Impact of Poor Surface Drainage on Pavement Performance

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ABSTRACT

This paper presents the causes of poor surface drainage and its impact on pavement's performance. In order to attain this factors initially investigated to understand the poor surface drainage such as; cross slope and amount run off and then the effects that this poor drainage impose on the structural as well as functional performances of the pavement. This study was conducted in bole sub-city specifically on Gerji road, Addis Ababa in which the road is known for discomfort and unsafe riding surface due to over flooding and pounding of water on the surface of pavement. Research results showed that the road in both right and left sides didn't attain the minimum value of cross slope for adequate drainage which is 2.5% and the other factor is the actual amount of runoff is much greater than the designed one. This factor come up with high value of IRI for the right and left side of the road and also the value of mean RRD for the road is 0.95mm. This research concluded that drainage condition has strong relationship with the structural and functional inadequacy of pavements as well as on intensities of distresses.

Keywords: *Poor surface drainage, structural and functional performance*.

1 INTRODUCTION

The drainage system is designed to collect storm water runoff from the roadway surface and right-of-way, convey it along and through the right-of-way, and discharge it to an adequate receiving body without causing adverse on- or off-site impacts. It is very essential to have adequate drainage in the design of highways to function properly since it affects the highway's serviceability and usable life. When the provided structures fail to accommodate the discharge the road is said to have drainage problem. The problem on highway drainage structures is world-wide. The fact, known for centuries, is that as long as road structures and sub grade soil do not have excess water the road will work well. But increased water content reduces the bearing capacity of a soil, which will increase the rate of deterioration and shorten the lifetime of the road. In such cases, the road will need rehabilitation more often than a well-drained road structure. Mainly the problem was observed on poorly working structures, such as, culverts, ditches, grass verges, poor cross fall and cracks.

2 METHODOLOGY

The study area of this research located on bole sub city in wereda 13 and 14 of Addis Ababa, the road from Korea hospital junction to Mebrat hail round about.

Figure 1: Aerial photo for the study area

The strategy followed in this research was first started with problem identification which has been done through unstructured literature review, archival study and informal discussion with colleagues and professionals in the sector; and then the research design was formulated. In order to attain the objectives of this study, a descriptive research was formulated based on a research design which involved both quantitative and qualitative data types were collected and analyzed to describe the condition of drainage system and to measure the pavement performance quantitatively. The qualitative data that were used to describe the pavement and drainage condition are those collected in the preliminary visit stage of the data collection. The quantitative data are those that were collected in filed measurement.

The document search was mainly intended to collect causes of poor surface drainage system and its impact on pavement performance in Addis Ababa city. It investigates the reason for poor drainage system; assess the effect of poor drainage on structural and functional performance of pavement.

Finally, after an in-depth review of literature different tests were conducted like deflection test, roughness test and questionnaire was designed and distributed to end users and professionals to get their opinions. The data were then analyzed for cross-checking the validity and conformity of the information obtained through the overall research work. This was followed by thorough discussions in order to draw a conclusion and to forward recommendations based on the findings of the study. Pavement surface drainage was taken as independent variable and Cross slope, Structural performance of pavement and Functional performance of pavement were chosen as dependant variable.

The study populations for this research were pavement failures that occurred in bole sub city woreda 13 & 14 from Korea hospital to Mebrat hail roundabout, road users and professionals. Sampling technique was random systematic sampling includes choosing subjects from a population through unpredictable means. In its simplest form, all subjects have an equal chance of being selected out of the population being researched.

The collected data was used to determine the factors causing poor surface drainage and its effect on the performance of the pavement. Measurements that were needed for this study was cross slope of the road, actual amount of run off, deflection and roughness of the test road. Photographs were taken directly from the road sites during the field survey to illustrate the existing condition and related influences on the drainage and pavement structures.

