(For official use only)

सत्यमेव जयते

GOVERNMENT OF INDIA

MINISTRY OF RAILWAYS

LEAKAGE TREATMENT IN BUILDINGS

CAMTECH/2006/C/LEAKAGE/1.0

June - 2006

Centre
for
Advanced
Maintenanc***e***
TECHnology

उच्च अनुरक्षण प्रौद्योगिकी केन्द्र

Excellence in Maintenance

Maharajpur, GWALIOR - 474 020

LEAKAGE TREATMENT IN BUILDINGS

Foreword

Indian Railway holds the major chunk of civil engineering assets in the country. It is looked at as a premier organisation in respect of quality & workmanship.

It has been observed that even after ensuring strict quality control, workmanship leakage do occur in buildings. Adopting good construction practices/techniques and precautions during construction stage can prevent these leakages.

CAMTECH has made a nice attempt to provide knowledge about leakage, their causes and general remedies and also to give an idea about prevailing waterproofing system. Efforts have been made to cover need/requirement of the field personnel who are directly involved in construction and maintenance.

I hope this handbook will certainly prove to be a valuable source of technical knowledge and will be quite helpful for civil engineering personnel in railways.

CAMTECH/Gwalior ***Kul Bhushan***
Date : 27 .06.2006 ***Executive Director***

Preface

Indian Railway having a lot of stations, buildings, offices and residential accommodations is vast network spread all over India. Large number of buildings facing problem of leakage, the need of a suitable ready reference book on leakage treatment has been felt.

Objective of this book is to provide information about causes of leakage and their remedies, materials for damp proofing, prevailing system for water proofing in buildings. Every effort has been made to make this handbook useful to civil engineering personnel.

This handbook does not supersede any existing information from Railway Board, IRWM, RDSO etc. *This handbook is not statutory & contents are for the purpose of guidance only.* Most of the data, sketch and information mentioned herein available in some form or the other in various books or printed matter.

I am grateful for the assistance given by Shri D.K.Shrivastava, CTA/Civil/CAMTECH, who went through the complete text, collected information, data etc. Nice data entry has been done by Shri Ramesh Bhojwani, Console Operator, CAMTECH.

We welcome valuable suggestions from our readers for further improvements.

CAMTECH/Gwalior ***A. K.Dadarya***
Date : 23.06.2006 ***Director/Civil***

CONTENTS

Sr. No.	Description/Topic	Page Nos.
	Foreword	*i*
	Preface	*ii*
	Content	*iii*
	Correction Slip	*iv*
1.0	**Introduction**	**01**
2.0	**Causes of leakage**	**02**
3.0	**Material for damp proofing**	**10**
4.0	**Damp proofing methods**	**12**
5.0	**Damp proof treatments**	**14**
6.0	**Water proofing of flat roof**	**17**
7.0	**Prevalent water proofing systems**	**21**
8.0	**Advanced techniques for water proofing**	**37**
	References	*41*
	Notes	*43*

***

ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/2006/C/LEAKAGE/1.0/CS. # XX date ……

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No. of C.Slip	Date of issue	Page no. & Item no. modified	Remarks

Chapter 1

Introduction

One of the basic requirements in case of all buildings is that the structure should remain dry as far as possible. If this condition is not satisfied, it is likely that the building may become un habitable and unsafe from structural point of view. The entry of water or dampness into a building is termed as leakage.

Leakage in buildings is common and it is important to under stand the causes and measures to be taken for their prevention.

Most of the building materials having pores in their structure in the form of intermolecular space, as for example concrete, mortar, burnt clay bricks etc. expand on absorbing moisture from atmosphere and shrink on drying. These movements are reversible, i.e. cyclic in nature and are caused by increase or decrease in inter–pore pressure with the moisture changes, extent of movement depending on molecular structure and porosity of the material.

Building materials absorb the water from atmosphere or water flows over it and after condition of saturation, the seepage through the component of a building like, walls, RCC members, roof terraces and plastering etc. takes place.

Another reason for leakage is porosity of the building materials when buildings are exposed to atmosphere; water absorbed by the materials gradually and resulted in leakage through roof terrace and walls exposed to atmosphere.

Leakage in buildings usually occurs in walls, flat roof, and parapet wall and pitched roof etc.

Each of above has been covered in this book and feasibility and general remedial measures in specific cases has been suggested.

***

Chapter - 2

Causes of leakage

2.1 General

Action of rain: If the faces of wall exposed to heavy showers of rain are not suitably protected, they become source of leakage in a structure. Similarly leakages from roofs also permit rainwater or drain water to enter in a structure.

Exposed tops of walls, parapet walls and compound walls should be liable to get dampness or leakage in building.

Condensation: The moisture is deposited on the walls, ceilings etc. due to condensation process.

Miscellaneous: There are many miscellaneous causes of dampness or leakage as mentioned below:

i) If the structure is located on a site, which can not be easily drained off, leakage will enter the structure.
ii) The orientation of a building is also an important factor. The wall obtaining less sunshine and heavy showers of rain are liable to become damp and leaky.
iii) Newly constructed walls remain damp for a short duration.
iv) Very flat slope of a roof may also lead to the penetration of rainwater or drain water, which is temporally stored on the roof.
v) The dampness also caused due to bad workmanship in construction such as defective rain water drain and water supply pipe connections, defective joints in the roofs, improper connection of the walls etc.

2.2 Causes of seepage/ leakage in buildings and remedies

Seepage/ leakage mainly occurs from walls and roofs.

2.2.1 Leakage through roofs:

The causes of seepage/leakage through roofs are as under:

(i) Lack of proper slope thereby causing stagnation of water

Remedy: Adequate slope should be provided to prevent stagnation of water.

(ii) Lack of proper drainage system

Remedy: Sufficient drainage pipes should be provided.

(iii) Lack of gola, coping etc.

Remedy: Gola at junction point and coping on the top of the wall should be provided.

(iv) Poor maintenance of water pipe connections and joints

Remedy: Maintenance of water supply pipe connections and fitting should be leak proof.

(v) Poor quality of construction

Remedy: Good workmanship should be adopted during construction.

2.2.2 Leakage through walls

The causes of seepage/leakage through walls are as under:

(i) Non provision of damp proof course
(ii) Lack of plinth protection
(iii) Lack of chajjas, facias over openings
(iv) Poor orientation and wind direction
(v) Lack of stone cladding/ waterproof plastering and painting.

2.2.3 Leakage from upper floor

The causes of leakage from upper floor are as under:

(i) Crack in the closet and its trap

Remedy: It should be replaced.

(ii) Leakage from the concealed pipe joints

Remedy: It should be examined and replaced the same.

(iii) Encrustation and consequent formation of holes in the concealed water supply pipes, leaking out water in the surroundings.

Remedy: It should be replaced. This situation should normally arise after 20/30 years when complete pipe lines has rusted, the only remedy in this case is to replace the complete pipe line.

(iv) Improper disposal of washbasin waste pipe towards the mouth of nahani trap and also improper finishing of the floor area above the nahani trap.

Remedy: The proper disposal of waste pipe of washbasin towards the mouth of nahani trap is shown in the figure 1.

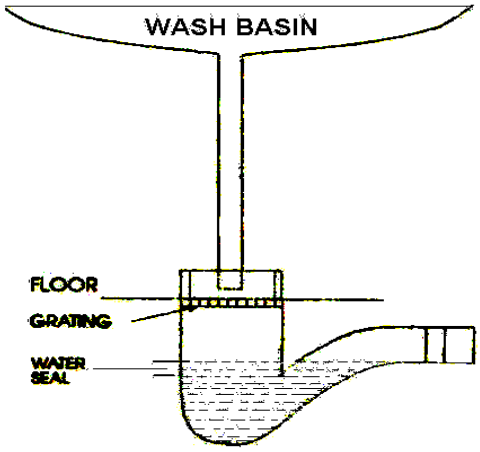


Figure No. 1

2.3 Effect of leakage

The structure is badly affected by dampness. The prominent effect of dampness is as follows:

i) A damp building creates unhealthy conditions for those who occupy it.
ii) The metals used in the construction of the building are corroded.
iii) Unsightly patches are formed on the wall surfaces and ceilings.
iv) Decay of timber takes place rapidly due to dry rot in a damp or leaky atmosphere.
v) The electric fittings are deteriorated due to dampness.
vi) The material used as floor coverings are seriously damaged.

2.4 Maintenance for seepage/ leakage

A well planned/ executed building should also have good maintenance programme. This includes

(a) Day to day maintenance.
(b) Preventive maintenance

Seepage in buildings is mainly due to neglected maintenance. The following steps are needed for avoiding stagnation of water and resulting seepage/ leakage in buildings.

- Cleaning of terraces, drains before monsoon and when chocked.
- Replacement of leaky/damaged washers in fittings.
- Replacement of leaky/damaged pipe line, gate valves. etc.
- Replacement of leaky/damaged gasket in flanges.
- Replacements of leaky/damaged joints in CI drain pipes.
- Replacement of leaky/damaged MS trays under Air Handling Units.

2.5 Measures to avoid seepage/ leakage in buildings

2.5.1 Leakage through walls and roof.

The following measures are needed to avoid seepage/leakage through walls :

- Provide damp proof course 25 to 40 mm thick generally of cement concrete mix 1:2:4 at plinth level using 10mm nominal aggregate with bitumen paint (IS:73 @ 1.5 kg per meter square) at the top. Add integral water proofing compounds confirming to IS.

- Just before the monsoon, the roof should be inspected in detail and any crack/ damage to top of parapet, bata, khurra, pointing (if any) should be repaired. Such annual repairs if carried properly would obviate the need of costly thorough repairs.

- Provide good compacted earth (preferably cc apron or brick-on-edge with good 1:3 cement mortar pointing) with descending slope away from plinth (plinth protection) on outer side of wall. This will stop seepage of water from soil/ foundation to superstructure. The top of plinth protection must be slightly lower than the DPC. The junction of wall and apron should be give a concave shape so that no water seeps in the foundations.

- Provide chajjas and facias on openings (windows, doors, etc.) with a drip course. This will stop entry of rainwater. Top of chajjas should have a slope of 1 in 40 and concave gola at the junction with the wall (as shown in figure no.2). Open box types of chajjas are not desirable, as dirt and the other material tend to choke the openings in such chajjas leading to ponding of the same. It leads to damping of wall.

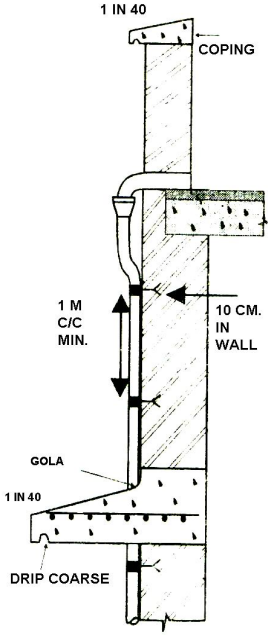


Figure 2

- Provide coping on parapet (as shown in figure no.2). Use sealing compound confirming to IS : 1834 in joints to render them water impervious.

