Appraising Pavement Surface Distresses And Expected Mitigation Measure On Selected Road Segment

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Abstract: The work visually inspects and evaluate the pavement failures and their causes as well as resolution methods. It is quite important to examine and identify the causes of the failed pavement to select a proper treatment option. The study consisted of two tasks: the first covers the detail visual inspection of the existing pavement failures, whereas the second investigates the actual causes of these failures. From Areka to Wolaita Sodo was selected for investigation. An intensive field work was carried out on the existing pavement condition of this road. It was found that most of the damaged pavement sections suffered from severe cracking, potholes and raveling failures. These failures might have been caused by fatigue failures on pavement structure due to the movement of heavily loaded truck - trailers. The damage could also be attributed to poor drainage, inadequate design and improper pavement materials.

Keywords: Fatigue failures, Pavement condition, Pavement failures, Surface distress

1. INTRODUCTION

Deterioration of highway pavement is a very serious problem that causes unnecessary delay in traffic flow, distorts pavement aesthetics, damages of vehicle and most significantly, causes road traffic accident that had resulted into loss of lives and properties (Van der Merwe & Ahronovitz, 2005). Pavement surface deformation affects the safety and riding quality on the pavement as it may lead to premature failures.

It is noted in (AASHTO, 2002; Van der Merwe & Ahronovitz, 2005) that, it is impossible to design a road pavement which does not deteriorate in some way with time and traffic, hence concluded that the aim of pavement structural design is to limit the level of pavement distress, measured primarily in terms of riding quality, rut depth and cracking, to a predetermined value (Omer et al., 2014). Generally, these values are set so that a suitable remedial treatment at the end of design period is strengthening overlay of some kind but this is not necessarily so and road can, in principle, be designed to reach a terminal condition at which major rehabilitation or even complete reconstructions are necessary. However, appropriate remedial treatments for roads which have deteriorated beyond a certain level are difficult task (Patrick, 2003).

Acceptable levels of surface condition (Patil et al., 2013) The expectations have been found to depend upon the class of the road and volume of traffic such that the higher the Geometric standard, and therefore the higher the vehicle speeds, the lower the pavement distress which is acceptable (Gidigasu, 1980). In defining these levels, economic evaluation also considered. Most specification sets a maximum rut depth of 20mm as failure criteria and also the riding quality, which is measured International Roughness index, as performance criteria. (Oguara, 2010).

Pavements do deteriorate due to time, climate and traffic. Hence, limiting pavement deteriorations which affect the riding quality from cracking, rutting, potholes and other such surface distresses to acceptable levels is important (Sharad & Gupta, 2009).

According to (Yang, 2004), Pavement failure may be considered as structural, functional, or materials failure, or combination of these factors.
Structural failure: is the loss of load carrying capability, where the pavement is no longer able to absorb and transmit the wheel loading through the structure of the road without causing further deterioration.

Functional failure: is a broader term, which may indicate the loss of any function of the pavement such as skid resistance, structural capacity, and serviceability or passenger comfort.

Material failure: occurs due to the disintegration or loss of material characteristics of any of the component materials. Also, pavement failures are classified as either deformation failures or surface texture failures (Charlie et al., 1984).

Surface texture failures: include bleeding, cracking, polishing, stripping and raveling. These failures indicate that while the road pavement may still be structurally sound, the surface no longer performs the function it is designed to do, which is normally to provide skid resistance, a smooth-running surface and water tightness. Other miscellaneous types of pavement failures include edge defects, patching and roughness (Okigbo, 2012).

Deformation failures: include corrugations, depressions, and potholes, rutting and shoving. These failures may be due to either traffic (load associated) or environmental (no-load associated) influences. It may also reflect serious underlying structural or material problems that may lead to cracking (Osuolale et al., 2012).

2. METHOD AND MATERIAL

2.1 Study area

The work will be conducted from Areka to Wolaita Sodo road segments which are 29 km long, located in Wolaita zone. The road segment is a link road that designated as B51-4 per (ERA,2013) which directly runs from Addis Ababa to Arba Minch.

