Design for Integrated Storm Water Drainage System of Rural Road

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Abstract— Drainage is the process of interception and removal of water from over and under the vicinity of the road surface. Drainage can be surface or subsurface. In the study area there is Dry River is passing near to the road, so in monsoon season the other river stream which passing through the road which make the damage to pavement. There is insufficient drainage facilities which could not passing through it. By collecting the last 10 years rainfall data thus we can measure the intensity of water flowing. There is the Chainage data which have every specific distance with water flow level. At high flow level there is need to provide efficient drainage system. Using this information, calculate the water flow discharge and make the design of culvert at the specific area. Another option is to remove surface water by permeable pavement surface at shoulder. Which drain out the surface water to subgrade. Pavement surface incorporate good drainage can be expected to have a design life of two to three times of un-drained pavement sections.

Key words: Soil Investigation, Rainfall Data, Discharge, Rural Drainage System.

I. INTRODUCTION

It is a well-known fact that water in pavement systems is one of the principal causes of premature pavement failure. Indian road network at over 3.3 million km falls under one of the world's longest road networks. Most of the highways and airfield pavements built in our country in the past 30 years or so, have very slow draining systems, largely because standard design practices emphasizes on density and stability but place little importance on drainage. Drainage is a key element in the design of pavement systems.

During the rains, part of the rain water flows on surface and part of it penetrate through the soil mass as gravitational water until it reaches to the ground water. Some water is retained in the pores of the soil mass and on the surface of the soil particles which cannot be drained by normal gravitational methods and this water is termed as held water. It is required that the surface water from the carriageway and shoulder should effectively be drained off without allowing it penetrate to subgrade.

The surface water from adjoining land should be prevented from entering the roadway. The side drains should have sufficient capacity and longitudinal slopes to carry away all the surface water collected. Also in waterlogged areas special precaution should be taken. There are many such roads which are not having the proper drainage system. This causes the failure of the roads due to many reasons like increase in moisture content, decrease in strength, mud pumping, formation of waves and corrugations, stripping of bitumen, cutting of edges of pavement, frost action etc. It is essential that adequate provision is made for road drainage to ensure that a road pavement performs satisfactorily. The main function of a road drainage system is to prevent flooding of the road and ponding on the road surface, to protect the bearing capacity of the pavement and the sub-grade materials to avoid the erosion of side slopes. The adequate drainage system is to remove precipitation from its surface as expeditiously as possible, failure to which early pavement distortions and deterioration eventually occurs. Furthermore, flood waters are a restrictor to free traffic movement and create unnecessary perils for the users of the facility. For this reason, road designers provide pavement crown and shoulder slopes to expedite the removal of surface water. Good drainage needs to be taken into consideration at the early design stages in order to secure a long life for the road. With a well-designed drainage system, future rehabilitation and maintenance works can be considerably reduced and thus limit the cost of keeping the road in a good condition.

A. *Objectives of study*

- To analyses existing runoff and discharge
- To provide an effective drainage system.

B. *Effects of Improper Drainage*

One of the major causes of road failure is its improper drainage. Improper drainage of the road causes destruction in the following ways

1) Road surface if made of soil, gravel or water bound macadam, it will become soft and losses strength.
2) Variation in moisture content in expensive soils causes variation in the volume of sub-grade and thus causes failure of roads.
3) Failure of formation slopes is also attributed to poor drainage.
4) If rain water is not properly drained and allowed to flow along the road side for long distances, slip and landslides may occur causing road failures.
5) Erosion of side slopes, side drains, and formation of gullies may result if proper drainage conditions are not maintained.
6) Flexible pavement’s failure by formation of waves and corrugations is due to poor drainage.
7) Continuous contact of water with bituminous pavements causes failures due to stripping of bitumen from aggregates like loosening or detachment of some of the bituminous pavement layers and formation of pot holes.
8) Excess moisture causes increase in weight and thus increase in stress and simultaneous reduction in strength of the soil mass. This main reason of failure of earth slopes and embankment foundation.

Erosion of soil from the top of un-surfaced roads and embankment slopes in also due to surface water.

