DRAINAGE FOR QUALITY IMPROVEMENT OF RURAL ROADS

S.K.Mazumder
(Individual Consultant)
Former AICTE Emeritus Professor
Delhi College oi Engineering (Now Delhi Technology University)
E-mail:somendrak64@gmail.com

Abstract: Although drainage costs very little, it is often found to be neglected. Like any other road, rural road will also be damaged and life reduced, if drainage system is not properly planned and designed.The paper deals with surface and subsurface drainge of road. The former helps in quick disposal of surface run-off from road surface and adjoining areas and the later helps in keeping the road healthy by intercepting water seeping from top or bottom of road.Methods of surfce and sub-surface drainage drainage have been explained with figures, photographs and tables.Hydrologic and hydraulic design principles have been discussed with relvant equations for computing flow and capacity of drain to convey the design flow.
Key words: Road damage,

INTRODUCTION

Adequate drainage is a primary requirement for maintaining the structural soundness and functional efficiency of a road. Pavement structure including sub-grade must be protected from any ingress of water; otherwise over a period of time it may weaken the sub-grade by saturating it and cause distress in the pavement structure. That is why rapid dispersal of water from pavement and sub-grade is a basic requirement in road design. Although drainage costs only about 2% (Mazumder,2012) of total road cost (8-10% including cross-drainage), it is found that drainage is often neglected thereby reducing the life of road, even though the structural and foundation design is sound. Damage to road due to inadequate drainage occurs in three ways, namely

(i)Overtopping of road by flood water due to inadequate cross drainage (Mazumder et al,2011)
(ii)Erosion of shoulders and embankment slopes caused by water running off the pavement
(iii)Weakening of pavement structure and sub-grade through infiltration/seepage of water.

Remedy lies in providing proper freeboard above HFL so that road is not overtopped; adequate cross-slope/camber and drainage system for quick disposal of surface run-off ; and proper sub-surface drainage by providing drainage layer. Following are the important factors which are required to be kept in mind before designing a drainage system for a road

      (a)Expected traffic , importance and configuration of the road-single or double lane
      (b)Drainage catchment areas and existing drainage systems
      (c)Geology, hydrologic and hydro-geologic conditions on the surrounding area
      (d)Geometric characteristics of the road e.g. alignment , road profile etc
      (e)Areas of extreme gradients and cross slopes , areas of excavation and land fill
      (f)Any limitations in and around highway which may affect the design of drainage

Primary objectives of writing this paper is to emphasise the above aspects for a healthy and increased life of roads in rural areas.IRC:SP:42(2014) gives guidelines on road drainage,

IRC:SP:50(2014) deals with urban road drainage, drainage measures for hilly roads are discussed in IRC:SP:48 (1998).

SURFACE DRAINAGE
Surface drainage is accomplished by providing cross-slope or camber to the pavement so that the runoff water can be cleared from the road surface rapidly. Normally a driver would prefer a flat surface for driving but some compromise has to be made between comfort and surface drainage requirement. The cross-slope/camber requirement differs for each pavement type. A mild cross-slope is sufficient in dense surfaces like bituminous concrete surface or concrete pavement but open graded bituminous surfaces and granular/ earthen surfaces require relatively steeper cross-slope for facilitating rapid flow. Granular or earthen surfaces require still greater cross-slope to avoid seepage of water to lower layers. But too much cross-slope may promote erosion of surface. The cross-slopes proposed for adoption in Indian Roads are given in Table-1. Typical cambers provided in a two lane road in the carriageway and shoulder are indicated in Fig.1. Earthen shoulders are subjected to severe erosion as shown in photo-1. By paving the shoulder with grass or brick, erosion of shoulder can be eliminated as illustrated in photo-2.

