FLEXIBLE PAVEMENT DISTRESS EVALUATION AND MAINTENANCE ALTERNATIVE IN KABUL AFGHANISTAN

(A CASE STUDY ON DISTRESS EVALUATION OF KABUL JALALABAD ROAD NH-1)

Dissertation-2

Submitted In partial fulfillment of the requirements of the degree of

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by

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April 25, 2017

DECLARATION

I, Abdul Moqtader Yousufzai (Reg. No 11509594, hereby declare that this research report entitled **"Flexible Pavement Disstress Evaluation and Maintenance Alternatives in Kabul Afghanistan"** submitted in the partial fulfillment of the requirement for the award of degree of Master of Civil Engineering, in the school of Civil Engineering, Lovely Professional University, Paghwara, is my own work. This research in this report has not been submitted fully or in part to any other University or institute for any purpose.

Date: April 25, 2017

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CERTIFICATE

This is to Certify that the Dissertation report entitled **“Flexible Pavement Disstress Evaluation and Maintenance Alternatives in Kabul Afghanistan”** Submitted Individually by the Student (Abdul Moqtader Yousufzai Reg No: 11509594) of Civil Engineering, Lovely Professional University, Paghwara, carried out the work under my Supervision and guidance for the Award of Degree. This Report has not been submitted to any other institute or University for the award of any degree.

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Abstract

Premature failures are mostly occurring in the flexible pavement that decreases the service performance and life of pavement. Major causes of the premature pavement failure are weather condition, temperature of the asphalt concrete, moisture damage of the pavement, traffic load. Type of bitumen, mix design and construction are the variables that affect the moisture damage of the Asphalt concrete and the most important variable is the selection of bitumen. This study aimed to evaluate and determines types of flexible pavement distresses its causes and to analyze the Pavement Condition Index (PCI) of the pavement and maintenance alternative for the distresses. 10 km length of NH-1 which is coming under Asian Highway 1 (AH-1) was selected, starting from Kabul custom to Pule-charkhi, to carry out the pavement distress survey the overall length divided on 10 sections each 1 km length and each section divided on samples each has 300 sqm areas. After the survey the observation showed that the most commonly pavement distressed found in the highway were cracks, Bleeding, Depression, Bumps and Sags, Patching, Rutting, and pot holes, which have different limits. After the testing of the samples collecting from the road surface and base in the laboratory The result indicate that distresses are due to temperature change, moisture, heavy load, increase amount of traffic, and selection of pavement grade based on the causes and survey. PCI was calculated for each section and for overall road based on ASTM D6433.

Keywords: premature, distress, PCI, ASTM D6433

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CHAPTER 1

INTRODUCTIONS

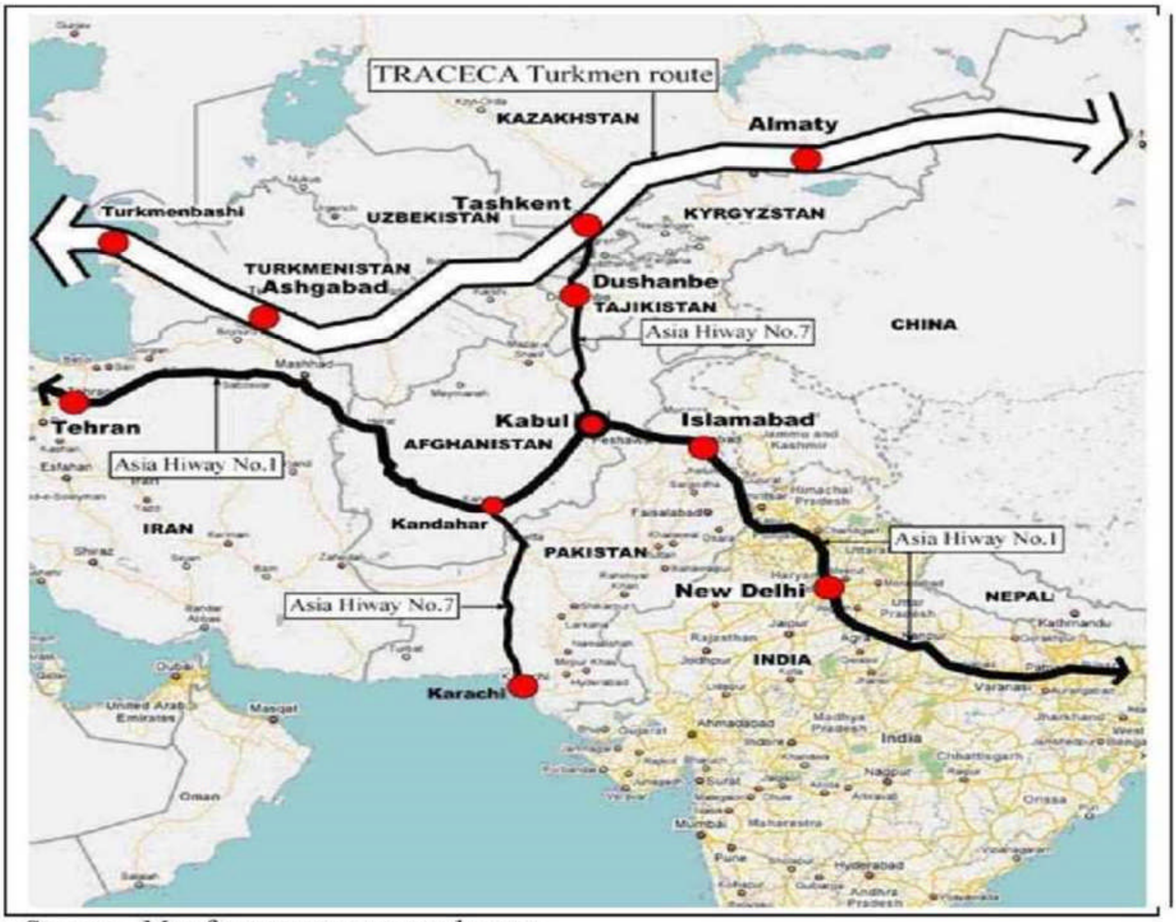
The Study Area is located in the Kabul City starting from Kabul National Army University with the coordinate of UTM UPS WGS 84 Easting 520591 and Northing 3821427 the study area is Kabul-Jalalabad road National Highway NH-1 which connects the Pakistan with Afghanistan Center Kabul and Afghanistan with Iran. Kabul-Jalalabad road is the transit road and use for transit of the goods and other materials from the Neighbor of Afghanistan the study area is the witness of a lot of distress with different types and severity level due to mix traffic (heavy and light-weight) along with more volume of traffic. Site plan on Figure1.

The project site was divided into 10 sections each 1km and each section divided on Sample units each 300sqm section 1 to 5 are in the urban area and has 14 cm asphalt concrete (for heavy and light-weight vehicles) and section 6 to 10 are in the mountain area and having the 14 cm of pavement (for heavy and light-weight vehicles).

The purpose of this case study is to determine the existing distress on the road and the causes of the distress due to which distress happened and to prevent the developing of existing distress along with maintenance alternatives for the distress by performing and conducting the survey on the area (reconnaissance survey, preliminary survey and detail survey by measuring the distress and its severity level), photograph of the site, traffic survey (volume count of the vehicles), destructive tests, coring, sampling and testing of the asphalt and other layers of the pavement along with sub grade soil.

Pavement Distresses are visible deficiencies on the road Pavement and the decline process starts after the opening of the road for use. The decline process of road pavement surface starts very slowly at the beginning which may not be visible and after passing of time these are accelerate faster. to prevent the premature decline and to minimize the distress and avoided it is required to use the best design, construction and maintenance practice which can be achieved by finding and evaluating the types and severity level of the distress, examining the premature failure of the pavement, finding causes of the distresses and to present the maintenance method for stopping and preventing of the developing of the distresses. It is very important to select the evaluation method such that minimize the coast and maintenance the road pavement cheaper as it is effect on economic evaluation of the pavement.

In Afghanistan the evaluation process of pavement failure is not properly done and most of the road pavement not evaluated even maintenance works are not done on time. There is no proper maintenance and evaluation system of the pavement distress, no control of the loading and traffic on the road and lack of the budget for the evaluation and maintenance of the road. Because of the above factors the road condition is decline and distresses are increased and developed in the shortest time with high severity level.



Source: Map from www.map.google.com.

Figure 1: International transport corridor.

1.1 Types of Pavement Distress and Distress Mechanisms

One of the principle reasons of the pavement evaluation is the experience of premature pavement failures and distresses that roads engineers have. especially the maintenance and repair work of the road pavement that many engineers' attention pavement evaluation and pavement distress problems rather than underlying causes of the premature failure and pavement distresses. There are many examples where the causes are not addressed and directly repair the distress after finding. An example is the development of cracking and potholes due to excessive moisture and weakening in the bellow layers. If the water is not removed and the moisture of the underlying layers are not controlled and properly treated by different methods and improve drainage the distress is appear very soon after repair work.

The purpose of this section is to describe the types of the pavement distress before evaluation of the existing distress and finding the maintenance alternative for the distresses.

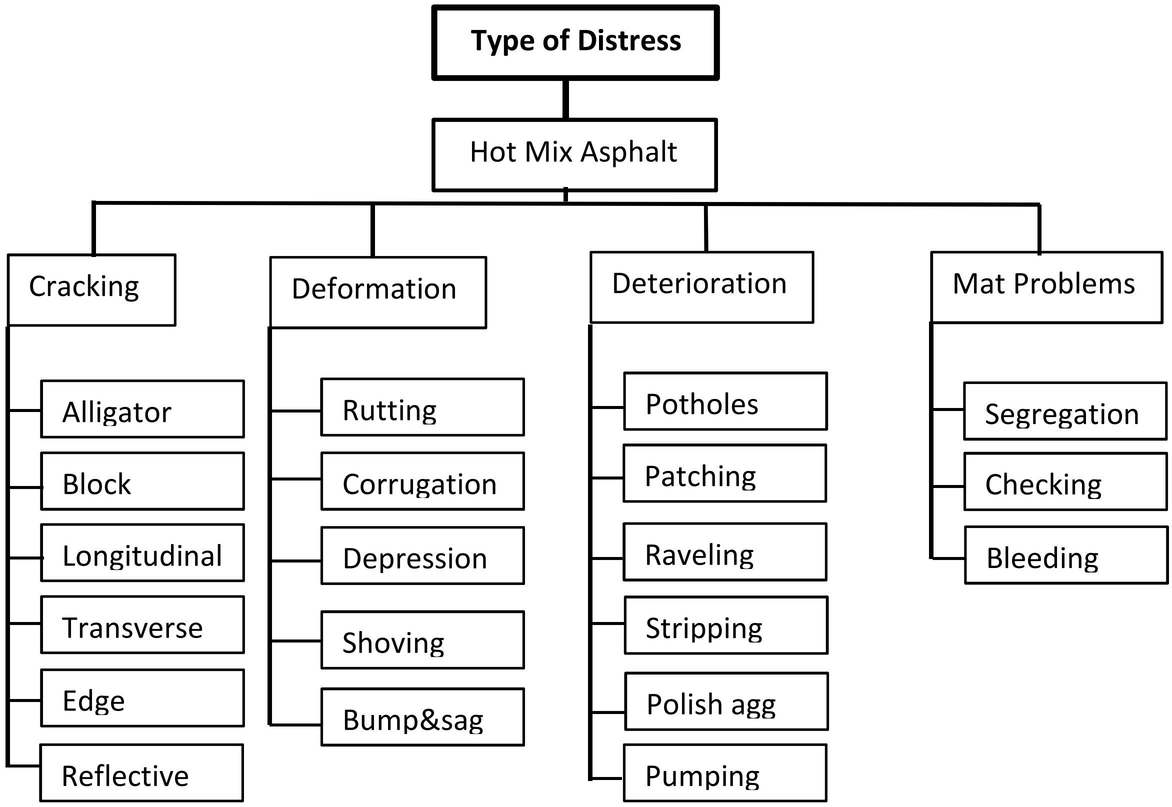


Figure 2: Distress Types

1.2 Surface Evaluation (Pavement Condition Index): Pavement Condition Index (PCI) is the rating or numerical rating of the surface pavement condition 0 is the worst condition while 100 is the best possible pavement condition PCI ranges are from 0 to 100. PCI identifies the different pavement distresses and links these defects to a cause. And it is very important to understand the present condition causes in selecting the appropriate remedy. The main purpose of this case study is to evaluate the PCI of the pavement surface and find the maintenance alternatives.