- **Down take pipes:** Down take pipes (shown in figure 2) should be provided @ 100/150 mm dia pipe for every 30/40 sq. m of roof area depending upon the intensity of rain fall in a particular area. In case any existing building has provisions, which do not meet the above criteria, it should be modified accordingly. PVC pipes should be preferred to AC/CI pipes as they are lighter and are also not susceptible to breakage/theft. They are also maintenance free. Because of longer length being available in PVC pipes, number of joints is also reduced, their by reducing the maintenance efforts and problems attendant with joints.

- The condition of wall plaster and pointing on roof (if existing) should be inspected thoroughly once a year during the annual periodical inspection of quarters by SE(Works)/ AEN's. As soon as if patch is noticed where plaster/ pointing has decayed, the same should be removed, surface cleaned properly and re-plaster/ re-pointing done in proper manner. When about 50-70% area of plaster/pointing is considered worn out, complete re-plastering and re-pointing should be done. It should be appreciated that every building material has a certain life after which it is disintegrated because of various environmental and other reasons. It is generally noticed that complete re-plastering of exterior surfaces and roof pointing requires replacement after its certain life. Hence it should be planned accordingly as a regular maintenance activity, otherwise, irresponsible damage would be caused to the building.

- Repainting/ plastering also minimises the seepage.

- Orientation of building and wind direction also plays important role in minimising seepage of rainwater from external surfaces. Provide minimum openings in walls on windward side.

- **Rising dampness:** Rising dampness of buildings is due to absence/failure of DPC. The solution lies in replacement of lowest possible bricklayer with new DPC or grouting the wall with chemicals using injection techniques specified by the respective manufacturers.

- **Apron:** Apron plays a very important part in safeguarding the foundation of the buildings from ingress of water around the building at least 90 cm wide apron with proper slope towards outside should be provided all around the building. Concave gola of 80 mm size should be provided at the junctions of wall and apron so as to prevent ingress of water at the junction.

- **Expansion joints:** Expansion joints can be perennial source of leakage if they are not provided and maintained in satisfactory condition. For preventing leakage at expansion joints as well as their smoother functioning for expansion. The sealing compound, which is used for sealing the expansion joints, should be inspected once a year carefully about its integrity. If the condition of the sealing at joint shows signs of decay, it should be replaced. If replacement is done in time, there will be huge saving in maintenance of buildings.

2.5.2 Safeguard for Plumbing Provisions

- Proper detailed layout drawings of sanitary - plumbing distribution system should be available. This should include all important junctions, slopes etc. Strict supervision to check slopes is essential before finally filling the joint including pressure testing before waterproofing or tiling.

- Work should carry out only with proper tools for all the plumbing such as their cutting, breaking, threading etc. Ensure proper caulking. Waterproofing once executed should not be disturbed or damaged for any reason.

- Proper clamping by clips in adequate numbers and location is essential to keep the pipes in steady position. Verify and satisfy about the adequacy of duct provisions for efficient layout of pipelines with necessary floor-to-floor access for maintenance. Water pipes at terrace should run along the parapet wall with proper support.

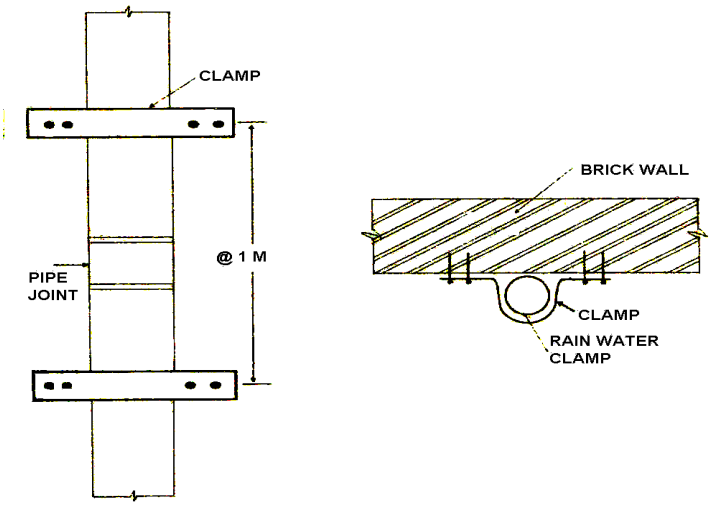


Figure - 3

Ensure proper placement and cross sectional provision and adequacy of rain water pipes. This is most important. Ensure provision of all inlet and outlet accessories for underground and overhead tank placed in the structure.

- Pipes should be fixed to walls with the help of pipe clamps embedded in brick wall spaced at an interval of 1m. It is advisable to provide clamp on both side of joint as shown in figure no.3.

- When pipe is passing through a wall or floor, a mild steel tube sleeve should be fixed and gap sealed as shown in figure no.4.

- GI pipes embedded in wall, ceiling or floor should be painted with bitumen paint or covered by black tape.
- PVC pipe embedded in soil or masonry should be coated with bitumen paint.
- Concealed pipeline can be provided just like concealed electric wiring. In such cases it is advisable to cover the pipe with tile in a row so that the pipe line can be exposed by removing a row of tile. All concealed pipe should be properly painted or covered with black tape before fixing shown in figure 5.
- Use bends and elbow fittings at correct locations.
- Concealed pipe should not be provided in areas where iron content of water is high it poses enormous maintenance problem.
- If the water supply and drainage pipes cross each other, provide offset in water supply system. It applies for anti-syphonage pipe. Give appropriate priority to locate drainage down take pipes in preference to water distribution system.
- The jointing of pipes must be supervised be SSE (Works) cent percent. RTV Silicon compounds (manufactured by Pidilite, STP etc.), though costly, may be used where leak proof joints is of paramount importance.

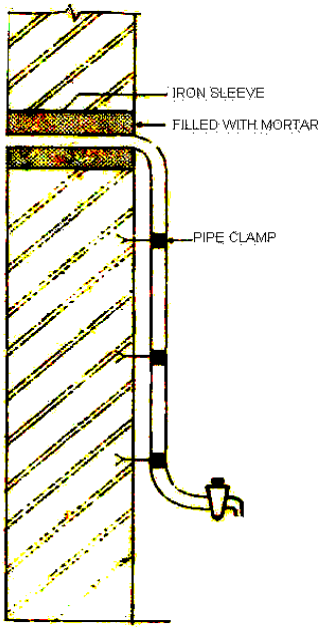


Figure - 4

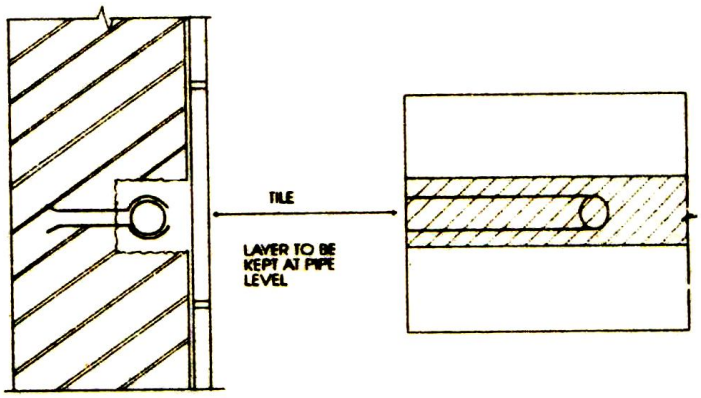


Figure - 5

2.6 Dampness and its causes

Visual Effects	Occurrence	Time	Reasons
Line of efflorescence more or less horizontal, with stained and damp area below.	Just above floor level	All the time although height may vary with the season	Rising ground moisture by capillary action
Persistent	One spot	All the time, but may dry up for a while in summer	Plumbing leak.
Widespread efflorescence and moulds	Mainly on massive construction	During first year after building or longer. There are impervious surfaces	Entrapped water introduced during construction
Dampness widespread or in patches, without efflorescence but often with moulds	On or behind cold surface	In cold weather or on sudden change from cold to warm humid weather.	Condensation
Dampness in patches, with a little or no efflorescence	On plastered surfaces	Appears when air is humid; disappears when air is dry.	Condensation, encouraged contamination with deliquescent salts.
Dampness in patches with brown staining	Wall surface behind cooking platform and chimney hood.	More marked in humid air	Condensation in flue.
Efflorescence or staining in patches, often with rings spreading out from focal points	External surfaces mainly exposed to rain, often near opening or external architectural features	After heavy rain or rain for longer period without a good drying weather	Rain penetration through walls.
Water drops spreading out from focal points.	Internal surfaces mainly exposed to rain, often near openings or external architectural features.	After heavy rain or rain for a longer period without a good drying weather	Rain penetration through walls

***

Chapter - 3

Material for Damp proofing

3.1 Requirement of ideal material for damp proofing

Following are the requirement of an ideal material for damp proofing.

- It should be impermeable or should have very low permeability.
- It should have strong adhesion with substrata.
- It should be sufficiently elastic so as to withstand expansion and contraction of substrata due to temperature fluctuations.
- It should have high resistance to abrasion and cracking.
- It should be resistant to ultra violet rays.
- It should be breathable i.e. permit vapour transmission.
- Its application should be easy.
- It should be durable.

3.2 Materials used for damp proofing

The materials commonly used to check dampness can be divided into the following four categories:

a) **Flexible material:** Material like bitumen felts, plastic sheeting (Polythene sheet) etc.
.

b) **Semi rigid materials:** Materials like mastic asphalt or combination of materials or layers.

c) **Rigid materials:** Materials like first class bricks, stones, slates, cement concrete etc.

d) Grout consisting of cement slurry and acrylic based chemicals/polymers.

3.2.1 Commonly used materials for damp proofing.

- **Hot bitumen:** This is a flexible material and is placed on bedding of concrete or mortar. This material should be applied with a minimum thickness of 3 mm.

- **Mastic asphalt:** This is semi rigid material and it forms an excellent impervious layer for damp proofing. Good asphalt is a very durable and completely impervious material. It can withstand only very slight distortion. It is liable to squeeze out in very hot climates or under heavy pressure. Experienced men of specialist firms should lay it.

- **Bituminous felts:** This is a flexible material. It is easy to lay and is available in rolls of normal wall width. It is laid on a layer of cement mortar. An overlap of 10 cm is provided at the joints and full overlap is provided at all corners. The laps may be sealed with bitumen, if necessary. Bitumen felt can accommodate slight movements, but it is liable to squeeze out under heavy pressure and it offers little resistance to sliding. The material is available in rolls and it should be carefully unrolled, especially in cold weather.

- **Metal sheets:** The sheets of lead, copper and aluminium can be used as membranes for damp proofing.

- **Combination of sheets and felts:** A lead foil is sandwiched between asphalt or bituminous felt. This is known as lead core and it is found to be economical, durable and efficient.

- **Stones:** two course of sound and dense stones as granites, slates, etc. laid in cement mortar with vertical breaking joints can work as an effective damp proofing course. The stones should extend for full width of the wall. Some times stones can be fixed, as in case of roof surfaces, on the exposed faces of the wall, etc.

- **Bricks:** Dense bricks, absorbing water less than 4.5 % of their weight, can be used for damp proofing at places where damp is not excessive. The joints are kept open. Such bricks are widely used when a damp proofing course is to be inserted in an existing wall.

