IRC:34-2011

RECOMMENDATIONS FOR ROAD CONSTRUCTION IN AREAS AFFECTED BY WATER LOGGING, FLOODING AND/OR SALTS INFESTATION

(First Revision)

INDIAN ROADS CONGRESS
ESTABLISHED 1934
सन्मार्गात् लोक सेवा

INDIAN ROADS CONGRESS
2011

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Published by

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector 6, R.K. Puram,
New Delhi-110 022

MAY, 2011

Price Rs. 400/-
(Packing & postage extra)

First Published	:	January, 1970
Reprinted	:	May, 1974
Reprinted	:	May, 1980
Reprinted	:	August, 1996
First Revision	:	May, 2011
Reprinted	:	May, 2012

Printed at Aravali Printers & Publishers Pvt. Ltd., New Delhi-110 020
(500 copies)

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INTRODUCTION

In water logged areas, due to water, whether from capillary rise, seepage from earthen shoulders or penetration from pavement layers, the subgrade of pavements gets saturated. Reduction in load carrying capacity of subgrade is related to the degree of saturation of subgrade. The strength of pavement layers laid over the subgrade is dependent on the support of subgrade. Due to loss in load carrying capacity of subgrade, the strength of pavement layers also reduces. Load from traffic remaining the same with the reduction in strength of subgrade, pavement deterioration gets accelerated. It is common observation that pavement which behaves very well during summer months suddenly starts getting damaged on on-set of monsoon. During the prolonged period of monsoon, the pavement gets affected by water develops cracks which get converted into potholes.

Pavements with good drainage remain intact even during monsoon. The water entering the subgrade has to be drained out or prevented from reaching upto subgrade level.

Realizing the advantages that can be had by keeping water away from subgrade, Shri Mahesh Kumar Convenor H-4 Committee Engineer-in-Chief Haryana PWD, thought to have a re-look into the IRC:34:1970, "Recommendation for road construction in water logged areas". The work of rewriting the revised version was done by a subgroup consisting of Shri Arun Kumar Sharma, CE, MORT&H, Mrs. Minimol Korulla, Chief Consultant and Ms. Shabana Khan, Consultant, Macaferri. Their valuable contribution is greatly acknowledged.

The revision of document includes recommendations to use modern materials and techniques for solving problems associated with water logging. Some of the modern techniques recommended are

a) Drainage of storm water into underground aquifer by vertical drain.
b) Drainage of sub sub-surface water by edge drains, Fin drains etc.
c) Drainage of water by French drains.
d) Depressing of level of sub soil water by drainage composites.
e) Capillary cut off by geomembrane.

Recommendations for some case studies have been made in the revised document. The draft revision was approved by H-4 Committee (Personnel given below) in the meeting held on 13.10.2010. The Highways Specification and Standards Committee deliberated on this document on 22.10.2010 and cleared for presentation in Council Meeting. At Nagpur Council Meeting the document was cleared with authority to Convenor to modify as per comments of Council members. The Convenor further reviewed the document in light of the comments of the Council members. The document was submitted for printing by the Convenor on 12.03.2011.

Kumar, Mahesh	-	Convenor
Sharma, Arun Kumar	-	Co-Convenor
Mathur, Sudhir	-	Member-Secretary

1 SCOPE

These recommendations deal with the problem of road construction in waterlogged areas, including those subjected to flooding and/or infested with detrimental salts like sulphates and carbonates. The recommendations relate both to the construction of new roads and to the remedial measures to be adopted in the case of existing roads.

1.1 For the purpose of these recommendations for coarse grained soil, water logged areas are considered to be those where the level of subsoil standing water is such that for prolonged periods the bottom of subgrade immediately below the pavement is well within the capillary fringe of the water table i.e. within about 1.5 m. For embankment with fine grained soils the capillary fringe of water table may be up to 10.0 m.

1.2 Remedial measures for following situations are included in these recommendations:

i) **Existing roads on low embankments and subgrade within capillary fringe :** Such roads frequently get damaged whenever water stands on the ground. (for details refer **para 4.5.2.5 and 8.1**).

ii) **Construction of new carriageway at a higher level, compared to the existing carriageway on low embankment :** The water from central verge saturates the inner shoulder of existing carriageway (for details refer **para 8.2**).

iii) **Drainage of water from roads in cutting :** Wet portion of side slopes is an indication that phreatic line is cutting the side slopes. Higher water level in side slopes will saturate the subgrade below the pavement (for details refer **para 8.3**).

iv) **Hill roads with phreatic line cutting the side of hill slope :** Wet portion of side slope of hill above pavement is an indication that phreatic line is above the pavement level. Higher water table will soak the subgrade (for details refer **para 8.4**).

v) **Bund roads by the side of rivers/canals :** In general bund roads along canals are located at a higher level with respect to full supply level in the canal. In case full supply level in the canal is at a higher level, than level of bund road, subgrade of bund road will get affected by seepage water from canal (for details refer **para 8.5**).

vi) **Drainage of pavement at bends in hills :** Lack of drainage in hills will soak the subgrade of pavement (for details refer **para 8.6**)

vii) **Drainage of land between road and rail track :** Effective drainage of water from area between road and rail track is required, otherwise the standing water will saturate the subgrade of pavement (for details refer **para 8.7**).

viii) **Drainage of road with built up areas on both sides of road and discharging water on road :** Lack of effective drainage will result in soaking of subgrade of pavements (for details refer **para 5.3 and 8.8**).

ix) Road embankments over-topped by flood water, the subgrade will get soaked due to water (for details refer **para 5.2 and 8.9**).

1.3 Due to soaking of subgrade, frequent formation of cracks in pavement and then conversion of cracks to potholes are common in all these cases mentioned in **para 1.2** above. Water in pot holes accelerates deterioration of pavements. These cracks and potholes require frequent repairs. These roads in addition to capillary rise of ground water leading to softening of subgrade may also be affected by flooding and/or ground water infested with detrimental salts like sulphates and carbonates.

2 ISSUES INVOLVED IN ROAD CONSTRUCTION IN AREAS AFFECTED BY WATER

2.1 Due to Water Logging

As a result of migration of water by capillary action from the high water table/high flood level, the subgrade soil gets further saturated and this leads to a gradual loss in its bearing capacity. With the loss in bearing capacity of soil, axle load remaining the same, deterioration of pavement gets accelerated. It is important to ensure the drainage of storm water and lowering of subsoil water so that subgrade remains dry. Remedial measures should be taken to keep water away from subgrade.

2.2 Due to Flooding

Where continuous flooding for long periods takes place the progressive deformation of subgrade and pavement is accentuated by ingress of water from the top of the wearing surface, earthen shoulders or sides of embankment. The flood water saturates the subgrade thus reducing the bearing capacity. In case of bituminous pavements, the already inadequate waterproofing of the surface is impaired further by stripping of the binder due to prolonged contact with water. While in the concrete pavement, water in the subgrade may lead to pumping and cracking of pavement.

2.2.1 Embankment should be designed to withstand the effect of flooding.

2.2.2 Sufficient cross drainage structures should be provided so that water can pass across the embankments.

2.2.3 In case flood water cannot be allowed to flow across the embankment, due to likelihood of submergence of human settlements on the other sides of embankment, then embankment should be designed to withstand the effect of flood water. Good quality granular soil should be used in embankment construction so that the soil remains intact during flooding. During high floods, phreatic line should remain well within the cross section of earthen embankment. Services of geotechnical/irrigation engineer should be taken for design of such embankment which is more or less acting as an earthen dam. Seepage across embankment and possibility of piping should be taken care of.

2.3 Due to Presence of Detrimental Salts

The problem is aggravated if in addition to water logging and/or flooding, harmful salts like sulphates of sodium, calcium or magnesium and sodium carbonate are present either in the sub grade soil or in the ground water. Damage to crust from harmful salts can be in two ways - due to physical or chemical effect.

2.3.1 *Physical effect of the harmful salts*

In waterlogged areas (infested with detrimental salts), the salts keep on moving up with capillary moisture. During subsequent evaporation of the salt-laden water, the salts are left behind and they get concentrated in the surface layers. The salts increase many times in volume upon hydration under suitable humidity and temperature conditions. Alternate* hydration and dehydration results in repeated formation of salt crystals occupying much more volume than the amorphous salts lodged in the voids. In due course, these repeated volume changes break up the structure of the pavement, working from the top downwards particularly due to seepage/capillary rise.

