

# Study of Causes of Potholes on Bituminous Roads –A Case Study

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**Abstract**—Development of potholes on Indian roads and streets is a very common phenomenon. Potholes are one of the public's main local concerns, as they are highly visible defects. Many perceive that the quality of local roads may be deteriorating, with potholes being one of the main causes. Therefore it is a need to carry out timely inspection and maintenance of potholes to avoid inconvenience to road users.

Congested roads, high traffic, and pothole problems are major concerns for any modern city planning. Since roads indirectly contribute to the economic growth of the country it is extremely essential that the roads are well laid out and strong. India is a developing nation, there is a constant demand for good quality infrastructure, transportation and services. But since India is a huge country with quite a sizable population this problem still has not been addressed in totality.

The study analyzes pothole problem on the roads of Chandigarh and its causes for assessing the riding quality. In the present work various problematic areas are taken into account to assess the causes of pothole formation and adopt the long lasting solution to tackle the problem to prevent the deterioration of road surfaces.

**Keywords:** Pavement deterioration, Flexible (bituminous) pavements, Pothole origin, Formation of pothole.

## 1. INTRODUCTION

### 1.1. Background

India is said to be the fastest developing countries today only after China. Although India is doing exceptionally well in fields like education, industrialization and fashion there are still certain areas where the country is lagging behind. India's road network is gigantic and said to be only after the United States of America. But one of the striking underlying facts is the condition of the roads. India is home to several bad roads be it the metropolitans, the cities or the villages. Bad road conditions are nothing new to India and the problem is being addressed since the last 30 years. Since roads indirectly contribute to the economic growth of the country, it is extremely essential that the roads are well laid out and strong. India has a total of about 2 million kilometers of roads out of which 960,000 kilometres are surfaced roads and about 1 million kilometers of roads in India are the poorly constructed

ones. Although the figures look pretty impressive but the underlying fact is that 25 percent of villages in India still having poor road links. The other problems faced by the Indian roads are; bad riding quality, poor geometrics, and insufficient pavement thickness.

### 1.2. Growth of Vehicles in Chandigarh

Chandigarh with its high population growth rate, coupled with high economic growth rate has resulted in ever increasing demand for vehicles creating excessive pressure on the city's existing transport infrastructure. Fig. 2 below, shows how the traffic has increased in last 14 Years.

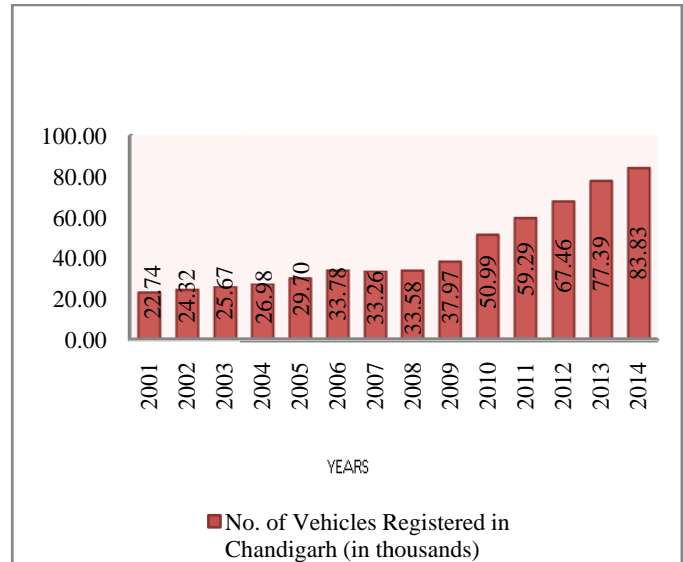


Fig. 1: Graphical Representation of Growth of vehicles

It is clear from above graph that the trend of registered vehicles in the city is gradually increasing. As the number of vehicles registrations has increased, the traffic on roads has increased which has led to the excessive load on the pavement surface ultimately causing its deterioration and thus formation of pothole takes place.

