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ANALYSIS AND EVALUATION OF FLEXIBLE PAVEMENT DEFECTS

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ABSTRACT

According to the research, the flexible pavement defects and its causes has been defined in terms of decrease in serviceability which was due to the development of different types of deteriorations like cracks, surface defects, disintegration etc. on the flexible pavement. Before going into the maintenance part, we will try to focus on the various defects and its causes. There are so many reasons for bituminous pavement failures. The level of correction in the existing surface will extend the life of maintenance works and strengthening the layer as well. According to my study, there are mainly 2 parameters I have figured out which are: - *pavement cracking* and surface defects on the pavement. While other distresses have been excluded including these parameters while stepping for maintenance part. With the study of maintenance techniques, there are various methods we are going to adopting for pavement protection which will help to increasing the life of the pavement and failure delay. The motive of this study was to analyse and evaluate the various causes of pavement defects, and provision of remedies to improve the various failures of the surface. Based on the past researches of researchers, various techniques have been studied with their measures which are helpful for increasing the life of serviceability. This case study attempts to identify the various parameters that affect the performance of the flexible pavement and by rid of this problem by applying the remedial measures over the particular stretch. LPU main gate to Rama-Mandi was chosen as a case study. It is a pursuit towards a study of the road condition of Punjab with respect to varying soil, traffic and climatic conditions, periodic performance evaluation of selected roads of representative types and development of distress prediction models for roads of Punjab. To achieve this aim, we divide the entire area into no. of sample units. By taking the measurement of each part, we measured the various type of defects, corresponding to that we found out pavement condition Index (PCI). A PCI is a numerical index which tells us about the condition of the road as per its range that is 0 to 100 which was coming out to be very poor. Testing was done to know the reason of the pavement failures and we found out that the most of the pavement was damaged by alligator cracks by repetitive heavily loading of the vehicles and surface defects. Pavement also damaged due to poor drainage and inadequate designing and poor quality of material.

KEYWORDS: Flexible Pavement, Distresses, Analysis, Evaluation

Pavement is anything which is being covered or paved, that is the covering of solid material like floor laid so that is to make a comfortable and hard surface for travel. Road pavement is a durable material for surface which is resting on an area design to sustain vehicular traffic or walk traffic, such as a road or pedestrian. Pavement is generally classified as

a) Flexible pavement

b) Rigid Pavement

c) Semi-Rigid pavement

d) Composite pavement

FLEXIBLE PAVEMENT

The pavement which constructed with different number of layers of granular materials and covering of one or more of the waterproofing asphalt layer is considered as flexible. The flexible pavement will deflect under the load of the wheels. The purpose of this design of a flexible pavement is to prevent the excessive bending of any layer of the pavement structure, An over stressing may done if it fails in the design of the layer, which will cause the pavement directly to fail. In these flexible pavements, due to the strength of each layer is different; the load distribution pattern changes from one layer to another. The strongest material is to be provided on the top layer and the weakest layer is to be provided to the bottom layer.

RIGID PAVEMENT

Rigid pavements are those pavements which are constructing from reinforced concrete slabs (RCC) or cement concrete. The grouted concrete roads are the categories of semi-rigid pavements. The design criteria of this type of pavement are based on providing a cement concrete slab of sufficient strength to sustain the loads from vehicular movement. The rigid pavement has high modulus of elasticity and rigidity to distribute the load over a large area of the soil.

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SEMI-RIGID PAVEMENT

The type of pavements in which a semi rigid base layer, which is usually made up of cement-stabilized base or cement treated base, is laid with a top flexible layer of bituminous mixture. Typical examples of semi rigid pavements are the lean-concrete base, soil-cementand lime-pozzolana concrete construction.

COMPOSITE PAVEMENT

The pavements are called "composite" since they consist of layers of the different materials bonded together. They are provided for their strength purpose wherever it requires. A composite type of pavement is the one which consists of multiple structurally significant layers of heterogeneous composition. The type of composite pavements generally provides are:

1. Asphalt concrete over plain concrete cement (AC/PCC)
2. Plain concrete cement over plain concrete cement (PCC/PCC)

PROBLEM DEFINING

A highway which is either flexible or rigid can get deteriorated in its level of serviceability due to various causes. These factors are

1. Traffic loading
2. Environmental Factors
3. Quality of the material
4. Drainage

According to IRC, a pavement is designed for its design period of 10 years. After its design period pavement is likely to fail and needs maintenance operations to extend its life further. But sometimes it may fail earlier to its design period because of low quality of material or may by other factors. So the possible causes which arise has been mentioned below.

