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Utilization of Rubber Waste in Road Construction

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Abstract- The growth rate of vehicles is the backbone of economic development of any country. India is the second fast growing automobile industry in the world. In today's era, solid waste management is the thrust area. On the other side, the traffic intensity is also increasing. As a result amount of waste tiers is also increasing. The increasing consumption of waste tire has generated many problems such as increasing landfill space, environmental pollution and causing health hazards. Parallel to this the increasing of roads constructions as a result of heavy traffic on roads. This study reviews to the use of crumb rubber (waste tyres in powder form) in bitumen using the wet process. The study focuses on the crumb rubber as a replacement to the total weight of bitumen. The design or life span for all highways and urban roads is 10 – 20 years. Unfortunately, damages or distresses on pavements are still occurring before reaching the maximum period of the designed life road serviceability. Among the major influencing factor that is contributing to this distress is the repeated heavy traffic loading on the road surfaces. Moreover, the use of waste crumb rubber in road construction as a pavement surface has a better skid resistance, fatigue crack resistance and increased rut resistance. The review includes physical tests that are used to determine the physical properties of bitumen and modified crumb rubber mix. The physical tests involve penetration test, softening point test, and ductility test. The expectations from the study are to develop bitumen with waste crumb rubber that would minimize the costs of bitumen and providing better physical properties compared to the convention bitumen based on the tests that was conducted.

Keywords – Increasing Consumption, Waste Tire, Solid Waste Management, Maximum Period, Heavy Traffic Loading, Develop Bitumen, Waste Crumb Rubber.

INTRODUCTION

Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials are poses environmental pollution in the nearby locality because many of them are non-biodegradable. Traditionally soil, stone aggregate, sand, bitumen, cement etc. are used for road constructions. Natural material being exhaustible in nature, its quantity is declining gradually day by day. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, by which the pollution and disposal problems may be partly reduced. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of waste tyres in road making in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low volume roads in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximize the use of solid wastes in different layers of the road pavement. In India, over 15 million waste tires are

generated annually. Not only are these tire mounds eyesores, they are also environmental and health hazards. The little pools of water retained by whole waste tires create an ideal breeding ground for mosquitoes. Aside from the persistent annoyance, mosquitoes have been shown to spread various dangerous diseases. Equally hazardous are tire fires, which pollute the air with large quantities of carbon smoke, hydrocarbons, and residue. These fires are virtually impossible to extinguish once started. Currently, the only large scale methods to use waste tires are through burning for electric power generation, production of cement in cement kilns, energy to run pulp and paper mills, and recycling at tires-to-energy facilities. In 1990, the Environmental Protection Agency (EPA) estimated that out of the 242 million waste tires generated that year, 78% of the tires were either stockpiled, a land filled, or illegally dumped. While some states burn waste tires this is only a temporary solution because of the tires, in many cases, tend to float back up to the surface. Land filling waste tires has also become more and more expensive as landfill space has decreased. Asphalt acting as a binder for aggregates is a very important ingredient affecting the life cycle and travel comfort on roads.

LITERATURE REVIEW

Various activities like packing consume almost 50- 60%of the total plastics manufactured. Plastics materials lack the quality of bio-decomposition thus leaving them to no option against being land filled or combusted as it is. Both of these processes are unhealthy to environment, hence leading to contamination of air and land. There has been tremendous increase in the consumption of plastic raising from 4000 tons/annum (1990) to 4 million tons annum (2009) and it is still expected to rise up to significant level of 12 million tons/annum by 2016. According to the research, 158,943,925 tonnes of plastic waste will be created in 2023 and 43% of global plastic waste will be mismanaged at the end of its life. Chennai Corporation commissioner Rajesh Lakhoni says, "Of the 3,400 tons of plastic generated in the city every day, 35 to 40 tons is plastic waste and most of that is plastic bags. A plastic is a type of synthetic or man-made polymer; similar in many ways to natural resins found in trees and other plants. The annual available capacity for procured tyres retreading is 4.8 million for bus and truck tryes and 4.5 million for car and jeep tyres. Bureau of Indian Standard has prepared standards for retreaded tyres. It becomes hard to recover useful substances from plastic waste since rubber compound in tyre because compounds like black carbon, zinc oxide, process oil, and Sulphur are present in vulcanized stage. The process of retarding produces tyre crumb as it’s by-product. Hence, before applying new rubber the old tread of tyre is buffed to produced crumb. On the basis of study conducted on behavior of cryogenic ground tyre crumb at Rubber Technology, the tyre crumb has a large number of uses like rubber extender, asphalt modifier for road surfacing, modifier implastics, making sports surfaces, safety surfaces, soil treatment etc. IIT Kharagpur revealed that properties of vulcanizates containing crumb rubber depend on size, loading, hardness, cross links and nature of polymer matrix of the crumb. The reclaim process is not environmentally friendly unless expensive scrubbers and effluent treatment plants are installed. Many types of research were carried out by many scholars and professors of civil engineering in this field, to find the ways and crumb rubber mix in conventional bitumen to improve in engineering properties of bitumen.