The data gathered from the site by Roughometer III was processed by Roughometer III processing software to obtain international roughness index and the deflection reading from the dial gage was analyzed by the mathematical formula for computing representative rebound deflection. Topographic survey data was analyzed to obtain cross slope by excel sheet, the aerial photo and slope of the study area was analyzed using ArcGIS software.

The data collected and analyzed through different method was presented using tables, charts, graphs, maps and field survey photos.

3 RESULTS AND DISCUSSION

For computing the factor that affects surface drainage system and its impact on the pavement performance is very essential to use technical method to reach on valuable result. Priority is given for the technical part of the analysis because the root problem can only solved by technical computations so that the results of technical analysis are presented. Even though Questionnaire survey supplementary for the analysis of the research problem the results of them added strength to the results obtained from the root method of the analysis which is technical solution. Therefore the results of supplementary methods are presented next to the technical method.

3.1 Factors in a Road Surface Drainage

The factors that were considered in a road surface drainage problem are the road cross slope and amount of runoff.

3.1.1 Cross Slopes

The cross slopes of the road are measured from the surveyed points (easting, northing and elevation) using excel sheet. As the AACRA drainage manual indicates the maximum and minimum cross slope for adequate drainage is 5% and 2.5% respectively.

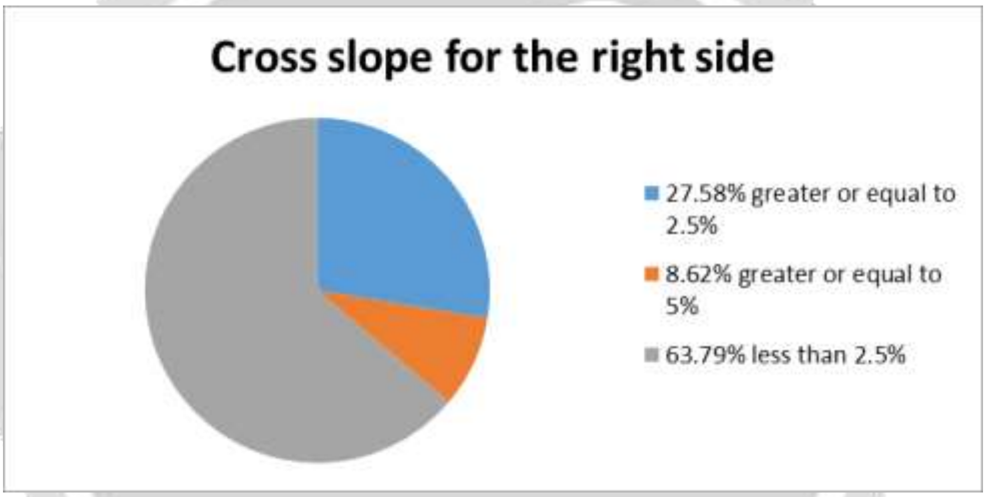

Figure 2: Cross slope for the right side

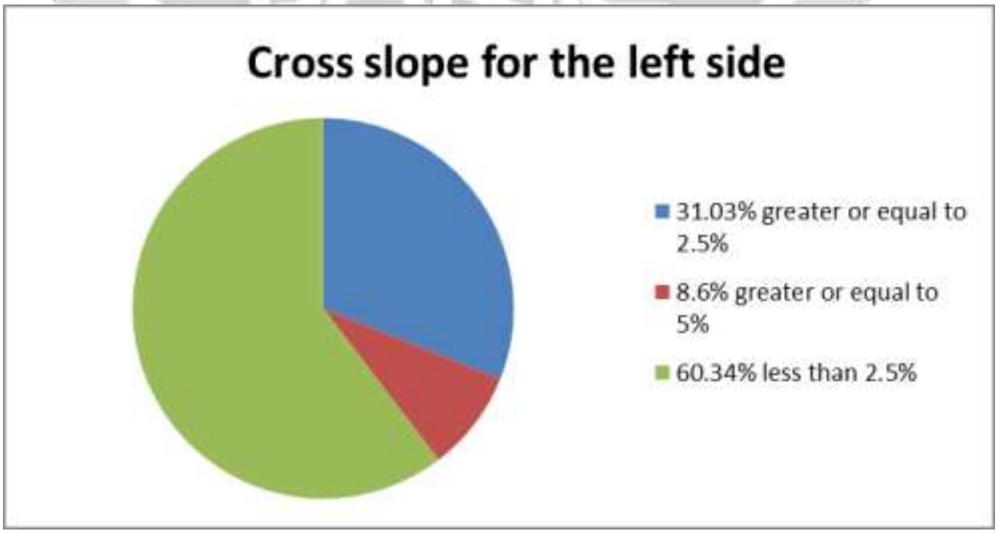

Figure 3: Cross slope for the right left side

From the surveyed data the cross slope for right and left sides of the road is expressed by percent on the pie chart below; from the total points surveyed for the right and left sides of the road as the chart indicates about 63.79% and 60.34% respectively didn't meet the minimum requirement of cross slope for adequate drainage which is about 2.5%. The maximum limit of cross slope to provide adequate drainage is 5% but as the data shows about 8.62% of the surveyed data exceeds this limit but about 27.58%of the data satisfy the minimum requirement of cross slop for good and safe drainage system.