Table-1: **Proposed Camber/Cross-slopes**

Surface Type	Non-kerbed roads	Roads with kerb
Earthen, Gravelled or WBM Surface	3–5%	–
Thin open graded bituminous surfacing	2.5–3%	2.5–3%
High type bituminous surfacing	2.0–2.5%	2.5%
Cement concrete surfacing	2.0%–2.5% in case of transverse tine or brush texturing	2.5%
	2.5%- in case of longitudinal Tine texturing	2.5%
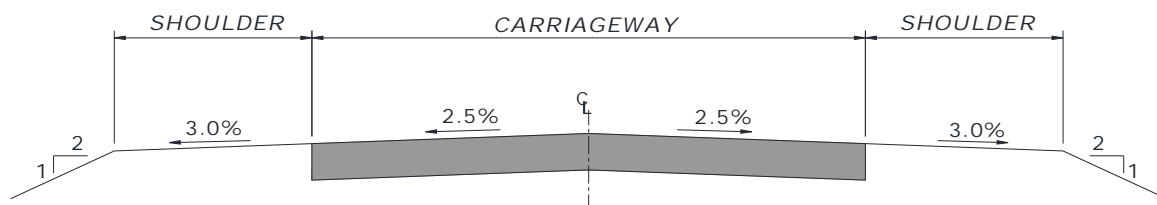
Fig.1: Typical Double Camber in a Two Lane Road without Curb

Normally in plain areas road sub-grade elevation in fill sections is so fixed that the difference between formation level (top of sub-grade) and highest water table/high flood level is not less than 0.6 to 1 meter and between formation level and ground level not less than 1 meter. There are three important aspects of surface drainage design in which the road engineer is particularly interested. First of all he is concerned with fast dispersal of precipitation on the road surface so

Photo-1 Severely Eroded Earthen Shoulder   **Photo-2** Brick Surfaced Shoulder

as to minimize danger to moving vehicles. This is achieved by proper geometric design of the road, e.g. by crowning the carriageway or one side cross fall, giving proper cross slope to the shoulders and verges, providing requisite longitudinal gradient etc. Second requirement is that water from road and the surrounding area shall be successfully intercepted and led away to natural outfalls. This is accomplished by a system of suitable surface drains, shallow ditches by the side of the road or deep catch water drains on the hill slopes. Thirdly the engineer must build adequate cross drainage structures at river crossings and minor streams.

SUB-SURFACE DRAINAGE

Sub-surface drainage is as important as surface drainage for long life and better performance of pavement. The moisture which reaches lower layers of pavement from all sources like ingress of moisture from pavement surface, seepage and capillary rise of ground water is termed as sub-surface moisture/water and disposal of this moisture is termed as subsurface drainage. Consequences of lack of effective sub-surface drainage system results in premature failure of pavement with formation of cracks, settlement, rutting and boggy action in the case of flexible pavement and crack and fragmentation of cement concrete slabs. The various sources from which sub-surface water/moisture arise are as follows:

(a) From the cracks/holes formed in the pavement, water can seep below

(b)From the failed transverse and longitudinal joints

(c)Through the longitudinal joint between pavement and shoulder

(d)From earth filled shoulders and median, if any

(e)From capillary saturation when water table is high.

(f)Seepage water from the adjoining higher ground in the cut section

Provision of granular sub-base (GSB) cum drainage layer above sub-grade as shown in Fig.2 helps in sub-surface drainage. It intercepts moisture leaking/seeping from top and arrests capillary water from bottom. Drainage layer must be extended up to the embankment faces for the purpose of free flow of the sub-surface water.
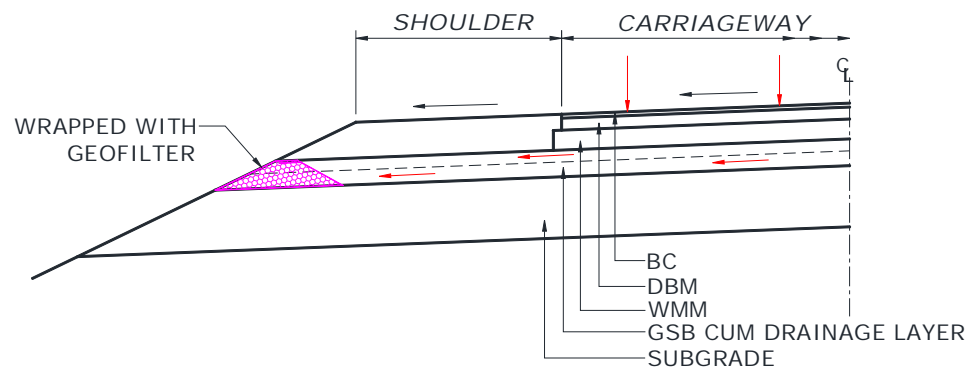
Fig.2 Showing GSB cum Drainage layer for sub-surface Drainage

