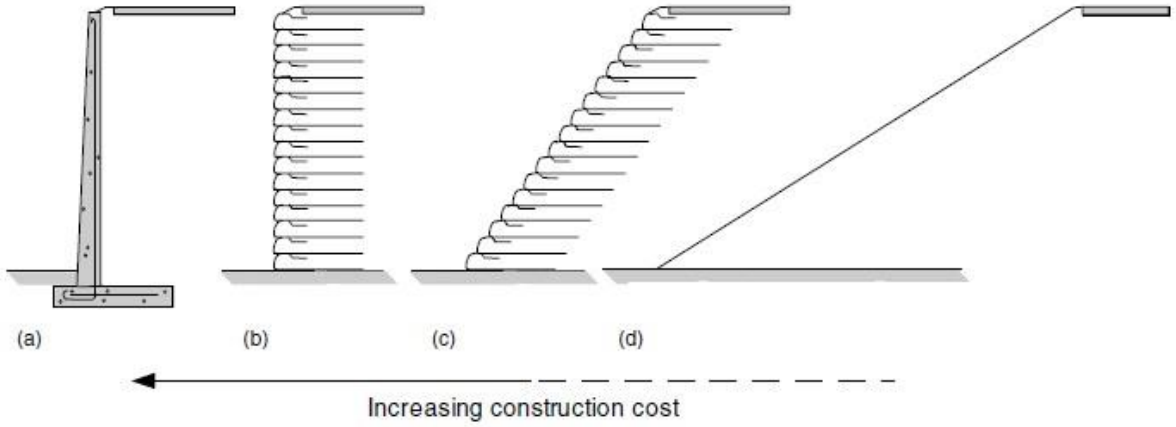
construction of very steep embankment side slopes or a vertical reinforced soil wall. For example, vertical reinforced soil walls have been used to both construct dams for reservoirs and increase the height of existing dams.

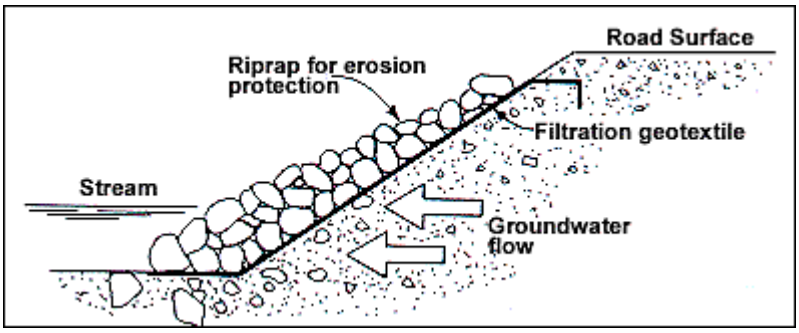


Reinforcement function of geosynthetics used to optimize the design of earth retaining structures(a) concrete retaining wall; (b) reinforced wall; (c) reinforced slope; (d) unreinforced slope.

Geosynthetic products typically used as reinforcement elements are geotextiles and geogrids. Additional products include geocells and fiber reinforcement. Reinforced soil walls generally provide vertical grade separations at a lower cost than traditional concrete walls. Reinforced wall systems involve the use of facing elements such as precast panels, cast-in-place concrete panels, or modular block systems. Alternatively, steepened reinforced slopes (with facing inclination below approximately 70^0) may eliminate the use of facing elements, thus saving material costs and construction time in relation to vertical reinforced walls.
As indicated in above figure, a reinforced soil system generally provides an optimized alternative for the design of earth retaining structures by combining lower cost and decreased right-of-way requirements.

9.4.6.2.3 Filtration Function

The filtration function involves movement of liquid through the geosynthetic and, at the same time, retention of soil on its upstream side. Geotextiles are the product generally used for the function of filtration. Applications include geotextile filters for trench drains, blanket drains, interceptor drains, structural drains, toe drains in dams, filters for hard armor (e.g., rip-rap, gabions, fabric-form) erosion control systems, silt fences, and silt curtains. Both adequate hydraulic conductivity (provided by a geotextile with a relatively porous structure) and adequate soil retention (provided by a geotextile with a relatively tight structure) should be offered by the selected product. In addition, considerations should be made regarding the long-termsoil-to-geotextile flow compatibility such that the flow through the geotextile will not be excessively reduced by clogging during the lifetime of the system.



The geosynthetic-to-soil system should then achieve an equilibrium that allows for adequate liquid flow with limited soil loss across the geotextile throughout a service lifetime compatible with the application under consideration. Filtration concepts are well established in the design of soil filters, and similar concepts are used in the design of geotextile filters.

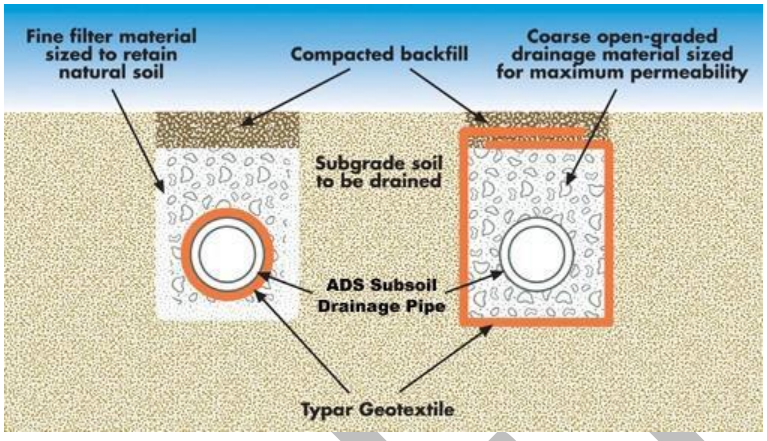
As the flow of liquid through the geotextile increases, the geotextile voids should be larger. However, large geotextile voids can lead to an unacceptable situation called soil piping, in which the soil particles are continuously carried through the geotextile, leaving large soil voids behind. The liquid velocity then increases, which accelerates the process and may lead to the collapse of the soil structure. This process can be prevented by selecting a geotextile with voids small enough to retain the soil on the upstream side of the fabric. It is the coarser soil fraction that must be initially retained. The coarser-sized particles eventually create a filter "bridge," which in turn retains the finer-sized particles, building up a stable upstream soil structure

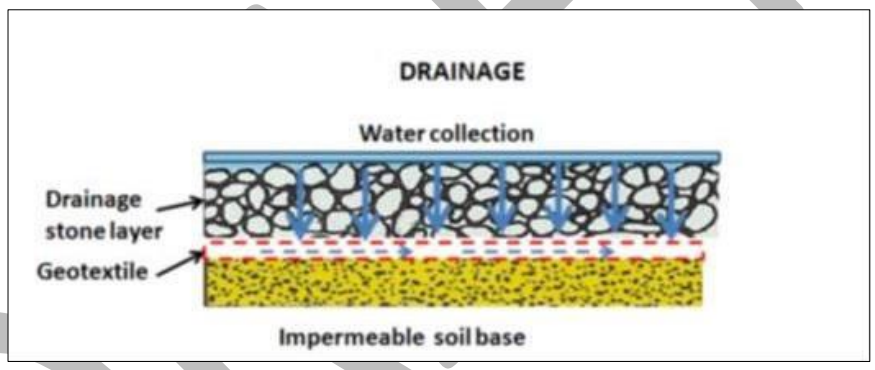
Some of the soil particles will rest on or embed them within the geotextile structure, and will cause a reduction in the hydraulic conductivity or permittivity of the geotextile. Although some partial clogging should be expected, the designer should ensure that the geotextile will not become excessively clogged, that is, that the flow of liquid will not be decreased to a point in which the system will not adequately perform its function. Thus, the geotextile voids should be large enough to allow the finer soil particles to pass. Clogging potential creates a special problem when geotextiles are used to wrap pipes due to the restricted area available for flow (i.e., a portion of the geotextile is covered by the pipe walls). Any clogging will significantly reduce the flow into the pipe. Either the flow capacity of the geotextile should be increased proportionally to the covered area (i.e., the total pipe area divided by geotextile area available for flow, which is usually the area of the holes in the pipe) or the geotextile should only be used to wrap gravel placed around the pipe. Design guidelines are available for clogging evaluation of non-critical, non-severe cases. but laboratory testing is strongly recommended in important applications.

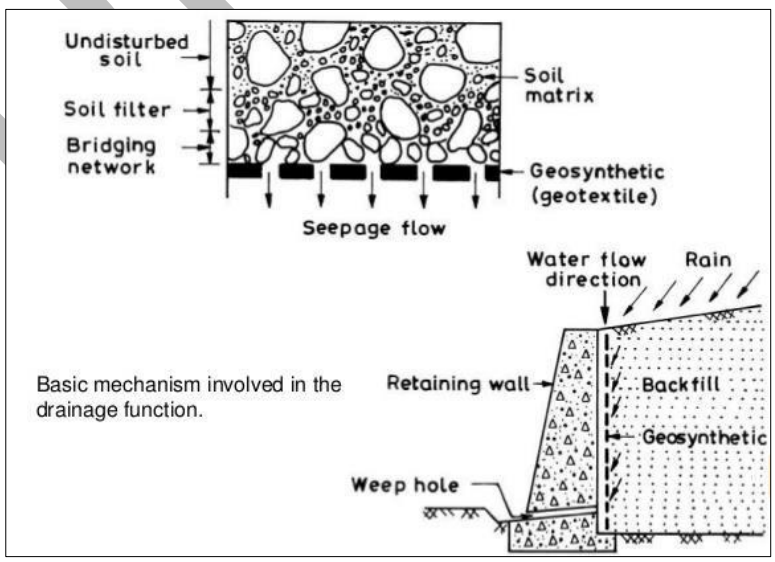
9.4.6.2.4 Drainage Function

Geosynthetics provide a drainage function by transmitting liquid within the plane of their structure. The geosynthetics generally used for drainage purposes are geotextiles and

geocomposites. The drainage function of geosynthetics allows for adequate liquid flow with limited soil loss within the plane of the geotextile over a service lifetime compatible with the application under consideration. Thick, needle-punched nonwoven geotextiles have considerable void space in their structure and can convey liquid in their plane (on the order of 0.01 to 0.1 l/sec/m width of geotextile). Geocomposite drains can transmit one to two orders of magnitude more liquid than geotextiles. Proper design should dictate what type of geosynthetic drainage material is necessary.





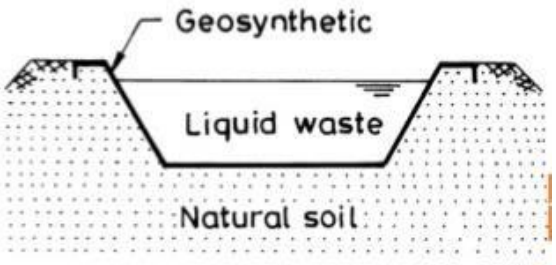


Basic mechanism involved in the drainage function.

Calculating the thickness of the liquid in or above a liquid collection layer is an important design step because one of the design criteria for a liquid collection layer is that the maximum thickness of the liquid collection layer must be less than an allowable thickness. The thickness of liquid in a liquid collection layer depends on the rate of liquid supply. A typical case of liquid supply is that of liquid impinging onto the liquid collection layer. Two examples of liquid collection layers with such a type of liquid supply can be found in landfills: (1) the drainage layer of the cover system, where the liquid that impinges onto the liquid collection layer is the precipitation water that has percolated through the soil layer overlying the drainage layer; and (2) the leachate collection layer, where the liquid that impinges onto the leachate collection layer is the leachate that has percolated through the waste and through the protective soil layer overlying the leachate collection layer.

9.4.6.2.5 Barrier Function

The barrier function can be performed by geosynthetic products that have adequately low hydraulic conductivity as to provide containment to liquid or vapor. The barrier function may be provided by several types of geosynthetics, namely, geomembranes and geosynthetic clay liners (GCLs). Other geosynthetic products also used as infiltration barriers include membrane-encapsulated soil layers (MESLs) used with paved or unpaved road construction, asphalt-saturated geotextiles used in the prevention of bituminous pavement crack reflection problems and geofoam used for insulation against moisture and extreme temperatures.



Geosynthetic barriers are commonly used as liner for surface impoundments storing hazardous and nonhazardous liquids, as covers above the liquid surface of storage reservoirs, and as liner for canals used to convey water or chemicals. Geosynthetic barriers are also used as secondary containment for underground storage tanks, and in applications related to dams and tunnels. Of particular relevance for groundwater applications is the use of geosynthetic barriers for seepage control (HDPE vertical barrier systems).

A common application of geosynthetics as infiltration barriers is base and cover liners for landfills. In landfill applications, infiltration barriers are typically used instead of (or in addition to) low-hydraulic conductivity soils. Base liners are placed below the waste to prevent liquids from the landfill (leachate) contaminating the underlying ground and the groundwater. Geosynthetic cover liner systems are placed above the final waste

configuration to keep precipitation water from entering the waste and generating leachate. If a building or other structure is constructed on a landfill, a geosynthetic barrier may be placed under the building foundation to provide a barrier for vapors such as landfill gas.

9.4.6.2.6 Protection Function

Geosynthetics (mainly geotextiles) can be used to provide stress relief and protect other materials such as geosynthetics (mainly geomembranes) against damage. A common example is the use of geotextiles to provide protection against puncture of geomembranes in waste and liquid containment systems. Adequate mechanical protection must be provided to resist both short-term equipment loads and long-term loads imparted by the waste. Experience has shown that geotextiles can play an important role in the successful installation and long-term performance of geomembranes by acting as a cushion to prevent puncture damage of the geomembrane.

In the case of landfill base liners, geotextiles can be placed (1) below the geomembrane to resist puncture and wear due to abrasion caused by sharp-edged rocks in the subgrade, and (2) above the geomembrane to resist puncture caused either by the drainage aggregate or direct contact with waste materials. In the case of landfill cover liners, geotextiles can be placed below the geomembrane to reduce risk of damage by sharp objects in the landfill and above the geomembrane to prevent damage during placement of drainage aggregate or cover soil. Key characteristics for the geotextile cushions are polymer type, mass density, method of manufacture, and construction survivability. The selection process of a geotextile that fulfills a protective function of a geomembrane involves the following three steps:

(1) selection of polymer type and method of manufacture;

(2) evaluation of the geotextile's capacity to provide puncture protection for the geomembrane; and

(3) evaluation of construction survivability.

9.4.6.3 Geosynthetic Applications in Landfill Design

The multiple uses of geosynthetics in the design of modern municipal solid waste landfills is a good illustration of an application in which different geosynthetics are used to perform all the functions discussed above. Virtually all the different types of geosynthetics have been used in the design of both base and cover liner systems of landfill facilities. The extensive use of geosynthetics in modern landfills has been triggered by the economical and technical advantages that geosynthetics offer in relation to traditional liner systems. A geomembrane infiltration barrier and geocomposite sheet drain collection layers of a few millimeters in thickness can provide equivalent performance as a soil infiltration barrier with a gravel collection layer and graded granular filter layer of up to several meters in thickness.

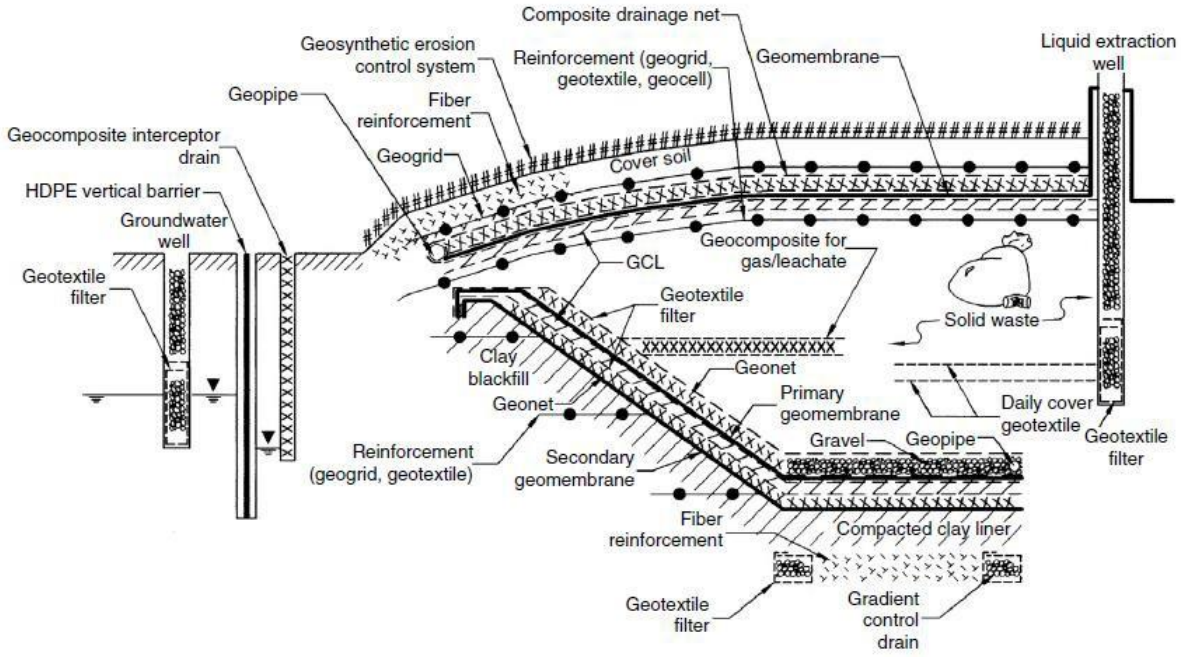
Landfill base liners are placed below the waste to minimize the release of liquids from the waste (i.e., leachate). Leachate is the main source of contamination of the soil underlying the landfill and, most importantly, the groundwater. Landfill cover liners are placed above the final waste configuration to prevent water, usually from rain or snow, from percolating into the waste and producing leachate. Waste containment systems employ geosynthetics to varying degrees. The figure illustrates the extensive multiple uses of geosynthetics in both the cover and the base liner systems of a modern landfill facility.

The base liner system is a double composite liner system. Double composite liner systems are used in some instances for containment of municipal solid waste and are frequently used for landfills designed to contain hazardous waste. The base liner system shown in this figure includes a geomembrane/GCL composite as the primary liner system and a geomembrane/compacted clay liner composite as the secondary system. The leak detection system, located between the primary and secondary liners, is a geotextile/geonet composite. The leachate collection system overlying the primary liner on the bottom of the liner system consists of gravel with a network of perforated pipes. A geotextile protection layer beneath the gravel provides a cushion to protect the primary geomembrane from puncture by stones in the overlying gravel. The leachate collection system overlying the primary liner on the side slopes of the liner system is a geocomposite sheet drain (geotextile/geonet composite) merging into the gravel on the base. A geotextile filter covers the entire footprint of the landfill and prevents clogging of the leachate collection and removal system. The groundwater level may be controlled at the bottom of the landfill by gradient control drains built using geotextile filters. Different types of geosynthetics (e.g., geogrids, geotextiles, fibers) can be selected for stabilization of the foundation soils.

The cover system of the landfill contains a composite geomembrane/GCL barrier layer. The drainage layer overlying the geomembrane is a geocomposite sheet drain (composite geotextile/geonet). In addition, the soil cover system may include geogrid, geotextile, or geocell reinforcements below the infiltration barrier system. This layer of reinforcements may be used to minimize the strains that could be induced in the barrier layers by differential settlements of the refuse or by a future vertical expansion of the landfill. In addition, the cover system could include a geogrid or geotextile reinforcement above the infiltration barrier to provide stability to the vegetative cover soil. Fiber reinforcement may also be used for stabilization of the steep portion of the vegetative cover soil. A geocomposite erosion control system above the vegetative cover soil is indicated in the figure and provides protection against sheet and gully erosion.