Nitu H. Deshmukh Et al.(2017) Author conducted the test which were done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. From the result of the test, the penetration value for normal bitumen was 69 mm. The penetration value

decreased with the increased amount of the rubber crumb waste added. Lower penetration value prove that grade of asphalt is harder, giving additional strength to the road and reduces water damage. Softening Point Test was done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. From the result of test, the softening point for normal bitumen was 42.75˚c. Softening Point increased with the increased amount of the rubber waste added. The result showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased. Ductility test was done for both normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. The result found that the rubber waste added will harden the bitumen. The bitumen becomes more viscous and harden, which would be useful to obtain stiffer bitumen asphalt.

Shubham Bansal et al (2017) Discarded waste materials like crushed plastic bottles, thrown away polythene bags and used rubber tires were the minor constituents of the binder along with bitumen as major constituent. Shredded plastic waste, having particle size around 650 microns with specific gravity 1.18 was used in the binder mix. All binders were divided into three series namely A, B and C. Series A and B represents the binary mixes i.e., Bitumen (B) + Plastic (P) and Bitumen (B) + Rubber (R) respectively while Series C is the tertiary mix with varying proportion of plastic and rubber both in bitumen. All the mixes having varying percentages of binder constituents are represented as Bitumen Mix (BM) as illustrated in table 1. Penetration test, Ductility test, Softening Point test and Specific gravity test were performed to analyze the physicochemical properties of various binders.

Nabin Rana Magar, (2014) investigates the performance of crumb rubber modified bitumen by varying the sizes of crumb rubber. The test results of common laboratory test on plain bitumen and crumb rubber modified bitumen shows that the penetration values and softening points of plain bitumen can be improved significantly by modifying it with the addition of crumb rubber which is a major environmental pollutant. The best size to be used for crumb rubber modification is suggested as (0.3-0.15mm) size for commercial production of CRMB.

Siddharth Rokade, (2012) The Crumb Rubber was added to 60/70 grade bitumen in varying percentage. The mix was prepared with 5 % bitumen and the varying percentages of Crumb Rubber. The bitumen, when mixed with Crumb Rubber, is termed as Crumb Rubber Modified Bitumen (CRMB). The results observed that the Marshal Stability Value is increased from 4% to 12% Crumb Rubber and then it is decreased 15% of Crumb Rubber of the weight of bitumen is the optimum dose for getting enhanced strength characteristics of the mix.

Nuha S.Mashaan, (2012) In their study presented the application of crumb rubber modifier in the asphalt modification of flexible pavement. From the results of the previous study, it aspires to consider crumb rubber modifier in hot mix asphalt to improve resistance to rutting and produce pavement with better durability by minimizing the distresses caused in hot mix asphalt pavement. Hence, road user would be ensured of safer and smoother roads.

Mashaan et al, (2011) The penetration is a measure of hardness or softness of bitumen binder which shows an effect by adding crumb rubber to bitumen binder; it decreases as rubber content is increased. The penetration shows lower values as rubber content increases at different

mix conditions of rubberized bitumen binder, indicating that the binder becomes stiff and more vicious The softening point refers to the temperature at which the bitumen attains a particular degree of softening. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases

Becker et al, (2001) claimed that blend properties will be influenced by the amount of crumb rubber added to the bitumen. Higher amounts indicated significant changes in the blend properties. As rubber content generally increases, it leads to increased viscosity, increased resilience, increased softening point and decreases penetration at 25°C.

