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Utilization of Waste Tire in Bitumen Product

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ABSTRACT

The waste generation from old rubber tires has been increasing and causing environmental degradation with the escalation of vehicles number especially in the cities. Bitumen is extensively used in flexible pavement construction and as its manufacturing industries were still growing, the cost has not been much affordable. This study aimed at evaluating the possibility of a partial replacement of ordinary bitumen by tire rubber waste, with the purpose to reduce not only the amount of rubber wastes dispersed in the nature, but also the material cost, while keeping or improving the bitumen product performance. The study used rubber waste powder as partial replacement to ordinary bitumen by 5%, 10%, 15%, and 20% of its weight and, with adequate samples, properties of the bitumen product were investigated, after checking the standard quality of used bitumen 60/70 grade. It was established that more adequate results were achieved at 5% of replacement, which showed the penetration value of 61.66 tenths mm, the softening point value of 52.750C, and the viscosity of 134 sec. Regarding the cost estimation of this new bitumen, a cost reduction of around 5.3% was realized. Therefore, the use of rubber waste powder would contribute not only to the reduction of the quantity of respective waste in the environment, but also influence on the material affordability. The use of other grades of bitumen than 60/70, as well as the strength and durability performance may be a good scope for further studies.

Keywords: Bitumen product, heating, penetration, softening point, waste rubber tire, viscosity.

1. INTRODUCTION

Bituminous materials are used widely all over the world in different construction areas like roof waterproofing products, asphalt for highway, etc. All bituminous materials consist primarily of bitumen which has strong adhesive properties, and a consistency ranging from liquid to solid. On one side, bitumen has been in use as a binder for many years, and alongside its performance, not only it still may offer a short lifespan of pavements, due to fatigue loading, etc. (Nagórska et al., 2015), but also its cost has been high until today. On the other side, the dumping of old car tires resulting from traffic increases in developing cities remains a big environmental issue. About 60% of waste tires are disposed of in the urban and rural areas, and they are causing a huge problem both economically and ecologically. In recent decades, studies have been proposing the use of waste tire rubber in partial replacement of aggregates for flexible pavement, as a sustainable solution of cleansing the environment (Ongarbaev et al., 2013; Mashaan et al., 2014). The comparison between flexible and rigid pavement regarding their application and respective life span proved that most of the Rwandan roads are built with flexible pavement which in some cases, was not lasting longer due to many reasons like traffic loading, poor adhesion between asphalt and aggregate, the ageing process, as well as materials properties. Therefore, in front of this study stood a need for improving this quality as well. Locally, the use of old rubber tires would be of many benefits as its amount was increasing, and a sizeable portion was disposed improperly located and operated dumpsites, resulting in adverse impacts on the environment and health, as they are not degradable (MININFRA, 2019). Currently, the only little amount of waste rubber tires was being used in the fabrication of shoes and for decorations. The main aim of this experimental study was to search for an answer to the following question: Can the tire rubber waste be used in form of a powder as a partial replacement in bitumen, so that to achieve not only an affordable and strong bitumen product, but also to contribute to the environment protection? Therefore, the general objective is to conduct the assessment of properties for bitumenmixed with tire rubber waste powder, and the cost estimation of the new bitumen product. The specific objectives are the following, among others: to identify properties of bitumen and underline the weakness, to collect and prepare the tire rubber waste, to mix the ordinary bitumen with rubber wastes powder and test the new product, as well as to estimate its cost. The tests result like penetration, softening point and viscosity are used to confirm the quality of the newly manufactured bitumen. However, other investigations like on the strength and durability performance, or the use of another grade of bitumen may be a good area for further study. For a matter of consistency, in this study, the ordinary bitumen means standard or conventional bitumen, while bitumen product means bitumen mixed with rubber waste, under laboratory conditions. The use of waste plastic and waste rubber tires in flexible highway pavements may increase both the Marshal stability value and the density of the mix with comparison to 60/70 grade bitumen (Rokade, 2012). While investigating the effect of waste plastic and crumb rubber on physical properties of bitumen, among other conclusions, Chirag (2013) established that the properties of bitumen such as penetration, softening point and ductility were improved with the addition of the waste plastic and crumb rubber. Lo Presti (2013) conducted a literature review study on recycled tire rubber modified bitumen for road asphalt mixtures; dispute many advantages realized, he observed some technology struggle and offered some suggestions for its improvement. In his study, Magar (2014) investigated the modification of bitumen with 15% by weight of crumb rubber with varying sizes and gave recommended sizes to obtain the best results.

1.1 STATEMENT OF PROBLEM

The plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the pavements and we can achieve road stability, minimizing cost of the bitumen. This study highlights the developments in using plastics waste to make plastic pavements. The rapid rate of urbanization and development has led to increasing plastic waste production. As plastic is non-biodegradable, it remains in environment for numerous years and disposing plastic wastes at landfill are unsafe since toxic chemicals percolate out into the earth, and under-ground water and pollute the water bodies. Due to littering routines, insufficient waste management scheme, plastic waste disposal to be a big problem for the civic authorities, especially in the urban areas. Plastic disposal is one of the major problems for developing countries like in India. Scarcity of bitumen needs a deep thinking to ensure fast pavement construction. At present the disposal of waste plastic has become a major waste management problem in the world. Hence, efforts have made to identify the potential application of waste plastic in civil engineering projects. The aim is to use of waste plastic in bitumen for road pavement construction.