The figure also illustrates the use of geosynthetics within the waste mass, which are used to facilitate waste placement during landfilling. Specifically, the figure illustrates the use of geotextiles as daily cover layers and of geocomposites within the waste mass for collection of gas and leachate. Geotextile filters are also extensively used for leachate collection and detection blanket drains and around the gravel in leachate collection

trenches at the base of the landfill. Geosynthetics can also be used as part of the groundwater and leachate collection well system. The use of geotextiles as filters in groundwater and leachate extraction wells is also illustrated in the figure. Finally, the figure shows the use of a HDPE vertical barrier system and a geocomposite interceptor drain along the perimeter of the landfill facility. Although not all of the components shown in the figure would normally be needed at any one landfill facility, the figure illustrates the many geosynthetic applications that can be considered in landfill design.



Multiple use of geosynthetics in landfill design

9.4.6.4 Geosynthetic Applications in Rehabilitation of Flexible Pavements

Since the 1970s the concept of geotextile reinforcement of surfacing seals has been used successfully internationally with hundreds of millions of square metres installed worldwide. Pavement instability generally occurs due to heavy loading, water ingress, inadequate drainage and time.

Pavement rehabilitation strategies with flexible overlays require drainage improvements such as sub soil drains, surface sealing, structural improvements with full depth asphalt, or sub-grade reinforcement and sufficient structural overlay thickness to adequately support the design load. Increased traffic volumes and loadings induce reflective cracking within overlays that are under designed, or in overlays placed on unsuitable base material.

Without adequate maintenance paved roads rapidly deteriorate. The escalating cost of paved road rehabilitation highlights the need for cost effective solutions to this problem. In general, rehabilitation of paved roads can be divided into:

• Those requiring minor strengthening or surface improvements
• Those requiring substantial strengthening and waterproofing

These categories may overlap with a single procedure able to both water proof and strengthen the pavement, this being achieved by incorporating a reinforcing and waterproofing interlayer in the form of a paving fabric, to provide protection of the unbound granular road pavement beneath.

Many pavements that are considered to be structurally sound after the construction of a new overlay, prematurely exhibit a cracking pattern similar to that which existed in the underlying pavement. Reflective cracks destroy surface continuity, decrease structural strength, and allow water to enter the pavement layers. Thus, the problems that weakened the old pavement are extended upwards into the new overlay. Cracking in new overlay surfaces is due to the inability of the overlay to withstand shear and tensile stresses created by movements of the underlying pavement due to either traffic loading (tyre pressure) or by moisture ingress and thermal effects(expansion and contraction).

Fatigue associated cracking occurs when shear and bending forces due to heavy traffic loading create stresses that exceed the fracture strength of the asphalt overlay. This is a structural stability problem. The function of bitumen impregnated paving fabric is to prevent the penetration of surface water and oxygen into the road pavement. Waterproofing prevents the ingress of water, exacerbation of environmental factors and consequent pumping of the structural pavement layers under traffic loads.

Despite surface cracking in wearing courses, paving fabric impregnated with bitumen maintains its waterproofing properties. The penetration of oxygen can result in further ageing of the existing base course, with subsequent cracking occurring due to brittleness. The infiltration of moisture weakens the shear strength of base layers, which with the combination of time and traffic and loss of fines due to pumping, leads to surface deformation and loss of bonding of the surface seal coat.

Paving fabrics utilise the tensile strength of the geotextile and the elastic recovery properties of bitumen to bridge cracks and inhibit reflective cracking, this in turn ensures a waterproof surface is protecting the structural integrity of road pavement.

Paving fabrics has been proven to provide the following benefits:

- Prevent the ingress of water by providing a more flexible, homogeneous waterproof layer
- Stabilising pavement moisture content and curbing loss of fines due to pumping
- Bridging shrinkage cracks retarding their propagation to the surface.
- Acts as a stress absorbing interlayer allowing larger deflections in the order of 2–3 mm
- Reinforces and prolongs fatigue life when structural layers are weak/susceptible to rutting
- Cost effective alternative to expensive structural layer replacement
- Resistance to shrinkage from hot bitumen (polyester melting point; 260ºC)
- Nonwoven needle punched construction provides bitumen reservoir
- Robustness retards stone penetration and settlement
- Prolongs surfacing life span
- Provides surfacing foundation for future seals

9.4.6.4.1 Paving Fabric

The geotextile should be rolled out slowly (using a fabric applicator) immediately after spraying the tack coat and as close behind the sprayer as practicable. The dispensing of fabric should be controlled by adjusting the rubber spreader bar to match road profile to ensure wrinkle free application. All wrinkles smaller than 5mm can be dispersed and smoothed by brooming. The dispensing rate of fabric can be increased with the use of experienced personnel. Adjoining or adjacent rolls should be overlapped by a minimum of 100 mm, with the overlapped join receiving additional binder. Placement of fabrics along straight alignments is straight forward; however caution should be exercised on curves of less than 100m radius due to creasing of the fabric. Where the paving fabric is to be placed around a curve, it should be 'cut and butted' at regular intervals along the inner side of the curve (to minimise overlap thickness). Resulting overlaps should be hand sprayed with additional bitumen so that the geotextile is fully saturated. Wrinkles larger than 25 mm should be treated in the same manner.

For all reseal applications, the fabric should be applied over the full width of the pavement. Paving fabric should be rolled prior to the asphalt application. Where rolling and/or construction traffic causes the tack coat to bleed up through the fabric, a blinding coat of 7 mm aggregate may be applied in advance of the seal coat to prevent pick-up. Rollers or vehicles should not stand on the laid fabric as this may lead to a build-up of binder on the surface of the fabric. Trafficking of the paving fabric should be limited to a minimum, with aggregate seal coatings or asphalt surfacing placed as soon as possible.

9.4.6.4.2 Asphalt Application

Asphalt surfacing should be laid directly over paving fabric, residual heat transferred to the tack coat reactivates and draws bitumen into the fabric interlayer. Rolling of asphalt can proceed as normal and in accordance with specifications. Asphalt should be applied to a

minimum thickness of 40mm dense and open grades, with 20mm the accepted thickness in ultra-thin applications.

9.4.6.5 Geosynthetic Applications in preventing Soil Erosion

Geotextiles are highly effective in controlling soil erosion due to their salient properties (e.g.per cent cover, geotextile-induced roughness, water holding capacity)which mimic that of vegetation in terms of its erosion-control ability (e.g. per cent cover of soil, water retention, roughness imparted to flow).The performance of these products can be evaluated rapidly using simple and cost-effective methods available in the literature. Studies have shown that vegetation can reduce erosion rates by up to 90%, however, establishing effective vegetation cover is difficult and may take years. Exposed soils that are highly erodible are susceptible to high erosion risk; therefore the application of geotextiles is imperative in this regard. Modification of the local microclimate by geotextiles also enhances the establishment and growth of vegetation.

Soil erosion is a complex phenomenon and a major environmental problem in many regions of the world, affecting both agricultural and non-agricultural land, such as steep slopes used in road construction and embankments. Large soil erosion rates arise when there is large imbalance between the rate of soil loss and rate of soil formation, in other words when the rate of soil loss is greater than the natural rate at which soil is formed. Natural rates of soil formation are very slow. These can be minimized or even avoided by adopting best management practices (BMPs) in erosion control which target factors responsible for accelerating erosion rates.

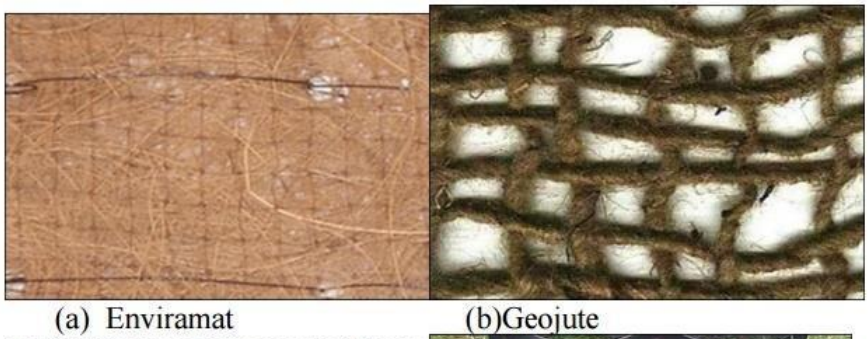
Geosynthetics have 6 primary functions, namely: filtration, drainage, separation, reinforcement, fluid barrier, and protection. Geotextiles are used as filters to prevent soils from migrating into riprap and other armor materials, while maintaining water flow, in coastal and stream bank protection systems to prevent soil erosion. Geotextiles or geocomposites can be used as drainage media by allowing water to drain from or through soils of low permeability. Geotextiles are used as separators to prevent road base materials from penetrating into the underlying soft subgrade and maintain the design thickness and roadway integrity. Geotextiles and geogrids can also be used as reinforcement to add tensile strength to a soil matrix and thereby providing a more competent structural material.

In addition to the primary function, geosynthetics usually perform one or more secondary functions. The process of erosion on bare soil begins typically with wind blowing or water falling on unprotected slopes. Detached soil particles then collide and displace more soil particles which move downslope, thus increasing the erosive force of the wind or water. Vegetation provides good soil cover to protect soil from eroding by intercepting rainfall and reducing the power and impact of erosive rain drops, as well as decreasing the volume of water flowing over the surface of the soil. Where vegetation establishment is slow or difficult, the use of simulated vegetation in the form of geotextiles is essential in

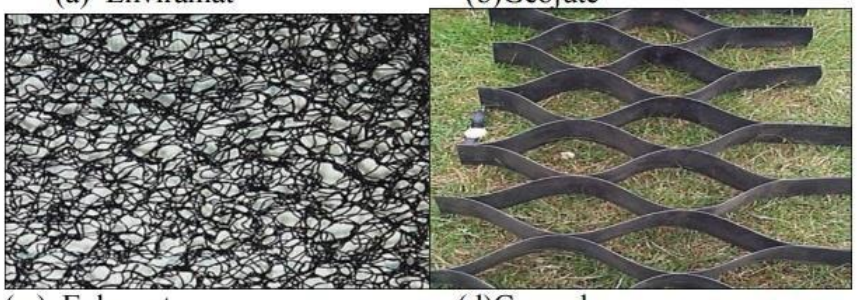
controlling erosion pending the full re-establishment of vegetation. Geotextiles or erosion control blankets can be used to control runoff and erosion from eroding slopes and aid the establishment of vegetation. Erosion control materials (in the form of geotextiles) aim to mimic vegetation and provide the necessary ground cover in the absence of natural vegetation, since in any programme of soil conservation; ground cover is an essential element.

Erosion control geotextiles are made from both natural and synthetic materials in different shapes, sizes and physical characteristics. These products are classified into four groups namely:Bionets, Biomats, Geocells and Geomats. The figures below give examples for each classification as used in this study.

Biomats (for example Enviramat), made of fibres from natural materials are held together by two lightweight mesh layers made either from natural or synthetic materials. Bionets (for example Geojute) are made from natural fibres of jute or coir yarns spun into woven meshes. Geomats and Geocells are both three dimensional products made from synthetic materials, but differ in their structure. Geocells are honey-comb structures, manufactured by gluing together nonwoven geotextile strips or by the extrusion of high density polyethylene. Geomats are also non-woven but made of filaments or fibres of about 20 mm thick, held between lightweight grids or manufactured as randomly distributed filament or fibre mats.

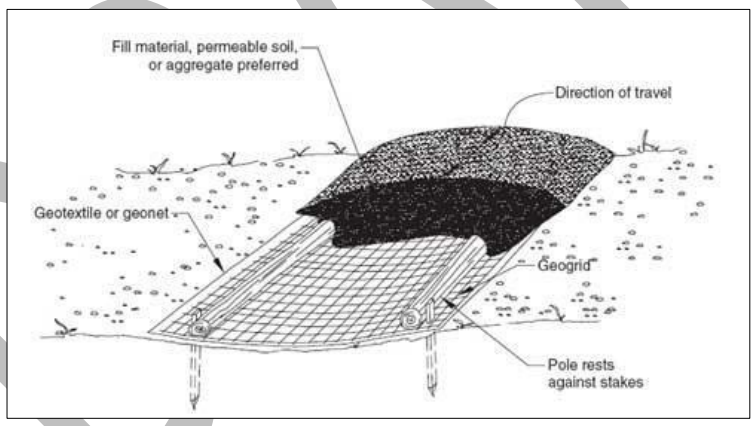


(a) Enviramat (b)Geojute



(c) Enkamat (d)Geoweb

Geojute is made from a natural degradable product. Enviramat is a combination of natural and synthetic products. Geocell and Enkamat are made from purely synthetic products that are non-degradable.


Fill material, permeable soil, or aggregate preferred
Direction of travel
Geotextile or geonet
Geogrid
Pole rests against stakes

10. MEASUREMENTS AND PAYMENTS

Every public work undertaken by the LSGIs shall be executed under the direct control and supervision of the Assistant Engineer or through Overseer or other technical employees empowered by Assistant Executive Engineer. The progress and quality of the work shall be inspected and test checked by them directly and they are either jointly or separately responsible for the satisfactory completion of such work. The Assistant Engineer shall inspect and ensure the quality of goods and materials used for the execution of work.

If TS to any work has been accorded by an Engineer of a Government department or another Panchayat or Municipality the Assistant Engineer shall inspect the quality and progress of that work and eligible traveling allowance shall be given to the Engineer from the concerned LSGIs.

All below mentioned body shall have the right to inspect the execution of public work at any time.

- Any elected member of the LSGI
- Social Audit Committee appointed by the LSGI
- The sub committee appointed by the Grama/Ward Sabha
- Any beneficiary committee connected with the public work
- The Inspecting Officers deputed by the LSGI or Government for this purpose

Payment for all the works shall be based on measurements recorded at various stages of the work by the Overseer/ Assistant Engineer as the case may be and duly checked by superior officers. The contractor or his authorised agent shall be present at the time of recording of each set of measurements and shall sign the measurement book and/or level field book in token of his acceptance. If the contractor fails to be present at the time of taking measurements either in person or through his authorised agent or fails to accept the measurements or file objections to the measurements with reasons before check measurement, the measurements taken by the Engineer / Overseer shall be deemed to be correct subject to check measurements.

The measurement book in the form given in Appendix 2100E1 is the original record of actual measurements. Except for quantities of work paid on level basis, all measurements are recorded in the measurement book. Works for which the Assistant engineer has accorded TS the Overseer shall record the measurements. The measurements shall be checked by an officer higher in rank to the officer who has

recorded the measurement, but not by an officer below the rank of an Assistant Engineer. If an Assistant Engineer holds full additional charge of a Sub division, the Executive Engineer shall nominate another officer under his Division, not below the rank of an Assistant Executive Engineer to check the measurements recorded by the Assistant Engineer, who holds additional charge. All measurements shall be recorded directly in the

measurement book or in the field book and the description shall be lucid to enable easy identification and check. All the Measurement books and Field books belonging to each Section/ Subdivision/ Division shall be numbered serially and pages of each book shall be machine numbered and a register of them shall be maintained in K.P.W. Form 84 in the Sub Division/Division Office, showing the serial number of each book, names of sections to which issued, the date of issue and date of return so that its eventual return to the correspondingoffice may be watched. ~~The completed measurement books shall be sent to the Division Office for final record.~~

The above procedure shall be adopted for the maintenance of Standard Measurement books also. A movement register shall be maintained in the Section, Sub Division and Division offices for noting the receipt and return of measurement books and LF books.

As a general rule, earth work shall be measured by level section where the total quantity exceeds 300 cum. and where the site conditions are such that level sections, will give correct indications of the quantity of work involved. If the site conditions are not suitable for working out the quantities through level sections, orders of the officer who accorded technical sanction shall be obtained for taking measurements otherwise, than by level sections in cases where the total quantity exceeds 300 cum. Where level sections are taken for computing the quantity of earth work the initial levels and final levels shall be entered in properly numbered field books (Appendix 2100E2) by the concerned Assistant Engineer. Computerized calculation methods shall be utilized for earthwork computation wherever available. The agreement authority shall approve the proposals for earthwork in the initial level sheets. The method of measurement as indicated in the standard data book in metric system shall be followed. Where there is no specific direction in this matter in the standard data book, the Indian standard method of measurement for building work shall be followed (I.S. 1200 as amended from time to time).

Electronics device shall be utilized for earthwork computation as far as possible wherever available in which case computerized print out duly signed by the contractor and verified by the Assistant Engineer checked by the Assistant Executive Engineer shall be treated as records.

If an item of work is measured in incomplete stages, up to date measurements shall be recorded each time and the quantity for payment at any stage shall be worked out by deducting the total quantity already paid from the up to date quantity measured at that time. In making interim payments, care shall be taken to see that no over payments are made. For this purpose, if tape measurements are taken for earthwork, requiring level calculation a deduction of not less than 10 percent shall be made in the quantity assessed for payment.

In case of works, which will be covered up, measurements shall be taken prior to such covering up and got verified checked and accepted even though a bill may not be immediately due. In case of works like demolition of an existing structure etc., which cannot be measured after execution of the work, pre measurement of the work to be done shall be taken and got check measured before the commencement of the work.

Overwriting is not permitted in MBooks. In case of errors, the entry shall be scored off and new entry shall be made along with the initials of the measuring authority.As far as possible single MB shall be used for a single work. Ie, more than 2 works shall not be recorded in a single MB.

In the case of maintenance of buildings, standard MB (base MB) can be used for recording recurring measurements.

In the case of temporary works to be demolished after the function, the implementing officer shall take photos of the works with the officials infront of the structure which shall be included in the file.

The contractor shall jointly be responsible for the correctness and completeness of the measurements with the verifying and checking officers.The items of test check by Executive Engineer should invariably include R.C.C./Reinforcement/other high value item which will also ensure structural safety.

Interim bills may be paid at suitable intervals according to the stage of execution of the work subject to availability of funds. Assistant Engineer/Contractor shall prepare the bill on the basis of measurements taken by him and deal with it after getting the bill accepted by the contractor. After verification and check measurement, the Assistant Executive Engineer or Executive Engineer will pass the bill and effect payments as per powers delegated to them.

Payment for deposit works shall be made by the concerned officers as per powers delegated for passing and payments of bills.

10.1 MEASUREMENT OF WORKS

The Assistant Engineer / Overseer / Contractor shall take measurements in time so as to get the same checked and bills passed as per terms of contract. The contractor may also furnish measurements, in which case these shall be checked by Assistant Engineer and further checked by Assistant Executive Engineer. Any corrections shall be brought to the notice of the contractor, to be effected accordingly.

10.1.1 Recording Measurement of Work

The Assistant Engineers / Overseers are given powers to record measurements of works subject to certain rules & regulations. It shall be clearly borne in mind that these powers are given only to accept sound work.

i. Measurements shall be recorded date wise. The measurements shall be signed with name & designation. If any item is going to be covered by another item so as to be inaccessible for subsequent measurement, it shall be finally measured and measurements got checked 100 % before covering.
ii. The measurements for works as per the specifications shall only be recorded. The recording of measurements in the Measurement Book means accepting the work. Therefore any inferior work below acceptance norms shall not be recorded.
iii. The signature & designation with date of the checking/ cross checking officer shall be invariably got recorded, however the responsibility of getting the measurements checked lies with the officer / contractor who records the measurements.
iv. In the case of CC/RCC works measurements shall be made only after curing period/ availability of test results
v. While recording measurements for composite items, i.e. single items in the tender which includes many sub items; Viz.
    - Composite masonry of stone & brick.
    - Item of door, which includes frames, panels, fixtures etc.
    - Items of w/c. containing the pan, flushing cistern, with connections, valves P/S trap or urinals stands consisting of urinal pot, connecting water supply pipe, flushing tank with overflow, disposal pipe etc.

