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GOVERNMENT OF INDIA
MINISTRY OF RAILWAY

WATER PROOFING OF ROOFS

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RESEARCH DESIGNS AND STANDARDS ORGANISATION
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FOREWORD

The problem of leakage from roofs of buildings/ structures is experienced by all the Zonal Railways. Leakage of roofs not only causes inconvenience to users but also reduces the service life of buildings and structures.

During one of the review meeting held on 12.9.98 at Railway Board, Member Engg. desired RDSO to carry out study on this subject and issue guidelines. These instructions were reiterated by Member Engineering during Chief Engineer's conference held on 10th & 11th Nov., 1998 at Ooty.

In compliance to Railway Board's instruction, the available literature, including IS: Codes on the subject, was studied to find out solution to problem of leakage of roofs. In addition, literature from various leading manufacturers/ suppliers of water proofing system was also collected and studied.

This report has been prepared based on the study of literature and covers various aspects like basic requirements for water proofing of roofs, prevalent water proofing system and repair of leaky roofs etc. It is expected that this report will serve as a guideline to field engineers associated with design/ construction/ maintenance of buildings/ other structures and help them in arresting the problem of leakage.

Any suggestion for improvement in this report is welcome.


(A.K. Harit) 15-9-99

Executive Director/ B&S
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CONTENT

<u>Sl.No.</u>	<u>Subject</u>	<u>Page No.</u>
1.	Introduction	1
2.	Probable causes of leakage in roofs	1
3.	Standards & Codes of Practice dealing with water proofing of roofs	2
4.	Basic requirement of arresting leakage of roofs	4
5.	Prevalent water proofing system for roofs	9
6.	Measures to prevent leakages in new construction	39
7.	Inspection and maintenance of leaky roofs	39
8.	Conclusion	44
9.	Recommendations	47
	References	

WATER PROOFING OF ROOFS

1. INTRODUCTION:

1.1 Indian railway is spread over a large network with route length of about 63000 km. The Railway establishment began in India prior to 1856. Due to operational reasons, large number of stations/ office buildings, residential buildings etc. were constructed from time to time. Most of these building have flat roofs with lime surkhi/ bituminous treatment as water proofing course. Due to weathering effect, leakage from roofs takes place and causes inconvenience to users of buildings. Leakage of roofs also leads to faster deterioration of building material, thus it reduces its service life. The problem of leakage from roof of buildings is experienced by all the Zonal Railways and various methods/ techniques are tried to arrest the leakage. Most of the time the treatment adopted proves to be effective only for a limited period.

1.2 In order to find out effective solution to the problem of leakage of roofs, the available literature, including IS Codes, on this subject was studied. In addition, literature from various leading manufacturers/ suppliers of water proofing system was also collected and studied.

1.3 This report has been made out describing various aspects related to this subject. As the subject has been studied specifically for flat roofs, the suggestion & recommendations made in this report are relevant to new/ old flat roofs only.

2. PROBABLE CAUSES OF LEAKAGE IN ROOFS:

As most of the buildings are old, water proofing system on the roofs get deteriorated due to weathering effect and become ineffective due to development of cracks/debonding/ disintegration of water proofing material etc. This may be one of the major cause for leakage of roof in old buildings. In

addition, the basic requirements for effective drainage of water from the roofs may not have been fulfilled in old buildings.

Stagnation of water due to undulation in roof surface, provision of less no. of drainage pipes or choking of same and improper detailing of junction of parapet and roof etc., is another major contributor in making the roof leaky.

Leakage/ over-flowing of water storage tanks provided over the roofs, may be one of the cause for leakage/ seepage of roofs.

Junction of roof and parapet wall is a vulnerable location for leakage. Water seeps through junction and causes wetness in ceiling/ walls.

Sometimes the leakage problem is observed in new buildings also, probably because of improper water proofing material, poor workmanship and due to poor design which does not fulfill the basic requirement of water proofing of roofs.

3. STANDARDS & CODES OF PRACTICE DEALING WITH WATER PROOFING OF ROOFS:

Following is the list of various IS Codes which deals with water proofing of roofs:

- | | | |
|------|--------------|---|
| i) | IS 1322:1993 | Specification for bitumen felts for water proofing 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 downpipes 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 water-proofing 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 water-proofing 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.

4. BASIC REQUIREMENT OF ARRESTING LEAKAGE OF ROOFS:

4.1 Following are the basic requirement for water proofing of roofs:

- i) *Provision of adequate slope.*
- ii) *Provision of adequate openings for drainage of water.*
- iii) *Proper detailing at junction of roof with parapet wall.*
- iv) *Proper treatment at expansion joint*
- v) *Provision of effective water proofing system over the roof.*

4.2 Provision of adequate slope:

It is absolutely essential that roofs are provided with adequate slope to ensure effective drainage. If water stagnates over the roof, it will find way to move downward through the pores/ cracks of roof material, resulting in wet ceilings / walls. The slope of roof should be such that the water gets drained off quickly by achieving adequate velocity under influence of gravity. Indian standards specify a slope of 1 in 100 or steeper depending upon the type of water proofing system provided over the roof.

4.3 Provision of adequate openings:

Adequate openings in numbers and size, are necessary to allow the water to get drained off quickly. If, openings are inadequate, water may stagnate over roof and result is leakage/ seepage. The number and size of openings depends upon the area of roof and intensity of rain fall of the region in which building is situated. Rain water pipes having bell mouth inlet at the roof surface, are found to give better drainage effect. The spacings in between outlet pipes should not be more than 6 m. The size of rain water pipes, depending upon the average rate of rain fall and roof area, should be as specified in Clause 5.3.2 of IS:2527-1984 "Code of Practice for Fixing Rainwater gutters and Downpipes for Roof Drainage" which are as given in Table-1. Average rainfall intensity may be obtained from local office of Indian meteorological deptt.

Table-1
Sizes of Rainwater Pipes for Roof Drainage

Dia of pipes	Average rate of Rainfall in mm/h (Roof area, m ²)					
	50 m ²	75 m ²	100 m ²	125 m ²	150 m ²	200 m ²
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

4.4 Proper detailing at junction of roof with parapet wall:

Junction of roof with parapet wall is a vulnerable location for leakage. Even if, there is very minute space at this location, water is likely to leak through it and may cause wetness in wall and ceiling. Therefore, it is necessary that detailing at the junction of roof and vertical face of parapet wall is done very

carefully. As per IS: 3067-1988 "Code of Practice for General Design Details and Preparatory work for Damp Proofing and Water Proofing of Building" the fillet (angular on concave, not convex) of 75mm should be provided all along the junction of parapet wall with roof. Coping on the top of parapet wall should also have 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 fig.1.

4.5 Expansion Joints:

Expansion joints in buildings/ other structures may become source of perennial seepage due to failure of expansion joint fillers and sealants. Therefore, it is necessary that expansion joints are properly designed & treated. Expansion joint should be treated with suitable non-absorbent, compressible, non-brittle and water tight sealants so that no leakage occurs through joint. Joint fillers should confirm to IS: 3414 -1968 "Code of Practice for Design & Installation of Joints in Buildings" or IS:1838 (Pt.I or Pt.II)-1984 "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 Fig. 2.

4.6 Provision of effective water proofing system over the roof:

In order to arrest leakage of water through the roofs, it is necessary that roofs are provided with suitable water proofing system. A water proofing system should have the following properties:

- a) It should be impermeable or should have very low permeability.
- b) It should have strong adhesion with substrata.
- c) It should be sufficiently elastic so as to withstand expansion and contraction of substrata due to temperature fluctuations.

