SOME ASPECTS OF HYDROLOGY APPLICABLE TO HIGHWAY ENGINEERING

by

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In considering the volume of goods and passengers transported, by far, road transport is the most significant sector of three transport systems viz. road, air and sea transports. Roads are very important to the social and economic development of any country.

For highway work, vast sums of money are being spent yearly by Sri Lankan Government. In 1984 alone, a sum of Rs.400 million was spent, out of which about Rs.150 million was spent on highway drainage structures such as bridges and culverts. Similarly, out of a total sum of Rs.715 million spent in 1985, about Rs.265 million was spent on highway drainage structures. These figures show the significance of highway work in relation to the national economy.

Sri Lanka, with abundance of rainfall, experiences regular floods. The floods that occurred during the latter part of 1983 caused extensive damage to the entire network of roads. The cost of repair was calculated at Rs.78 million.

The structures which are not properly designed to cater to anticipated floods, would result in costly maintenance. Also the failure of structures may lead to fatal accidents resulting in loss of valuable human lives. Therefore the proper application of the knowledge in Hydrology, is of paramount importance to the highway designers.

Improved traffic service and a material reduction which reduces the total cost of construction and maintenance can be achieved by judicious choice of hydrological design criteria.

Applicability of Hydrology in highway work

In actual design practice, the structural design of any drainage structure is dependent on hydrological design. But, in most countries the importance given to the determination of the design flood is much less in comparison to the structural design. Less accurate, over simplified methods are sometimes used for hydrological analysis.

This is due to :

(1) Difficulties in collecting necessary hydrological data
(2) Non availability of processed data
(3) Reluctance to devote much engineering time on hydrological analysis because processing of raw data and other related calculations usually take a fairly long time.

Luckily for Sri Lanka, most of the new bridges are constructed in close proximity to old bridges whose performances are known. These are being employed successfully in designing new structures.

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The objective of this article is to suggest ways of improving the existing practices in determining design flood magnitudes for highway structures.

Selection of a method to determine the design flood

For highway work in Sri Lanka, it is highly desirable to apply a method which is simple and fairly accurate which can be applied even by engineers not specialised in Hydrology. Also such a method should be wide in its application so as to include structures of all sizes irrespective of whether hydrological data is available or not.

A regional flood frequency analysis has most of the properties mentioned above. Highway engineers in most countries employ this method for determining the design flood. However, it is not popular in Sri Lanka mainly due to the non availability of regional flood frequency curves.

Apart from its ease of use, an advantage of the regional flood estimation technique is that it ensures a consistent design approach to flood estimation within each region. When numerous structures need to be designed within a region, the estimation of design flood by different designers using a variety of techniques may result in some structures not having the same level of flood risk in service. This may lead to certain sections of roads being cut by floods more frequently at some locations than at others.

This method also has the advantage that it can be applied even to ungauged sites.

The procedure suggested here is to develop :

(1) Regional flood frequency curves
(2) Correlations between mean annual flood and catchment characteristics.

Having developed above relationships, it is extremely easy to determine the design flood magnitude corresponding to any desired return period, using catchment characteristics.

Due to space limitations, this article deals only with the preparation of regional flood frequency curves.

Selection of a suitable return period

The recurence interval or the return period is the average interval between years with a flood exceeding a given magnitude and is, therefore, the reciprocal of the probability of a flood exceeding this magnitude occurring in any one year.

Selection of the return period corresponding to the design flood is one of the first and most important steps in the hydrological analysis.

The size and the importance of the highway drainage structures do not warrant the use of Probable Maximum Flood as the design flood. Therefore, there is a fair amount of risk of failure involved in any drainage structure.

Selection of a suitable return period is a complex problem which involves the consideration of many factors, some of which are mentioned below:

(1) Potential loss of life if the structure failed.
(2) Availability of financial resources.
(3) Importance of the highway
(For defence highways, higher return periods may have to be used.)
(4) Interruption to traffic, in case of failure.
(5) Value of near by properties at risk.
(6) Cost of damage in case of failure.
(7) Impact to the local economy in case of failure.
(8) Availability of detours.

Ideally, before selecting the return period, each structure and its location should be carefully studied.

Following guide lines for the selection

of the return period can be suggested for the use of highway drainage structures in Sri Lanka.

Drainage structure	Suggested return period (Years)
Bridges on very important roads	100
Culverts on very important roads	25
Bridges on important roads	50
Culverts on important roads	15
Bridges on minor roads (Except submersible bridges)	25
Submersible bridges on minor roads	10
Culverts on minor roads	5

Regional Flood Frequency Analysis

This method has been developed, with variations, by the United States Geological Survey in collaboration with a number of State Agencies in the period since 1945.

In this technique, flood data from a more or less geographically homogeneous region are pooled to provide a more stable estimate of the flood frequency curve. The flood data for the analysis are standordised to the same scale by dividing by the mean annual flood which is the arithmetic mean of the annual floods.

Regional flood frequency curve is essentially a graph plotted with average oberved floods (standordised) as the vertical axis and their corresponding average return periods as the horizontal axis.

The area to be chosen for the regional analysis should be hydrologically homogeneous on the basis of geology, topography, and mean annual rainfall. It should have data gathering stations with sufficient usable records of data. At least a 5 year continuous and reliable flood record is necessary for any station within the region to be considered in the regional analysis.

There are slight variations in the procedures adopted by different Institutions in determining the regional flood frequency curve.

The method suggested in the Flood Studies Report (FSR) is a adopted in this article. (Flood Studies Report was the result of an extensive research programme and was published by the Natural Environment Research Council, U.K.)

Procedure for deriving the regional flood frequency curve as given in the FSR

(1) Select a hydrologically homogeneous region based on geology, topography, mean annual rainfall etc.

(2) For the selected region, collect flood data i.e. peak annual flood Q and the corresponding year, for each station having atleast 5 year records.

(3) If there are any missing peaks in these records, complete them using appropriate methods..

(4) Calculate the mean annual peak flood $\bar{Q}$ for each station.

(5) For each station, assemble $Q/\bar{Q}$ with the plotting position appropriate to the Gumble Variate Y. The expected value of the i^{th} smallest order statistic Y is given by $Y = E(Y_{i,N})$ in a sample of N, which can be calculated using the Gringorten formula.

(6) Divide the y axis into categories of width 0.5 units such as -2.0 to -1.5, -1.5 to -1.0 etc. Plot average values of $Q/\bar{Q}$ at the average values of Y.

This is the regional frequency curve which is smooth upto about Y = 3.0. To Extend the curve, following procedure is suggested.

(1) Divide stations in the region into 4 or 5 groups. (Neighbouring stations should not appear in the same group).

(2) Take 4 highest values of $Q/\bar{Q}$ in the group regardless of the station.

(3) Associate them with expected order statistics $E(Y_{1,M})$, $E(Y_{2,M})$ etc., M - total no. in the group.

(4) Average these values and plot these against average $Q/\bar{Q}$ on the same graph and draw a smooth curve.

For ungauged catchments, a relationship has to be developed between the catchment characteristics and the average annual rainfall in order to employ the above curve.

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