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Design and Construction of Roads in Flood Affected Areas

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Abstract

Bangladesh is a flood prone country. Floodwater causes enormous damage to the road infrastructure of the country. Every year it is observed that the roads of the flood affected areas become unusable after flood. The process of rehabilitating the roads consumes a lot of valuable resources of the country. In this context, this paper investigates the vulnerability of the roads under prolonged submergence and presents a parametric study on the road construction materials that are affected by the long-term flooding condition.

INTRODUCTION

Flood is a perennial problem for Bangladesh. Almost every year it is observed that the roads of the flood affected area become unusable after flood. Lots of resources are required to rehabilitate the roads. Also the rehabilitation process needs valuable time during which the damaged roads remain unusable or only partially usable. During the reconstruction time congestion, vehicle operating cost and inconvenience of the users increases greatly. This is particularly important for major highways of the country. As roadway carries the largest share of passenger and freight movement of the country, any disruption in road network would impose significant loss to the economy of the country. In this context it is essential to design and construct roads, at least the major ones, that can withstand long-term flooding condition.

At present the roads of the country are designed and constructed using standard manuals such as Road Note 31 and AASHTO Design Guide. These manuals provide guidelines for adverse drainage condition and other environmental variables. Considering the environmental variables in the USA and UK, detailed studies have been performed on effects of these factors on road pavements in Transport Research Laboratory, UK and AASHTO Laboratory in USA. The major concerns in the design and construction of road pavement are stability of fills and slopes, drainage, capillarity and frost heave, permafrost, elasticity, rutting etc. Numerous research works have been carried out on these aspects in the laboratories mentioned above. As long-term inundation by floodwater is not a very common phenomenon in these countries, research in this regard is almost non-existent. Even in Bangladesh where flood is very common, comprehensive research on the effect of inundation by floodwater on road pavement has not been done yet.

This paper presents the results of the study on the effects of long term inundation on different layers of road pavement structure. The objective of the study is to identify the parameters of pavement structure, which are affected by flood. The results of the study is expected to help in modifying the present road pavement design and construction practice to build roads that are capable of withstanding stresses caused by long term inundation.

FLOODS IN BANGLADESH: ITS EFFECT ON ROADWAYS

Flood is a recurring problem in this extremely flat and riverine country. The earliest flood recorded in the history of Bengal is that of 1584-85 in the Meghna Basin, which caused the death of about 200,000 people and widespread damage to cattle, food-grain and crop (Hassan, 1998). In the current century and after independence in 1971, flood has hit this country time and again. Analyzing the data of flood incidences it is observed that the frequency of major floods has increased in recent years. Studies reveal that in the country moderate floods have occurred once in every two years while severe floods have occurred with an interval of 6-7 years. The scars of the devastating flood of 1988 were still alive in the memories of the people of this country when the flood of 1998 struck. In fact the country has just recovered from the devastation and finished the reconstruction and rehabilitation of the infrastructures damaged by the flood of 1988 when the flood of 1998 struck.

Flood of 1998 affected about 76 percent areas of the country. The floodwater had started its onslaught by the middle of June 1998 and stayed until the end of September, ’98. Considering the duration and extent of the flood of 1998 it is recognized as one of the most devastating floods in the history of this country.

The extent of damages of the roads of the country caused by the flood is summarized in Table 1. It shows that the total cost of the damage stands at about Taka 1641 crore which is about 11.4 percent of annual GDP of the country (Annual Flood Report, 1998).

After flood it is observed that most of the roads in flood-affected areas become badly damaged. The damages to the roads can be divided into two categories. One category of damage involves the failure of the embankment on which the roads are constructed. Usually this type of collapse is caused by the slope-failure of the embankment, which is the subject matter of geotechnical engineers. The other category of damage involves failure of the pavement structure. In this case, one or more layers of pavement structure may collapse resulting in the damage of the road. This also includes damage to the surface layer. The results of the study presented in this paper deals with the second type of damage only. The study investigates the effect of inundation by floodwater and its duration on strengths of different layers of pavement structure.