- **Mortar:** The mortar to be used for bedding layers can be prepared by mixing one part of cement and three parts of sand by volume. A small quantity of lime is added to increase the workability. For plastering work, the water-proof mortar can be prepared. It is prepared by mixing one part of cement and two parts of sand and pulverised alum at the rate of 12 kg/cum of sand.

- **Cement concrete:** A cement concrete layer is in the proportion of 1:2:4 is generally provided. Depth of cement concrete layer varies from 40 mm to 150 mm.

***

Chapter - 4

Damp proofing Methods

4.1 General principles of damp proofing:

The general principles to be observed in case of all damp proofing methods are as follows:

- The damp proofing course may be horizontal or vertical.
- The horizontal damp proofing course should cover the full thickness of the wall.
- At junction and corners of a wall, the horizontal damp proofing course should be laid continuous.
- The mortar bed, which is prepared to receive the horizontal damp-proofing course, should be even.
- The damp proofing course should be laid so as to make a continuous protection.
- The damp-proofing course should not keep exposed to on the wall surface, other wise it is likely to be damaged by carpenters, tile layers, etc.

4.2 Method of damp proofing

Due to leakage in building it is affected badly by dampness. Following methods are generally adopted to prevent the dampness in a structure.

4.2.1 Membrane damp proofing

This consists in providing layer or membrane of water repellent material between the source of dampness and the part of the structure adjacent to it. This type of layer is commonly known as Damp Proofing Course and it may comprise of material like bituminous felts, mastic asphalt, silicon, epoxy, polymers, plastic or polythene sheets, cement concrete etc. Depending upon the source of dampness, DPC may be provided horizontally or vertically in walls and floors.

4.2.2 Integral damp proofing

This consists in adding certain water proofing compounds with the concrete mix to increase its impermeability. Such compounds are available in market in powdered as well as liquid form. The compounds made from clay, sand, or lime (chalk, talc, fuller's earth etc.) help to fill the voids in concrete and make it water proof.

Another form of compound like alkaline silicates, aluminium sulphates, calcium chloride etc. reacts chemically when mixed in concrete to produce waterproof concrete. Many commercially made preparation of water proofing compounds are commonly used. The quantity of water proofing compounds to be added to cement depends upon the manufacturer's recommendations.

4.2.3 Surface treatment

As described earlier the moisture finds its way through the pores of material used in finishing. In order to check the entry of the moisture in to the pores, they must be filled up. Surface treatment consists in filling up the pores of the surface subjected to dampness. The use of water repellent metallic soaps such as calcium and aluminium oleates and stearates is much effective in protecting the building against the ravages of heavy rain. Bituminous solution, cement coating, transparent coating, paints and varnishes fall under this category. In addition to other surface treatment given to walls, the one commonly used is lime cement plaster. The walls plastered with cement, lime, and sand mixed in proportion of 1:1:6 is found to serve the purpose of preventing dampness in wall due to rain effectively.

4.2.4 Guniting

This consists in depositing an impervious layer of rich cement mortar over the surface to be water proofed. The operation is carried out by use of a machine known as cement gun. The assembly broadly consists of a machine having arrangement for mixing materials and a compressor for forcing the mixture under pressure through a 50mm dia flexible hosepipe. The hosepipe has a nozzle at the free end to which water is supplied under pressure through a separate connection. The surface to be treated is first thoroughly cleaned of dirt, dust, grease or loose particles and wetted properly. Cement and sand usually taken in proportion of 1:3 to 1:4 are then fed into the machine. This mixture is finally shot on the prepared surface under a pressure of 2 to 3 kg/sq.cm by holding the nozzle of the cement gun at a distance of 75 to 90 cm from the working face. The quantity of water in this mix can be controlled by means of regulating valve provided in the water supply hose attachment. Since the material is applied under pressure it ensures dense compaction and better adhesion of the rich cement mortar and hence the treated surface become waterproof.

4.2.5 Cavity wall construction

This consists in shielding the main wall of the building by an outer skin wall leaving a cavity in between the two. The cavity prevents the moisture from travelling from the outer wall to the inner wall.

***

Chapter - 5

Damp proof treatment

5.1 Damp proofing treatment in building

It can be broadly divided in to the following categories:

i) Treatment to walls
ii) Treatment to parapet wall
iii) Treatment to pitched roof
iv) Treatment to flat roofs

5.1.1 Treatment to walls

As explained earlier wall can get damp due to penetration of moisture from its external face to internal one, due to porosity of bricks and mortar joints. Various treatments given to exposed surface of walls to prevent dampness include pointing, plastering, painting etc. It is observed that plaster made out of cement, lime and sand mixed in proportion of 1:1:6 serve as very effective rendering to protect the wall against dampness in normal weather conditions. In area of heavy rainfall, cement plaster of 1:4 mixed with water proofing compounds serves the purpose effectively. In exposed brickwork, dampness can be prevented by painting the surface with waterproof cement paint or with colourless liquid water proofing compounds.

5.1.2 Treatment to parapet walls

The flat roof has a parapet wall and there are cracks in it or its plaster is very porous or defective, rainwater may find an easy access to the wall below and make the wall and some portion of the ceiling damp. Rainwater may also leak through cracks at the junction of the parapet wall and the roof slab. In cases where asphalt layer is provided over the grading material for the water proofing treatment to the roof slab, the asphalt layer covering the roof is turned up against the parapet for a height of at least 15-cm. Providing coping of brick, concrete or stone on its top further protects the parapet wall.

In case, the water proofing of roof is carried out by providing lime terracing, the layer of terracing is taken right up to the edge of the roof and a 15 cm high rounded triangulated fillet is built up there. This is necessarily done to prevent the soaking of water through the parapet in case the rain water pipes get choked up and the water stands on the roof. In addition a drip course is also some times provided over the lime gola to prevent water from parapet to fall directly over its junction with roof.

5.1.3 Treatment to pitched roofs

In general rainwater is liable to leak through a pitched or sloped roof on account of the following reasons,

i) Due to insufficient roof slope.
ii) Due to insufficient lap in roof covering material i.e. AC or CGI sheets, tiles, slates etc.
iii) Due to inadequate treatment to rain water gutter.

All the above-referred causes can be taken care of by proper design and construction. However, design and installation of rain- water gutter or valley gutter needs extra special attention with respect to its capacity, position, fixing, water tightness and freedom to accommodate expansion or contraction in any direction. The slope of the gutter should not be flatter than 1: 100 in straight length and it should be made steeper in portion where the gutter is not straight. The gutter should be leak proof and all the joints in the gutter should be made tight. The work of laying roofing should be carefully supervised and it should be ascertained that the sheets or tiles project beyond the edge of the gutter. Lead flashing should be continued up to the vertical face of the parapet wall and should stop inside the body of the wall. As in case of flat roof, stone or brick coping should itself protect the parapet wall. The provision of damp proofing course layer is laid in a valley gutter. If the architect wants to provide a projection in the face wall to decorate the structure, a sloped junction should be stressed. A layer of damp proof course should further protect the junction.

5.1.4 Treatment to flat roofs

All the flat roofs in the modern age are generally constructed with reinforced cement concrete. This material removes all the defects of flat roofs except that the roof should be made waterproof. Detail description is given in next chapter.

5.1.5 Treatment for the roofs of multi-storeyed buildings

In case of multi-storeyed buildings, besides water proofing, thermal insulation is an equally important factor to be kept in view. This is achieved by increasing the thickness of the grading by using economical and effective materials. The water proofing treatment is generally given to roof of multi-storied building and other important structure may be divided in the following steps;

- Painting of the top of roof slab uniformly with a layer of hot bitumen spread at the rate of 1.70 kg of bitumen per square metre of roof surface.

- Spreading immediately coarse sand at the rate of 0.6 cum of sand per 100 sq.m of roof surface when the bitumen is still hot.

- Laying cinder concrete 1:15 (1 cement and 15 cinder of 13 mm and down gauge) in an average thickness of 15 cm, the slope for the proper drainage of roof being given to this layer.

- Laying 7.6 cm thick layer of lime concrete over the consolidated layer of cinder concrete, the lime concrete being prepared by mixing 50 % of mortar consisting of lime and sand mixed in the ratio of 1:2 with brick ballast 25 mm and down gauge.

- Spreading 13 mm thick layer of cement mortar 1:3 and laying tile bricks flat and open jointed over the mortar. Finally grouting the joints in the bricks with cement mortar 1:3

***

Chapter - 6

Water proofing of flat roof

6.1 General

Flat roofs require relatively heavier and costlier water proofing treatment as compared with pitched roof or sloped roofs. The specification of material used for this purpose should be such that it performs the function of water- proofing as well as provides adequate thermal insulation. Stagnation of water on the roof is considered to be the root cause of leakage and dampness in flat roofs. This can be avoided by providing adequate roof slope and rainwater pipes. In case of RCC slab roofing with proper grading above a slope of 1in 100 is considered desirable. This may be achieved either by varying the thickness of the terracing material or by constructing the roof slab with a slope, or by providing part slope in the roof slab and part in the terracing material. In addition to the slope, the size and the spacing of the rain water pipes or the out lets require due consideration for the proper drainage of the roof. In general practice, one 10 cm dia pipe is considered suitable for every 30 sq.m of the roof area to be drained.

6.2 Water proofing of flat roofs

All the flat roofs in the modern age are generally constructed with reinforced cement concrete. This material removes all the defects of flat roofs except that the roof should be made water- proof by employing any one of the following methods;

- **Finishing:** For ordinary buildings of cheap construction, finishing of roof surface is done at the time of laying cement concrete. The finishing of flat roof is carried out in cement mortar of proportion 1:4 i.e. one part of cement and four parts of sand by volume.

- **Bedding concrete and flooring:** In this method, the surface of RCC slab is kept rough and on this surface a layer of concrete is laid. The concrete may be brickbats lime concrete (1:2:4) or brickbats cement concrete (1:8:14), the thickness of concrete layer is about 10 cm. The surface of the bedding concrete is provided by suitable flooring such as tiles, terrazzo, Indian patent stone, etc. A convex joint is provided at the junction of parapet wall and roof.

- **Mastic asphalt and jute cloths:** In this method, a layer of hot mastic asphalt is laid on the roof surface. Jute cloth is spread over this layer. Then, one more layer of mastic asphalt is applied so that the jute cloth is sandwiched between the two layers of mastic asphalt. Sand is then sprinkled over the entire surface of roof. For better grip, lead sheets are inserted at the junction of parapet wall and roof.

6.3 Guidelines for leak proof flat roof

Water proofing system on the roofs get deteriorated due to weathering effect and may become ineffective due to development of cracks/de-bonding/ disintegration of water proofing material etc. Stagnation of water due to undulation in roof surface, provision of less number of drainage pipes or choking of same and improper detailing at junction of parapet and roof etc., are other major contributors in making the roof leaky.

6.4 Basic requirement of arresting leakage of roofs

6.4.1 Provision of adequate slope

It is absolutely essential that roofs are provided with adequate slope to ensure effective drainage. The slope of roof should be such that the water gets drained off quickly by achieving adequate velocity under influence of gravity. A slope of 1 in 100 or steeper, depending upon the type of water proofing system, is required for effective drainage.