2.3.2 *Chemical effect of the harmful salts*

The damage due to chemical action is mainly on account of sulphates of calcium, magnesium or sodium. Construction works specially vulnerable to this type of attack are those containing cement like cement concrete pavements and stabilized soil cement base/subbase courses.

2.3.2.1 *Cement concrete*

The sulphates present in the subsoil which migrate to the top by capillary action, react with the free lime liberated from cement resulting in the formation of gypsum. The reaction is accompanied by a considerable increase in the volume of the solids which is known to lead to the destruction of the hydrated cement matrix. After gypsum has been formed, or if calcium sulphate itself is found in that soil or ground water, tri-calcium aluminate in the hydrated cement combined with sulpho-aluminate which gives rise to further expansion of volume and damage. Apart from the formation of gypsum and calcium sulpho-aluminate, the decomposition of hydrated calcium silicate by sulphate solution is an additional factor affecting the durability of concrete. However, this would occur normally only in the case of calcium or magnesium sulphate solution which is found generally in waterlogged areas near the sea.

Dissolved carbon dioxide and bicarbonate salts present in certain marshy and rice growing areas also take part in the leaching of lime liberated from hydration of cement and slowly attacking the cementitious calcium silicate hydrated gel formed. Such solutions are characterized by pH value in the acidic range, usually below 5.

Concrete is not directly attacked by solid sulphate salts, but only by their solutions in water so that it is the amount of salts dissolved in the ground water that determines the rate of

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* (As a result of research carried out in India, it has been demonstrated that crystallization of sodium sulphate takes place when temperature is below 32 degree celsius and relative humidity above 80 percent. In northern parts of the country these conditions exist generally during the period of winter rains)

attack. As a result of chemical action of sulphates, the cement concrete pavements suffer internal disintegration and gradual falling from the underside. The process described is, however, slow.

2.3.2.2 *Soil cement*

Presence of sulphates in waterlogged areas has a detrimental effect on soil cement mixtures similar to that in the case of cement concrete pavements.

2.3.2.3 Bituminous construction

It does not appear that these salts, in the concentration they normally occur in soil, ground water or sea water have any detrimental chemical effect on bituminous construction.

2.3.2.4 Water-bound macadam

Salts do not directly affect un-surfaced water bound macadam constructions provided the filler material used in them is inert and free of harmful constituents.

3 RECOMMENDATIONS ON METHODS OF ROAD CONSTRUCTION IN AREAS AFFECTED BY WATER

3.1 The recommendations are divided into the following three groups :

a) Road construction in areas where the problem is of water logging.

b) Road construction in areas where in addition to water logging, flooding for prolonged periods is also expected.

c) Road construction in areas where in addition to water logging, harmful salts are present in the subsoil or ground water.

3.2 Different treatments are suggested under each group. Some of these can be made use only on new construction, and others on old, while some hold good for both. Broad guidelines about these are provided at the beginning of each section.

4 RECOMMENDATIONS FOR ROAD CONSTRUCTION IN AREAS WHERE THE PROBLEM IS OF THE WATER LOGGING ALONE

The remedial measures recommended under paragraphs 4.1 to 4.6 could be utilized both on new constructions and existing roads. However, the capillary cutoff technique described under para 4.7 will be found economical only on new roads.

4.1 Depressing the Level of Subsoil Water by Drainage Measures

Satisfactory results could be achieved by providing 1.50 to 1.80 m deep drainage channels (below the ground line) as close to the road bank as shown in **Fig. 4.1**. These channels are connected by suitable outfalls to natural drainage. Alternatively, buried drains of suitable design such as French/Fin drains could be provided at the edges of the pavement for lowering of water table. Either of these measures will be effective in keeping the bottom of subgrade above the capillary fringe. This method of drainage is applicable to all types of road construction (whether rigid or flexible) and should be preferred wherever economically feasible.

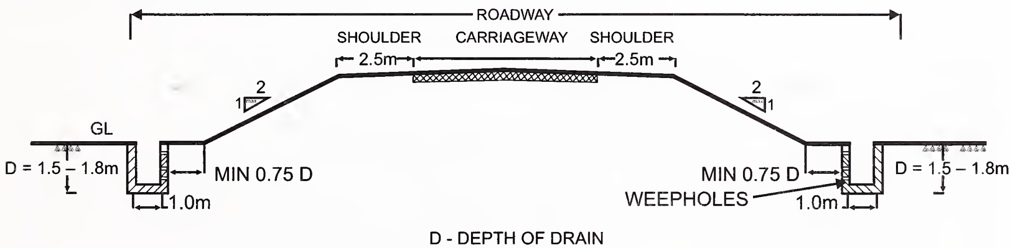


Fig. 4.1 Deep Drains For Lowering Water Table in Embankment

Note : Weepholes in lined drain to facilitate seepage of ground water into drain

4. 2 Raising of the Embankment

Where it is too expensive or impractical to provide deep drainage channels as specified in para 4.1 above, it is recommended to do a careful examination of the economics of the case, and an embankment of such height may be provided that the bottom of the subgrade remains at least 1.5 m above the highest water-table/highest flood water level as shown in **Fig. 4.2**. The earth work over existing road surface shall be as per Clause No.300 of MORT&H Specifications which is reproduced below :

"Earthwork over existing road surface: Where the embankment is to be placed over an existing road surface, the work shall be carried out as indicated below.

i) If the existing road surface is of granular type and lies within 1.0 m of the new formation level, it shall be scarified to a depth of 50 mm or as directed so as to provide ample bond between the old and new material. The thickness of the soil layer, if any, interposed between the bottom of the sub-base and the top of the scarified surface, shall not be less than 0.5 m, and the soil shall meet the specified properties and compaction requirements as for the subgrade.

ii) If the existing road surface is of bituminous type or cement concrete, and lies within 1.0 m of the new sub-grade level, the bituminous layer shall be removed completely and the requirements specified in para (i) above are to be met with.

iii) If the level difference between the existing road surface and the new formation level is more than 1.0 m, the existing surface shall be roughened, after ensuring that minimum thickness of 0.5 m of subgrade is available".

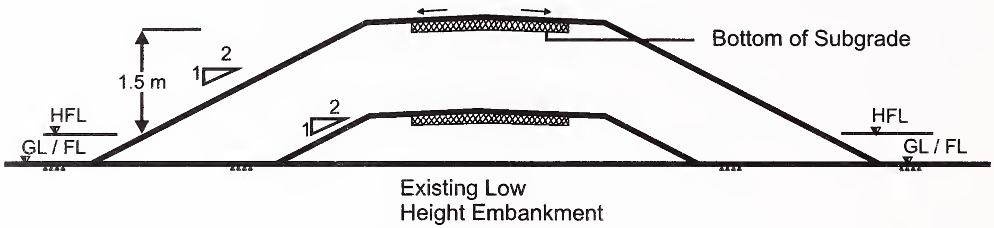


Fig. 4.2 Raising of the Embankment

4.3 Drainage of Storm Water into Underground Aquifer

In case, it is not possible to provide drainage system for disposal of storm water then the storm water can be drained into underground aquifer by providing vertical drains. For more details about vertical drains for storm water drainage refer IRC:SP-50. Cross-section of vertical drain is shown in **Fig. 4.3**. Salient features of vertical drains are:

a) The discharge of storm water is in permeable strata.

b) The perforations in the PVC pipe are covered with Geotextile.

c) The inlet pipes of vertical drain are 750 mm above the bottom of inlet chamber so that debris will not enter the vertical drain. The debris stored in the inlet chamber can be cleaned.

d) Inflow of storm water is through removable perforated R.C.C cover slab

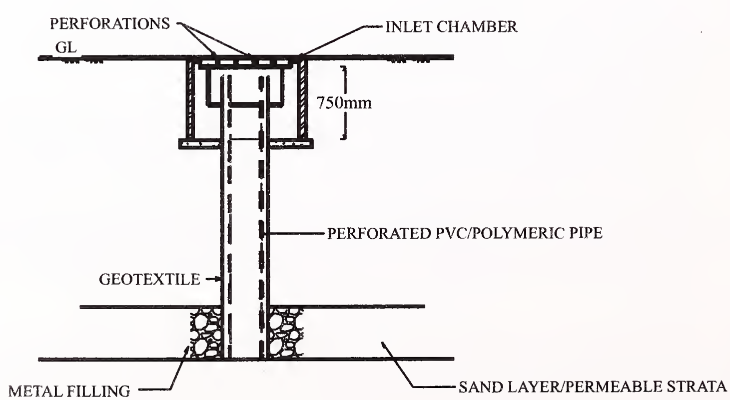


Fig. 4.3 Discharge of Storm Water into Underground Aquifer

4.4 Providing Thickness of the Pavement as Per Subgrade Strength

Efforts should be made to provide longitudinal drains or sufficiently high embankment or capillary cutoff or discharge of water into ground aquifer to keep subgrade dry. The thickness of the pavement should be determined as per IRC:37 and construction as per MORT&H "Specifications for Road and Bridge Works".

