STUDY OF RIGID PAVEMENT DISTRESSES
On NH-146 National Highway Infront of SATI Vidisha, (M.P)

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Abstract: **–** Concrete pavements require upkeep to give good quality service levels during its service periods. A study of rigid pavement distresses has been conducted on NH-146 Dewas-Sagar National Highway for 1.0 km stretch from Ahemdpur intersection to district court towards Bhopal to assess the pavement quality and distress type using pavement evaluation technique (PCI-Pavement Condition Index) which provides quantitative & qualitative assessment based on visual inspection. Pavement Condition Index is classified in natural numbers between 0 & 100 taking 0 is the poor condition &100 as the best possible condition. Rate of pavement deterioration can qualitatively evaluated based on "Pavement Condition Index "developed by U.S Army Corp of engineers in late 1970's & 1980's. It is a numerical number indicator that classifies surface condition of the pavement based on the distress featured on the pavement surface. This methodology of pavement evaluation is a prominent tool for management of roads & life cost analysis. In this study average PCI for 1.0 km of length of road has been worked out 52.89 and the major distresses observed are Longitudinal Crack PCI value 32 on slab no-75. The PCI value study is helpful for deciding the maintenances & life cycle cost analysis of the pavement per km length.

Key words – Rigid Pavement, Pavement Condition Index.

INTRODUCTION

In general way, road is public way for passage of vehicles, people & animals. Before the emerging of mechanized vehicle was the animal drawn conveyance that prevailed these did not necessitate the same need as the vehicles now days because as well as cargo, the traffic was smaller. Thus examination of pavements in general & rigid solution in partially became an important theme to be addressed. Evolution of traffic, contributed to the necessity of refining the pavements by reforming materials as well as construction methods. The most dominant advantage of using concrete rigid pavement is its durability & ability to remain under traffic stresses. As rigid pavements often serve a life cycle 20 to 30 yrs with little maintenance of rehabilitation, it is vividly used in high trafficked areas of road. The visual inspections are done walking over the pavement & it is done to formulate the rate of pavement deterioration, thus determining rehabilitation needs. The work elaborate in this case study addresses rigid pavements and intends to contribute to the improvement of the assessment of the pavement condition index in order to reduce potential evaluation errors. As the rehabilitation cost of the rigid concrete pavement is expensive, this methodology allows for the assessment of the conditions along life period with minimum cost & in this way it is possible to play maintenance action & to adopt adequate measures prolonging good service levels & life period.

LITERATURE REVIEW

Mezhould S., etal, (2018) Corps of engineers step up traffic tests was reanalyzed to extend a structural deterioration model for rigid pavements. A concrete pavement structural deterioration model has been developed that expects performance in terms of a structural condition index (SCI). This model expect the pavement SCI values at any treatment level based on the two parameters C_O and C_F. Until the traffic coverage level equals C_O the SCI is 100, and when traffic arrives at C_F the SCI is 0.

Mezhould S., etal, (2016) A compound pavement is a multilayer structure where an uppermost layer is located over a rigid layer. A major factor is structural lack of the pavement due to insufficient structural design. Structural evaluation was performed 3 year after the opening to traffic in classifies to entrance the bearing capacity of each pavement layer. For this reason, nondestructive tests were conceded out by using (1) a traffic speed deflect meter (TSD), and (2) a falling weight deflect meter (FWD), in accordance with the standard ASTM D4694 (ASTM 2009).

Christopher Williams, R., etal, (2015) Classify the most proper rehabililitation technique for composite pavements and to calculate three pavement performance displays: reflective cracking, international roughness index (IRI), and pavement condition index (PCI).The poorest pavement provision based on PCI. Composite pavement, evaluated to usual flexible or rigid pavement, can be a more gainful substitute because they may give better levels of concert, both structurally and functionally.

Hu, J., etal, (2014) While joint sawing has been generally used in concrete pavement to prevent unrestrained cracking, best timing of joint sawing is important to ensure suitable cracks control is considered joint locations. The joint cracks time (or crack initiation time) deliberate by the strain gages were usually consistent with the visual observations.

Wu, L., etal, (2014) A general problem of crack removal algorithms is that removed crack image components are typically split is their crack paths. Pavement protective maintenance is defined by AASHTO'S leading team for pavement preservation as "affect the right treatment to be right pavement at the right time ". Image-processing method to evaluate road conditions is considered as a promise non-destructive technique to measure pavement distresses by analyzes pavement surface images.