Recording of the measurements signifies that all the sub items are completed as per the specification. However, if it is necessary to release payments for such item, then proportionate payments for work done & measured shall be recorded.

10.1.2 Recording False and Incorrect Measurement or Advance Measurement - Punishment for:

The basic document for effecting payment is the Measurement Book and all payments to the contractors are governed by the measurements recorded there us & bill recorded. If false, incorrect, or excess measurements are recorded, it leads to payment not due and Govt. money is misappropriated. The punishment for such act/lapse is severe and the incumbent shall be proceeded against as per rules.

10.1.3 Check Measurement:

The measurements of aggregate collected at road side and the steel for RCC slab work are to be got checked by Assistant Executive Engineer before spreading/concreting

to ensure that complete aggregate is collected and steel bars as per design are used. This principle shall be followed thoroughly.

Measurement book and Field Book shall be only purchased from govt. authorized agencies. No M.Book/ Field Book purchased from open market shall be used for recording measurements.

Measurement of works of estimate not exceeding rupees fifty thousand shall be done by an Overseer and those exceeding rupees fifty thousand shall be done by an Assistant Engineer. Check measurement shall be done by the Assistant Engineer in the case of measurement noted by an Overseer and by Assistant Executive Engineer in the case of measurement noted by an Assistant Engineer.As far as possible 5% of the works with estimate PAC betweenRs5 Lakhs to 50 lakhs and 10% of works having PAC more than 50 lakhs shall be test checked by an Executive Engineer.

No partial payment or final payment shall be allowed to any contractor or BCwithout ensuring the quality of work or ratebased on the measurements recorded in the measurement book, as the case may be, in respect of any work. The Contractor or Executive Committee Convener of the BC, and the Head of the Institutions in the AA as the case may be shall inform in writing the AE the fact of completion of the work and the measurement of work and check measurement shall be completed within one week of receipt of such information and after that final payment of the work shall be made within two weeksto the extent possible. If any contractor/ BC executes the work in a non-measurable or non-quantifiable manner or is unsatisfactory then no payment shall be made. Check measurement of the work is not to verify the quantity alone, but the quality also as per specification. So the check measuring authority shall make sure that quality is also adhered to in the work.

MEASUREMENT BOOK **(As per para 2109)**

Circle/Division
Subdivision/Section
Measurement Book No

Notes

1. The measurement book is the basis of all accounts of quantities, whether for work done by piece work for by contract, or of materials received for specific works which have to be measured, and should be so kept that the transaction may be readily traceable into the accounts.

2. (a) Measurements shall invariably and neatly be recorded direct in the measurement books at site, and not copied into them later on at leisure, from measurement sheets.

(b) Erasures and over writings in the measurement books are strictly prohibited and will be seriously noticed. If mistakes are made, they should be corrected by neatly scoring off the incorrect entries and inserting the correct once between the lines. Dated initials of the recording officer shall be insisted on, on each page of the measurement book in the case

of original entries, and initials, in the case of each and every correction. In the case of contract work, the contractor's signature should be taken in the measurement book in token of the contractor's acceptance of the measurements recorded either at the time of

measurement or in any case, before payment, to avoid complaints of omissions, incorrectness, etc.

3. (a) No officer below the rank of a 2nd Grade Overseer in responsible charge of a work, is empowered to measure a work and make either an entry or a correction in the measurement books in respect of particulars, measurements or rails. Measurements relating to all supplies and services shall also be recorded by the 1st grade overseer/ 2nd grade overseer. No member of the clerical staff except the account section responsible for the preparation and checking of the bills, is allowed to make arithmetical corrections. Such corrections noticed in the preparation of bills, shall be invariably attested by the bill preparing officer, while those noticed during audits shall be attested by the Passing Officer. The store-keepers in charge of departmental stores may be permitted to record supply bills, and conveyance charges of stores moved to and for, in measurement books issued to them.

(b) The theoretical issue of departmental materials and receipts and issues of other items based on measurements against each item in a bill shall be noted in remark column by a technical subordinate while preparing a work bill and during audit.

(c) The officer to whom a measurement book is issued shall be its custodian until it is finally returned to the Sub Division office for record after completion or transferred in the meantime by official transfer, to his successor on relief. Except when the book is sent officially to other offices for preparation, audit and payment of bills, book must always be kept in the personal custody of an officer not below the rank of a Lower Division Clerk.

4. (a) For easy identification and check, the descriptions of the locality and items must be lucid; and the measurements shall be recorded systematically item by item of the sanctioned estimates noting also the respective item numbers. The total of the quantities under the different items as entered in the quantity column of the measurement book should be in the case of each bill, an up-to-date quantity and not a 'since last' quantity.

(b) For large works separate measurement books shall be kept by the measuring officer for each individual work or contract, or if found necessary or convenient separate books may be set apart for different classes of works or subheads of works, in which himself and the checking officer will have with them at the time of any measurements or check measurement all the previous measurement in one and the same book for easy reference and guidance. Promiscuous recording of measurements of one and the same work indiscriminately in different measurement books, is prohibited and if resorted to will be seriously noticed.

5. In the case of extra items or extra rates, the orders sanctioning its execution or provision should invariably be quoted in the measurement books and bills before the auditing wing

passes such claims for payment. The measuring officer may however record extra items if any in the measurement book if he is satisfied that they are covered at least by the written orders of the inspecting officers in the workspot order book though not at the time of measurement regularised by the formal sanction of the competent authority. The audit

wing will all the same defer passing of such items until formal sanction is secured. Such items will however be entered in the quantity columns but the rates and amounts will be noted therein only on receipt of formal sanction from sanction of competent authority to such items. This stipulation is precautionary to ensure that the measurement and check measurement of extra items which it may be difficult or impossible to measure at a later stage of work should not be lost sight of , while closing or checking interim bills or at the time of final payment.

6. The measuring officer shall be responsible for closing the bills in the measurement books and taking care to enter therein correctly, all references previous measurements and all receipts and issues of materials utodate and effect all recoveries, they shall be observed as an orthodox rule, as the measuring officer is primarily and wholly responsible for all entries made by him in the measurement book and for the bills as corrected and finally passed by on for audit on the basis of those measurements. In fact the bill will be an exact copy of the closing abstract as made out by the measuring officer, in the measurement book.

7. From the measurement book all quantities should be clearly traceable to the documents on which payments are made reference to voucher in which the quantities are entered for payment as well as date of entry should be given by endorsement upon the original entries in the measurement book. No contract certificate or bill should be signed without crossing out the connected entry in the measurement book and the document on which the payment is made should invariably bear a reference number and page of the book in which detailed measurements are recorded.

8. The measurement books are thus one of the most important initial records relating to the execution and payment of works, they should be carefully checked by Divisional/ Sub divisional officer to see that they are kept as per complete records of each kind of work done for which certificates have been granted. The eventual return of all books to the division office for record should be insisted upon.

9. Name of officer and check measuring officer shall be noted below the signature.

Name of Work: Date of measurement

Name of contractor_____ Agreement No.

Reference to estimate		Particulars	1	2	3	4	5	6		7		8			9		Remarks
Sub head	Item no		Measurement up-to-date					Rate		Total value to date		Deduct previous measurement			Since last measurement		
			No	L	B	D	Contents or area	Rs	p	Rs	p	book	Page	quantity	Quantity col (58)	Value at rate in col. 6	

Appendix 2100E2 Level Field Book (As para 2109)

Rules to be observed in leveling and survey operations

1. In all surveys the survey line should be shown with a fine red line that it may be at once apparent with what degree of accuracy a plan has been made.

2. it is also directed that on every convenient occasion tie lines shall be introduced to check the general accuracy of the work

Though the features of the ground may not need these tie lines for filling in detail, they must not be omitted, as the general accuracy of survey is the chief point to be ensured

3. It is further directed that all levels should be checked either by returning to the point originally started upon or by closing on a bench mark known to be accurately determined. Under no circumstances shall levels be run from one point to another without the accuracy of the work being inconsistently proved.

4. The adjustments of instruments including chains and tapes, should be checked and if necessary adjusted before using. Field book level or survey must be carefully preserved records. Under no circumstances shall nay page or part of a page be torn from the book. Entries shall invariably and neatly be recorded direct in the field book in ink at site. Pencil entries should be avoided but if unavoidable these shall be in indelible pencil and shall not be inked in, but left untouched. Erasures and overwriting s in the field book are strictly prohibited. And will be seriously noticed. Any mistakes made should be neatly scored off and corrected in red ink between lines. Dated initials of the recording officer are to be insisted on, on each page of field book in the case of each and every correction.

5. The greatest care must be exercised in the use of optical instruments. Peons or lascars must on no account be allowed to touch an instrument beyond in the actual carriage of it, and then it should be seen that the instrument is being conveyed in a proper way o avoid injury. The officer using an optical instrument must take it out of its box and return thereto with his own hands. Instrument boxes should always be kept locked and the key kept in the custody of the officer in charge, who is responsible for all instruments issued to him.

Purpose:

Locality:

Date: Name of Officer:

Back sight	Intermediate sight	Foresight	Height of Collimation	Reduced Level	Distance	Remarks

Assistant Executive Engineer Executive Engineer

10.2 PAYMENT OF WORK BILLS

Bills are normally paid at suitable intervals according to particular stages of execution of work as per the agreement for which the contractor shall submit the bill. The Assistant Engineer shall then verify the bill by taking requisite measurements.

Deviations and Extra Items

Alterations in sanctioned designs, except of a minor nature, shall not be made in a work without the approval of the TS authority. The agreement authority shall be kept informed then and there of all deviations ordered by authorities subordinate to him. All deviations, which involve major structural alterations, whether excess cost is involved or not shall be reported to the authority who technically sanctioned the estimate and his approval obtained before effecting the deviation.

The Engineers under the control of the work shall be careful to adhere to the estimate as far as possible and shall not carry out excess quantities as a matter of course. If, however, in any item, excess over estimate quantity is inevitable and has to be carried out, the authority competent to sanction the excess amount involved shall deal with the case and concurrently report the fact to the Agreement Authority. If excess is due to additional works not contemplated in the estimate, it will not be justifiable to carry out the additional works without sanction of the authority that sanctioned the estimate. Once it is decided that excess quantity in an item shall be carried out, the contractor shall be notified in writing to that effect by the Engineer. The agreed rate for the concerned item shall be applicable for excess quantity in that item upto 25% of the agreed quantity and upto 1% of the contract price. For excess beyond this limit, and for the extra items the agreement authority shall fix the rate by negotiation with the contractor for works within their powers of T.S. and by the Chief Engineer in other cases.

- Deviation from the quantities in agreement which may result in exceeding the contract value shall be taken up only after the approval of the competent authority.
- Extra/substitution of item shall be executed only after the approval of the competent authority.

10.2.2 Measurement and Payment of Beneficiary Committee

Measurement of work bill in respect of beneficiary committee is also same as described above, an amount of 25% of the estimate or Rs. 1,00,000 (One lakh), whichever is less may be given in advance to the Convener of the Executive Committee of the BCbefore the commencement of work with the sanction of the LSGI and interim -payment may be sanctioned in proportion to the work executed and proportionate portion of advance may be deducted from it and the interim payment and the remaining portion of advance amount shall be deducted from the final bill.

In case the BC owes to the LSGI, that amount shall be recovered from the convenor/ chairman/ executive committee members respectively in that order. If the work is dropped during execution liability shall be fixed to the entire members of the executive committee equally in case RR cannot be effected on convenor/ chairman.

10.2.3 Payment of Work bill

The officer competent to make payment for the work bill shall be authorized to effect payment up to a maximum of 75 % of the bill amount without detailed scrutiny, if the officer is satisfied of genuineness of the bills subject to the condition that if any excess payment is noticed, the officer who authorized the payment shall be held responsible.

The officer, who passes the bill, before making payment, will record a certificate to this effect in the bill

10.2.4 Preparation of Bills

If the progress mentioned in the project is shown in the construction one part bill shall be prepared and given each month. Otherwise, part bill can be given if considerable quantity of work has been done.

After completing the work and before preparing the bill, whatever be the method of implementation, a report including the monitoring details of in the various stages of the monitoring committee concerned should be obtained.A report certifying that the work has been completed satisfactorily shall be prepared,signed and given to the LSGIsconcerned within 2 weeks since thecompletion of the work along with the bills.

The engineer has the personal responsibility for the standard of the work, measurementsand the rates of the bills and the strictness and transparency.The LSGI can

recommend for the departmental action against engineer, Overseer who commits mistakes in these mattersto the CE, LSGD.

The measurement of each item of the completed work shall be recorded in themeasurement book and shown to the convener of the beneficiaries committee. They

shallbe made convinced of the correctness of the measurements and a certificate to that effectshall be obtained.

If there is any dispute about any measurement the convenor / contractor shall approvethe decision of the EE concerned.

10.2.5 Passing the bill and making payment

After necessary checking the LSGIs shall pass the bills forpayment within a month according to the availability of fund.Before passing the bill for payment the implementing officer shall make sure thatthe addition, subtraction and multiplication of the measurements recorded in themeasurement book are correct and that the bill have been prepared in accordancewith the rates given in the contract agreement.

It shall be ensured that all the refunds as per rules have been completed from the last bill of the contractor/convenor. The whole responsibility of it is with the LSGI implementing officer.If for any reason the bill amount could not be paid within the prescribed time 75% of the bill amount shall paid as advance.10% of the part bill amount of each contractor should be deducted and kept asretention. But the retentionincluding the security amount need not exceed the 10% of thecontract amount.

In case of excess payment to contractor by any manner, that can be recovered from the contractor from another bill or by RR.

The taxes and the welfare fund as per rules shall have been recovered from thebill amount of the contractor. But this deduction of taxes and welfare fund exceptIncome taxneednot be made from the bill of the beneficiaries committee.

The payment of the beneficiaries committee shall be according to their actualexpenses or the bill amount as per the contract agreement whichever is less.

If the total expenditure of the construction is more than the bill amount, the excessamount shall be collected as voluntary service or donation by the beneficiary Committees.

The final bill shall be given only after checking the book of accounts of incomeand expenditure approved by the general body of the beneficiary committee,muster roll, vouchers etc.It is on the basis of these accounts scrutinized thus that the actual expenses of theBC are to be calculated.

The method of giving money to the approved agencies like NirmitiKendram,Coast Ford, and Habitat etc. is as follows.

- After the contract agreement is signed the 20% of the agreement amount can be given as advance.
- In the order of producing the certificate for spending the 90% of the previous advances 2nd, 3rd and 4th installment each at the rate of 20% can be given.

- After the completion of the work 90% of the total bill amount should be given.
- The balance 10% can be given after the checking and approval of the LSGI is concerned.
- All the records of the work shall be handed over to the local government organization within 15 days since the completion of the work.

In the case of works undertaken by Nirmiti, KLDC, etc, works shall be under the close supervision of that agency and the quality, measurement, check measurement shall be responsibility of that agency, even if the implementing officer can inspect the site for the genuinity of the works if required. The measurement shall be made in the MBook owned by that agency.

10.2.6 Performance Report

After the completion of the work a performance report stating whether the work was completed in the prescribed form, estimate and specification and if any alteration was made and whether the objectives of the work was attained, and how much was spent and what the objectives attained and what are the environmental problems to be submitted to the secretary within a month along with a report of the monitoring committee.

10.2.7 Social auditing

In the Grama Sabha being met after the completion of the work the accounts in respect of the steel, cement, bitumen, metal etc. and the amount spent and the important technical details and the aim of the work should be explained.

SECTION- 11

11. MAINTENANCE OF STRUCTURES

11.1. MAINTENANCE OF ROADS

The maintenance of road is an elaborate activity and includes maintenance of basic records, maintenance of structures and tools & plants required including carrying out inspection of all the structures at regular prescribed intervals. Even when roads are constructed in highest quality, over a period of time, they will show signs of distress due to the effects of increase in vehicular traffic, climatic effects and other reasons.

Traffic on most of the roads have exceeded their capacities, and do not cater to the needs of modern multi axle heavily loaded vehicles. Moreover, reclassification to higher categories is done without properly designed upgradations. Hence, this has resulted in deterioration of roads which in turn causes loss to the economy by way of increased fuel consumption, wear and tear to vehicles, accident costs and increased travel times. The

need of the hour is to create a road network of desired level of service for which upgradation of existing roads shall be done in a phased manner.

Maintenance of all elements of the road is important but the condition of the pavement is the most important in predicting the performance of the road.. Road maintenance is required on a regular basis to keep these effects to a minimum, extend the life of the road and provide a high level of service to users.

All maintenance and repairs are to be carried out as per relevant codes and specifications of IRC and similar instruction/orders issued by the competent authority on the subject.

The basic objectives of maintenance are

a. Affording riding comfort, convenience and safety to the public
b. Preservation of the investment in roads and appurtenances
c. Preservation of the aesthetics and compatibility of highway system with environment; and
d. Accomplishing necessary expenditure of resources with continuing emphasis on economy.

Ordinary Repairs

All items of routine maintenance except renewal of surface required for keeping the road in good condition and which are of a repetitive nature shall be included under ordinary repairs. The following are some of the main items normally included under this head:

(i) Filling up potholes and patchwork to black topped surface.
(ii) Thorough repairs including clearing of jungle growth, sectioning and forming of berms, clearing side drains
(iii) Clearing of culvert and opening outlets.
(iv) Filling up erosions and removal of slips.
(v) Repairs to pitching, retaining walls, masonry works, culverts.
(vi) Painting Signboards, Kilometer stones, Hectometer stones, Guard stones, Boundary stones, road markings etc.
(vii) Planting avenue trees and maintaining the same.

Maintenance of traffic signs and markings shall also be an inevitable component of maintenance activity.

The patchwork shall be measured by volumetric measurements of broken stones collected for the work and paid for with necessary utilization certificate.

Renewal of surface:

This provides for resurfacing the road at regular intervals or when found necessary. Normally the following periodicity may be adopted for renewals.

Concrete roads	once in 10 years
Bituminous Roads	
Chipping carpet	once in 3 years
BM and AC	once in 7 years

If in any particular reach renewal has to be carried out earlier than the period mentioned above the necessity shall be specifically brought to the notice of the Executive Engineer and his sanction shall be obtained. A renewal coat shall be done after all the defects, like pothole, undulations etc. has been rectified.

The funds available under renewal shall not be utilized to upgrade the surface of the road. All up-gradation shall be considered as original work.

The renewal of surface shall be done as per provisions in Section 3000 of Specification for Road and Bridge Works published by MoRTH

Special Repairs

Special repairs are such items of repairs, reconstruction, or additional construction found occasionally necessary to keep the road in good condition. These may be divided into

a. Special repairs to roads, such as construction or reconstruction of retaining walls, raising a portion of the road, widening of pavements, maintenance of shaller, construction of drains etc.
b. Special repairs to culverts up to 6mts span, construction and maintenance of road side drains These may include reconstruction as well as construction of new culverts if found necessary.
c. Emergency works related to VVIP visit.
d. Repairs to flood damages.
e. Repairs to drought and other natural calamities.

The nature of repairs consequent of floods, drought and other natural calamities may fall under one or other of the above categories or may be a new type of work such as training of a river course etc. Even when a flood damage work comes under the category of special repairs to roads or to culverts, this is kept distinct from original repairs mentioned in (a) and (b) above since the financing is from an allocation specially earmarked for this purpose.