4.5 Lowering Water Entrapped in the Pavement

4.5.1 *Roads on low height embankments*

If practical and economically possible, the bottom of subgrade level should be raised by minimum 1.50 m above the general ground level/high flood level. Work of raising the embankment shall be done as per Clause 13.1 of IRC:36 or relevant clauses of MORT&H Specifications for Road and Bridge Works. In case resources don't justify raising of embankment, then lowering of local water table is second best alternative.

4.5.2 *Drainage of sub surface water*

For details, reference can be made to IRC:SP-50 Clause No.8.5.

4.5.2.1 Salient requirements are given below for ready reference

a) Darcy's Law is applicable for subsurface flow of water.

b) Field observations and discharge measurement on the completed works to assess the performance of subsurface drainage arrangement should be carried out. Based on the measurement, the depth of subsurface drain is increased or additional provision for subsurface drain is made at closer spacing.

c) Some typical arrangements indicating use of formation drains and drainage blanket is shown in **Fig. 4.7.5**. The drainage can be affected by installation of solid pipes with open joints, perforated pipes surrounded by free draining material or the filter. The filter material is required to prevent fine soil particles from flowing into the system, at the same time it should have required degree of permeability to drain off the required quantity of water. Also, the filter material must be more permeable than the surrounding material for stable flow situations and filter material not to flow into perforations or joints in drainage pipes.

4.5.2.2 Aggregate filters

Requirements of aggregate filter given in IRC:SP-50, Clause 8.6 is reproduced for ready reference, "A properly designed and installed aggregate filter should be able to retain soil and prevent soil particle movement, thus eliminating piping potential. Properly, designed aggregate filters ensure that there are no large voids within the filter and particularly at the soil filter interface of a subsurface drainage structure. A single component aggregate filter may be used to protect relatively coarse soils whereas drainage through fine soils usually requires a multi-layered aggregate filter. A multi-layered filter consists of a fine aggregate gradation which retains the natural soil particles at their original positions and a coarser filter aggregate which prevents particles of the fine aggregate filter from migrating into the perforations of a drainage pipe or granular water transport medium." A properly designed and installed aggregate filter should be able to retain soil and prevent soil particle movement, thus eliminating piping potential. Grading requirements for filter material given in MORT&H specifications for road and bridges works is reproduced in **Table 4.5.2.5**.

Table 4.5.2.5 Grading Requirement for Filter Material Percent by Weight Passing the Sieve

Sieve Designation	Class I	Class II	Class III
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	50-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-10
1.4 mm	59-96	-	0-5
710 micron	35-80	6-18	-
355 micron	14-40	2-9	-
180 micron	3-15	-	-
90 micron	0-5	0-4	0-3

Note 1 : When the soil around the trench is fine grained (fine silt or clay or their mixture) then Class I grading, when coarse silt to medium sand or sandy soil then Class II grading and when gravelly sand then Class III grading should be adopted.

Note 2 : The thickness of backfill material around the pipe should not be less than 150 mm. Therefore considering that the minimum diameter of the pipe as150 mm, the width of the trench should not be less than 450 mm.

4.5.2.3 Fabric filters

Requirements of filter fabrics given in IRC:SP-50 Clause No 8.7 is reproduced below for ready reference.

"Filter fabrics or Geotextiles are generally manufactured from polyester or polypropylene or similar fibres, either woven or non-woven in variety. Specification of Geotextile has been covered in MORT&H Specifications for Road & Bridge Works. For subsoil drainage system bio-degradable fabric filters are not used as their life span is very short. Geotextiles eliminate the need for aggregate filters, as mentioned in **para 4.5.2.2**. The fine pore size and high permeability of non woven geotextile make them suitable filter for a broad range of soil gradations. Also, such filters are available with varying pore sizes and permeability properties so as to meet the need of nearly all subsurface drain designs. Use of filter fabric is shown in **Fig. 4.5.2.3**.

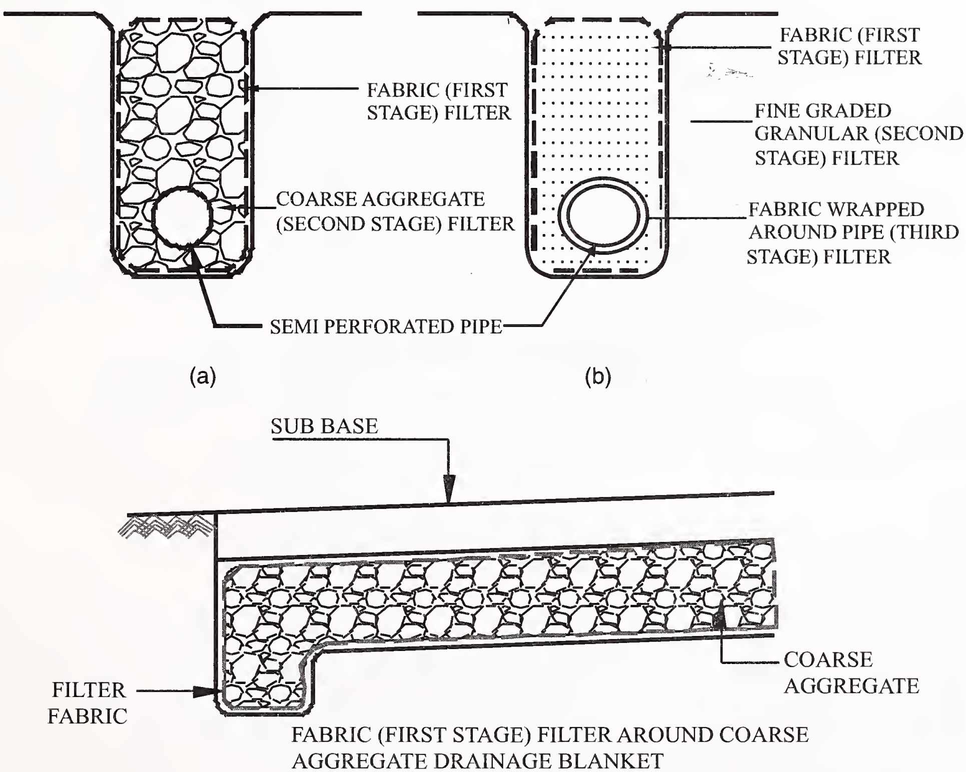


Fig. 4.5.2.3 Use of Fabric as Filters

4.5.2.4 Close jointed perforated pipes, open jointed un-perforated pipes, surrounded by filter material laid in a trench or aggregate drains to drain the pavement courses. Sub surface drains designed by using Geosynthetic and approved by the Engineer can also be used. The work of subsurface drains shall be executed as per relevant clause of MORT&H specifications.

4.5.2.5 Drainage of low height embankments by edge drains

Drainage of low height embankment by edge drain is recommended for embankment constructed with granular soil which allows flow of water in pavement/embankment to edge drain. Trench is cut along the road on both earthen shoulders adjacent to carriageway in sufficient width and depth from top of surface. In the trench, 150 mm dia suitable P.V.C/ polymeric/synthetic pipe (lower half periphery perforated) can be laid in a proper slope 1 in 100 so that the water coming out of pavement is first collected in longitudinal drain and then drained out of embankment as shown in **Fig. 4.5.2.5**. The pipe in longitudinal trench shall have holes in lower half. Perforation diameter should be decided as described in Clause No. 12 of IRC:42 as reproduced below.

Size of the holes may be close to D85 size of material surrounding the pipe subject to being minimum 3 mm and maximum 6 mm. D85 stands for size of the sieve that allows 85 percent of the material to pass through it. The back fill may consist of sand gravel material or crushed stone satisfying the grading of **Table 4.5.2.5** (in case where no specific design exercise based on filtration and permeability criteria has been carried out). The back fill should be free of organic material, clay balls and other deleterious material.