Bianchini, A., (2013) Pavement management relies on the estimate of the condition of a pavement at unusual times during the life of the structure. The assortment of the condition indicators & the information of how they are use in any pavement condition evaluation model on fundamental for be appropriate the rating in pavement management. The joint investigation of PCI values & distresses is the key to capable pavement management.

Jahanshahi, M. R., etal, (2013) A RGB-D sensor is used to detect & measure defects in pavements. This sensor structure consists of a RGB color image, & an infrared projector & a camera that acts as a depth sensor. Various road conditions with patching, cracks & potholes are separately detected, most significantly, measure, using the projected approach. Traditional pavement condition-assessment measures comprise manual or semi automatic advance.

METHODOLOGY

In this study, It is intended to apply pavement condition index (PCI) methodology to access rigid concrete pavement distress & for better understanding the process , work started from ahmedpur intersection to district court as shown in location map covering length of 1.0 km pavement length was divided in to 100 slab of each 10m length. Detailed observation were made on both left and right of the slab by visual inspection of distresses and were recorded as shown in table-3.1 Study of every rigid pavement distress were observed as length, width and depth of crack and distresses type was identified and marked. Severity level was calculated using PCI method as shown in Table-3.1 The causes of distresses has been observed and detailed to present possible maintenance solution for each of them.