Various types of failures are:

1) Alligator Cracking or Fatigue Cracking

2) Block Cracking

3) Hungry Surface

4) Formation of Corrugations

5) Depressions

6) Fatty surface or Bleeding

7) Formation of Potholes

8) Loss of Aggregates

9) Stripping

10) Reflection Crack

MATERIALS AND METHODS

General

This chapter deals with the presentation of data obtained from the site which are conducted on flexible pavement. In order to achieve the present study, we studied the different type of defects on the pavement and their causes as well.

The survey of data collection was done by two ways: first was walking along the road and observe the various defects and second was by means of measurement. That is the whole area is to be selected by no. of chainage corresponding to that sample units will be calculated.

RESULTS AND DISCUSSION

The data is done by means of sample units. The area under different types of defects was observed, measured and then a survey sheet was prepared of these sample units on the stretch. The type of defects is taken as their severity level as small, medium or large according to their respective conditions.

For that, we have prepared a sample sheet of different types of distresses. The whole area was selected in chainage into the equal parts. By taking each and every part in account, we started the survey. According to ASTM, there should be minimum 30 sample units under the given stretch. So we found 45 sample units in the whole area.

Therefore the chainage is coming around

The length of the stretch= 9.7 kms~10 kms

The no. of calculated sample units= 45

Therefore, chainage is coming out to be 10,000/45= 222.222 metres.

The sample units are collected on both side of the road starting from LPU main gate to Left to right and coming from Rama Mandi to right to left respectively.

At every part, we calculate the atleast one sample unit. The survey sheet of the various defects corresponding to their severity level as shown below:

Table 1: Data sheet of various type of defects

Asphalt Road Surface Distress Data Sheet											
Branch—Transportation Engineering Station – LPU Main gate to Rama MandiSampleUnit-45 Surveyed by— Satya Pal Singh Sample Area(in metres)—700 sq.m (approx i.)							 7 m SKETCH 100 m				
S. No.	**Distress Type**	**Level of Distress Severity**			**Chain age in metres**	**Right**	**Left**	**Dimension (in metres) H/B/L**			**Remarks**
		L	**M**	**H**				**H**	**B**	**L**	
1	Longitudinal cracks	√			0+000		√	-	-	3.4	At the end of flyover, chaheru
2	Alligator cracks		√		0+222		√	-	0.15	0.17	Near petrol pump, chaheru
3	Patches			√	0+444		√	-	0.32	0.51	Near petrol pump, chaheru
4	Potholes		√		0+666		√	0.0 06	0.23	0.23	Near police booth, haveli
5	Slippage crack	√			0+888		√	-	1.3	1.7	Near to haveli
6	Longitudinal cracks		√		1+1111		√	-	-	4.2	Near to haveli
7	Pothole		√		1+1333		√	-	0.19	0.1	At Haveli
8	Swelling	√			1+1555		√		0.5	3.2	Near showroom At haveli
9	Alligator cracks	√			1+1777	√		-	2.4	8.1	Uphill, haveli
10	Transverse Cracking			√	2+2000	√		-	-	3.2	Near police booth, haveli
11	Alligator cracks with longitudinal cracks			√	2+2222	√		-	0.8, -	3.0, 0.6	Along some steps
12	Alligator cracks with potholes	√			2+2444	√		0.15	2.2, 0.12	8.8,0.25	Near side lane to LPU
13	Transverse cracks		√		2+2666	√		-	-	3.6	Along some steps
14	Longitudinal cracks			√	2+2888	√		-	-	2.4	At uphill on Flyover
15	Alligator cracks			√	3+3111	√		-	0.7	2.2	Near LPU
16	Alligator cracks	√			3+3333	√		-	2.7	4.9	In front of LPU main gate
17	Patches	√			3+3555	√			0.5	1.4	Near McDonalds, Haveli-Viva collage
18	Block cracking with patching		√		3+3777		√	-	2.2, 0.7	2.5, 3.3	Near hotel grand resort, Haveli
19	Alligator crack	√			4+4000	√			3.0	13.7	Near hotel grand resort, Haveli
20	Longitudinal crack with alligator cracks	√			4+4222		√		2.5,-	5.8,12.8	Near modi resort viva-Rama Mandi
21	Longitudinal cracks with small potholes			√	4+4444		√		-,0.016	10.4, 0.011	Along some steps toward Jalandhar Cantt.