Adequate signboards and road markings, not provided as per requirements, shall also be included in special repairs.

Necessary provisions shall be made in the estimate for carrying out periodical maintenance including clearing of drains, jungles, painting of sign boards, road markings and shaller maintenance etc. during the defect and maintenance liability period.

For renewal coat, the defect and maintenance liability period shall be 3 years. All the periodical maintenance including clearing of drains, jungles, and shaller maintenance etc. in the defect and maintenance liability period shall be done by the contractor for the up keep of the road. After the end of 3 years (defect and maintenance liability period), ordinary repairs (annual maintenance) shall be done for next 2 years. After end of 5 years, surface renewal shall be done.

11.2 REPAIR AND REHABILITATION OF BRIDGES

All bridges are to be kept in good condition and their rehabilitation and strengthening needs shall be attended to as and when they arise. It is now well recognized that bridges not only require systematic maintenance but also strengthening or rehabilitation during their service life. IRC: SP-40 "Guidelines on Techniques for Strengthening and Rehabilitation of Bridges" provides guidance on basic approach to repair and rehabilitation, identification, assessment and diagnosis of distress, repair materials and repair and strengthening techniques to be adopted in respect of concrete bridges. These guidelines may be followed while undertaking rehabilitation or strengthening of concrete bridges.

Bridge structures, like any other structure, deteriorate with time. Causes could lie in the inadequacy of design detailing, construction and quality of maintenance, overloading, chemical attacks, atmospheric effects, abnormal floods and erosion, abnormal earthquakes, etc. The often used terms in the case of maintenance of bridges are maintenance, repair and rehabilitation, strengthening and replacement.

Maintenance: It refers to the work needed to be done to preserve the intended load carrying capacity of the bridge and safety of the public using it.

Repair and rehabilitation: It refers to the maintenance work of larger “Scope” and “Cost” than simple routine maintenance. “Rehabilitation” aims at rehabilitating (ie, restoring) the 'bridge to the service level it originally had or was intended to have.

Strengthening: It refers to improving the existing load carrying capacity of the whole(or of the affected components) of the bridge to the value it originally had (but has lost now) or was intended to have (but never actually had). ‘Widening’ or ‘Raising’ the deck may also be included here.

Replacement: It refers to reconstruction of the whole bridge or of its major components, since the cost and/or the extent of repair or strengthening may be beyond the acceptable economic or technical limits.

IRC:SP-40, Guidelines on Techniques for Strengthening and Rehabilitation of Bridges provides guidance on basic approach to repair and rehabilitation, identification, assessment and diagnosis of distress, repair materials and repair and strengthening techniques to be adopted in respect of concrete bridges. These guidelines may be followed while undertaking rehabilitation or

strengthening of concrete bridges.

Steps Involved in Repair and Rehabilitation

Various steps involved in arriving at an appropriate solution to the problem of a distressed bridge and implementation of remedial measures can be broadly identified as:

i) Identify signs of distress and need for rehabilitation through routine inspection and study of construction drawings.
ii) Carrying out special inspection by expert team.
iii) Investigation of type and extent of distress and the causes thereof based on in-situ and laboratory tests.
iv) Analysis of investigation data supplemented by structural analysis and formulation of detailed plans for repair or strengthening.
v) Implementation of repair or strengthening measures.
vi) Documentation of repair works done.
vii) Evaluation and monitoring of rehabilitation measures.

Major causes of distress

The single main cause of premature deterioration of concrete bridges is corrosion of reinforcing and prestressing steel. The problem of corrosion is of special significance in hot and humid coastal environment which is highly conducive to corrosion. steel re High humidity (more than 80 %RH), porosity of concrete, inadequacy of cover, cracks in cover concrete, use of rusted steel reinforcement without proper cleaning and lack of proper grouting in cable ducts are some of the factors which aggravate the problem. Another important cause of failure of prestressing steel is stress corrosion cracking or hydrogen embrittlement which occurs at high stress levels. Other important causes of deterioration of concrete are aggregate alkali reaction and alkali silica reaction. It results either in pop-outs or cracks in concrete caused by expansion of reactive aggregates.

Concrete also suffers deterioration due to leaching action and sulphate attack. Some other factors responsible for deterioration of concrete bridges are:

i) Poor detailing
ii) Lack of strict quality control during execution
iii) Foundation movements due to scour, earth pressure or seismic activity
iv) Inadequate untensioned steel reinforcement in the anchorage zones of prestressing cables
v) Malfunctioning and damage to expansion joints
vi) Inadequate provision for movement due to temporary shrinkage and creep resulting in excessive displacement of bearings
vii) Poor drainage and lack of waterproofing of bridge decks
viii) Lack of preventive routine maintenance

Signs of distress

Manifestation of distress in concrete bridges caused by various factors either individually or in combination are as follows;

- Cracking due to corrosion or map cracking caused by chemical reaction between the mineral aggregates and cement paste; a serious problem in PSC bridges

- Scaling, which is local flaking or peeling off of the surface portion of concrete exposing coarse aggregates
- Delaminations parallel to the concrete surface at or near the level of reinforcing steel, indicating corrosion steel and ultimate spalling of concrete.
- Leaching in the form of accumulation of white slat or lime deposits on concrete surface.

- Spalling caused by corrosion of steel leading to local weakening, exposure of reinforcement, loss of prestress and ultimate structural failure.
- Rust stains on concrete surfaces indicating corrosion of steel
- Deformation in the form of localized swelling or expansion indicating compressive failure of concrete or initial stages of spilling.
- Excessive deflection of superstructure or movement of bearings indicated by closing or widening of expansion joints, tilting piers/abutments and well foundations due to sever scour or any other reason
- Displacement of railings longitudinally or transversely.
- Failure of flooring where provided.

The signs of distress and need for rehabilitation is identified through inspection, and type and extent of distress and the causes are identified based on in-situ and laboratory tests. After analyzing the data, an appropriate solution to the problem of a distressed bridge is finalized for implementation.

Investigation of Distress

The technical personnel responsible for bridge inspection should be well trained and experienced so as to correctly interpret the observations relating to distress in various components of the structure. A visual survey complemented by a judicious selection of techniques for further investigation of defects, already identified, is a sound approach to any rehabilitation problem. Careful and systematic close visual inspection allows identification of most common forms of deterioration. However, such inspection can be carried out only on exposed surfaces of concrete.

A variety of non-destructive/ destructive testing and evaluation methods are available for investigating different properties of concrete in addition to the vital visual inspection. Tests are aimed at assessment of strength and other properties and to locate and obtain comparative results indicating permeable regions, cracks or laminations and areas of lower integrity than the rest.

Some of the commonly used testing/ evaluation methods are brought as under:

Non-Destructive tests (NDT)

Rebound and penetration tests: These are used to assess the comprehensive strength, uniformity and quality of concrete. Schmidt Hammer and Windsor probes are commonly used devices.

Ultrasonic pulse velocity measurement: Pulse velocity measurements are used to assess the homogeneity of concrete, presence of cracks, voids etc quality of concrete relative to standard requirements, quality of concrete of one element relative to another and elastic modulus values of concrete.

Determination of concrete cover: Concrete cover can be measured with the help of covermeters or pachometer which are portable battery operated magnetic devices and are designed to detect the position of reinforcement and measure depth of concrete cover.

Resistivity test: The procedure involves measuring the resistance between the reinforcing steel and concrete surface by four-electrode method common in geophysical testing and provides an indication of the rate of corrosion in reinforcing steel.

Half cell potential measurement: When steel corrodes in carbonated or chloride contaminated

concrete, a potential difference exists between the anodic half cell areas and cathodic half cell on the steel. This difference in electric potential in the corrosion cell can be measured in a moist concrete by placing a copper/ copper sulphate half cell on the concrete surface and measuring the potential difference between the half cell and the steel reinforcement with the help of a standard reference cell. The method gives indication of corrosion of reinforcement at the time of measurement but gives no information about rate of corrosion and the results are influenced by

changes in environmental conditions. The test is rapid, inexpensive and relatively easy and extremely useful in assessing corrosion performance of a bridge when used in conjunction with data from other tests, ie. resistivity and chloride content tests. This is one of the most widely used methods of electro-chemical testing of concrete structures.

Gamma radiography: Gamma radiographic technique is used for detecting voids in grout and defects in prestressing strands or wires which are broken or out of position. Gamma radiography of concrete is quite expensive and has health hazards from radiation and should be used only with proper precautionary measures.

Destructive/ Partially destructive tests

Most of the destructive tests are done by taking concrete core samples drilled from the structure using a coring machine. Portable compact core drilling machines are today commercially available. Core drilling can, however, weaken the structure and should be done only under expert engineering guidance.

i) Carbonation: Depth of carbonation in a concrete bridge component can be measured by spraying freshly broken concrete surfaces or cores with a 2% solution of phenolphthalein in ethanol. The solution is a pH indicator with colour change occurring around pH 10. Magenta areas of the exposed concrete surface after spraying represent uncarbonated concrete surface and the colourless areas represent carbonated concrete.

ii) Moisture content: Moisture content at the level of steel reinforcement may be determined from concrete samples taken in the field and oven-dried in the laboratory.

iii) Pullout strength: It is possible to assess the compressive strength of hardened concrete by correlating it to the pulling force (For pulling embedded metal devices inserted in concrete by casting or drilling). It is, however, difficult to get reliable data for making a proper correlating and assessment.

Laboratory tests

The following are some of the main tests conducted in the laboratory on representative core samples of concrete and steel to supplement the results of visual observations and field tests:

- Compressive strength of concrete
- Cement content and air voids in concrete
- Static and dynamic modulus of elasticity
- Splitting tensile strength
- Petrographic examination of aggregates to check alkali aggregate reacyion
- Chloride ion penetration in concrete
- Tensile strength of reinforcing steel
- Sulphate content
- Permeability testing

Formulation of repair plans

The data from the investigations from the basis of the decision regarding selection of an appropriate rehabilitation plan out of the following available options:

- Whether to go for total replacement if the damages are too extensive and the cost of repair is prohibitive to take up.
- Localised repairs in the structure

- Rehabilitation and/or strengthening

Some of the important criteria for deciding the most appropriate rehabilitation plan from the available options may be identified as:

- Reliability and technical feasibility
- Availability of expertise

- Cost of repairs/ rehabilitation for both short-term and long-term measures
- Importance of the bridge in terms of political and socio-economic considerations
- Estimate of residual life of the bridge and life expectancy anticipated for various available options
- Risks involve with any changes in safety level or reduction in load carrying capacity
- Availability and efficiency of repair material and equipments
- Feasibility of traffic diversion or duration of lane closures so as to cause minimum inconvenience to traffic
- Access for repairs
- Time involved in implementing the repair plan
- Need for enhancing load carrying capacity
- Availability of expert supervision during implementation of rehabilitation measures
- The technique and materials should be resistant to environmental changes

Repair Materials

Selection of a repair material must be based on an evaluation of damage, characteristics of the repair material and local conditions. Repair material must be compatible with the concrete being repaired. A wide variety of materials differing in cost and performance are today available for repair and maintenance of concrete. These are low viscosity polymers, very rapid setting cement, special concrete for overlays, apart from Portland cement mortar or concrete. The final selection depends on many factors such as physical and chemical properties, mechanical response, long term durability, cost and record of field performance. Basically, the repair materials can be grouped into:

- Cementitious system
- Polymer modified cementitious system
- Polymer concrete system
- Reactive thermosetting resin system

The following are some major repair materials currently used for repai/ rehabilitation or strengthening of bridges.

i) Unmodified Portland cement mortar or grout: These are generally mixtures of cement and suitable aggregates.

ii) Latex modified Portland cement mortar or concrete: These are Portland cement mortar or concrete modified by addition of a latex emulsion. These are suitable for use in members with thickness greater than 13mm but are not recommended in thinner sections.

iii) Epoxy resin compound: Because of their property of high strength after setting, excellent adhesion to concrete surface and high chemical resistance, epoxy resin mortars and grouts are extremely useful for repairs. These are currently being used for anti-corrosive coating for reinforcing steel, painting of exposed concrete surfaces, patch repair of cracks and pressure grouting of cracks and voids. Epoxy adhesives are used for bonding steel plates externally to the concrete surfaces. Epoxy resins are available in a variety of formulation for use at different temperatures.

iv) Polymer concrete: Although other materials have been useful to make polymer concrete, the most successful has been either an epoxy system with curing agents or methyl meta-acrylate monomer with an initiator and promoter. Polymer concrete

composites provide excellent means of protection to damaged concrete structures in the form of patching and surface coating. They possess very high strength and are reported to be more durable and resistant to most chemicals and acids in comparison to ordinary concrete and exhibit excellent bond to parent concrete.

v) Grunite/ shotcrete: Synthetic silica shotcrete as a combination of polymer modified cement microsilica pozzolana and super plasticizer both as dry and w et mix can

significantly improve quality of concrete. It is particularly suitable for patching large areas of shallow scaled or spilled concrete surfaces of beams, pier caps and underside of decks and replacing worn concrete surface. Properly applied shotcrete is a structurally adequate and durable material having excellent bonding property. Special variants of shotcretes result from the addition of fibre or synthetic resins.

vi) Polyster resin mortars and grouts: Use of these materials is generally restricted to small repairs because of high shrinkage property exhibited. Common materials used are polyurethane resin, acryl resin and unsaturated polyster resin.

Techniques of repair and rehabilitation

Repair and remedial measures vary according to the location, form and severity of distress of deterioration. These may range from protective coatings or patch repairs in the case of mild deterioration to reconstruction or replacement of key elements in the case of severe distress. Some commonly used techniques of repair and strengthening of distressed concrete bridges are as follows:

i) Patching and grouting: Patching is carried out for repair of deep and wide cracks and for replacement of spalled concrete. Dry-pad mortar or conventional replacement mortar are normally used for filling cavities and around rebars. For very large areas shotcrete may be used. Cracks are also repaired by means of pressure grouting with epoxy resins for fine cracks and Portland cement grout for larger cracks.

ii) Hydrodemolition: Hydrodemotion technique involves selective removal of damaged concrete by means of one or more high speed water jets without using any abrasive. Hydrodemolition is unanimously accepted as the best process for concrete removal.

iii) Vacuum grouting: Vacuum grouting with epoxy resin or cement grout can be used for filling up voids in cable ducts. The equipment used sucks the air out of the cavity and then via a relay valve presses the injection material into the cavity.

iv) Epoxy injection: Epoxy injection for sealing fine cracks as small as 0.05mm has been successfully applied in the recent years. The epoxy is injected under pressure to penetrate the very fine and tortuous cracks that may exist.

v) External prestressing: External prestressing consists of adding cables placed externally to the girders with new anchorages at suitable locations. It can be used to compensate the loss of prestress in the cables and partly/ fully restore the bridge deck to its original serviceability level. It can also be used for strengthening a bridge deck to carry higher super-imposed dead and live load corresponding to increased vehicular loading.

vi) Epoxy bonded steel plates: Steel plates bonded to concrete surface with epoxy structural adhesive can strengthen RCC members in flexure and shear. The technique is relatively simple in application, speedy in execution without traffic disruption and involves little increase in dead weight.

vii) Full depth concrete overlay/ deck slab replacement: Where deterioration of large areas of concrete surface of bridge decks has occurred, it may not be possible to repair it by crack repair or patching. In such cases, a full depth concrete overlay may be required. Similarly, where the deck slab has become structurally weak due to loss of cross prestress or other reasons, complete replacement of the deck slab may have to be resorted to. The overlays can be of dense Portland cement concrete with special quick setting admixtures of latex modified cement concrete. They should be bonded

structurally to the underlying old concrete and should match the underlying concrete in thermal properties. In all such cases of overlays or deck replacement, the work can be carried out over half the width of the deck while permitting traffic on the other half. Traffic management or restrictions may be required during the course of the work.

Repairs to masonry structures

Existing masonry bridges are sometimes considered as historical landmarks and need preservation. Strengthening and widening will, therefore, mean maintaining the same appearance. Widening is usually not possible but strengthening can often be done. Strengthening of masonry bridges ensuring pleasant appearance is a delicate task and needs advice from experts in this field. The following gives an idea of the general defects and remedial measures for such arch bridges in stone or brick masonry:

i) Loss of bond for the crown stone: Flat jacks have been successfully used for pushing the stone back to its original position. Generally, low pressure cement grouting is done to strengthen the old mortar. The mortar is sometimes replaced by epoxy mortar also, though epoxy is not ideal.

ii) Longitudinal cracks along the direction of traffic: It is possible to refill the mortar joints with cement mortar. Fine cement grouting (injection) can be adopted for remedial measures. Generally it is cheaper and better to grout the cracks with cement than with epoxy.

iii) Transverse cracks: Injection of cement will provide a good bond between stones and brick masonry.

iv) Strengthening of arch rings: The arch ring can be strengthened in two ways- by adding material to the intrados or to the extrados. Adding to the intrados causes the least disturbance but is more difficult to complete successfully. Also it results in a reduction in headroom or clearance which is often restricted and will, in most cases be the cause of new damage to the intrados as experienced on many bridges even where the headroom/ clearance satisfies legal limits. Extra material may be placed by shuttering and pumping concrete or by fixing a mesh to the intrados and spraying concrete. In both cases, any shrinkage of the new concrete will tend to make the old and the new material separate radially. Also these impervious rings prevent natural drainage between the stones or brick work of the arch so that special provision must be made to deal with water or under severe climatic conditions, such as inmountainous regions, with ice.

Repairs to steel structures

Deck replacement of older steel bridges: Many of the old bridges have either warped steel plates with a bituminous surfacing or a concrete deck. Due to insufficient waterproofing, the steel plates are often corroded. Depending on the type of bridge and the load carrying capacity of its structural components, the new concrete deck is placed as a non-composite action with stringer and/or cross beams or as a totally composite element. The use of light weight concrete is often preferred in such cases where reduction in dead load is an important factor. Sometimes to save weight, a type of steel grid decking is used where the grids can be either left open or filled with concrete.

Strengthening of structural members: Strengthening usually involves more conventional techniques such as installing new diaphragms to exiting double compression members, strengthening or replacement of diagonals. Plate girders may be strengthened by external prestressing cables, anchored and fixed on the web in the required parabolic curvature acting in a similar way as in prestressed concrete.

Repair of cracks: Cracks can be due to any one or a combination of the following reasons:

- Poor detailing so that high stress concentrations are present
- Increased traffic loading beyond what was anticipated by the designer
- An unexpected secondary structural action
- Inadequate analysis of complex stresses
- A large undetected fabrication flaw

Crack repair methods depend on the root cause of crack initiation. The structure and especially those components which influence the overall safety of the structure should be analysed. Repairs can be made by techniques such as drilling holes at the crack tip, cutting out the cracked material and bolting plates in place, cutting out the crack and rewelding with a higher class weld strengthening the connection by introducing stiffening and by changing the structural action so that loads are supported in a way that prevents high stress range from developing.

Underwater welding: Arc welding has become an accepted procedure in underwater construction, salvage and repair operation. Structural quality welds have been produced by means of special equipment and procedures that create small, dry atmosphere in which the welding is performed. However, this process is expensive. Gas welding underwater is not considered to be a feasible procedure.

Use of steel arch superposition scheme: This can be used to strengthen old truss bridges. The strengthening scheme consists of superimposed arches, hangars and additional floor beams. The concept of combining a truss with an arch is by no means a new system. The idea is that a light arch can carry a significant load if properly supported laterally. In this case, the truss with its cross beams provides the lateral support while the arch in combination with the hangars and additional floor beams provides the increased load carrying capacity. Additional floor beams and hangars are used for two reasons:

- The more uniform the load distribution, the more efficient the arch will be in carrying the load.
- The floor systems of many old truss brides get deteriorated and are sometimes under-designed and unreliable.