Location of the roads selected for studies

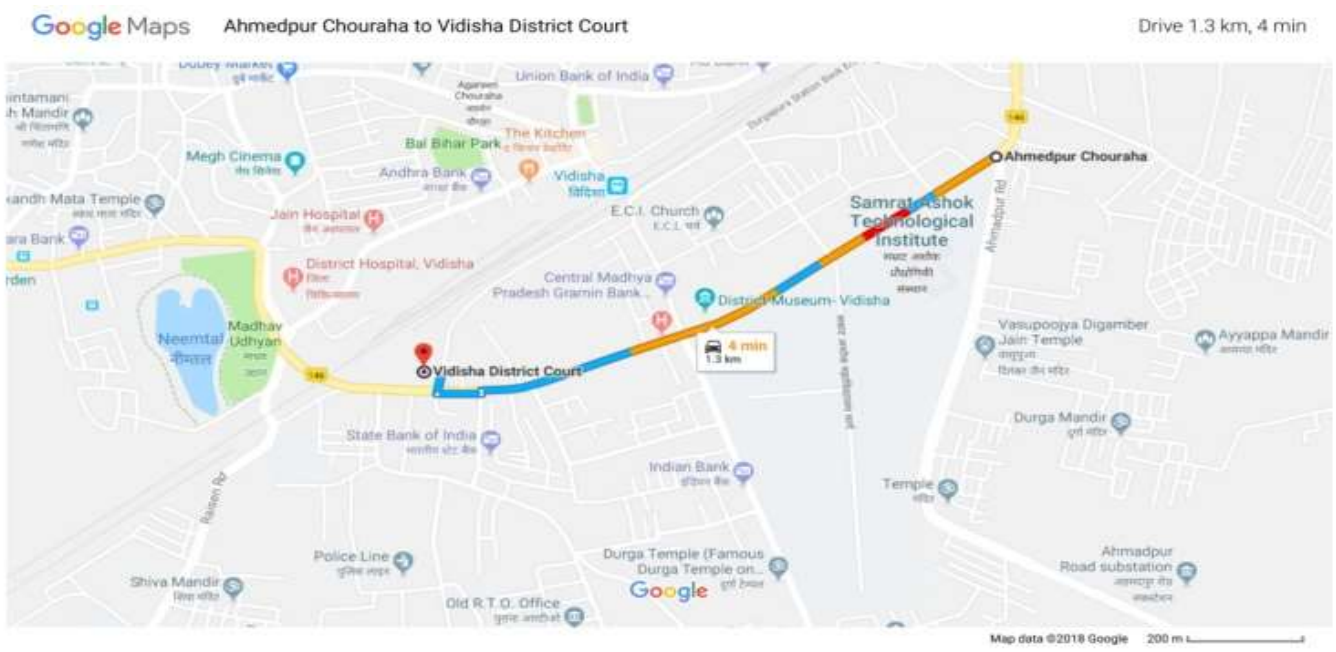


FIG: 1.1 MAP SHOWING THE PROJECT LOCATION

Cross Section of NH-146 Road

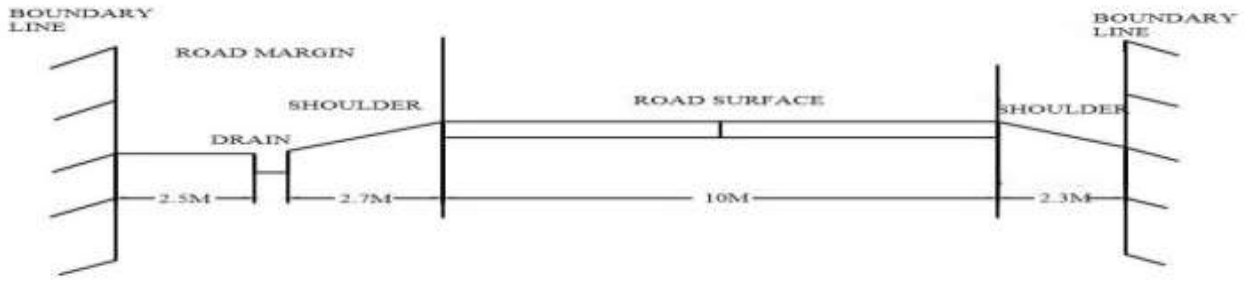


FIGURE NO-3.2 CROSS SECTION OF NH-146 ROAD

FIG: 1.2 CROSS SECTION OF NH-146 ROAD

Pavement Condition Index Rating Scale

The PCI is a numeric index that rates the surface condition of the pavement from 0 to 100, where 0 its poor condition and The 100 is best possible condition.

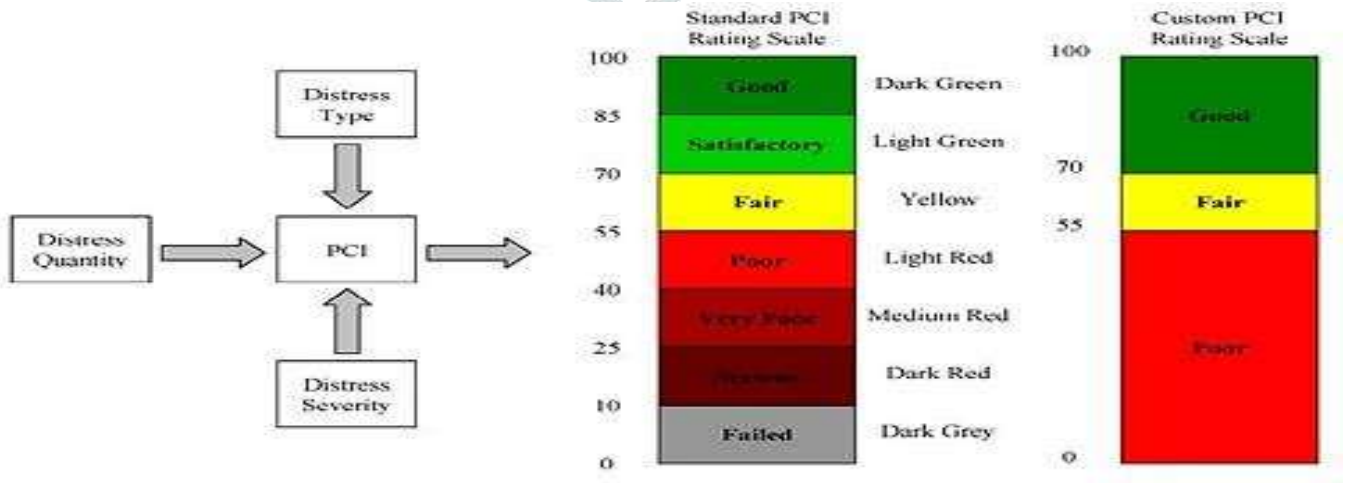


FIG-1.3 PAVEMENT CONDITION INDEX RATING SCALE

Data Analysis Procedure

For distresses analysis of the road using pavement condition index (PCI) evaluate is recorded manually by a visual evaluation survey walking above each slab of the sample unit, recording and drawing all distresses existing in the slab along their severity level on the data sheet.

