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Review on Indian Highway Study on Causes of Failure Of Bituminous Pavement

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ABSTRACT

The study on the causes of failure of bituminous pavements on Indian highways identifies key factors contributing to premature deterioration. Common causes include poor mix design, inadequate compaction, subgrade failure, poor drainage, overloading of vehicles, and extreme weather conditions. Structural distresses like rutting, fatigue cracking, and potholes are often linked to insufficient binder content, oxidation, and water infiltration. Construction deficiencies, such as improper layer bonding and poor-quality control, further accelerate pavement failure. The study emphasizes the need for improved material selection, quality assurance, and maintenance strategies to enhance the longevity of bituminous pavements in India.

Keywords: Pavement failure, Bituminous Roads, Traffic Study, Pavement Design.

I. INTRODUCTION

Human sensitivity has revealed a need for movement that has led to a gauge of society's progress since the dawn of time. The history of civilization is the history of this mobility or mode of transportation. Modern, effective transport is a fundamental component of any nation's infrastructure and is essential to its proper development. Transport refers to the movement of people and things from one location to another in either British or American English. The words "across" and "to carry" are derived from the Latin trans and portare. One of the most crucial requirements for every nation's economic development, especially that of developing nations, is a well-developed road network infrastructure. As a result, many emerging nations spend a large sum of money building roads, even if they understand the importance of making significant financial investments in the capital development of highways.

Few people give maintaining roads the priority it deserves. New development is thought to be more glamorous than maintaining what already exists. Unfortunately, water penetration can cause pavement structure to be ruined in just one season. The frequency of maintenance operations varies with traffic, topography, climatic conditions, the kind of roads, and grading and repairing potholes and ruts for paved roads.

Maintenance activities may be necessary at various times throughout the year. Pothole repairs, surface patching, crack sealing, and road surface marking are some of them. Any nation's economic, industrial, social, and cultural progress is aided by transportation.

Since any good produced, whether it be food, clothing, industrial products, or medicine, requires transportation at both the manufacturing and distribution stages, transportation is essential for the economic development of any region. The lack of suitable transport infrastructure hinders the nation's socioeconomic progress. The effectiveness of a nation's transport system reflects the level of its social and economic development.

II. HIGHWAY PAVEMENT FAILURE

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reacting characteristics, and low noise pollution. The major Flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom most of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Failure may be caused by

- Inadequate Stability
- Excessive application of stresses
- Plastic deformation Failures in sub base or Base course.
- Inadequate stability
- Loss of binding action
- Loss of bearing course materials

- Inadequate wearing course
- Rutting due to high variation in ambient temperature.
- Uncontrolled heavy axle loads.
- Limitation of pavement design procedures to meet local environmental conditions.

There are various category of Distress or failure: these which are responsible for the highway failure Such as cracking may be longitudinal, fatigue, transvers, reflecting, block, edge cracking. And others Such as rutting, corrugation, shoving, depression, overlay bumps, potholes, patching, reveling, stripping, polished aggregate, pumping, segregation, checking, bleeding and delamination.

HIGHWAY MAINTENANCE

Preserving and keeping each type of roadway, roadside, structures as nearly as possible in its original condition as constructed or as subsequently improved and the operation of highway facilities and services to provide satisfactory and safe transportation, is called maintenance of Highways. The various maintenance functions includes: -

1. Surface maintenance
2. Roadside and drainage maintenance
3. Shoulder and approaches maintenance
4. Snow and ice control
5. Bridges maintenance
6. Traffic service Highway maintenance is closely related to the quality of construction of original road.

- Insufficient pavement or base thickness or improper construction of these elements soon results in expensive patching or surface repair.
- Shoulder care becomes a serious problem where narrow lanes force heavy vehicle to travel with one set of wheels off the pavement.
- Improperly designed drainage facilities, mean erosion or deposition of material and costly cleaning operation or other corrective measures.
- Sharp ditches and steep slopes require manual maintenance as compare to cheap maintenance of flatter ditch and soil by machine.