HYDROLOGICAL AND HYDRAULIC DESIGN OF ROADSIDE DRAINS

As mentioned earlier, longitudinal drains/ditches along the road collect the surface run-off from the road surface and adjoining areas for smooth disposal of flow to nearby streams/nallas /depressions. Longitudinal roadside drain originates at a ridge point of natural ground along the proposed alignment of road and ends at a predetermined outfall, be it a proposed culvert or an existing stream. Designer of road drainage system must be familiar with

    (i)   the terrain through which the road is passing , soil, subsoil and cover conditions,

    (ii)   the natural drainage system prevailing before the road construction

    (iii)   rivers and its tributaries draining the area, ponds and other water bodies

    (iv)   topographic features like habitats, industries, marketing places, institutional buildings, existing roads, foot tracks, cable lines, gas ,electrical and telephone lines, railway lines etc.

    (v)   details of exiting drainage, canals , marshy land, waterlogged and flooded areas, forest areas, agricultural areas, rural and built up areas etc.

    (vi)   rainfall and run-off, high water marks etc. including photographs/videos at site.

Although most of these information are available from the relevant updated topo-sheets of the area, a site visit by the drainage engineer is obligatory. He/She can collect many of the vital information needed for drainage design by interacting with local people, panchayats and district authorities, central and state Govt. organizations (e.g. PWD, Irrigation, Agriculture etc.) who may be in possession of similar data to meet their own requirement.

Hydrological design involves computation of flow through the drain whereas hydraulic design of drain section is necessary to ensure that the capacity of drain is sufficient to convey the design flow up to the outlet point/cross-drainage structure.When the road runs along a ridge or water shade lines, the cost of road embankment and the drainage works is the least. However, unlike a canal, a road has to connect rural and urban areas and it may not be always possible to align it along the ridgelines all along the road. No drain is needed in reaches where the road runs along the ridge/watershed line. In hilly and sub-hilly terrains, intercepting drains are required only along the foot of the hills. In areas where the road is in cut, drains are needed on both sides of the

road. In a sloping terrain, intercepting drain is needed on the upstream side only. Usually unlined drains are provided in rural and agricultural areas where land is cheap and available ROW is sufficient to accommodate unlined drains having larger size compared to lined ones. Where the road runs on high embankments, run-off from the road surface should be collected in a road side gutter with curb and disposed through the intermittent drainage chutes at suitable intervals so that the water flowing in the gutter does not spread out to the road surface beyond a permissible limit. Since stepped chutes are self-dissipating structures, no additional energy dissipater is required at the toe of road in high embankment. Where service roads are required in built up areas, it is desirable to provide an inner drain at the junction between the carriageway and the service road .

Hydrological Design

Hydrologic design involves computation of design discharge for the drainage system. Design discharge can be estimated by use of rational method given by equation -1

$$Q= 0.028\ P\ A\ I \tag{1}$$

Where,

Q = Maximum runoff in cumecs

A = Catchment area in hectares

I = Rainfall intensity in cm/ hr for the selected frequency and flow duration equal to the time of concentration, Tc

P = Coefficient of run-off for the given catchment characteristics.Values of run-off coefficients (P) for different kind of surfaces are available in IRC:SP:42,

A= Catchment area in hectare which can be measured from either survey data or by using survey of India topo-sheets or by use of Digital Elevation Model (DEM) readily obtained from Shuttle Radar Topography Mission (SRTM) data (http://srtm.usgs.gov). These data are freely available and very useful for delineating catchments in GIS platform for small areas in a hilly terrain. Google Earth Images are also very useful in delineating small catchment areas. Google Earth Imageries are freely available and widely used these days.