6.4.2 Provision of adequate openings

Adequate openings in numbers and size, are necessary to allow the water to get drained off quickly. The number and size of openings depends upon the area of roof and intensity of rainfall of the region in which building is situated. Rain water pipes having bell mouth inlet at the roof surface, give better drainage effect. The spacing in between outlet pipes should not be more than 6 m. The size of rain water pipes, depending upon the average rate of rainfall and roof area, should be as given in table. Average rainfall intensity may be obtained from local office of Indian meteorological deptt.

Sizes of rainwater pipes for roof drainage

Dia of pipes	**Roof area (m^2)**					
	50 m^2	75 m^2	100 m^2	125 m^2	150 m^2	200 m^2
	Average rate of Rainfall in mm/h					
50	13.4	8.7	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7

6.4.3 Proper detailing at junction of roof with parapet wall

Junction of roof with parapet wall is a vulnerable location for leakage. It is necessary that detailing at the junction of roof and vertical face of parapet wall be done very carefully.

Following should be ensured:

- The fillet (angular or concave, not convex) of 75mm should be provided all along the junction of parapet wall with roof.
- Coping on top of the parapet wall should also be provided with adequate slope alongwith the provision of drip course on either side.
- Water proofing system should be extended from roof to parapet wall for a minimum height of 150 mm with a chase. General arrangements at junction of roof with parapet are given in figure 6.

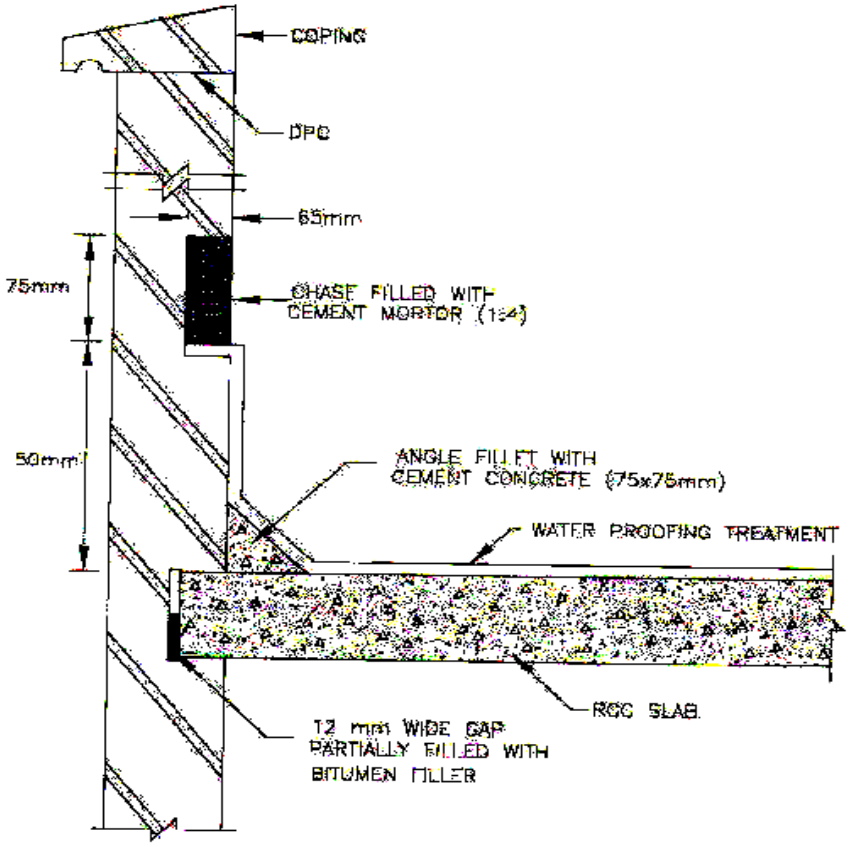
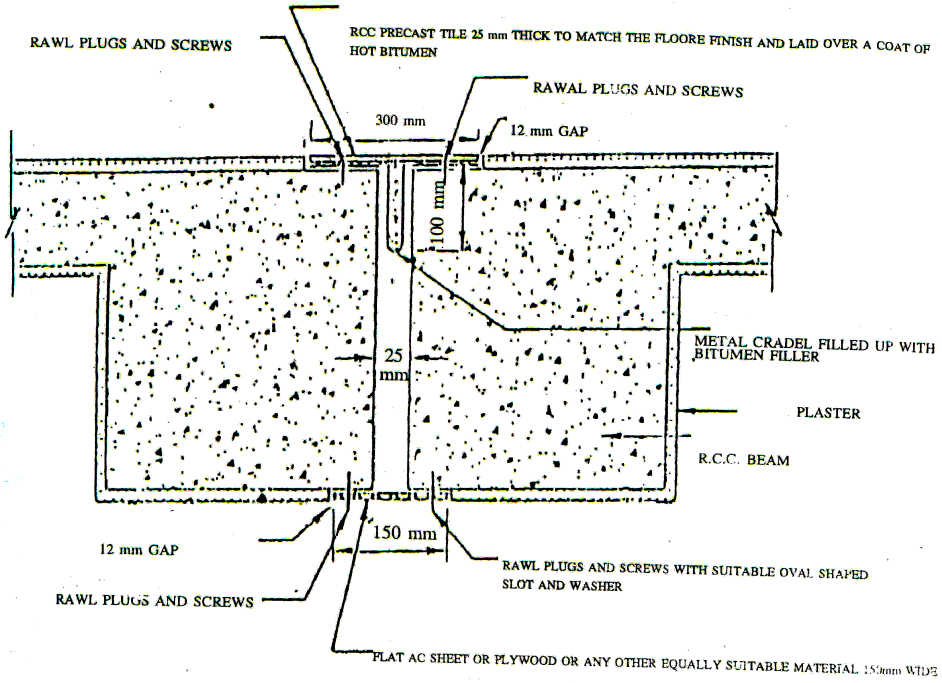


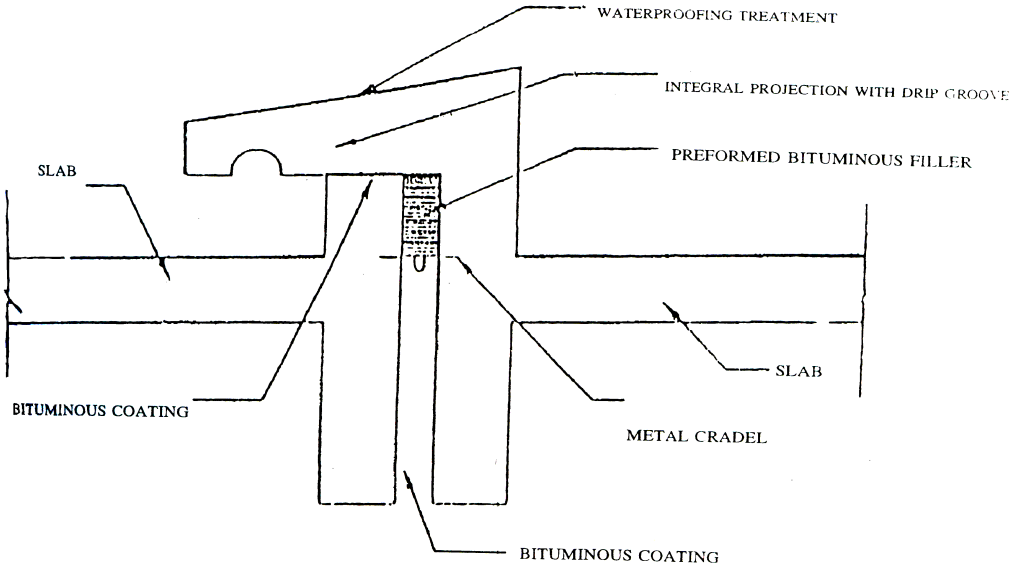
Figure - 6
General arrangement at junction of roof and parapet wall

6.4.4 Expansion Joints:

Expansion joints in buildings/ other structures may become source of perennial seepage due to failure of expansion joint fillers and sealants. Expansion joint should be treated with suitable non-absorbent, compressible, non-brittle and watertight sealants so that no leakage occurs through joint. Joint fillers should confirm to IS: 3414 - *Code of Practice for Design & Installation of Joints in Buildings* or IS:1838 (Pt.I or Pt.II)- *Specification for Preformed Fillers for Expansion Joint in Concrete Pavement and Structures*. Sealing compound should confirm to IS: 1834 - *Specification for Hot Applied Sealing Compounds for Joints in Concrete*. General Arrangements for an expansion joint are shown in figure 7.



Expansion joint at floor level



Expansion joint at roof level

Figure - 7

***

Chapter - 7

Prevalent water proofing system for roofs

7.1 Various water proofing system

i) Lime concrete terracing.
ii) Mud-Phuska treatment.
ii) Water proofing using polyethylene films.
iii) Water proofing using polymer cementitious slurry coatings.
iv) Waterproofing using polymer modified bitumen membranes.
vi) Waterproofing using bitumen felts.

7.2 Lime concrete terracing

This system consists of laying, ramming & compaction of lime concrete to a desired slope. Lime concrete used in this system is a mixture of hydrated fat lime (conforming to IS: 712) pozzolanic material (calcinated clay pozzolana conforming to IS: 1344) and concrete aggregate (broken burnt clay bricks conforming to IS: 3068 or natural stone aggregate conforming to IS: 383) having maximum size 25mm. This system is suitable for new as well as old roofs.

7.2.1 Application Procedure

Various steps involved in this system are as under:

i) Preparation of lime concrete

One part of slaked lime and two parts of burnt brick pozzolana, by volume, shall be mixed on a watertight platform. This shall then be sprinkled with required quantity of water and well ground in a mill or using mechanical grinder to obtain lime pozzolana mortar. Coarse aggregate and lime pozzolana mortar, in proportion of 2½: 1 parts by volume, shall be used for preparation of lime concrete. In case of hand mixing, coarse aggregate shall be staked to an even surface on the platform and lime pozzolana mortar shall than be evenly spread over the aggregate and the whole thoroughly mixed in just sufficient quantify of water to obtain concrete of uniform consistency. The mixing shall be done by turning it over and over several times - until all the aggregates are covered with mortar and a concrete of uniform consistency is obtained. In case of machine mixing, two and a half parts by volume of clean saturated surface dry coarse aggregate shall first be fed into the mixer and then one part, by volume, of lime. Pozzolana mortar shall then be added to the mixer and the content mixed well. Mixing shall be continued until there is a uniform distribution of the material. Final adjustment of water, to obtain concrete of required consistency may be made by adding clear water, if necessary, and turning the ingredients in the mixer.

ii) Laying, ramming & compaction of lime concrete

Before laying of lime concrete, all preparatory work described in IS 3067 i.e. cleaning of roof surface, attention to cracks by filling with cement sand slurry, provision of adequate numbers of opening and fillet at the junction of roof and parapet wall shall be completed. Roof surface should be made rough to develop sufficient bond between lime concrete and base concrete. After cleaning, roof surface shall be painted with hot bitumen of grade 80/100 @ 1.7 kg/m^2 blended with coarse sand. Subsequently, laying of lime concrete shall be started from a corner of a roof and proceed diagonally towards centre and other sides considering the slopes required for draining the rain water smoothly. The average thickness of lime concrete shall not be less than 100mm. On flat roof, slope of 1 in 60 shall be given. However, in heavy rainfall area, slope of 1 in 40 is recommended.