![Figure 1. Areka to Wolaita Sodo road segment](image.png)

2.2 Method of data collection

In order to meet the objectives of the study, a concise method of data collection has to be devised and implemented to get a reasonable quality output.
2.3. Field Work

During field observation, it was necessary to begin by conducting visual inspection and site inventory of the whole stretch of the road segment. The initial site visit was undertaken on the whole portion of the road. After finishing the initial visual inspection, the conditions of the road failures along the road section were categorized. Nine major types of failures were observed based on their severity and extent level of damage along the study road. The measurement of defects and cracks are done sectioning the road segments in to ten block and focusing only on major type of defects that are pronounced in that location by measuring their width(mm) and length(m) of exposure level.

1. **Alligator cracking** - Series of interconnected cracks caused by fatigue failure under repeated traffic loading.
2. **Block cracking** - Interconnected cracks that divide the pavement up into rectangular blocks.

### Table 1. Measurement of Alligator cracking and Block cracking

| Block | Type of Distresses | Length (m) | Width (mm) | Block | Type of Distresses | Length (m) | Width (mm) |
|-------|--------------------|------------|------------|-------|--------------------|------------|------------|
| 1     | Alligator-Cracking | 2440       | 620        | 1     | Block-Cracking     | 1160       | 1790       |
| 2     |                    | 2520       | 880        | 2     |                    | 1450       | 1950       |
| 3     |                    | 2730       | 1420       | 3     |                    | 1860       | 2260       |
| 4     |                    | 2420       | 950        | 4     |                    | 1340       | 1420       |
| 5     |                    | 2610       | 1140       | 5     |                    | 1230       | 1640       |
| 6     |                    | 2650       | 1360       | 6     |                    | 1440       | 2160       |
| 7     |                    | 2840       | 1040       | 7     |                    | 1720       | 2340       |
| 8     |                    | 2750       | 1350       | 8     |                    | 1360       | 1450       |
| 9     |                    | 2680       | 1230       | 9     |                    | 1640       | 1230       |
| 10    |                    | 1570       | 860        | 10    |                    | 1240       | 3240       |

3. **Edge cracking** - Cracks which occur parallel to and within 300 mm of the inside and/or outside of the pavement edge line marking.
4. **Rutting** - Longitudinal depressions left in the wheel paths after repeated loadings, combined with sideways shoving of the pavement material.
### Table 2. Measurement of Edge cracking and Rutting

| Block | Type of Distresses | Length (m) | Width (mm) | Block | Type of Distresses | Length (m) | Width (mm) |
|-------|--------------------|------------|------------|-------|--------------------|------------|------------|
| 1     | Edge Cracking      | 1240       | 540        | 1     | Rutting            | 520        | 430        |
| 2     | Edge Cracking      | 2210       | 1230       | 2     |                     | 330        | 280        |
| 3     | Edge Cracking      | 2830       | 3450       | 3     |                     | 450        | 650        |
| 4     | Edge Cracking      | 2650       | 2840       | 4     |                     | 270        | 220        |
| 5     | Edge Cracking      | 2740       | 1670       | 5     |                     | 210        | 350        |
| 6     | Edge Cracking      | 2520       | 2380       | 6     |                     | 340        | 420        |
| 7     | Edge Cracking      | 2840       | 2650       | 7     |                     | 530        | 460        |
| 8     | Edge Cracking      | 2560       | 1460       | 8     |                     | 440        | 370        |
| 9     | Edge Cracking      | 2650       | 840        | 9     |                     | 320        | 340        |
| 10    | Edge Cracking      | 1320       | 620        | 10    |                     | 820        | 4460       |

5. **Raveling** - the progressive disintegration of a hot mix asphalt layer from the surface downward as a result of the dislodgement of aggregate particles.

6. **Depressions** - Localized pavement surface areas with slightly lower elevations than the surrounding pavement.

