Investigations on potholes distress in bituminous pavement: A case study

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ABSTRACT

Development of potholes is a very common failure in most of the highways in Hyderabad city. Potholes are highly noticeable loopholes in this terrain. Potholes are holes in the roadway that vary in size and shape. These are mainly caused due to the presence of excess water within roads. Environmental conditions, road pavement structure, materials used and traffic loading play their individual role in formation of potholes. Tyre load, interaction of the environmental conditions and water in pavement structure are major causes of potholes. As riding quality of potholes of distressed pavement is been reduced, many of the road would feel discomfort able while travelling on these roads. Therefore, there is a need to carry out well-timed inspection and maintenance of potholes to avoid inconvenience to road users. In this work various distressed pavement areas are taken into account to assess the causes of pothole formation and adopt best solution to resolve the problem and prevent deterioration of road surface.

Keywords: Causes of Pavement failure, Asphalt pavements, Origin and formation of Pothole.

1.1. Background

The most widely used paving material in road construction is the Hot Mix Asphalt. During the last two decades, road infrastructure has expanded significantly as a result of the extensive construction of new roads essential to satisfy the persistent growth in traffic volume. Bituminous materials are composed with the bitumen and aggregates. The most expensive material in a bituminous mixture is the bitumen binder and it is most commonly used in the surface and binder course of flexible pavements. The main purpose of aggregates in bituminous mixtures is resist the load coming from vehicles, while bitumen binds aggregates together (Read et al. 2003) Over the life span of pavement due to heavy vehicular loads and stiffness due to aging (Yang et al. 2013), the pavement gets deteriorated in the form of Pothole, Raveling, Fatigue cracking and Rutting (Zheng et al. 2013). In India several metropolitans, the cities or the villages have bad roads. In rainy seasons especially in urban areas like Hyderabad due to the poor drainage facilities water is stagnated on road surface for longer duration. Due to this condition of the roads will become worst because water will reduce the binding property of bitumen and it Leeds to pothole and raveling problems. Due to this road user are facing problems like bad riding quality, poor geometrics, and insufficient pavement thickness. Every year Hyderabad roads are over laid after monsoon seasons for this government is spending lot of money and also material usage also increased. This problem is not occurred because of rain water there may be reason of poor mix design and compaction of bituminous mixes and also with high traffic volume.

In Hyderabad population increased drastically over a last two decades, along with incremental increase in economic growth indirectly proportional to demand for vehicles gradually raising excessive pressure on city's existing transportation infrastructure. Traffic on roads increased as the number of registered vehicles increased which has led to cause deterioration of pavement due to excessive load on it resulting in formation of potholes.

2. POTHOLE PROBLEM

A **pothole** is a structural failure in surface of road, primarily failed in asphalt pavement due to heavy traffic loading above affected area and presence moisture in soil structure (Miller, J. S., & Bell inger, W. Y. (2014)). Due to the introduction of water, soil below the pavement weakens initially and losses the strength in holding supporting soil. Traffic breaks the unsupported asphalt affected surface area. Bituminous mixture and soil below the pavement are ejected out to create hole in pavement due to continued traffic action.
Potholes are bowl-shaped holes existing on the top of Bitumen roads. 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.

2.1. Formation of Pothole

Water & traffic are two factors entertain the formation of pothole. soil beneath the pavement loses its strength due to increase of water content in it resulting in breaking point of pavement due to stress caused by load. A precursor failure pattern known as alligator (or crocodile) cracking is progressively formed from fatigue of road surface giving raise to potholes croll, J. G. (2009). Eventually, fatigue cracks gradually plucked or forced out of surface between chunks of pavement due to continued wheel load resulting pothole (Dong et al. 2014).In freezing and thawing areas openings can be created for water entry by frost heaving. In spring the saturation of supporting soil is caused due to thawing of surface portions of soil which cannot drain still frozen lower layers and weakening it (García et al. 2013).