## 2. POTHOLE PROBLEM

A pothole is a type of disruption in the surface of a roadway where a portion of the road material has broken away, leaving a hole. Most potholes are formed due to fatigue of the road surface. The chunks of pavement between fatigue cracks are worked loose and may eventually be picked out of the surface by continued wheel loads, thus forming a pothole.

A pothole is generally a bowl - shaped hole in the pavement surface having minimum width of 6". The severity of potholes may be defined depending on their depth as follows:-

- Low – severity potholes are less than 1" deep.
- Moderately severe from 1"- 2" deep.
- High – severity greater than 2" deep.



Fig. 2: Showing Depth of Pothole

### 2.1. Formation of Pothole

The formation of potholes is exacerbated by low temperatures, as water expands when it freezes to form ice, and puts greater stress on an already cracked pavement or road. Once a pothole forms, it grows through continued removal of broken chunks of pavement. If a pothole fills with water the growth may be accelerated, as the water "washes away" loose particles of road surface as vehicles pass. Potholes can grow to feet in width, though they usually only become a few inches deep, at most. If they become large enough, damage to tires and vehicle suspensions occurs. Serious road accidents can occur as a direct result, especially on motorways where vehicle speeds are greater.

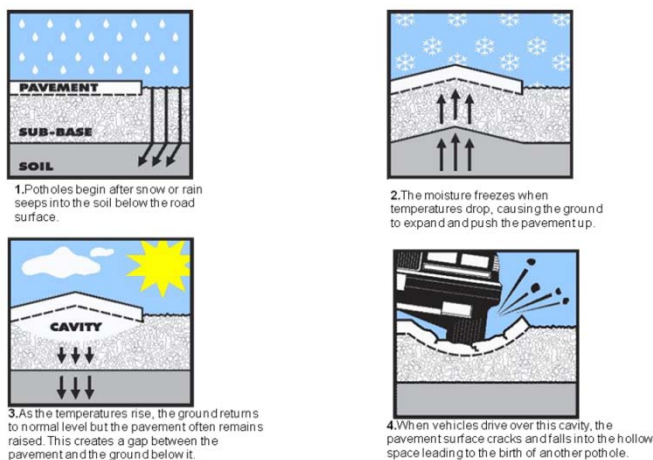


Fig. 3: Formation of a Pothole

### 2.2. Causes of Potholes

The primary cause of formation of potholes in roads is the presence of excessive water. The formation of potholes differs somewhat depending on the environmental conditions, traffic loading, road pavement structure and materials used. The majority of potholes are caused by the interaction of the environmental conditions, water in the road pavement structure and tyre loads. Potholes can also (less frequently) result from diverse, non-structural causes such as-

- Diesel (or other chemical) spillages.
- Mechanical damage to road surfaces from vehicle rims and/or accidents and fires.
- Damage caused by falling rocks in cuttings.
- Animal hooves on the road surface in hot weather.
- Poor road design over certain sub grades (expansive, collapsible, dispersive)
- Lack of bond between the surfacing and WBM base.
- Insufficient bitumen content.

Potholes are generally caused when the pavement or the base can't support the traffic loads. Two factors are almost always present in pothole failures: water and traffic. Heavy traffic or other factors may create cracks, which allow water to seep into the pavement base and soften it. The pounding of traffic causes the weak base to migrate, leaving nothing to support the pavement above it and thus initiating the formation of a pothole. Further traffic impact eventually causes the unsupported pavement to break up. Potholes may also be created in freeze/thaw situations. When water in the pavement or base freezes, it expands and pushes the pavement above it up. The swelling expansion forces can cause a pavement to weaken, resulting in potholes.

### 2.3. Flexible (Bituminous) Pavements

Flexible pavements are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name imply, are considered to be flexible. A flexible pavement will bend under the load of a tyre. In flexible pavements, as shown in Fig. 4 the load distribution pattern changes from one layer to another, because the strength of each layer is different.