The thrust of the arch can be resisted by one of the following means:

- The abutments, provided they are adequate and in good condition, or they can readily be repaired or strengthened.
- A reinforced lower chord
- Superimposed cables or rods
- Properly designed and detailed stringers or floor slab

The arch superposition scheme can be considered as an overall strengthening measure. The load carrying capacity of the entire structure is upgraded, thus allowing the live load to be increased. There is no need for temporary shoring of jacking for the installation of the superpositioned elements. The increase in dead load can be expected to be in order of approximately 15 to 20%. The slender arch contributes only modest amounts of additional stiffness to the truss.

Excessive vibrations: These can be overcome by suitable structural alterations and increased damping for which a specialist in dynamic behavior of structures may have to be consulted.

Monitoring

After the rehabilitation/ strengthening of the structure is completed, it is essential that the bridge structure is kept under observation and its condition monitored regularly so as to ascertain its performance and the efficiency of the measures adopted. The monitoring may involve inspections at more frequent intervals, carrying out certain laboratory and field tests as well as condition

surveys and measurements to detect even small strains, movements, changes in deformations etc.

11.3 REPAIR AND MAINTENANCE OF BUILDINGS

All Government buildings are to be maintained properly. As a matter of convenience, heads of various departments of the State are authorized to arrange and carry out maintenance works of buildings under their administrative control provided the annual maintenance cost of any building or group of buildings in one campus does not exceed Rs. 1,00,000 in each case and the estimate does not exceed 10% of the capital cost of building.

Layout Plans & Building Plans

The Assistant Engineer, in-charge of the section is to maintain correct layout plans of the area with position of roads, buildings, gardens, water supply, electric O/H lines, sewer & w/s lines etc.

Similarly the detailed building plan of the individual building showing plan elevation & section shall also be maintained for record & reference purpose. For any new work in an existing building, as built drawings shall be furnished along with the proposal.

Protection of Govt. Property

All the properties in-charge of the department like buildings, lands, parks, gardens, grounds etc. are required to be protected from unauthorized encroachments, unauthorized construction, use etc.

Periodicity of certain items of ordinary repairs

Maintenance of building includes white washing, coloring, painting, repairs to doors, windows, roofs, sanitary & water supply fittings, structural repairs, internal roads, fencing, compound walls etc.,

White washing in Government buildings shall be carried out once every year. One coat will normally suffice.

Distemper washing when provided shall normally be carried out once every two years. Here also one coat will suffice. However, in buildings where distemper washing is badly soiled, the bottom portion of the wall for a height of 2 meters may be distempered with one coat even in years when the full distempering is not done.

Water proof colored cement washing like snowcem etc. need be redone only once in 2 years. The renewal need be of only one coat. If fungus or moss growth is observed here and there, such portions may be cleaned and touched up with the waterproof cement wash of the same color (snowcem etc.). Ordinary cement washing wherever provided may be redone every year.

Painting of walls, woodwork and doors and windows is to be normally redone once

every two years. As an exception to the above painting of walls etc. in the case of laboratories, hospitals, such other buildings as are considered by the Executive Engineer to require special treatment may be carried out once every year. One coat of paint will do in all cases except where the old paint has peeled of or has shown blisters. In such cases the old paint has to be completely scraped and two coats of new paint applied.

Painting of iron work including fittings and fastenings in doors, windows etc. shall be redone once every year with one coat. Where the existing paint is damaged and rust or corrosion is seen, the particular area shall be thoroughly cleaned of all old paint and two coats of paint one base coat and one final coat shall be applied. Particular attention to this aspect is necessary in respect of buildings within half a mile of the seashore where ironwork is subjected to severe corrosion.

Galvanized iron work as in pipes, or G.I. sheets etc. need not be painted for the first 2 years. Thereafter because of gradual wearing out due to abrasion etc., the protection afforded by galvanization gradually wears out and hence after the first two years such items may also be included along with ironwork for painting purposes.

Varnishing and wood oiling are to be redone once in two year with one coat.

Wherever there are thatched roofs, re-thatching shall be done normally once every year with one old and one new cadjan leaf.

In case of prestigious buildings declared as such by the Chief Engineer, the Chief Engineer concerned will issue special instructions regarding periodicity and items of maintenance work to be carried out.

MAINTENANCE AND REHABILITATION

It is the reinforced concrete (RCC), a composite structural material, which is utilized for variety of structural uses. But it has been observed that RCC has not proved to be durable due to large number of factors, including variations in production, loading conditions in service life and subsequent attack by the environmental factors. However, a well constituted, properly compacted, and cured concrete used in RCC continues to be substantially water tight and durable as long as capillary pores and micro-cracks in the interior do not become interconnected pathways leading to surface of concrete.

The general approach for durability is to demand impermeability of concrete as the first line of defense against any of the deterioration process. In most of the cases, penetration of water and/ or aggressive chemicals during the service life of structures is the primary reason for deterioration. Addressing the issue of deterioration, carbonation, chloride ingress, leaching, sulphate attack, alkali-silica reaction and freeze-thaw are the known responsible natural causes.

Permeability of concrete

As deterioration process in concrete begins with penetration of various aggressive agents, low permeability is the key to its durability. Concrete permeability is controlled by factors like water-cement ratio, degree of hydration/ curing, air voids due to deficient compaction, micro cracks due to loading and cyclic exposure to thermal variations. The permeability of concrete paste is a function of water-cement ratio. Given good quality materials, satisfactory proportioning and good construction practice, the permeability of the concrete is a direct function of the porosity

and interconnection of pores of the cement paste. Interconnected porosity is related to:

Capillary porosity	-	High water-cement ratio
	-	Inadequate curing
Air voids	-	Improper compaction
Micro cracks	-	Loading effects

- Weathering
- Initial care
- After care
- Secondary effects

Macro cracks
- Placement
- Hardening process
- Intrinsic chemical attack
- Corrosion of reinforcement

For understanding the permeable character of concrete, it is necessary to understand the mechanism of formation of pores, capillaries and air voids during hardening process due to hydration of cement paste.

Capillary porosity: The volume of hydrated cement product is significantly higher than the volume of its constituents. As a result of hydration, increased volume of hydrated gel eventually fills part of capillary pore volume. This helps in creating discontinuity in capillary pores. Whereas any lessening in the hydration process will not give the full benefit from this phenomenon. It can be shown that 100gm of anhydrous Portland cement requires about 23gm of water (a water cement ratio of 0.23) after about a month's hydration under normal conditions. However, for achieving full hydration as well as to render the mortar/ concrete workable, excess water is required. This extra volume of water entrapped in the cement paste after completion of hydration leaves interconnected pores, called capillaries in hardened concrete, which become means of passage for external/ environmental chemicals into the concrete. This porosity is termed as capillary porosity. The porosity obviously increases with the increase in w/c ratio.

Air voids: Air voids (much larger than capillary pores) form due to inadequate compaction in the form of discrete air bubbles (as in air entrained concrete) of much larger size than capillary pores. These air voids may get interconnected by capillary pores system.

Micro cracks: During service life of a reinforced structure, it is subjected to various types of loading conditions and also exposed to extreme exposure conditions of temperature variations. Micro cracking combined with capillary porosity is generally responsible for ingress of aggressive chemicals in RCC.

Macro cracks: Some minor cracking in concrete structures would occur within the normal practice. Proper design and detailing coupled with proper construction practice can control the crack width. Any crack width, which allows aggressive chemicals to travel freely into the concrete, is termed as macro crack. Macro cracking in concrete could be due to variety of reasons, which includes:

- Improper placement of concrete
- Settlement cracks of fresh concrete
- Cracking due to
    - Intrinsic sulphate attack
    - Alkali aggregate reaction
    - Heat of hydration
    - Increased volume of corroded reinforcement exerting bursting pressure on concrete
- Excessive loading

Aggressive Deteriorating chemical agents

The deterioration of RCC is basically related to loss of water tightness of cover concrete and migration of aggressive chemicals through interconnected porosity, which in turn chemically attacks on its constituents.

(a)Corrosion of reinforcing bar - Due to carbonation of concrete

- Due to ingress of chloride

(b)Sulphate attack
(c)Alkali silica reaction

Corrosion of reinforcing bars: Steel reinforcement in concrete is protected from corrosion by a combination of
-the formation of a passivating protective layer on steel surface due to chemical reaction under highly alkaline environment and
-the environmental protection provided by the concrete cover.
The hydration reactions of Portland cements release alkalies giving it a high pH in the range of 12.6 to 13.5. Even though oxygen and moisture may reach the steel surface, it will not corrode and will remain passive as long as high pH is maintained and the cover concrete is intact. The two common conditions that lead to the loss of passivity of steel in concrete are

i) Reduction of alkalinity of concrete surrounding the steel with pH lower than 11 to 11.5
ii) Presence of chemicals which destroy the passivity even while the alkalinity of surrounding concrete remains high.

Carbonation: The alkalinity in concrete is provided by hydroxides of calcium, sodium and potassium present in the hardened cement gel. Permeation of carbon dioxide into concrete through interconnected pores and its reaction with these hydroxides causes chemical reaction. Because of this reaction, the alkalinity of concrete gets reduced. This process is called carbonation of concrete. Carbonation of concrete can be a problem in areas where the concentration of CO2 is high and relative humidity is moderate (50-60%).
Chlorides: These may be present in the fresh mix or may penetrate from external source into the hardened concrete. Due to the deleterious effect of chlorides on the corrosion protection of the reinforcement, the chloride content of the mix is limited to certain values in relation to cement in almost all standards. During use of the structures, chlorides may penetrate into the concrete from various sources. The most important of these are sea water.
Sulphate attack: The term sulphate attack is generally used to mean the deterioration of concrete as a result of physical-chemical interactions between the minerals in hardened Portland cement paste and sulphate ions from the environment. The sulphate attack on concrete manifests itself in the form of expansion, cracking, loss of mass and/or disintergration.
Alkali Silica Reaction: Chemical reactions between aggregates containing certain reactive constituents and alkalis and hydroxyl ions released by the hydration of cement can have a deleterious effect on concrete. When the aggregates in cement concrete contain reactive forms of silica, the phenomenon of chemical reaction is referred to as alkali-silica reaction. Expansion and cracking, leading to loss of strength, elasticity and durability are among the physical manifestations of alkali silica reaction.

Durability aspects

Durability is defined as the continued ability of the structure to withstand the expected wear and deterioration and perform satisfactory in the normal operating conditions throughout its intended life without the need for undue maintenance. What is implied is that the designer should expect certain degree of deterioration during the service life and provide required design inputs to adequately control it. Design for durability is highlighted in IS:456-2000. In the codes, the requirements on durability are expressed in terms of minimum cement content, maximum water/ cement ratio, minimum grade of concrete and minimum cover to reinforcement. These design

parameters are related to specific exposure conditions. The general approach is to demand impermeability of concrete as the first line of defense against any of the deterioration process. The parameters mentioned above play a significant part in enhancing the durability, a comprehensive approach to design reinforced concrete structures for durability should give equal attention to the type and quality of component materials, the selection of mix proportions, the control of processing conditions. The design and detailing aspects should aim at minimizing the

size and number of joints and cracks due to thermal gradients, drying shrinkage, creep and loading.

Condition Survey

Condition survey is an examination of concrete for the purpose of identifying and defining area of distress. The objective of condition survey of a building structure is

a) To identify - causes of distress and
-their sources

b) To assess - the extent of distress occurred due to corrosion, fire, earthquake etc
- the residual strength of the structure and
- its rehabilitability

c) To prioritise the distressed elements according to seriousness for repair and

d) To select and plan the effective remedy

Condition survey of a building/ structure is generally undertaken in four different stages to identify the actual problem so as to ensure that a fruitful outcome is achieved with minimum efforts and at the least cost. The four stages of condition survey are:

a) Preliminary inspection- To assess and collect necessary information for a thoughtful planning
b) Planning- Involves preparation of field documents, grouping of structural members and classification of damage
c) Visual inspection- Evaluation of structural soundness and identifying the typical distress symptoms together with the associated problems
d) Field and laboratory testing- for validating the findings of visual inspection

Considerations for repair strategy

In the Condition Survey report, before arriving at the repair strategy, it shall include the following considerations:

i) Identification of the cause of problem and its source is the fundamental to the success or failure of the repair. A lack of attention at this point can put at risk the whole job.
ii) For arriving at an effective and economical solution, systematic documentation of all observations is essential, which will greatly facilitate in diagnosing and making assessment of the extent of damage
iii) Available space and accessibility will determine the selection of repair method and repair strategy
iv) Accessibility to the areas identified for repairs needs consideration
v) Depending upon the scope and scale of repairs, the repair strategy has to suit and dovetail the on-going activities in the building
vi) The prioritization of repairs and their sequencing are important components for deciding the repair strategy
vii) Major repair procedure may demand propping the structural members to relieve a part or full component of the load acting on the member. If the building requires extensive propping, vacating the building may become the pre-requisite.

viii) Safety measures to prevent any immediate major mishap shall be prescribed without loosing further time.

ix) The report should also include requirements on safety measures to be adopted during execution of repair jobs

Non Destructive evaluation test

A number of non-destructive evaluation (NDE) tests for concrete members are available to determine in-situ strength and quality of concrete. Some of these tests are very useful in assessment of damage to RCC structures subjected to corrosion, chemical attack, and fire and due to other reasons. The term 'non destructive' is used to indicate that it does not impair the intended performance of the structural member being tested/investigated. The non-destructive evaluation have been broadly classified under two broad categories viz 'in-situ field test' and laboratory test'. These tests have been put under five categories depending on the purpose of test as under:

i) In-situ Concrete Strength
ii) Chemical Attack
iii) Corrosion Activity
iv) Fire Damage
v) Structural Integrity/Soundness

TABLE
(Refer CPWD, Handbook on repair and Rehabilitation of RCC buildings)

Selection of repair materials for concrete

Selection of repair material is one of the most important tasks for ensuring durable and trust worthy repair. Though, the pre-requisite for a sound repair system is the detailed investigation and determining the exact cause of distress, yet an understanding of the process of deterioration of the repair materials under service conditions is vital. Since, cementitious products have a tendency to shrink and hardening with age, it is essential that the repair material for repairing concrete or plaster should be of non shrink type and compatible with parent material. Besides being of compatible properties, repair materials for cement concrete/ mortar shall also be easy to apply and require no attention after the repair has been applied. The essential parameters for deciding upon a repair material for concrete are:

- Low shrinkage properties
- Requisite setting/ hardening properties
- Workability
- Good bond strength with existing sub-strate
- Compatible coefficient of thermal expansion
- Compatible mechanical properties and strength to that of sub-strate
- Should allow relative movement, if expected, particularly in case of sealing of cracks or dealing with expansion joints
- Minimal or no curing requirement
- Alkaline character
- Low air and water permeability
- Aesthetics to match with surroundings
- Cost
- Durable, non-degradable or non-biodegradable due to various forms of energy, life, UV rays, heat etc
- Non-hazardous/ non polluting

Materials for repair

Wide range of materials for repair of concrete is available differing in cost and their performance. Their application range covers:

i) Materials for surface preparation
ii) Chemical rust removers for corroded reinforcement

iii) Passivators for reinforcement protection
iv) Bonding agents
v) Structural repair materials
vi) Non-structural materials
vii) Injection grouts
viii) Joint sealants
ix) Surface coating for protection of RCC

Though, these materials are being marketed under their brand names, yet these could be classified in the following categories:

- Premixed cement concrete/ mortars (modified with non-polymeric admixtures/ additives)
- Polymers/ latex modified cement additives for mortars/ concrete/ cement slurry
- Epoxy resins
- Chemicals for corrosion inhibitor, removal of rust

1. Premixed Cement Concrete/ Mortars

Though, cement concrete and mortars are most natural repair materials for carrying out the repairs to RCC. Yet, they are not favoured as a repair material due to its inherent undesirable properties like drying shrinkage, slow setting, low workability, prolonged curing requirement, permeability, etc. Types of cement to be used in a repair work depend on its suitability for the intended use.

Ordinary Portland cements- Grade 33 and 43 may be used for most of the repair purposes, if necessary with modification by suitable admixtures or additives. Whereas Grade 53 cement or a cement having still higher fineness could be more suited for injection grouting of cracks or honey combed concrete preferably with non-shrink admixture in suitable proportion. The hydrated gel of OPCs on its hardening has high pH, ranging from 12.5 to 13.5. These cements have an additional advantage of being used for passivating coats over reinforcing bars for their corrosion protection.

Rapid hardening Portland cements- It gains strength more rapidly at early ages but has its ultimate strength comparable to OPCs. It is suited where early strength is required.

Portland slag cements and Portland Pozzolana cements- Generally, such cements have low heat of hydration, better sulphate and chloride resistance and have low permeability. These are more suited for use in marine structures and in structures having contact with soils and water containing high percentages of sulphates and acids.

Shrinkage compensating expansive cements- Shrinkage compensating expansive cements are used to minimize cracking caused by drying shrinkage in repair concrete in addition to its use in concrete structures. These cements are designed to expand by small extent during the first few days of hydration. To achieve proper performance of shrinkage compensating expansive cements, inclusion of appropriate amount of reinforcing steel in concrete is necessary. For maximum expansion, additional moisture beyond that added as mixing water must be supplied during curing of the concrete.

Fly Ash (FA), Silica Fume (SF), Rice Husk Ash (RHA), Ground Granulated Blast Furnace Slag (GGBS) and metakaoline, which have good pozzolanic properties are being used as mineral additives in concrete and mortars with certain advantages in regard to their impermeability, resistance to leaching, resistance to chloride and sulphate attack and better crushing strength. Such additives

are to be used with caution, while repairing flexural structural members requiring protection of reinforcement against corrosion. The types of admixtures added to concrete or mortar during its mixing to modify one or more properties of the repair concrete/ mortar/slurry in plastic or hardened state are retarding admixtures, water reducing admixtures, air-entraining admixtures, super plasticizing admixtures etc. Water-cement of the mix plays a vital role in controlling shrinkage, water permeability, percentage of capillary pores and enhancing strength. The

plasticizers and super plasticizers can be gainfully used to control water/ cement ratio without any compromise on the workability.

2. Polymer Modified /mortars and Concrete (PMM/PMC)

The process technology of making the latex-modified mortar and concrete is similar to that of the conventional binding systems. Most polymers, such as latexes, are in the dispersed form. These are initially mixed in water in required proportion and then added to the cement mortar or concrete. The latex-modified mortar or concrete, are placed similar to normal concreting and cured under optimum conditions. OPC is widely used for polymer modified mortars and concrete including all other Portland cements depending upon their applications. However, air entraining cement are not used because air entrainment occurs due to latex application.

Polymer Latexes: Latex modification of cement mortar and concrete is governed by both cement hydration and polymer film formation process in their binder phase. The cement hydration process generally precedes the polymer formation process. In due course, a co-matrix phase is formed by both cement and polymer film formation processes. This yields on a monolithic inter-woven matrix of solidified polymer and its continous film with hydrated cement and this binds the aggregate strongly. Consequently, the properties of hardened cement mortar/ concrete are improved.

Redispersible polymer powers: The principles of modification of cement mortars / concrete is almost the same as that of polymer latex modification except that it involves addition of redispersible polymer powders. Mostly these are used by dry mixing with cement and aggregate premixtures followed by wet mixing with water.