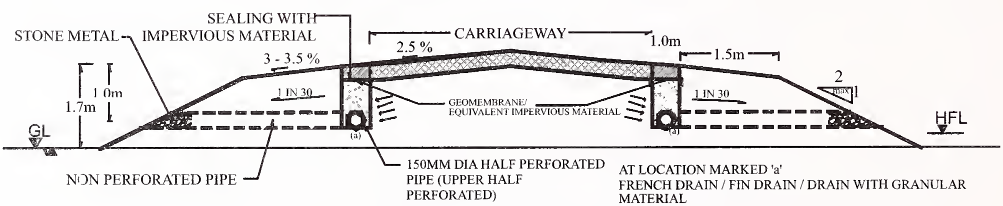


Fig. 4.5.2.5 Drainage of Low Height Embankment by Edge Drains

The trench is then filled with granular material. The top of trench is covered with impervious material/Geomembrane so that surface water does not enter the trench. Across the trench, at every 10 m interval, a cross trench of same size is to be provided. In the cross trench the pipe shall not be perforated. Alternatively fin drain/French drain with perforated PVC/ polymeric/synthetic pipe 150mm dia can be considered. The top of Fin drain/French drain can be sealed by impervious material/geomembrane. Geomembrane should be protected with Type-I geotextile (IRC:SP-59). For definition of French drain/Fin drain, refer **paras 4.5.2.6 and 4.5.2.7**. The water collected in drain shall be suitably disposed off. Subbase shall have better permeability then overlaying layers.

Location of subsurface drain with respect to pavement layers can be adjusted depending upon the location where water is entrapped. Location of drain with respect to pavement layers is shown in **Fig. 4.5.2.5.1**.

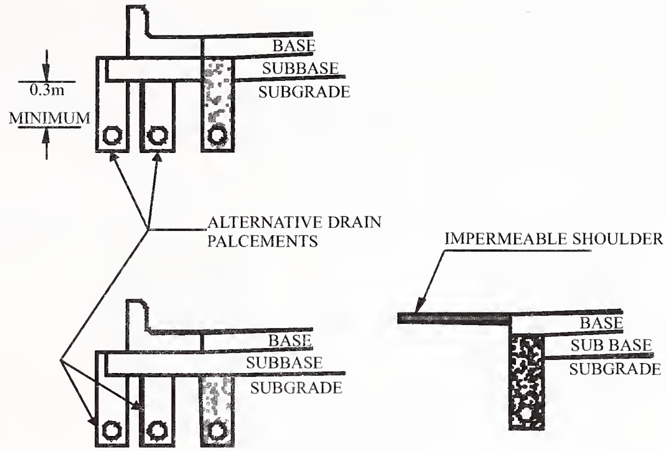


Fig. 4.5.2.5.1 Location of Subsurface Drain

4.5.2.5.1 Specification of Geomembrane

Geomembrane should contain not less than 95 percent of pure HDPE polymer and a balance not higher than 5 percent of carbon black, antioxidants and thermal stabilizers.

Raw Material: High Density Polyethylene

Thickness - ASTM D 5199: $\geq$ 0.75 mm

Permeability: 1 x 10^{-12} to 1 x 10^{-15} m/s

Puncture Strength - ASTM D 4833: $\geq$ 180 N

Tear resistance - ASTM D 1004: $\geq$ 90 N

Note : Equivalent ISO and IS codes are given in **Annex-1**

4.5.2.6 French Drains

French drains are edge drains which consist of two components, permeable drainage media and filter media. Permeable drainage media ensures that water can be transported within the drain. The filter ensures controlled movement of ground water from the soil into the subsurface drain. In some instances, a porous pipe is installed at the base of the trench to increase the water transport capacity of the drain. For french drains permeable drainage media is graded gravel aggregate and filter media is Geotextile. French drains are shown **Fig. 4.5.2.6**.

4.5.2.7 Fin Drains

Fin drains are edge drains which are also referred as drainage composite edge drains that can be used for pavement drainage purpose. It consists of plastic spacer/net enveloped in a

Geotextile. The plastic spacer/Geonet substitutes for the aggregate and acts as drainage medium. The Geotextile acts as filter. Fin drains with thick plastic core are normally capable of transporting water both vertically and horizontally with the structure, while thinner Fin drains normally required the addition of a pipe to transport the water away, shown in **Fig. 4.5.2.7.** For specification of drainage composite as fin drain, refer **para 4.6.2**.

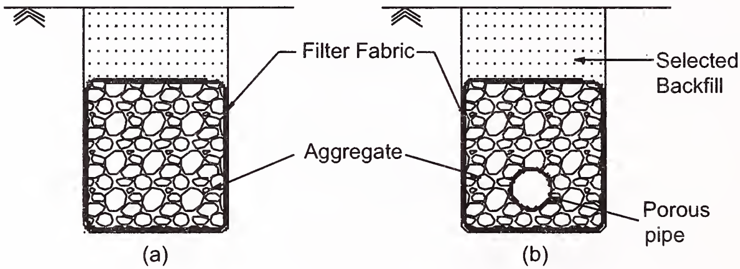


Fig. 4.5.2.6 French Drains

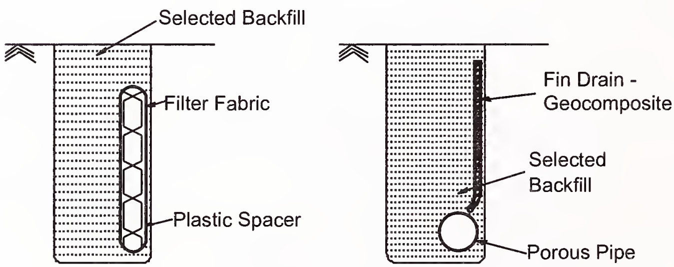


Fig. 4.5.2.7 Fin Drains

4.6 Depressing The Level of Subsoil Water by Drainage Composites/Drainage Channel

Depression of subsoil water level can be achieved by providing the drainage channel with drainage composite or V-shaped drain below which aggregate drain at the edges of the pavement for the lowering of water table and connecting these by suitable outfalls to natural drainage as shown in **Fig. 4.6.**

Drainage composite shall be able to meet the drainage and protection requirements in structurally demanding water draining application. It should be able to effectively eliminate hydrostatic pressure against below grade structures and aid in dewatering saturated soil by collecting and conveying groundwater to a drain pipe for discharge.

4.6.1 Drainage composite shall be made with lightweight three-dimensional, high-compressive strength polyethylene core and heat bonded/needle punched polypropylene/ polyester geotextile, provided on one side or both sides of the core as per requirements.

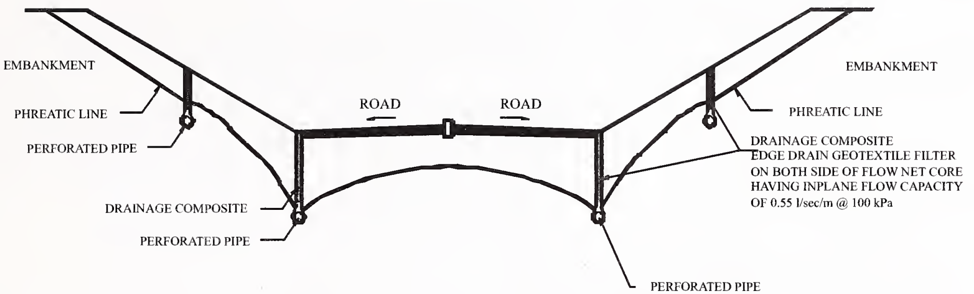


Fig. 4.6 Typical Cross Section of Road in Cutting with Drainage Composite

4.6.2 *Desirable properties of drainage composite*

4.6.2.1 *Geotextile properties*

Apparent Opening Size - EN ISO 12956	: ≤ 0.15 mm
Permittivity - EN ISO 11058	: ≥ 100 1/m². sec

4.6.2.2 *Property of composite material*

Widewidth Tensile Strength - EN ISO 10319		: ≥ 16 kN/m
CBR Puncture Resistance - EN ISO 12236		: ≥ 3000 N (Drainage composite property)
Mass per Unit Area - EN ISO 9864		: ≥ 710 g/m² (Drainage composite property)
In plane permeability - EN ISO 12958		
Hydraulic gradient (i = 1)	@100 kPa	: ≥ 0.55 l/m.s (Drainage composite property)
	@ 200 kPa	: ≥ 0.45 l/m.s (Drainage composite property)
Thickness of composite material EN ISO - 9863		: ≥ 4.5mm (Drainage composite property)

Note : Equivalent ASTM and IS codes are given in **Annex-1**

This method of drainage is applicable to all types of road construction (whether rigid or flexible) and should be preferred wherever economically feasible.