• In snowy country, improper location extremely low fills and narrow cuts leave no room for snow storage, creating extremely difficult snow removal problems.

III. RESEARCH MOTIVATION

Roads are pavements specifically designed to carry men and material to various destinations and should last for the period for which they have been designed. Rigid or Flexible pavements are constructed to fulfill the need of transport and the bitumen roads belong to the category of flexible pavements whereas cement concrete roads belong to the category of rigid pavement. Failure of bitumen roads is a very common problem and has been drawing the attention of the state and central government authorities like NHAI, RDC, and RRDA, PMGSY etc. The phenomenon of failure has been observed to occur in national highways, state highways, rural roads and even internal roads of the metros. There are multiple reasons for failure of bitumen roads and a variety of known and unknown factors responsible for such failures. More important factor is the error in following instructions given in the manuals for every stage of road construction, may it be raising of a new road or improvement of existing road in all the cases the guidelines given in the manuals in respect of materials to be used, quality control measures to be strictly adhered to and number of checks and rechecks by different agencies engaged in the task of constructing quality bitumen roads.

SCOPE OF WORK

It is necessary to consider the need of uses and environment which uses features of existing terrains, operating condition, traffic load & environment condition Determining the amount rational expenses, in terms of life cycle cost of the pavement, requires determination and consideration of the above issues already at the planning and design stage. In many cases the ordering party analyses only the initial investment costs omitting the operating expenses for the pavement in the long term.

Maintenance work on roads may have a direct and noticeable effect on people's quality of life. Aside from the obvious advantages of proximity to medical facilities, educational opportunities for our kids, and commercial hubs where we can engage in commerce, drive economic growth, and generate employment opportunities. Maintaining roads increases their safety. They allow for shorter stopping distances, making them more accident-proof. When there are fewer collisions, there is less potential for serious harm or death. Which not only prevents the real-world consequences for those who may experience this type of event, but also saves money in terms of healthcare. When the road is level, we can cruise along in luxury and maintain a steady speed. Goods get it reach their destination unscathed, and vehicles suffer less wear and tear from road imperfections. With lower fuel prices, car owners now have more disposable cash. Consistently maintaining roads has far-reaching, tangible advantages that improve life in every sector of society.

IV. LITERATURE REVIEW

[1] Ehsan Solatiyan et al. The application of paving fabric at the interface of bituminous layers as a rehabilitation strategy has proved its effectiveness in extending the pavement service life by delaying the manifestation of reflective cracking on the surface. However, this enhanced performance relies on the adhesion bond supplied at the interface, which in the case of debonding, the structural benefits provided by the interlayer can be compromised. Gaining authentic knowledge about the bonding condition at a reinforced interface exposed to different conditioning impacts helps to improve the reliability of the input data, which has not been adequately considered in the mechanistic-based design methods proposed for reinforced bituminous structures. This research was dedicated to understanding the mechanical behavior of double-layer bituminous layers composed of two different hot mixtures and reinforced with paving fabric when subjected to freeze-thaw cycling. To attain this objective, the initial step involved determining the optimal dosage of bitumen for use as a tack coat at the interface of the paving fabric, which was established as 0.0014 m3/m2 through asphalt retention tests.