HAZARDS OF TYRE WASTE

However, with the use of waste tire rubber in bitumen, it will definitely be environmentally beneficial, it can improve the bitumen binder properties and durability, and it will also have a potential to be cost effective. Conventional bituminous materials have been used satisfactorily in most highway pavement Environmental factors such as temperature, air, and water can have a profound effect on durability of these pavements. The ideal bitumen should be strong enough, at optimum temperatures, to withstand rutting or permanent deformation, and soft enough to avoid excessive thermal stresses, at low pavement temperatures, and fatigue, at moderate temperatures. After adding the waste tire rubber in bitumen, the properties of the bitumen will be checked. As disposal of waste tires has become a worldwide problem and has caused worry to administrators, researchers and environmentalists. This paper is intended to study the feasibility of the waste tire rubber as a blending material in bitumen, which is used for road construction. The Waste tire rubber appears to possess the potential to be partially added in bitumen, providing a recycling opportunity. If Waste or used tire rubber can be added in bitumen for improving the properties, and disposing off the tires, thus the environmental gains can be achieved. The accumulation of ELTs and premature pavement failures are both interconnected and dependant of each other due to enormous increase in traffic density and axle loading respectively. The use of RTR in asphalt pavements started 170 years ago, with an experiment involving natural rubber with bitumen in the 1840s, attempting to capture the flexible nature of rubber in a longer lasting paving surface. In 1960s scrap tyres were processed and used as a secondary material in the pavement industry.

- These waste tyres are produced carbon by burning process.
- This amount of tyres is very large manner so it becomes dangerous as well as uncomfortable to placing, because of Land problems to our country.
- Potentially harmful substances were found exposed to highly acidic solutions.
- Aside from the persistent annoyance, mosquitoes have been shown to spread various dangerous diseases.
- Equally hazardous are tyre fires, which pollute the air with large quantities of carbon smoke, hydrocarbons, and residue.
- Not only are this tyre mounds eyesores, they are also environmental and health hazards. The little pools of water retained by whole waste tyres create an ideal breeding ground for mosquitoes.
- These fires are virtually impossible to extinguish once started

One application was introduced by two Swedish companies which produced a surface asphalt mixture with the addition of a small quantity of ground rubber from discarded tyres as a substitute for a part of the mineral aggregate in the mixture, in order to obtain asphalt mixture with improved resistance to studded tyres as well as to snow chains, via a process known as "dry process". In the same period Charles McDonalds, a material engineer of the city of Phoenix in Arizona (USA), was the first to find that after thoroughly mixing crumbs of RTR with bitumen (CRM) and allowing it to react for a period of 45 min to an hour, this material captured beneficial engineering characteristics of both base ingredients. He called it Asphalt Rubber and the technology is well known as the "wet process". By 1975, Crumb Rubber was successfully incorporated into asphalt mixtures and in 1988 a definition for rubberised bitumen was included in the American Society for Testing and Materials (ASTM) D8 and later specified in ASTM D6114-97. In 1992 the patent of the McDonald's process expired, and the material is now considered a part of the public domain. Furthermore, in 1991, the United States federal law named "Intermodal Surface Transportation Efficiency Act" (then rescinded), mandated its widespread use, the Asphalt-Rubber technology concept started to make a "quiet come back". Since then, considerable research has been done worldwide to validate and improve technologies related to rubberised asphalt pavements.