TABLE NO 1.1 MEASUREMENT OF SEVERITY LEVEL OF ROAD DIMENSION

Distress Type	Severity level	Roads
Longitudinal, Transverse and Diagonal Cracks	Low	≤ 13mm
	Moderate	≥13mm and ≤ 50mm
	High	≥50mm
Faulting	Low	≥3mm and≤13mm
	Moderate	≥ 10mm and ≤ 20mm
	High	≥20mm
Corner break	Low	≤ 13mm
	Moderate	≥ 13mm and ≤ 50mm
	High	≥ 50mm

$$n_{min} = \frac{Ns^2}{\left(\left(\frac{e^2}{4}\right)(N-1)+ e^2\right)}$$

Note: rounding n_{min} to the next highest whole number.

Where:

e- Reasonable error in estimating the section PCI. Commonly, e= +/- 5 PCI points;

s- Standard deviation of the PCI from one sample unit one more within the section. When operating the initial observation the standard deviation is assumed to be 15 for PCC pavements. The indicated should be enquiring as described under after PCI values are determined. FOR consecutive inspections the standard deviation from the previous investigation should be used to determine n;

N- Total number of sample units in the section.

If receive the 95% confidence level is demanding capacity of the number of sample units evaluated must be confirmed. The number of sample units was evaluated based on an expected standard deviation.

$$S = \sqrt{\sum_{i=1}^{n} \frac{(PCI_i - PCI_f)}{(n-1)}}$$

Where:

PCI_i – PCI of surveyed sample unit I;

PCI_f– Mean PCI of surveyed sample units;

n –Total number of sample units surveyed.

Finally, one the number of sample units to be survey has been determined, evaluate spacing internal of the units apply systematic random sampling.

$$i = \frac{N}{n_{insp}}$$

Where:

N – Total number of sample units in the section

n_{insp}- Number of sample units to be inspected

Calculation of PCI for PCC Pavement

Exclusive combination of Distress type and severity level, it has to be listed the number of slabs in which they arise.

For example, in the figure 1.4 there are two slab include low –severity longitudinal cracking.

FIG: 1.4 – LOW SEVERITY L/T/D AT TWO ROAD SLABS.

So, in the data sheet it will look like this:

TABLE 1.2 – EXAMPLE OF HOW TO FILL A PCC SURVEY DATA SHEET.

Distress Type	Severity Levels	Number of Slabs	Density %	Deduct Value
3	L	13		

Calculation of Density

The measure percentage of density, divide the number of slabs listed from a specific distress by total number of slabs in Sample unit (usually 100) and multiply by 100. For example:

Density % = 13/100×100= 13%

TABLE 1.3- EXAMPLE OF HOW TO FILL A PCC SURVEY DATA SHEET AFTER DV.

Distress Type	Severity Levels	Number of Slabs	Density %	Deduct Value
3	L	13	13	11.8

Calculation of Corrected Deduct Value

The Pavement Condition Index (PCI) is given by:

PCI = 100 – HCDV

Where:

100 – Maximum PCI

HCDV- Highest corrected deduct value (CDV)

TABLE 1.4- EXAMPLE OF A PCC SURVEY DATA SHEET FILLED.

Distress Type	Severity Levels	Number of Slabs	Density %	Deduct Value
3	L	13	13	11.8
15	L	8	8	4.1
10	L	18	18	3.2
14	L	17	17	5.2
8	L	11	11	8.8
9	L	9	9	9.1
16	L	11	11	9
12	L	4	4	9.2
3	M	37	37	36
2	M	9	9	13.1
12	M	6	6	20
3	H	16	16	32
12	H	7	7	33

To determinate the PCI, first the CDV is determinate if only the first three lines of Table 4.5 are considered as having Distresses recorded, only one DV is bigger than five ( ), so the PCI:

PCI = 100 – (11.8+4.1+3.2)

= 100 – 19.1

= 80.9

Otherwise, if more than one DV is bigger than five, in order to determine the maximum CDV another procedure is followed First, the maximum allowable number of distress, "m", are calculated.

$$m = 1 + (9/95) * (100 * HDV) \leq 10$$

Where:

HDV – Highest deduct value.