4.7 Capillary Cutoff

4.7.1 As an alternative to the recommendations contained in **paras 4.1 and 4.2**, a capillary cutoff could be provided to arrest the capillary rise of water in the embankment. Provision of capillary cutoffs could, however, may prove to be expensive and may be justified only in special circumstances.

4.7.2 The capillary cutoff may be a layer of coarse or fine sand and graded gravel. For details refer IRC:36-2010. Layer thicknesses recommended for different situations are given in **Table 4.7.2**.

Table 4.7.2 Recommended Thickness of Layer of Capillary Cutoff

Sr. No.	Situations	Minimum thickness of granular layer (mm) classified as per IS 1498		
		Fine Sand (425 micron to 2 mm)	Coarse Sand (2 mm to 4.75 mm)	Graded Gravel (4.75 mm to 20 mm)
1)	Subgrade 0.6 - 1.0 m above HFL (PI > 5)	350	150	150
2)	Subgrade 0.6 - 1.0 m above HFL, the subgrade soil being sandy in nature (PI < 5; sand content not less than 50 percent)	300	100	100

4.7.3 The cutoff should be placed at least 0.15 m above the ground level or the standing water level, whichever is higher, as illustrated in **Fig.4.7**. But in no case it shall be positioned higher than 0.6 m below the top of the sub grade. When provided, the cutoff medium should extend under the berms as well i.e. for full formation width as shown in **Fig. 4.7** (for location of cutoff with respect to ground level/high flood level). Apart from sand/granular material, Drainage Composite as specified in **para 7.2.2** of this document can be considered as suitable alternative for capillary cutoff. Drainage composite has Geomembrane on the underside and geotextile filter on upper side. The drainage composite serves dual function of cutoff as well as drainage media. The impermeable sheet helps in capillary cutoff, drainage core allow the free flow of water and geotextile acts as separator and filter. The embankment surface on which capillary cutoff is to be provided should have camber for gravity flow of water through the drainage composite.

The surface of the embankment/sub-grade at all times during construction shall be maintained at such a crossfall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

4.7.4 Suitable types of capillary cutoffs are listed under **Section 7**. For any cutoff medium say high density polythene sheet or drainage composite, it will be advisable to cover it with a 15 cm thick layer of granular material like sand for the dual purpose of acting as a drainage course for water infiltrating from the top and of protecting the envelope during construction against rupture by sharp particles in the fill material. For drainage composite there is no need of additional cover of granular layer as the composite consists of geotextile as one component which will provide protection while acting as a filter and the core of drainage composite (geonet) will provide the drainage path.

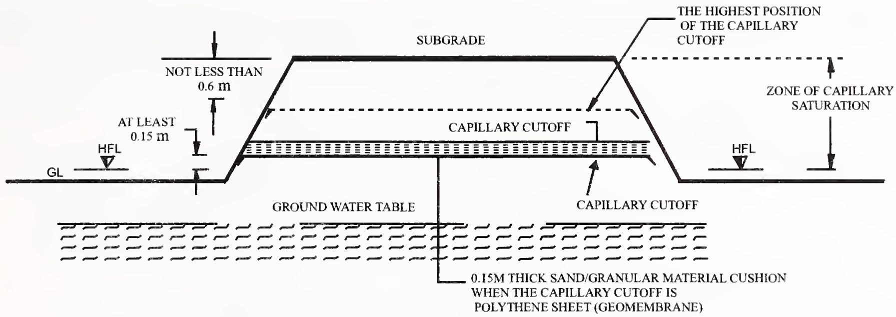


Fig. 4.7 (a) High Water Table

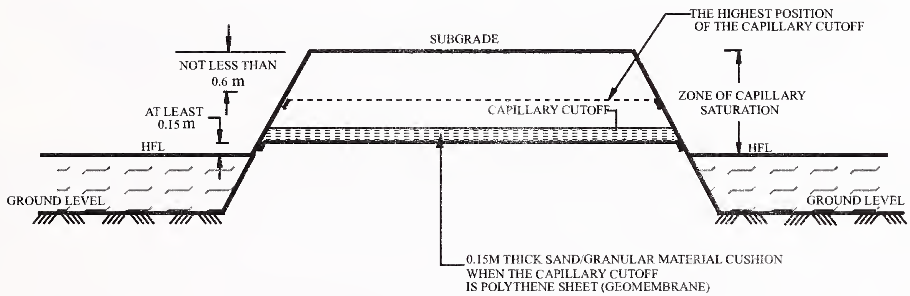
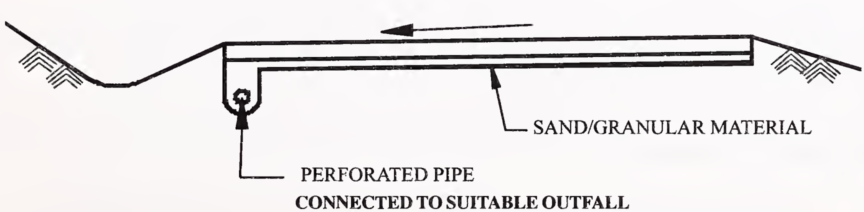


Fig. 4.7 (b) Standing Water on Either Side of Embankment

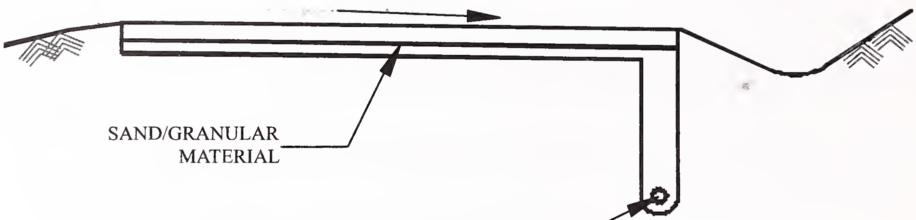
Fig. 4.7 Sketches Illustrating Desired Position of Capillary Cutoff for Preventing the Rise of Capillary Moisture

4.7.5 *Technique for capillary cutoff and lowering water table*

Drainage blanket and a small drain can be used for capillary cut off as shown in **Fig. 4.7.5(a)** while deep drain can be used for lowering water table. Combination of capillary cutoff and deep formation drain is shown in **Fig. 4.7.5 (b)**.



(a) Drainage blanket and small drain to prevent water table from rising into pavement layer



(b) Drainage blanket combined with deep formation drain
Fig. 4.7.5 Techniques for Lowering Water Table

5 RECOMMENDATIONS FOR ROAD CONSTRUCTION IN AREAS WHERE IN ADDITION TO WATER LOGGING, FLOODING FOR PROLONGED PERIODS IS ALSO EXPECTED

In the case of roads subjected to flooding in addition to water logging, the following measures may have to be taken over and above those recommended in **Section 4** against water logging. The three treatments suggested could be applied equally on new constructions as well as on existing roads.

5.1 Raising of the Embankment in Flood Prone Areas

5.1.1 In areas subjected to frequent floods where the highest flood level is not too much above the natural ground level, it is recommended that the embankment should be raised so that the bottom of the subgrade is at least 1.50 m above the highest recorded flood level as detailed in **para 4.2**.

5.1.2 The embankment will be subjected to wave action due to floods. To protect the embankment from wave action, stone pitching of designed thickness over graded filter/ geotextile is required.

5.1.3 *Provision of balancing culverts*

Sufficient number of cross drainage structures as per site requirement should be provided, for movement of water across the embankment. For free flow of water across the embankment at least 2 culverts/km should be provided.

5.1.4 In case, water current hits the embankment, cross drainage structures of adequate waterway should be planned.

5.1.5 In case, it is not possible to provide sufficient cross drainage structures for water to flow across the embankment, then the profile of road embankment should be as indicated in **Fig. 5.1**.