Table 1: Assessment of Damages to Highways Caused by Flood of 1998

RHD Roads	Length Sub-merged (km)	Damaged Road (km)		Damaged Bridges & Culverts (No)		No. of Dama-ged Ferry Ghats	Imm. Repair Cost (mil. Taka)	Rehabilitation Cost (mil. Taka)		Total Cost (mil. Taka)
		Emban -kment	Pave-ment	Badly	Partial			Short Term	Long Term	
National Highway	1381.2	623.6	599.3	88	232	13	678.4	490.9	918.1	2087.8
Regional Highway	783.9	329.8	329.2	59	126	7	374.3	268.4	502.0	1144.8
Feeder Road	7457.5	3376.1	3315.9	229	470	34	3761.9	2720.5	5087.6	11570.0
Mecha. Equipment	-						30.0	70.0	0	100.0
Total	9622.6	4329.5	4244.4	376	828	54	4845.1	3549.9	6507.7	14902.6

Source: Roads and Highways Department.

METHODOLOGY AND RESULTS

The main objective of the research project is to investigate the extent of damage to road pavement structure caused by inundation from floodwater. For this purpose, detailed laboratory tests have been performed on surface and subsurface layers of flexible pavement structure. As almost all of the major roads of the country are constructed as flexible pavement, only this type of pavement has been examined in the study. California Bearing Ratio (CBR) tests have been performed on samples of sub-grade layer and Marshal Stability and Flow tests

have been performed on the samples of surface layer. To simulate the effect of inundation by floodwater, the samples were kept in water for 4, 7, 30 and 45 days. To simulate the weathering action the samples were passed through alternate drying and wetting cycles. Sub-grade layer samples have been collected from Katchpur area along Dhaka-Chittagong highway and from Aminbazar area along Dhaka-Aricha highway. A total of 12 sets of samples were prepared for the purpose of testing.

Table 2 and Fig. 1 show the effect of inundation on the density of the test samples. Table 3 and Fig. 2 presents the effect of the same on strength of sub-grade material measured in terms of CBR value.

Table 2: Effect of Inundation by Flood on Unit Weight of Sub-grade Material

Compaction (No of Blows)	Average Unit Weight (pcf)			
	4-day Soaking	7-day Soaking	30-day Soaking	45-day Soaking
56	108	106	104	103
35	103	100	98	97
10	94	89	86	84

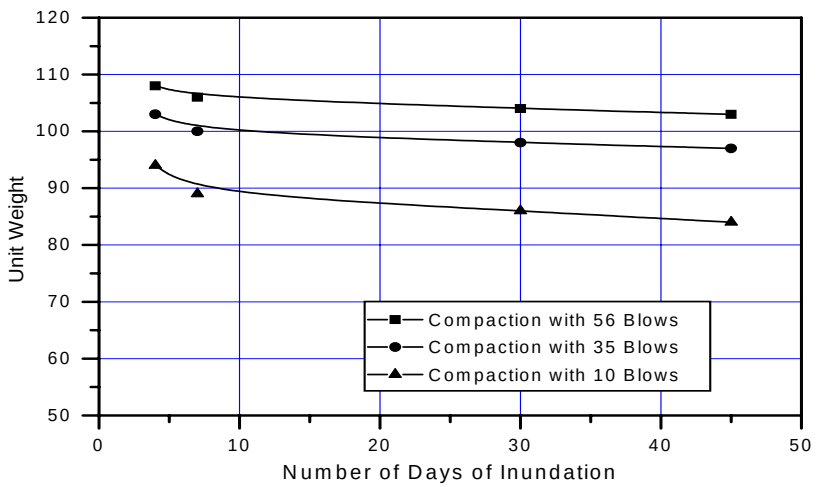

Figure 1: Effect of Inundation on Density of Sub-grade

Table 3: Effect of Inundation by Flood on CBR of Sub-grade Material

Compaction (No of Blows)	Average California Bearing Ratio (CBR) Value			
	4-day Soaking	7-day Soaking	30-day Soaking	45-day Soaking
56	3.5	3.4	3.1	3.0
35	2.7	2.5	2.2	1.9
10	1.6	1.2	1.1	1.0

