The Effect of Poor Drainage on Road Performance in Hargeisa

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Abstract— This paper aims to investigate the many implications of poor drainage on the state of road pavements. Early pavement deterioration due to poor drainage results in road structural failures and driving difficulties. It is crucial to provide proper drainage to stop or reduce early pavement failures and improve road performance. A field survey of the current state of the offered drainage system and its consequent effects on pavement performance was conducted on the main roads in Hargeisa city as a case study. This analysis revealed that the majority of roads in Hargeisa City had insufficient drainage, which led to serious distresses and pavement deterioration. Design principles are based on prior experiences in the design and construction of appropriate drainage.

Keywords: Effects, Poor Drainage, Road Performance, Premature Failures, Design Guidelines

I. INTRODUCTION

Water is the main contributor to the failure and drainage of roads. Water can be in form of groundwater. Surface water (streams and rivers) or rain, as runoff from the surrounding areas. In addition. Water may flow laterally from the pavement edges or it may seep upward from a high-ground water table. The water flow can damage the road in several ways. (Rokade et al., 2012) Reported that water-related damage to pavement can cause one or more of the following forms of deterioration.

A: reduction of the base, sub-base, & subgrade strength, B: differential swelling in expansion subgrade soils, C: stripping of asphalt in flexible pavements, D: frost heave and reduction of strength during frost melt, E: movement of fine particles into base or sub-base materials resulting in a reduction of hydraulic conductivity considerably.

The damage to the road can be recused if the flow of water is controlled. Minor damages can easily be repaired as part of regular maintenance provided to the road and its structure. If the flow of water is not properly managed, the deterioration of the road will be more serious and occur more rapidly. This will lead to higher maintenance demands and in the worst cases result in serious damage which may obstruct the traffic flow.

Recently Hargeisa is facing extensive water logging during the rainy season (April to August) as a result of the serious problem of poor drainage. Inadequate drainage problems become one of the most common sources of complaint from the residents in Hargeisa city and this problem becoming worse year after year. Poor existing drains and their improper operation and management mainly cause serve flooding which creates damage and problems to the road pavement and road users. As shown in Figure 1 a flood obstructed traffic flow.

Fig. 1: Flooded road obstructed traffic flow

In addition, decreases are spread and give problems to the population such as malaria and diarrhea. This critical situation was severely aggravated because the natural drainage system, which conveys storm runoff from the areas to the Wadi was not fully operated and existing drains were blocked with a huge amount of garbage, solid waste, sand accumulation, and vegetation.

II. LITERATURE REVIEW

A drainage system includes pavement and the water handing system. They must be properly designed, built, and maintained. The water handling system road surface, shoulders, drains, culverts, curb, gutter, and storm sewer. When a road fails, whether its asphalt, concrete, or gravel, inadequate drainage often is a major factor. Poor designs can direct water back onto the road or keep it from drainage away. Too much water remaining on the surface combines with traffic action to cause potholes, cracks, and pavement failure. Many researchers demonstrating that poor drainage can adversely affect pavement performance. (Rokade et al., 2012) reported that inadequate drainage leads to a major cause of pavement distress due to a large number of costly repairs before reaching their design life. He found that pavement service life can be increased by 50% if water can be drained without delay. Similarly, a pavement system incorporating good drainage can be expected to have a design life of two to three times that of an undrained pavement section. (CEDERGREN et al., 1972) evaluated early field tests that include both drained and undrained pavement sections. Based on these field data, he estimated that a flooded undrained pavement experiences 10 to 70,000 times the damage from load event compared to a drained pavement. As a conservative single value, he suggested that an undrained pavement experiences 15 times that damage compared to a well-drained pavement.

To achieve proper drainage drains or ditches along the side of the road are essential to collect water from the road surface and surrounding areas and lead it to an exit point where it can be safely discharged. (Forsyth et al., 1988) presented several case studies related to pavement drainage. They reported that the use of edge drains usually improves the durability of pavements. Forsyth et a. concluded that the percentage of cracked slabs in the undrained sections exceeds that in the drained sections by a ratio of 2.4 to 1. The use of edge drains was also examined by (New & Design, 2002) for conventional asphalt pavements with unbound dense-graded aggregate bases, the addition of edge drains appeared to reduce fatigue cracking, but not rutting. The use of asphalt-treated permeable base sections with edge drains produced significantly less rutting than did unbind dense-graded aggregate base sections. However, the fatigue cracking performance for both types of base sections with edge drains was comparable.

