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Strengthening and drainage of flexible pavements

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ABSTRACT

Pavement should be strong enough to resist the external stresses and to distribute the external load and transfer the load through different layers to subgrade and the drainage system of roads should be good enough to discharge the rainwater as quickly as possible. The study highlights the need for strengthening of pavement and ways to improve the drainage system for the road pavement of Raipurrani to Naraingarh which is a part of state highway (SH-01) in Haryana state. This study also includes the collection of required field data like existing pavement structure, traffic data, pavement surface condition, and rebound deflection by using Benkelman Beam Deflection (BBD) technique and finally on the basis of data analysis design for overlay has been discussed for the pavement. It also includes the drainage condition of the road length and needs for improvement in the drainage system for a particular flexible pavement. The surface drainage system is discussed in this study, as it includes the interception and disposal of runoff water from the surface as well as subgrade.

Keywords— *Overlay, Strengthening, Drainage, Rebound Deflection*

1. INTRODUCTION

Pavements are the key elements of the infrastructure of any country whose functions are to promote transport activities, economic activities and to improve the standard of living. Flexible pavements are those which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The layers of flexible pavement reflect the deformation of the lower layers onto the surface of the layer. The flexible pavement layers transmit the vertical or compressive stress to the lower layer by grain to grain transfers through the point of contact into each granular structure. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel. Due to the ability to distribute the stresses to a larger area in the shape of a truncated cone, the stress gets decreased at the lower layers. Therefore by taking full advantage of the stress distribution characteristics of the flexible pavement may be constructed in a number of layers and the top layers have to be the strongest as the highest compressive stresses to be sustained by this layer, in addition to the wear and tear due to the traffic. In case of increased wheel loads and more vehicle repetitions, no amount of routine and periodic maintenance can prevent rapid structural deterioration. Therefore the existing pavement is to be strengthened by providing additional pavement layer or overlaying one or more layers above the existing flexible pavement.

Highway drainage is the process of removing and controlling excess surface and sub-surface water within the right way. This includes interception and diversion of water from the road surface and sub-grade. The installation of suitable surface and sub-surface drainage system is an essential part of highway design and construction. Roads need to be well drained to stop flooding; even surface water can cause problems with ice in the winter. Water left on standing on pavements can also cause maintenance problems, as it can soften the ground under a road making the road surface break up and as well lead to an accident from the road users.

2. METHODOLOGY

2.1 Structural Evaluation of Pavements by Benkelman Beam Test

Performance of flexible pavements is closely related to the elastic deflection of pavement under the traffic loads. The deformation or elastic deflection under a given load depends upon the type of subgrade soil, its moisture content, and compaction of soil, the thickness, and quality of pavement layers, drainage conditions, pavement surface temperature etc. Pavement deflection is measured by the Benkelman Beam which consists of a slender beam of 3.66m length pivoted at a distance of 2.44m from the tip. By suitably placing the probe between the dual wheels of a loaded truck, it is possible to measure the rebound and residual deflections of the pavement structure. The characteristic deflection for design purposes shall be taken as given in equations (1) and (2) The formulae to be used in the calculation are as follows:

Characteristic Deflection,

$$Dc = x + 2\sigma \text{ ……for major arterial roads (like NH \& SH)} \quad (1)$$

$$Dc = x + \sigma \text{ ……for all other roads} \quad (2)$$

Where,
x = Mean deflection, mm
σ = Standard deviation, mm
The characteristic deflection (Dc) value to be used for overlay design from IRC: 81-1997.