1.3 Geography and Climate of the Area

The case study is done on Kabul-Jalalabad Road which is located in north eastern part of the Country. Kabul Jalalabad road (NH-1) is the Asia Highway No1 road which connects Islamabad to Kabul and Kabul to Tehran and 10 km stretch of the road is selected for the investigation which is starting from Kabul National Army University with the coordinate of UTM UPS WGS 84 Easting 520591 and Northing 3821427.

Afghanistan has continental climate having the high temperature of +45 °C in summer and -22°C in winter. Climate condition of the Afghanistan ranges from dry or arid in the south and southwest to semiarid in the other part of the country. Annual perception of the country varies from less than 100mm in the areas having low level i.e., 75mm in Farah province and more than 1000mm in the mountain areas i.e., 1170mm in south salang the study area has the Annual precipitation of 550mm maximum value and 165mm of minimum value the mean value of 316mm and the temperature is varies from 38 °C to -8 °C mean temperature is 5.3

℃. The precipitation occurs mostly in the winter seasons especially from February to April. Potential evapotranspiration annually varies in the northern plains between 1200mm and 1400mm and in the southern and southwestern plains reached to 1800mm. it is relatively less in high mountain which is reached to 1200mm. The data is gathered from Watershed ATLAS of Afghanistan which is approved by Ministry of Irrigation, Water Resources and Environment.

Table1: Climate of Project Area

Climate Factrs	Unit	Max Value	Min Value	Mean
Annual precipitation	mm	550	165	316
Temperature	Cº	38	-8	4.3
Wind Speed	Mile/h	2.6	1.2	1.7

1.4 Terrain Condition of the Area

Kabul has the mix terrain (Plain, Rolling, Mountain and Steep) the study area is starts from the plain terrain with cross slope less than 10% crossing the rolling and mountain terrain and end at steep terrain having cross slope more than 60%. Bases on distresses existence and severity the tests have taken from site are mentioned in the map Figure 2.

Figure 3: Study Area Map

CHAPTER 2

TERMINOLOGY

PCI	Pavement condition index
AC	Asphaltic concrete
FA	Fine aggregate
CA	Coarse aggregate
VMA	Voids in mineral aggregate
VFA	Voids filled by asphalt
PSI	Present serviceability index
IRI	International roughness index
PSI	Pavement structural number
TP	Test pit
GPS	Global positioning system
DV	Deduct value
CDV	Cumulative deduct value
TDV	Total deduct value
GMM	Theoretical maximum specific gravity of asphalt concrete
ESAL	Equivalent single axle load
HMA	Hot mixed asphalt
H	High severity
M	Medium severity
L	Low severity

CHAPTER 3

REVIEW OF LITERATURE

For better understanding of the purpose and scope of research it is necessary to studies relevant to the research and have been studied which are:

Sharad.S.Adlinge, Prof.A.K.Gupta (2015) Civil,J.J.Magdum college of Engineering, Shivaji University, India "1.Quick growth in traffic loading particularly on new roads where the design is created on lesser traffic is a key cause of cracking. After building of good road, traffic of other roads also changes to that road, this quickens the fatigue failure (Alligator Cracking). 2. Heat deviation fluctuating from 50 C^0 to below zero state in the plain areas of north and central India indications to bleeding and cracking. 3. Establishment of poor shoulders indications to edge failure. 4. Delivery of week clayey subgrade outcomes in corrugation at the surface and rise in roughness. 5. Poor drainage situations particularly through rainy periods, energy the water to go in the asphalt from the sides as well as from the upper surface. In case of open classified bituminous coating, this occurrence develops extra hazardous and the top coat becomes separate from the lower coats. 6. If the heat of bitumen/ bituminous combinations is not kept correctly, then it also leads to pavement failure. Overheating of bitumen decreases the binding property of bitumen. If the temperature of bituminous mix has been depressed then the compaction will not be correct leading to longitudinal corrugations.

E. Horak[1] and S.J. Emery[2] (2014) Section of Civil and Bio systems engineering, University of Pretoria, South Africa "the definite burning mix asphalt consumed 1% lime arranged for stripping defense. Specified the grading and tillite grout contented, the outcome would have been hard and severe mix to compress. Archives displays that lime (0.3%) was added throughout the trial period and then almost absent. From laboratory testing specified that on site grouts was very fine which decrease the binder efficiency at the design binder content of 5.1% for Job Mix formula. Extra grouts existing in the mix since the ash were 3-5% which is outside the 2% activate cost for mix roughness and high difficulty. The ash outcomes displays that tillite grout which was added in mix would have been adding to the constructability difficulties, which be and overcome by lifting mix and paving heats. X-ray deflection and isotope testing on the grout resources check that arranged lime was chiefly replaced by the tillite grout, with its similarity in color, same fine grout sizing and existence willingly accessible from the plant cyclone dust collector. The end outcome was a thin mix to complement the agreed lime so as to be paved the essential requirement of compactness and air void content. The replacement of arranged lime with extra fantastic fine tillite grouts to the mix caused the located mix to become brittle, break up and failing prematurely with the detected initial cracking. The nonappearance of the arranged lime perhaps caused initial stripping, rise in porosity and permeability which further accelerate the premature failure".

Mike C. Cook,P.E. (2013) California Division of Transportation **Stephen B. Seeds, P.E.** Applied Pavement Technology, Inc. **Haiping Zhou, P.E., Ph.D., R.Gary Hicks, P.E., Ph.D.** MACTEC Engineering and Consulting, Inc. the paper has offered an summary of the afresh established Caltrans guide for the Search and Remediation of Distress in Flexible Pavement. To numerous working pavement engineers and operators, this guide can be valuable reference. It delivers a comprehensive explanation on numerous kinds of distress usually seen in flexible pavements, the device that reasons the pain, the aspects that effect pavement distress and presentation. It also defines a overall procedure and numerous methods that can be used for the examination of pavement distress and developing coast active repair actions that report both the distress and the reasons. New tools and methods established to support the search and engineers to examine and remediation of the pavement and to assistance over all procedure and to discovery the answer of the difficulties.

Hsienjen Stephen Tien, Eng.D.[1] and David A. Eastwood, P.E.[2] (2012) "Founded on the assessment of reports offered and ground and laboratory assessment, the pavement distress happened as outcomes of mixture of the following: unlawful practice of the pavement constructions (roadway construction misuses), Unclear meaning of the soil categories and properties to be used as structural fills under the pavement provided, Unsuccessful Drainage scheme producing surface water ponding below the pavement, Design difficult, and construction problem of the pavement.

Mahmoud El-Saied Solyman[1] and Hassan Salama[2] (2012) Construction engineering and Services [1]Department, Zagazig University, Zagazig, Egypt, [2] Civil and Environmental Engineering Division, Al-Azhar University "Bases on the investigates of crosswise surface outline numbers which collect for 10 sections on the road network in Egypt it is found from ground examination that flexible pavement rutting harm are as bellows: 1. Analysis of the transvers surface profile of the highway section presented that Sixty % of the disaster happened in the Hot Mix Asphalt, Thirty % on the base layer, and Ten % on the subgrade. 2. The sections which have rutting problem are due to construction related problem and insufficient pavement cross sections especially in HMA. Appearance of the premature rutting at the initial phase of the pavement lifetime guarantees this decision. 3. The road have been studies carried 49% excess heavy loaded trucks and the rutting is due to heavy truck axle loads."

Taesoon Park (2007) Seoul National University of Technology, Division of Civil Engineering, 172 Gong Reung Dong, Nowongu, Seoul, Republic of Korea "the reasons of the bleeding difficult that happened next the boiling in place founded on the ground measurement and laboratory testing outcomes are as bellow: 1. Hot in place recycling (HIPR) technique is a feasible and financial reintegration method for weakened asphalt pavement. 2. No important or measureable variation in stage or asphalt content due to the reprocessing process was noticed. 3. The external coat displayed higher asphalt content than the reprocessed coat. The asphalt content of the surface layer was 2-3% beyond the optimal asphalt content as shown in the job mix formula (JMF). 4. The bleeding in the driving lane was affected by high asphalt contents in the surface layer.

Jyh-Dong Lin, Jyh-Tyng Yau, Liang-Hao Hsiao (2003) Division of Civil Engineering National Central University, Taiwan Taoyuan, Chungli, 32054, Taiwan 2003 "Pavement weakening from period to period is categorized by distresses such as rutting, cracking, stripping, corrugation, potholes, etc. The back propagation neural grid is practical in this investigation to examine the connection among roadway distresses and International Roughness Index (IRI). The outcome of the examination verifies that IRI can be used whichever to assess the excellence of pavement projects or to completely answer to the appearances of the pavement weakening procedure, which can be used as the source for road maintenance evaluation. It was initiate that sever potholes. Digging/patching and rutting have the maximum connection to IRI. Man-holes, stripping, and corrugation have les connection. Cracking, alligator cracking, bleeding, and road level are the least connected to IRI. It was decided that the sensitivity simulation examination outcome founded on the skilled back-propagation neural network infers development in the IRI value of pavement after positive extent or amount of repair for each distress type.

CHAPTER 4

RATIONALE AND SCOPE OF THE STUDY

Academic research is done to investigate in specific problem and consider all factors related and affecting the problem. Specially research in Flexible pavement distress which is very important to know about the observation of distresses, severity level, overall condition of the payment, causes of the distresses, maintenance, how to prevent development of distresses and improve the quality of pavement in terms of level of services. So research in mention area can help for prevention of distresses in flexible pavement and increasing the quality of the surface.

CHAPTER 5

OBJECTIVES OF THE STUDY

The main objective of this case study is to evaluate the distress and maintenance alternative of the Kabul Jalalabad road which is include the bellow points:

1. Determine the distress type and severity level.
2. Calculate the PCI (pavement condition index) and maintenance alternative for the distresses.
3. Find the main causes of the distress and avoid future distresses in flexible pavement.