[2] Abhinav Kumar et al. In most of developing countries across the world, pavement design is still based on an empirical approach that may result in premature failure or overdesigned pavements. A shift from an empirical to a semi-mechanistic or mechanistic approach is the need of modern time. In this regard, computational tools such as finite element (FE) are being successfully utilized to gain deeper insights because such tools have allowed researchers to study the complex behavior of bituminous concrete (BC) materials. It is well recognized that BC material typically exhibits viscoelastic/visco-elasto-plastic behavior depending on applied loading (including temperature) conditions. However, due to the complexity of the whole procedure yet many pavement design tools consider them as pure elastic material. The aim of this research is to develop FEM based simple and practical framework to evaluate the structural response of BC material with viscoelastic

material characterization which can be an effective tool to predict field behaviour with commonly available pavement material tests. Such a framework will be helpful in analysing variations in the critical response of BC pavement with varied traffic loads and ambient temperatures. The framework provides a relatively simple procedure to obtain the viscoelastic parameters of BC mix with a creep compliance test conducted at different temperatures. It was concluded that Creep compliance data if pre-smoothened by the Power law model reduces mathematical optimization issues to some extent. Furthermore, with the obtained parameters, a 3-dimensional FE model was developed to obtain sensitivity to critical stresses, strains, and vertical deformations at desired conditions. Material characterization of unbound granular layers was evaluated through resilient modulus based on empirical relations. Analysis was carried out taking into consideration the traffic load, contact pressure, mix type, air-void, and temperature variation.

[3] Mohit Nandal et al. The development of a new road has a variety of ramifications for the environment, using considerable quantity of materials and energy. Also, the cost of crude oil, which is the principal source of bituminous binder, has substantially grown in recent years. This has resulted to a rise in the overall price of bituminous blends. Developing innovative materials and technology to incorporate greener material, waste and recycled materials into the manufacturing cycle of bituminous mixes is a solution that enhances both sustainability and cost-efficiency of the bituminous pavement industries. Sustainable materials have increasingly been adopted in construction of roads nowadays because people are more concerned about its ramifications towards surroundings. However, people keep seeking to discover the most appropriate sustainable materials to be utilized in developing road pavement. In the current research, the two primary components of bituminous mixture i.e. bitumen and aggregates are focused and reviewed. Furthermore, the study presents a brief outline of several recycled materials which have been effectively used into bituminous layers of flexible pavement. Review findings suggest that the usage of secondary material not only offers an effective waste disposal approach but also minimize requirement for traditional material and lowers the total building cost. An effective and appropriate system of transportation is crucial for the development of any nation. The purpose of this review study is to establish the applicability and effectiveness of the waste material that has been used in the bituminous layers of flexible pavement.

[4] Hebah Jahan et al. The use of foamed bitumen technology (FBT) in constructing pavements has demonstrated considerable environmental and economic benefits. This technology reduces greenhouse gas (GHG) emissions and saves energy and natural resources by enabling the manufacture to be carried out at lower temperatures. Research has concentrated mainly on investigating the performance of foamed bituminous mixtures (FBM) to determine their efficacy for pavement construction. In addition to laboratory studies, many researchers have investigated the field performance of these mixtures across the world. These studies indicate that the fatigue life of FBMs is comparable to or slightly superior to that of HMA. In addition, their sensitivity to temperature is lower compared to HMA. On the other hand, FBM tends to have lower ITS, resilient modulus, moisture resistance, and rutting resistance. This paper reviews the development of FBT based on the findings from existing research studies. The impact of this technology on the environment and economy, as well as its future scope for increased applicability as a sustainable construction practice, is discussed. While there are numerous advantages this technology can offer over traditional methods such as hot mix asphalt (HMA), there are several aspects that still need to be investigated to utilize it fully.

[5] Vivekanand Korishetti et al. Recycling is an attempt to effectively utilize the used material to manufacture new material of acceptable or if possible superior quality materials. Recycling promotes resource preservation, energy efficiency, and cost-effectiveness in manufacturing. Recycling can be effectively applied for bituminous pavements. The scarified bituminous material from the surface course can be mixed with fresh aggregates and/or fresh binder to relay new pavements performing the same function as in the original application. Thus scarified bituminous material, which is milled from asphalt surface is recycled in hot mix asphalt. Hot mix recycling has shown to be an effective method due to its low cost and capacity to produce mix of a high calibre. Thus, reclaimed asphalt pavement recycling is necessary for use for technical, economical, and environmental reasons. The purpose of the study is to assess the effectiveness of hot asphalt mixtures using recycled asphalt pavement (RAP). Bituminous material that had been scarified was obtained for the current investigation from a national highway in Belagavi, India. It was discovered that the project location has a BC-II and PMB-40 gradation. The site-recycled material underwent a bitumen extraction test to determine its gradation and binder concentration. In the current laboratory experiment, four different sorts of mixes were created and put to the test. New bituminous mixes were made using the BC-II