The subsurface drainage is a key element in the design of pavement. The NCHRP (New & Design, 2002) performed an extensive study of many subsurface drainage systems, NCHRP project 1-34, the performance of pavement subsurface pavement drainage, and summarized findings on the effectiveness of subsurface drainage on flexible pavements. They found that structural capacity and drainage ability were key factors in the performance of flexible pavements. If either factor was poor, there was an increased incidence of rutting and fatigue cracking. It was noted that these factors should be carefully considered during the design phase of flexible pavements. (New & Design, 2002)stated that another key factor in the performance of subsurface drainage was whether edge drain outlet pipes were clogged. Clogged outlet pipes were found to have a detrimental effect on the performance of flexible pavements. Clogged outlets led to increase fatigue cracking and rutting and could lead to stripping. In addition, permeable base sections were found to have better fatigue performance than all other types of evaluated pavement sections. However, there was not a significant difference in the rutting performance of permeable base sections and other sections. (MARKOW, 1982) developed a predictive model of pavement performance that includes the effect of moisture on pavement materials properties and the quantity of the subsurface drainage. In this model, the duration of pavement wetness is first estimated taking climatic conditions as well as drainage into account. Then assuming the pavement system has a 50% reduction in strength when wet.

III. Design Guidelines

Drainage is the most important aspect of road design. Proper design of drainage is necessary for the satisfactory and prolonged performance of the pavement. In designing drainage, the primary objective is to properly accommodate water flow along and across the road.

A. Surface Drainage

The surface drainage elements include road surface, side drains, culverts, curbs, gutters, and storm sewer systems. These elements work together as a system to prevent water from penetrating the pavement, remove it from the travel lanes to the side drains or gutter, and carry it away from the road.

B. Road Surface

The road surface geometric features, carriageway cross slope, longitudinal gradient, and shoulders enable the water to flow from the road surface to side drains that collect and lead water away from the road.

C. Cross-section slope

Drainage of the road pavement is provided by shaping the road carriageway with a camber or cross slope. The camber is the slope from either side of the center line towards the road shoulders. For roads with asphalt surfaces, the camber is normally 2 to 3% because water will easily flow off the hard, waterproof surface. On earth and gravel roads, the camber needs to be steeper because the water will flow more slowly and the surface is often uneven. Gravel and the earth's surface also absorb some of the surface water unless it is quickly drained away from the road. Thus it is recommended that the camber is 5 to 7% on sharp curves, the camber is often substituted with a super elevation which leads the water to the inside of the curve. The super elevation is installed with a gradual change of the road cross-section from a camber shape to a road surface shaped with a cross slope. At the same time, super elevation provides a certain resistance to a vehicle from skidding off the road due to the centrifugal force.

D. Longitudinal

Providing the vertical alignment of the road with a gentle longitudinal gradient improves the road surface drainage. This slope facilitates the discharge of water from sections of the road surface with limited cross-slope. Steep road slope causes surface water to move rapidly and makes surface drainage difficult to control. This problem starts when the longitudinal gradient exceeds 8% due to the steep grade, it becomes more difficult to evacuate water from the carriageway. This will result in accelerated wear of the road surface. If the steep slope cannot be avoided by realigning the road, an alternative is to provide an erosion-resistant surface to this section, such as stone pavement, asphalt, or concrete. Equally the side drains need to be protected similarly.

E. Shoulders

Shoulders directing water flow to the side drains or ditches. They should slope more than the carriageway to keep water moving to the side drains. If shoulders slope less, water will build up during heavy rain at the joint between shoulder and carriageway, flooding traffic lanes. For asphalt roads, the shoulders slope is normally 3 to 5% while for gravel and earth surfaces is 8 10%. When the surface runoff water penetrates the shoulders a filter column just below the shoulders can be constructed by making a shallow excavation, then filling it with crushed rock, gravel, or sand. At the trench bottom, perforated pipes are placed to drain the filtered water into ditches or streams.

F. Side Drains

The function of drains or ditches along the side of the road is to collect water from the road surface and the surrounding areas and lead it to an exit point where it can be safely discharged. The side drains need to have sufficient capacity to collect all rainwater from the road surface and dispose of it quickly and in a controlled manner to minimize damage.

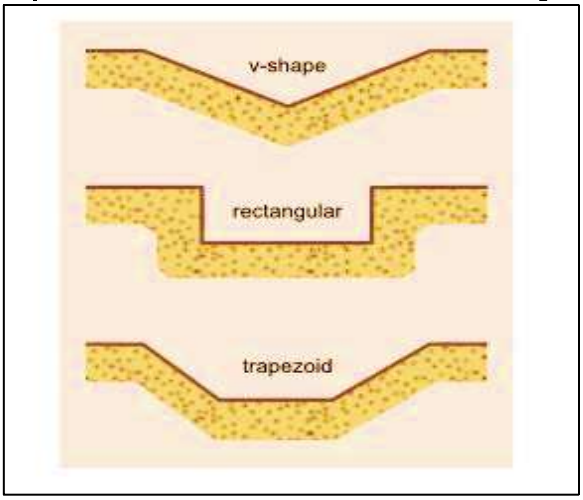

Fig. 2: The common shapes of side drains.