For example, considering Table 4.5:

$$m= 1+ (9/95) * (100 - 36) = 7.0631$$

This means that only seven distresses have to be considered for this PCI calculation.

Secondly, the "m" highest DVs have to be entered on line 1 of the following table, including the fraction obtained by multiplying the last DV by the fractional portion of "m". If less DV are available, enter all of the DVs. Sum the DVs and enter it under "Total". Count the number of DVs greater than five and enter it under ″q".

TABLE 1.5- EXAMPLE OF PROCEDURE WHEN YOU HAVE MORE THAN ONE DV GREATER THAN FIVE

#	Deduct Values										Total	Q	CDV
1	13.1	11.8	9.2	9.1	9	8.8	5.2	4.1	3.2	3.2 * .0631= 0.20	73.7	7	48.1
2	13.1	11.8	9.2	9.1	9	8.8	5	4.1	3.2	0.20	73.5	6	48
3	13.1	11.8	9.2	9.1	9	5	5	4.1	3.2	0.20	69.7	5	45
4	13.1	11.8	9.2	9.1	5	5	5	4.1	3.2	0.20	65.7	4	46.5
5	13.1	11.8	9.2	5	5	5	5	4.1	3.2	0.20	61.6	3	46
6	13.1	11.8	5	5	5	5	5	4.1	3.2	0.20	57.4	2	48.2
7	13.1	5	5	5	5	5	5	4.1	3.2	0.20	50.6	1	48

Finally the PCI is given by:

$$PCI = 100 - (47.11) = 52.89$$

Determination of PCI of the Section

The PCI section (PCI_s) is calculated as the area weighted PCI of the randomly surveyed sample units (PCI_r) using:

$$PCI_s = PCI_r = \frac{\sum_{i=1}^{n}(PCI_{ri} \cdot A_{ri})}{\sum_{i=1}^{n} A_{ri}}$$

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 - Total number of sample unit surveyed

Structural Condition Index

The Structural Condition Index (SCI) is derived from the Pavement Condition Index and it is the summation of structural components from PCI. The use of SCI differentiates the two types of distresses: one is structural- related due to loads, and the other is non- structural-related therefore, it can be described by the equation (Rolling, 1988):

$$PCI = 100 - \alpha \sum_{i=1}^{dt} \sum_{j=1}^{sl} f(T_i, S_j, D_{ij})$$

Where:

α- An adjustment factor depending on the number of distress types with deduct values in excess of 5 points;

dt- Total number of distress types;

sl – Total number of severity levels for each distress type;

$f(T_i, S_j, D_{ij})$ – Deduct Value for distress type T_i,at severity level S_j, existing at density D_{ij}.

The PCI may conceptually also be considered as follows:

$$PCI = 100 - D_S - D_E - D_M - D_C - D_O$$

Where:

D_S - Structural deduct due to distress types, severities, and densities associated with load (e.g., shattered slab);

D_E - Environmental deduct due to distresses associated with environmental effects (e.g., raveling, weathering);

D_M – Materials deduct due to distress associated with material used in construction (e.g., pop-outs);

D_C – Construction deduct due to distress associated with construction procedures (e.g., bleeding);

D_O – Operations deduct due to distress associated with operations and maintenance of the pavement (e.g., patching /utility cuts):

Similar to the PCI definition, the SCI can be defined as (Rolling, 1988):

$$SCI = 100 - \alpha \sum_{i=1}^{m} \sum_{j=1}^{n} f(T_i, S_j, D_{ij})$$

TABLE 1.6 – EXAMPLE DATA FOR SCI CALCULATION (DISTRESS 3 AND 14)

Distress Type	Severity Levels	Number of Slabs	Density %	Deduct Value
3	L	13	13	11.8
12	L	4	4	9.2
3	M	37	37	36
2	M	9	9	13.1
12	M	6	6	20
3	H	16	16	32
12	H	7	7	33
16	L	11	11	9
15	L	8	8	4.1
14	L	17	17	4.9

Adjusted Deduct Value

DV numbers to calculate the SCI must be summed as follows.