22	Patches	√			4+4667		√		3.1	7.9	Underpass, Rama Mandi
23	Potholes	√			4+4889		√	0.005	0.12	0.20	Near underpass, Rama Mandi
24	Edge cracks	√			5+5111	√		-	-	1.1	In front of resident colony, Rama Mandi
25	Alligator cracks	√			5+5333	√		-	0.5	4.3	Along some steps, Rama Mandi
26	Block cracks			√	5+5555	√		-	4.2	11.7	Near police booth, Rama Mandi
27	Longitudinal with alligator cracks			√	5+5777	√		-	-,0.9	29.7,3.7	Near police congestion-diversion Signboard
28	Edge cracks		√		6+6000	√		-	-	1.9	Along some steps
29	Alligator cracks, potholes				6+6222	√		0.011	1.2,0.08	7.6,0.11	Close to Indian oil Petrol pump
30	Alligator cracks		√		6+6444		√	-	1.7	3.9	In front of petrol pump, Rama Mandi
31	potholes	√			6+6666	√		0.005	0.12	0.13	On the curve
32	Patching		√		6+6889	√		-	0.6	0.6	Along some steps
33	Alligator cracks	√			7+7111		√	-	1.0	1.9	Along some steps
34	Longitudinal cracks with alligator cracks			√	7+7333	√		-	18.5,3.3	8.7	Near octroipost
35	Longitudinal cracks	√			7+7555	√		-	-	3.4	Near railway station, Jalandhar cantt.
36	Both Alligator cracks and weathering and raveling	√			7+7777	√		-	1.9, 0.8	7.2, 6.5	Near railway station, Jalandhar cantt.
37	potholes	√			8+8000	√		0.009	0.13	0.13	In front of diversion board, toward Phagwara
38	Alligator cracks		√		8+8222	√		-	1.0	4.4	Along some distance
39	Patching			√	8+8444	√		0.006	1.1	3.0	Along some distance
40	Edge cracks	√			8+8666	√		-	-	1.5	Near to intersection, Jalandhar-Phagwara road
41	Block cracks with longitudinal cracks			√	8+8888	√		-	2.3, -	9.6,13.3	Along some distance
42	Slippage cracking	√			9+9111	√		-	0.6	1.4	In front of railway crossing, Jalandhar cantt.
43	Transverse cracks		√		9+9333	√		-	-	4.0	In front of railway crossing, Jalandhar Cantt.
44	Weathering and Ravelling		√		9+9555	√		-	1.7	7.1	Nearvivacollage
45	Block cracks		√		9+9778	√		-	3.0	2.8	Chaheru near underpass

Table 2: Calculation of PCI

Distress Severity	Quantity		Total	Density %	Deduct Value	CDV	PCI
1L	3.4		3.4	0.48	4	4	96
2M	0.15	0.17	0.32	0.045	12	12	88
3H	0.32	0.51	0.83	0.118	8.8	8.8	91.2
4M	0.23	0.23	0.46	0.066	16.7	16.7	83.3
5L	1.3	1.7	3.0	0.42	1.6	1.6	98.4
6M	4.2		4.2	0.6	8	8	92
7M	0.19	0.10	0.29	0.04	18.6	18.6	81.4
8L	0.5	3.2	3.7	0.53	1	1	99
9L	2.4	8.1	10.5	1.5	15.8	15.8	84.2
10H	3.2		3.2	0.45	11	11	89
13M	3.6		3.6	0.51	6	6	94
14H	2.4		2.4	0.34	11	11	89
15H	0.7	2.2	2.9	0.41	21	21	79
16L	2.7	4.9	7.6	1.08	11	11	89
17L	0.5	1.4	1.9	0.27	0.2	0.2	99.8
19L	3.0	13.7	16.7	2.38	18.7	18.7	81.3
22L	3.1	7.9	11	1.57	3.4	3.4	96.6
23L	0.12	0.20	0.32	0.045	12	12	88
24L	1.1		1.1	0.49	1	1	99
25L	0.5	4.3	4.8	0.68	8.6	8.6	91.4
26H	4.2	11.7	15.9	2.27	14.7	14.7	85.3
28M	1.9		1.9	0.27	5.03	5.03	94.97
30M	1.7	3.9	5.6	0.8	20.3	20.3	79.7
31L	0.12	0.13	0.25	0.035	9.8	9.8	90.2
32M	0.6	0.6	1.2	0.171	3.5	3.5	96.5
33L	1.0	1.9	2.9	0.41	21	21	79
35L	3.4		3.4	0.48	4	4	96
37L	0.13	0.13	0.26	0.037	10.1	10.1	89.9
38M	1	4.4	5.4	0.77	8.8	8.8	91.2
39H	1.1	3.0	4.1	0.58	16	16	84
40L	1.5		1.5	0.21	10	10	90
42L	0.6	1.4	2.0	0.28	2.3	2.3	97.7
43M	4.0		4.0	0.16	7.2	7.2	92.8
44M	1.7	7.1	8.8	1.25	9.3	9.3	90.7
45M	2.8	3.0	5.8	0.83	2.2	2.2	97.8