CHAPTER 6

RESEARCH METHODOLOGY AND MATERIALS

6.1 Research Methodology

Research of flexible pavement required accurate data and Terminology to be adopted for the performing of the research and especially in research to Evaluate the surface and Calculate the Pavement Condition Index and find the causes of the distressed and chose maintenance alternative all depend on the accuracy and methodology for the observation and data collection and methodology to perform the research. The terminology adopted for this research is as below:

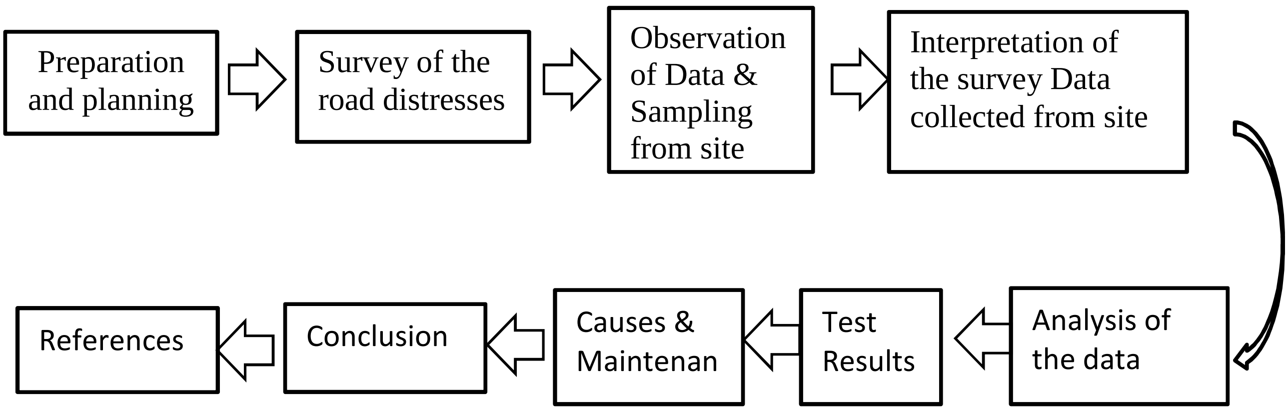


Figure 4: Research Methodology

6.2 Site Visit and Reconnaissance Survey

Before collecting the data practically from site the site reconnaissance survey has been done in vehicle and to visit the site and preliminary check the condition of the pavement and records that which type of the distress are exist on the pavement Surface. The purpose of this survey is to know about the existing distresses on the pavement surface and before starting collection of data from site to study about the distresses which are exist and to determine in the reconnaissance survey and to know how to measure the distress and determine the severity level of each distress for collecting the data we used the survey of distresses as per ASTM D-6433 Pavement condition index survey.

6.3 Field Distress Survey and Sampling

The study area have only one branch of 10 km road along the Kabul Jalalabad Road (NH-1) as per the site condition and different exit points and sub roads connected to the road the branch is divided on 10 sections each 1 km and each section are divided on 33 sample unit each sample unit is 300 square meter and total number of sample units are 330. And to identify the sample unit easily the GPS has been used for the survey to record the coordinate on each sample units instead of marking each sample units which can find easily by the inspector or surveyor if checking the previous sample unit and to locate the sample unit easily in road pavement surface. The GPS point able to accurately relocate the sample units to allow verification of current distress data by using the GPS we can find the previous sample unit which records on data sheet with GPS point or coordinate and can relocate it easily in the location necessary.

The number of sample unit is selected for inspection which providing the 95% confidence level. The study area is on NH-1 which has more traffic and it is difficult to inspect all sample units of the section so we select the sample unit to inspect to obtain 95% confidence of the PCI within a sections. The number of the sample units inspected is determined based on the ASTM D-6433 formula as calculated bellow:

n= $\frac{}{(- (\quad) \quad)}$ ………..1

N=Total number of sample units in the section.

e=acceptable error in estimation the PCI of the section which is commonly +- 5 PCI points.

S= standard deviation of the PCI from one sample unit to another within the section. For performing the initial inspection is assumed 10 for flexible pavement.

n= $\frac{*}{(- *(\quad) \quad)}$ = 15 sample units and both section 30 sample units.

To determine the accurate PCI of the pavement for obtaining the 95% confidence level is critical and the number of sample units inspected must be confirmed. The actual standard deviation is calculated and based on actual standard deviation the number of sample units inspected are determined. After calculation of the PCI for all sample units and sections the actual standard deviation is calculated to check and confirm the number of the sample units inspected if it is less then, if the number of sample units inspected are less the additional sample units are inspected and the PCI are determining based on all inspected sample units.

The actual standard deviation is estimated as S=((PCIi − PCIs)2/(n − 1))0.5=14.73..2

Actual number of sample units to be inspected is: n= $\frac{* \quad .}{(- *(\quad) \quad . \;)}$ = 14 for both section =28 is less than number of sample units inspected so no need for additional sample units to inspected.

After the number of sample units determined the first sample unit is selected randomly from first sample units and the space between two sample units are determined as bellow:

Space=total length of the branch/number of sample units to be inspected 10075/31=325m.

Before inspector start the survey and inspection to site field he should have enough knowledge about the distresses type, severity level and how to measure the distresses because the wrong recording of data and selecting of severity level will affect the sample PCI and whole section PCI. Each sample unit should inspect and survey individually. Sketch the sample unit including orientation and dimension and record the branch, section number, station, and type of the sample wither it is random or additional as well as the size of sample unit. And type of distress along with its dimension (length, breadth or diameter) with distress severity level. So thus before starting actual work inspector should carefully study all type of distresses to identify the distress types accurately 95% of the time. Linear measurements should be considered accurately along with area measurements when both are in within 10% and 20% respectively if re-measured. Severity of distress should be determine based on riding quality and should be consider subjectively.

The survey conducted for this case study was done by walking over the road with a 4 inspector team member and all sample units have being surveyed which was selected. During surveyed and inspection of the sample units by walking over the road first determined the type of distress and recorded on the survey form. After type of distress the sample unit is recorded wither random or additional then measured the distress and noted in the survey form after measuring the distress the severity level are noted based on ride quality and visual inspection along with dimension of the distress severity. Beside that site pictures are kept and the GPS coordinate was recorded and noted for each distress to determine the exact location of the distress on the road section. Then moved to section sample unit for inspection and survey. As the current condition of the road is fair, not too bad almost all of the sample units have only one single distress which have recorded in survey form.

6.4 How to Measure the Distresses

Table 2: Distress Measurement and Severity Level

No	Type	Severity Level			How To Measure
		Low	Medium (M)	High (H)	
1	Alligator Cracking	Longitudinal, fine hairline cracks which are parallel and only few are connecting each other and not spelled.	Development of light cracks which become as a network of cracks and lightly spelled	Cracks network development that the pieces are well defined and spelled at the edge.	Alligator cracking is measured on Square meter. If 2 or 3 type of severity is occurred at same area each of them should separate and recorded which is difficult if these cannot separate then the high severity should be consider.
2	Block Cracking	unfilled cracks having <13mm width or Filled cracks with any width which filled by satisfactory filler without faulting.	Unfilled crack having width of 13 to 50mm or filled crack having any width with faulting of <10mm	Unfilled crack having width of >50mm or filled crack having any width with fault of >10mm	Block cracking measured by square meter of surface and if different severity exist each of them should be noted separately but mostly it is in one severity level.
3	Bleeding	Asphalt does not stick to shoes or tire of the vehicle and occurred during some part of the year	Asphalt stick on shoes and tire of vehicle and occurred during few weeks of the year	Asphalt sticks to shoes and tire and occurred extensively and several weeks of the year	Bleeding is measured in square meter of the area and polished aggregate should not be count if bleeding is counted
4	Longitudinal/ Transverse Cracking	Unilled crack having width less than 10mm or filled crack having any width with good condition	Unfilled crack having width of 10 to 75mm or filled crack having any width surrounding by light cracks	Unfilled crack having width more than 75mm or filled crack having any width surrounding by medium or high severity	Longitudinal and Transverse cracks measured in linear meters. If severity is varies along the length each serverity should be measured separately
5	Depression	Having depth of 13 mm to 25 mm	Having depth of 25mm to 50 mm	Having depth of more than 50 mm	Depression is measured in square meter of square feet of surface area

6	Slippage Cracking	Crack having average width of less than 10mm	Crack having average width of 10 to 40 mm or the surrounding area of crack having secondary cracks or spelled	Cracks having the average width of >40mm or the surrounding area of crack is broken	Slippage Cracking measured on square meter of surface area and noted the high severity level in case of variety of severity level
7	Bumps and Sags	It is measured based on the riding quality	Medium Severity riding quality	Caused high severity riding quality	Bumps and Sag measured in Linear Meter if occurred with other distress both are recorded
8	Patching	It is recorded based on condition of the disstress	Patch in moderate condition is recorded as medium severity level	Badly deteriorated patching is recorded as high severity level	Patching is measured in square meter of the surface area
9	Rutting	Rutting having mean depth of 6-13mm	Mean depth of 13 to 25mm	Rutting having depth of >25mm	Rutting is measured in square meter of surface area and severity is measured based on mean depth
10	Potholes	If depth 13-25mm and Dia 200-450mm and if depth 25-50mm & dia100-200mm	Depth 13-25mm dia 450-750 & depth 25-50mm dia200-400mm & depth >50mm dia 100-450mm	Depth 25-50mm dia 450-750mm & depth>50mm	Potholes are measured by the counting the number that are low, medium and high severity

Figure5: Medium Alligator cracking **Figure6: Block cracking**

Figure7: High severity Depression **Figure8: Low Severity Corrugation**

Figure9: Medium Severity Depression **Figure10: High Severity Potholes**

Figure11: Medium Severity Pitching

Figure12: High Severity Rutting

Figure13: Medium Severity Slippage cracking

Figure14: Medium Severity Transvers

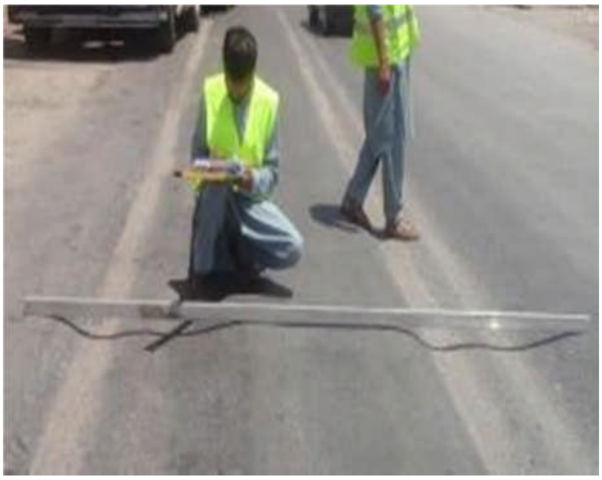


Figure15: Medium Weathering & raveling

Figure16: High Severity Rutting

6.5 Sampling and Testing of the Pavement Materials

To perform the Evaluation of the pavement distress it is often required to collect the sample of placed materials to site and evaluate the characteristics of materials placed on site. This required careful testing of materials and to conduct these tests required to collect the sample from the site. Then tests these collected samples on laboratory. As per field distress survey it is clearly shown that cracks and deformation is more in the pavement and along the distress survey the tests also should performed to find the causes of the distresses. So for this purpose the samples have been taken from the pavement surface (Core cutting) and the sample of the Sub grade soil have been taken to perform tests Figure-1.