33+4.1+ 4.9 =43

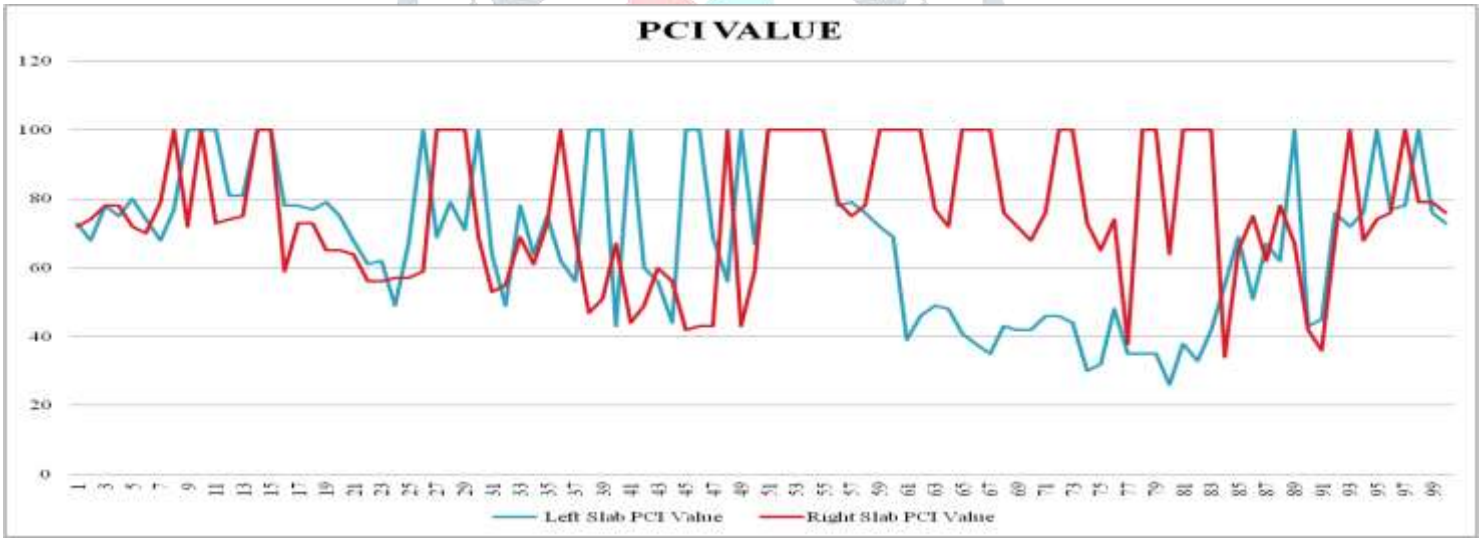
With the total, and having more than one structural distress an adjusted deducted value (ADV) is needed. This ADV is taken from the CDV abaci representing the curves the number of structural distresses (q1 -1 structural distress, q2 -2 structural distresses and so on) and the value is 33

After having the ADV the procedure is:

SCI = 100 -33 = 77

SCI of 77 in a rigid pavement is defined as structural failure and is consistent with 50% of the slabs in the traffic area exhibiting structural cracks.

COMPARE TO LEFT & RIGHT SLAB PCI VALUE

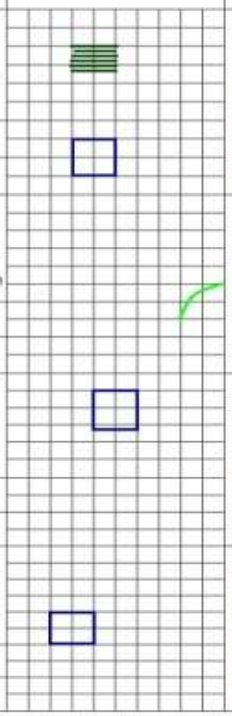
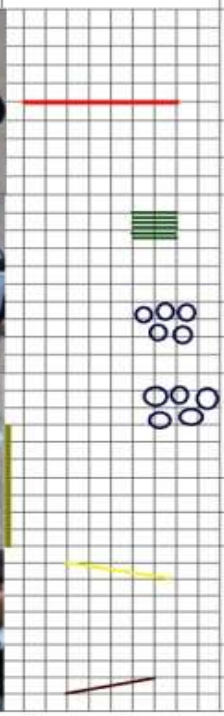