### Table 3. Measurement of Raveling and Depressions

| Block | Type of Distresses | Length (m) | Width (mm) | Block | Type of Distresses | Length (m) | Width (mm) |
|-------|--------------------|------------|------------|-------|--------------------|------------|------------|
| 1     | Raveling           | 860        | 1640       | 1     |                    | 780        | 160        |
| 2     | Raveling           | 1130       | 1890       | 2     |                    | 980        | 220        |
| 3     | Raveling           | 2240       | 4250       | 3     |                    | 1730       | 430        |
| 4     | Raveling           | 1680       | 2650       | 4     |                    | 1210       | 380        |
| 5     | Raveling           | 1450       | 2480       | 5     | Depressions        | 1540       | 250        |
| 6     | Raveling           | 1840       | 3240       | 6     |                    | 1350       | 330        |
| 7     | Raveling           | 2060       | 3870       | 7     |                    | 1670       | 410        |
| 8     | Raveling           | 1730       | 2560       | 8     |                    | 1230       | 310        |
| 9     | Raveling           | 1640       | 2930       | 9     |                    | 1140       | 240        |
| 10    | Raveling           | 940        | 2210       | 10    |                    | 1010       | 440        |

7. **Bleeding** - Excess bituminous binder on the pavement surface can create a shiny, glass-like, reflective surface that may be tacky to the touch.

8. **Potholes** - A hole in a road surfaces that result from gradual damage caused by traffic or weather.
### Table 4. Measurement of Bleeding and Potholes

| Block | Type of Distresses | Length (m) | Width (mm) | Depth (mm) |
|-------|--------------------|------------|------------|------------|
| 1     | Bleeding           | 970        | 380        | 1          |
| 2     |                    | 1120       | 460        | 2          |
| 3     |                    | 860        | 350        | 3          |
| 4     |                    | 1230       | 570        | 4          |
| 5     |                    | 1040       | 610        | 5          |
| 6     |                    | 1180       | 650        | 6          |
| 7     |                    | 950        | 440        | 7          |
| 8     |                    | 890        | 410        | 8          |
| 9     |                    | 1270       | 640        | 9          |
| 10    |                    | 760        | 330        | 10         |

| Block | Type of Distresses | Length (m) | Width (mm) |
|-------|--------------------|------------|------------|
| 1     |                    | 34         | 320        |
| 2     |                    | 70         | 540        |
| 3     |                    | 180        | 1230       |
| 4     |                    | 130        | 850        |
| 5     |                    | 90         | 620        |
| 6     |                    | 120        | 760        |
| 7     |                    | 150        | 1080       |
| 8     |                    | 110        | 770        |
| 9     |                    | 80         | 650        |
| 10    |                    | 22         | 200        |

### Table 5. Measurement of Patching

| Block | Type of Distresses | Length (m) | Width (mm) |
|-------|--------------------|------------|------------|
| 1     | Patching           | 180        | 540        |
| 2     |                    | 220        | 480        |
| 3     |                    | 310        | 760        |
| 4     |                    | 230        | 650        |
| 5     |                    | 150        | 440        |
| 6     |                    | 270        | 710        |
| 7     |                    | 340        | 830        |
| 8     |                    | 170        | 520        |
| 9     |                    | 250        | 660        |
| 10    |                    | 300        | 640        |
3 RESULTS AND DISCUSSION

3.1 Performance Evaluation of the distresses

The condition survey was conducted at every 3km interval for failure types of Alligator cracking, Block cracking, Edge cracking, Rutting, Raveling, Depressions, Bleeding, Potholes, and Patching. The extent and severity of failure were summarized as shown below. The variations of extent of different failure types in respect with the stations of the project road are plotted using graphs.

3.1.1 Alligator cracking

The extent of Alligator cracking varies along the stations of the project road as shown in Figure 2 below. In most of the stations from 0km to the end of the project road, the percentage extent of Alligator cracking is more than 78%. The stations from 0-29km experience mostly percentage extent of between 78%-92%. In our study most of the road suffers from Alligator cracking because of the road insufficient pavement thickness and lack of major maintenance for the last several years.

![Figure 2. Variations of Percentage Extents of Alligator Cracking](image)

3.1.2 Block cracking

The extent of Block cracking varies along the stations of the project road as shown in Figure 3 below. In most of the stations from 0km to the end of the project road, the percentage extent of Block cracking is more than 38%. The percentage extent of the Block cracking at 6-9km and 27-29km is observed about 62%. The stations from 0-29km experience mostly a Block cracking percentage extent of between 38%-62%.
3.1.3 Edge cracking
The extent of Edge cracking varies along the stations of the project road as shown in Figure 4 below. In most of the stations from 0km to the end of the project road, the percentage extent of Edge cracking is more than 41%. The stations from 0-29km experience mostly Edge cracking percentage extent of between 41%-95%.