Water Soluble Polymers: These, being water soluble, are mainly used for improving workability of cement mortar and concretes and prevents 'dry out' phenomenon due to increased viscosity of water phase in the modified cement mortar / concrete and a sealing effect due to formation of a very thin impervious film in them. In general, these do not contribute to any improvement in strength of modified system. These are normally used at polymer: cement ratio less than 3% by weight. When added in powder form, it is advisable to dry blend the polymer with cement aggregate mixture before adding water.

Liquid Resins: Liquid thermosetting resins are polymerisable low molecular weight polymers and pre-polymers. These are added to cement mortars/ concrete in a liquid form. Polymer content in the cement mortars/ concrete is generally higher than the latex system. In this modification, polymerization is initiated in presence of water to form a polymer phase and simultaneously the cement hydration occurs. As a result a co-matrix phase similar to latex modified systems is formed and this binds the aggregates strongly. Consequently, the properties of hardened cement mortar/ concrete are improved.

Monomers: Principles of modification of cement composites remain the same except that here monomers are added instead of liquid resins. In such a case of modification, polymerization and cement hydration takes place simultaneously and at the same time during or after curing to make it a monolithic matrix which binds aggregate. Generally, such a system of modification is not successful because of degradation of monomers by alkalis present in cement paste and

interference of cement hydration and difficulty in uniformly dispersing monomers and other components during mixing.

Physical and mechanical properties of polymer modified mortars/ concrete

Admixing of polymer latex in cementitious mixtures modifies the following physical and mechanical properties:

- Better workability compared to conventional mortar/ concrete

- Improved water retention property
- Better resistance to bleeding and segregation
- Increased resistance to crack propagation
- Increased tensile and flexural strengths
- Good chemical resistance
- Reduction in strength with increase in temperature
- Low drying shrinkage with increase in polymer: cement ratio
- Increased waterproofness or water tightness
- Good resistance to chloride ion penetration
- Good resistance to moisture transmission
- Improved adhesion or bond strength to various sub-strata
- Better abrasion resistance
- Durability and non-degradability

Fields of application

i) Polymer Modified Mortars/ Concretes (PMM/PMC) are used to make up the damaged/ lost cover concrete due to their better bond with substrate, including reinforcement.

ii) Ultra Rapid Hardening Polymer Modified Shotcrete is used as repair and protective material for concrete structures with leaking and flowing water and it is often used for urgent construction and repair works.

iii) For the purpose of improving the flexural behavior and durability of conventional ferrocenent, Polymer Ferrocements have been developed using latex modified mortars instead of ordinary cement-sand mortars.

iv) Anti washout underwater concrete are used because of their anti washout or segregation resistance, flow ability, self leveling ability and bleeding control.

v) Hydrated type flexible water proofing materials are polymer modified pastes or slurries with very high polymer: cement ratio of 50% or more and have been widely used as liquid applied water proofing membrane materials, repair materials etc.

vi) Polymer modified cement mortars as well as slurries are used as bond coats and grouts due to their very good adhesive qualities on cementitious as well as metallic surface.

3. Epoxies and Epoxy Systems including Epoxy Mortars/ concretes

The epoxy resin materials have good mechanical strength, chemical resistance and ease of working. These are being used in civil engineering for high performance coatings, adhesives, injection grouting, high performance systems, industrial flooring or grouting etc. Diluents are modified epoxy systems which are used for lowering the viscosity and improving handling characteristics. Coal tar epoxy resins combinations with polyamine hardener have been widely used as water resistant protective coatings for ships and other marine structures. Coal tar plays an important part in the improvement of corrosion resistance of epoxy resin system. Rubber modified epoxy system is used to improve drawback of brittleness and low elongation of unmodified epoxy resins. Interpenetrating Polymer Networks (IPN) are used with advantage in coatings for protection of concrete structures and steel reinforcement bars against corrosion due to their good

resistance to chlorides and chemicals.

Epoxy resins are used with aggregate to produce epoxy mortar or epoxy concrete, which is used for structural repairs of concrete, RCC besides its use in new construction in industrial flooring, foundation grouting, roads etc. Composite fibre system comprises of a fibre reinforcement layer that is wrapped to the exterior surface of the structural element to be retrofitted. The fibre composite reinforcement layer consists of atleast one fabric layer that is

located within a resin matrix. The composite reinforcement layer provides a quick, simple and effective means for increasing the resistance of the structural element to failure during the application of loads.

Field of Applications

IPN coatings are being used for protection to reinforcing bars against corrosion in RCC structures located in highly aggressive environment. These are also used as surface coatings for RCC structures for arresting further carbonation of cover concrete or other chemical attack by sealing their surface against ingress of environmental aggressive chemicals and their consequential attack on concrete. Epoxy coatings in conjunction with epoxy grouting have been used to render leaking roofs, toilets, bathrooms as impervious. However, their use in exposed locations directly exposed to sunlight is to be avoided. Polyurethane coatings are used as surface coatings on exposed RCC structures as they have excellent UV resistance. These coatings have good elasticity and abrasion resistance also. These are used as such or as a finishing coat over other coating systems. Epoxies are used as bond coats and grouts due to their excellent adhesive qualities on cementitious as well as metallic surface. Due to excellent mechanical properties and bond characteristics with most of the materials epoxy mortars/ concrete are used to make up the damaged or lost cover concrete etc.

4. **Surface Coatings**

   Protective coatings over structural concrete should necessarily possess following properties:

   i) Posses excellent bond to substrate
   ii) Be durable with a long useful life normally 5 years
   iii) Little or no colour change with time
   iv) Little or no chalking
   v) Should have maximum permeability to allow water vapour escape from concrete substrate
   vi) Should have sufficient impermeability against the passage of oxygen and carbon dioxide from air to concrete
   vii) Should be available in a reasonable range of attractive colours

Rehabilitation and Retrofitting methods

The decision to repair or replace a structure or its component can be taken only after consideration of likely service life of the structure is established based on the technical and economical evaluations. Once a decision, based on preliminary investigations, is taken to carry out the repairs, proper diagnosis, identification and extent of distress in structural members has to be correctly assessed. The repair strategy shall be based on evaluation and available alternative methods of repair and material. Priority should be assigned to

- repair of structural defects to ensure safety of the structure and
- Protection of the structure from further deterioration

Depending upon the specific condition of deteriorated structure, the option of the repair methods could be one or more of the following:

- Grouting and crack repair
- Patch repair

- Replacement of structurally weak concrete
- Replacement of spalled, and/ or delaminated concrete
- Replacement of carbonated concrete surrounding steel reinforcement
- Cleaning and passivating the corroded steel reinforcement

- Concrete overlays with normal, low or highly fluid concrete, latex modified concrete and corrosion protection such as jacketing etc
- Re-alkalisation of carbonated concrete
- Electro-chemical removal of chloride from concrete
- Water proofing and/or protective coating

The following are important factors to be considered for selection of repair methods:

- Type and extent of distress
- Location of distress
- Environmental exposure
- Availability of skill
- Availability of time and access for repairs
- Appearance
- Cost

The repair methods available are carried out for structural repairs to a distressed structure either singly or in combination of more than one, depends upon the nature and extent of distress. Formwork shall be provided for supporting the structure, if necessary.

Register of buildings

This is a very important register to be maintained in each Buildings Division of the P.W.D showing therein inventory of all the buildings under its charge, constructed, purchased or acquired by the Govt. irrespective of the manner in which the Govt. funds are allotted for such procurement. The register shall be in the form given in Appendix 2900A. It shows year of construction, cost, use of building, occupant, maintenance cost etc. The number allotted to such buildings in the Register of buildings is displayed prominently in front face on each building. All government buildings shall have a name display board and list of all offices housed there in.

Whenever a new building is completed, the maintenance of which is to be attended by the Building Division, details regarding the building shall be added to the register. Disposal of any building or part by dismantling or sale shall be recoded in the building register. Transfer of control of any building or part of the building from other Divisions or Departments etc. shall be incorporated in the Building Register. Alterations or additions of substantial nature in such buildings shall also be noted. Similarly, if the extent of land surrounding a building is increased or decreased by acquisition, transfer or otherwise, the fact shall be noted in the register. The intention is that the register shall give full and up-to-date information about the buildings under the maintenance charge of every building

division. Possession Certificate showing property rights of the land / building shall be obtained from concerned authorities and maintained in proper order.

Inventory in the Buildings

An inventory of all the fixtures in each building viz. electrical fixtures, like fans, lights, geysers, Air-conditioner or Civil fixtures like mirrors, basins, taps, flushing cisterns etc. and furniture if provided shall be maintained building wise. In case of non-residential buildings such inventory of fixtures is to be got signed from the representative of the user department, at the time of first occupation. Thereafter the user department is responsible for their safety. In case of residential buildings the inventory is to be got signed from each new occupant and checked by the Assistant Engineer concerned when the residence is being vacated. Any shortfall is to be made good by the occupant.

Maintenance of Government Buildings

Designated PWD Civil Engineers and Electrical Engineers under the control of each Government building shall be responsible for its upkeep and maintenance. All maintenance and construction shall be done under their supervision and direction. Other quasi government agencies or private agencies shall not carry out any modification, minor or major works in such government buildings.

Fixing of maintenance grant

Each building or group of buildings in one campus forming one administrative unit shall have an annual maintenance grant fixed by the Chief Engineer (Buildings). This grant is intended to meet the, cost of ordinary repairs such as petty repairs to walls floors, doors and windows, roof etc., white washing, painting etc. which are of a recurring nature. This grant shall be fixed on the basis of a standard estimate for its ordinary repairs. Annual cost shall include proportionate amounts for items like painting. The grant also includes cost of maintenance of water supply, sanitary installations and electric installations.

Divisional Officers will program the works in the Divisions suitably under the various sub heads of account and forward them to the Chief Engineer before 15th November every year for incorporating in the budget for the coming financial year. Total budget provision is allotted by Chief Engineer (Buildings) amongst the divisions under the different sub heads in April of every year and the Divisional Officers shall plan their programs within the funds so allotted.

Maintenance of buildings shall be taken up-as soon as the monsoon is over and all items according to the sanctioned estimate carried out. If changes are required in the approved estimate for any reason it shall be effected before according sanction to the estimate. On no account shall the limits set out for carrying out the repairs exceeded.

The fixing of grant for ordinary repairs subject to the conditions laid down above shall be approved by the Chief Engineer, Buildings and recorded in the register for typical maintenance estimate kept in that office. The approval and copy of sanctioned estimate shall be forwarded to the Executive Engineer Building Division concerned for recording. In

any particular case where the grant of 2% will not meet the needs of the situation, sanction of the Government shall be obtained for the fixation of the grant.

In some cases requiring expenditure by way of labour charges may have to be met from the maintenance, as for instance, wages of staff appointed to look after rest houses,

or staff for operation of water supply scheme to colonies, cleaning of toilets and urinals in the office complex etc. The amount required for such engagement of workers may be considered as over and above the 2% ceiling fixed for ordinary maintenance grant. The nature of workers to be employed, the number and the grades of persons shall however be got sanctioned by Government as per rules in force.

In the case of certain classes of buildings like Tourist Bungalows, Rest Houses etc. Linen curtains, crockery etc. originally provided at Government cost and responsibility for renewal is with the P. W. D, shall be dealt with as part of special repair. The cost on account of these need not be included as part of the ordinary maintenance grant of the concerned building. In all other cases such charges shall not be incurred by the P.W.D. except under special orders of Government.

The grant fixed for ordinary repairs for every building shall be revised once in every five years or as often as found necessary. In all cases where the existing grant is altered, the alteration shall be on the basis of the standard estimate and the then current schedule of rates. The ceiling of 2% of capital cost will not apply in such cases. Revisions shall also be noted in the typical maintenance register.

Maintenance grant do not include expenditure. Like - a) Municipal taxes, b) Service charges, c) Water charges, d) Telephone, e) Electricity, f) Internal roads etc.

Fixing of Rent for Building

When government buildings are not available it may be necessary to hire private buildings for government purpose. The officers of the administrative department will locate suitable buildings, get the consent from the owner and furnish a copy of same along with a certificate that no other private building at a lesser rate of rent is available shall be forwarded to the Assistant Executive Engineer, Buildings, Sub

Division of the locality. The Assistant Executive Engineer will then issue a certificate that no government building in his charge is available in the locality for the purpose. The administrative department will then decide to take the building on rent.

The Executive Engineer, Buildings Division will act as the Estate Officer of all government buildings.

Once the building is decided to be taken on rent the head of the occupying office will forward the following documents to the Assistant Engineer Buildings Section of the locality for fixing rent of the building.

1) Consent document in original with dated countersignature.
2) Land value certificate indicating the market value of land on the date of occupation/proposed date occupation issued by the Thasildar.

3) Age certificate of the building issued by the local authority.
4) A list of officers and staff of the office with a note on special request of space if any.
5) The prescribed proforma duly filled up and signed.

The Assistant Engineer is responsible for taking exact measurements and working out rent as per the guidelines prescribed in the specific proforma Appendix 2800F. The

construction material, construction method etc. shall be properly verified on site and the rent workedout The Assistant Engineer shall prepare the rent calculation on the basis of clause 2809.5 and approve the same and issue rent certificate if the rent calculated is within his powers of sanction and if not forward it to the superior officer to approve the rent calculation as per delegation of powers.

The rent calculation and processing shall be completed within 20 days in the section office and 10 days in each higher office. The competent authority of the occupying department, who shall get the administrative sanction from the competent authority of their department and pay the rent from their funds, shall forward the rent certificate. On receipt of the administrative sanction the concerned officer of the occupying department shall execute a lease deed with the owner of the building in the form given in Appendix 2800G and pay the rent to the parties from the date of occupation or date of agreement whichever is earlier. The occupying department or the occupant shall pay the electricity and water charges for the building during the period of occupation. Once a building is occupied and rent fixed for the same, revision of rent will be permissible only after the expiry of a period of 3 years from the date of agreement or date of occupation whichever is earlier. Any revision of rent shall be made only on specific request from the owner of the building and shall be effective only from the date mentioned above or from the date of application for revision of rent whichever is later. Notwithstanding the above if any alterations or additions are made to the rented building by the owner at the request of the occupying department rent may be revised to allow for the above alteration or additions from the date of completion of the same.

If the rent demanded by the owner is higher than the P.W.D. rate of rent the same has to be treated as special rent. In case of special rent approval of the Government Rent Committee constituted for this purpose shall be obtained before the administrative department passes orders. Government will fix the procedure for this from time to time through technical circulars or orders. If special rent is sanctioned the same shall be valid for five years and the owner can demand revision only after this period. The lease deed shall be executed specifying this period

Rent Calculation

The capital cost of a building at current rates as per technical circular of the Chief Engineer from time to time will be calculated and depreciated capital cost worked out at the rate provided as detailed under clause 2810.2.1. The cost of actual land limited to 3 times of the plinth area of the main building and 1V times that of the outhouse will also be calculated at the rate as per the land value certificate issued by the Thasildar. This will be

added to the depreciated cost of the building to arrive at the total capital cost. 6 % (Six Percent) of the capital cost will be taken as the annual rent. It shall be the responsibility of the owner to do the maintenance work as also to pay the taxes due to the building and premises. The details of rent calculation for partially occupied building etc., will be worked out based on the technical circular issued by the Chief Engineer from time to time.

Valuation of Building

First a detailed plan and specifications of the items of work in the structure shall be prepared. It is likely that certain details like mortar proportions or quantity of steel used in R. C. work cannot be found out by usual observation. In such cases assumption may be made that the mortar or concrete of the type used contains the minimum proportion of cement material, which will be required for the stability of the concerned portion of the structure. Similarly in R. C. work, in the absence of any other data, the minimum of steel necessary for the particular item may be assumed as having been used. With regard to foundations a few examination pits shall be taken to find out depth and nature of foundations.

Cost Estimation

An estimate shall be prepared for the construction of the structure using the current PWD schedule of rates. Where non-standard items of work are done, special data for the same shall be worked out on the basis of prevailing market rates. In case the building is electrified, the estimated cost of electrification shall be worked out in consultation with the Assistant Engineer, Electrical Wing of PWD. For leveling site, only the minimum quantity necessary for construction of a building of the size shall be assumed unless there is evidence at site that extra quantity of work was involved and it is possible to measure such extra quantity. Leads and lifts for materials shall be worked out as if the structure is being constructed by the department at that site. If any item of work done is sub- standard as compared to the same item as per P. W. D. specifications, suitable percentage reduction may be made for the same. Similarly, if any item of work is of especially superior standard as compared with the corresponding item of P. W. D specification, a suitable extra percent on the rate of the concerned item due to such superior work may be allowed.

Depreciation

From the estimated cost of the building worked out on the above basis, depreciation shall be deducted for the period, which had elapsed after the building was constructed. The age of the building shall be ascertained by local enquiries including enquiries from local bodies like Municipalities, etc., having jurisdiction over the area. The facts ascertained through such local enquiries shall also be verified by examination of the condition of the building and its component parts.

Depreciation is effected from the estimated capital value worked out and above. The depreciation is applied successively for each year, i.e., by compounding the depreciation annually. The depreciation constant for calculation is given in Table 2800.1

Table 2800.1 Depreciation Constant

Extract (tfG.O. (Ma.) N«. S-.WB.JI/C.S., dated I Gti May 195(5 to tie Chief Engineer, F.W.D,

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The description of various categories of building are given in the table below

Type	Description
A	Buildings with brick or stone masonry in lime or cement mortar with R.C.C. or tiled roof over good quality Teak of wood and R.C.C. framed structure
B	Building with brick or stone masonry in mud mortar or laterite in lime mortar with tiled, A.C. or G.I. sheet roofing over country wood or steel.
C	Buildings with sundried brick or laterite in mud mortar with country wood over tiled, .A.C. or G.I. roofing
D	Buildings with mud walls, and thatched roof over country wood or bamboo rafters etc. And Temporary sheds thatched buildings of inferior type construction.

The depreciation for electrical installation shall be 6% and that of water supply and sanitary fittings shall be4%.

In addition to normal depreciation, deductions shall be made for damages in any point of the structure. When allowing normal depreciation rates, it is expected that the structure is maintained properly. Hence depreciation does not cover special damages such as cracked walls, damaged roof, rotten state of wood work etc. A reasonable amount, which may be more or less equal to the cost of rectification, shall be deducted from the depreciated value of the building to arrive at the final cost to be intimated to the revenue authorities.

Powers of the officers of the P.W.D. regarding valuation of buildings shall be as per delegation of powers given in section 200. The maximum time that can be allowed for completing such valuation in the section office shall be 30 days.

In all cases of valuation of buildings, the Assistant Engineer concerned shall make the preparation of the plan, specifications and estimate. Where the valuation has to be approved by officers higher in rank than Assistant Engineer sufficient time (15 days in each of the higher offices) shall be allowed. Before the valuation is approved it is imperative that the officer who is competent to approve the valuation shall inspect the structure with the plan and estimate and satisfy himself about the various provisions made therein

Lease of Government Property/ Buildings

The government may provide its land or buildings on lease for public use to other agencies like bank/ societies/ public undertakings etc. for a specific period on remittance of monthly rent. The Government and the lessee shall enter into an agreement as per Appendix 2800H. Under no circumstances government land or building shall be leased free of cost. Chief Engineer Buildings shall fix a reasonable rent and the agreement executed.