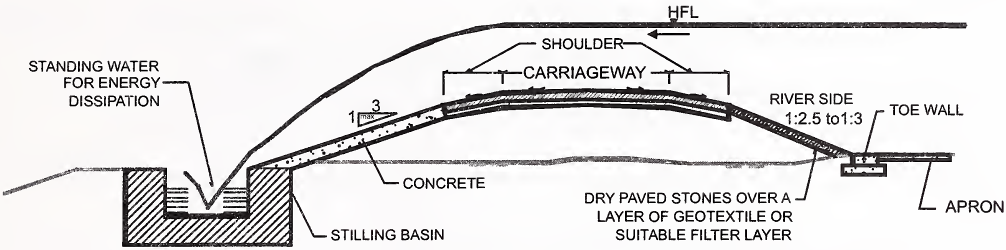


Fig. 5.1 Cross-Section of Road which gets Overtopped by Flood Water

Note : in the stretches where bank are not overtopped by flood by water, these should be protected against erosion as per IRC:56-2010.

5.1.6 Submersible bridges or causeways may be designed and constructed in areas subject to overtopping during floods.

5.2 Provision of Cement/Asphaltic Concrete Surfacing

In situations where it is considered inevitable to let flood water pass over the road, also traffic is heavy and flooding expected for prolonged periods, cement concrete surfacing of appropriate thickness should be provided for at least two lanes of traffic. Wider paved surfaces perform better under flooding due to distribution of traffic load in a wider area. If the pavement at the designated place of water crossing is flexible even then there is merit in providing a layer of 50 mm bituminous concrete as wearing coat. The cement concrete pavement should be provided for at least two lanes of traffic. The cement concrete pavement, when provided, should have a dry lean concrete/cement/lime stabilized soil base of 15 cm thick underneath the slab. When asphaltic concrete is selected as the surfacing, the mix should be dense graded and resistant to flood conditions.

The profile of the downstream side of embankment should allow smooth flow of water down the embankment. For dissipation of energy of flow of water, a trough can be provided as shown in **Fig. 5.1**.

5.3 In built up areas with houses/shops on either side of road, the water stagnates on the road surface. In case neither underground sewer system, deep drains, raising of sub grade of existing road nor sub surface drain can be provided on an existing road, it is better to suggest realignment of the road. Till such time the bypass road is ready, the road crust as shown in **Fig. 5.3** may be provided. Use of well dressed stone/concrete paver block over a layer of cement concrete (stone set in cement mortar) can be considered. For further details following guidelines can be referred:

IRC:SP-63: Guidelines for the use of interlocking concrete block pavement

IRC:SP-20: Rural Road Manual (Clause 8.10.2)

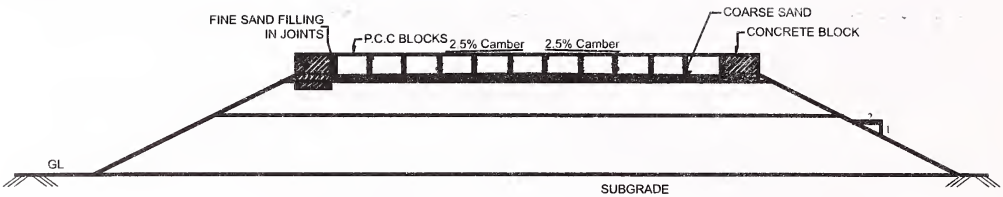


Fig. 5.3 Stone Set/PCC Block Pavement

6 RECOMMENDATIONS FOR ROAD CONSTRUCTION IN AREAS WHERE IN ADDITION TO WATER LOGGING, DETRIMENTAL SALTS ARE PRESENT IN THE SUBSOIL OR GROUND WATER

The following recommendations apply generally to construction of new roads. On existing roads, measures outlined in **paras 4.1 to 4.6** may be adopted for relief.

6.1 No special measures are considered necessary from the standpoint of physical/ chemical action of harmful salts except those stated in **Sections 4 and 5** if the concentration of sulphates in the subgrade soil is below 0.2 percent (as sulphur trioxide) in ground water. Similarly, sodium carbonate concentrations of up to 0.2 percent in subgrade soil and 0.02 per cent in the ground water are considered unharmful. Salt concentrations may be determined in accordance with the procedure laid down in relevant I.S.I Standards - IS 2720, Part XXIII 'Methods of Test for Soils: Determination of Calcium Carbonate', and IS 2720, part XXVII-'Methods of Test for Soils: Determination of Total Sulphate'.

No damage is expected from dissolved carbon dioxide or bicarbonate salt solutions (met with in certain marshy areas) provided the pH value of the solutions is higher than 5.

Where the concentration of these salts is in excess of the safe limits specified above, special measures as indicated below are recommended as a guide for road construction. These measures are in addition to those recommended in **Section 4**.

6.2 Flexible Pavements

6.2.1 *Roads with granular base with or without bituminous surfacing*

Even if concentration of salts in the subgrade or ground water is higher than the safe limits described in **para 6.1**, no special measures other than those set forth in Section 4 are considered necessary for water bound macadam roads with or without bituminous surfacing except that the filler used in water bound macadam and soling should be inert and free from harmful salts.

6.2.2 *Stabilized soil construction*

a) Mechanical Stabilization

b) Cement, Lime and flyash stabilization - For details refer "Guidelines for soil and granular material stabilization using Cement, Lime and Fly Ash" (IRC:SP-89)

c) Bituminous stabilization

If the above constructions are contemplated in waterlogged areas infested with salts, the soil used for stabilization should not contain more than 0.2 percent of total soluble sulphates and carbonates or stabilization shall be with the cementitious materials which are resistant to Cl and SO_4 salts.

Besides this, to prevent the harmful salts in the sub grade or ground water from coming in contact with stabilized soil course, a suitable capillary cutoff out of those described in **para 4.7** should be provided underneath the pavement extending across the full width of the roadway.

6.3 Rigid Pavements

When sulphates are in excess of the safe limits prescribed in **para 6.1**, the following additional measures are recommended during the construction of cement concrete pavements over and above the provisions of **paras 4.1 and 4.2**.

6.3.1 Since all types of concrete, irrespective of the type of cement used, are more vulnerable to salt attack during the initial period of hardening than when fully set, it is of importance to prevent contact between the ground water and concrete in the early stages. For this purpose, applying a light coat of bitumen to the underside of precast units, protecting cast-in-situ concrete by a thin bituminized coating on the base just below the slab, or provision of one of the capillary cutoffs mentioned in **para 4.7**, are some of the measures recommended for adoption under relatively mild conditions of exposures to sulphate attack, viz., when sulphate concentration in soil is upto about 0.5 percent.

Under more severe conditions, i.e. when sulphates are in excess of 0.5 percent, the bituminous coatings used should be thicker (For the purposes of this specification, thin coats are considered to be those in which the rate of application of straight-run bitumen is 12 kg per 10 m^2 and thick coats are those in which the rate of application is 20 kg per 10 m^2) as they are known to possess higher durability.

Furthermore, the following measures are suggested as suitable for minimizing adverse chemical effect of the sulphates on concrete:

i) Designing a dense, well-compacted, high quality concrete which will have low permeability against ingress of sulphate solution. (This is recommended even when SO_3, in water is above 0.02 percent).

ii) Use of special sulphate resistant cement, Pozzolanic cement, Portland slag cement or high performance concrete as per IRC:SP-70.

6.3.2 In areas where there is danger of damage from dissolved carbon dioxide or bicarbonate salts as evidenced by pH values of below 5, the provision of a waterproof layer below the concrete pavement, such as heavy duty bituminized paper or polythene sheet, and use of a dense, well compacted, high quality concrete are the measures recommended for adoption.

7 SUITABLE CAPILLARY CUTOFFS

7.1 Provision of Sand Blanket

Sand blanket of adequate thickness over the full width of embankment is recommended as an effective capillary cutoff. The thickness of the sand blanket needed to intercept capillary action depends on the particle size of sand and may be determined from the following formula:

$$t = \left(\frac{8}{d}\right)^{0.92}$$

where

t = thickness of sand layer in cm

$$d = \frac{2d_1 \times d_2}{d_1 + d_2}$$

d = mean particle diameter in mm

d_1 = aperture size of sieve (mm) through which the fraction passes

d_2 = aperture size of sieve (mm) on which the fraction is retained.

The sand shall be compacted after adding sufficient moisture to permit easy rolling. Alternatively, it can be compacted dry if the facility of vibratory roller is available.