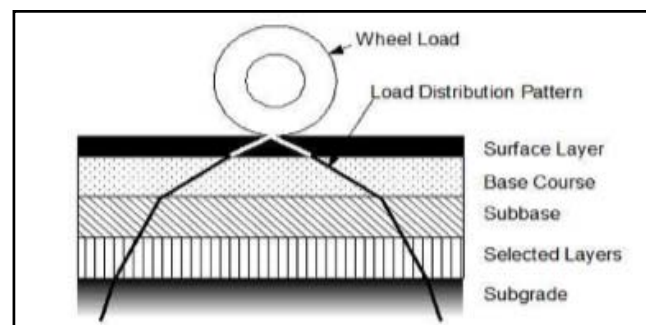


Fig. 4: Load Distribution of Flexible Pavement

The strongest material (least flexible) is in the top layer and the weakest material (most flexible) is in the lowest layer. The reason for this is that at the surface the wheel load is applied to a small area, the result is high stress levels, deeper down in the pavement, the wheel load is applied to larger area, and the result is lower stress levels thus enabling the use of weaker materials.

## 2.4. Potholes in Flexible Pavements

Various types of cracks such as transverse, longitudinal, and alligator cracks are formed due to temperature changes in the pavement layer and repetitive vehicle loads on the pavement surface. The pavement material fails due to various types of stresses and deflections occurring at the cracks. The cracks start widening forming more crack area, which leads to forming of potholes. Each type of cracking undergoes loading effect in the form of deformation, breaking of pavements, and bending stress development.

- Transverse cracking is associated with cold temperature. As the pavement is cooled, thermal stresses are induced as a result of AC's tendency to contract, as well as friction between the AC and the base layer that resists contraction.
- Longitudinal cracking occurs due to shrinkage.
- Alligator cracks are caused due to decrease in relative bearing capacity of subgrade in spring season.

## 2.5 Objective of Study

As common to almost all the cities, Chandigarh has been witnessing traffic congestion and pothole problem in the past few years. With the increasing traffic flow in the city, the occurrence of potholes on the city street is increasing. In Chandigarh, it has been observed that potholes are being found even on the newest roads constructed hence it is imperative to study of occurrence of potholes on Chandigarh roads. The study assesses the present scenario of the extent of occurrence of potholes on the roads of Chandigarh and its causes for assessing the riding quality. The data is to be collected around the city to analyze the pothole problem and suggest the long lasting solution to tackle the problem to prevent the deterioration of road surfaces.

## 3. METHODOLOGY

### 3.1 Survey And Site Visit

Field survey is required to get current information about present situation of potholes on Chandigarh roads. Site visit is carried out to check the presence of potholes on various V's in Chandigarh along with which traffic volume is examined.

### 3.2 Data Collection

The data for study of different roads is collected. After surveying certain sections of road which are highly distressed are selected for further investigation to find out the cause of distress on the road. The following sections of different V's are selected after visual examination:

- V1 Road - Petrol Pump opp. Kalagram - The stretch shown in the Fig. along the Chandigarh - Kalka highway was selected.
- V2 Road - CITCO Petrol pump, Madhya Marg
- V3 Road - PGI to Nayagaon
- V4 Road - 35-D Market
- V5 Road - Opp. # 2060, Sector 15-C
- V6 Road - Opp. # 3309, Sector 15- D
- V7 Road - Cycle track, PEC University of Technology

Once the roads are selected after visual examination, the selected sample of road is collected for checking the bitumen content and carrying gradation test to identify the cause of occurrence of pothole. The samples are collected using core cutter alongside the pothole to examine the samples in the laboratory. The core sample is removed using the core retrieval unit and the core samples are immediately wiped dry and the identification number is marked.