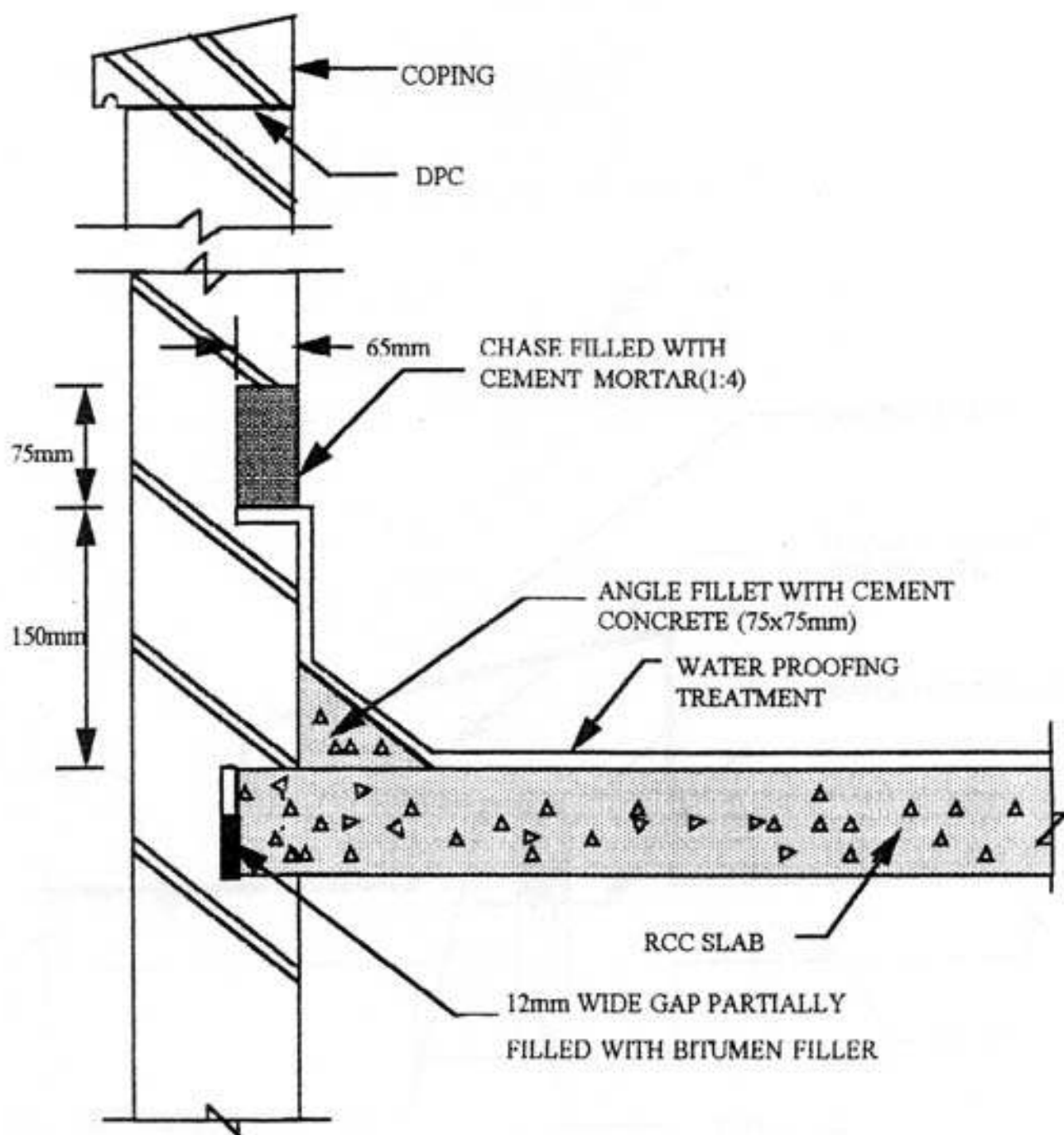


Fig. 1

**GENERAL ARRANGEMENT AT JUNCTION OF ROOF AND
PARAPET WALL**

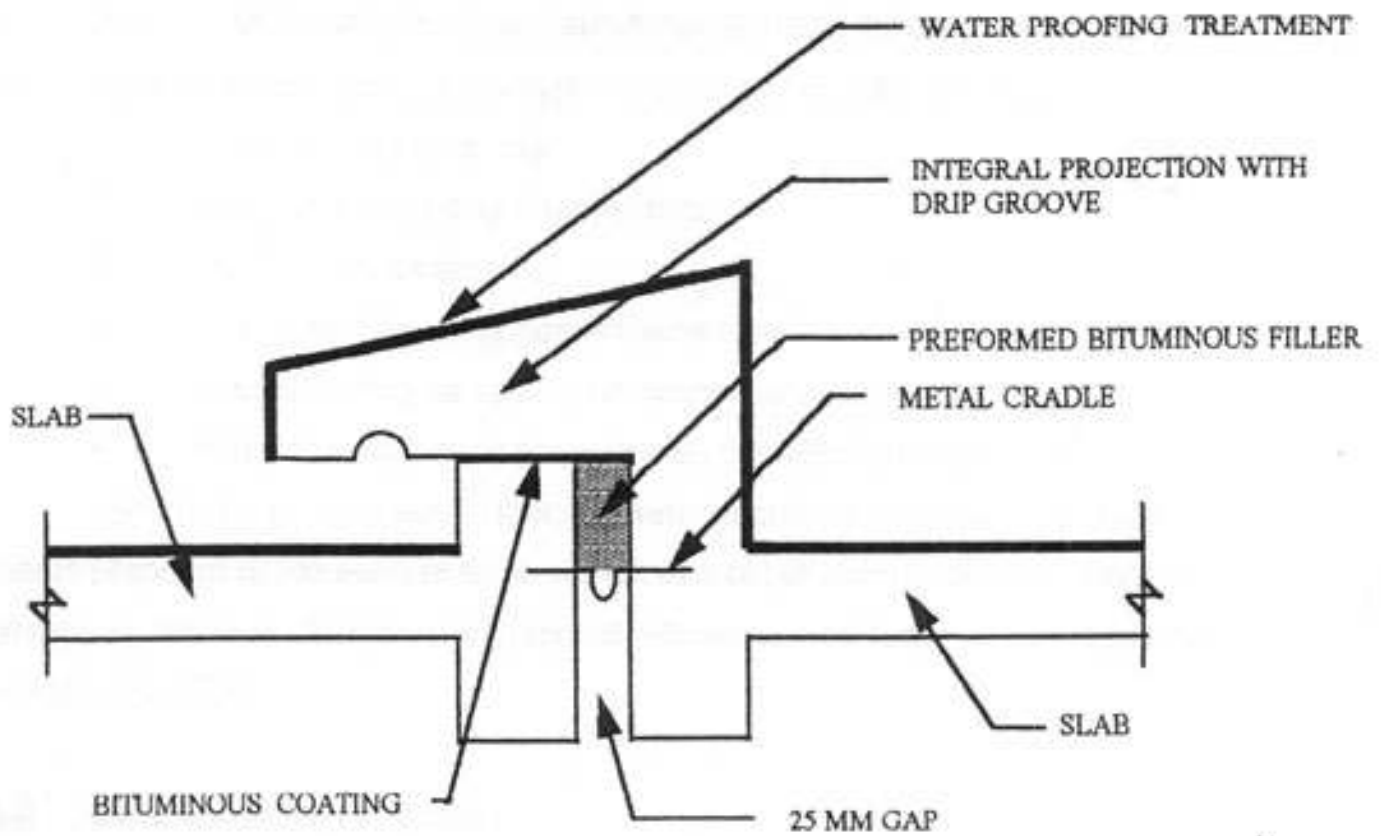


Fig. 2

GENERAL ARRANGEMENT AT EXPANSION JOINT

- d) It should have high resistance to abrasion and cracking.
- e) It should be resistant to ultra violet rays.
- f) It should be breathable i.e. permit vapour transmission.
- g) Its application should be easy..
- h) It should be durable.

5. PREVALENT WATER PROOFING SYSTEM FOR ROOFS:

5.1 Various water proofing system prevalent in our country are as under:

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

Literature study revealed that all water proofing systems described in Indian Standard or literature of firms are for new constructions. For old building/ structures, these systems may be adopted with some modifications as suggested in Para 7.3 & 7.4.

5.2 Lime Concrete Terracing:

5.2.1 This system consist 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 712-1984) pozzolanic material (calcinated clay pozzolana conforming to IS 1344-1981) and concrete aggregate (broken burnt clay bricks conforming to IS: 3068-1986 or natural stone aggregate conforming to IS 383-1970) having maximum size 25mm. This system is suitable for new as well as old roofs.

5.2.2 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 water tight 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 $2\frac{1}{2} : 1$ 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 then be evenly spread over the aggregate and the whole thoroughly mixed in just sufficient quantity of water to obtain concrete of uniform consistency. The mixing shall be done by turning it over and over several times - until all the aggregate 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 3067-1988 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 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 laying it shall be initially rammed with a rammer weighing not more than 2 kg and the 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, it is advised that the ramming and compaction of lime concrete should be done by a tamping machine developed by C.B.R.I., Roorkee. Details of tamping machine, as furnished by C.B.R.I. Roorkee, are given in Annexure-1.

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, $1\frac{1}{2}$ kg of Bael fruit to 100 litre of water by boiling) or a solution prepared by soaking drynuts 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 detail of treatment at junction between a lime concrete water proofed roof finish and masonry walls are illustrated in the fig. 3.
- v) **Finish:-** In case of accessible roof finish, one layer of burnt clay flat terracing tiles (according to IS:2690:1975 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. Some of the non shrinkable polymer modified mortar available in market are Zentrivial FM (marketted by MC Bauchemie (India) Pvt. Ltd., Mumbai), Nitolite GR (marketted by FOSROC Chemical India Ltd., Bangalore) etc.

User's are advised to refer IS: 3036:1992 "Laying lime concrete for water proofed roof finish" for detailed specification & guidance.

5.2.3 Advantages & Limitations:-

This treatment provides excellent insulation against heat in addition to water proofing. It is a time tested technique . However, this technique is slow and labour intensive and requires strict supervision and quality control.