After lying it shall be initially rammed with a rammer weighing not more than 2 kg and finished to the required evenness and slopes. Further consolidation shall be done using wooden 'thapies' with rounded edges. The workmen will sit close together and beat the surface lightly. The beating will normally have to be carried on for at least seven days until the 'thapi' makes no impression on the surface and rebounds readily from it when struck. In order to achieve more progress, ramming and compaction of lime concrete can be done mechanically with the help of a tamping machine developed by C.B.R.I., Roorkee.

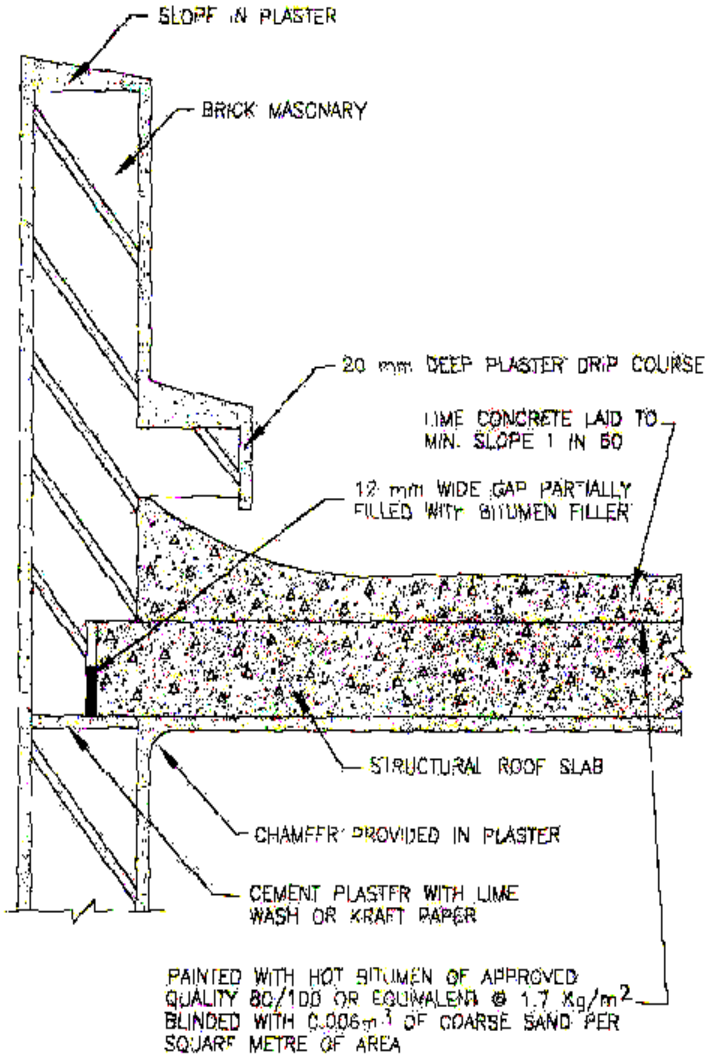
During compaction the surface shall be sprinkled liberally with lime mortar and small proportion of sugar solution (i.e. solution prepared by mixing, 3 kg of jaggery, 1½ kg of Bael fruit to 100 litre of water by boiling) or a solution prepared by soaking dry nuts of terminalia chebula in water, for obtaining improved water proofing of concrete. On completion of beating, the mortar that comes on the top shall be smoothened with a trowel or float.

iii) Curing

The lime concrete after compaction shall be cured for a minimum of 10 days or until it hardens, by covering with a thin layer of grass or straw, which shall be kept wet continuously.

iv) Treatment at junction of roof and parapet

All along the junction of roof surface with parapet wall, a strip of lime concrete fillet shall be laid and finished smooth. Typical details of treatment at junction between lime concrete water proofed roof finish and masonry walls are illustrated in the fig. 8.



Details at junction between lime concrete water proofed roof finish and parapet wall

Figure - 8

v) Finish:

In case of accessible roof, one layer of burnt clay flat terracing tiles (according to IS:2690 Part-1 and Part-2) may be laid over a thin layer of lime mortar. However, in the extreme condition where there is considerable expansion and contraction, two layers of tiles may be put on the top of lime pozzolana concrete. These tiles should be joined with non-shrinking impervious cement mortar.

7.3 Mud-phuska treatment

Mud phuska treatment is a common insulating cum water-proofing treatment used in comparatively hot dry region i.e. Punjab, U.P. etc., where rainfall is not heavy. This treatment usually consist of the following courses:

i) A layer of hot bitumen 80/100 or equivalent.
ii) A coat of mud phuska of 100 mm average thickness consisting of puddled clay conforming to specification as laid down under IS: 2115.
iii) A layer of 25mm mud plaster consisting of puddled clay mixed with chopped straw 30 to 35 kg per cubic meter of soil.
iv) One or two layer of tile laid on a bed of mud mortar and pointed in 1:3 cement sand mortar.

7.3.1 Material

i) **Soil for Mud Phuska:** The soil for mud Phuska shall be free from gravel and coarse sand (of particle size greater than 2mm), vegetable matter and fine kankar particles. The soil shall also be free from harmful and efflorescent salts. The coarse material shall not exceed 25% by mass. The plasticity index of the soil shall be between 10- 15 percent. Generally soil suitable for brick making is suitable for mud-phuska.

ii) **Soil for Mud Plaster and Mud Mortar:** The soil shall be free from vegetable roots, gravel and coarse sand of particle size greater than 2mm. The coarse material shall not exceed 10% by mass. The soil shall also be free from harmful and efflorescent salts. The plasticity index of the soil shall be between 10-15 percent.

iii) **Mud Plaster:** The mud plaster shall be prepared from soil conforming to above. The dry soil shall be reduced to fine powder and mixed with water in a pit, adding wheat straw 6% by mass and cow dung 12% by mass. The mixture shall be allowed to rot for a period of not less than 7 days. During this period, it shall be pugged manually using spades, if necessary, to get a homogeneous mass free from lumps and clods.

The consistency of the mortar shall be adjusted by taking it in a trowel and observing how it slides off the face of trowel. The mortar shall readily slide off, but at the same time shall not be so wet as to part into large drops before falling. Alternatively, slump test may be performed in accordance with the procedure laid down in IS: 1199. The slump should be about 70mm.

iv) **Mud Mortar:** Mud mortar, used as bedding under brick tile layer, shall be prepared in the same manner as mud plaster but without any addition of fibrous reinforcing material and binding material. The mud mortar may be used immediately without any rotting period.

v) **Brick Tiles:** These shall conform to the requirements given in IS: 2690 (Part-1) or IS: 2690 (Part-II).

7.3.2 Application Procedure

Various steps involved in this system are as under:

i) **Preparatory works:** Prior to application of treatment, preparatory works like filling of cracks by cement sand slurry, provision of adequate number of drain outlets, provision of 75 mm fillet at junction of roof slab with parapet wall, provision of a groove / chase in parapet wall etc. as described in IS: 3067- *Code of Practice for General Design Details & Preparatory Works for Damp Proofing and Water Proofing of Buildings*, shall be completed.

ii) **Cleaning of roof surface:** The surface of roof and the part of the parapet and gutters, drain mouths, etc. over which the water proofing treatment is to be applied shall be thoroughly cleaned of all foreign matter, namely fungus and dust etc. by wire brushing and dusting.

iii) **Application of Bitumen over cleaned roof surface:** After cleaning of roof surface, a coat of hot bitumen (residual type bitumens 80/100) over the roof surface shall be applied evenly over the entire surface without any gap. Bitumen coat is extended over the vertical surfaces meeting with the slab. Bitumen commonly used is residual type petroleum bitumen of grade 80/100 or hot cutback bitumen. Residual type bitumen is heated to a temperature of not less than 165^0 C and not more than 170^0 C. The quantity of bitumen to be spread per 10 sq. m. of the surface is approx. 17 kg.

iv) **Laying of Mud -Phuska:**

- **Preparation:** The soil shall be stacked in required quantities in about 300mm high stacks over a level ground and the top surface divided into suitable compartments of convenient size by bunding. The estimated quantity of water corresponding to optimum moisture content shall be added about 12 hours before the use and allowed to soak. The stacks of soil shall then be worked up with spades and hands to ensure proper distribution of moisture at the time the soil is to be used.

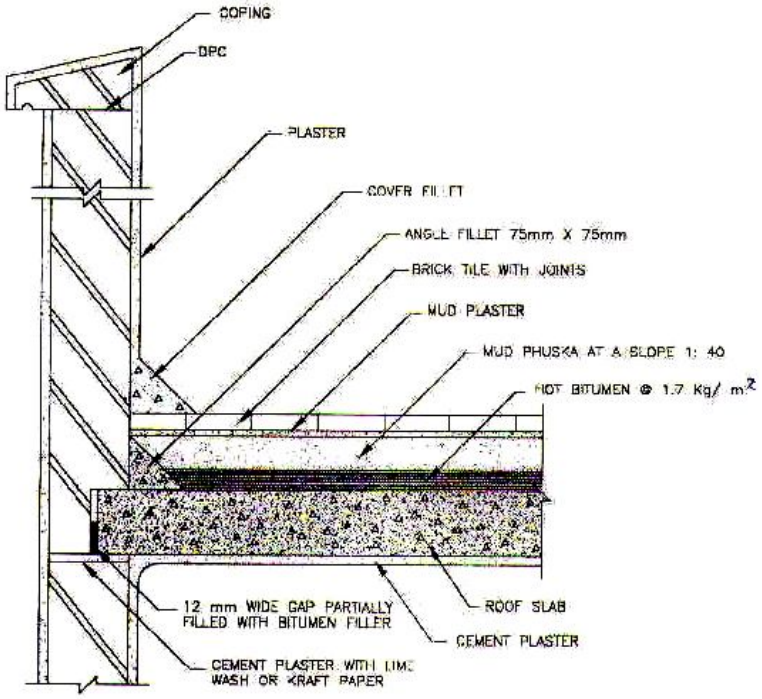
- **Laying:** The Mud-Phuska prepared as above shall be carried to the surface to be covered and laid in loose thickness not greater than 150mm. The surface shall then be brought to the slope of 1 in 40. It shall then be rammed manually with wooden rammers and 'thappies' so as to obtain maximum density. Normally a Mud Phuska layer, laid to a compacted thickness of not less than 100mm, is considered adequate.

  The surface shall be allowed to dry for a period of not less than 24 hours. If any cracks appear, these shall be filled with a grout of the binder material.

v) **Applying mud plaster:** After laying the mud phuska, mud plaster shall be laid to a total thickness of not less than 25mm over the surface. The plaster may be applied in a single coat or two coats of 15 mm and 10 mm.