Cross slope is the main requirement for the road to have adequate drainage. So every road need to meet the minimum requirement which is 2.5% without exceeding maximum limit which is 5% otherwise the water sleep or pond at the surface of the road especially on the right side due to this problem it is very difficult for the road users to acquire the benefit intended from the road and sometimes traffic diverts due to over flooding of the road. These pounding of water infiltrate through cracks, potholes and different defects of pavement and weaken the pavement and decrease the life of the pavement.

3.1.2 Runoff Estimation

The peak discharge was used for the design of drainage structures. So in order to identify weather the drainage structure can accommodate design runoff or not. This is accomplished by comparing the actual runoff verses the design one. Runoff is computed by the rational formula and it is a function of catchment area, coefficient of runoff and intensity

$$Q = CIA / 360$$

From table runoff coefficient (C1) for multi-units detached is 0.40-0.60, (C1') for asphaltic surface is in the range of 0.7-0.95,(C2') for an improved areas is 0.10-0.30 for roof C3 is 0.75-0.95.from this different value of run off coefficient the weighted run off coefficient need to be calculated,

$$C_w = \frac{\sum C_i A_i}{A}$$

where, C_w = weighted runoff coefficient
C_i , A_i = runoff coefficient and area respectively for cover type i
A = total drainage area.

The higher values of runoff coefficients are usually appropriate for steeply sloped areas and longer return periods because infiltration and other losses have a proportionally smaller effect on runoff in these cases. In the case of this study about 0.63km of the study road is steeply sloped, about 0.937km is flat, 0.327km is less steeply sloped and the return period that was used is 20 years which is relatively higher for drainage structure design.

3.1.3 Intensity Duration Frequency Curve

The rainfall intensity (I) is the average rainfall rate in mm/hr. for duration equal to the time of concentration for a selected return period. It is obtained by using the intensity duration frequency (IDF) curve for a given region. The IDF curve provides a summary of a site's rainfall characteristics by relating storm duration and frequency to rainfall intensity (assumed constant over the duration).The rain fall data gathered form Ethiopian Metrology Agency of bole station is analyzed with the aid of excel sheet to give the IDF curve. The given data for computing IDF curve is Annual Maximum Daily Rainfall data of 10 Consecutive Years, Rainfall Intensity for 30minute in order to increase the accuracy and Frequency of 20 Years Return Period.