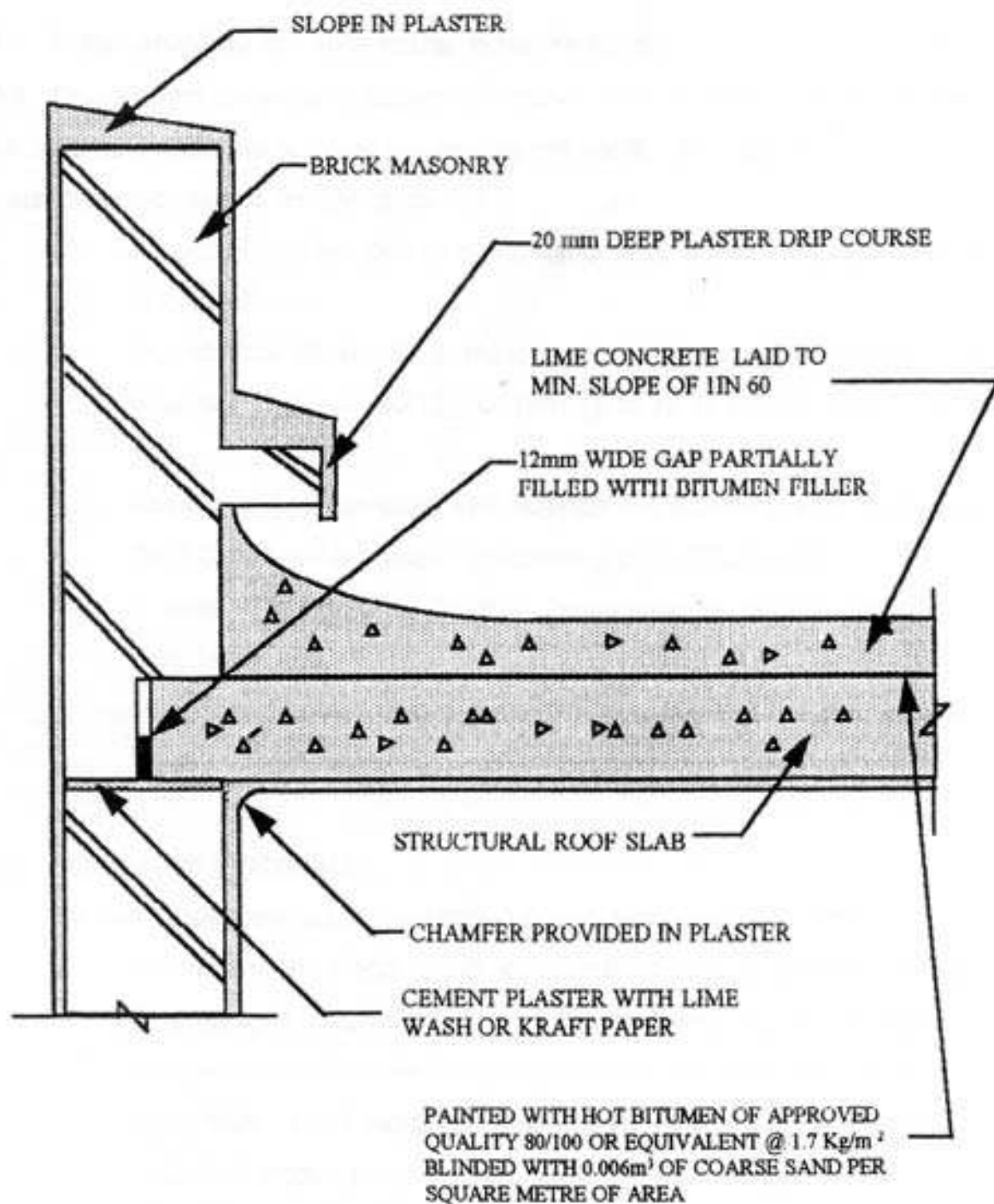


Fig.3

**DETAIL AT JUNCTION BETWEEN LIME CONCRETE
WATER PROOFED ROOF FINISH AND PARAPET WALL
(As per IS: 3036 - 1992)**

5.3 Water proofing of roofs using bitumen felts:

5.3.1 This system consists of laying of bitumen felts over-sloped roof surface. This method is suitable for new as well as old roofs. This treatment generally consist of application of following courses:

- i) A coat of bitumen primer conforming to IS: 3384-1986 at the rate of $0.27 \text{ l /m}^2 \text{ min.}$
- ii) Application of bonding material i.e. hot industrial blown type bitumen 85/25 or 90/15 conforming to IS:702-1988 @ $1.2 \text{ kg/m}^2 \text{ min.}$
- iii) Laying of Hessian base self finished felt type-III grade -1 or glass fibre base type-II grade-1 conforming to IS: 1322-1993.
- iv) A coat of hot applied bitumen conforming to IS:702-1988 @ $1.2 \text{ kg/m}^2 \text{ min. and}$
- v) Pea -sized gravel or grit devoid of fine sand at the rate of $0.006 \text{ m}^3/\text{m}^2$.

5.3.2 Application Procedure:

Various steps involved in application of this system are as under:

- i) **Provision of slope and completion of preparatory works:-**
Prior to application of water proofing treatment, roof surface should be provided with a minimum slope of 1 in 100 with cement concrete or cement sand mortar or lime surkhy mortar. After provision of required slope, all preparatory works like filling 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:3067-1988 "Code of Practice for General Design Details & Parapatory 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 Primer: -** After cleaning of roof surface, primer shall be brushed over at the rate of 0.27 l/m^2 (min.) and left till it is dry.
- iv) **Preparation of Bonding Material:-** After application of primer, bitumen bonding material i.e. industrial blow type bitumen of grade 85/25 or 90/15 conforming to IS 702:1998 shall be heated to working temperature.
- v) **Treatment of gutters and drain mouths:-** At least two layers of felt shall be laid in gutters even when only one layer of felt has been specified for the roof. A priming coat shall first be applied. Over this, the first layer of felt shall be bonded with hot bitumen followed by the successive layer of felt securely bonded together and finally painted with a coat of hot bitumen at not less than 1.5 kg/m^2 . The felt layer laid separately in gutter shall be overlapped with corresponding layer on the roof proper. The felt layers laid separately in the gutters shall be carried down into the outlet pipes to a minimum depth of 100 mm. Where there are walls, grooves shall be cut out at a reasonable height and felt tucked in the grooves which shall then be filled in with cement mortar.
- vi) **Treatment of the main roof:-** The felt is normally laid in lengths at right angles to the direction of run-off gradient, starting at the lowest level and working upto the crest. Before application the felt shall be first cut to required lengths, brushed clean of dusting materials and laid out flat on the roof and allowed to soften. This serves to eliminate curls and subsequent stretching. Each length

of felt prepared for laying as described above shall be laid in position and rolled up for a distance of half its length. The hot bonding material shall be poured on to the roof across the full width of the rolled felt and the felt is steadily rolled out and pressed down. The excess bonding material is squeezed out at the ends and is removed as the laying proceeds. When the first half of the strip of felt has been bonded to the roof, the other half shall be rolled up and then unrolled on to the hot bonding material in the same way. Minimum overlaps of 100 and 75mm shall be allowed at the end and the sides of strips of felt. All overlaps shall be firmly bonded with hot bitumen.

- vii) **Junction of parapet wall and roof:-** Felt shall be laid as flashing with minimum overlaps of 100 mm. The lower edge of the flashing shall overlap the felt laid on the flat portion of the roof and the upper edge of the flashing shall be tucked into the groove made in the parapet on the vertical face of the wall. Each layer shall be so arranged that the joints are staggered with those of the layer beneath it. After all the layers specified have been laid and the flashings properly bonded, the groove shall be filled up with cement mortar (normally 1:4) or lime mortar (1:3), or cement concrete (1:3:6) which when set, will satisfactorily secure the treatment to the wall. The groove filling shall be properly cured by watering for at least 4 days after filling to ensure satisfactory strength and to avoid shrinkage cracks. Typical details of treatment are given in Fig. 4.
- viii) **Surface finish:-** A surface finish of pea- sized gravel or grit shall be provided at the rate of $0.008 \text{ m}^3/\text{m}^2$. This affords a measure of protection to the treatment and increases its durability. On the flashing and at the drain mouths, the gravel or grit may be omitted and instead of two coats of bituminous paint at the minimum rate of