1. To find the bitumen content and to know about the thickness of the asphalt concrete.
2. To find the stability of the asphalt concrete.
3. Specific gravity of the asphalt concrete.
4. Air voids percentage in the asphalt concrete.
5. Optimum Moisture Content of the sub grade soil.
6. Maximum Dry Density of the sub grade soil.
7. CBR of the subgrade soil.

Figure17: Core cutting

Figure18: Core cutting

CHAPTER 7

ANALYSIS AND TESTS

This section describes the Pavement Condition Index (PCI) calculation as per ASTM 2007 (American Standard of Testing Materials. and starts with an introduction of the Pavement Condition Indices based on the distress survey data collected from site, introduction of pavement Condition Rating, Procedure and calculation of PCI.

7.1 Pavement Condition Indices

This section has focused to predict the condition of the pavements which function as a cumulative traffic, pavement characteristics and environmental condition over the service life. Pavement condition can be measured based on the distresses and failure occurred in the pavement. The first efforts established in the 1950s for the pavement performance evaluation that pavement considered to be satisfactory or unsatisfactory. The pavement condition index combines all the deterioration of the pavement in single number and this number indicates the condition of the pavement either to be good or not. Pavement performance measured by different types of the pavement condition indices from different perspectives.

7.1.1 Pavement Condition Index (PCI)

PCI developed by the US Army Corps of Engineers in 1979. This method evaluates the pavement condition based on Pavement distresses visual examination, Severity of the distresses observed on the pavement surface. Pci provides the number to pavement surface and indicates the maintenance alternatives and shows that pavement surface required to maintenance, repair, or overlaid. PCI used to indicate general condition of the pavement surface by numerical number from 0 to 100. 0 represent the worst section and 100 representing best possible condition which has been standardized by ASTM for roads and parking lots Pavements, Figure15.

Table3: Typical Pavement M&R Strategies.

PCI	Rating	Strategy
85 to 100	Good	Routine Maintenance
70 to 85	Satisfactory	Preventive Maintenance
55 to 70	Fair	Minor Rehabilitation
40 to 55	Poor	Minor Rehabilitation
25 to 40	Very Poor	Major Rehabilitation
10 to 25	Serious	Reconstruction
0 to 10	Failed	Reconstruction

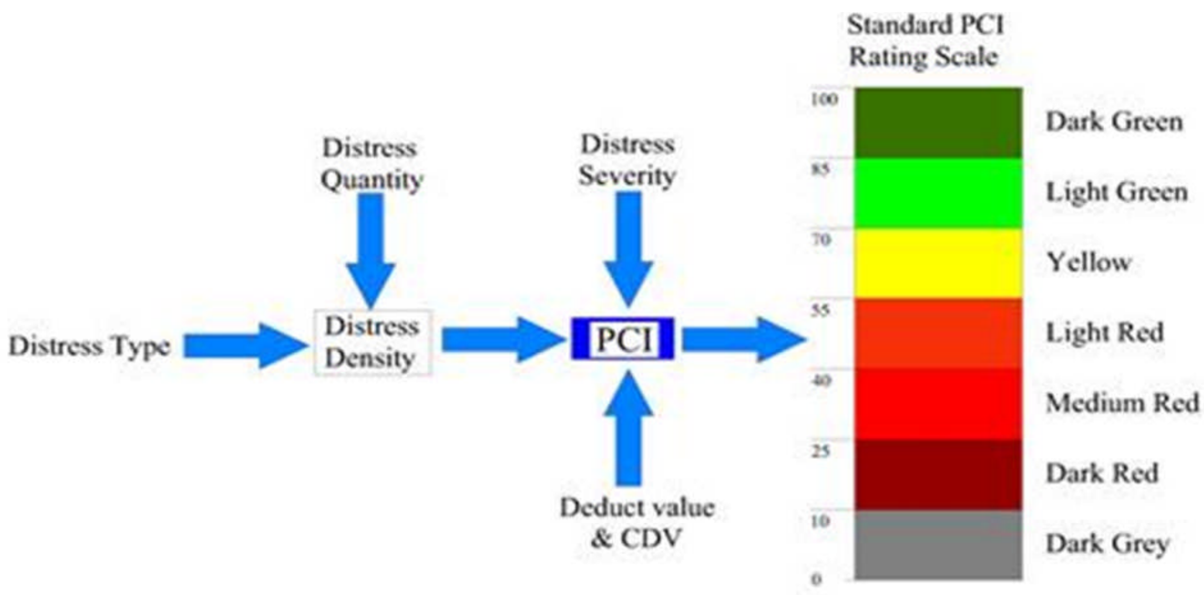


Figure19: Standard PCI Rating Scale

7.2 PCI Calculation Procedure

The pavement is divided into Branches and the branches divided into sections and each section is divided into sample units.

Pavement Branch: it is an acknowledgeable or identifiable part of the pavement network that is entity and has a distinct or obvious function. For example each parking or roadway area is a different branch.

Pavement Section: An adjacent pavement area having a same condition, maintenance, construction as well as same traffic volume and design.

Pavement Sample Unit: it is a subdivision of the pavement section which has the standard size of 2500 SF +-1000 SF.

Pavement Distress: External defects and indicator of deterioration of the pavement condition which is caused by Fatigue, loading, environment, design, construction problem, and combination of these. Typical distresses are Cracks, Deformation, Deterioration and mad problem which are classified on the Low, medium, and high severity level based on the severity and development of the distress and its effect on pavement surface which can identify from surface visibility.

Distress Density: Ratio of the distress upon the area is called distress density and measured by percentage which is obtained by dividing of total quantity of each distress type at each severity level by total area of pavement section.

Deduct Value (DV): it is statistical weight number of distresses by which determining the combined condition index for each type of distresses. For each type of the distress and severity level the deduct value curve exist as per the ASTM D-6433 to find the deduct value for each severity level of pavement distresses.

Corrected Deduct Value (CDV): Corrected deduct value (max CDV) is used to find the PCI for the pavement so there for it is required to adjust the cumulative or total deduct value (TDV). CDV adjust TDV to adjust it for a range of 0 to 100 by using the curves of the CDV-TDV. In case there is only one deduct value, then the deduct value is used instead of the CDV for determining the PCI as per ASTM PCI=100-maxCDV.

7.3 PCI Calculation

To calculate the PCI of the sample unit's five basic steps involved which are as bellow:

Step1. Every Sample unit is inspected and distress data noted on the Survey distress form of the Flexible pavements.

Step2. The deduct Values are determined for each sample units from the deduct value curves based on the density of the distress along with severity level figure17.

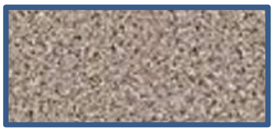
Step3. Total deduct value is calculated by summing all deduct values of individual sample unit.

Step4. The corrected deduct value (CDV) is computed based on the total deduct value and greater individual deduct value from graph the corrected deduct value is computed figure 18.

Step5. The Pavement Condition Index (PCI) is computed using the corrected deduct value relation PCI=100-CDV and rating the pavement based on the value of the PCI.

7.4 PCI Results for Road Sections and Random selected sample units

Table 4: PCI Results for Road Sections and Random Selected Sample Units

Kabul Jalalabad Road Pvamenent distresses Evaluation **Branch:Road Proj NH-1 Station:0+000-10+130** **Sample units: From 1 to 32, Sample Area:300 sqm** **Surveyed by: Abdul Moqtader Yousufzai** **Date: 07,08, and 09 of July 2016**	**Sketch:** **30 M** **10 M** 

1. Alligator Cracking	**7. Edge Cracking**	**13. Potholes**
2. Bleeding	**8. Reflection Cracking**	**14. Rutting**
3. Bumps and Sags	**9. Lane/Shoulder Drop Off**	**15. Showing**
4. Block Cracking	**10. Longitudinal Cracking**	**16. Slippage cracking**
5. Corrugation	**11. Patching (L,M,H, sqm)**	**17. Swelling**
6. Depression	**12. Polished Aggregate**	**18.Weathering & Raveling**

Distress Severity	Location	Quantity	Total	Density	Deduct Value	CDV	PCI	Area (Aai)	PCIai*Aai	Section PCIs	Rating
6L	0+000	9X1	9	3.00	6.4	6.4	93.6	300	28080		
4M	0+325	11x1.2	13.2	4.40	38.1	38.1	61.9	300	18570		**Satisfactory**
16M	0+650	1.2x1	1.2	0.40	5.8	5.8	94.2	300	28260		
16M	0+975	4.5x1	4.5	1.50	13.7	13.7	86.3	300	25890		

								1200	**100800**	**84.00**	
10M	1+300	9	9	3.00	16.8	16.8	83.2	300	24960		**Fair**
1L	1+625	25x3	75	25.00	45.2	45.2	54.8	300	16440		
1M	1+950	30X1	30	10.00	48.2	48.2	51.8	300	15540		
								900	**56940**	**63.27**	
6M	2+275	8X3	24	8.00	26.05	26.05	73.95	300	22185		**Fair**
3M	2+600	15	15	5.00	52	52	48	300	14400		
10M	2+925	8	8	2.67	13.6	13.6	86.4	300	25920		
								900	**62505**	**69.45**	
1L	3+250	3x1	3	1.00	11	11	89	300	26700		**Satisfactory**
1L	3+575	10x1	10	3.33	21.2	21.2	78.8	300	23640		
11M	3+900	20X7.5	150	50.00	57	57	43	300	12900		
								900	**63240**	**70.27**	
11M	4+225	30X9	270	90.00	58	58	42	300	12600		**Poor**
14M	4+550	30X8	240	80.00	65.15	65.15	34.85	300	10455		
13H	4+875	2.3X0.8	1.84	0.61	45	45	55	300	16500		
								900	**39555**	**43.95**	
11L	5+200	10X2	20	6.67	12.6	12.6	87.4	300	26220		**Satisfactory**
1L	5+525	3x1	3	1.00	11	11	89	300	26700		
1L	5+850	10x1	10	3.33	21.9	21.9	78.1	300	23430		
								900	**76350**	**84.83**	
11L	6+175	30X5	150	50.00	33.45	33.45	66.55	300	19965		**Poor**
11M	6+500	20X6	120	40.00	58	54.2	45.8	300	13740		
1M	6+825	20X5	100	33.33	64	64	36	300	10800		
								900	**44505**	**49.45**	
1M	7+150	10X7	70	23.33	59	59	41	300	12300		**Very Poor**
6H	7+475	15X5	75	25.00	60.9	60.9	39.1	300	11730		
18H	7+800	30X7	210	70.00	73.1	73.1	26.9	300	8070		
								900	**32100**	**35.67**	
14H	8+125	25X6	150	50.00	62.2	62.2	37.8	300	11340		**Very Poor**
14H	8+450	30X5	150	50.00	84.15	84.15	15.85	300	4755		
1L	8+775	30X7	70	23.33	44.1	44.1	55.9	300	16770		
								900	**32865**	**36.52**	
14M	9+100	10X7	70	23.33	54.85	54.85	45.15	300	13545		**Poor**
4M	9+425	30X5	150	50.00	33.85	33.85	66.15	300	19845		
1L	9+750	20X5	100	33.33	49	49	51	300	15300		
14M	10+075	30X5	150	50.00	62.2	62.2	37.8	300	11340		
								1200	**60030**	**50.03**	
PCI of the Branch								**9600**	**568890**	**59.26**	
Standard Deviation of PCI										**14.73**	

Table 5: Surveyed samples distress percentage Compared to total area of Road surveyed.