7.2 Some of the Other Capillary Cutoffs

7.2.1 *High density polyethylene (HDPE) sheet*

Providing a High Density Polyethylene sheet, manufactured from HDPE resins, duly contrasted, that comply with the most rigorous requirements established for their use. The sheet shall contain not less than 95 percent of pure HDPE polymer and a balance not higher than 5 percent of carbon black, antioxidants and thermal stabilizers. For specification of geomembrane refer **para 4.5.2.5.1**.

7.2.2 *Provision of drainage composite*

Prefabricated drainage composite (plastic spacer encased between impermeable layer of low density polyethylene Geomembrane and Non-woven geotextile) of adequate thickness over the full width of embankment is recommended as a capillary cutoff. This will avoid the additional sand blanket, which is generally provided in any other method of capillary cutoff.

7.2.2.1 Properties of drainage composite for capillary cutoffs:

Geotextile properties

Apparent Opening Size - EN ISO 12956		:	$\leq$ 0.15 mm
Tensile strength - EN ISO 10319		:	$\geq$ 8 kN/m
Permittivity - EN ISO 11058		:	$\geq$ 100 *l*/m^2.sec

Properties of Drainage Net

Mass per unit area - EN ISO 9864		:	$\geq$ 410 g/m^2

Impermeable geomembrane

Water proofing extruded film by Polyethylene

Property of Composite material

Widewidth Tensile Strength MD - EN ISO 10319		:	$\geq$ 13.5 kN/m
CBR Puncture Resistance - EN ISO 12236		:	$\geq$ 2.2 kN
Mass per Unit Area - EN ISO 9864		:	$\geq$ 830 g/m^2
In plane permeability - EN ISO 12958			
Hydraulic gradient (i = 1)	@100 kPa	:	$\geq$ 0.6 *l*/m.s
	@ 200 kPa	:	$\geq$ 0.55 *l*/m.s
Thickness of composite material EN ISO - 9863		:	$\geq$ 5 mm

Note : Equivalent ASTM and IS codes are given in **Annex-I**

7.2.3 *Granular material cutoff (Refer* ***para 4.7.2****)*

8 GUIDELINES/REMEDIAL MEASURES FOR SOME SPECIFIC PROBLEMS

8.1 Existing Roads on Low Embankments and Subgrade within Capillary Fringe

Such roads get frequently damaged whenever water stands in the adjoining ground. For long term maintenance free pavement, it is suggested that subgrade of the pavement should be raised as mentioned in **para 4.2**. In case there are difficulties in raising the embankment, the level of sub soil, should be lowered as brought out in **para 4.5**. Schematic arrangement for providing subsurface drains in low height embankment is shown in **Fig. 4.5.2.5**.

8.2 Addition of New Carriageway to the Existing Carriage on Low Embankment Fig. 8.2

Water falling in the sloping central verge needs to be collected and disposed off by drainage system consisting of water inlet chamber, open drains and hume pipe culvert (below the existing embankment).

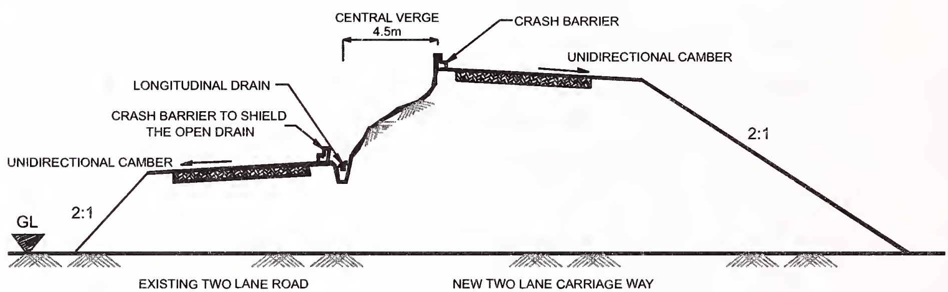


Fig. 8.2 Dual Carriageway with New Carriageway at Higher Level

8.3 Drainage of Water from Road in Cutting

Pavements of such roads gets affected by water table of adjoining high bunds. To lower the level of underground water, there is generally a need to provide aggregate drains on either side of road as shown is **Fig.8.3**. Subsurface drains below V-shaped drain are effective in lowering water table. For specifications of aggregate drains refer **Table 4.5.2.5**.

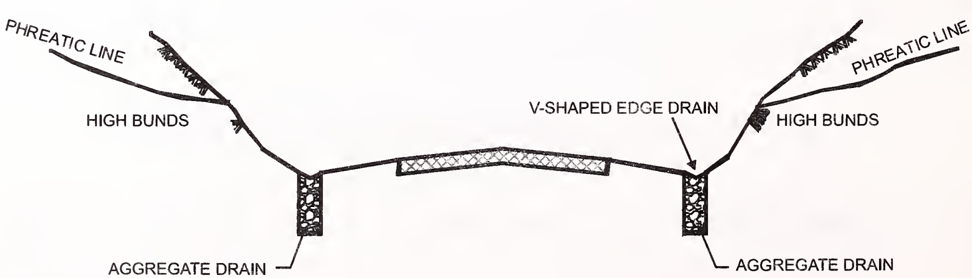


Fig. 8.3 Road in Cutting

8.4 Hill Roads with Phreatic Lines Cutting the Bottom of Hill Slope Fig. 8.4 (a)

8.4.1 Wetting of slope marked a, b in **Fig. 8.4** or water oozing out of pavement is an indication of high water table on the Hill side. Sub soil hydraulic studies needs to be carried out to plot the phreatic line. In case the pervious layer is located at shallow depth, the solution to the problem lies in lowering the phreatic line well below the pavement by providing on Hill side, subsurface drain as shown in **Fig. 8.4 (a)**. V-shaped drain for storm water on hill side should be provided. The water so intercepted in the drains may be suitably disposed off.

8.4.2 For pervious layer located at a depth where it is not practical to provide vertical subsurface drain as shown in **Fig. 8.4 (a)**, horizontal perforated pipes into the hill side, and at the face of hill slope breast wall in dry rubble stone masonry should be provided. Behind the breast wall granular filter should be considered. Alternatively free draining wire crate wall/Gabion (machine made woven wire crate of wire dia 2.7 mm as per IRC:56-2010) retaining wall should be provided. The perforated pipes may project outside the breast wall so that seepage water can be collected directly in the open longitudinal drain. Concrete caping at pipes shown in **Fig. 8.4 (c)** shall be provided. For details refer to **Fig. 8.4 (b) and 8.4 (c)**.

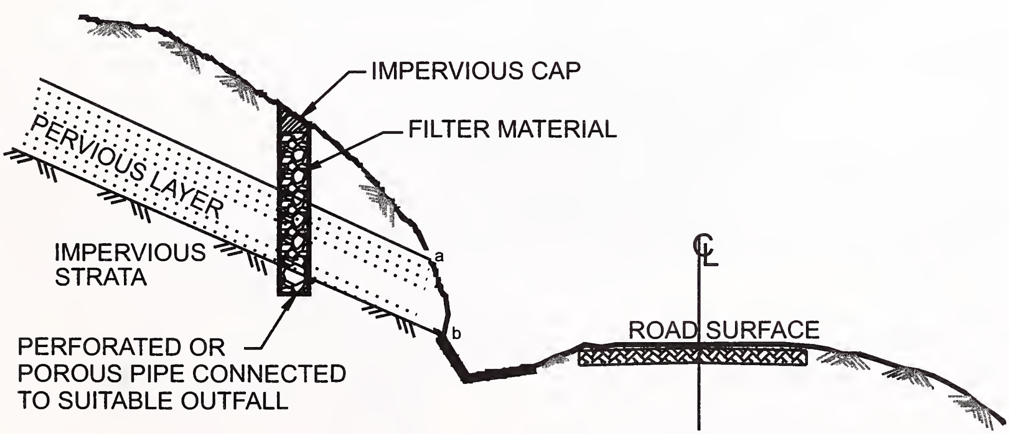


Fig. 8.4 (a) Sub Surface Drain at Cut Slopes

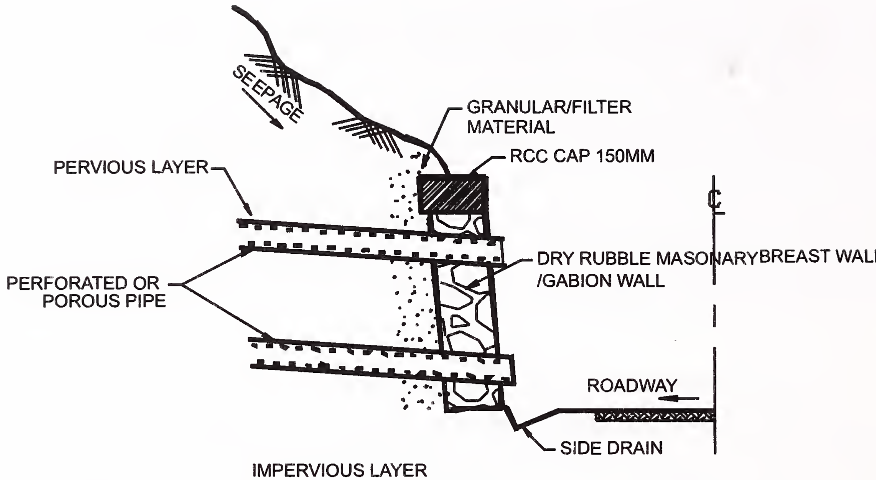


Fig. 8.4 (b) Cross-Section of Hill and Road Showing Arrangement for Collection of Sub Surface Flow