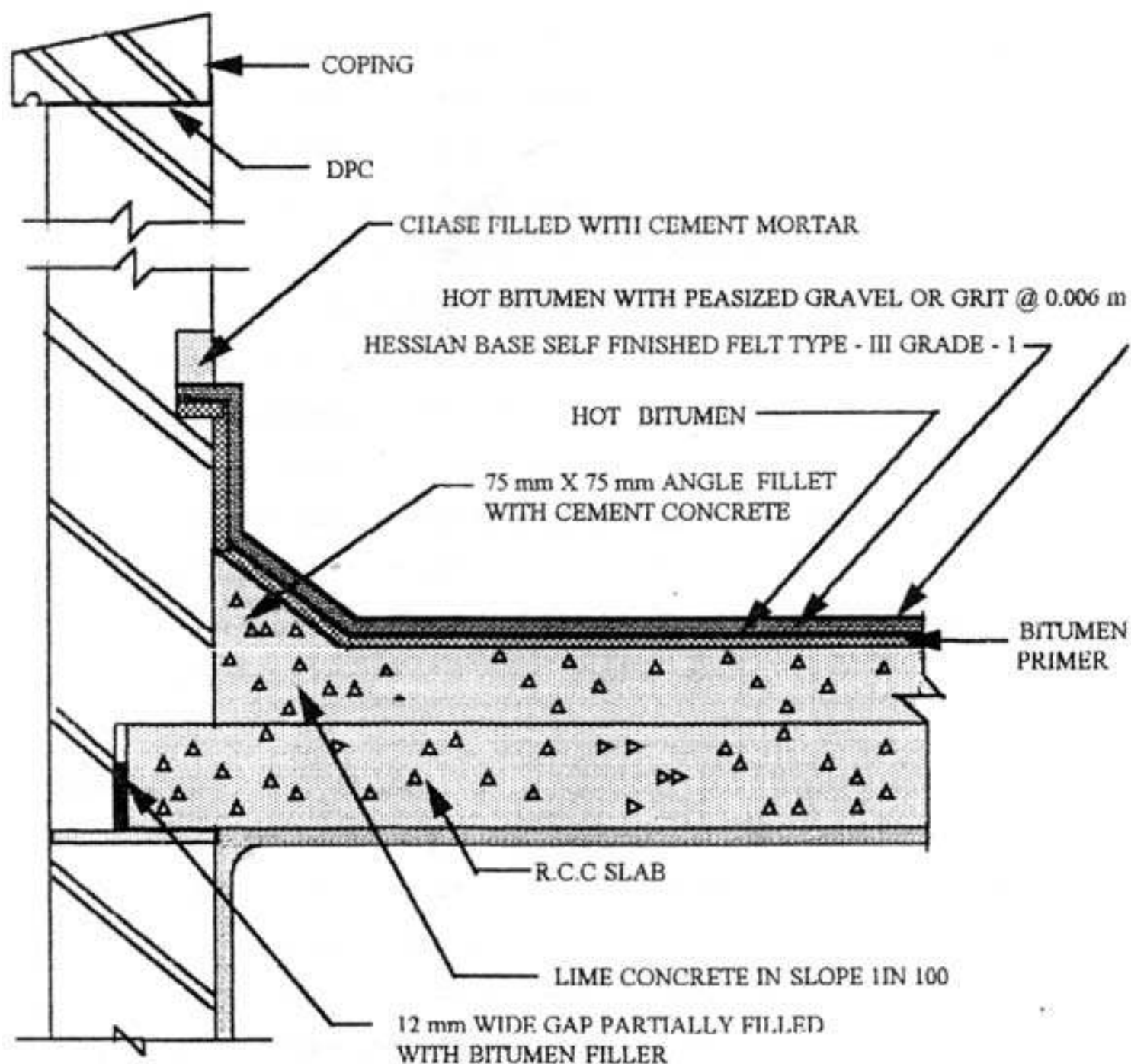


Fig. 4

TYPICAL DETAIL OF WATER PROOFING TREATMENT USING BITUMEN FELT

0.1 kg/m² per coat or a single coat of bituminous emulsion at the rate of 0.5 kg/m² may be applied.. In order to prolong the life of the waterproofing treatment or when the roof surface is subjected to foot traffic the following surface treatment are recommended:

- a) Cement concrete flooring tiles conforming to IS: 1237-1980
- b) Burnt clay flat terracing tiles conforming to IS:2690-1975.

Alternatively, a screeding of proportion of 1:4 of cement and sand 45mm thick can be laid over the roofing treatment and marked of squares of 600mm made with expansion joints provided at a distance of 3m which shall be properly caulked with bituminous compound.

For detailed specification & guidance, users are advised to refer IS: 1346-1991 "Code of Practice for Waterproofing of Roofs with Bitumen Felts" and IS: 1322-1993 "Bitumen Felts for Water Proofing and Damp Proofing -Specification".

5.3.3 Advantages & Limitations:

This system is quick and easy in application but it has limited life of 4-6 years only. Thus high recurring cost. Bitumen felt lap joints are weak in strength. After loss of top bitumen cover, water gets entrapped between roof surface and tar felt through the joints, which affects the roof adversely. Considering limitations, this system should not be used for water proofing.

5.4 Mud-Phuska Treatment:

5.4.1 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:

- 1) 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: 2115-1980.
- 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.

5.4.2 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 ii). The dry soil shall be reduced to fine powder and mixed with water in a pit, adding wheat straw 6% by mass and cowdung 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: 1199-1959*. 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)- 1975 or IS: 2690 (Part-II)-1975.

5.4.3 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 75mm fillet at junction of roof slab with parapet wall, provision of a groove / chase in parapet wall etc. as described in IS: 3067-1988 "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 cut back bitumen. Residual type bitumen is heated to a temp of not less than 165° C and not more than 170° C. The quantity of bitumen to be spread per 10 sqm. of the surface is approx. 17 kg.

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

a) **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.

b) **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 15mm and 10mm.

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.

- vi) **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 6mm and not more than 15mm. 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. Typical details for the treatment are given in Fig. 5.

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

Users" are advised to refer IS: 2115-1980 "Code of Practice for Flat Roof Finish: Mud-Phuska " for detailed specification & guidance.

5.4.4 Advantages & Limitations: This treatment provides excellent insulation against heat in addition to water proofing. . It is cheap and reasonably durable. This treatment is suitable only for comparatively hot and dry region of the country.

5.5 Water proofing using polyethelene film:

5.5.1 It consist of laying of polyethylene film on slopped roof surface. This system is suitable for new as well as old roofs. This system is being tried on old

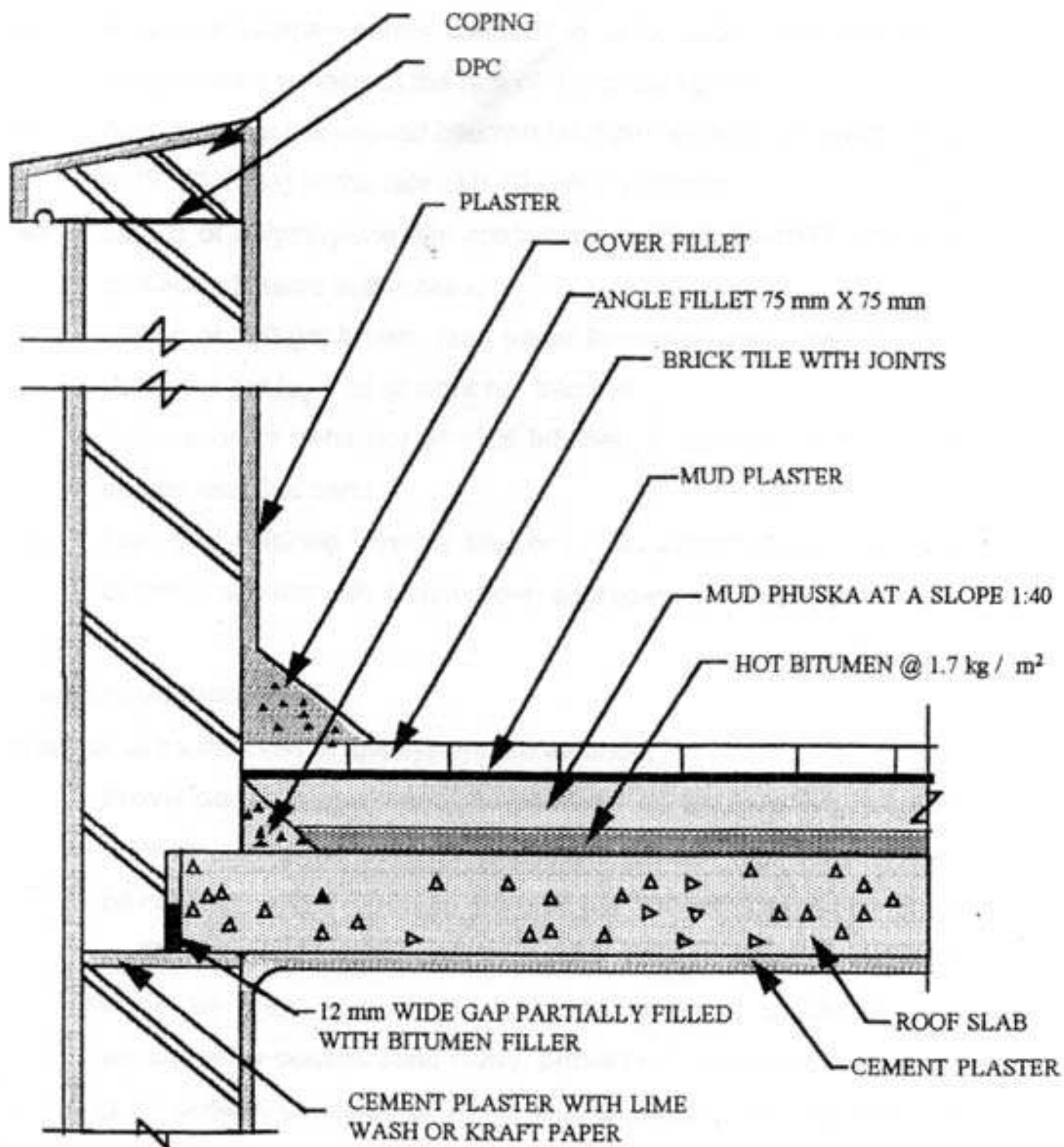


Fig. 5

WATER PROOFING OF ROOFS USING MUD PHUSKA

buildings in RDSO. This treatment generally consist of application of following courses:

- i) A coat of bitumen primer conforming to IS: 3384-1986 applied to the prepared surface at the rate of 0.3 to 0.5 kg/m².
- ii) Application of hot applied bitumen (straight run bitumen conforming to IS: 73-1961) at the rate of 0.70 kg/m² minimum.
- iii) Laying of polyethylene film conforming to IS: 2508-1977 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/m² dusted with fine sand.
- vi) Laying of finishing layer of tiles or Indian patent stones i.e. 1:2:4 cement concrete with 10mm down aggregate or cement concrete

5.5.2 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 75mm 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 no. of laps are 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:-** Typical details of treatment at junction of roof with parapet wall are shown in Fig.6. Where down water pipes are provided to drain off the rain water, 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.
- 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: 1237-1980;
- b) Burnt clay flat terracing tiles conforming to IS: 2690 (Part-1): 1975 or IS 2690 (Part-2): 1975.
- c) Indian Patent Stone i.e. 1:2:4 concrete 40mm thick with 10 mm down aggregate.