Type of Distress	Distress Area of surveyed sampled	Distress% /Total area of samples surveyed
Alligator Cracks	471	4.906
Block Cracks	163.2	1.700
Bumps and Sags	15	0.156
Depression	108	1.125
Longitudinal Cracks	17	0.177
Patching	710	7.396
Potholes	1.84	0.019
Rutting	760	7.917
Slippage Cracks	5.7	0.059
Weathering & Raveling	210	2.188

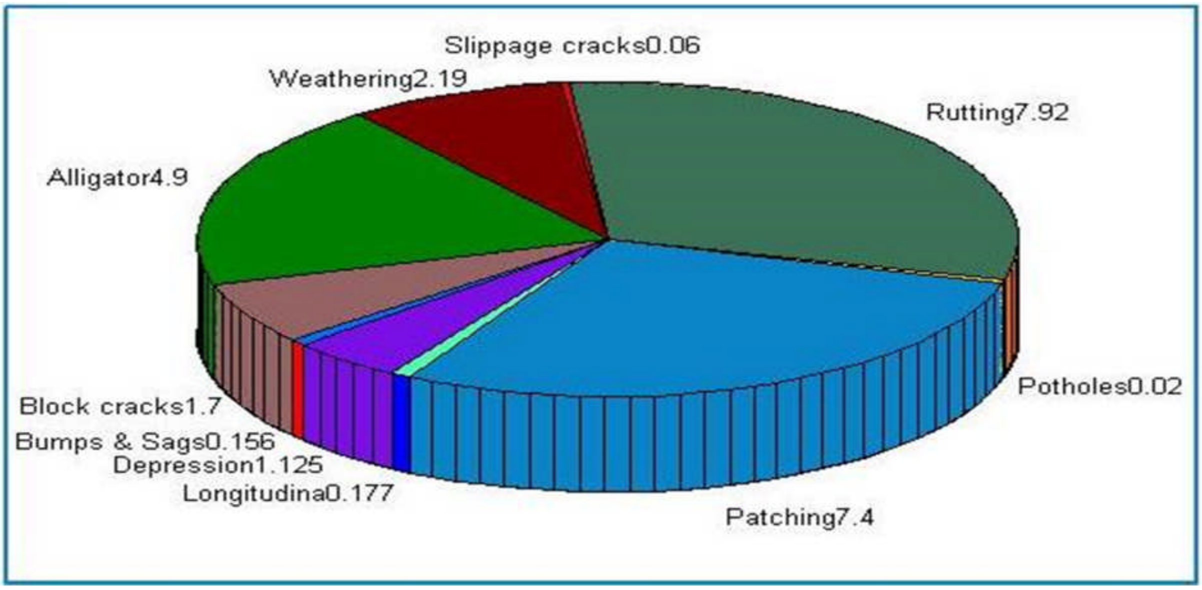


Figure 20: Distresses Pie Chart Combination.

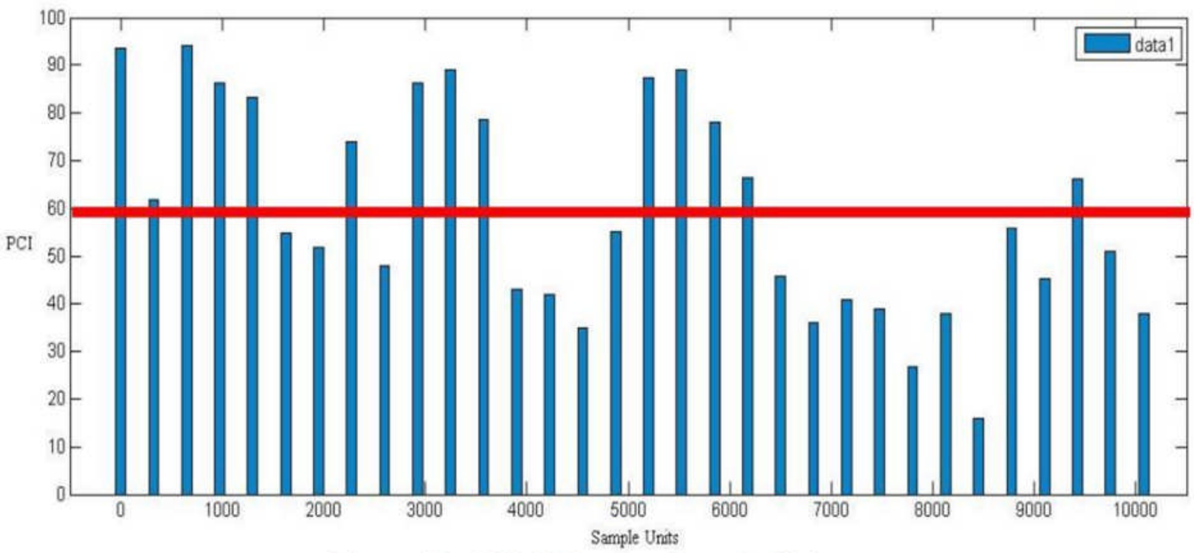


Figure 21: PCI Values on Sample Units.

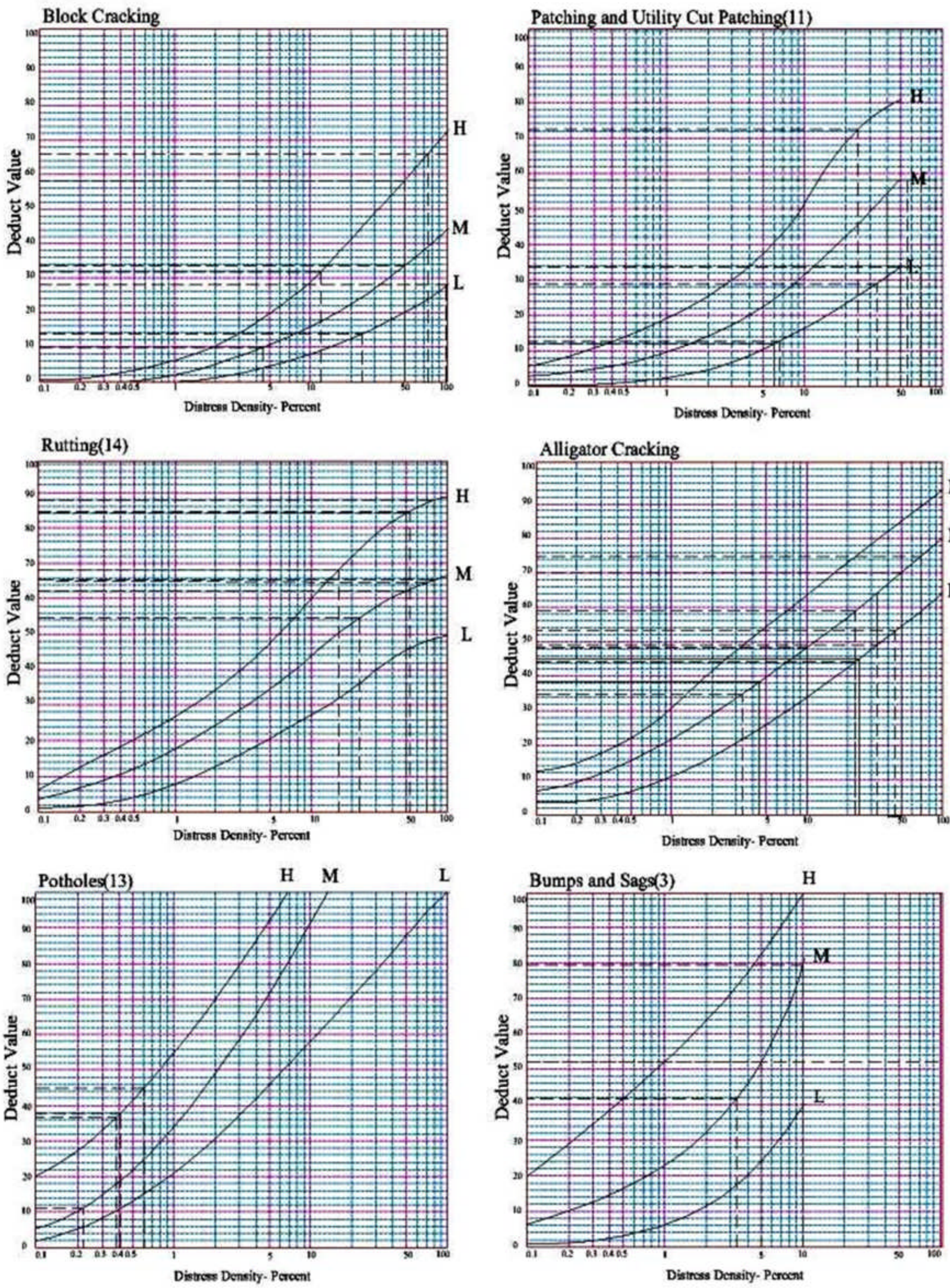


Figure22: Deduct Value Curve graphs

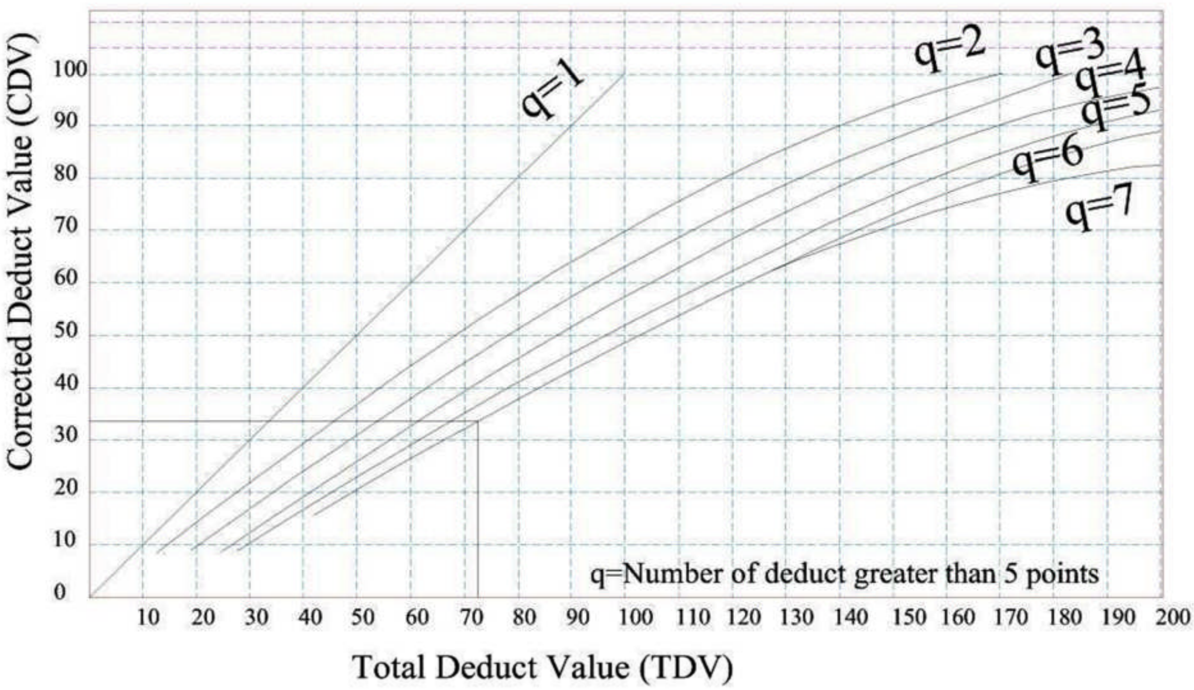


Figure 23: Total Deduct Value Curve graphs

7.5 Tests and Results

It is very important to perform the test on pavement layers of Flexible Pavement to find the result and determine the causes of the distresses exist so the samples collected from site were kept in standard condition based on ASTM and AASHTO and the results are recorded. All the tests are performed in Non-governmental laboratory Asia Geo Engineering and Ally Engineering Solution (AGE & AES).