Table 3: Pavement condition index for 1 sample unit having no. of distresses

Distress	Quantity		Total	density	DV
11M	0.8	3.0	3.8	0.54	17.1
11H	0.6		0.6	0.085	7.1
12L	2.2	8.8	11	1.57	15
12L	0.12	0.25	0.37	0.053	14.8
18M	0.7	3.3	4.0	0.57	7.6
18M	2.2	2.5	4.7	0.67	1.7
20L	2.5	5.8	8.3	1.18	11.7
20L	12.8		12.8	1.8	5.6
21L	10.4		10.4	1.48	6
21L	0.011	0.016	0.027	0.003	2.5

Determination of allow able no. of deducts:

m=1+(9/98)*(100-max DV)

m=1+(9/98)*(100-17.1)m=8.61<=10

Now, arranging the deduct value in a descending order

Table 4: Deducted Values

S. No.	Deduct Values									Total	q	CDV
1	17.1	15	14.8	11.7	7.6	7.1	6	5.6	1.52	86.42	8	-
2	17.1	15	14.8	11.7	7.6	7.1	6	2	1.52	82.82	7	41.8
3	17.1	15	14.8	11.7	7.6	7.1	2	2	1.52	78.82	6	39.7
4	17.1	15	14.8	11.7	7.6	2	2	2	1.52	73.72	5	39
5	17.1	15	14.8	11.7	2	2	2	2	1.52	68.12	4	38
6	17.1	15	14.8	2	2	2	2	2	1.52	58.42	3	37.6
7	17.1	15	2	2	2	2	2	2	1.52	45.62	2	34
8	17.1	2	2	2	2	2	2	2	1.52	32.62	1	32.9

Therefore, PCI=100-maxCDV=100-41.8 =58.2

Rating= Fair

Table 5: Pavement condition index for 1 sample unit having no. of distresses

Distress	Quantity		Total	Density	DV
27H	0.9	3.7	4.6	0.65	26
27L	29.7		29.7	4.24	9.7
29L	1.2	7.6	8.8	1.25	13
29M	0.08	0.11	0.19	0.027	13
34L	3.3	8.7	12.0	1.71	16.9
34L	18.5		18.5	2.67	9
36L	1.9	7.2	9.1	1.3	12.5
36M	0.8	6.5	7.3	1.04	8.9
41H	2.3	9.6	11.9	1.7	10.4
41L	13.3		13.3	1.9	6.5

Determination of allowable no. of deducts:-

m=1+(9/98)(100-HDV)

m=1+(9/98)(100-26)=7.79

Table 6: Deducted Values

S. No.	Deduct Values								Total	Q	CDV
1	26	16.9	13	13	12.5	10.4	9.7	7.11	108.61	8	-
2	26	16.9	13	13	12.5	10.4	9.7	5.61	107.11	7	54
3	26	16.9	13	13	12.5	10.4	4.43	4.43	100.66	6	49.2
4	26	16.9	13	13	12.5	3.5	3.5	3.5	91.9	5	47.2
5	26	16.9	13	13	2.76	2.76	2.76	2.76	79.94	4	45.8
6	26	16.9	13	2.18	2.18	2.18	2.18	2.18	66.8	3	42.9
7	26	16.9	2	2	2	2	2	2	54.9	2	41.0
8	26	2	2	2	2	2	2	2	40	1	40.0