Typical details for complete treatment for new roofs are shown in Fig. 6. For old roofs, details are shown in Fig. 7.

5.5.3 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.
 - iii) 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.
- User's are advised to refer IS: 7290-1979 for detailed specification & instructions.

5.5.4 Advantage & Limitations:

This system is quite effective and durable. It involves large no. of steps and requires strict quality control & supervision. If adequate precautions are

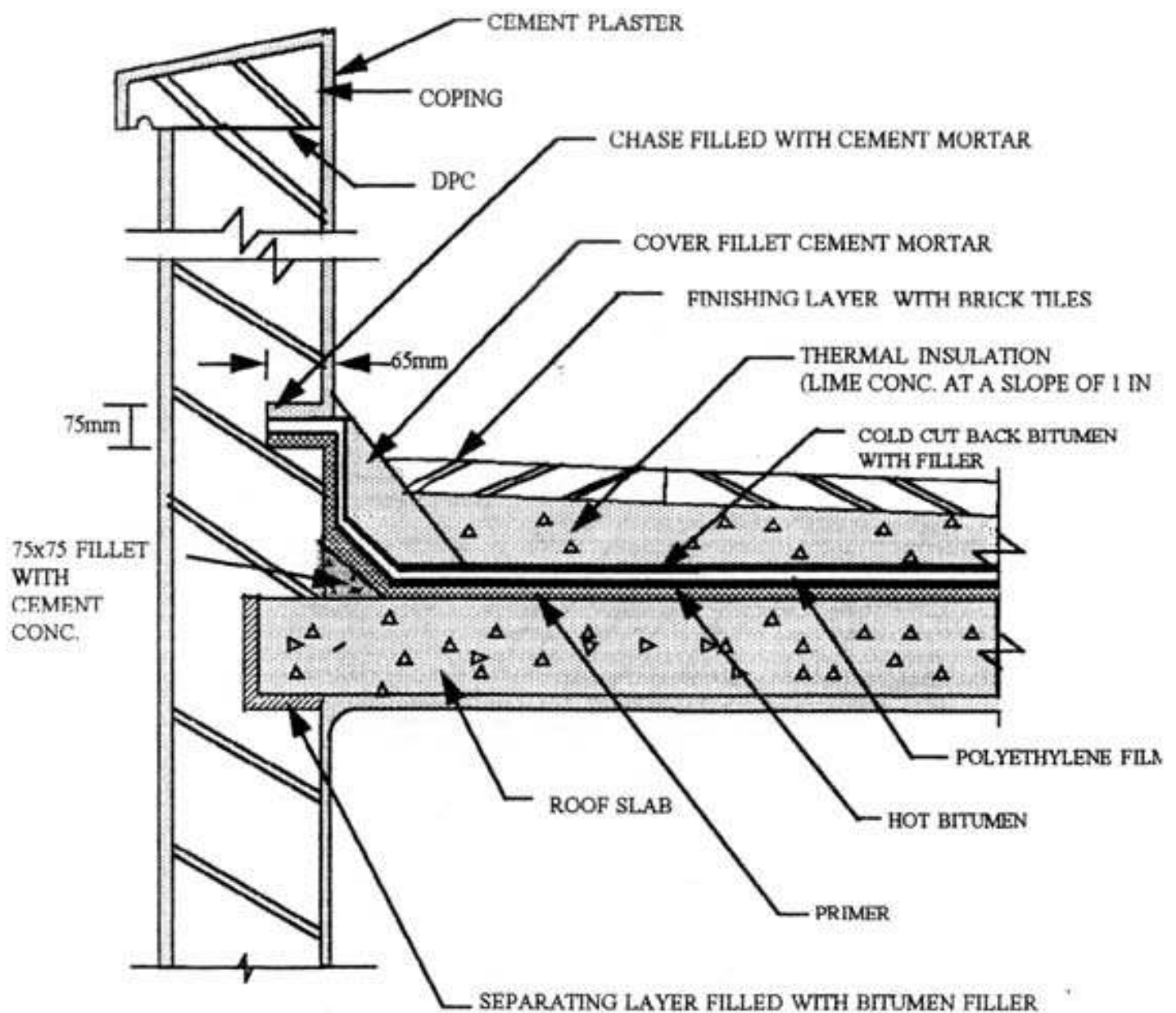


Fig. 6

**TYPICAL DETAIL OF WATER PROOFING TREATMENT USING
POLYETHYLENE FILM (FOR NEW ROOF)**

(AS PER IS:7290-1979)

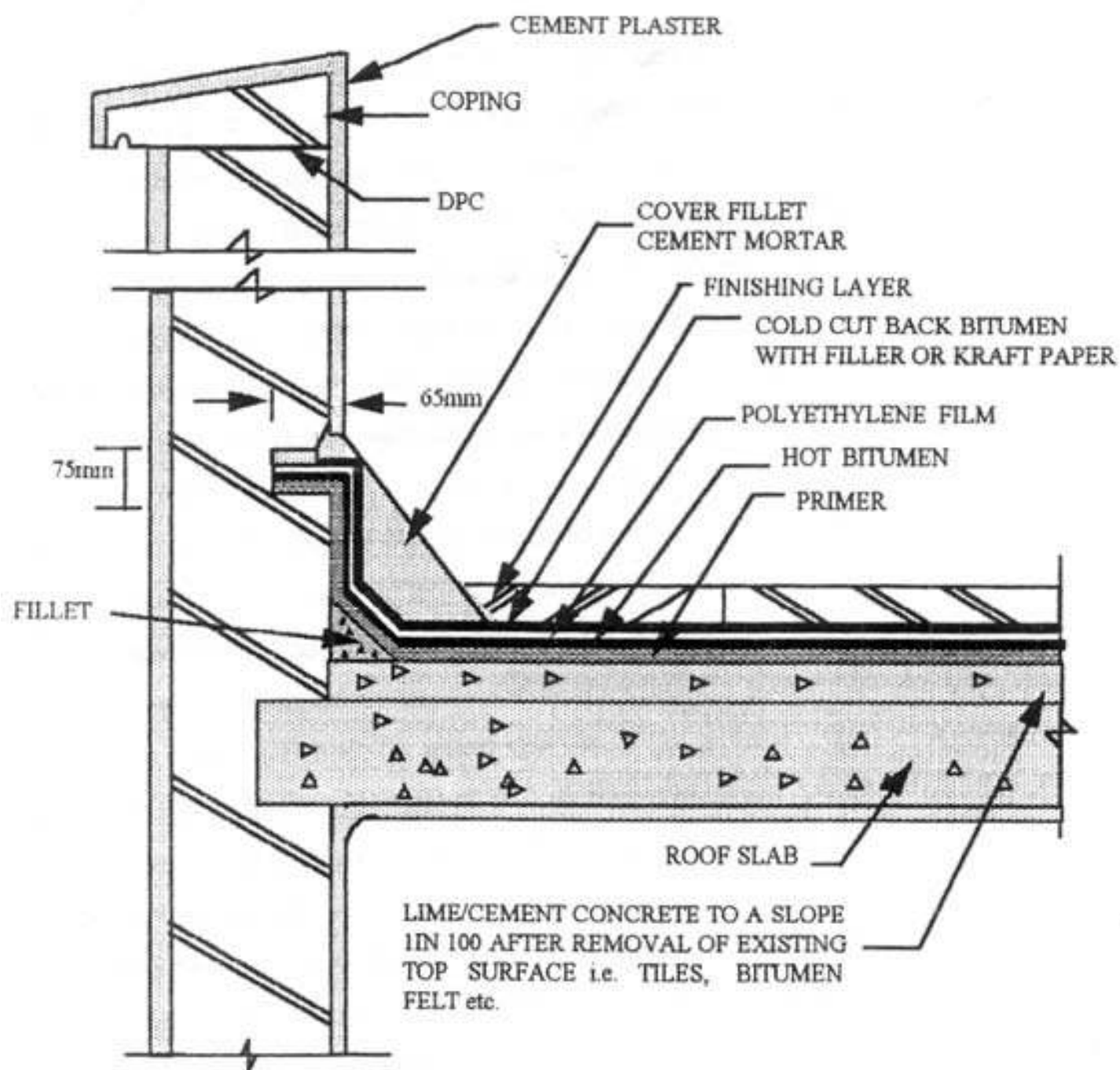


Fig. 7

**TYPICAL DETAIL OF WATER PROOFING TREATMENT USING
POLYETHYLENE FILM (FOR OLD ROOFS)**

(AS PER IS:7290-1979)

not taken, the film may get punctured or may develop wrinkles which may lead to its damage and affect its durable life.

5.6 Polymer modified cementitious slurry coating:

5.6.1 In order to obtain water proofed roofs polymer modified cementitious slurry coatings are applied over the base concrete. This technique of water proofing is latest development in the field of water proofing. It has been reported that currently this technique is more preferred world over. Polymer imparts significant improvement in impermeability. During the process of hydration the fine polymer particles form coating over the cement particle, thus interconnected voids are eliminated and continuous film is formed which has excellent water tightness. Polymer also improves the bond between old concrete and treatment. Polymer modified cementitious slurry have 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 consist of the polymer, liquid additives and clean water. Dry blend consist 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 recommended. To impart more flexibility, it is desirable to use some reinforcement like fibre glass cloth sandwiched between two coats. This coating should be covered by screed concrete to protect it against physical damage. There is no relevant IS or any other standard. Users are requested to follow specifications and instructions as per manufacturers' recommendations. This system can be used over new as well as old roofs.