gradation. Two mixes were proportioned, and recycled materials were used to partially replace the coarse and fine aggregates in the BC-II mix, respectively. The mixes were produced using the Marshall approach and the MS-2 criterion. The mixes were investigated in terms of their Marshall properties, moisture susceptibility through ITS & TSR tests. The recycled mix when combined with fresh aggregates and binder to compensate for loss in gradation and ageing of binder respectively results in a mix of properties similar and even better than fresh bituminous mix.

[6] Amarendra Kumar Sandra et al. In the present study, reasons for early distresses noticed on the bituminous pavement of a four-lane divided highway between the Pardi and Agrasen sections of National Highway 6 from km 498.000 to km 544.000, in India, were investigated. The total length of the road project is 46km. A detailed pavement condition mapping was carried out, and various distresses were noticed on the surface. To assess the reasons for the distresses, combined cores of the bitumen surface course and the base course were taken from 57 locations, 29 on the left-hand side and 28 on the right-hand side of the carriageway, and mix properties were evaluated in the laboratory. The investigation on the mixes revealed that bituminous cores collected from both the surface course and binder course have no resemblance to the job mix formula. Non-homogeneity of layer thicknesses, variation in mix properties, variation in aggregate gradation and high fillerbinder ratios were observed. Aside from the laboratory investigation, the physical condition of bitumen cores was studied and the conditions of the pavement layers were assessed based on the deflection basin parameters. This paper presents a systematic procedure adopted for identifying the causes of early distresses, and appropriate treatments are suggested for rectification.

[7] Gagan Deep Singh et al. Since there is a constant increase in high traffic intensity, Bituminous Pavements are predicted to function better these days. Bituminous Pavements perform poorly in moisture-induced conditions. Moisture damage causes stripping or the separation of the binder from the aggregates. According to a thorough literature analysis, adding polymers to asphalt binders helps to enhance the bond between the aggregate and the binder, which may help to improve numerous features of asphalt pavements and aid to meet the aforementioned standards. The widespread usage of plastic in products such as wrappers, carry bags, and cold drink bottles has serious environmental and economic consequences. The safe disposal of these plastic wastes is a major social concern. Also, high temperature mixing

of bituminous materials in Hot Mix Plants (HMA) generates toxic gases, affects global warming and reduces the hauling distance of the asphalt concrete pavements. The present study was conducted to investigate the impact of partial replacement of Low-Density Polyethylene (LDPE) waste in bituminous mixes at four different percentages of bitumen contents 4.2%, 4.7%, 5.2% and 5.7%. Furthermore, Sasobit an organic additive of Warm Mix Asphalt Technology at constant percentage of 3% by weight of bitumen was also used with Varying percentages of LDPE, such as 2%, 4% and 6% respectively. This Study examined the effect of above-mentioned types of mixes on Marshall Properties. The inclusion of plastic increased the stability of the mixes. The maximum stability achieved with 4% plastic and 3% sasobit. The addition of sasobit lowers the Tensile Strength Ratio (TSR) value but well under specified limits. Hence, Low-Density Polyethylene with sasobit can be well utilized in bituminous mixes.