Therefore, PCI=100-MaxCDV=100-54 =46

Therefore, Rating = Poor Calculation Procedure:-

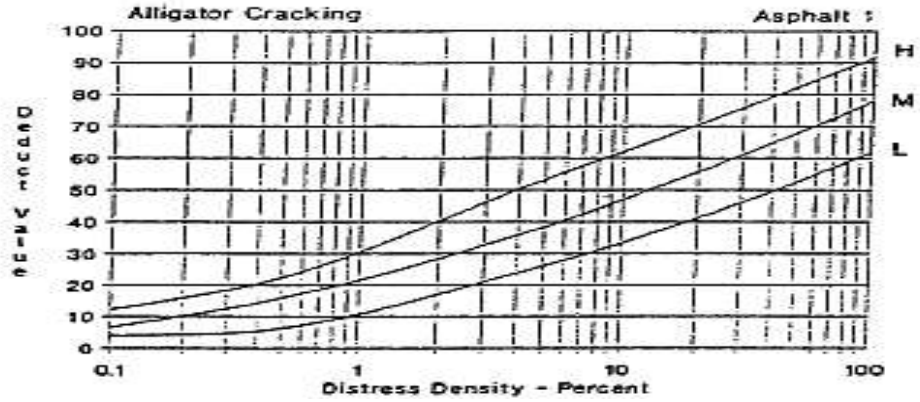
Here, we've arranged all the values of each distress in terms of its severity level. Then, calculate the density by dividing the total quantity of each distress of each severity level by the total area of the sample and multiplied it with 100.

For example, In the first distress 1L, the total quantity was calculated as 3.4. Therefore, density was (3.4/2500)*100 =0.136%

Then, calculated the deduct values (D.V) of each distress of each severity level from the distress deduct value graph as per ASTM-D6433

Here, I have mention the deduct value graph of alligator cracking.

Table 7: Alligator cracking distress table



The next step will be to find out the maximum corrected deduct value (CDV). Hereistheprocedureof maximum CDV:-

If no value or only one value is greater than 2 then the total value will be used in the place of maximum CDV for calculation of the CDV otherwise the maximum CDV will be calculated as Arrange all the values of C.V in their descending order. Calculate the no. of deducts from the given formula

m=1+(9/98)(100-HDV)< =10

where, m= no. of deducts including fractions and should be less than or equal to10 HDV=Highest individual deduct value

For example,

m= 1+(9/98)(100-HDV)m= 1+(9/98)(100-26)m= 7.79

Now, after calculating "m" we are going to calculate CDV based on distress severity chart by arranging the maximum deduct values in a descending order.

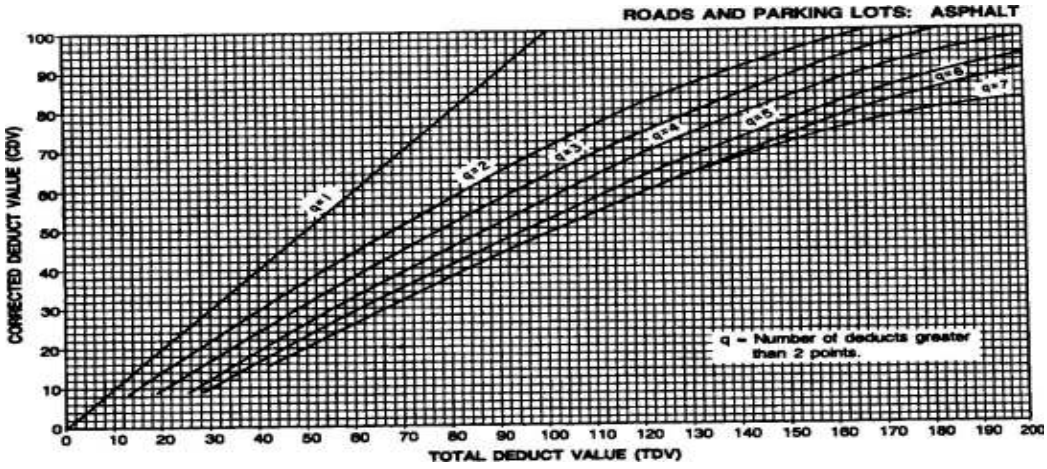
Table 8: Deducted Values

#	Deduct Values								Total	q	CDV
1	26	16.9	13	13	12.5	10.4	9.7	7.11	108.61	8	-
2	26	16.9	13	13	12.5	10.4	9.7	5.61	107.11	7	54
3	26	16.9	13	13	12.5	10.4	4.43	4.43	100.66	6	49.2
4	26	16.9	13	13	12.5	3.5	3.5	3.5	91.9	5	47.2
5	26	16.9	13	13	2.76	2.76	2.76	2.76	79.94	4	45.8
6	26	16.9	13	2.18	2.18	2.18	2.18	2.18	66.8	3	42.9
7	26	16.9	2	2	2	2	2	2	54.9	2	41.0
8	26	2	2	2	2	2	2	2	40	1	40.0

(Since, m= 1+(9/98)(100-26)=7.79<8

So, we use the highest 7 deducts and 0.79 of 8th deducts Therefore, 9*0.79=7.11)

CDV is calculated from the graph.