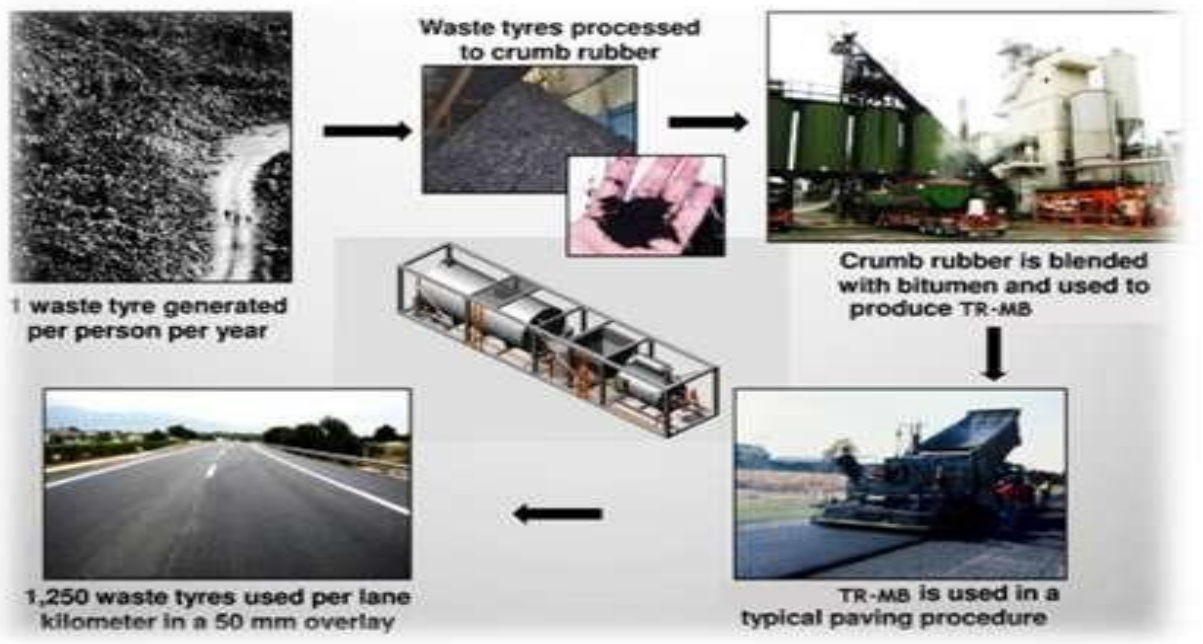

Figure 1- Scheme of rubberized asphalt production through the "wet process"

USES OF RUBBERISED BITUMEN

(i) Rubberised Bitumen as a Slurry Material- Research at the Highways Research Station at Chennai, India indicates that rubberised bitumen pavement has improved resistance to rutting,

moisture damage and age hardening compared with conventional bitumen pavement. The viscosity and susceptibility to changes of temperature of bitumen are changed markedly by addition of a small percentage of rubber. Rubber powder from waste vehicle tyres is recommended for improving the performance of bitumen binder. The durability of surface dressing containing rubber is increased. Bituminous concrete made with rubberised binders possesses much greater stability at high temperatures and at the same time it does not become brittle when cold. This increases its resistance to heavy traffic under varying climatic conditions. Reflection cracking over cracks in concrete roads can be reduced by the use of rubberised bitumen mastic surfacing. Specially compounded rubberised bitumen with a high softening point and low penetration with 5- 10% rubber is extensively used as a joint sealing compound in the construction of concrete slab roadways. The surfacing of steel decked bridges is described. Use of rubberised bitumen is considered cost effective. Fig 2 followed by aggregate application with standard chip spreaders. This process had two distinct construction problems.