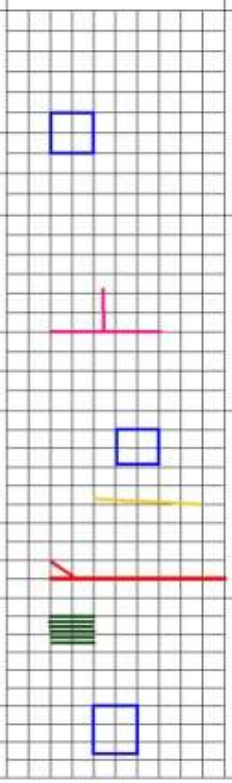
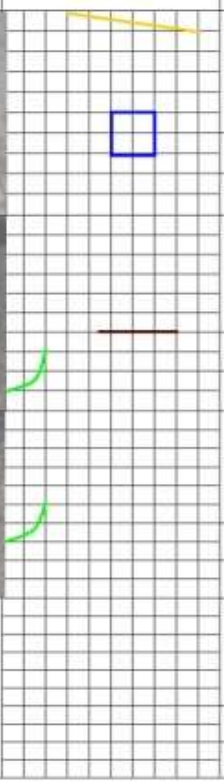
DATA SHEET

SERIAL NO/ SLAB NO	DISTRESS TYPE/L/W/D				ODD SLAB PCI	ODD SLAB SCI	EVEN SLAB PCI	EVEN SLAB SCI	DISTRESS TYPE/L/W/D				SEVERITY LEVEL
1	16 10	180 CM 1.75 M	120 CM 1.7 M	0.2 CM 0.3 CM	73	92	72	90	3	217 CM	2.2 CM	0.3 CM	L M L
2	2	1.65 M	3.7 CM	0.7 CM	68	88	74	96	16 8	178 CM 3 M	100 CM 20 CM	0.2 CM 0.25 CM	M L L
3	10	1.4 M	1 M	1 CM	78	97	78	98	8 5	3 M 6 M	9 CM 0.4 CM	0.4 CM 0.3 CM	L L L
4	10	1.9 M	1.8 M	0.4 CM	75	93	78	96	14 15	2 M 1.8 M	0.5 CM 0.3 CM	0.2 CM 0.2 CM	L L L
5	10	1.2 M	1.3 M	0.5 CM	80	97	72	93	14 10	3 M 1.7 M	0.3 CM 1.4 M	0.1 CM 0.3 CM	L L L
6	12	2.2 M	0.7 CM	0.3 CM	74	96	70	91	15 2	1.8 M 1.2 M	2.5 CM 2.7 CM	0.3 CM 0.5 CM	L M M
7	10 14 3	1.4 M 2 M 3.9 M	1.3 M 0.3 CM 1 CM	0.3 CM 0.3 CM 0.3 CM	68	91	79	96	2	1.2 M	0.3 CM	0.2 CM	L L L L
8	16 10	1.6 M 2.8 M	1.3 M 1.2 M	0.3 CM 0.25 CM	77	94							L L
9							72	93	3 3	3.4 M 3.7 M	0.5 CM 0.5 CM	0.2 CM 0.2 CM	L L
10													
11							73	95	3	3.8 M	0.4 CM	0.2 CM	L
12	16	1.9 M	1.2 M	0.5 CM	81	97	74	91	8 3	1.5 M 3.7 M	1 M 0.3 CM	1.5 CM 0.2 CM	L L L

TABLE NO-3.1 DISTRESSES TYPE, DIMENSTION, SEVERITY LEVEL, PHOTO OF SLAB, SKETCH OF SLAB, PCI & SCI VALUES

LOCATION.....

SR / SLAB NO	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL	ODD SLAB SKETCH	PHOTO ODD SLAB	PHOTO EVEN SLAB	EVEN SLAB SKETCH	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL
1	16 1.8 M 1.2 M 0.2 CM L 10 1.7 M 1.7 M 0.3 CM L PCI VALUE 73 SCI VALUE 92					3 2.2 M 2.2 CM 0.3 MM M PCI VALUE 72 SCI VALUE 90
2	2 1.7 M 3.7 CM 0.7 CM M PCI VALUE 68 SCI VALUE 88					16 1.7 M 1 M 0.2 CM L 8 3 M 20 CM 0.2 CM L PCI VALUE 74 SCI VALUE 96
3	10 1.6 M 1.1 M 0.5 CM L PCI VALUE 78 SCI VALUE 97					8 3 M 9 CM 0.4 CM L 5 6 M 0.4 CM 0.3 CM L PCI VALUE 78 SCI VALUE 98
4	10 1.9 M 1.8 M 0.4 CM L PCI VALUE 75 SCI VALUE 93					14 2 M 0.5 CM 0.2 CM L 15 1.8 M 0.3 CM 0.2 CM L PCI VALUE 78 SCI VALUE 96