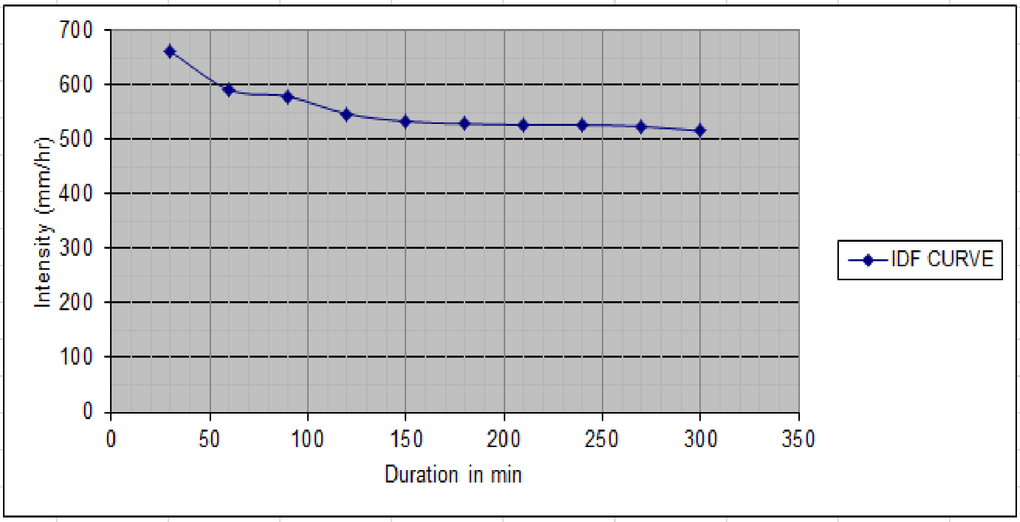

Figure 4: Intensity duration frequency curve

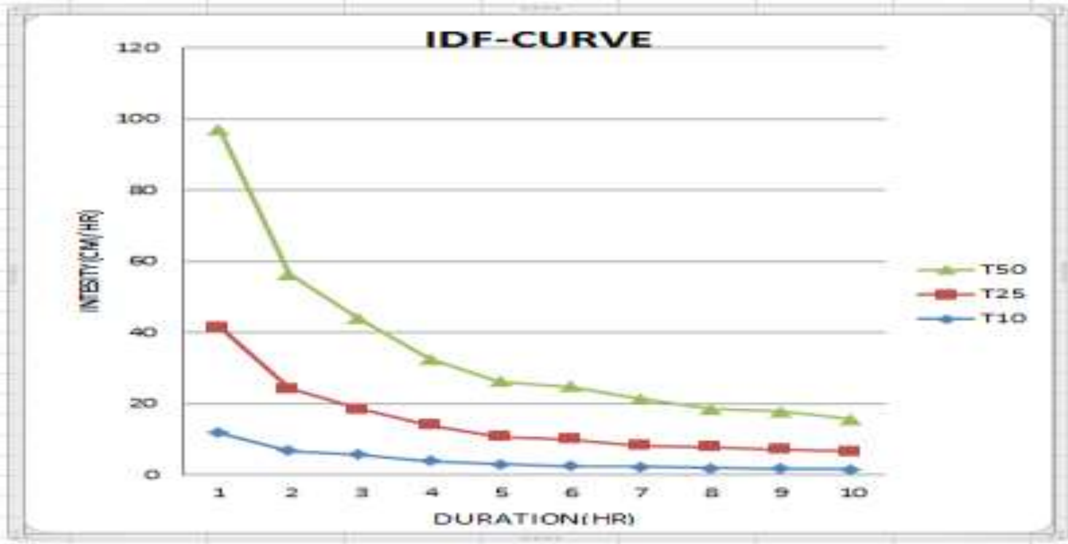

Figure 5: Intensity duration frequency curve

The time of concentration need to be calculated first in order to find rain fall intensity from the IDF curve.

$T_{C} = 0.0195Kc^{0.77}$

Where K_c= $[(L)^3 / H]^{0.5}$, L =Length of road of the section

H =Elevation difference from contour line is 1

$= ((2000)^3 / 1)^{0.5}$

=90855.13

=<u>128.22 min</u>.