Tests have been selected based on site condition and Distresses exist on the pavement to reach to adequate result and find out the main causes due to which the distresses occurs and developed and bellow tests have performed:

7.5.1 Extraction of Bitumen and stability value

Sample for this test is taken from two locations which has high severity Rutting and high Severity cracks to determine the bitumen content in the pavement and find out the causes of the high severity Rutting and cracking and to know whether variation in bitumen content effect the condition of the pavement or not. The test has performed based on ASTM D 2172 and found that Average Bitumen Content is 4.59% and lies in the range of (4-6.5) %.

The stability value requires for the pavement is 8KN and the achieved stability values obtained is 9.698 KN details are in Appendix1.

7.5.2 Theoretical Maximum Specific Gravity of Asphalt Concrete (GMM).

To find out the Density of Compacted Asphalt concrete and maximum specific gravity of asphalt concrete this test have performed according to ASTM D2041 at 25° C. the specific gravity should be greater than 2.5 and the obtained theoretical maximum Specific Gravity is 2.52. along with GMM the Air voids percentage, Resistance of plastic flow of asphalt concrete are find out and details are in the Table 12 and Appendix1.

Table 6: Test Results of Air voids, Stability and flow.

Unit Weight Gr/cc		**Air void %**		**VMA %**		**VFA %**		**Stability (Kn)**		**Flow at 0.25mm**	
Req	Obt	Req	Obt	Req	Obt	Req	Obt	Req	Obt	Req	Obt
2.4	2.36	3 to 5	6.50	12 to 14	15.20	65 - 75	58.50	8.00	9.70	4 to 8	11.30
Not Specified		ASTM		MORTH		MORTH		ASTM D1075-1979		ASTM D1075-1979	

7.5.3 Sub Grade soil CBR (California Bearing Ratio) Test

The purpose of this test is to determine the stability of the soil some time distresses are occurs due to weak foundation or sub grade soil and less thickness of the pavement and due to less stability the permanent deformation occurs at foundation and same occurs at the pavement of the road and cracks are finding on the surface of road so it is necessary to determine and find the stability of foundation soil for this purpose the CBR Test are performed on collected soil but before performing the CBR test tests of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) should be performed the purpose of the OMC is to determine the optimum water observed by the soil and based on that amount of water we are adding the water in CBR Test and the purpose of the MDD is to find the maximum dry density and based on OMC we are finding the dry density of the soil means in which amount or percentage of water the soil will compact or reached to maximum dry density and after performing the OMC and MDD the CBR test are performing and finding out the stability of the foundation soil details are in Appendix1.

7.6 Causes and Problems of the Distresses

The distresses that identified and measured during the surveys are listed and the causes of these distresses are found out through different factors which are discussed below in details:

7.6.1 Alligator Cracking

It is structure failure, and create problem of Roughness and may further deteriorate to a Pothole the causes of this type of the distress from literature reviews are as under:

- ❖ Inadequate structural support
- ❖ Decrease in load supporting characteristics or loss of support of the pavement layers (Sub grade, Sub base or Base).

- ❖ Sudden increasing of loading or heavier and more loads in comparison to the Design load.
- ❖ Improper design of pavement.
- ❖ Poor Construction of the road and poor compaction of the road layers.

Table7: Current Traffic Volume Count on the Road.

Volume/Day	Volume/Year	Total Volume in ESAL
16027	5849855	58498550

7.6.2 Block Cracking

This type of failure is also structure failure and crate problem of roughness on the pavement and water infiltration. Water inters in the cracks and increases the moisture content of the base and further develop and create the potholes and deteriorate the pavement the causes of this type of cracks are as under:

- ❖ Hot Mix Asphalt Shrinkage and variation or cycling of daily Temperature
- ❖ Inability and wrong selection of asphalt binder to contract and expand with cycling of Temperature which is due to Aging of Asphalt Binder and wrong selection and poor choice of Asphalt Binder in The Mix Design.
- ❖ Increase or high Void Content.
- ❖ Hardening of the Asphalt Concrete due to Oxidative.

7.6.3 Longitudinal and Transverse Cracking

These cracks allow water to inter in the pavement layers, Roughness, indicate beginning of the Alligator cracking and structural failure the causes of these types of cracks are:

- ❖ Poor construction of road joints and construction of joints on wheel path will cause the longitudinal joints.
- ❖ Fatigue of the Asphalt Concrete Pavement causes these types of joints.
- ❖ Pavement Contraction due to Temperature Variation.

7.6.4 Slippage Cracking

These types of cracks having half-moon or U shaped cracks which having two ends pints in the wheel path and create the problems of roughness and water infiltration and possible causes of the slippage cracks are:

- ❖ Sudden braking of the vehicles especially heavy vehicles.
- ❖ Turning of the vehicles cause the pavement to slide and deform which has low strength and poor bonding with underlying layers.
- ❖ It occurs due to accelerating on wheel paths.

7.6.5 Bleeding

Bleeding is a picture of the asphalt binder on the surface of the pavement when the pavement surface is wet it create problem of the loss of skid resistance and possible causes of the bleeding are as under:

- ❖ When bitumen fills the voids of the asphalt binders bleeding occurs in the hot weather condition then the bitumen expands onto the pavement surface because during cold weather the bleeding is not reversible and accumulate on the surface of the pavement which is due to:
- ❖ Increase in asphalt binder in the hot mix asphalt due to mix design or manufacturing.
- ❖ Increase in the bitumen during DBST or SBS application.
- ❖ Excessive prime coat or tack coat application on base course.
- ❖ Decrease in Hot Mix Asphalt Voids for example not enough voids that bitumen take place in voids during hot weather.

7.6.6 Depression

Pavement surface having lower elevation in comparison to the surrounding area of the surface pavement and its clearly visible after rain when fill by water and the problems due to depression are Roughness and vehicle hydroplaning and the possible causes are:

- ❖ Sub grade settlement due to poor compaction or huge filling
- ❖ Frost heave action.

7.6.7 Bumps and Sag

Small upward displacement of the pavement surface is called the bumps which is different from shoves because shoves caused by unstable pavement and bumps caused by different factors and create problem of roughness and discomfort to the road users the causes are as:

- ❖ Frost heave
- ❖ Bulging or bulking of bellow layers.
- ❖ Buildup of material due to infiltration in cracks and traffic loading.

Sags are small downward displacements of the pavement surface. But when the bumps is perpendicular to the wheel path and having the minimum space of 3m then distress called corrugation.

7.6.8 Patching

If the area of the existing pavement is repair and replace by new pavement is called the patching. However it is different from the original pavement and creates problems of roughness and discomfort of road users the possible cause are:

- ❖ It is occurs by los of aggregate from the pavement surface.
- ❖ Oxidized asphalt binder is also cause the Patching.
- ❖ Due to poor compaction the patching occurs.
- ❖ When asphalt concrete laid on road and not compacted in proper temperature and letting to cold then compact also cause the patching.

- ❖ Less amount of bitumen content in the asphalt concrete.
- ❖ Over heating or burning of asphalt concrete in plant more than specific temperature.

7.6.9 Rutting

Pavement surface depression in the wheel track or path due to which uplift occurring along the sides of the rutting. Rutting has two types one is Mix Rutting in which sub grade does not rut only the pavement surface rut and exhibit depression in wheel path due to Compaction and mix design. Second is sub grade rutting in which sub grade depression occurs and exhibit the depression in wheel path in sub grade due to load in result the settlement of the pavement surface and depression in the path of the wheel. When water fill the rut hydroplaning of the vehicle occurs and danger because rut tend to move or pull the vehicle on the rut path the causes of the rutting are as:

- ❖ Permanent deformation in the layers of the pavement or consolidation of the sub grade or movement of the materials due to loading of traffic.
- ❖ Less compaction of the hot mix asphalt in the initial stage during construction.
- ❖ Sub grade rutting (inadequate pavement structure).
- ❖ Improper design of mix or preparation of mix for example increase in asphalt content, excessively mineral filler, Incorrect grading, and insufficient quantity of angular aggregates.
- ❖ Hot weather temperature effect on pavement.
- ❖ Effect of Heavy loads of the traffic.
- ❖ Slow speed vehicle effect and stop/start frequently with stationary condition.

7.6.10 Potholes

Potholes are small bowl-shaped depression in the road. They are develop progressively first small depression on the top of the pavement surface and over time it is downward into the lower layers of the road pavement. Mostly occurs in the pavement having less thickness 25-50mm and seldom occurs in the pavement having thickness more than 50mm. it creates the problems of roughness and moisture infiltration which results on serious damages of vehicles. Potholes are classified based on Location, Shape, Length, location of pothole, and Depth. The possible causes of the potholes are:

- ❖ The main cause of the pothole is the Fatigue cracking. After the fatigue cracking becomes sever the water inter to the pavement surface layers and after passing of time and the cycling of the temperature water try to overcome to the surface of the road and well that portion of the surface and deteriorate and create the pothole.
- ❖ If there is any slash point in the sub grade layer and having excessive amount of the water content cause the pothole because slash pint has less strength and depressed the pavement surface and change to pothole on the pavement surface.
- ❖ Excessive amount of water content in the base course during frost heave action cause the pothole.
- ❖ Absence or inadequate drainage system cause the pothole.

7.7 Maintenance and Repair of the Existing Distresses

Based on the PCI Calculation of the existing road surface the PCI value of the branch is 59.26 and it is the number of the pavement surface and indicates the maintenance alternative for the pavement surface which has been standardized by ASTM.

Table8: Range of Branch PCI Value.

PCI	Rating	Strategy
55 to 70	Fair	Minor Rehabilitation

And as the major parts of the existing distresses are various type of cracking with Depression, Bumps and sags, Bleeding, Patching, Rutting and Potholes so various methods should be introduce to avoid development of these distresses and maintain these.