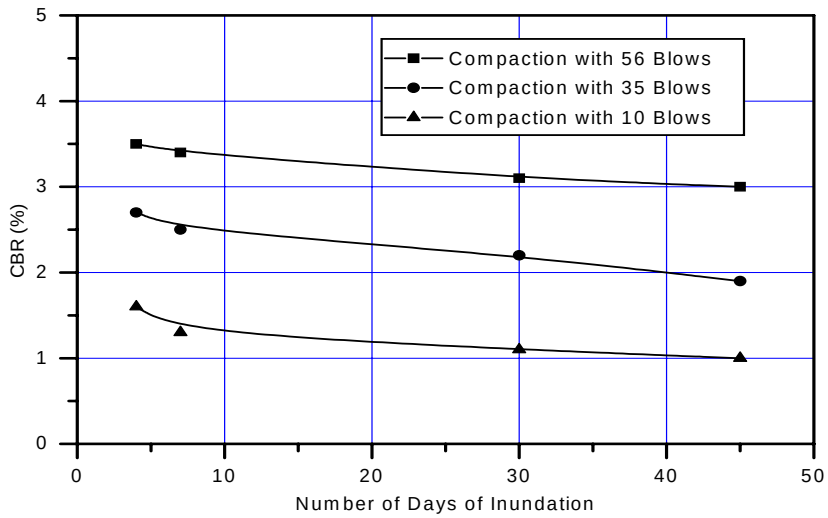

Figure 2: Effect of Inundation on CBR of Sub-grade

From these results, it is evident that both unit weight and CBR reduces with the number of days of inundation by water. As the road pavement is designed with the CBR value of 4-day soaking, relative changes are calculated on the basis of this value. In the case of inundation for 45-days, the unit weight reduces by 4.6, 5.8 and 10.6 percent for compaction efforts of 56, 35 and 10 blows, respectively. In the case of CBR the reductions are 16.7, 29.6 and 37.5 percent, respectively. This implies that the more compact the material, the lower will be the loss of unit weight and strength caused by inundation. It is expected that the

sub-grade soil become saturated within four days. The subsequent loss of strength and unit weight may be caused by the loss of fine particles from the sample.

For surface layer, the samples were prepared in the laboratory and the optimum bitumen content was estimated. It was found that the optimum bitumen content is 4.75 percent. Marshall test samples have been prepared for surface layer used for medium traffic using the same aggregate and bitumen content mentioned above. Four sets of samples have been prepared to test the initial strength and flow as well as the effects of inundation for 4, 7 and 30 days with alternate drying and wetting cycles. The results of Marshall Stability and Flow tests on the samples are presented in Table 4 and Fig. 3.

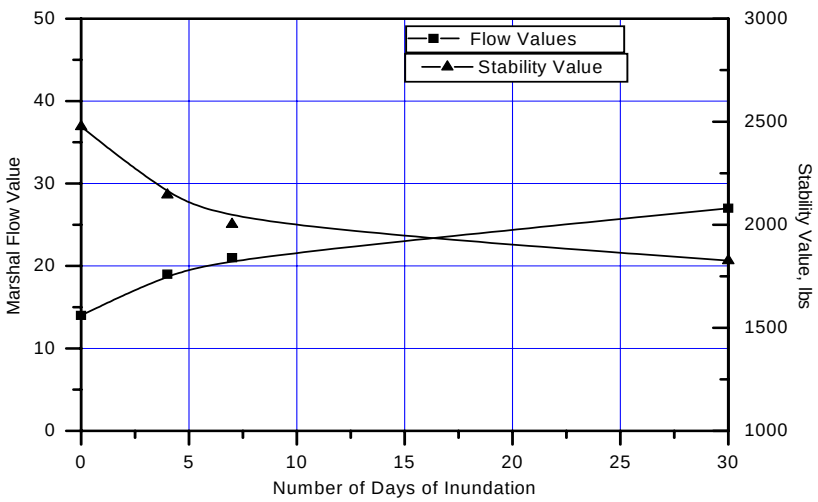

Figure 3: Effect of Inundation on Flow and Stability of Bituminous Surface Layer

From these results, it is evident that stability and flow of flexible pavement is affected by the duration of inundation by water. In the case of inundation for 30-days, the flow value increases by about 93 percent and stability reduces by 26 percent. The figures also imply that the longer the period of inundation, the more severe will be the deterioration although the rate of destruction may decrease.