Though the potholes developed are only to depths of few inches usually, they can grow to several feet in width. Damage to tires, vehicle suspensions and wheels is likely to occur if potholes become large enough. Especially on those roads where vehicle speeds are designed greater serious road accidents may occur as direct outcome (Wilson et al. 2001 and Maher et al. 2001)

Main causes for formation of potholes:

1. Localized failure of Freeze/thaw during traffic because of insufficient pavement thickness.
2. Insufficient drainage
3. Failures at castings (manhole and drain casings) and utility trenches.
4. Pavement defects and cracks left unmaintained and unsealed so as to admit moisture and compromise the structural integrity of the pavement

2.2. Causes of Pothole

The primary reason for formation of potholes in road is due to presence of excessive water. These formation differs depending on environmental aspects, material used, traffic loading and road pavement structure. Tyre load, interaction with environmental conditions and water in road pavement are majority causes for potholes. Pothole can also (less frequently) result from diverse, non-structural causes such as-

- Diesel spillages.
- Road surface damage mechanically from vehicle rim and/or fires and accidents.
- Falling rocks in cuttings causes damage.
- In hot weather animal hooves on the road surface.
- Certain sub grades are designed poorly (expansive, collapsible, dispersive)
- Surfacing and WBM base loses their bond.
- Inadequate bitumen content.

When the pavement or the base can't support the traffic loads potholes are generally caused. Water and traffic are the two factors almost present in the failure of pothole. Water is allowed to percolate into the pavement base and soften it due to heavy traffic creating cracks. The weak base is migrated leaving nothing to support the top surface of pavement because of pounding in traffic thus opening the founding of a pothole. Unsupported pavement is eventually broken up by further traffic impacts. Potholes can also be occurred in thaw/freeze conditions. The swelling of pavement because of expansion pavement due to base freeze can also weaken it, originating pothole.

2.3. Potholes in Flexible Pavements

Numerous types of cracks such as longitudinal, alligator and transverse cracks are formed due to change in temperature between the layers of pavement and repetitive vehicle loads on surface of pavements. Due to various types of deflections and stress occurring at the cracks pavement material fails. More crack area is formed due to the widening of crack where it starts, forming pothole. Each type of cracking has its individual loading effects in the form of deformation,

Bending stress development and breaking of pavements.

- Cold temperature is accompanied with transverse cracking. As a result of AC's tendency to contract, thermal stresses are induced after the pavement is cooled. Friction between the AC and the base layer can resist contraction.
- Longitudinal cracking transpires due to shrinkage.
- Due to decline in relative bearing capacity of subgrade in spring season Alligator cracks are caused.

2.5 Objective of Study

As common to almost all the cities, Hyderabad 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 Hyderabad, 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 Hyderabad roads. The study assesses the present scenario of the extent of occurrence of potholes on the roads of Hyderabad 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 Hyderabad roads. Site visit is carried out to check the presence of potholes on various R's in Hyderabad 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 are selected after visual examination:

- R1 Road - Chengicherla to Medipally Main road.
- R2 Road – Cherlapalli to ECIL X road
- R3 Road - Narapally X Road to Korremula
- R4 Road - Medipally to Ghatkesar (NH163)

Figure 1: Chengicherla to Medipally Main road.

Figure 2: Medipally to Ghatkesar (NH163)

Figure 3: Narapally X Road to Korremula

Figure 4: Cherlapalli to ECIL X road

Figure 5: Road Samples Collected Using Core Cutter

Figure 6: Soxhlet Extractor

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. Total 8 samples were collected from four different locations.

Bitumen Extraction test - In this study bitumen extraction test is conducted by using 'Soxhlet extraction' method. The binder from the mixture shall be extracted in accordance with AASHTO T 164. This test is useful for determination of bitumen binder content in the mix and for checking gradation of aggregate in the mix.

Bitumen content = (A-B) / B * 100 %

Where A = Weight of sample of bituminous mix with filter paper

B = Weight of sample with filter paper after extraction

- ✓ Gradation test – The test was performed before extraction and after extraction of bitumen to find the percenta of aggregate size distribution in the mix. Percentage of aggregate size distribution in mix effect the engineeri properties of mix.

4. RESULTS

4.1 Data Analysis

In this study four different location was selected in Hyderabad city. All these four section are having BC layer with VG30 binder. 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.

Table x: Obtained percentage of bitumen content from cores

S.NO.	Sample	I	II	III	IV
1	Weight of sample, g (A)	1000	1000	1000	1000
2	Weight of filter paper and material before extraction, g	1065	1065	1065	1065
3	Weight of filter paper and material after extraction, g	1014	1020	1025	1011
4	**Bitumen content (%)**	**4.79**	**4.22**	**3.76**	**5.07**