5.6.2 Application of polymer modified cemenetitious slurry coating :-

Broadly 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, loose materials or any other deposits of contamination. Cracks and depression shall be filled up by fillers (cement sand mortar as per recommendation of suppliers). Prepared surface shall be thoroughly prewetted for one hour.
- ii) **Preparation of polymer modified cementitious slurry:-** Dry blend and liquid blend shall be mixed 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, fibre glass 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 strictly as per manufacturers'/ suppliers instructions. Users are advised to collect complete literature from manufacturer and study carefully prior to application of treatment.

A typical diagram for this system suggested by M/s Structural Water Proofing Co. is given in Figure 8.

5.6.3 Available material :

Various firms were asked to send the literature and test results of water proofing product marketed by them. Most of the firms sent the brochures of their products but did not submit test results. It has been mentioned in brochures that their products are highly suitable for water proofing as they develop excellent bonds with old concrete, breathable and have limited flexibility to accommodate crack in substrate. This description does not indicate quantified properties. Only M/s FOSROC Chemical Bangalore, submitted test results of their products BRUSH BOND RFX. M/s FOSROC has submitted test results for adhesion, abrasion resistance, accelerated weather test (UV Test - 5000 hrs.), elongation and tensile strength. Their product has been tested to ASTM C836 "Standard specification of high solid content, cold liquid apply elastomeric membrane" which are applicable for water proofing of building decks subjected to hydrostatic pressures. M/s Structural Water Proofing Company, has replied that their product does not get affected by ultra violet rays. MBT India and MC Bauchemie claims that this system is effective upto 70m water head.

In the absence of standard specification and suitability test certificate, it is extremely difficult to comment on the suitability of products marketed by various firms, unless their product is tested in the field. Therefore, it is desirable to use such product selectively. It is recommended that products of only such firm, who have obtained ISO-9000 certificate for quality product, should be used till relevant standard and suitability test for the system are developed.

Name of some of the firms who are in this field and who have obtained ISO-9000 certificate, alongwith their product name and approximate cost as advised by them are given in Table-3. Actual cost may differ depending upon location of site and condition of roofs.

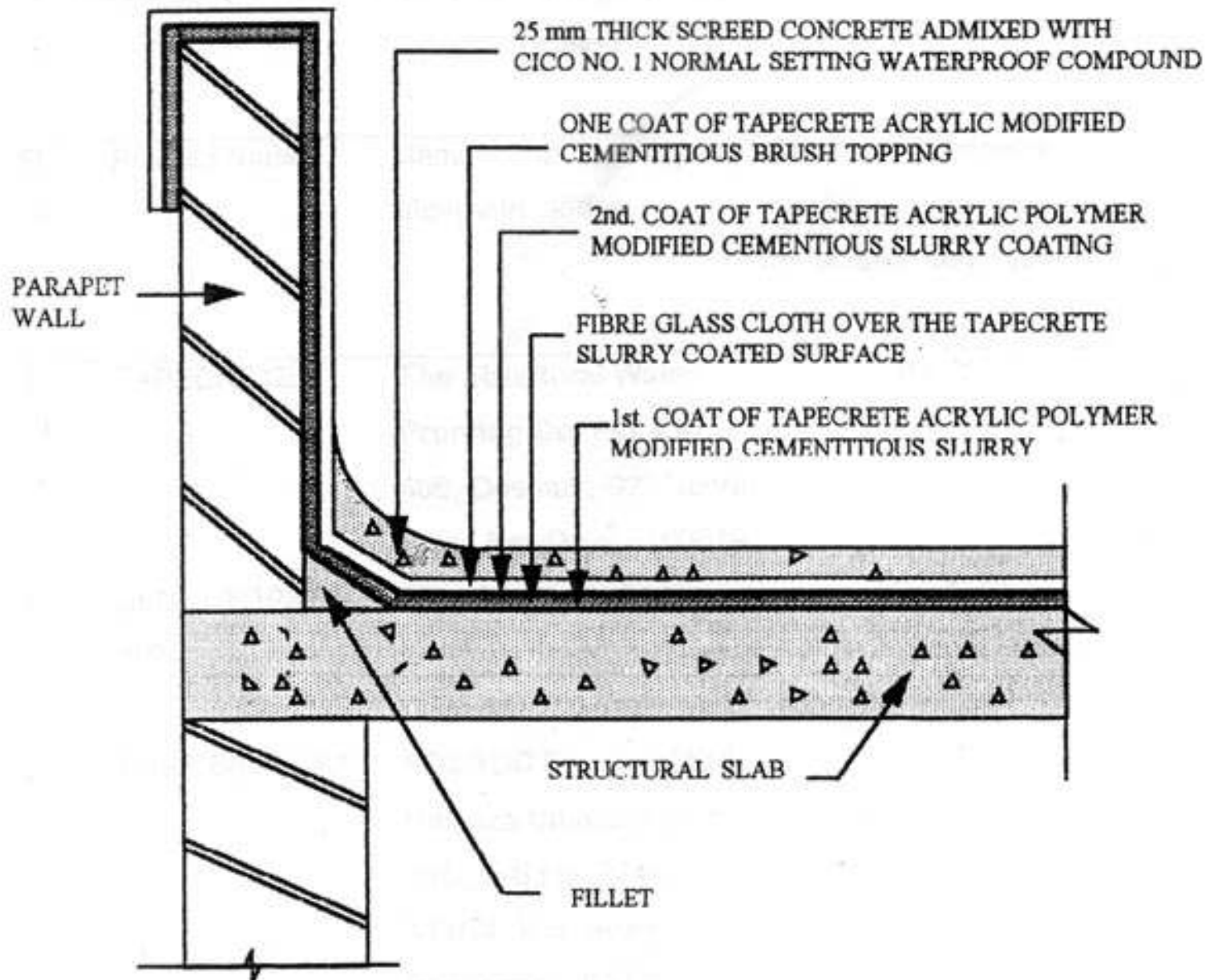


Fig.8

WATER PROOFING OF ROOF USING POLYMER MODIFIED CEMENTITIOUS SLURRY

(AS SUGGESTED BY M/S STRUCTURAL WATER PROOFING CO. PVT. LTD.)

Users are advised to obtain complete literature from respective firms prior to adoption of their material for water proofing of roofs.

Table-3

Sl. no.	Product Name	Name of company alongwith address	Cost of application of treatment (excluding cost of screed concrete) per sqm.
1.	TAPECRETE	The Structural Water Proofing Co. Pvt. Ltd., 406, Deepali , 92, Nehru Place, New Delhi-1100019	Rs.250
2.	SIKA TOPSEAL-107	Sika Qualcrete Ltd., 24-B, Park Street, Calcutta- 700 016	Rs. 350* * including cost of screed concrete
3.	Brush Bond RFX	FOSROC Chemical Ltd. Hafeeza Chamber, 2nd floor, P.B.No. 2744, 111/74, K.H. Road, Bangalore- 560 027	Rs. 310
4.	Master Seal- 550	MBT India Pvt. Ltd. 20/8 Old Rajinder Nagar, New Delhi- 60	Rs. 332
5.	Zentriflix Elastic	M.C. Bauchemie Pvt. Ltd., 201, Vardhman Chamber, Sector- 17, Washi, New Bombay- 400 703	Rs. 450

5.6.4 Advantages & Limitations:

This system is simple, easy to apply and involves only few steps. Literature study revealed that this system possess all desirable properties of ideal water proofing system but there is no relevant Indian or any other country standards. Thus, there is need for further study regarding this treatment, so that standards specifications, code of practice and acceptance criteria may be evolved.

5.7 Water proofing using polymer modified bituminous membrane:

5.7.1 Use of polymer modified bituminous membrane for water proofing is quite popular in Europe. This system is an ideal water proofing system which has all the ideal properties and long durable life. 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 is substrate. The extent of improvement depends upon type of polymer, correct material formulation, temp and mixing speed. The most commonly used modifiers in practice are Alactic poly propylene (APP) and styrene-butadiene-Styrene (SBC). Polymer modified bituminous membrane use a number of non-woven fabrics for reinforcement to improve their characteristics like lap joint strength, tensile strength and flexibility. Non-woven fibre glass mat and non-woven polyester mat are generally used as reinforcement. Polymer modified bituminous membrane are obtained by sand-wiching non-woven polyester fabrics or fibre glass 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. There is no relevant IS Specification. Therefore, users are advised to follow specification /instruction as per manufacturers' / suppliers' recommendation. This system is suitable for new as well as old roofs.

5.7.2 Method of application :- Steps involved in this water proofing system may be as given below:

- 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:3067-1988 should be completed.
- ii) Laying a coat of cold applied bitumen primer @ 0.2 to 0.4 l/sqm on entire roof surface.
- iii) Laying 85/25 grade hot blown bitumen @ 1.2kg/sqm all over the surface.
- iv) Laying 2.5-3mm thick polymer modified bituminous membrane with non-woven polyester fibre glass mat reinforcement, applied by torch with sealing all the joints.
- v) Laying 85/25 grade hot blown bitumen @ 1.2 kg/sqm 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 strictly as per manufacturers' recommendations. Users are advised to collect complete literature from manufacturers and study completely prior to application of treatment.

A typical scheme for laying of bitumen membrane as suggested by M/s STP Ltd. is shown in sketch 9.