Table 4: Effect of Inundation by Flood on Unit Weight of Sub-grade Material

Number of Days of Inundation	Flow	Stability (lb)
Initial Values	14	2476
4-Day Inundation	19	2145
7-Day Inundation	21	2002
30-Day Inundation	27	1826

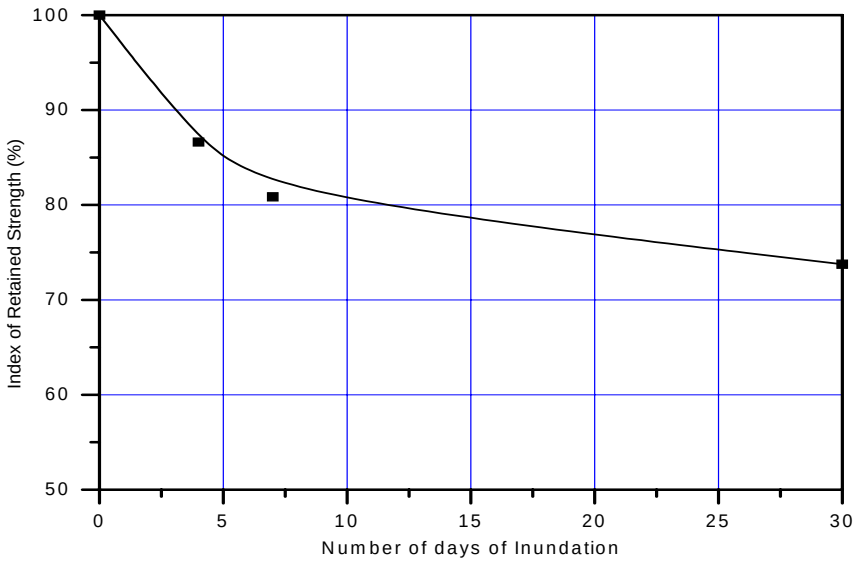

Figure 4: Effect of Inundation on Stripping and Swelling of Bituminous Mixture

The results of Marshall Stability tests can also be interpreted in the form of Immersion-Compression Test (AASHTO Designation T165) which is widely used as an indirect measure of the tendency of aggregates to strip or swell under the effect of moisture (Oglesby and Hicks, 1982). The test result is presented as a

numerical index of resistance of bituminous mixture to the detrimental effect of water as shown below.

$$\text{Index of Retained Strength (\%)} = \frac{S_2}{S_1} \times 100$$

where, S_1 = Strength of dry specimen, and S_2 = Strength of immersed specimen.

The results of the analysis are presented in Fig. 4. It shows that the strength of the sample reduces by 26 percent for 30 days of immersion. This loss can be attributed to stripping or swelling of bituminous mixture caused by water.

CONCLUSIONS

From the results of the study it can be concluded that the period of inundation by floodwater affects the strength of pavement layers significantly. In the case of inundation of road surface for 45 days the CBR of sub-grade material may reduce by about 30 percent for medium compaction. Also in the case of surface layers the strength reduces substantially.

The results of the study imply that long-term inundation should be considered as a design parameter for designing roads in Bangladesh. As flood is a perennial problem for Bangladesh and measures to prevent flood is not economically feasible, strategies to cope with flood may prove to be economically more justified. Considering the cost of rehabilitation of roads after the flood of 1998, it can be concluded that even the increased initial cost to construct roads capable of withstanding inundation by flood would prove to be much better in economic terms.

In this study only two layers of pavement structure and some specific parameters of the materials have been examined. In order to develop working guidelines, detail testing and analysis is required.

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