II. BASIC OF DRAINAGE SYSTEM

- Cross slope: Cross slope is provided to provide a drainage gradient so that water will run off the surface to a drainage system such as a street gutter or ditch. Water will flow faster on a paved surface. Therefore the slope of a road surface does not need to be steep. The cross slope should not be too steep. If it is, the water running off the side will start eroding the shoulder and sides of the road.

- Longitudinal drainage: Main objective of longitudinal drainage is collection and removal of water that is on the road and immediate surrounding or water from adjacent area. It's fundamental for maintaining safety of traffic by eliminating water from the road surface at the same point reducing the possibility of water infiltrating into the road and pavement layers or foundation which may lead to deterioration. Longitudinal surface drainage systems include gutters, channels, ditches, permeable land surface and swales complemented by their respective manholes, retain facilities and catch basins.
- Subsurface drainage system: The need for subsurface drains as alternatives to open drains depends on site conditions; however they require careful consideration owing to their high cost. These types of drains are required in urban areas, places with subsoil wells and in some types of cuttings. Subsurface drains include under drains and trench drains. They serve the following purposes; intercept water before it gets to the road, lower the water table and remove excess free moisture from the road.
- Subsurface drainage consists of three basic elements. A permeable base which is required to provide for rapid removal of water which enters the road structure, a method of conveying the removed water away from the road structure and this may consist of a base sloped towards a drainage ditch.
- Granular drainage layer: A well maintained granular drainage layer is uniform in thickness, the width detailed in the plans and specifications, and of the proper material gradation.
- Under drains: A well maintained system of transverse and longitudinal drainage pipes effectively intercepts and carries water out of the granular layer. Under drains carry water from the granular drainage layer to edge drains. Edge drains are installed under shoulders, longitudinally adjacent to the pavement.

III. Literature Review

Dr. L.Yesodha et al (2015) "The investigations were carried out by field surveys to obtain the sag points longitudinally and along the cross sections to determine their geometric properties. The drainage system is primarily concerned with saturated gravity flow, which can be determined by application of Darcy's law. The information needs on highway geometrics, surface drainage and subsurface drainage, climate, and soil properties. The details such as, Road Cross sectional details and Rainfall data for last 10-year, were collected from Highway Department , respectively and the laboratory tests on sub-grade material was conducted on three soil samples collected at every 300 m interval at a depth of 1 m below the earth surface. Laboratory investigations included determination of Gradation, Natural Moisture Content (NMC), Optimum Moisture Content (OMC), Maximum Dry Density (MDD), and Permeability (K). From the above soil tests it was observed that, the soil type is well-graded soil. Natural properties of soil and sub-surface drainage system were designed as par Hydraulic and Hydrological parameters."

IV. Methodology

Hydrological analysis is a very important step prior to the hydraulic design of road drainage system. Such analysis is necessary to determine the magnitude of flow and the duration for which it would last. Hydrological data required for design include drainage area map, direction of flow and other surface drainage facility.

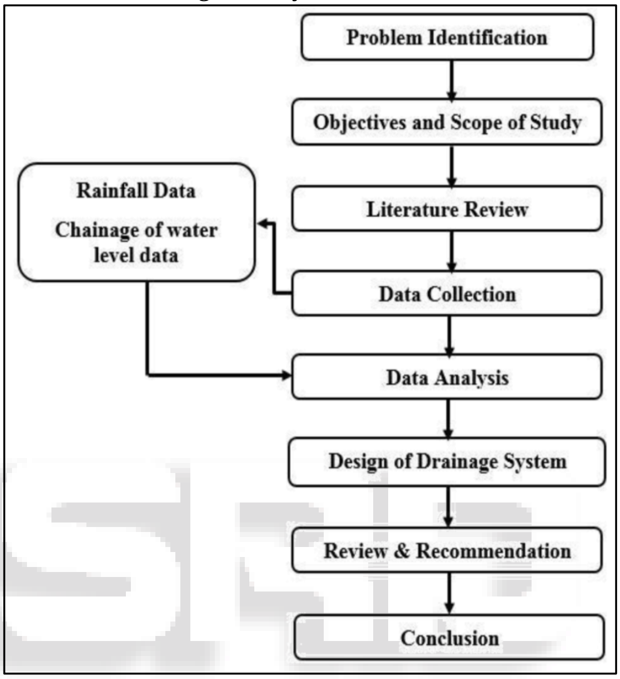

Fig. 1: Methodology

V. Data Collection

Hydrological calculation: Hydrologic analysis for all locations within the project limits.