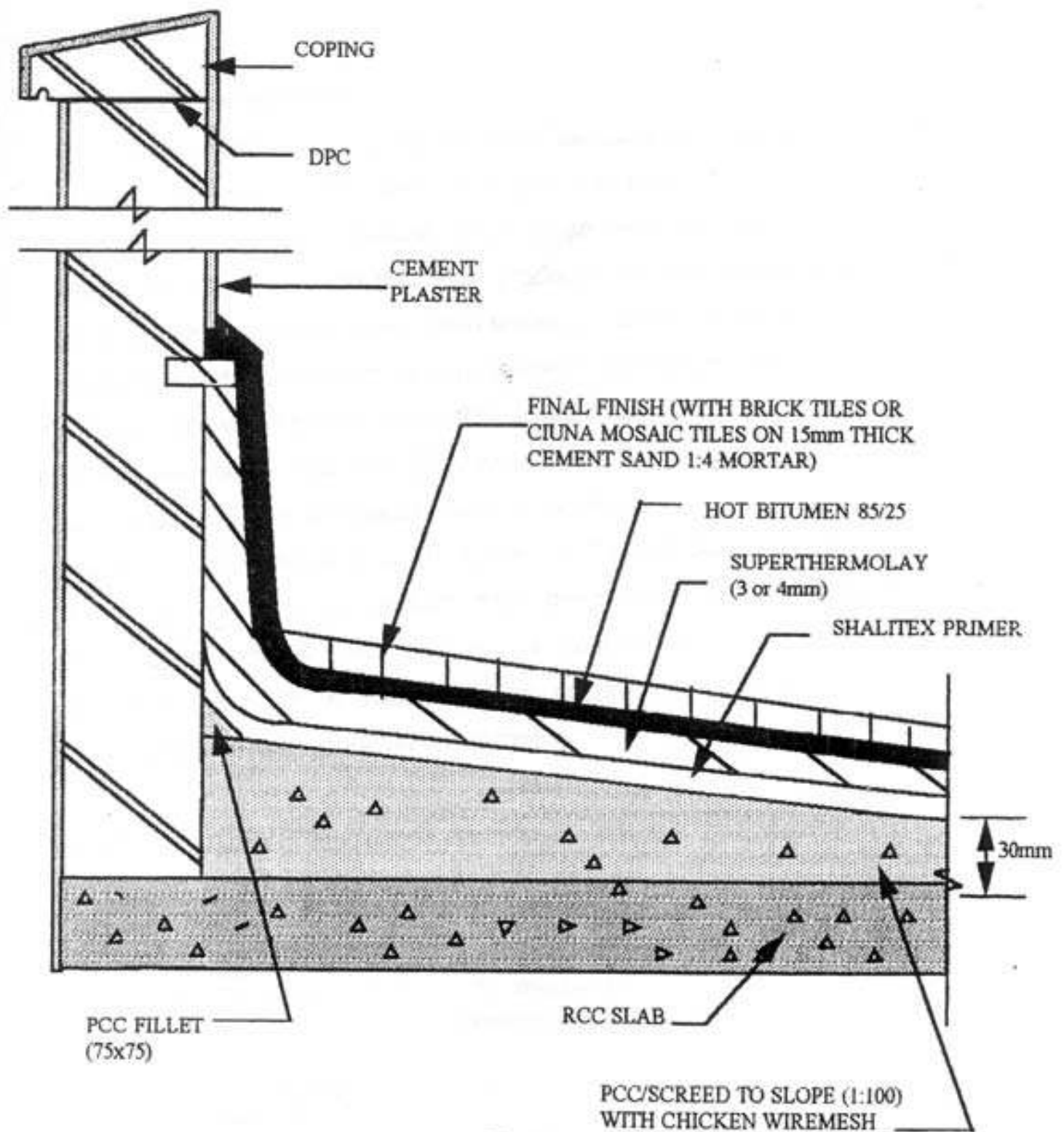


Fig. 9

WATER PROOFING OF ROOFS USING SUPER THERMOLAYPOLYMER MODIFIED BITUMINIOUS MEMBRANE

(AS SUGGESTED BY M/S S.T.P Ltd.)

5.7.3 Available material:

Various firms were asked to send literature on water proofing system marketed by them. Only two firm sent the brochure of their bituminous membrane products. Literature about these products was studied. It was noticed from the literature that their products are perfectly suitable for water proofing . These products have been tested by manufacturers for properties like softening point, penetration, tensile strength, elongation tear resistance, lap joint strength etc. Product of M/s STP Limited have been tested for aging and UV test (weather-o-meter test- 2000 hrs.) M/s STP Ltd claims that their products comply with UE Atc (European Union of Technical Agreement) MOAT 27-1983 and MOAT 30- 1984 and CGSB (Canadian General Standards Board) 37-GP-86M July-1980. Their products have been tested as per ASTM standard. Name of material, supplier and approx. cost of treatment as furnished by suppliers are given in Table-4. The actual cost of treatment may differ depending upon site condition and location.

Table-4

S.No.	Name of Product	Name & address of supplier	Approx. cost.of treatment/ sqm (excluding cost of regrading)
1.	Super Thermolay-Torchseal	STP Ltd., 570, Phase-V Udhyog Vihar, Gurgaon-122 016	Rs.528/-
2.	Aquashield-Glasseal	-do-	Rs. 425/-
3.	CICO Shield	The Structural water proofing Co. Pvt. Ltd., 406, Deepali , 92, Nehru Place, New Delhi- 1100 019	Rs. 340/-* *excluding cost of surface finish.

5.7.4 Advantages & Limitations:

This system is ideal for use, as it has all the desirable characteristics including long durable life. This system appears to be comparatively costly. There is no relevant Indian Standard for this system. Thus, there is need for further study regarding this treatment, so that standards specifications, code of practice and acceptance criteria may be evolved.

5.8 Comparison of various water proofing system:

It may be seen from the previous paragraphs that water proofing system using bituminous felt has limited life of 4-6 years. Thus, recurring cost of this system will be high, as the treatment will require replacement periodically. Considering the above limitations, this system is not suitable. Systems of lime concrete terracing & Mud-Phuska for water proofing are time proven systems, though they are very slow tedious and labour intensive. These system require strict quality control and supervision, which may not be possible in all the cases. Other three systems of water proofing using polyethylene film, polymer modified cementitious slurry and polymer modified bituminous membrane also appears to be suitable. Among these systems, there are well laid down specification for water proofing system using polyethylene film but it involves more number of steps and required strict supervision and quality control. The system of water proofing using polymer modified cementitious slurry is quite easy in application and has all the desirable properties but there are no standard specification, Code of practice & acceptance criteria for the system. Similarly, Water proofing system using polymer modified bituminous membrane is also an ideal system which has all the desirable tested properties including long durable life but appears to be comparatively costly and does not have standard specification. Therefore, it is worthwhile to try both these systems on experimental basis on some important buildings.

6. MEASURES TO PREVENT LEAKAGE IN NEW CONSTRUCTION:

In new construction, the problem of leakage can be prevented by extending roof by 30cm or so beyond supporting walls and by satisfying basic requirement of water proofing of roofs at design & construction stage. Extension of roof will eliminate chances of leakage on supporting walls, as the vertical joint on supporting wall is eliminated. Basic requirement of water proofing of roofs i.e. provision of adequate slope, no. of openings, proper detailing at junction of roof & parapet wall, proper treatment at expansion joint & provision of effective water proofing system have been described in para 4 & 5.

7. INSPECTION AND MAINTENANCE FOR LEAKY ROOFS:

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

7.2 Thorough inspection:- The inspection of roof should cover all the essential aspects which may affect water proofing system and may cause leakage in the roofs. Following aspect should be specifically covered:

- a) Availability of adequate slopes (minimum 1 in 100)
- b) Provision of fillet (angular or concave, not convex) 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 source of permanent leakage of water like
 - over head water storage tanks
 - 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.

7.3 Attention to roof leaking at isolated points:

7.3.1 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 water proofing has been fulfilled. If basic requirement for a leak proof roof as mentioned in para -4 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 location 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.

7.3.2 Suggested Course of Action for Roofs Leaking at Isolated Points:

Following course of action is suggested 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 Fillet 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 Tile Joints:-** 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:
 - a) **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.
 - b) **Provision of Adequate Slope:-** Mostly old roofs have not been provided with adequate slope. For lime concrete terracing, a slope of 1:60 has been recommended in IS:3067. Provision of recommended slope is must in order to ensure effective drainage of rain water. 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 regrading of roof surface, level should be marked on roof and parapet . Subsequently existing lime concrete surface should be made rough. After that regrading 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 should be ensured. If necessary, roof surface should be regraded using Mud-phaska and Mud plaster. After regrading, layer of mud-plaster should be allowed to dry before relaying of top surface.

- c) **Re-laying of Top Surface:-** After completion of regrading, 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.

7.4 Attention to roofs leaking heavily:

If heavy leakage is observed at large no. 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 are 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 compound like "Plastiseal" marketed by STP Limited. Subsequently, if necessary, regrading should be done as suggested in para 7.3.3 (viii). After regrading fresh water proofing system may be provided. Water proofing treatment may be any among various systems as mentioned in

para 5 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. Typical arrangements for repair of old roofs using polyethylene film are shown in Fig. 7.

8.0 Conclusions:

8.1 Leakage of roof not only causes inconvenience to users but also reduces the life of the structure.

(Para 1.1)

8.2 Stagnation of water due to undulating roof surface, provision of less no. of drainage points or choking of the same, and improper detailing at junction of parapet and roof etc. is one of the major contributors in making the roofs leaky.