Side's drains can be constructed in three common forms Rectangular shape, V- shape, or a trapezoid as shown above (figure 2). The V-shape is the standard shape for drains or ditches constructed by the motor grader. However, it carries a lower capacity than other cross-section shapes the rectangular shape requires less space but needs to be lined with rock or concrete to maintain its shape. This shape is often used in urban areas where there is limited space. The trapezoid-shaped side drain carries a high flow capacity and by carefully selecting the right gradients for its side slopes, will resist erosion. In urban areas especially commercial and residential areas the drains should be covered with concrete slabs or small blocks for easy inspection and cleaning. The exact dimensions of the side drains are dependent on the expected amount of rainwater and the distance to the next existing point where the water can be diverted away from the road. The rational method and manning formula can be used in calculations. In flat or slightly undulating terrain, a longitudinal slope is to be used between 2% and 5% in drains. With gradients, less than 2% silting occurs easily while with gradients steeper than 5% the ditches will easily erode. Use rubble. Or fabric to slow water flow on the steep slope, or pave them to prevent serious erosion. Installing a short section of storm sewer may also be considered.

G. Culverts

Culverts are the most common cross drainage structures used on roads. They are built using a variety of materials, in different shapes and sizes, depending on the preferred design and construction practices. Culverts are required to allow natural streams to cross the road. And discharge surface water from drains and the areas adjacent to the road. Culverts form an essential part of the drainage system on most roads.

Fig. 3: Types of culvert outlets, end wall structures, and wing walls.

Culverts are constructed using different materials. The most common practice of culvers is based on the use of precast concrete pipes, in-situ concrete boxes, and corrugated steel pipe culverts. The box culvert is generally built with 1,2,3,4, cell of width 1m to 3m, and the pipe culvert is built with 1 to 3 rows of pipes with diameters commonly ranging from 0.6m to 1m. Wing walls and aprons of concrete or stone pitching are used to protect the culverts from water flow erosion and scouring on the upstream and downstream sides. Culverts should slope enough so water will flow. A minimum drop of 15cm across the road is desirable. This will keep sediment from accumulating in the culvert but will not cause extensive erosion at the discharge end.

H. Curb Gutter and Storm Sewer system

Curb and gutter are preferable in areas with limited right of way or where open drains are unacceptable. Short sections of the curb and gutter may be used at spot locations without requiring a storm sewer. Storm sewer systems collect water from the street and adjoining property and deliver it to open surface waterways (i.e. streams, rivers, lakes). Short sections of storm sewer may be useful in areas with steep slopes where runoff is eroding open drains, causing a problem storm sewer is also helpful at intersections and other locations. It is important to maintain curb, gutter, inlet, and storm sewer systems. They should be inspected every year.

I. Subsurface Drainage

This type of drainage is quite an important factor in pavement design. The basic design strategies promoted are to prevent water from entering in pavement and to remove quickly any water that infiltrates. The changes in moisture content of subgrade soil are caused by fluctuations in the ground water table, percolation of rainwater, and movement of capillary water. In subsurface drainage, it is required to keep the variation of moisture in subgrade soil to a minimum. To achieve this, a subsurface system was proposed by (Zumrawi, 2013) as given in figure 3. This system forms a filter layer of porous materials, well-graded or crashed stones (chipping) of a minimum thickness of 20cm are to be placed directly below the buffer course. This layer is provided with proper slopes in both longitudinal and transverse directions. It is mainly designed to intercept capillary water and consequently reduce the wetting effects of the subbase. A perforated pipe of 15cm diameter is to be placed at the far end of the drainage layer below the filter columns of porous materials, 20cm minimum width is to be located over the pipes to the level of the base.