7.7.1 Maintenance and Repair of Cracking

Cracking due to loss of sub grade support or due to less strength of sub grade should be removed and remove patching the sub grade or remove the slash area in sub grade or foundation and replace with materials having enough stability.

On large fatigue cracking area indicating general structure failure an HMA (Hot Mix Asphalt) overlay on entire area should be laid.

Low severity Cracks less than 12.5 mm can be repair by Seal to prevent further development of cracks and entry of the water through cracks into subgrade which can increase the years in service life of the surface.

Non-working cracks should be repair by filling. The criteria for non-working cracks are: cracks having less than or equal to 6mm horizontal movement annually. And based on FHWA (Federal Highway Administration) cracks having less than or equal to 3mm horizontal movement are non-working cracks and should be filled.

Working cracks having horizontal movement of more than or equal to 6mm and based on FHWA 3mm should be sealed. Working cracks can be longitudinal and transverse to the pavement but most often transverse.

High severity cracks having more than 12.5 mm width should remove and overlay to repair the cracks area.

Slippage cracking area should be removed and replaced or the area should be seal by the bitumen to prevent entrance of the water through cracks.

7.7.2 Repair of Bleeding

Bellow repair measure can reduce or eliminate the bleeding on the surface but cannot correct the underlying problem of the bleeding.

Minor bleeding can be repair and correct by applying the coarse sand on the pavement surface.

Major bleeding can be repair by removing the excessive bitumen content by the grader or by heater planer.

7.7.3 Repair of Depression

The depression area should be removed and dig up to depth of the subgrade to remove the root cause or poor subgrade or frost heave and replacing then patching over the replacing area of subgrade.

7.7.4 Repair of Bumps and Sags

Small bumps and sag having depth less than 1/3 inch should be left untreated and bumps and sags having depth of more than 1/3 inch should level and overlay. High severity bumps and sags due to frost heave should remove the route cause and underlying materials and replace with suitable materials and overlay.

7.7.5 Repair of Patching

The patch area should cut and remove then applied the bitumen coat for binding of the layers then overlay by asphalt concrete.

7.7.6 Repair of Rutting

Rutting having less than 1/3 inch of deep should be left untreated and deeper rutting should be level first then after that overlay the rutting area if rutting is due to sudden tire wear or poor mix design. Rutting due to subgrade rutting should be removed and replace the subgrade and overlay by HMA.

7.7.7 Repair of Pothole

After determining the causes of the potholes the area should cut and remove then replace the los materials and dry the bottom surface of the potholes and applied the bitumen coat then overlay.

7.7.8 Repair or Treatment Performance

Performance of the treatment is depending on crack preparation and the type of material used for treatment. It has been found that based on selection of materials and preparation the crack sealants can provide up to 9 years of service and the performance of crack filling is 8 years. The crack treatment should be laid not more than 12.5mm on both side of the cracks and the surface should be flushed with road surface.

Emulsions or asphalt materials when placed in cracks which are unrouted can provide 2 to 4 years of service performance and hot applied rubber and fiber modified asphalt can provide 6 to 8 years of service performance.

7.7.9 Materials for Crack Sealing and Filling

Sealing materials should be selected such that adhere to the walls of the cracks and with movement of the cracks due to loading stretch and resist to damage and abrasion. Elastomeric materials should select for the sealant which is the perfect materials for the sealing which have low modulus of elasticity and easily extend and stretch 10 times of the non-stretch dimension. Sealant has high viscosity at ambient temperature and mostly used in high elevation areas. Sealing should be hot before applied to the area for the good adhesion and bonding purpose to the walls of the cracks.

Filling materials applied on non-working cracks and should be selected such that has good bonding with walls of the cracks and have abrasion resistance due to traffic loading and damage. Hot applied rubber and polymer asphalt are the suitable materials for crack filling. Cold emulsion products such as Styrene Butadiene Rubber (SBR) due to good bonding properties with walls of cracks are suitable materials for filling. Specification of sealing and filling materials based on AASHTO are lists in Table.

Table9: Specification for Crack sealing and filling.

Material	Specifications AASHTO	Application Type	Approx Life (Years)
Asphalt Emulsion	M 140, M 208	Filling	2 to 4
Asphalt Cement	M 20, M 226	Filling	2 to 4
Fiber Modified Asphalt	No Specification	Filling	6 to 8
Polymer Modi-fied Emulsion	M 140, M 208	Filling & Sealing	3 to 5
Asphalt Rubber	No Specification	Sealing	6 to 8
Low Modulus Asphalt Rubber	No Specification	Sealing	5 to 9
Silicone	No Specification	Sealing	4 to 6

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 Conclusion

Based on study and survey have performed it found that the existing distresses are Cracking, Deformation, Deterioration and mad Problem and based on Analysis and calculation of Pavement Condition Index (PCI) the branch have 59.26 which is coming in the range of 55-70 require the Minor Rehabilitation. The finding and conclusion are listed below:

I. PCI for the branch has calculated based on ASTM D6433 and found that branch has the PCI of 59.26.
II. Based on PCI calculation Value Minor Rehabilitation is required.
III. The main cause of all type of cracking which is developing in short time is maintenance there is no proper maintenance due to which the minor and low severity cracks are change to medium and high severity cracks in short time due to entrance of the water in the winter seasons.
IV. The Main causes of the Alligator Cracking based on study are 1) Traffic Volume which exceed the design volume. 2) Absence of Drainage. 3) Heavy loaded truck which carries loads more than Design Load. 4) Selection of wrong grade of the bitumen which not expands and contract due to temperature cycling as the area has different temperature during summer and winter.
V. Causes of the block cracking based on study and core tests which have taken from site are: 1) Increase of void content based on core test. 2) Selection of wrong grade of bitumen.
VI. Longitudinal and transverse cracking cause is Poor construction of joints.
VII. Cause of the slippage cracking based on study is the sudden braking of the heavy vehicles.
VIII. Deformation (depression, bumps and sags) occurs on site due to frost heave action because there is no proper drainage to flow the water and water is observed by the base of the surface.
IX. Causes of the rutting based on study are: 1) Heavy loads of the traffic. 2) Based on Core cutting test and analysis improper design of Mix is the main cause of the rutting.
X. Patching causes based on study are loss of aggregate from the pavement due to wrong selection of the bitumen and second less amount of bitumen content based on test the bitumen content is 4.5% less than HMA Mix design.
XI. The main cause of the potholes is alligator cracking in which the water entrance occurs and further developed on potholed with passing of time and due to heavy loaded traffic.
XII. Working cracks (cracks having more than 6mm horizontal movement annually) should seal and non-working crack should maintain by filling the cracks.

8.2 Future Scope

Research is performing in the specific area and problem to investigate on specific problem and find out the rout cause of the problem and used it in the future projects for avoiding the occurrence of problem on which investigation performed. The future scope can be list in bellow points:

I. To improve the standard and code for construction of flexible Pavement.
II. Accurate distresses observation method and analysis of Pavement Condition Index.
III. Factors and causes of distresses and how to prevent further development of the distresses.
IV. Improve the quality of the pavement surface or Level of Services.

CHAPTER 9

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CHAPTER 10

APPENDIX

ASIA GEO ENGINEERING & ALLY ENGINEERING SERVICES

Engineering Survey, Design & Construction Material Testing Services

EXTRUCTION OF BITUMEN AASHTO T164-94 / ASTM D2172-88

Project:	**Kabul - Jalalabad Road Distress Evaluation (Research Purpose)**
Client:	Research Project
Contractor:	Abdul Moqtadir
Laboratory	Asia Geo Engineering & Ally Engineering Services
Location	Road Edge
Purpose	Extruction of bitumen from asphalt mixture and determination of density
Date Sampled:	Mar 10, 2017
Date Tested:	Mar 13, 2017
Specification Requirements, %	

Specimen Reference No:	**Units**	**1**	**2**	
Mass of sample and bowl before extraction	W5	4653.0	4567.9	*Measure*
Mass of sample and bowl after extraction	W4	4557.0	4479.0	*Measure*
Mass of oven-dried filter paper	W3	21.0	21.1	*Measure*
Mass of filter paper after extraction	W2	25.7	26.3	*Measure*
Mass of bowl	W1	2704.0	2704.0	*Measure*
Mass of sample before extraction	g	1949.0	1863.9	$A = W5 - W1$
Mass of mineral matter in the extract	g	4.7	5.2	$B = W2 - W3$
Mass of extracted mineral aggregate	g	1853.0	1775.0	$C = W4 - W1$
Percent Bitumen Content	%	**4.68**	**4.49**	$D = \frac{A - (B + C) \times 100}{A}$
Average Value, %				**4.59**

Note:

Tested by:	Abdul Moqtader	Certify by:	AGE & AES
Signature:			

ASIA GEO ENGINEERING & ALLY ENGINEERING SERVICES

Engineering Survey, Design & Construction Material Testing Services

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES (Gmm)

AASHTO T 209-94 / ASTM D 2041-03a

Project:	**Kabul - Jalalabad Road Distress Evaluation (Research Purpose)**
Client:	Research Project
Contractor:	Abdul Moqtadir
Laboratory	Asia Geo Engineering & Ally Engineering Services
Location	Road Edge
Purpose	Extruction of bitumen from asphalt mixture and determination of density
Date Sampled:	Mar 10, 2017
Date Tested:	Mar 14, 2017
Specification Requirements, %	NR

Specimen Reference No:	Units	1	2	
Mass of jar, plate, sample and water.	W3	4539.0		*Measure*
Mass of jar, plate, and sample	W2	2573.0		*Measure*
Mass of jar, plate, and water	W4	3860.0		*Measure*
Mass of jar and plate	W1	1448.0		*Measure*
Mass of Sample	g	1125.0		A = W2-W1
Mass of Water in full jar	g	2412.0		B = W4-W1
Mass of water used	g	1966.0		C = W3-W2
Volume of Sample Particles	ml	446.0		D= B - C
Maximum Specific Gravity (Gmm)		**2.52**		A / C B -
Average Value	Kg/m³			**2.52**

Note:

Tested by:	Abdul Moqtadir		Mar 15, 2017 AGE & AES
Signature:		Certify by:	

RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES USING MARSHALL APPARATUS BY TOTAL WEIGHT OF MIX

(AASHTO T 245) (ASTM D 6926) (ASTM D 6927) (ASTM D 2041)

Project:	**Kabul - Jalalabad Road Distress Evaluation (Research Purpose)**
Client:	Research Project
Contractor:	Abdul Moqtadir
Laboratory:	AGE & AES (Asia Geo Engineering & Ally Engineering Services)
Location:	Road Edge

AGE&AES

Compaction Blows	75	Grade of Binder	60/70	Project:	Kabul-Jalalabad Road	Sample No:	A-01
Specific Gravity of Binder	1.030	Absorbed Binder of Aggregate (%)	0.54	Location:	Road Edge	Material:	Wearing Course
Bulk Specific Gravity of Aggregates	2.65 (Gsb)	Effective SG of Aggregates	2.690	D/Sampled:	Mar 15, 2017	Date Tested:	Mar 15, 2017