1. Gradation test analyzes the proportion of mix aggregates in the sample.

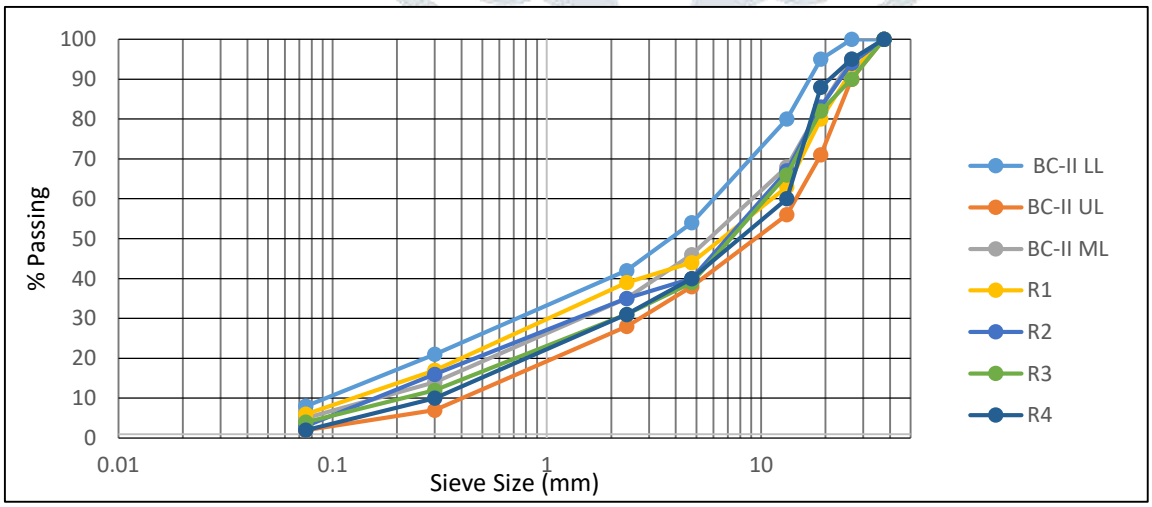

Figure 7: Grain Size Distribution Curve after extraction

→ 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.

Air voids content: Air void content was found for core samples collected form field. From the test result it was observed that R1, R2 and R3 samples having air void content less than 3%. As per MoRT&H recommendation min air void content is 3% and maximum is 6%. Due to less air void content pavement become brittle material and when vehicle passes on the road due to the vehicular load pavement gets cracks on surface.

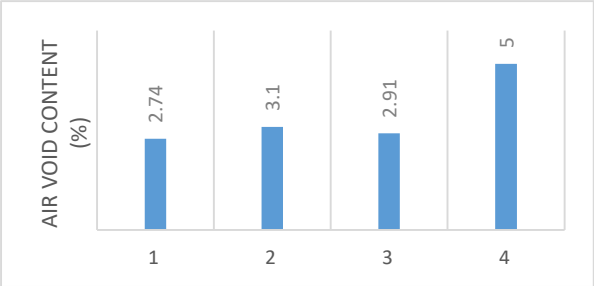

Figure8: Percentage of air void content

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 Hyderabad like the Medipally to Ghatkesar (NH163) highway and Chengicherla to Medipally Main road the following causes were identified – Fast moving vehicles cause removal of binding material in BC course thus exposing the base course to damaging effects of climatic variations and causing deterioration of pavements. On Medipally to Ghatkesar (NH163), 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 R3 road *i.e.* road from Narapally X Road to Korremula 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 Industrial road such as R4 Cherlapalli to ECIL X road 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. The inadequate binder content and inferior type of binding material used is the main causes for distress in pavements.

5. CONCLUSIONS AND RECOMMENDATIONS

When developing the road network maintenance programs pavement condition assessment play a vital role. Due to increase in population, Hyderabad road network is under extreme pressure in current scenario. Expansive growth in personalized vehicles due to excessive growth in private number of vehicles, partly due to absence of reliable public transportation.

5.1 Conclusions

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

1. From extraction test bitumen content is found for four section R1, R2, R3 & R4 are 4.79%, 4.22%, 3.76% and 5.07%. According to MoRT&H minimum binder content is 4.5% but in section R2 and R3 binder content is less than minimum requirements.

2. From gradation analysis it was observed that R2 and R3 roads having higher fine particles than the coarse aggregate. Due to higher finer particles in mixtures it leads to lower binder content.
3. 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.
4. Air void content of R1, R2 & R3 are less than 3% which is less than minimum criteria. Pavement gets premature cracks on surface.
5. Form the field observation it was observed that proper drainage system not there. 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***

- Use of surface dressing must be increased as regeneration process. specifying techniques and materials for the maintenance, repair of highways and repair of highways are to be ensured by local highway authorities. 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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