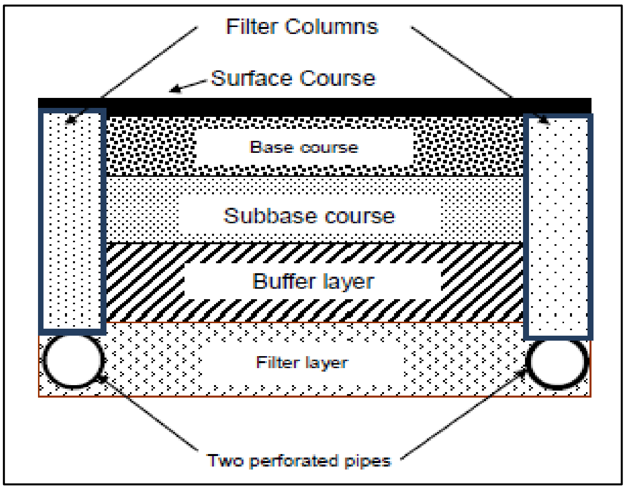

Fig. 3: Schematic sketch of recommended subsurface drainage system after (Zumrawi, 2013)

IV. CASE STUDY

The primary objective of this paper is to investigate the effects of inadequate drainage on road pavement conditions. To achieve this objective a field survey program was conducted on two major roads in Hargeisa city road number one in Hargeisa and 150 roads in the 26 June district. The field survey was carried out by visual inspection to evaluate the existing conditions of the drainage system and investigate its effects on-road performance. Photographs were taken directly from the road sites during the field survey to illustrate the existing condition and related obstacles in the drainage and the pavement.

A. Road number one

This is a major collector road in Hargeisa capital city of Somaliland running through the most crowded areas in Hargeisa. The road is a single carriageway of two lanes divided by a median of 1 m in width. The road length and width are 12km and 10m respectively. A service road of single 6m width and 2km or 3km length is located in different directions of the road. Rehabilitation and maintenance of this road by widening and strengthening parts of the pavement were carried out in 2012. A small portion of the road is constructed on expansive asphalt concrete base course. The road was maintained during the last decade and still suffered from severe distresses.

Fig. 4: The side drains and the culverts were blocked with sand accumulation garbage and roots.

Study. It was observed that the part of the carriageway of the road is connected with a side drain located far from the edge of the road at a distance of about 4m in general, most of the drain is open earth drain with a small cross-section of 1m width and not more than 1m depth. The condition of the drain and its structures is very poor and getting deteriorated with time. The drain suffered from low capacity, natural siltation, absence of inlets, indefinite drainage outlets, lack of proper maintenance, and over and above disposal of solid waste into the drain and the crossing culverts. The drain is blocked with sand accumulation, rubbish, and roots as shown in photo 2. It is clear that the drain and culverts are being converted into dumpy places and subsequently obstructing the water flow.

This bad condition of the side drain and its structures remains the same throughout the year causing the runoff water to flow on the surface of the road and unable to run off through the path far from the failed drain. The resultant effect of this critical situation causes serious distress and damage to the pavement. The road edges suffered from the detachment of the asphalt layer due to continuous contact of water leading to the stripping of asphalt from aggregates resulting in severe pavement distresses of cracking, potholes, and failure of edges as shown in Figure 5.

Fig. 5: Serve pavement distresses cracking, potholes, and failure edges.

B. 150 Road

150 road is one of the most important roads on 26 June District, Hargeisa that connects western and eastern with the central part of the town. The road of 8km in length consists of dual carriageways and eight lanes divided by a median 7m width. Unfortunately, the road does not get proper construction. Of low-quality construction materials adversely affects the performance of the road. This sometimes occurs in the form of improper grading of aggregates. This road has no gradation and missing mostly road cross-sectional elements. For this reason, the study concentrated on this critical part of the road. This road is selected as a case study due to the serious problems and failures caused by the lack of a proper subgrade layer and the accumulation of subsurface water in the pavement structure.

The road suffered from severe distresses of potholes, cracking, rutting, and heavy depressions. Rehabilitation of the road was carried out in 2019 by Hargeisa local municipality.

During excavation work, it was observed that the subgrade soil was fully saturated with surface water encountered at 1m depth. As seen in figure 4. Accumulation of sewage water disposed of neighbor houses into the subsoil.

Fig. 6: Accumulation of subsurface water on the road.

In the field survey, it was observed that the side drain was full of dirty water and refuse dumps. The inlets on the curb were blocked with soil accumulation as shown in

Fig. 7: The side drain is full of refuse dumps and dirty water.

Failure and serve distress were observed on the road surface. It was found that the surface runoff water penetration through the cracks and potholes causes a progressive inward penetration of the zone of soil movement leading to soil expansion and ultimately failure of the pavement. Therefore, the major cause of pavement deterioration is inadequate drainage. Significant cracking, potholes, heavy depression, and edge failure as shown in Figures 8 & 9.

Fig. 8: Serve failure of road edge due to water ponding on surfaces.

Fig. 9: Serve failure of edges and potholes.

V. Discussion

In the two case studies above, the factors which contribute to poor drainage and road pavement conditions in Hargeisa city are.