Figure 2- Rubberised bitumen applied as a slurry seal

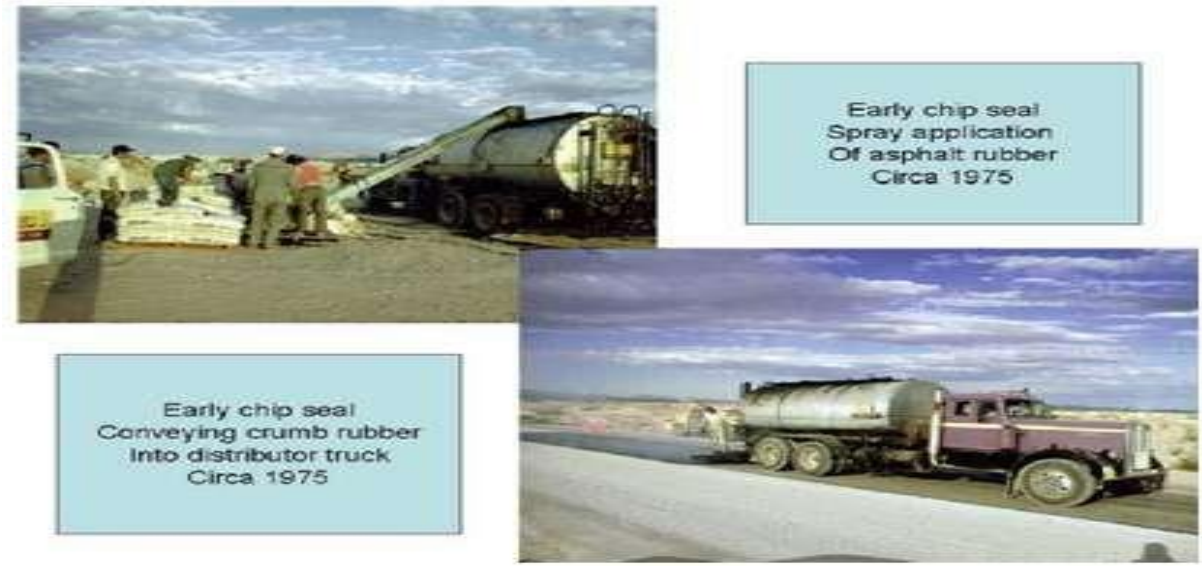

Figure 3- Crumb rubber chip seal

(ii) Rubberised Bitumen as a Chip Seal Application- In 1971, technology had developed to the point that standard bitumen distributor Lorries were employed to apply a uniform thickness of binder to the pavement, Figure 3. Although problems with distribution and segregation of materials were encountered on the early projects, these were recognized as primarily equipment limitations. Within the next few years equipment was developed with pumping, metering and agitation capabilities needed to handle the highly viscous rubberised bitumen materials. As noted earlier, the Arizona Department of Transportation (ADOT) monitored the development of AR and placed a Band-Aid type maintenance application of AR in 1964. In 1968, experience from trial and error and the burning of a couple of distributor boot lorries led to improvements in mixing to a satisfactory degree that AR could be safely and consistently placed with a distributor lorry by using a diluent (kerosene). From 1968 - 1972, ADOT placed AR on six projects that were slated for reconstruction. The cracking on these projects was generally typical of a failed pavement needing at least a six-inch overlay or complete reconstruction.

MATERIALS AND MIX DESIGN

It provides a background on the materials used in crumb rubber modified bitumen and the specifications for those materials. Specific topics will include a discussion of the production and properties of CRM, the shipping and handling of CRM, the properties of the asphalt cement as they relate to asphalt rubber.

(i) Bitumen- Bitumen is a black viscous liquid, containing polycyclic hydrocarbons soluble in trichloroethylene, toluene etc. It produced from crude petroleum oil by a refinery process, or found as a natural deposit. Bitumen is a black, highly viscous and very sticky liquid or semi-solid, found in some natural deposits. It is also the by-product of the fractional distillation of crude petroleum. Generally in India bitumen used in road construction of flexible pavement is of grades 60/70 or 80/100 penetration grade.

(ii) Bitumen Composition and Structure- Whiteoak (1990)63 and Airey (1997)64 explained the four main chemical compositions of bitumen are: Saturates, Aromatics, Resins and Asphaltenes. Resins are normally black or brown solid with high polarity having molecular weight range between 500 to 50,000. Due to the high polarity of the resins, it is very adhesive in nature. The resins portion of the bitumen play like a peptizing agent for the asphaltenes and work as stabilizers, which can keep everything unitedly in the bitumen. 65 Asphaltenes are generally black or brown amorphous solids with highly polar having high molecular weight (between 1,000 and 100,000). There is a relation between molecular weight and size of the asphaltenes molecule i.e. higher the molecular weight, larger the molecules. The rheological properties of bitumen are strongly affected by asphaltenes content. As bitumen heated the gel structure (Figure 3.1, A-sol structure, B-gel structure) of the micelles are decomposed on heating and regenerated on cooling. The asphaltenes micelles may break down when it goes through a long-term heating and decrease the molecular weight. Moreover, asphaltenes content also determine the rigidity and stiffness of the bitumen. Aromatics are mainly dark brown viscous liquid with low polarity and molecular weight range between 300 to 20,000. It plays like a dispersion medium for the asphaltenes and gives gum characteristics to the bitumen.