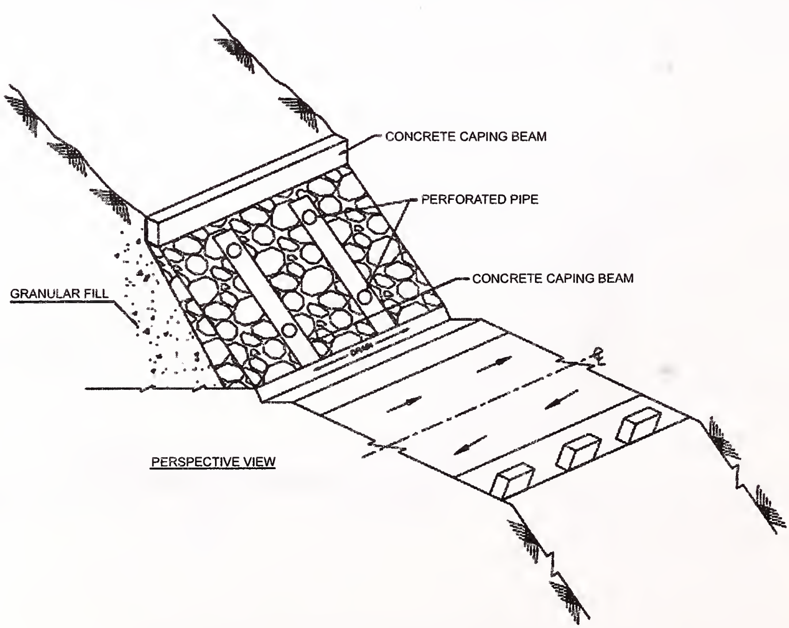


Fig. 8.4 (c) Perspective View of Hill and Drainage Measures

8.5 River/Canal Running on One Side of the Road

Phreatic line should be below the pavement on bund road. For lowering the phreatic line (if it affects the subgrade) sub-surface drain towards the river/canal as shown in **Fig. 8.5** can be considered. The seepage water so collected in drain should be suitably disposed off. In case of single lane carriageway, camber should be opposite to river side.

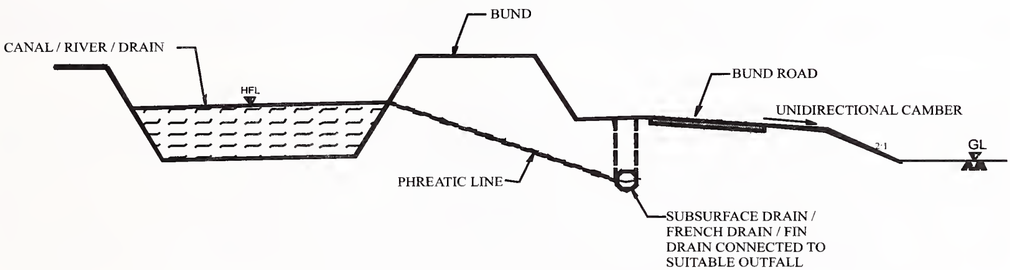


Fig. 8.5 River/Canal on One Side of Carriageway

8.6 In Hill Roads at Bends/Hair Pin Bends

8.6.1 Hill roads at bends get damaged due to flow of water from the hills. At such bends after extra widening paved shoulder with cement concrete paver block/stone set in 1 m width on hill side can be considered.

8.6.2 At bend locations, rigid pavement in general performs better as compared to granular pavement with bituminous wearing coat.

8.7 Drainage of Land Between Road and Rail Track

8.7.1 If sufficient land is available between road and rail track, for disposal of storm water, open drain/underground sewers should be provided. These open drain/underground sewers need to be connected to suitable outfall.

8.7.2 In case there are difficulties in providing open/underground drain and water stagnates between (A) and (B) shown in **Fig. 8.7**, at such locations where water table is low, storm water can be discharged into the underground aquifer by providing vertical drains shown in **Fig. 4.3**. Alternatively aggregate drain/french drain suitably connected to outfall can be considered.

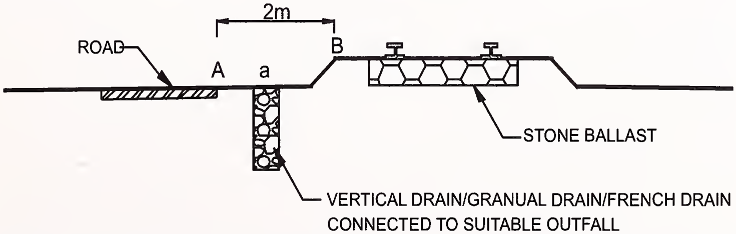


Fig. 8.7 Drainage of the Area Between Road and Rail Track Marked A and B.

8.8 Drainage of Area with Habitation on Either Side of Road

i) Raise the sub grade as suggested in **para 4.2**. In case it is not economically viable to raise the subgrade then underground sewer for disposal of storm water should be considered. Stone set pavement performs very well in such areas as mentioned in **para 5.3**.

8.9 Road Embankments which get Overtopped by Flood Water at High Velocity

Whenever flood water is overtopping an embankment, at such location, possibility of providing a bridge should be considered. Till such time bridge/cross drainage structures is constructed, the width of pavement may be increased (for dispersal of traffic load on a wider area) and the embankment suitably treated to withstand the effect of overtopping of flood waters. The pavement width at such location should be two lanes with paved shoulders. For passing the water over topping the embankment, downstream side slope of embankment may have to be covered with cement concrete. On upstream side of embankment dry stone pitching may be provided for protection against erosion as per IRC:89. If stones of suitable size and weight are not available, alternatively mattress (machine made woven wire crate as per IRC:56-2010) filled with small stones over a layer of filter geotextile or suitable filter layer may be provided. For dissipation of energy, water trough and details of treatment to the embankment are covered in **Fig. 5.1**. Pavement to be provided in embankment is covered in **para 5.2**.

The solutions as recommended in **para 8.1 to 8.9** are for guidance purpose and combination of solutions can be adopted as per site requirements. For site specific design for recommendation made in **para 8.1 to 8.9**, service of specialist shall be taken. For design of drainage following guidelines may be referred for further details

- IRC:SP-42 - "Guidelines on Road Drainage".
- IRC:SP-50 - "Guidelines on Urban Drainage".

Annex-1
(Clause 4.5.2.5.1)

S. No.	Designation (ISO)	Designation (ASTM)	Designation (IS)	Title
1)	EN ISO 12956	ASTM D 4751	IS 14294	Test Method for Determining Apparent Opening Size of a Geotextile
2)	EN ISO 11058	ASTM D 4491	IS 14324	Test Methods for Water Permeability of Geotextiles by Permittivity
3)	EN ISO 10319	ASTM D 4595		Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
4)	EN ISO 12236	ASTM D 4833	IS 13162	Geosynthetics -- Static puncture test (CBR test)
5)	EN ISO 9864	ASTM D 5261		Test Method for Measuring Mass per Unit Area of Geotextiles
6)	EN ISO 9863	ASTM D 5199		Test Method for Measuring the Nominal Thickness of Geosynthetics
7)	EN ISO 12958	ASTM D 4716		Geotextiles and geotextile-related products -- Determination of water flow capacity in their plane

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)