11.4 MAINTENANCE OF MINOR IRRIGATION STRUCTURES

CAUSES OF FAILURE OF WEIRS AND THEIR REMEDIES

1. Piping:

Water seeps under the base of the weirs founded on permeable soils. When the flow lines emerge out at the downstream end of the impervious floor of the weir, the hydraulic gradient or the exit gradient may exceed a certain critical value for the soil. In that case, the surface soil starts boiling and is washed away by percolating water. With the removal of the surface soil, there is further concentration of flow lines into the resulting depression and still more soil is removed. This process of erosion thus progressively works backwards towards the upstream and results in the formation of a channel or a pipe underneath the floor of the weir, causing its failure.

Remedies: Piping failures can be prevented by

(i) Providing sufficient length of the impervious floor so that path of percolation is increased and the exit gradient is decreased.

(ii) Providing pile at downstream ends

2. Rupture of Floor Due to Uplift:

If the weight of floor is insufficient to resist the uplift pressure, the floor may burst and effective length of impervious floor is thereby reduced. The final failure, however, is due to the reduction of the effective length with the consequent increase in the exit gradient.

Remedies: Failure due to rupture of floor may be prevented by

(i) Providing impervious floor of sufficient length

(ii) Providing impervious floor of appropriate thickness at various points and

(iii) Providing pile at the upstream end so that the uplift pressure to the downstream is reduced.

3. Rupture of Floor Due to Suction Caused by Standing Wave:

The standing wave or hydraulic jump formed at the downstream of the weir causes suction, which also acts in the direction of uplift pressure. If the floor thickness is insufficient, it may fail by rupture.

Remedies: Failures can be prevented by

(i) Providing additional thickness of floor to counterbalance the extra pressure due to the standing wave.

(ii) Constructing the floor thickness in one concrete mass instead of in masonry layers.

4. Scour on the Upstream and Downstream of the Weir:

When the natural waterway of a river is contracted, the water may scour the bed both at upstream and downstream of the structure. The scour holes so formed may progress towards the structure, causing its failure.

Remedies: Such failures can be prevented by

(i) Taking the piles at upstream and downstream ends of the impervious floor, much below the calculated scour level.

(ii) Providing suitable length and thickness of launching aprons at upstream and downstream sides, so that stones of the aprons may settle in the scour holes.

Effects of Construction of a Weir on the Regime of River

The weir is an obstruction thrown in the path of water. Due to its construction, therefore, the regime of river is affected in the following ways;

1. The silt supporting power of a river or channel mainly depends upon the hydraulic slope. When the weir is constructed the heading up of water leads to flattening of the surface slope on the upstream side.
2. Due to decrease in the water surface slope, the silt carrying capacity is decreased, and the bulk of silt charge of the river water deposits in the pond, leading to the formation of irregular shoals at upstream of the weir.
3. Also due to silt excluding devices provided at the head regulator, the canal takes less silt in the pond.
4. The water passing the weir and through the scouring sluices now contains a deficient silt charge because much of it has been deposited upstream. In orderto maintain a constant silt charge, the flowing water as at the downstream scours the bed. This results in a progressive degradation or retrogression of bed levels downstream. The retrogression may undermine the stability of a work by an increase in exit gradient beyond safe limits. During high floods, the retrogression of bed may be from 0.3 to 0.5 m, while at low water levels, it may be as high as 1.2 to 2m.
5. As the silting and consequent shoals formation at upstream increases, the resistance to flow of river is increased due to tortuous route the water has to take about shoals. It overcome this resistance, increased head is required. The river starts regaining its original slope, and the afflux is extended more and more to the upstream. A stage is then reached when the upstream section of the river cannot take up any more silt, and the normal silt charge is passed on the downstream side. The silt excluding device will also discharge more silt downstream.
6. Due to this, river below the weir will carry an excessive silt charge with a lower discharge. This will result in progressive silting up downstream, an increase in tortuosity and, therefore, a recovery of bed levels downstream. The process of recovery of downstream bed levels after the initial retrogression is slow and steady, and it may take 20 to 30 years to regain the original bed slope. The recovery of levels to the downstream may lead loss of control on the silt regulation. Hence, sufficient margin should be provided between canal F.S.L. and the pond level so that the crest level of the head regulator can be increased in the event of necessity.

GENERAL MAINTENANCE GUIDELINES OF CHECK DAMS

Check dams require regular maintenance as they are used primarily as a temporary structure and thereby are not designed to withstand long-term use. Dams should be inspected every week that it is sited in the channel and after every large storm. It is important that rubble, litter, and leaves are removed from the upstream side of the dam.This is typically done when the sediment has reached a height of one-half the original height of the dam.

Further, maintenance is required when removing the check dam altogether. In order to ensure the future flow is not adversely altered, the check dam must be fully removed, including any parts that may have been dislodged and washed downstream or any newly developed bare spots where the check dam once was situated.

Check dam structures need to be properly operated and maintained so that they can continue to operate and function effectively and efficiently. Some general guidelines on the types of maintenance works required are as listed below. This list provides some of the normal maintenance work required and may not be applicable to all the various types of check dams as it depends on many factors such as the types, materials used and site conditions and location of the check dam structures.

a. Inspect check dam structures periodically (once a fortnight) as required and after each run-off producing storm, and throughout the dry season for any damages where risk of peat land fire is high. Some of the possible damages include:
    - Damages or deterioration of the main embankment materials e.g. sand-bagsand timber logs
    - Excessive seepage resulting in weak water level control
    - Bank erosion or scouring
    - Undermining of base of structure e.g. due to seepage
    - Bed degradation and erosion especially immediately downstream of structure
    - Washouts of check dam materials
    - Accumulation of sediments and debris
    - Damages to concrete structure or gates (if provided)
b. Repair, replace or reshape damaged component of check dam immediately / periodically especially those check dams using temporary materials such as sand bags and timber logs
c. Remove any excessive sediments accumulation if necessary, as sometimes the existence of sediments upstream actually helps to improve the impermeability of the check dam. However, if the accumulated sediments have impaired the effectively and safety of the structures, then works to clean and removed the sediments will have to be carried out. Sediment removed shall be disposed of properly.
d. Regular inspections should be made to insure that the center of the check dam is lower than the edges
e. Erosion caused by high flows along the bed and around the edges of the dam should

be repaired immediately

f. Clear all debris along canals that impedes the water flow when water has reached the optimum level. Regular monitoring of water levels especially during the dry periods in accordance to Standard Operation Procedure. Constant surveillance for fires in and around the site

g. Remove check dam structure when no longer needed

11.5 MAINTENANCE OF MINI WATER SUPPLY SYSTEMS

Objective

The objective of an efficient operation and maintenance of a water supply system is to providesafe drinking water as per designed quality and quantity, with adequate pressure at convenientlocation and time at competitive cost on a sustainable basis.

"Operation refers to timely and daily operation of the components of a Water Supply System such as headwork, treatment plant, machinery and equipment, conveying mains, servicereservoirs and distribution system etc., effectively by various technical personnel, as a routinefunction."

"Maintenance is defined as the act of keeping the structures, plants, machinery and equipmentand other facilities in an optimum working order". Maintenance includes preventive /routinemaintenance and also breakdown maintenance. However, replacements, correction of defectsetc. are considered as actions excluded from preventive maintenance.

The infrastructure created in any scheme should satisfactorily last for the entire designperiod of the project. To ensure this, the various components of the project needmaintenance during the project period for deriving maximum services out of them.Without planning both technically and financially for the proper maintenance andoperation of the systems, these will not function correctly after commissioning and theanticipated benefits will not be realised. In rural areas of developing countries, a keyto ensuring proper O & M is the participation of community from the conceptualstages of project and their performances been taken fully and seriously intoconsideration.Therefore user should know the most likely cost of O&M. TheOperation and Maintenance cost of a scheme depends on the capital cost, fixed costand variable cost.

The various maintenance works for a Water Supply Scheme are listed as below:

1. Maintenance of the source.
2. Maintenance of transmission system
3. Maintenance of treatment units, if any.
4. Maintenance of storage reservoirs
5. Maintenance of distribution system
6. Maintenance of pumping machinery

1. Maintenance of Source :

Wells, like all other engineering structures, need regular, routine maintenance in the interest of a continuous high level of performance and a maximum useful life. The maintenance of wells and pumps is often neglected, since the greater portion of both the well and the pump are located beneath the ground surface. The nature of deterioration which occurs in a well may not be readily discernible during operation and may not be recognized until the well fails. The deterioration usually develops slowly to a critical point and then accelerates rapidly to failure. Therefore, any neglect of well maintenance often results in the complete loss of the well.

In most of the cases tube well forms the source of rural water supply scheme.Waste materials should not be disposed near the source. This will cause healthhazards due to water borne diseases.The following point should be observed:

- There should be periodic development of tube well after a period of 3 years. Thiswill rejuvenate the source. Otherwise the discharge of tube well may decrease with time.
- There should be continuous monitoring of water level charges. Over a fixedinterval of time, which would indicate the health of the source.

2. Maintenance of Transmission System

The objective of O&M of transmission system is to achieve optimum utilization of the installedcapacity of the transmission system with minimum transmission losses and at minimum cost.To attain this objective the agency has to evolve operation procedures to ensure that thesystem can operate satisfactorily, function efficiently and continuously, and last as long aspossible at lowest cost.

3. Maintenance of Lined Canals Transmitting Raw Water

Cavity or pockets or any activity detected behind the lining should be carefully packed withsand or other suitable material. Care should be taken to ensure that the lining does not getdamaged or displaced. Damaged portion of lining should be removed and replaced with fresh lining of good quality bypreparing a thoroughly compacted sub-grade before laying fresh sub-grade. The cracks in thelining should be filed with standard sealing compound. An

effective sealing may be obtainedby cutting 'V' groove along the face of the cracks before filing with sealing compound. Packingwith powdered clay upstream of the cracks my seal minor crack on the lining.Displaced portion of the joint filter should be removed and fresh filter (CHECK)

4. Transmission through Pipes

In the case of gravity transmission line, where direct feeding in to OHTs is envisaged then itshould be ensured that design head is developed. Otherwise water will be reaching only theOHT at lower elevation at the cost of OHT at higher elevation. This can be ensured by suitablyregulating the sluice valves.All valves installed in the transmission main should be inspected daily to ensure that there isno leakage otherwise leakage should be attended. If attending leakage requires stoppage offlow through pipes the same can be attended on a pre-fixed monthly shutdown day.

Problems in Transmission Mains

(i) Leakage - Water is often wasted through leaking pipes, joints, valves and fittings of the transmissionsystem either due to bad quality of materials used, poor workmanship, and corrosion, age ofthe installations or through vandalism. This leads to reduced supply and loss of pressure.Review of flow meter data will indicate possible leakages. The leakages can be either visibleor invisible. In the case of invisible leaks sections of pipeline can be isolated and searchcarried out for location of leaks.Most common leaks are through the glands of sluice valves. Leaks also occur through expansion joints where the bolts have become loose and gland packing is not in position.Leaks through air valves occur due to improperly seated ball either due to the damage of thegasket or due to abrasion of the ball, through the gland of the isolating sluice valve or throughthe small orifice.

(ii) Air Entrapment - Air in free form in rising main collects at the top of the pipeline and then goes up to higherpoints. Here, it either escapes through air valves or forms an air pocket which in turn, resultsinto an increase or head loss. Other problems associated with air entrainment aresurging,corrosion, reduced pump efficiency and malfunctioning of valves or vibration. In rare cases, bursting of pipes also is likely to occur due to air entrainment.There should always be air valve chamber with cover slabs for the protection of the air valveand it should always be kept leakage free and dry. Frequent inspection should be conductedto check, whether Air valves are functioning properly and to ensure that there is no leakagethrough air valve.

(iii) Water Hammer - The pressure rise due to water hammer may have sufficient magnitude to rupture thetransmission pipe or damage the valves fixed on the pipeline. Water hammer in water supply system occurs due to rapid closure of valves and sudden shut off or unexpected failure ofpower supply to the pumps. The care should be taken to open and close sluice valvesgradually.

(iv) Scouring of Pipeline - Scouring is done to clean the transmission lines by removing the impurities or sediment thatmay be present in the pipe. This is particularly essential in the case of transmission linescarrying raw water.

(v)Leakage Control

- Visible Leaks: The maintenance staff during surveillance operation can report visibleleaks found by him to his superiors. Critical areas where leaks often occur have to beidentified and appropriate correct measures have to be implemented.
- Invisible Leaks: Lead detection equipment have to be procured for detection of nonvisibleleaks and action to control these leaks should be initiated to control the overallproblem of water lost.
- Chlorine Residual Testing: A minimum free chorine residual of 0.2 mg/lit at the receiving reservoir of atransmission system is needed to be maintained. Absence of residual chlorine could indicatepotential presence of contamination in transmission system.

The following steps which are required to be taken are:

1. Testing of residual chlorine
2. Checking the chlorination equipment at the start of the transmission system.
3. Searching for source of contamination along the transmission system which has
5. Caused the increase in chlorine demands.
6. Immediate rectification of the source of contamination

7. Maintenance of Treatment Units

A layout plan of the entire plant indicating the flow pattern shall be maintained.

a) Maintenance of Slow Sand Filter : (REQD?)

For cleaning :-

i. Close the inlet valve.

ii. Allow water to deplete about 10 to 20 cm below the sand surface.

iii. Allow the drying of sand bed.

iv. Remove the top 1-2 cm of sand layer by manually. Manual operations ispreferred till labour is cheap.

v. After cleaning, level the sand surface.

For re-commissioning

i) The filter after cleaning allow water from under side so that dissolved gas or airentrapped. When bed was exposed to escape and also to provide water cushion so thatwhen inlet valve is opened, sand bed is not disturbed.

ii) Opening inlet valve and ripening of filter is required. Dissolved oxygen (D.O) inthe treated water should not be less than 3 mg/lt. If D.O. is less than 3 mg/lt then recirculate the water treated through cascade aerator to increase the D.O. level in theeffluent.

iii) After several years of operation-by means of cleaning, sand depth may reachminimum. Part of this removed sand has to be replaced back while resanding.

iv) For replacing the old sand when removed while cleaning, if decided to be usedagain, it should be washed immediately after taking out from the filter otherwise sandwill become septic due to oxygen demand by micro organisms present in sand.

(Ripening of filter = to allow the growth of micro organisms for purification process,time allowed to develop micro organism not less than 4 weeks.(Range 2 – 8 weeks).

b) Maintenance of setting tanks:In setting tanks, the basic maintenance is in the form of painting the surfacesand removal of sludgeat the bottom. If any damp patches or leakage‟s are noticed the same shall berectified immediately.

Operation and Maintenance of Disinfection Systems:

C1) Differential pressure chlorinator:

The most frequently expected problem is development of holes in the rubberbag. In such cases the rubber bag needs to be replaced, as a preventive maintenance, itis preferable to change the rubber bag once a year. The inlet and outlet pipe joints,control valves, drain valves and air release cock are to be maintained watertight. TheMS container shall also be painted at least once in two years. The diaphragm shouldbe replaced periodically, the rubber washer should be replaced. The container must becleaned at least fortnightly so that there are no. encrustations on container walls &logging of pipes.

C2) Dosing Pumps:

a) Diaphragm of the dosing pump shall be replaced after 3000 hours of operationor as recommended by manufacturer.

b) Chemical storage tank shall be cleaned once in month and it shall be coveredwith proper lid

c) Dosing pump valves shall be cleaned with weak acid once in month to preventclogging

d) Settings of dosing pump shall not be disturbed when power supply is off as itwill disturb the calibration

e) Electronic solenoid is prone to burning due to sudden voltage fluctuationshence it should be provided with constant voltage stabilizer

C3) Silver ionization plant :

a) Regular cleaning of electrodes shall be ensured

b) Silver electrodes of the Silver Ionization plant shall be replaced after 9-12 months of operation .

8. Maintenance of Storage Reservoirs

To prevent bacterial contamination of water and to maintain hygienic conditionof water it is necessary that clear water storage tanks are periodically cleaned anddisinfected. It may be necessary to clean them once in three months or more frequently (if required). A program shall be prepared and display boards shall beexhibited near the tank indicating last

cleaning date and the next cleaning date. Menentering the tank should use clean pair of gum boots, which are washed just beforeentering the water tank. Brushes used must also be in clean condition, preferably theyshould be soaked in bleaching powder solution at least for one hour before use. Alsohand gloves shall be used in cleaning.

(i) Cleaning Operation :

The water level in the tank may be got depleted by consuming the water onprevious day before taking up cleaning to avoid wastage of water. About 75 mm ofwater can be kept in the tank to which decanted, clear bleaching powder solutionhaving concentration of 10 mg/lt chlorine may be added and the bottom and side wallsof the tank scrubbed well using the brush and thoroughly cleaned. Dirty water can beadded to the tank and the bottom and side walls of the tank cleaned and washedthoroughly. On completion of the cleaning, it is necessary that the side walls and thebottom of the tank is disinfected using a strong solution of decanted clear bleachingpowder solution having a strength of 50 mg/lt of chlorine. Solution may be splashedon the side walls and bottom of the tank by means of small cans and the entire wallsurfaces and bottom of the tank drenched by the solution. About one hour of reactionperiod may be allowed to complete disinfection to take place. The tank may berecommissioned after one hour and put in to normal use.

(ii) Safety Precautions

Proper tools and implements as indicated above must be used. Usage of gum bootsand hand gloves are necessary in order to prevent contamination of the tank and alsoto prevent skin irritation to workmen due to chlorine solution. Tank must be properlyventilated by keeping all manholes in open position when the cleaning operation is inprogress.Un-trained workmen shall not be engaged for cleaning. Workmen shall not bepermitted into tank containing water more than 15 cm depth. Water level should bereduced prior to allowing men inside to prevent accidents. Guard bars may beprovided an outlet/scour opening provided at the bottom and side walls of the tankmay be checked frequently and covers are to be replaced in position and locked.

9. Maintenance of Distribution System:

Distribution system has the likelihood of getting contaminated causingsecondary pollution of once treated water before it reaches the consumers. Hence, thedistribution system needs and deserves a careful maintenance.A complete inspection of the distribution system and pumping mains shall be madeonce and the survey must be made for leakages in the distribution system, sluicevalves, fire hydrants, scour and air valves. Underground leakages in a distributionsystem is generally indicated by dampness. Flooding of water and extra growth ofvegetation above the pipe line at the place of leak. Leakage frequently occurs in houseservice ferrule connections. A record shall be maintained to indicate the major repairsand leakages occurred with reasons for the same which can be used to checkunaccounted water loss in the system and to have close check on these leakages

pronepoints. Scour valves shall be operated and dirty water let out once in a month. Glandpacking in sluice valves should be replaced once in 3 to 6 months or more frequentlydepending on the leakage in gland, frequency of operation of valve etc. Excessleakages in air valves shall be attended to in time.

In this project as the operation and maintenance of all the above units are to bemanaged by the community without any financial contribution from the government itis essential to educate the beneficiary community about the cost involved. Thefollowing example is presented to arrive at the approximate cost and contribution bythe beneficiary.

10. Maintenance of Pumping Main :

The pumping mains are often very long and generally laid along the road hence damage to pipe may be caused due burst in pipe lines, tampering by unauthorized persons, temperature variations, vehicular traffic, etc. Such unauthorized persons, temperature variations, vehicular traffic, etc. Such damages should be observed and attended to immediately. Readymade pipe sleeves, rubber sheets, and pipe clamps, etc shall be always be kept in stock to stop the leakages in cracked pipes temporarily.If the pipes have developed major cracks or severely damaged such pipes need to be replaced with good ones.The appurtenances in the piping main such as sluice valves, scour valves, air release valves, etc shall be protected against tampering by unauthorized persons by always closing the lid and locking the valve chambers.