(Para 2)

8.3 In order to obtain water proofed service, roofs need to be designed, constructed and maintained to satisfy basic requirements. Basic requirements are as under:

(Para 4.1,4.2,4.3, 4.4 & 4.6)

- i) Provision of adequate slope depending upon type of treatment but not flatter than 1 in 100.
- ii) Provision of adequate openings in size and numbers to drain out rain water.
- iii) Provision of 75mm fillet all along junction of roof with parapet wall alongwith provision of slope & drip course in coping.
- iv) Provision of an ideal water proofing system on roof surface.

8.4 In new construction, leakage can be prevented by extending roof by 30cm or so beyond supporting wall & by satisfying basic requirement of water proofing of roofs.

(Para 6)

- 8.5 i) All Water proofing systems described in Indian Standard or literature of firms, are for new construction. These systems may be adopted for old roofs with some modification as suggested in para 7.3 & 7.4.

(Para 5.1)

- ii) Among various water proofing systems, bitumen felt based water proofing systems has limited life. Thus recurring cost is high. Therefore, this system should not be used for water proofing.

(Para 5.3)

- iii) Lime concrete terracing and mud-phauska treatment for water proofing are time proven technique. They may continue to be adopted where ever they are found suitable. These techniques are slow, tedious & labour intensive, thus, it is desirable to try other 3 systems ie., water proofing system using polyethelene film, polymer modified cementitious slurry & polymer modified bitumen membrane which appears to be more suitable.

(Para 5.2, 5.4, 5.5, 5.6 & 5.7)

- iv) Well laid down specification for water proofing system using polyethylene film are available.

(Para 5.5)

- v) Polymer modified cementitious slurry based water proofing system is quick and easy in application but there are no laid down specification. Considering ease in application and other desirable properties, it is worthwhile to try this system on Railway buildings. As there are no specification for this system, it is desirable to use material of reputed manufacturer/ supplier only who has obtained

ISO-9000 certificate. After gaining experience, specification needs to be prepared.

(Para 5.6)

- vi) Polymer modified bituminous membrane based water proofing system is expected to last long as compared to other system as it has been tested for aging test also. Though treatment appears to be costly, it is worthwhile to use this system on some buildings as there are no specification for this system, it is desirable to use material of reputed manufacturer/ supplier who has obtained ISO-9000 certificate. After going experience, specification needs to be prepared.

(Para 5.7)

- vii) There is need to carry out further study regarding water proofing system using polymer modified cementitious slurry and polymer modified bituminous membrane to prepare detailed specification and code of practice. This study can be entrusted to institute like CBRI/ Roorkee.

(Para 5.6 & 5.7)

3.6

- i) For old leaky roofs, thorough inspection, covering all aspect which may affect water proofing, is essential. Further course of action depends upon the observation of inspection .

(Para 7.1)

- ii) In any case first of all action needs to be taken to fulfill basic requirements of water proofing.

(Para 7.2 & 7.3)

- iii) Subsequently, depending upon condition of leakage through roof isolated repair or complete replacement of water proofing system may be carried out.

(Para 7.2 & 7.3)

9. Recommendations:

9.1 Roofs of all building shall be designed to fulfill basic requirement of roofs which are as under:

- i) Provision of adequate slope depending upon type of treatment but not flatter than 1 in 100.
- ii) Provision of adequate opening in number & size.
- iii) Provision of 75mm fillet all along the junction of roof with parapet alongwith provision of slope and drip course in coping.
- iv) Provision of water proofing system over entire roof.

(Para 8.3)

9.2 In new construction, it is desirable to extend roof for 30cm or so beyond supporting walls.

(Para 8.4)

9.3 For water proofing of roofs, anyone among 5 water proofing systems i.e. Lime concrete terracing, Mud Phaska treatment, water proofing system using polyethylene film ,polymer modified cementitious slurry coating or polymer modified bituminous membrane, may be adopted.

(Para 8.5)

9.4 Polymer modified cementitious slurry coatings and Polymer modified bituminous membrane based water proofing system should be tried on buildings.

(Para 8.5)

9.5 For arresting leakage of roofs in old building thorough inspection shall be done. Based on observation during inspection, future course of action shall be decided. While opting remedial measure, first of all action should be taken to fulfill basic requirements of water proofing. Subsequently, depending upon condition of leakage through roofs, isolated repair or complete replacement of water proofing system shall be carried out.

(Para 8.6)

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References:

- i) IS 3067-1988 Code of practice for general design details and preparatory work for damp proofing and water proofing of buildings.
- ii) IS 2527-1984 Code of practice for fixing Rain water gutters and downpipes for roof drainage.
- iii) IS 3036-1996 Code of practice for laying lime concrete for a water proofed roof finish
- iv) IS 1322-1993 Specification for bitumen felts for water proofing and damp proofing (Fourth Revision)
- v) IS 1346-1991 Code of practice for waterproofing of roofs with bitumen felts (Third Revision)
- vi) IS 3037-1986 Specification for bitumen mastic for use in water-proofing of roofs (First Revision)
- vii) IS 4365-1967 Code of practice for application of bitumen mastic for waterproofing of roofs.
- viii) IS 7290-1979 Recommendations for use of polyethylene film for water proofing of roofs.
- ix) "Water Proofing of Buildings" Course Notes issued by Central Building Research Institute, Roorkee.
- x) " Water proofing Understanding the science" by V.D. Gupta, published in Civil Engineering & construction Review, May, 1999.
- xi) Literature on various products sent by :
 - a) **The Structural water proofing Co. Pvt. Ltd.,** 406, Deepali , 92, Nehru Place, New Delhi- 1100 019
 - b) **STP Limited,** 570, Phase-V, Udhog Vihar, Gurgaon- 122 016

- c) **MBT India Pvt. Ltd.** 20/8 Old Rajinder Nagar, New Delhi- 60
- d) **M.C. Bauchemie Pvt. Ltd.,** 201, Vardhman Chamber, Sector- 17, Washi, New Bombay- 400 703
- e) **Sika Qualcrete Ltd.,** 24-B, Park Street, Calcutta- 700 016
- f) **FOSROC Chemical Ltd.** Hafeeza Chamber, 2nd floor, P.B.No. 2744, 111/74, K.H. Road, Bangalore- 560 027.

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केन्द्रीय भवन अनुसंधान संस्थान, रुड़की !

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BHAGWAN DASS
Scientist,
B.P.P.P. Division

No. BPPP/BD/99

Dated 7.6.1999

FAX No. 91-0522-458500 / 450398

Subject : TAMPING MACHINE FOR RAMMING & COMPACTING LIME CONCRETE
LAID OVER CONCRETE ROOFS.

Dear Shri Gupta,

Please refer your fax No. CBS/BMC/LOE (98) dated 03.06.99
addressed to Dr. L.K. Agarwal regarding the Tamping Machine
developed by this Institute.

I am enclosing herewith the technical details of this machine for
your information. In case, you still need some other information
on this machine, please feel free to write to us.

With kind regards,

Yours sincerely,

Bhagwan Dass

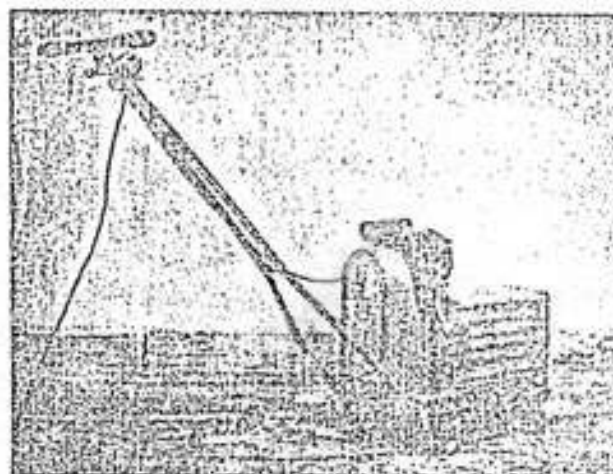
(BHAGWAN DASS)

Encl : As above.

Shri B.M. Gupta,
Director/B&K/CB-II,
Research Designs & Standards Organisation,
Ministry of Railway, Govt. of India,
LUCKNOW- 226 011.

P.S. We have tried repeatedly to reply by fax but it could
not be done due to communication error.

TAMPING MACHINE FOR LIME CONCRETE TERRACINGS



- Application/Uses** : Suitable for tamping lime concrete terracings laid on flat roofs.
- Salient Technical Features** : The machine has three identical tamping units with mounted on an angle iron chassis. The entire machine may be moved forward and backward on two rollers provided below the chassis. The machine can tamp a roof surface of about 50 to 60 sq.m./hr. with high density and resistance to water penetration. The power requirement is 0.5 HP.
- Environmental Aspects** : No special measures are required.
- Level/Scale of Development** : Prototype designed and tested.
- State of Commercialisation** : Two licencees, Technology in production
Indian Patent No. 107725
- Major Components/ Raw Materials** : Standard steel section, electric motor, cam and roller follower and pulleys.
- Major Plant Equipment & Machinery** : Standard mechanical workshop facilities.
- Techno-economics** : Estimated capital investment is about Rs.10 lakhs.
Cost of Tamping Machine would be about Rs.20,000/-.
- Technology Package** : Manufacturing drawings and specifications of standard components.

For further details please contact :

Director

Central Building Research Institute, Roorkee-247 667. (INDIA) .

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