After the application, the coat of plaster shall be allowed to dry. The surface shall be checked once more for slope and evenness with a straight edge and spirit level and made up wherever necessary by application of the plaster.

v) **Paving with brick tiles:** After application of mud plaster, the brick tiles shall be laid flat on a thin layer of mud mortar. The tiles shall be laid close to each other and the thickness of joints shall not be less than 6 mm and not more than 15 mm. It shall be ensured while laying tiles that mud mortar rises vertically in joints to a height of about 15mm. The brick tile shall be allowed to dry for a period of 24 hours before grouting the joint. After drying, the joint shall be grouted with cement sand mortar (1:3). It shall be ensured that the joints are completely filled by mortar. The mortar shall be allowed to set for a minimum of 12 hours before further pointing of the joints, which need to be done only if necessary. Before pointing, the grouted joints shall be brushed clean with a soft brush. Details for the treatment are given in figure 9.



Waterproofing of roofs using Mud-phuska
Figure - 9

vii) **Curing:** The surface of finished roof shall be kept wet for a period of not less than 7 days.

7.4 Water proofing using polyethelene film

It consists of laying of polyethylene film on slopped roof surface. This system is suitable for new as well as old roofs. This treatment generally consists of application of following courses:

i) A coat of bitumen primer conforming to IS: 3384 applied to the prepared surface at the rate of 0.3 to 0.5 kg/m^2.

ii) Application of hot applied bitumen (straight run bitumen conforming to IS: 73) at the rate of 0.70 kg/m^2 minimum.

iii) Laying of polyethylene film conforming to IS: 2508 with cold cutback adhesive in overlaps.

iv) Laying of 100 gm brown kraft paper laminated insitu over the film with semi hot layer of straight run bitumen.

v) Application of semi hot applied bitumen at the rate of 0.7 kg/m^2 dusted with fine sand.

vi) Laying of finishing layer of tiles or Indian Patent Stones i.e. 1:2:4 cement concrete with 10 mm down aggregate or cement concrete.

7.4.1 Application procedure

Various steps involved in this system are as under:

i) **Provision of slope and completion of preparatory works:** Prior to application of water proofing treatment roof surface shall be provided with a minimum slope of 1 in 100 with cement concrete or cement sand mortar or lime surkhy mortar. After provision of slope all preparatory works like filling up of cracks in roof structures by cement sand slurry, provision of adequate number of drain outlets, provision of 75 mm fillet at junction of roof slab with parapet wall, provision of a groove/ chase in parapet wall etc. as described in IS:3067-1988 shall be completed.

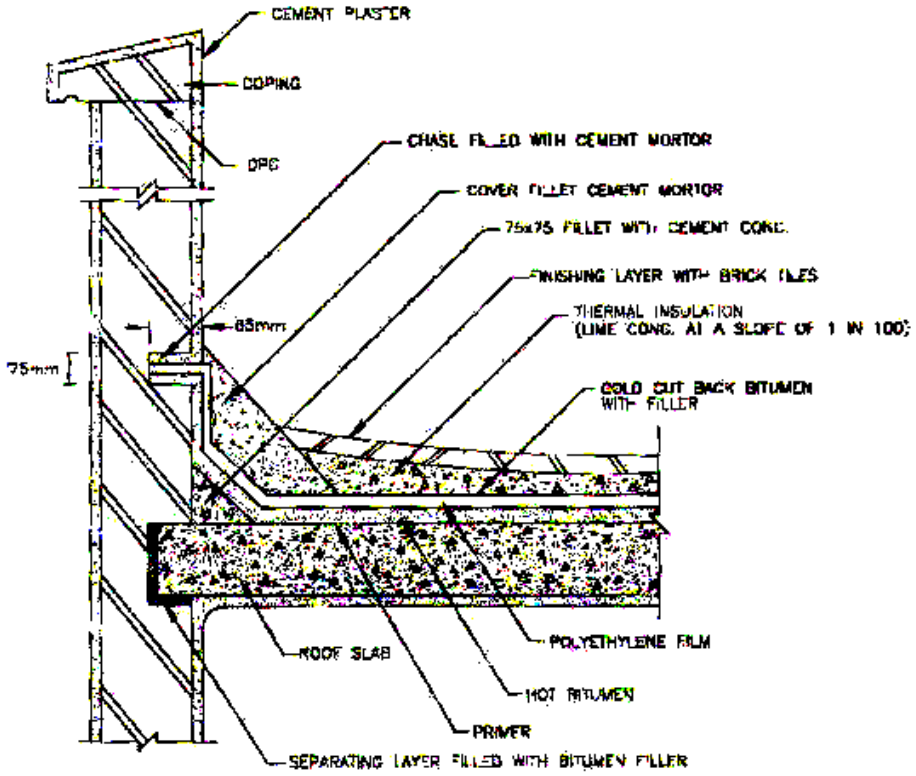
ii) **Method of laying:** After completion of preparatory works, a coat of primer shall be applied on the prepared roof surface by brushing and allow it to dry for 6 to 12 hours. Then a coat of hot bitumen shall be spread on the roof surface and allowed to cool to a temperature so that the film may be laid without any damage to it.

The polyethylene film shall be carefully laid and pressed on the bituminous layer. The film shall be pressed down with the help of a gunny cloth so as to prevent any damage to the film. The next length of the polythelene film shall be similarly laid down with proper longitudinal and end overlaps firmly pressed on the bituminous layer. The joints and overlaps shall be carefully sealed with the help of cutback bitumen applied over the upper surface of lower layer of polyethylene film. Minimum width of lap shall be 10 cm between adjacent films and at the ends. As far as possible for flat roof the film shall be laid at right angles to the direction of flow of water with overlap facing downwards. Width of film should be selected in such a way so that number of laps is minimum.

On polyethelene film 100 gm brown kraft paper shall be fixed with semi hot layer of straight run bitumen. The technique of fixing kraft paper to polyethelene film is to paint semi hot bitumen on the paper, reverse it and laminate over the film.

Kraft paper shall be coated with semi hot applied bitumen at the rate of 0.7 kg/m^2 dusted with fine sand. After finishing roof surface, treatment shall be applied to parapet, gutters and drain mouth.

iii) **Treatment at the junction of roof with parapet wall:** Details of treatment at junction of roof with parapet wall are shown in figure 10. Where down water pipes are provided to drain off the rainwater, extra piece of polyethylene film shall be provided in the opening covering the edge of the water pipe and covered with cement plaster 1:6.



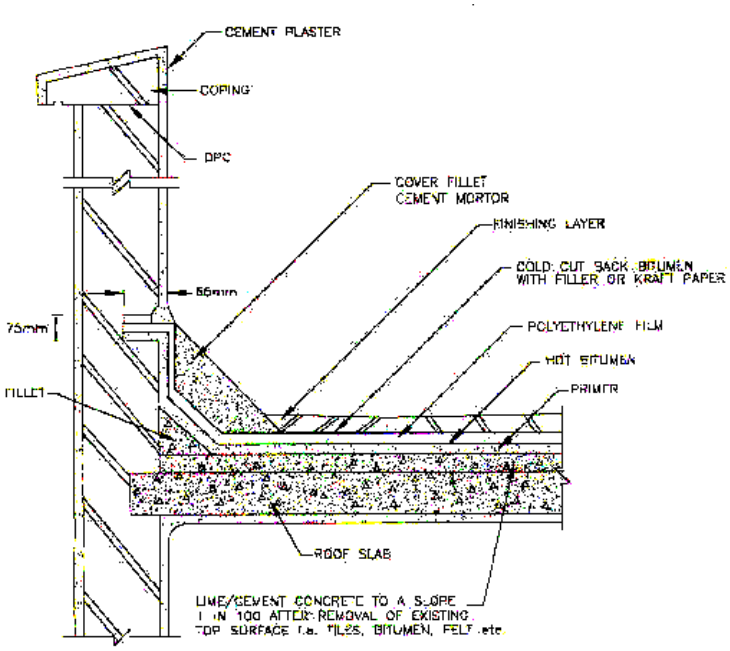
Water proofing treatment using polyethylene film for new roofs

Figure- 10

iv) **Surface Finish:** After completion of treatment, roof shall be provided with any one of the following:

a) Cement concrete flooring tiles conforming to IS: 1237;
b) Burnt clay flat terracing tiles conforming to IS: 2690 (Part-1) or IS: 2690 (Part-2);
c) Indian Patent Stone i.e. 1:2:4 concrete 40 mm thick with 10 mm down aggregate.

Typical details for complete treatment for new roofs are shown in figure 10. For old roofs, details are shown in figure 11.



Water proofing treatment using polyethylene film for old roofs

Figure - 11

7.4.2 Precautions in laying polyethelene film

i) The roof surface should be reasonably smooth so as to avoid puncturing of film. Primer should not be applied on wet surface.

ii) Excessive bitumen should not be used for bonding the film to the prepared surface, which may otherwise result in the film sliding and wrinkling.

iv) Over stretching of the film shall be avoided at the time of laying, which otherwise leads to wrinkles when the film retracts.

iv) The laying of the film should be immediately followed by subsequent operations of covering with bituminous compositions. It is found that if the film is left, exposed, it can lead to softening of bitumen layer underneath causing wrinkles, which may possibly lead to damage. The work should not be carried out at high temperature.

v) The workman should preferably walk barefooted or with canvas shoes to prevent damage to the film.

7.5 Polymer modified cementitious slurry coating

Polymer modified cementitious slurry coatings are applied over the base concrete. This technique of waterproofing is latest development in the field of waterproofing. Polymer imparts significant improvement in im-permeability. Polymer modified cementitious slurry has coefficient of expansion very similar to concrete thereby it does not get cracked due to thermal variation of concrete.

Polymer modified cementitious slurry coatings consist of a liquid blend and a dry blend. The liquid blend consists of the polymer, liquid additives and clean water. Dry blend consists of locally available Portland cement and aggregates. These blends are mixed in specified ratio generally 2:1 (cement: polymer) by weight and applied by brush on a prepared clean surface. Generally, two coats are provided. However, manufacturer's recommendations should be followed in this regard. To impart more flexibility, it is desirable to use some reinforcement like fibreglass cloth sandwiched between two coats. This coating should be covered by screed concrete to protect it against physical damage. This system can be used over new as well as old roofs.

7.5.1 Application of polymer modified cemenetitious slurry coating

Following steps are involved in application of this system.

i) **Preparation of roof surface:** The surface shall be cleaned to remove all dust, foreign matters, lose materials or any other deposits of contamination. Cracks and depression shall be filled up by fillers. Prepared surface shall be thoroughly pre wetted for one hour.

ii) **Preparation of polymer modified cementitious slurry:** Dry blend and liquid blend shall be mix into the desired ratio as per recommendation of supplier. The mix shall be stirred thoroughly, until no bubbles remain in the mix. Any lump found in mix shall be removed.

iii) First coat of polymer modified cementitious slurry shall be applied by brush on wet cleaned surface.