Maintenance of Pumps :-

Normally a centrifugal pump does not start pumping water immediately after switching on due to failure of priming. This may be due to a clogged foot valve or entrapment of air on the suction side. It is suggested that the pump is reprised by allowing more water to fill the suction line by opening the by-pass valve on the delivery side. Usually this may be sufficient. If the pump still does not deliver water then detailed inspection has to be done for any mechanical clogging of the foot valve or due to visible leaks on the suction side. In case of submersible pumps since suction head in zero, the above problems will not arise.

If the pressure gauge on the delivery side does not register a gradual increase it means that the water is not being delivered at the desired pressure or at the desired quantity. This may be due to any leakage on the pumping main or burst of the pipeline due to the closure of any valve on the pumping main. In such case, the pump has to be shut down and inspection undertaken on the delivery side for any leakage.

If the motor itself does not start or if the speed is slow it indicates electrical problem due to single phase current, low voltage or no power supply to the main switch or any fuses might have been blown. In such case, the main switch is to be switched off and verification done for the required voltage or replace any burnt fuses. During running of the pumps the ammeter should always show the designed value of consumption of power. If the pump is over loaded for any reasons and if the voltage is lower, it will indicate a higher value of

amperage in which case also the motor is to be switched off and resumed only after the required voltage is observed. If all the above problems persists, if any vibrations are noticed and if any unusual noise is observed the manufacturer is to be contacted.

In case of submersible pumps, if there is no discharge it may be due to:

- Chocked strainer
- Water level in the well being lower than the pump level
- Single phase current, low voltage or no power supply to the main switch or any fuses might have been blown.

If the problem is with the power supply the remedial measures as discussed above shall befollowed.If the water level in the well is below the pump level, then sufficient time shall be allowed for recuperation to raise the water level above the pump level. If this problem persists it may be necessary to lower the pump. Hence it is essential to maintain the record of water table in bore well and pump capacity observed to see whether pump needs to be lowered. When none of the above are the causes for no discharge, the pump shall be removed and checked for the fault.

11.6 MAINTENANCE OF WASTE MANAGEMENT SYSTEMS

OPERATION & MAINTENANCE PROTOCOLS

Vermi composting unit

- Chop the waste to size less than 5cm before placing in the Basin/ pot/ tank.
- Thickness of waste layer should not exceed 15 cm.
- Use one basin/ pot/ tank for the first 15 days and then use the second basin/ pot/ tank after filling the first.
- Sprinkle cow-dung powder along with waste.
- Protect the vermi basins/ pots/ tanks from mouse, ants and other pests. - Keep the waste covered with wet sack or cloth piece.

- Sprinkle water over the cover sack/cloth to maintain moisture of 50-55%.
- Avoid over sprinkling of water and stagnation of liquid at the bottom of the basin.
- Vermi Basin/pot/tank should not be exposed to direct sun light or rainfall.
- Prevent introduction of excessive hot, sour and oily substances and also bones, meat & fiber materials.
- For removing the vermi compost, expose the basin/pot/tank with contents in shaded sunlight for 2-4 hours and remove the compost from the top and use the basin/pot/tank with earthworms for further composting of bio-wastes.
- Compost taken out should not be dried under sunlight.
- Renew the base layer annually.
- Collection of Wash out from the basin in the final stages of composting for vermi wash.

Aerobic bin

- A 6 inch layer of fresh cow dung is laid as the first layer.
- A 6 inch layer of dried leaves is laid on top of the cow dung layer.
- Above that 6 inch layer waste is added and inoculum containing enzymes made from cow dung is sprayed, this hastens composting.
- Alternate, 6 inch layers of dried leaves and waste sprayed with inoculum is repeated till the bin is filled.
- Once the first bin is filled, start using the second bin. By the time the second bin is filled the contents in the first bin will turn into compost. If not, take it out and dry it in dry beds.

Windrow Composting

- The pre-processed MSW is transferred onto the compost pad (platform) into windrows.
- Windrow Formation: Windrows can be formed by means of bucket loaders or by manual labour, depending on the size, shape, and spacing of windrows
- Windrow Turning: The outer layers of piles are moved to inner layers by turning the windrows. This process is repeated once every week for 5 weeks, high temperatures within the windrow (55 to 65°C) sanitize the material. During the rainy season where the interstitial spaces are filled with water, more frequent turning is necessary (interval of 3-4 days).
- A turning schedule should be established based on the rate of decomposition, moisture content, porosity of the material, and the desired composting time (often a function of land availability).
- Each windrow should be allowed to stay on the compost pad for 35 days and at the end of the 35th day the compost is ready for use.
- Each windrow should have a flag board depicting the age of the waste.
- Fresh incoming waste is always depicted by —Age 1‖. The numbering on the windrow changes from Age 1 to Age 2 on the second day; Age 2 should be changed to Age 3 on the third day and so on.

- Each windrow may be turned manually or mechanically. This turning process has to be done every 7th day. Hence, only those windrows having a flag board showing Age 7, 14, 21 and 28 should be turned.
- Fresh water or leachate stored in the leachate tank should be sprinkled during the turning process to maintain the moisture content of the waste. Figure below shows a quick and simple method to test moisture content.
- Temperature should also be monitored and maintained within 55-60°C.
- On the 35th day, the compost is successively sieved through two stage screening system of 35mm followed by 16mm. Screened material coming out of this section is uniform in texture but contains semi-solid organic compost, which requires further stabilization. The rejects from the 35 mm screen are sent to the RDF and the 35mm – material is sent to the 16 mm screen. The rejects from the 16mm (16mm+) screen are to be put back on the windrow as protective covering from bird menace, vermin and for odour control.
- Curing: Screened material coming out of the coarse segregation section requires further maturation and moisture control for producing a product that is beneficial for plants and soil. The curing piles are placed either in a storage area or covered area for a minimum duration of 2 weeks. In general, the area needed for the curing process is one quarter of the size needed for the windrow/composting process. The completely cured well composted material does not release foul odour and is ready for final screening and for the preparation of the finished product for marketing.
- The degree of maturity is determined through either oxygen uptake or carbon dioxide production rate. (Determination of maturity is explained in Municipal Solid Waste Management Manual of CPHEEO)
- Compost Refinement: At the end of composting phase, the material usually contains 30 to 35% moisture. The composting is normally taken to be complete when the active decomposition stage is over and the C/N ratio is around 20:1. The refinement section also consists of a feeder conveyer and a trommel with 4mm perforations. The screened product which is less than 4mm is passed through ADS (air density separator or de-stoner) to remove sand and grit. Then the compost can be put in bags and stored for sale. The remaining material greater than 4 mm in size should be put on top of the fresh incoming waste heap, to speed up the process of composting and for absorbing excess leachate. The residue material from the ADS is inert laced with fine organic material. This should be kept out of the composting stream. The finished product is dark brown with an earthy smell, fragile and rich in organic matter content and nutrients.
- Leachate Management: Leachate generated during composting varies with seasons. The compost pad surface should be designed with proper gradient and surface drainage system so that the entire leachate from windrows is directed through drainage pipes to collection tank. This leachate can be utilized for moistening the waste placed in the windrows, as required. In case leachate production is higher than consumption, the leachate tank should be provided with treatment facilities for treating before disposal. Normally, the leachate tank is provided with a surface aerator for reducing the BOD content. Treated leachate

could be subsequently used for irrigation as a fertiliser. (Detailed design of aerobic windrow composting plants from 50 – 500 TPD MSW input capacity is available in the ‗Inter-Ministerial Task Force on Integrated Plant Nutrient Management using City Compost', Government of India, 2005.)

Biogas plant

- The initial filling for a new biogas plant should if possible consist of either slurry from another plant or fresh cattle dung.
- After removing straw and waste fodder from the dung, it should be mixed sufficiently with water to avoid separation of solid and liquid material inside the digester. The amount of cattle dung should be 2-3% of the total amount of slurry for initial loading; it can be diluted with water. As a thump rule, 1kg of dung requires 1liter of water.
-The substrate should be free of stalks and other impurities in order to avoid scum formation and blockage of the inlet and outlets pipes.
- Cow dung, waste from kitchen, water from rubber sheet and other degradable waste can be filled in the Plant.
- Egg shell, coconut shell, orange, lime, pickles, disinfectants, dettol, soap water, plastic, wood pieces, metal and sand cannot be put in the plant.
- Chopping of the fodder into pieces of 3-5 cm length for fast digestion.
- The plant must be fed regularly in order to achieve regular gas production.
- For units with water jacket, add a little kerosene or oil or aqua culture to the water or else use mosquito net for preventing the possibility of mosquito growth.
- The overflowing slurry should be removed from the outlet. Otherwise it can block the flow and the gas pressure might increase until it escapes through the inlet pipe or blows off the water trap. Therefore the outlet and the slurry canal must be cleaned.
- Cleaning the slurry and feeding the plant should be a part of daily routine. The problem becomes less, if a proper slope is maintained and the slurry canal is shaded off from direct sunshine.
- The slurry can be directed towards the plants for fertilization.
- Depending on the type of waste, the plant may need several days to weeks to achieve a stable digesting process. Cattle dung can be expected to yield good gas production within one or two days.

Operation and Maintenance Protocol of Slaughter Houses

Slaughtering of animals should be done in hanging position. This will helps to segregate waste at different stages to recover resources to reduce quantity of waste. The O&M Protocol shall be followed as given below;

1. Reception of animals using raised platform and ramp.
2. Antimortem examination by Veterinary Surgeon.
3. Segregation of diseased animals keeping it in isolation pen

4. Resting of animals in Lairage for a period of 24 hours and they should not feed fodder or any other thick food except water.
5. Leading of animals to slaughter hall through barricade and ramp.
6. Butchers should have butchers license and ensure their entry of slaughter house through main entrance.
7. Butchers should change their dress and entry into slaughter hall with working dress after taking bath.
8. Tying of legs using slink.
9. Killing of animals in cubicles using Halal Method/Stunning in Stunning box.
10. Hooking of tied leg of animal to the hook of electrical hoist and raise to the 5 m high rail. Use of manual hoist in case of power failure.
11. Hanging of animal in head down position and move to outside the cubicle for bleeding and blood collection in wheeled tray and conical hopper.
12. Conveyance of blood to store room.
13. Lowering of animal to 3 m high rail and transfer to shackle and chain system and simultaneous release of electrical hoist.
14. Removal of horn and hooves using scissors type cutter and move carcass to next section manually.
15. Evisceration (removal of contents from stomach) and transferring of stomach content to wheel barrow placed underneath.
16. Washing of carcass
17. Removal head using meat cutter
18. Removal of hides manually
19. Washing of carcass
20. Splitting of carcass to four pieces and transfer it to hook in the rail provided in despatch section at 2 m height.
21. Post mortem examination of meat by Veterinary Doctor.
22. Despatch of meat with seal to market/meat stall.
23. Removal of blood, hide, hook, horn head etc to store for further process in vessels.
24. Heating of blood with rice bran in vessels for making fish feed or manure.
25. Heating of fat recovered from stomach/oil trap of waste water treatment plant for melting and safe storage.
26. Salting of hide for safe storage, if it is to be stored in the compound.
27. Heating of bones in vessels for removal of fat and safe storage of bones.
28. Solid Waste except undigested stomach content to biogas plant for treatment.
29. Undigested waste from stomach and dung to compost plant for treatment
30. Wash water to septic tank and soak pit for treatment and disposal.
31. Washing of slaughter house with water first and then with hot water from solar water heater.
32. Use of pressure jet water cleaner for minimising water use.

Guideline for Cleaning and Hygiene Maintenance

The following general guideline should be followed for hygiene maintenance within the slaughter house.

- All parts of the product zone should be readily accessible to sight and reach for cleaning and

inspection

- Where necessary for proper cleaning and inspection, equipment should be easily demountable. To facilitate this dismantling, quick opening devices that require no tools or, such simple tools as a mallet and an open – end wrench shall be provided. Bayonet joints, butterfly clamps, spring bolts, and other similar devices are desirable for connecting or closing parts of equipment. Where parts should be retained by nuts and bolts, the design shall provide for fixed studs with wing nuts, rather than bolts to a tapped hole
- Interior corners of equipment shall be provided with radii (minimum 6mm), except where greater radii are required to facilitate drainage and cleaning.
- All welding within the product zone shall be continuous, smooth, even and relatively flush with the adjacent surfaces
- All parts of the product zone shall be free of recesses, open seams and gaps, crevices, protruding ledges, inside threads, inside shoulders, inside bolts or rivets and deal ends.
- Where necessary for sanitary maintenance, equipment shall be constructed and installed so as to be completely self-draining
- Care shall be taken to prevent contaminating product by lubricants used in overhead motors, gears, and similar devices. If drip pans are necessary, they should be easily accessible for inspection and removable for cleaning.
- All safety or gear guards shall be readily removable for cleaning and inspection
- All external surfaces that do not contact with food products shall be free of pen seams, gaps, crevices and inaccessible recesses.

PUBLIC SWIMMING POOLS

Care must be taken during the design, operation and maintenance of the public swimming pools. Safety parameters like water quality, Safety equipments, provision of showers, lighting arrangements etc are to be considered starting from its design stage for providing the service to the customers. Swimming pool needs to be designed taking into consideration recirculation of water with proper disinfection as well as various safety factors.

DESIGN

All swimming pools shall be designed and constructed to withstand all anticipated loading for both full and empty conditions. All appurtenances to the pool, such as diving boards and slides, shall be designed to carry the anticipated load. Designers may refer IS 6494 for providing the guidance on the procedures and the precautions to be taken during construction of swimming pool to ensure the water tightness of the structure.

***Shape* -** The shape of any swimming pool shall be such that the circulation of pool water and control of swimmers' safety are not impaired.

- A long and rectangular pool may be ideal for sports and exercise as it gives length and breadth, but the shape of a pool for recreation largely depend on the choice of the owners, available space for making the pool and the design of the house.
- In sports normally the swimming pool are 50 m long, minimum 21 m wide and 1.8 m overall depth.

There shall be no underwater or overhead projections or obstructions which would endanger patron safety or interfere with proper pool operation. All corners formed by intersection of walls and floor shall be rounded with at least a 1-inch (2.5 cm) radius.

Construction Material

Swimming pools shall be constructed of materials which are inert, stable, non-toxic, watertight and enduring. Sand or earth bottoms are not permitted. Bottom and sides must be white or a light colour, with a smooth and easily cleanable surface. The finish surface of the bottom in shallow areas shall be slip-resistant.

Floor Slopes

Slope of the floor of the pool should be made downward toward the main drain. All slopes should be uniform. The slope in shallow areas should not exceed 30 cm vertical in 3.6 m horizontal except for a slope directed downward from a transition point, which shall not exceed 30 cm vertical in 1m horizontal. In portions of the pool with a depth greater than 1.5 m, the front slope of the deep area shall not be steeper than 30 cm in 1 m. The slope requirements are illustrated in Fig.1.

Transition Point

The boundary line between the shallow and deep areas shall be marked by a line of contrasting colour at least 4 inches (10 cm) wide on the floor and walls of the pool and with a buoyed safety rope with coloured buoys, installed at least 30 cm on the shallow side of the transition point. In other pools having adjoining shallow and deep areas, a safety rope with coloured buoys shall be installed where the water depth reaches 1.5 m.

Pool Walls

Where the pool depth is 1 m or less, pool walls shall be vertical to the floor and the junction of the wall with the floor shall consist of a cove with a radius not exceeding 15 cm. Where the pool depth exceeds 1 m, pool walls shall meet one of the following criteria:

i) The wall shall be vertical for a distance of at least 1.5 m below the water level, below which the wall may angle to the floor; or

ii) The wall shall be vertical for a distance of at least 1 m below the water level, below which the wall shall form a curve to the floor. The curve shall be tangent to the pool wall and shall have a radius of curvature at least equal to the vertical distance between the center of curvature and the pool floor.

All junctions between pool walls, and between pool walls and the pool floor, shall be coved with a minimum radius of 25 mm.

Water Depth

Water depth at the shallow end of the swimming pool should be around 1 m. The beginner's area of the pool shall be visually set apart from, but may be adjoined to the shallow area and shall not adjoin to the deep area.

Diving Area

The dimensions of the diving area of a pool that has diving boards or platforms of three meters or less in height shall conform to those shown in Fig.2. In such pools, the distance from the plummet to the pool wall ahead shall be at least 11 m. Swimming pools with diving facilities in excess of three meters in height shall comply with dimensions given in Table 1 and illustrated in Fig.3. If the pool is used for swimming as well as diving then transition slope from the deep to the shallow end shall not be steeper than one in three.

There shall be no obstruction extending from the wall or the floor into the clear area of the diving portion of the pool. There shall be an unobstructed distance of 5 m above the diving board measured from the center of the front end of the board, and this clearance shall extend at least 2.5 m behind, 2.5 m to each side, and 5 m ahead of the measuring point. Handrails shall be provided at all steps and ladders leading to diving boards. Platforms and diving boards which are one meter or higher shall be protected with guard railings. One meter diving board guard rails shall be at least 76 cm above the diving board and extend to the pool water's edge. All platforms or diving boards higher than one meter

shall have guard rails which are at least 76 cm above the diving board or platform and extend to the pool water's edge. Three meter platforms and boards shall have a side rail barrier.

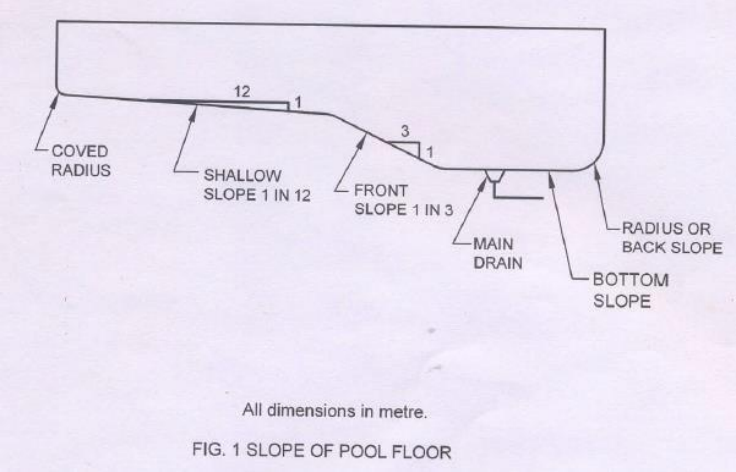

FIG. 1 SLOPE OF POOL FLOOR

Ladders, Step-Holes, Steps and Ramps

Swimming pool shall have at least two means of egress, located near opposite ends. A means of egress shall consist of a ladder, step-holes and grab rails, stair, ramp, or zero-depth edge. Pools of 9 m or more in width shall have at least four means of egress that shall be located near each end and on opposite sides. The distance from any point with a depth greater than 76 cm in the swimming pool to a means of egress shall not exceed 15 m. At least two ladders or sets of step-holes shall be located at the deep area of the swimming pool when more than one diving board is provided.

Step-holes shall have a minimum tread depth of 12 cm. Where step-holes or ladders are provided, there shall be a handrail or grab rail at the top on both sides which extends to the edge of the pool. Steps shall be of contrasting colour or marked to contrast from the pool floor and have uniform size treads of at least 30 cm and a rise of no more than 30 cm. Steps shall be located where the water depth is 1.4 m or less and shall have no pointed or sharp edges. One sturdy handrail or grab rail per 4 m of step width or fraction thereof, extending the length of the steps, shall be provided. All ladders, step-holes, and steps shall have slip-resistant surfaces. Slope of the ramp shall not be more than one in twelve. Ramp shall have a slip-resistant surface; handrails on both sides and its width shall not be more than 1.4 m.

Table 1 Dimensions of swimming pools with diving facilities in excess of three meters in height