1) Construction on new alignment - A hydrologic analysis is required to determine the need for, and necessary capacity of drainage features (culverts, open channels, storm drainage systems, etc.)
2) Reconstruction on existing horizontal and vertical alignment - A hydrologic analysis shall be performed for all drainage features located within the project limits having a history of flooding, and for open and closed drainage systems with a remaining service life less than the design life of the highway improvement.
3) Resurfacing, Restoration and Rehabilitation (3R) - A hydrologic analysis is required for all drainage features having a history of flooding, or in need of replacement or major repair. Extension of a culvert to flatten side slopes usually does not require a hydrologic analysis, but shall require a hydraulic analysis to establish the flow of water in the new drainage pattern.
4) Pavement Preventive Maintenance Projects - No hydrologic analysis is required.
5) Culvert replacement or relining project - A hydrologic analysis is required.

A. Rainfall Data of last 10 years

Storm frequency refers to the chance that a given intensity of rainfall will occur within a specific span of years. It is determined from historical data that indicate that a particular intensity of rainfall can be expected once in 10 years. A drainage system designed for such intensity is intended to be capable of withstanding 10 years storm, runoff, or flood. It is possible that such a storm will not occur at all during any 25-year period. It is also possible, however that two or more such storms will take place in a single year. For highways, cross drains (small culverts) passed under major highways to carry the flow from defined watercourses are typically designed to accommodate a 25-year storm. Larger culverts and bridges on major highways are designed with capacity for 100-year storms. For rural highways, the storm used for design can range from a 10- to 50-year storm, depending on the highway size.

Year	rainfall
2005	911
2006	630
2007	705
2008	526
2009	488
2010	648
2011	649
2012	502
2013	868
2014	1790
2015	1650
Avg	852

Table 1: rainfall data

1) Rational Formula

Catchment area (A) = 2400 hectors
Last 10 years max rainfall F= 32 cm
1 hour rainfall intensity = 0.521F
Avg of intensity of rainfall (I0) = 16.67 cm/hr.
Distance from critical point of structure (L) = 8.50 km
Fall in level from Critical point to Structure (H) = 18.889m

Concentration Time Te $= \left(0.87 \times \frac{L^3}{H}\right)^{0.385}$ =3.62hr.

Coefficient of runoff (P) = 0.7

Critical intensity of rainfall(IC) IC = $I0\left(\frac{2}{Ic+H}\right)$ = 7.21 cm/hr.

Discharge (Q) = 0.028PA = 339.30 cumecs = 340 cumecs

Calculation of velocity Manning's formula

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

V= Mean Velocity of flow in m/sec.
R= hydraulic radios in meter = A/P
A= water area i.e. area of flow in sq.m.
P= Wetted perimeter in meter
S=1/450
n= coefficient of roughness = 0.035