**Table 1: Data Sheet for Bitumen Extraction (V1 Road)**

S.NO.	Sample	1
1	Weight of sample, g (A)	477
2	Weight of filter paper before extraction, g	3.5
3	Weight of filter paper after extraction, g	4.5
4	Weight of filter material on paper, g	1
5	Weight of aggregate after extraction, g	458.7
6	Weight of washed aggregates, g (B)	459.7
7	Bitumen content	3.76%



**Fig. 5: Road Samples Collected Using Core Cutter**

The tests that are to be carried are -

- ✓ Bitumen Extraction test - The bitumen extraction test is conducted by 'cold solvent extraction' method using dry samples of bituminous mix collected from the pavement layer. This test is useful for determination of bitumen binder content in the mix and for checking gradation of aggregate in the mix.

$$\text{Bitumen content} = (A-B) / B * 100 \%$$

Where A = Weight of sample of bituminous mix

B = Weight of sample after extraction

- ✓ Gradation test - The test is performed to determine the percentage of different grain sizes in the mix. The distribution of different grain sizes effect the engineering properties of the mix. Grain size analysis provides the grain size distribution.

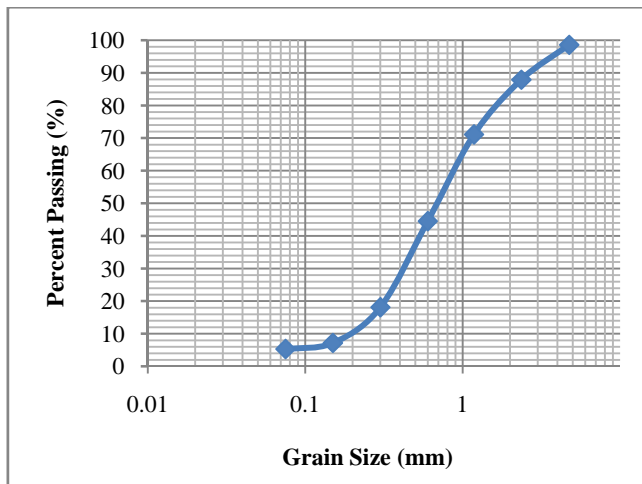
## 4. RESULTS

### 4.1 Data Analysis

The data obtained from the various tests on different samples are analyzed to find out the relevant cause of occurrence of pothole on bituminous pavements.

**CASE 1: V1 ROAD** – Analysis of bitumen content is done to find out the bitumen present and the results are shown below -

Gradation test analyzes the proportion of mix aggregates in the sample. The results are shown below –



Graph 1: Grain Size Distribution Curve (V1 Road)

→ From grain size distribution curve:

- % Gravel = 1.4
- % Sand = 93.3
- $D_{30} = 0.399$  mm
- % Fines = 5.3
- $D_{60} = 0.91$  mm
- $C_u = 4.992$
- $C_c = 1.037$

The gradation test carried out shows that the coarse grained aggregate in the mix is well graded gravel. The permeability of the mix will be high as it is GW. Therefore the ingress of water may take place at a higher rate.

**Similarly**, analysis was done for all the samples to identify the possible cause of formation of potholes.

### 4.2 Discussions

Some of the causes recognized for deterioration of pavements during investigation are high traffic load, poor gradation of aggregates in the mix and unsuitable material, low bitumen content, improper drainage resulting in accumulation of water

on the surface pavement which ingress in the pavement leading to pothole formation.

For major roads of Chandigarh like the Kalka highway and Madhya marg the following causes were identified –

Fast moving vehicles cause removal of binding material in WBM base thus exposing the base course to damaging effects of climatic variations and causing deterioration of pavements. On Madhya marg, repeated stress application due to heavy loads and poor mix proportioning are the identified cause which decrease the strength of sub-base or base course, thereby, increasing the chance of pothole formation.

The condition of V3 road *i.e.* road from PGI to Nayagaon is poor. A number of potholes can be seen. Lack of lateral confinement which results in loosening of total mass and formation of alligator cracks is the possible cause. Also, the traffic load on this road has increased tremendously over the years. The improper gradation results in opening up and loss of pavement material forming potholes.