I= Intensity of rainfall in cm/hr which can be determined from rainfall records for the area available with Indian Meteorological Department (IMD) or from the measurements taken from local meteorological stations. From these records, rainfall intensity-duration-frequency curves can be plotted forcdifferent frequencies (return period) . Duration should be equal to time of concentration (T_c) given by equation-2

$$T_C = \left(0.87 * \frac{L^3}{H}\right)^{0.385} \tag{2}$$

Here T_c is time of concentration in hour which is the time required for rain for travelling from hydrologically most distant point of catchment, L is the length in km from hydro-logically most distance point on water shed and the drain, H is the difference in elevation in m between the hydro-logically most distant point and the point in the drain where drainage discharge is to be computed.

Intensity of rainfall (I) can also be found by using iso-pluvial maps prepared by Central Water Commission for small/medium catchments. Detailed procedure for finding design rainfall intensity is given in IRC SP:13 (2004). Roadside drains for rural roads are to be designed for a return period of 10 years. The cross-drainage structures e.g. culverts and bridges are to be designed for a flood of 25 and 50 years return period respectively.

Hydraulic Design

Hydraulic design involves computation of drain cross-section required to convey the design drainage discharge for the different stretches of the drain. Conveying capacity of drain at any point should be equal to or more than the design discharge at that point. If Q_c is the carrying /conveying capacty and Q_d is the design flow, then $Q_c \geq Q_d$ so that the drain does not overttop at any point. Q_d can be found from hydrological considerations mentioned above and Q_c can be found by using Manning's equation (3)

$$Q_c=(1/N)AR^{2/3}S^{1/2} \tag{3}$$

Here,Qc is the capacity in m^3/s, N is Manning's roughness coefficient which varies with different types drain flow surface –Values of N for different kind of srfaces are given by Chow (1973) and RangaRaju (1993). N-values are also available in IRC:SP:42 (2014), R is hydraulic mean depth in meter given by the relation R=A/P,where A is cross-sectional area of flow in m^2 and P is wetted perimeter in m , S is the longitudinal bed slope of drain.Typical section section of an unlined intermediate drain for a rural road with separate service road is shown in Fig.3
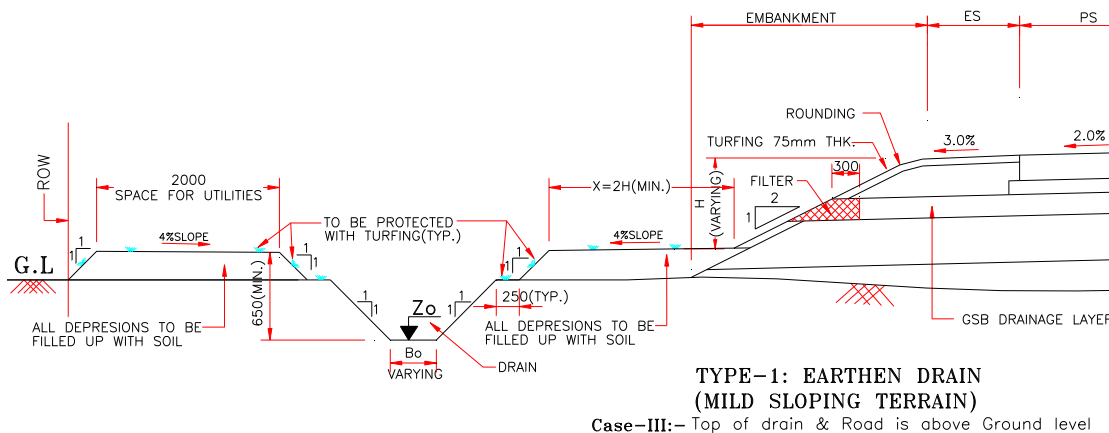
Fig.3 Typical Cross-Section of a Rural Road With Separate Service Road and

Intermediate Unlined Drain

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