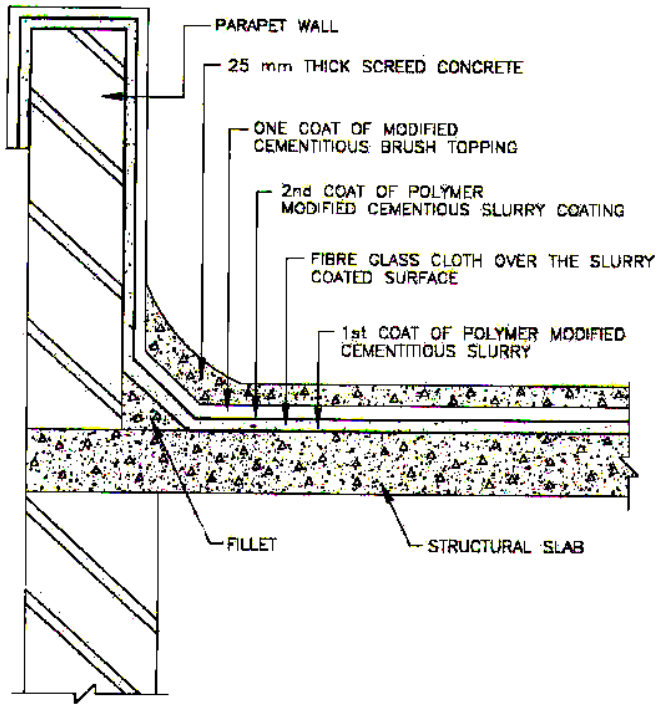
iv) Subsequently, fibreglass cloth shall be laid over first coat of polymer modified cementitious slurry.

v) Second coat of polymer modified cementitious slurry shall be laid over fibre glass cloth.

vi) Polymer modified cementitious brush topping shall be applied over second coat of polymer modified coating.

vii) On brush topping, screed concrete, 1:2:4 admixed with suitable integral water proofing compound 25 to 40mm thick to a min. slope of 1 in 100 with aggregate size down 10mm with maximum water cement ratio 0.45, shall be laid.

Above system may slightly differ from case to case depending upon the instruction of supplier of water proofing system. There is no relevant Indian standard/ other code of practice for this system. Therefore, work should be carried out as per manufacturers'/ suppliers instructions. Users are advised to collect complete literature from manufacturer and study carefully prior to application of treatment.



Water proofing of roofs using polymer modified cementitious slurry

Figure - 12

Since, there are no relevant Indian or any other standards available, this system needs to be adopted carefully.

7.6 Waterproofing using polymer modified bituminous membrane

Addition of polymer in bitumen improves its workability characteristics, penetration and softening behaviour, tensile and fatigue properties and capacity to bridge movement of cracks/ joints in the substrate. Non-woven fibreglass mat and non-woven polyester mat are generally used as reinforcement to improve their characteristics like lap joint strength, tensile strength and flexibility. Polymer modified bituminous membrane are obtained by sand-witching non-woven polyester fabrics or fibreglass mat between layers of high quality polymer modified bituminous. These membranes have high softening point, high tensile

strength, high tear & puncture resistance, high joint strength and low water vapour transmission. This system is suitable for new as well as old roofs.

7.6.1 Application procedure

Steps involved in this water proofing system may be as follows:

i) **Provision of slope and cleaning of roof surface:** Prior to application of water proofing treatment roof surface should be provided with a minimum slope of 1 in 100 with plain cement concrete. After provision of slope all preparatory works like filling up of cracks by cement sand slurry, provision of adequate number of drain outlets, provision of 75mm fillet at junction of roof slab with parapet wall, provision of a groove/ chase in parapet wall etc. as described in IS:3067 should be completed.

ii) Laying a coat of cold applied bitumen primer @ 0.2 to 0.4 l/sq. m. on entire roof surface.

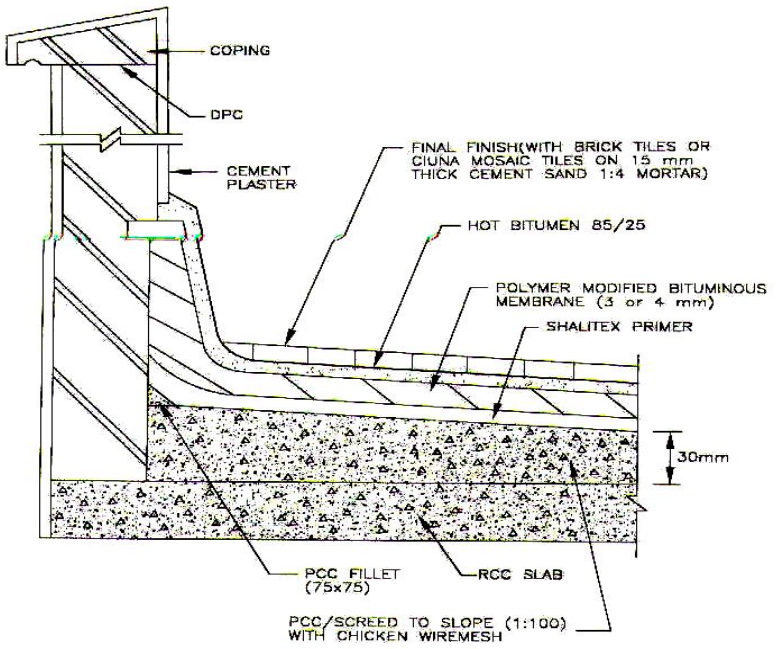
iii) Laying 85/25 grade hot blown bitumen @ 1.2 kg/sq.m. all over the surface.

iv) Laying 2.5-3mm thick polymer modified bituminous membrane with non-woven polyester fibreglass mat reinforcement, applied by torch with sealing all the joints.

v) Laying 85/25 grade hot blown bitumen @ 1.2 kg/sq. m. all over the surface.

vi) Final finish with china mosaic tiles on a 15mm thick grey cement plaster bed.

Method of application may slightly differ depending upon product and manufacturers' recommendations. As there is no relevant IS code of practice for this water proofing system, work should be carried out as per manufacturers' recommendations. Users are advised to collect complete literature from manufacturers and study completely prior to application of treatment.



Waterproofing of roof using polymer modified bitumen membrane

Figure - 13

7.7 Waterproofing using bitumen felts

This system consists of laying of bitumen felts over sloped roof surface. Life of this treatment is limited to 4-6 years only. Thus, recurring cost is very high. Therefore, this system should not be adopted for waterproofing.

7.8 Measures to prevent leakage in new construction

In new construction, the problem of leakage can be prevented by extending roof beyond supporting walls by 30 cm or so, in order to prevent locations having combined vertical and horizontal joints and by satisfying basic requirement of water proofing of roofs at design & construction stage. Extensions of roof will eliminate chances of leakage on supporting walls, as the vertical joint on supporting wall is eliminated. Basic requirement of waterproofing of roofs i.e. provision of adequate slope, number of openings, proper detailing at junction of roof & parapet wall, proper treatment at expansion joint described in para 6.4 & provision of effective water proofing system have been described in this chapter.

7.9 Inspection and maintenance for leaky roofs

Before taking any decision regarding remedial measures to be adopted for leaky roofs, it is necessary that the roofs are inspected thoroughly. The inspection should preferably be done during rainy season. Based on the observations, future course of action should be decided depending upon the condition of leakage in the roofs. Minor repairs at isolated locations may be carried out immediately on dry day and performance of repair should be observed after

next rainfall. Major repairs, like complete replacement of water proofing system, may be carried out after rainy season prior to next monsoon.

7.9.1 Thorough inspection

The inspection of roof should cover all the essential aspects, which may affect waterproofing system and may cause leakage in the roofs. Following aspects should be specifically covered:

a) Availability of adequate slopes (minimum 1 in 100)

b) Provision of 75mm fillet at the junction of roof and parapet walls.

c) Provision of adequate number and size of openings.

d) Provision of slope and drip course in copings.

e) Any sources of permanent leakage of water like overhead water storage tanks or leaking water supply pipe, broken down water drainage pipes, leakage at joints of down water drainage pipes (causes wetness in walls).

f) Undulations/ minor depression in roof surface where water may stagnate.

g) Growth of plants on the roof.

h) Condition of water proofing treatment, especially development of cracks/ debonding etc.

i) Condition of ceiling/ walls below the roof etc.

7.9.2 Attention to roof leaking at isolated points

During inspection, if it is observed that the leakage through roof is at isolated location, then such location should be carefully studied. It should be examined whether basic requirement for waterproofing has been fulfilled. If basic requirement for a leak proof roof are not fulfilled, any type of water proofing system will not work satisfactorily. Thus, first of all, action should be taken to ensure that basic requirement of leak proof roof are fulfilled. Leakage at isolated locations may be due to some defects at that particular location. Depending upon the water proofing system adopted on roof, action should be taken to rectify the defect. In case of roofs provided with bitumen felt, there may be debonding or leakage through joints. In that case, defective locations have to be identified, cut and removed and new layer of bitumen felt may be provided duly keeping desired overlap length. Similarly, in other bituminous treatment, existing bituminous layer may be removed and fresh layer may be laid. In case of roofs provided with lime terracing with tiles, there may be depression on roof surface or loss of cement mortar between tiles. Such defects may be rectified by fresh pointing/ plaster. Preferably pointing should be done with non-shrink polymer modified cement mortar. In case wetness is observed on the wall just below the junction of roof & parapet wall, condition of fillet & drain outlets need to be examined. Broken pipes may be

replaced and fillet may be constructed again after dismantling old fillet. Plaster on walls and coping should also be examined and repaired, if necessary.

7.9.3 Course of action for roofs leaking at isolated points:

Following course of action should normally be followed for repairs of roofs leaking at isolated points:

i) **Cleaning of roof surface and openings:** First of all, entire roof surface and all the openings should be cleaned so as to ensure effective and un-obstructed flow of rain water through the openings provided on the roofs. Weeds and any other foreign material on roof surface should be removed. The blockage in the openings should be cleared. It should be ensured that openings are functional.

ii) **Arresting permanent leakage of water from its sources:** If continuous leakage of water is observed on roof from any source, like over head water storage tank or leaking water supplying pipe lines etc., the same should be arrested by repairing over head water storage tank/ pipeline.

iii) **Identification and attention to locations of stagnated water:** Leakage of roof takes place only when water does not drain off quickly and stagnates over the roof surface. Generally, water stagnates over the depression formed in the roof surface. Thus, locations having depression in roof surface should be attended. Subsequently, it should be ensured that there is no location on roofs where water stagnates.

iv) **Repair of filet at junction of roof on parapet wall:** Condition of fillet at junction of roofs on parapet wall should be examined and any damage/ defective portion should be repaired.

v) **Repair to joints of tiles :** Condition of pointing at joints in between tiles should be examined and wherever mortar has come out, fresh pointing in cement mortar 1:3 should be done. After pointing curing should also be ensured.

vi) **Repair to plaster and coping on parapet:** Broken/ decayed plaster on parapet wall should be replaced by fresh plaster. Coping should also be attended alongwith provision of slope.

vii) After taking above steps, behaviour of roof surface should be watched and if leakage still persists, following steps have to be taken:

- **Removal of complete top surface and repair of lime concrete:** Entire top surface which may be consisting of tiles and bitumen felts etc. should be removed and condition of the layer below it i.e. lime concrete/ mud plaster should be examined. Minor cracks should be sealed with cement sand slurry or bitumen compounds after making ‘V’ groove in case of lime concrete. Defective concrete should be replaced by fresh lime concrete. In case of mud-phuska, minor cracks may be filled up by

bituminous compound. Decayed mud plaster and mud phuska should be replaced by fresh mud-phuska and mud-plaster.