[8] Aakash Singh et al. This paper comprehensively reviews present research on the potential for repurposing primary categories of waste plastics. These include Polyethylene Terephthalate (PETE), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS), and other variants such as Acrylonitrile Butadiene Styrene (ABS), Ethylene Vinyl Acetate (EVA), Polycarbonate (PC), and Polyurethane (PU). The focus is on their use in the construction of bituminous mixes via the dry process method. This method incorporates plastic waste into bituminous mixes by modifying the mixture or replacing aggregates. This practice has consistently demonstrated improvements in pavement performance, including increased stiffness, resistance to rutting, and fatigue. When bituminous mixtures are modified with the mixture modifying approach using low melting point plastics such as LDPE, HDPE, and LLDPE, a significant reduction in OBC is observed. Furthermore, the mixture modification approach has demonstrated higher resistance to moisture damage, rutting, and fatigue damage than the aggregate replacement approach. The potential benefits of using plastics in the bituminous pavement are substantial. This includes a reduction in the amount of waste sent to landfills, a decrease in reliance on finite natural resources, and the expansion of options for constructing bituminous pavements. Economic analyses have shown that using waste plastics can reduce pavement construction costs by 10%, with a minimal probability of leaching. Despite a multifold increase in the emission of greenhouse gases, an overall reduction in

environmental impact was observed from the life cycle assessment study. However, the use of PVC and dark-colored plastics is not recommended. Field studies conducted on roads constructed with waste plastic-modified bituminous pavements showed notable improvements. Most of these pavements exhibited higher Pavement Condition Index (PCI) values and lower International Roughness Index (IRI) values than conventional pavements. These findings underscore the superior riding quality and reduced deterioration associated with waste plastic incorporation. Moreover, in-plant production processes, plants require minimal modifications, as existing equipment used for feeding fibers is well-suited for adding plastics into the mixture. In conclusion, further research is essential to fully understand the impact of different types of plastics on pavement performance and to evaluate this process's potential environmental and economic implications. This paper seeks to bridge the gap in the literature by reviewing and discussing the performance of such mixes and constructed pavements in laboratory and field situations.

[9] Sivaprakash G et al. Fatigue and rutting are the major distress in the flexible pavement that occur when the strains at the bottom of the asphalt layer and top of the subgrade layer exceeds the allowable value. It becomes important for the pavement design engineers to perform analysis on the pavement structure in the fatigue and rutting distresses. There are many factors influences the distress in the pavement structure and few are traffic characteristics, material properties, and environmental conditions. The influence of material properties and temperature becomes major area of interest on the behaviour of pavement structure. This project attempts to study the influence of material properties and axle configurations in the temperature range of fatigue regime (-10 °C to 20 °C) on the behaviour of different pavement cross section. It also aims to investigate the fatigue life of pavement structure on the varying parameters.

[10] Sujit Kumar Pradhan et al. Use of the recycled asphalt pavement (RAP) material is necessary for the sustainable development of the road infrastructure. However successful incorporation of RAP in hot mix asphalt (HMA) has been only up to 30%. Considering the pressing need for higher utilization of RAP, the present study explores the performance of recycled HMA produced by incorporating Polanga oil as rejuvenator and also with softer binders separately for comparison purposes. A total of eleven mixes were designed, out of which there is control mixture with PG 70-X, five mixtures containing varying percentages of

RAP (30–70) added with the softer binder and another five containing the same variation in RAP with a rejuvenator (its content fixed at 5% by mass of RAP binder).

V. CONCLUSION

In conclusion, the study on the causes of failure of bituminous pavements on Indian highways highlights the critical need for improved design, construction practices, and maintenance strategies. Key issues such as poor mix design, inadequate compaction, subgrade instability, water infiltration, and overloading contribute significantly to pavement deterioration. Additionally, improper drainage and extreme climatic conditions exacerbate the problem, leading to distresses like rutting, cracking, and potholes. Addressing these challenges requires strict quality control during construction, the use of durable materials, periodic maintenance, and enforcement of axle load regulations. By implementing these measures, the longevity and performance of Indian highways can be significantly enhanced, ensuring safer and more durable road infrastructure.

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