From the table, we have got max.CDV=54

PCI=100 – maxCDV=100-54 =27

Therefore, Rating=Poor

Pavement Condition Index for Overall Section

$PCI_s = PCIr = \sum_{i=1}^{n} (PCI.Ari) / \sum_{i=1}^{n} Ari$

Where, PCI_r=area weighted PCI of randomly surveyed sample units,

PCI_{ri}= PCI of random sample unit i, A_{ri}= area of random sample unit i,

n=numberof randomsampleunits surveyed.

$PCI_s = \sum^{45}(96 + 88 + 91.2 \pm \text{————} \mp 46 + 58)(700) / \sum^{45}(700)$

1

PCI= 70.34 ≃70

Rating of overall section= Fair

Table 9: Severity level of distresses

Distresses	Severity level
Longitudinal Cracks	Moderate
Alligator Cracks	Heavy
Potholes	Low
Patches	Moderate
Transverse Cracks	Low
Edge Cracking	Low
Block Cracking	Moderate
Slippage Cracking	Low
Weathering and Raveling	Low

PROBABLEDEFECTS OFTHEPAVEMENT

Here we have mentioned the pictures of different types of defects that we have studied.

Transverse Cracks

These cracks are non-connected cracks which are formed perpendicular to the direction of the pavement.

Figure 1: Longitudinal cracks

Block Cracks

These cracks are similar to fatigue cracks. Only the difference is the cracks occurs over the entire area of the ground. These cracks divide the entire area in to rectangular pieces.

Figure 2: Block Cracks

Slippage Cracks

These are formed like crescent or horseshoe shape which are generally formed due to braking of the vehicles. Mostly these type of cracks shows on intersections due to stopping.

Figure 3: Slippage Cracks

Alligator Cracks

It is the series of interconnected cracks which are caused by fatigue failures. These are normally called as crocodile cracks. These interconnected cracks can be called as cells. Each cell size may go larger than 300 mm.

Figure 4: Alligator Cracks

Potholes

These are small bowl-shaped holes formed on the pavement. They have sharp corners and vertical sides near the top of the hole.

Figure 5: Potholes

Longitudinal Cracks

These are the long, straight cracks and formed parallel to the centre of the pavement. This could be occurred due to joint failure or frost heaving.

Figure 6: Longitudinal Cracks

Swelling

It is the upward budge in the pavement surface. Generally, it is caused by moisture due to expansion. Swelling is caused by expansion in the supporting layer of the pavement.

Figure 7: Swelling

Edge Cracking and Shoulder Drop Off

The type of cracking starts from edge of the pavement which may leads to alligator cracks after some days. The main causes of this type of defects are weak bases of the soil. Shoulder drop off of the pavement is caused by weak edges of the pavement.

Figure 8: Edge cracking and shoulder drop off

Weathering and Ravelling

It is the adhesion between the asphalt cement and aggregate. Deformation starts with breaking up of fine aggregates in small pieces and leaves small patches over the pavement and leaves rough surface.

Figure 9: Weathering and ravelling

CONCLUSION

The case study was undertaken to investigate the road failures on the particular stretch (LPU main gate to Rama Mandi) and purpose of this research is to analyze and evaluation of the pavement failures. Various results and conclusions are drawn below:

a) The technique is based on the past experiences by keeping literature reviews in mind and selected the simple and best suitable method of analysis.

b) Pavement condition Index (PCI) was found out to know the condition of the pavement according to its distress sheet as per severity level from ASTM-D6433. From the method of pavement condition index, we got to know the condition of the pavement of overall section which was coming out to be "Fair" by the rating. The reason of having high severity level was caused by alligator cracks.

c) Since the maintenance option is required because the pavement is severe. So minor defects can be repaired before it becomes major defects. And special attention will be given to the areas having high severity level defects.

d) Proper designing of flexible pavement is utmost importance for the major causes of defects. Since, the major causes of deterioration are due to alligator cracks which were arise due to cycling action of loading.

e) Control of surface water or infiltration is needed at some places near level crossing Rama-Mandi. It can be improved by providing adequate drainage.

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