A. *Poor Design and construction*

Poor style and construction normally, most of the aspect drains provided to roads in Hargeisa town area unit earth drains or ditches. Some drains are designed from bricks, stones, or concrete materials area unit opens drains while not covers. Others designed drains area units lined with a concrete block. Failures of the designed drain just like the collapse of bed, side walls, and covers caused by improper style and construction, settlement, or heave could cause the event of cracks and later failure. The drain channels in Hargeisa town were designed throughout the British district. For the last 3 decades, most of the drain channels area units designed by the engineers of the native municipality or by a contractor World Health Organization has no expertise in evacuation works. This ends up in a condition wherever preliminary studies that may facilitate the planning and construction conclusions don't seem to be done. This ends up in a poor acceptance of the evacuation that later on ends up in poor style and construction of evacuation systems.

B. *No local Standards of Practice*

There is a great need for adequate monitoring and control in the local construction process. This can be done by provision of standards method of practice which will be strictly followed, monitored, and maintained. The professional bodies in the country will play a very important role at this stage. They should be able to provide a local standard of practice for the country, maintain it and monitor compliance with the use of the standard. This is because a local standard will take cognizance of the local peculiarities that will affect the environment where drainage works are located.

C. *Poor Maintenance Culture*

Even if the drains and their structures, and culverts are well built they need adequate maintenance for sustainability. One of the main problems of drainage development in Hargeisa is attempted it is done unsystematically. The financing of the maintenance, rehabilitation, and conservation of the drainage network system in Hargeisa had always been left to the government at the state and local levels who because of their lack of maintenance culture do not release funds for drainage maintenance at the appropriate time. The drainage network was therefore left to deteriorate. The drainage worldwide was considered critical infrastructure in ay nation's life and was paid premium attention.

D. *Negative Attitude of Residents*

The attitude of residents in communities under which these drainage channels are constructed and located is so negative. The investigation conducted and seen in the photographs taken from the drains sites during the field survey clearly show that the residents have converted the drains and the culverts into rubbish dump places. This results in blockage of those drains and their subsequent failures which in turn does negatively affect conditions of the road pavement. There is a very urgent need for government agencies and concerned bodies to organize sensitization programs towards enlightening residents on the need to keep drains located in their communities clean and not use them as rubbish dump places. In situations where these residents refuse to heed environmental sensitizations and warnings, the enactment of laws to punish offenders with very strong enforcement machinery should be put in place.

E. *Use of Low-Quality Materials*

The low-quality construction materials such as bricks, concrete, and corrugated steel adversely affect the quality of drains and culverts. This sometimes occurs in the form of improper concrete mixture in the construction of drain channels. The use of extreme cohesive and expansive soil as foundation soil results in prolonged consolidation, heave, or settlement of the bed of the drain and culvert. The use of soil of low bearing capacity as foundation soil leads to the failure of the drains and culverts.

VI. Conclusions

The effect of poor drainage conditions on road pavement is very adverse. It causes pavement distresses and deterioration which affects the safety and riding quality on the pavement. The study investigated the case of pavement failures and damages in Hargeisa due to the poor drainage system and lack of experience during the last decade on several roads in Hargeisa city.

On basis of my previous experiences in the design and construction of drainage. The study provides design guidelines for a proper and efficient drainage system that leads to enhanced road performance and increases the service life of the pavement.

Regular annual evaluation of the drainage system is an important part of maintaining and managing roads. Before making any pavement surface improvements, make drainage improvements, it is most economical and effective to plan and upgrade drainage as part of road surface improvements.

Reference

[1] CEDERGREN, H. R., O'BRIEN, K. H., & ARMAN, J. A. (1972). Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections. (JUNE, 1972).
[2] Forsyth, R. A., Wells, G. K., & Woodstorm, J. H. (1988). Economic Impact of Pavement Subsurface Drainage. Public Works, 119(1), 61–64, 88.
[3] MARKOW, M. J. (1982). Simulating Pavement Performance Under Various Moisture Conditions. Transp Res Rec, 24–29.
[4] New, W. H. Y. A., & Design, P. (2002). 2002 Pavement Why a New Pavement Design Guide ?
[5] Rokade, S., Agarwal, P. K., & Shrivastava, R. (2012). Study on Drainage Related Performance of Flexible Highway Pavements. International Journal of Advanced Engineering Technology, 3(1), 334–337.
[6] Zumrawi. (2013). Pavement Design for Roads on Expansive Clay Subgrades. Available Online at Www.Ejournals.Uofk.Edu UofKEJ, November, 52–58. www.ejournals.uofk.edu