- **Provision of adequate slope:** Many of the old roofs may not have adequate slope. For lime concrete terracing, a minimum slope of 1 in 60 is necessary. Therefore, after removal of top surface, slope of existing roof should be examined and if necessary, re-grading of roof surface should be carried out using lime concrete/ cement concrete. Prior to re-grading of roof surface, level should be marked on roof and parapet. Subsequently existing lime concrete surface should be made rough. After that re-grading work should be taken up. After re-grading, top surface should be made smooth using cement plaster 1:3 and surface should be cured for 7 days. Similarly, on mud-phuska roofs a slope of 1 in 40 shall be ensured. If necessary, roof surface should be re-graded using mud-phaska and mud plaster. After re-grading, layer of mud-plaster should be allowed to dry before relaying of top surface.

- **Re-laying of top surface:** After completion of re-grading, a layer of burnt clay tiles should be laid. Old tiles may be used if they are in good condition. Tiles should be laid over 20 mm cement mortar 1:3. Tiles should be joined with impervious cement mortar.

7.9.4 Attention to roofs leaking heavily

If heavy leakage is observed at large number of location on the walls and on the ceiling,. it is an indication of ineffective water proofing treatment. In such cases, it will be necessary to remove entire existing water proofing material like bitumen felts/ mastic etc. After removing the existing water proofing material, fresh water proofing treatment has to be provided. In case of lime concrete terracing, tiles needs to be removed first. After removal of tiles, condition of lime concrete should be examined. If large number of cracks is observed, it is desirable to remove complete lime concrete. If lime concrete is in good condition with few isolated cracks, these cracks should be filled up with cement slurry or bituminous caulking compound conforming to IS:1580. Subsequently, if necessary, re-grading of roof should be done as suggested under para 7.9.3 (vii). After re-grading fresh waterproofing system may be provided. Water proofing treatment may be any among various systems as mentioned in this chapter except bituminous felt treatment. While providing fresh water proofing system, care should be taken that instructions as given in relevant standard/ literature are strictly followed. Prior to provision of fresh water proofing system, provision of basic requirement of water proofing of roof should also be ensured.

***

Chapter - 8

Advanced techniques for waterproofing

8.1 General

With advanced technology in polymers, various polymers have been developed for stopping leakages from terraces, walls, basements, toilets and water retaining structures. Prominent among these are

- Epoxy compounds
- Polyurethane coatings
- Polymer emulsions/ membranes
- Cementitious polymer compounds

All the above materials have their own advantage as well as limitation. No single product can provide an effective solution to the range of waterproofing application requirements. In every instance it is necessary to examine the causes of leakage and select the proper material suitable for the relevant problem and environmental factors.

8.2 Applications of various coating systems

Material	Applications
Bituminous coatings	Waterproofing of foundations, basements, floors, under-ground structures and pipelines as well as some use for waterproofing of roof slabs.
Water based coatings	Dampness and efflorescence, polymer modified cementitious coatings for waterproofing and mortars for repairs.
Epoxy coatings	Waterproofing and damp proofing of buildings domes, ducts, floors etc. Epoxy mortar or repairs. Low viscosity epoxies as grouting material.
Polyurethane	Waterproofing of building elements such as coating terraces, balconies, chajjas etc., storage tanks-external applications, sealants and moisture curable polyurethanes for damp proofing.
Polythylene film (IS: 7290)	Water proofing of building elements such as roof-slabs, terraces, balcony, chajja etc.

8.2.1 Surface preparation

Polymer based liquid membranes are chemical type of waterproofing coating systems which require clean, inert and mechanically sound surface to achieve effective bonding and better performance. The efficiency of the treatment also depends upon the proper surface

preparation and workmanship during its application. Therefore, following general precautions should be undertaken before the application of the protective treatment:

- The coating should be applied on smooth and mechanically sound surface.
- The surface should be free from cracks and pot holes, if any, which should be filled up with suitable sealant.
- All traces of mould, grease etc. if any, should be removed by using a suitable solvent or washing with soap solution.
- Loose mortar, dust particles etc. should be removed by the use of wire brush. Surface should be cleaned off loose matter and subsequently washed with water.
- Whenever fillet (gola) has not been provided at the junctions of roof and parapet, 75mm radius gola should be made with concrete and finished smooth with mortar.

The following additional precautions should be undertaken before the application of waterproofing coating on the old roof slabs, balconies and chajjas etc.

- Plants and shrubs on roofs, parapet walls and rain- water outlets should be uprooted and removed. Their roots should be removed fully.
- The roofs already treated with tar felt or any other bitumen-based treatment should be free from bitumen, in case of non-bituminous based treatment, as the coating may not have proper adhesion on such surfaces.
- The coating should not be applied directly on the slabs already treated with brick bat coba in cement or lime mortar, as the coating may not have required adhesion with the available surface of roof slab. Therefore, the above treatment should either be completely removed, if it has lived its life, or in case of surface erosion of brick coba, the eroded coba should be removed.

8.3 Top covering

To increase the life of the coating system, its resistance to wear and tear caused by use of terraces and effectiveness in the long term, it is suggested that coating should be provided with TOP-Covering. It also helps in setting right slopes for the proper drainage of rainwater, if required. The following materials can be used for covering the coating system and can be selected depending upon the availability of raw materials and cost in a particular situation. These treatments should be done by standard codes of construction practices.

8.3.1 Indian patent stone

IPS i.e. 1:2:4 concrete 30-40 mm thick using proper amount of super-plasticisers.

8.3.2 Brick Tiles/Burnt Clay Tiles

Cement: sand mortar should be used for laying and jointing the tiles, the mortar should have proper percentage of super-plasticisers.

8.3.3 Polymer modified concrete

The prestigious buildings may be provided top covering of polymer-modified concrete. 5-10% emulsion by weight of cement is generally used in the concrete and the thickness of concrete is more than 20mm. The above-mentioned treatment is costlier in comparison to other treatment but is very effective.

Note : The surface preparation and top covering are common for all type of polymers coating.

8.4 Advanced construction additives

- **Metallic Floor Hardener**

  It is a cementitious type binder containing clean and graded iron aggregate. It is designed to incorporate into fresh concrete slabs, provides a dense, tough surface capable of with standing the abrasion and impact loading in floors. It can be used in passenger and goods platform, work shop floors etc. It is available under many brand names like euco-plate H.D. etc.

- **Non-Oxidizing heavy duty metallic floor hardener**

  It is a cementitious type binder with non-oxidizing aggregate. It is designed to incorporate in to fresh concrete slab, provides a dense, tough surface capable of with standing the abrasion and impact loading on floor. It is specially formulated with a non-rusting aggregate for increased abrasion resistance in areas subject to frequent moisture or water exposure. It can be used in passenger and goods platforms, floors of subways washing siding, w/shops floors etc. It is available under many brand names like diamond plate etc.

- **Non - Metallic floor hardener**

  It is a quartz silica mixture of finely graded non-metallic aggregates, plasticisers and cement binder. It can be used wherever floor area is subjected to frequently wetting on both interior and exterior sides. It is useful in floor of parking areas, canteens etc. It is available under many brand names like super-flex etc.

- **Polysulphide Sealants**

  It is a two-part sealant based on a liquid polysulphide polymer. It is used for critical joint sealing and exhibits excellent adhesion to most construction materials, including concrete, brickwork, timber, glass, aluminium and stainless steel. It contains two parts

(a) Base compound and (b) accelerator in right proportion which, when mixed reacts chemically reaction to form a tough flexible rubber seal. It is applied in the joints between 5 to 50 mm in width of internal and external walls claddings, water retaining structures, retaining walls, subways, basements, tunnels and connecting joints like glass and aluminium. It is available under many brand names like pidiseal etc. It is ideally suited to expansion joints.

- **Instant leak plugging compound**

It is a compound, which solidifies immediately upon contact with leaking water. It is ideal for instantaneous sealing of leaks, surface dampness, water penetration and seepage points in basements, piles, water retaining structures etc. It is available under many brand names like pidipatch etc.

***

References

1. Indian Railway Works Manual (IRWM).

2. Building Construction by Shri Sushil Kumar.

3. IS codes: Following is the list of various IS Codes, for waterproofing of roofs:

   i) IS 1322:1993- Specification for bitumen felts for waterproofing and damp proofing (Fourth Revision)

   ii) IS 1346:1991- Code of practice for water proofing of roofs with bitumen felt (Third Revision).

   iii) IS 1580:1991- Specification for bituminous compound for water proofing and caulking purposes (First Revision)

   iv) IS 2115:1980- Code of practice for Flat roof finish; Mud- Phuska.

   v) IS:2527-1984- Code of practice for fixing rain water, gutters and down pipes for roof drainage.

   vi) IS:2645-1975- Specification for integral water proofing cement compound.

   vii) IS:3036:1992- Code of practice for laying lime concrete for a waterproofed roof finish (Second Revision).

   viii) IS 3037:1986- Specification for bitumen mastic for use in water-proofing of roofs (First Revision).

   ix) IS 3067:1988- Code of practice for general design details and preparatory work for damp-proofing and water proofing of buildings (First Revision).

   x) IS 3384:1986- Specification for bitumen primer for use in waterproofing and damp-proofing (First Revision).

   xi) IS 4365:1967- Code of practice for application of bitumen mastic for waterproofing of roofs.

   xii) IS 4911:1968- Glossary of terms relating to bituminous waterproofing and damp proofing of buildings (First Revision)

   xiii) IS 7193:1974- Specification for glass fibre base bitumen felts.

   xiv) IS 7290:1979- Recommendations for use of polyethylene film for waterproofing of roofs (First Revision).

xv) IS 9918:1981- Code of practice for in-situ waterproofing and damp-proofing treatments with glass fibre tissue reinforced bitumen.

xvi) IS 13182:1991- Recommendations for waterproofing of wet areas in building.

xvii) IS 13826-(Pt 1):1993 Bitumen based felts- Method of test Part 1- Breaking strength test.

xviii) IS 13826-(Pt 2):1993- Bitumen based felts- Method of test Part 2 -Pliability test.

xix) IS 13826 Pt 3):1993- Bitumen based felts- Method of test Part 3- Storage sticking test..

xx) IS 13826 (Pt 4):1993- Bitumen based felts- Method of test Part 4 - Pressure head test.

xxi) IS 13826-(Pt 5):1993-Bitumen based felts- Method of test Part 5- Heat resistance test.

xxii) IS 13826-(Pt 6):1993- Bitumen based felts- Method of test Part 6-Water absorption test.

xxiii) IS 13826-(Pt 7):1993- Bitumen based felts- Method of test Part 7-Determination of binder content.

***

NOTES

1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	

OUR OBJECTIVE

To upgrade Maintenance Technologies and Methodologies and achieve improvement in productivity and performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability, and Utilisation.

*The contents of this handbook are for guidance only & are **not statutory**. It also does not supersede any existing specification and instructions from Railway Board, RDSO, and Zonal Railways & the provisions of IRWM, BIS Codes/Reports on the subject. If you have any suggestion & any specific comments, please write to us **:***

Contact person	**:**	**Director (Civil)**
Postal Address	**:**	**Centre for Advanced Maintenance Technology, Maharajpur, Gwalior (M.P.) Pin code – 474 020**
Phone	**:**	**(0751) - 2470869, 2470803**
Fax	**:**	**(0751) - 2470841**