Chainage	GL(m)	HFL	Depth (m)	Mean Depth (m)	Length(m)	Area(A) (SQ.MT)	Diff. in GL(m)	Wetted Perimeter (p)(m)
0	96.5	94.5	0					
2.97	96	94.5	0	0	2.97	0	0.5	0
4.79	95.5	94.5	0	0	1.02	0	0.5	0
7.89	94.5	94.5	0.001	0.001	3.1	0.002	1	3.25
10.97	93.5	94.5	1.001	0.501	3.08	1.543	1	3.23
12.48	93	94.5	1.501	1.251	1.51	1.889	0.5	1.59
13.78	92.5	94.5	2.001	1.751	1.3	2.276	0.5	1.39
15.11	92	94.5	2.501	2.251	1.33	2.994	0.5	1.42
16.48	91.5	94.5	3.001	2.751	1.37	3.769	0.5	1.45
18.01	91	94.5	3.501	3.251	1.53	4.974	0.5	1.61
19.54	90.5	94.5	4.001	3.751	1.53	5.739	0.5	1.61
28.46	90	94.5	4.501	4.251	8.92	37.919	0.5	8.93
31.15	90.5	94.5	4.001	4.251	2.69	11.435	0.5	2.73
33.88	91	94.5	3.501	3.751	2.73	10.24	0.5	2.77
36.01	91.5	94.5	3.001	3.251	2.13	6.925	0.5	2.188
37.62	92	94.5	2.501	2.751	1.61	4.428	0.5	1.68
40.7	93	94.5	1.501	2.001	3.08	6.163	1	3.23
42.16	93.5	94.5	1.001	1.25	1.46	1.826	0.5	1.54
46.17	94.5	94.5	0.001	0.501	4.01	2.009	1	4.13
50.6	95.5	94.5	0	0	4.43	0.002	1	0
57.39	96	94.5	0	0	6.79	0	0.5	0
68.08	96.5	94.5	0	0	10.69	0	0.5	0
Total	93.2		37.52	37.515	67.28	104.133	13	42.748

Table 2: Calculation of Discharge

Surcharge at 200 m u/s, V = 2.44 m/s, Q= 253.75 cumecs , HFL = 93.505m , R = 2.4

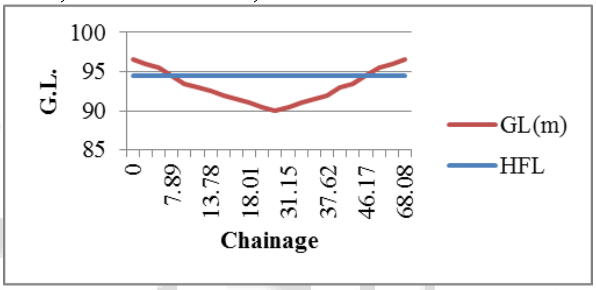

Fig. 1: Chainage and Ground level

- Soil Investigation: The purposed of Investigation was to determine the sub soil stratification of the soil, geotechnical and safe bearing capacity of the soil, so as to provide information and relevant works.
- Boreholes: Three boreholes having 100mm diameter were drilled with Rotary drilling method up to 15.00m depth below Existing ground level (EGL. Undistributed Soil samples were collected in the thin tubes in accordance with IS: 2132-1981 for finding soil parameters, field density, moisture content of soil. However, distributed soil collected during drilling for finding properties of the soil.
- Collection of samples: Undistributed soil samples were collected in the thin welled sampling tubes in accordance with IS: 2132-1981 for finding shear parameters, field density, moisture content etc. of soils. However, distributed soil samples were collected during drilling for finding index properties of the soil. The samples from split spoon sampling tubes were treated as distributed soil samples.

Borehole	Depth(m)	Stratification	CR & RQD
BH-1	0.0-0.3	Blackish brown gravelly clayey sand(SC)	-
	0.3-12.0	Blackish brown highly weathered very poor to poor	CR: 25.7%-38.3% RQD: nill-26%
	12.0-15.0	Blackish brown moderately weathered very poor to poor basalt rock	CR: 62%-63.3% RQD: 18.6%-19.3%
BH-2	0.0-0.4	Blackish brown non plastic silty sand (SM)	-
	0.40-13.5	Blackish brown highly weathered very poor to poor basalt rock	CR: 16%-45.6%
			RQD: nill-36.6%
	13.5-15.0	Blackish brown moderately weathered poor basalt rock	CR: 54% RQD:34.3%
BH-3	0.0-0.30	Blackish brown gravelly clayey sand (SC)	-
	0.30-6.0	Blackish brown highly weathered poor to poor basalt rock	CR: 32.6%-48.6% RQD: 27.3%-33.6%
	6.0-15.0	Blackish brown moderately weathered very poor to poor basalt rock	CR: 58.6%-72.6% RQD: 22%-35.6%