By using interpolation

120……………………….547.3

128.22……………………X

150……………………….533.2

(120-150)/ (547.3-533.2) = (120-128.22)/ (547.3-X)

= -30(547.3-X) = 14.1 * -8.22

= -16419 + 30X = -115.902

$\frac{30X}{30} = \frac{16303.098}{30}$

X=543.4 mm/hr

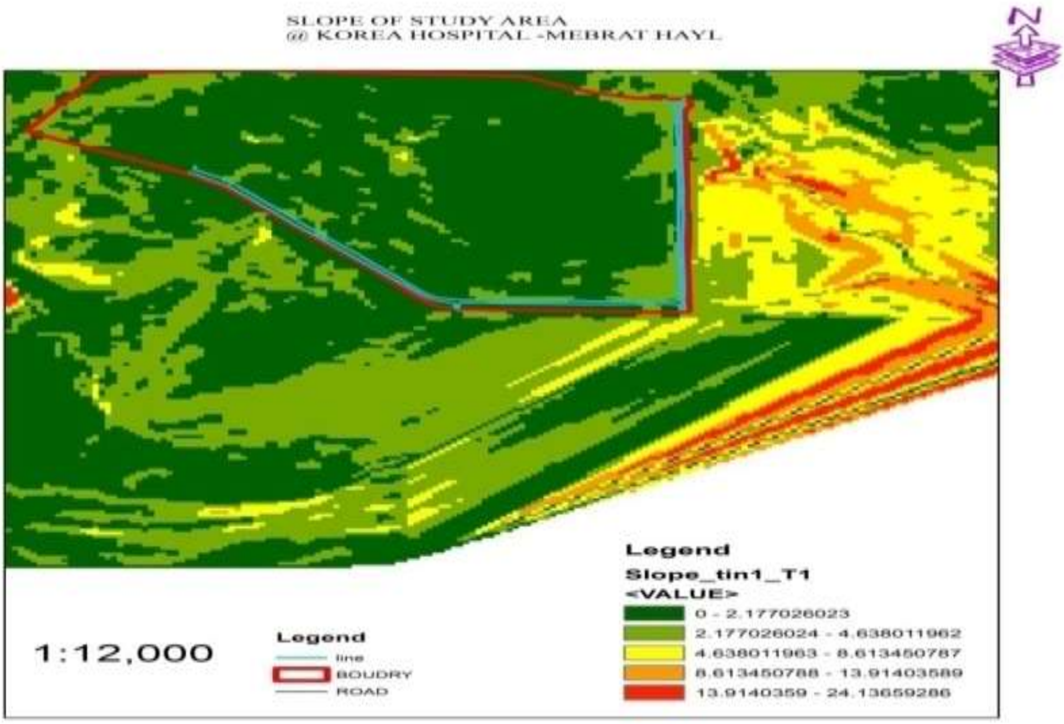

Figure 6: Area and slope of the study area

4 CONCLUSION

On the basis of the present investigation carried out, following conclusions have been made.

- The cross slope of the test road is not sufficient to provide adequate drainage since about 63.79% for the right side and 60.34% for the left side didn't attain the minimum requirement for adequate drainage which is 2.5%.and also the amount of actual run off is much greater by 28.6 m^3/sec from the design amount of run off for the total segment of the test road. According to the survey made for this thesis purpose, even some of the existing surface drains are not properly functioning.
- The results of the nondestructive structural evaluation based on deflection revealed that the pavement have a mean RRD value of 0.95mm which is much greater than the very bad limit which is 0.80 mm. Therefore the structural evaluation made on the road confirms that the pavement is not structurally adequate to serve the intended purpose.
- The result of roughness evaluation for right and left side is 5.9m/km and 6.1m/km respectively. The mean IRI values fall in the range of poor functional performance especially for the left side since left side of the road has high number of distresses which trap water and weaken the pavement performance which leads to failure of the road before it reaches its intended service life.

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