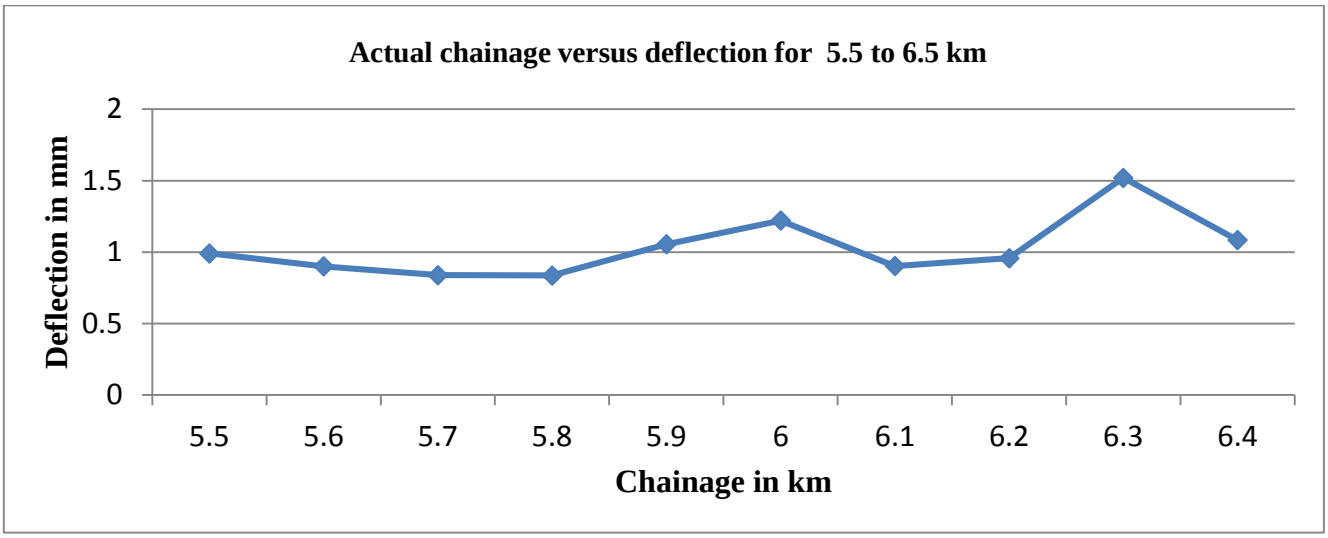

Fig. 1: Variation of characteristic deflection versus chainage

2.2 Pavement Condition Survey

This phase of operation, which shall precede the actual deflection measurement, consists primarily of visual observations supplemented by simple measurements for rut-depth using a 3-meter straight edge. Based on these the road length shall be classified into sections of equal performance in accordance with the criteria given in Table below.

Table 1: Criteria for classification of pavement sections

Classification	Pavement condition
Good	No cracking, rutting less than 10 mm.
Fair	No cracking or cracking confined to single crack in the wheel track with rutting between 10 mm and 20 mm
Poor	Extensive cracking and/or rutting greater than 20 mm. Sections with cracking exceeding 20 percent shall be treated as failed

2.3 Traffic survey

Traffic in terms of million standard axles shall be considered for the design of overlay. If sufficient data are available at the stretch with respect to the wheel load distribution of commercial vehicles or the vehicle damage factor and their transverse placement, the cumulative standard axles may be worked out based on actual data; otherwise, design traffic may be calculated as per the procedure is given in IRC: 37. Estimate of the initial daily average traffic flow can be determined by available 3- day count could also be used.

2.4 Highway Drainage System

Designing for proper drainage of highway systems is crucial to their success. Regardless of how well other aspects of a road are designed and constructed, adequate drainage is mandatory for a road to survive its entire service life. Excess water in the highway structure can inevitably lead to premature failure, even if the failure is not catastrophic.

Depending on the geography of the region, many methods for proper drainage may not be applicable. The highway engineer must determine which situations a particular design process should be applied, usually a combination of several appropriate methods and materials to direct water away from the structure. Erosion control is a crucial component in the design of highway drainage system. Designing a drainage system requires the prediction of runoff and infiltration, open channel analysis, and culvert design for directing surface water to an appropriate location.

Camber: Camber or Cant is the cross slope provided to raise the middle of the road surface in the transverse direction to drain off the excess rainwater from the road surface. The cross slopes can be expressed in slope as 1 in n or percentage as n% (for example 1 in 50 or 2% are same).

Table 2: IRC values of camber

Surface Type	Heavy rain	Light rain
Concrete/ Bituminous	2%	1.7%
Gravel/ WBM	3%	2.5%
Earthern	4%	3.0%

Storm Sewers: These are underground pipes that receive the runoff from a roadside inlet for conveyance and discharge into a body of water away from the road. Open Channels ditches may be trapezoidal or V-shaped. The trapezoidal ditch has a greater capacity for a given depth.

Culvert: A culvert is a closed conduit for passage of runoff from one open channel to another. For small culverts, stock sizes of corrugated metal pipe may be used. For larger flows, however, a concrete box or multiple pipes may be needed.

3. DATA ANALYSIS AND DISCUSSION

3.1 Traffic volume analysis

Summary of above three-day traffic volume data is given below:

Table 3: Summary of traffic volume data

	Total PCU/day	Consider maximum PCU/day
Day-1 (Saturday)	21964	**21,006**
Day-2 (Sunday)	20411	
Day-3 (Monday)	20644	

The IRC recommended Design Service Volumes for Two-Lane Roads for plain terrain and Curvature (Degrees per km 0-50) are 15,000 PCU/day. And the actual PCU/Day of selected stretch is 21,006 PCU/Day. So that based on IRC recommendation and present PCU/Day widening of the road is needed.

3.2 Calculation of Million Standard Axel for Overlaying

Let initial traffic on the stretch = 3350 CV/Day
A = Initial traffic × Lane distribution factor
Lane distribution factor = 0.75 (as per IRC: 81-1997 for two lane single Carriage way roads)

Hence,
A = 3350 × 0.75 = 2512.5
r = 7.5 % (assumed growth rate, as per IRC: 81-1997)
x= 10 year for state highway road as per IRC: 81-1997
F= 4.5 for plain roads carrying traffic great than1500 CV/day

$$\text{Ns} = \frac{365A[\{\{1+r\}^x\}-1]}{r} \times F$$

Ns = 58.370 msa.