Table 3: Soil Specification of borehole

– Rock Quality Designation: Rock-quality designation (RQD) is a rough measure of the degree of jointing or fractures in a rock mass, measured as a percentage of the drill core in lengths of 10 cm or more. It is the borehole core recovery percentage incorporating only pieces of solid core that are longer than 100 mm in length measured along the centerline of the core.

$$RQD = \left(\frac{l_{\text{sum of length of core pieces} > 100\text{mm}}}{l_{\text{tot core run}}}\right) \times 100$$

$l_{\text{sum of length of core pieces} > 10\text{cm}}$ = Sum of length of core pieces that are > 100 mm (4 inches) measured along the centerline.

$l_{\text{tot core run}}$ = Total length of core run

RQD	Rock Mass Quality
<25%	Completely Weathered rock
25-50%	Weathered rock
50-75%	Moderately weathered rock
75-90%	Hard rock
90-100%	Fresh rock

Table 4: Rock Quality Designation

– Core Recovery: Core recovery is boring hole core recovery. It is defined as:

l sum of pieces = Sum of length of core pieces

l total core run= Total length of core run

$$TCR = \left(\frac{l_{\text{sum of pieces}}}{l_{\text{tot core run}}}\right) \times 100$$

– Standard Penetration Test: The standard penetration tests were performing in accordance with IS: 2131:1981 using the standard split spoon sampler & 63.5Kg hammer at the desire intervals. The results of standard penetration test results are shown in below Table.

B.H No.	Depth (m)	Water Content (%)	Porosity (%)	Density (gm/cc)	Compressive Strength(kg/cm^2)	
					Dry strength	Saturated
BH-1	3	1.09	0.83	2.52	-	587.9
	6	0.87	-	3.11	642.2	-
	9	1.81	1.1	3.04	-	711.7
	13.5	0.6	-	3.03	648.5	-
BH-2	6	2.59	0.61	2.56	-	422.1
	9	2.1	-	2.15	395	-
	12	6.02	1.3	2.76	-	404
	15	0.74	-	2.04	388.9	-
BH-3	1.5	1.28	-	3.14	597	-
	4.5	1.36	0.5	3.09	-	636.2
	7.5	1.28	-	3.13	874.4	-
	10.5	1.52	0.47	2.9	-	618.1
	13.5	1.2	-	3.09	572.9	-

Table 5: Standard panetration test

B. Culvert Criteria for Minimum Size

Structure application	Minimum circular- pipe size (m)	Minimum deformed- pipe area(m^2)
Drive	0.381	0.102
Main line or public road approach (2 lanes)	0.381	0.102
Main line or public road approach (≥3 lanes)	0.9144	0.622

Table 6: culvert minimum size

1) Calculation for culvert

Headwater (Hw)
Hw depth= 4.5 feet
Diameter (d) = 0.60 m Culvert slop 1:30
Area = 0.291863 m2
K = 0.034
M = 1.50
C = 0.055
Y = 0.540
Friction loss Kf = 0.042
0.5s= 0.0005
Wetted perimeter (p) = 6.28
Hydraulic radius (R) = 0.500
Discharge Qc = 253.75 cf
V = 2.44m/s

Headwater (upstream water surface) elevation	31.851m
Culvert inlet invert elevation	30.48m
Culvert diameter	0.7m
Length of culvert	15.24m
Culvert outlet invert elevation	30.32m
Downstream elevation	30.32m

Table 7: Culvert Size

VI. Conclusion

– An approach to estimating design floods by taking into consideration of the critical storm duration for designing drainage culverts was proposed. Based on the estimated design floods, the hydraulic design of the drainage culverts was used to determine the dimensions and hydraulic variables of the optimal culvert sizes for the design floods.

- The results obtained from the unit hydrograph models applied in this study indicated that the computed runoff parameters were statistically in close agreement with the observed data.
- If the design method for drainage culverts used in this research was to be applied as a standard design method, a variety of subjective methods of estimating the design flood can be objectively achieved.

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