided, the floor slopes should not be flatter than 1 in 12, to ensure continuous and proper collection of sludge. For manual cleaning, the slope should be about 1 in 10.

The power required for driving the scraping mechanism in a circular tank depends upon the area to be scraped and the design of the scraper. The scraping mechanism is rotated slowly to complete one revolution in about 30 to 40 minutes or preferably the tip velocity of the scraper should be around 0.3 m/min or below. Power requirements are about 0.75 w/ m2, of tank area. Sludge and wash water should be properly disposed of without causing any problems of pollution if discharged into water courses.

For sludge blanket type vertical flow settling tanks, the slopes of the hoppers should not be less than 55° to horizontal to ensure smooth sliding and removal of sludge. lo such tanks special slurry weirs are provided with their crests in level with the top of sludge blanket for continuous bleeding of the excess sludge. Special types of consolidation tanks with a capacity of 30 min are sometimes provided to consolidate the sludge and recover water from it.

9.8.10.6 Filtration

Filtration is a process for separating suspended and colloidal impurities from water by passage through a porous medium or porous media. Filtration, with or without pretreatment, has been employed for treatment of water to effectively remove turbidity (e.g., silt and day), colour, microorganisms, precipitated hardness from chemically softened waters and precipitated iron and manganese from aerated waters. Removal of turbidity is essential not only front the requirement of