3.3 Hydrologic Analysis

The main objective of the hydrologic analysis is to estimate the maximum quantity of water expected to reach the element of the drainage system under consideration. A portion of rain infiltrates into the ground as groundwater and a small portion gets evaporated. The remaining portion of water which flows over the surface is termed as run-off. The details of rainfall in the Naraingarh area including intensity duration is shown in fig below.

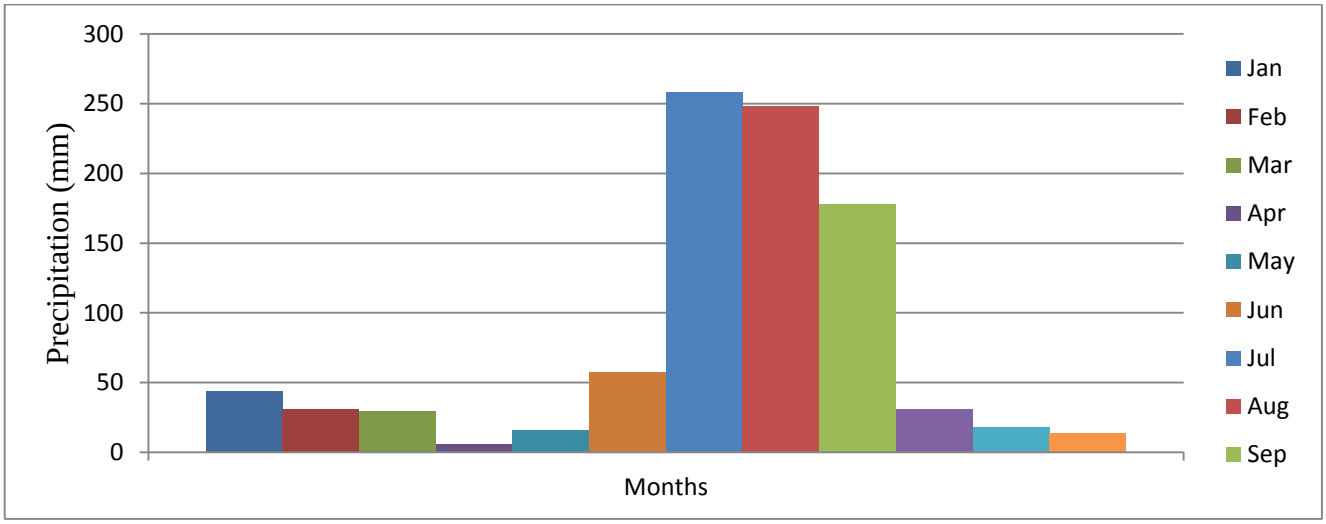

Fig. 2: Monthly precipitation of Naraingarh area of the year 2017

It is also necessary to find the drainage area from where water is likely to flow in. the rational formula used to estimate the peak runoff for highway drainage. The rational formula in its simplest form is given by

$$Q = C \times i \times A_d$$

Where, Q= Runoff, m/sec
C= Runoff coefficient
i= Intensity of rainfall, mm/sec
A_d= Drainage area

The value of runoff coefficient depends mainly on the type of surface and its slope. The C- values may be taken as 0.8 to 0.9 for bituminous and concrete pavements, 0.35 to 0.70 for gravel and WBM pavements, 0.4 to 0.65 for impervious soil.

4. CONCLUSIONS

- It is observed from data that average daily traffic (ADT) in PCU/day is more than the IRC recommendations for capacity per day of 2 lanes for plain rural areas.
- It has been found that 3 sections are having poor surfaces (1section = 1 km) from the surface condition survey, and structural evaluation also has conducted using Benkelman beam deflection test at a poor section within 3.0 km and found the characteristic deflection.
- Overlay thickness at each section (total 3.0 km) is calculated in 3 alternate designs like BC/DBM, DBM and BM are (i) 35/50, 85 and 120mm (ii) 35/40, 75 and 105mm (iii) 30/40, 70 and 100mm respectively, showing thereby BC/DBM combination even having better finish is having lesser thickness making it more economical.
- Camber of minimum 2% is given throughout the length to self-drain away rainwater from the pavement.
- A rectangular side drain (covered) of 0.4 m bottom width and depth 0.5 m with a minimum longitudinal slope 1 in 200 on both sides of the pavement in the urban area of Raipurrani of chainage 0.0 to 1.2 km for the disposal of excess rainwater from the pavement.
- The basic principles involved in controlling erosion and providing proper surface drainage have been reviewed. It is important to provide inherently stable soil slopes for highway cuts and fills and to protect them with grass or another cover from surface erosion.

5. FUTURE SCOPE

- Structural evaluation of the pavement can be done by using Falling Weight Deflectometer (FWD) and/or Light Weight Deflectometer (LWD).
- Total estimation of the cost of the overlay can be computed.
- Other pavement software can be used for evaluation of pavement.
- Use of geotextiles can be used for protection of embankments from erosion.

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