Binder by Wt of mix (%)	Specimen Height in (mm)	Mass Gms in air	Mass Gms in water	Mass Gms SSD wt in Air	Bulk Volume	(Gmb) Bulk Specific Gravity	(Gmm) Max Spec Grav (Loose Mix)	Unit Weight (g/cc)	(Va) Air Voids (%)	VMA (%)	VFA (%)	Stability Measured (kN)	Correlation Ratios (4"mold)	S Stability Adjusted (kN)	F1 Flow (mm)	F2 Flow (0.25mm)
Actual	Measure	Measure	Measure	Measure	Calc	Calc	ASTM D2041	Calc	Calc	Calc	Calc	Measure	Calc	Calc	Measure	Calc
4.59	69.00	1155.00	677.0	1158.0	481.0	2.401	2.520	2.401	4.7	13.5	65.3	9.7	1.00	9.7	2.8	11.2
4.59	58.00	948.00	555.0	951.0	396.0	2.394	2.520	2.394	5.0	13.8	63.8	10.0	1.00	10.0	2.9	11.6
4.59	59.00	1154.00	725.7	1233.0	507.3	2.275	2.520	2.275	9.7	18.1	46.3	9.3	1.00	9.3	2.8	11.2
4.59	**62.00**	**1085.7**	**652.6**	**1114.0**	**461.4**	**2.357**	**2.520**	**2.357**	**6.5**	**15.2**	**58.5**	**9.7**	**1.00**	**9.7**	**2.8**	**11.3**

Tested by:	Abdul Moqtader	Checked by:	Hamidullah Sediq	Certified by:	AGE&AES
Signature		Signature			

OPTIMUM MOISTURE CONTENT / MAXIMUM DRY DENSITY
(AASHTO T-180)

Project	Kabul - Jalalabad Road Distress Evaluation (Research Purpose)		
Client	Research Project		
Contractor	Abdul Moqtadir	Date Sampled	Mar 09, 2017
Laboratory	AGE & AES	Date Tested	Mar 16, 2017
Location	kabul,Afghanistan	No. of Blows	56
Sampling Method	Rundom Method	No. of Layers	5
		Volume of mould (m^3)	0.00213800

Compaction Curve AASHTO T-180 4.54 kg Rammer / 18 inch Drop

Test No.	1	2	3	4	5	6
Wt of Mould, gr	6997.0	6997.0	6997.0	6997.0		
Wt of Mould + Wet Soil, gr	11219.0	11561.0	11715.0	11530.0		
Weight of Wet Soil, gr	4222.00	4564.00	4718.00	4533.00		
Wet Density of Soil, kg/m³	1974.74	2134.71	2206.74	2120.21		

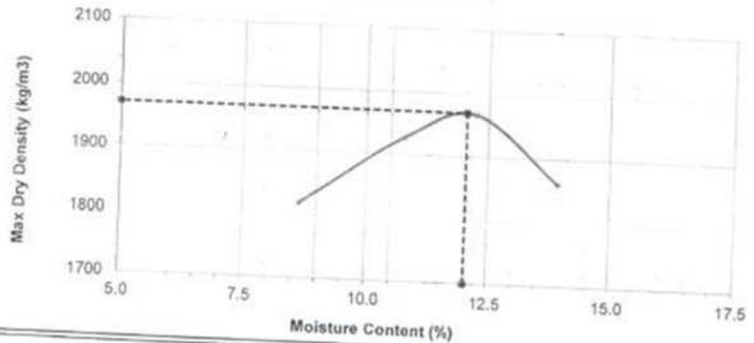
Moisture Content Determination

Moisture Content Con No	1	2	3	4	5	6
Wt. of Container, gr	49.27	25.92	53.03	53.21		
Wt. of Container + Wet Soil, gr	184.91	151.29	154.52	174.32		
Wt. of Container + Dry Soil, gr	174.10	139.09	143.44	159.50		
Weight of Water, gr	10.81	12.20	11.08	14.82		
Weight of Dry Soil, gr	124.83	113.17	90.41	106.29		
Water Content, %	8.66	10.78	12.26	13.94		

Dry Density of Soil

Dry Density of Soil, kg/m³	1817.36	1926.97	1965.82	1860.76		

OMC & MDD CURVE



Summary Result

Max Dry Density (MDD), kg/m³	1969.0
Optimum Moisture Content (OMC), %	12.1

Tested by:	Abdul Moqtadir		
Signature:		Certified by:	

AGE & AES

CALIFORNIA BEARING RATIO (CBR) AT 96 HOURS SOAKED

AASHTO T193 / ASTM D 1883

Project	Kabul - Jalalabad Road Distress Evaluation (Thisess Purpose)		
Client	Thisess Project	Date Sampled	Mar 09, 2017
Contractor	Abdul Moqtadir	Date Tested	Mar 21, 2017
Laboratory	AGE & AES	Ring Factor, kg/div	4.480
Location	Kabul - Jalalabad Road	Plunger Area (cm^2)	19.24
Sample Depth, m	1.0	Maximum Load (kN)	50

DRY UNIT WEIGHT DETERMINATION

Mould No.	1	2	3
No. of Blows	10	30	65
Wt. of wet soil + Mould, g	10901.0	11290.0	11767.0
Wt. of Mould, g	6480.0	6686.0	6884.0
Volume of Mould, cm^3	2112.0	2108.4	2108.4
Wt. of wet soil, g	4421.0	4604.0	4903.0
Wet Density, g/cc	2.093	2.184	2.326
Dry Density, g/cc	1.861	1.944	2.069
Maximum Dry Density (g/cc)	1.969		

MOISTURE CONTENT DETERMINATION

Can No.	A	B	C
Wt .of wet soil + can, g	274.26	266.37	222.00
Wt .of dry soil + can, g	250.00	243.10	203.60
Wt of Can, g	55.64	54.30	55.00
Water content, g	24.26	23.27	18.40
Wt. of dry soil, g	194.36	188.80	148.60
Moisture Content, %	12.48	12.33	12.38
Optimum Moisture Content (%)	12.10		

CBR (California Bearing Ratio) VALUE DETERMINATION

Penetraion	Mould No.			1		Mould No.			2		Mould No.			3	
	No. of Blows =			10		No. of Blows =			30		No. of Blows =			65	
mm	Dial Reading	Load (Kg)	Stress (kg/cm^2)	Corrected Stress	C.B.R %	Dial Reading	Load (Kg)	Stress (kg/cm^2)	Corrected Stress	C.B.R %	Dial Reading	Load (Kg)	Stress (kg/cm^2)	Corrected Stress	C.B.R %
0.00	0.0	0.0	0.0			0.0	0.0	0.0			0.0	0.0	0.0		
0.64	4.0	17.9	0.9			10.5	47.0	2.4			17.0	76.2	4.0		
1.27	12.0	53.8	2.8			22.0	98.6	5.1			35.0	156.8	8.1		
1.91	20.0	89.6	4.7			34.0	152.3	7.9			55.0	246.4	12.8		
2.54	28.0	125.4	6.5	9.2	13.087	48.0	215.0	11.2	17.00	24.18	76.0	340.5	17.7	27.20	38.69
3.18	36.0	161.3	8.4			64.0	286.7	14.9			95.0	425.6	22.1		
3.81	45.0	201.6	10.5			81.0	362.9	18.9			112.0	501.8	26.1		
4.45	51.0	228.5	11.9			95.0	425.6	22.1			132.0	591.4	30.7		
5.08	58.0	259.8	13.5	13.5	12.8	112.0	501.8	26.1	26.08	24.72	151.0	676.5	35.2	35.16	33.33
6.35	76.0	340.5	17.7			150.0	672.0	34.9			187.0	837.8	43.5		
7.62	94.0	421.1	21.9			187.0	837.8	43.5			222.0	994.6	51.7		

SWELL

Mould No	Initial Reading	24hr Reading	48hr Reading	72hr Reading	96hr Reading	Sample Height	Swell (%)
1	0.00	0.008	0.009	0.011	0.015	116.400	0.013
2	0.00	0.005	0.006	0.009	0.012	116.400	0.010
3	0.00	0.000	0.000	0.000	0.003	116.500	0.003

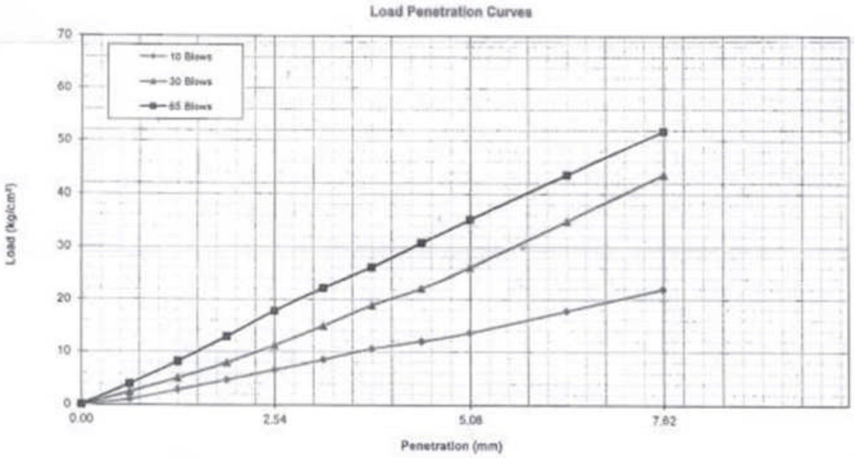
Remarks:

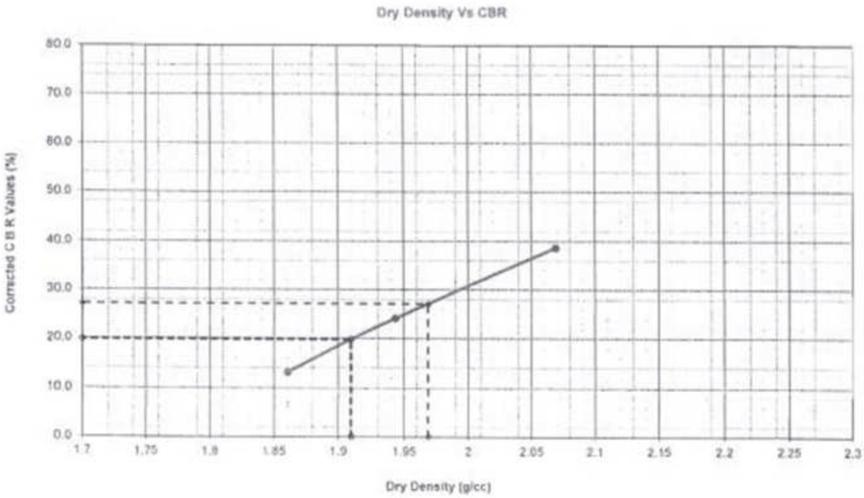
Tested by:	Abdul Moqtadir	Certified by:	
Signature:			

AGE & AES

CALIFORNIA BEARING RATIO (CBR) AT 96 HOURS SOAKED

AASHTO T193 / ASTM D 1883





Maximum Dry Density (g/cc)	1.969
CBR Value @ 100% of MDD (%)	27.1
CBR Value @ 97% of MDD (%)	19.8

Tested by:	Abdul Moqtadir	Certified by:
Signature:		

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