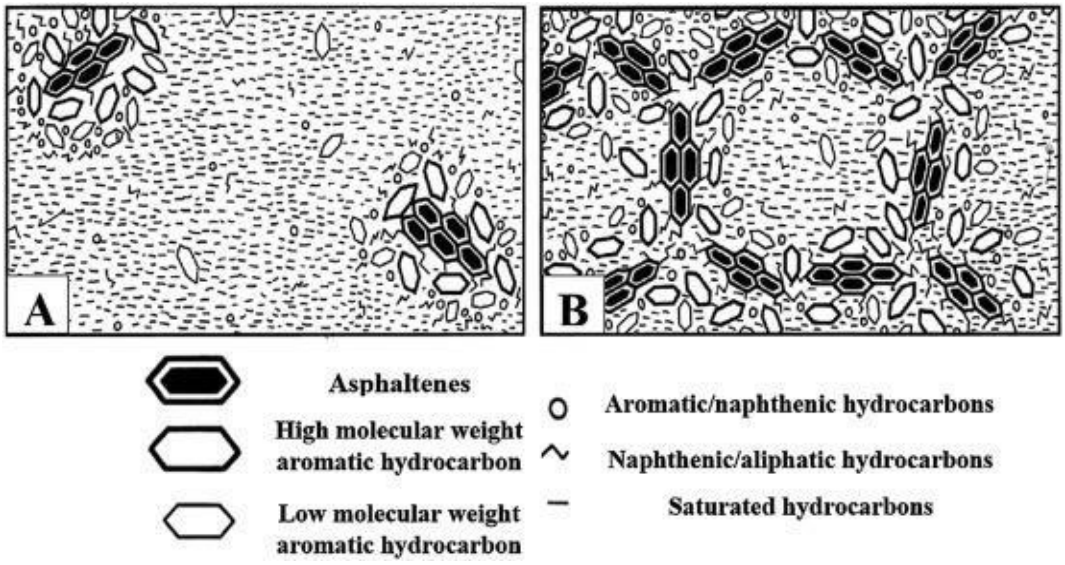

Figure 4- Sol-Gel structure of bitumen (Whiteoak, 1990)

CONCLUSION

After careful evaluation of the properties and taking various tests as per standards the results shown by 10% addition of rubber crumbs has best suitability for blending it with bitumen. This will help to dispose the waste tire rubber in a proper way and solve the problem of environmental

concerns up to a certain extent. This section deals with rubberised bitumen, a binder in hot mix asphalt and chip seal applications that results from the proper addition of crumb rubber to hot bitumen and then left in a heated state to react. Rubberised bitumen is used extensively in California, Arizona and Texas in the USA, in several countries of Western Europe, and in South Africa. It is also used to a lesser extent in parts of Canada and in a dozen more states in the USA. The benefits are many, including reduced long-term road maintenance and expense, significant noise reductions, improved traction and reduced accident rates in wet road conditions.

- Penetration value test result shows that Penetration value decreased with the increased amount of the rubber waste added. Lower penetration value making a harder grade of asphalt, giving additional strength to the road and reduces water damage. Lower Penetration thereby making a harder grade of asphalt, giving additional strength to the road and reduces water damage.
- Softening point test shows that Softening Point increased with the increased amount of the rubber waste added. This showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased. Increase of Softening Point, thereby giving it protection against hot climatic conditions.
- Ductility test result shows that the rubber waste added will harden the bitumen. The bitumen becomes more viscous and harden, which would be useful to obtain stiffer bitumen asphalt.
- The biggest advantage of using rubberized bitumen is that the road life increases in comparison to the normal bitumen whereas the cost increase on the road.
- Improved adhesion aggregates and binder thereby giving better strength, stability and longer life.

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