SR / SLABNO	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL	ODD SLAB SKETCH	PHOTO ODD SLAB	PHOTO EVEN SLAB	EVEN SLAB SKETCH	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL
5	10 1.2 M 1.3 M 0.5 CM L PCI VALUE 80 SCI VALUE 97					14 3 M 0.3 CM 0.1 CM L 10 1.7 M 1.4 CM 0.3 CM L PCI VALUE 72 SCI VALUE 93
6	12 2.2 M 0.7 CM 0.3 CM L PCI VALUE 74 SCI VALUE 96					15 1.8 M 2.5 CM 0.3 CM M 2 1.2 M 2.7 CM 0.5 CM M PCI VALUE 70 SCI VALUE 91
7	10 1.4 M 1.3 M 0.3 CM L 14 2 M 0.3 CM 0.3 CM L 3 3.9 M 1 CM 0.3 CM L PCI VALUE 68 SCI VALUE 91					2 1.2 M 0.3 CM 0.2 CM L PCI VALUE 79 SCI VALUE 96
8	16 1.6 M 1.3 M 0.3 CM L 10 2.8 M 1.2 M 0.3 CM L PCI VALUE 77 SCI VALUE 94			No Crack Found		PCI VALUE SCI VALUE

SR / SLABNO	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL	ODD SLAB SKETCH	PHOTO ODD SLAB	PHOTO EVEN SLAB	EVEN SLAB SKETCH	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL
9	PCI VALUE SCI VALUE		No Crack Found			3 3.4 M 0.5 CM 0.2 CM L 3 3.7 M 0.5 CM 0.2 CM L PCI VALUE 72 SCI VALUE 93
10	PCI VALUE SCI VALUE		No Crack Found	No Crack Found		PCI VALUE SCI VALUE
11	PCI VALUE SCI VALUE					3 3.8 M 0.4 CM 0.2 CM L PCI VALUE 73 SCI VALUE 95
12	16 1.8 M 1.2 M 0.5 CM L PCI VALUE 81 SCI VALUE 97					8 2 M 1 M 0.5 CM L 3 3.7 M 0.3 CM 0.2 CM L PCI VALUE 74 SCI VALUE 91

LOCATION.....

SR / SLAB NO	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL	ODD SLAB SKETCH	PHOTO ODD SLAB	PHOTO EVEN SLAB	EVEN SLAB SKETCH	DISTRESS TYPE/L/W/D/ SEVERITY LEVEL
13	16 1.8 M 1.1 M 0.5 CM L PCI VALUE 81 SCI VALUE 97					14 1.6 M 0.2 CM 0.1 CM L 14 1.2 M 0.3 CM 0.2 CM L PCI VALUE 75 SCI VALUE 92
14	PCI VALUE SCI VALUE		No Crack Found	No Crack Found		PCI VALUE SCI VALUE
15	PCI VALUE SCI VALUE		No Crack Found	No Crack Found		PCI VALUE SCI VALUE
16	10 1.9 M 1.2 M 0.5 CM L PCI VALUE 78 SCI VALUE 96					5 5.8 M 3 CM 0.5 CM M 3 8.7 M 0.5 CM 0.2 CM L PCI VALUE 62 SCI VALUE 78

RESULT

The evaluated pavement condition index is 52.89 which comes under poor condition. The maintenance of road is needed to improve the pavement condition for full-patch depth, Crack Sealing, Joint Resealing etc. To increase the sustainability of the road, Maintenance of road is needed.

CONCLUSION

In present study the PCI index of the 1 km length has been found as 52.83 current age of pavement is 8 yrs after construction. It indicate that proper regular maintenance of the pavement is essentially required with life cycle analysis as it is expected that the pavement may fail before its design life of 20 to 30 yrs. The approximate cost of maintenance is 5L.

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