3.1.4 Rutting
The extent of Rutting varies along the stations of the project road as shown in Figure 5 below. In most of the stations from 0km to the end of the project road, the percentage extent of Rutting is more than 7%. The percentage extent of the Rutting at 27-29km is observed about 41%. The stations from 0-29km experience mostly a Rutting percentage extent of between 7%-41%.
3.1.5 Raveling
The extent of Raveling varies along the stations of the project road as shown in Figure 6 below. In most of the stations from 0km to the end of the project road, the percentage extent of Raveling is more than 29%. The percentage extent of the Raveling at 6-9km is observed about 75%. The stations from 0-29km experience mostly a Raveling percentage extent of between 29%-75%.

3.1.6 Depressions
The extent of Depressions varies along the stations of the project road as shown in Figure 7 below. In most of the stations from 0-km to the end of the project road, the percentage extent of Depressions is more than 26%. The percentage extent of the Depressions at 6-9km and 18-21km is observed about 55%. The stations from 0-29km experience mostly a Depressions percentage extent of between 26%-58%.
3.1.7 **Bleeding**

The extent of Bleeding varies along the stations of the project road as shown in Figure 8 below. In most of the stations from 0km to the end of the project road, the percentage extent of Bleeding is more than 25%. The percentage extent of the Bleeding at 9-12km is observed about 41%. The stations from 0-29km experience mostly a Bleeding percentage extent of between 25%-41%.

3.1.8 **Potholes**

The severity of Potholes varies along the stations of the project road as shown in Figure 9 below. In most of the stations from 0km to the end of the project road, the depth of Potholes is more than 15mm. The depth of the Potholes at 6-9km is observed about 70mm. The stations from 0-29km experience mostly a Potholes depth of between 15mm-70mm.
3.2 Identifying Dominant Distresses

It is also strained to estimate the distribution of particular distresses in each block and the whole roads as well using the visual survey data. Distribution of major distresses in all roads is shown in Table 6 and Figure 10 respectively. From Graphical representations the majority of the road is affected by Edge cracking. Next to Edge cracking, Raveling is dominating than others.

Table 6. Distribution of Pavement Distresses

| S. N | Distress type    | Total Distress Density | % Age Distress Indicator |
|------|------------------|------------------------|--------------------------|
| 1    | Alligator Cracking | 853.42                 | 4.28                     |
| 2    | Block Cracking   | 1272.80                | 6.39                     |
| 3    | Edge Cracking    | 7783.33                | 39.05                    |
| 4    | Rutting          | 636.83                 | 3.19                     |
| 5    | Raveling         | 5126.67                | 25.72                    |
| 6    | Depressions      | 2100.83                | 10.54                    |
| 7    | Bleeding         | 1688.33                | 8.47                     |
| 8    | Potholes         | 76.00                  | 0.38                     |
| 9    | Patching         | 395.33                 | 1.98                     |
|      | Total            | 19933.55               | 100.00                   |
Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. Some Causes of Road Cracks and Deterioration are Defects caused during construction due to poor construction quality, Structural failure of base, poor highway facilities, Poor maintenance policy, Poor supervision and others. Pavement deterioration process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates, they must be implementation of the proper maintenance and repair work in suitable time; which will maintain the pavement in a safe and acceptable operational condition and helps to save cost of maintenance. Road maintenance is one of the important components of the entire road system. Even if the roads are well designed and constructed, they may require maintenance. Repair and maintenance procedures cannot overcome bad design problems but can help prevent these problems resulting from degradation. The possible causes of deterioration on Areka to Wolaita Sodo road are firstly, during implementation of road; Failure in the layers of the road (failure in Sub grade or other layers), the asphalt mixture arrival in the site is cold, the wrong way in the casting and compaction of asphalt and others. Secondly after implementation; Heat shrinkage of asphalt materials (change in temperatures and climate), High stress (Heavy traffic volume or increase vehicle weight), Lack of water drainage system and many more. Early detection and repair of road defects are important to maintain the permanence of road. The Suggested maintenance for the cracks and defects in Areka to Wolaita Sodo road are Crack seal (sealing of the crack) to prevent moisture entering(pumping) into sub grade through the cracks, improve (construct) drainage system, Reconstruction of the edge and support the edge with paving stones and patching.

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