For the market roads such as V4 and V5 increasing number of vehicles cause relative movement of pavement resulting in fatigue failure and improper drainage leading to accumulation of water further amplify the problem resulting in pothole initiation.

V6 road is the sector road which in front of the houses. The thickness of wearing course and water accumulation on the road leads to pothole formation. The V7 road that is the road provided for cyclists and pedestrians have low bitumen content. The inadequate binder content and inferior type of binding material used is the main causes for distress in pavements.

## 5. CONCLUSIONS AND RECOMMENDATIONS

Pavement condition assessment is a key component when developing road network maintenance programs. Chandigarh road network is under intense pressure today due to increase in population, explosive growth in the number of private vehicles which has increased the number of personalized vehicles, partly due to the absence of an efficient and reliable public transport system. The emergence of the new towns of Mullanpur and Naya Gaon adjoining the city, and the planned expansion of existing towns in the neighboring states are also likely to generate new travel corridors exerting further pressure on the city's arteries. Consequently, the well defined planned hierarchy of roads has been disturbed both due to intercity traffic and increased traffic within the city, including that from the wholesale markets.

### 5.1 Conclusions

The work deals with the causes of formation of potholes on Chandigarh roads. The conclusions and recommendations for future study are as follows -

1. Three types of cracks, namely, transverse, longitudinal and alligator cracks are identified as the starting points for the formation of potholes in a flexible pavement (bituminous pavement).
2. The various causes for the formation of potholes on Chandigarh roads are found to be
  - Increased traffic load
  - Inadequate thickness of wearing course
  - Poor mix proportioning of the material properties of the pavement
  - Low bitumen content
  - Improper drainage
3. Traffic loading plays a significant role in pavement failure. It produces stresses and deflections in the pavement at the edges of a crack, which lead to the formation of potholes. Due to wheel loading the crack deforms and the stress developed breaks the pavement at the edges of the crack. Continuous breaking and increasing area create potholes on the surface of the pavement.
4. Inadequate thickness of wearing course is the main reason for the lack of stability or strength of sub-base or base course. Under repeated stress application, the composite layer gets disturbed and leads to the formation of alligator cracks which ultimately results in the formation of pothole on bituminous pavement.
5. Poor mix proportioning of aggregates and low bitumen content results in a poor binding material which leads to slipping since the surface is not bound to the underlying base. It further results in the opening up and loss of pavement materials forming patches or potholes. Inadequate binder content and inferior type of binder used, results in a poor and brittle bituminous surfacing which cause cracking of the pavement.
6. Improper drainage leads to the accumulation of water on the surface which ingresses through the cracks on the roads and due to moisture variations results in shrinkage and swelling of the subgrade and other pavement materials which initiates pothole formation.

## 5.2 Recommendations

The most effective way to deal with potholes is to prevent them from happening in the first place and endeavour, where possible, to exercise the rule that prevention is better than cure.

Improving and enhancing the drainage system of roads; the surface water from the carriageway should effectively be drained off without allowing it to percolate to subgrade. The side drain should be sufficient enough to carry away all the surface water collected. Use of surface dressing must be increased as regeneration process. Local highway authorities should ensure that appropriate competencies are available to make the right choices when designing and specifying techniques and materials for the maintenance and repair of highways. The surface dressing must be done after proper

cleaning of the existing bituminous surface so that the bond between the layers is effective.

Traffic in the city should be regularized. As in the U.S. city of Mexico, a law should be enforced in the Indian city to regularize the load of traffic on a particular day. The law states that – On a particular day, the vehicles having a particular number as the last digit of their number plate are not allowed to move on the city roads that very day. This ensures that the traffic intensity is reduced which will ultimately reduce the stress on the surface and thus will not contribute much to pavement deterioration. Another way of regularizing traffic, is by improving the public transport system in the city, which will help commuters to lesser the use of private vehicles and in turn decrease the vehicle load on the surface of the bituminous pavement.

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