1.2 INTRODUCTION OF MATERIALS

Coarse aggregate

The Coarse aggregate consists of crushed rock, crushed gravel or other gravel or other hard material retained on 2.36 and passing on 4.75 mm IS sieve.

Fine aggregate

Fine aggregate consists of crushed or naturally occurring material or their combination passing 2.36 mm IS sieve but retained on 75µm.

Fly ash

Fly ash as a filler passing 75µm IS sieve. It is one of the residues generated in combustion of coal. Comprises of fine particles which rise with the flue gases. One of the major pollutants which originate from combustion.

Bitumen

Bitumen is a black or dark colored solid or viscous cementitious substance having an adhesive property. And it consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt. And also, it is a semi-solid hydrocarbon product produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process.

Waste rubber

Crumb rubber is obtained from truck or automobile tires. Whole truck tires contain 18% natural rubber compared to 9 percent in automobile tire. And the scrap tire is shredded into small pieces by the help of mechanical blades up to sizes of 1mm-75µm.

2. METHODOLOGY

Waste rubber tires were collected from roads sides, dumpsites and waste-buyers. The collected waste tires were sorted as per the required sizes for the aggregate. The waste tires were cut in the form of aggregate of sizes ranging from 22.4 mm to 6.00 mm in the tire cutting machine.

Fig.2.1 Rubber tire cutting machine (source:www.google.com/rubber tire cutting machine)

The waste rubber tires can be managed as a whole tire, as slit tire, as shredded or chopped tire, as ground rubber or as a crumb rubber product. The rubber of tire usually employed in bituminous mix, in the form of rubber particles are subjected to a dual cycle of magnetic separation, then screened and recovered in various sizes and can be called as Rubber aggregate. It was cleaned by de-dusting or washing if required. The rubber pieces (rubber aggregate) were sieved through 22.4 mm sieve and retained at 5.6 mm sieve as per the specification of mix design and these were added in bituminous mix, 10 to 20 percent by weight of the stone aggregate. These rubber aggregate were mixed with stone aggregate and bitumen at temperature between 1600c to 1700c for proper mixing of bituminous mix. As the waste rubber tires are thermodynamically set, they are not supposed to melt in the bitumen, at the time of mixing of rubber aggregate, stone aggregate and bitumen in hot mix plant.

3. APPLICATION OF WASTE RUBBER

This chapter deals with the use of waste rubber and fly ash in bituminous mixes, work done by Ghulamsakhi aziz and Zulufqar bin rashid in January 2018.

By using 2, 4, 6, 8, 10% of PET (polyethylene terephthalate) density increases and flow value also increases, Marshall Stability value with 5.3% waste plastic in 2900 kg and the percentage increases in stability value has been found to be 75.76% as compared to the mix without plastic.

3.1 USE OF RUBBER IN BITUMINOUS MIXES

The addition of rubber aggregate in bituminous mix decreases the quantity of stone aggregate by volume and increases the flexibility and flexural strength of the carpet layer of the highways. Aggregate is the granular material used in bitumen concrete mixtures, which makes up 90 to 95 percent of mixture weight and provide most of the load bearing characteristics of the mix. Due to which the quantity of aggregate is gradually decreasing which will need the alternative material as aggregate for the highway construction.

The waste Tires can be used as well sized aggregate in the various bituminous mixes if it is cut in the form of aggregate and can be called as rubber aggregate. This not only minimizes the pollution occurred due to waste Tires but also minimizes the use of conventional aggregate which is available in exhaustible quantity.

Crumb rubber of sieve fraction 2.36 mm was used to substitute a fraction of the fine mineral aggregates of similar sieve size (2.36 mm) so that the overall grading was maintained. Proportions of 0%, 1% 2%, 3%, 4% and 5% of crumb rubber by weight of the aggregates were used in the asphalt mix and desired plastic to asphalt ratio was added from 2-10% by weight of bitumen. At the result highest flow values are exhibited by 5% crumb rubber and 10% LDPE.

Fig.3.2 waste tyres (Source www.google.com/rubber)

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By adding 0-4% crumb rubber in bitumen specific gravity, softening point, flash & fire point are increasing and ductility, penetration are decreasing. But up to 1% addition of crumb rubber obtain value are within the limit. Stability and flow of bitumen mix are within the limit up to 1% of crumb rubber. By replacing 5% aggregate of size passing 19mm and retained on 13.2mm by rubber aggregate obtained marshal stability and flow value are within optimum limit. Penetration value decreased with the increased amount of the rubber waste added. Lower Penetration thereby making a harder grade of asphalt, giving additional strength to the road and reduces water damage. 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.

3.2 OBJECTIVES

To study on polymer modified asphalt mixtures to evaluate engineering properties using marshal stability.
To study basic properties of aggregates and plain bitumen.
To study the strength and stability characters of BC mix for 60/70 grade bitumen. To study the effect of waste plastic on strength and stability characteristics of BC mix. To study characteristics of bitumen.
To study performance of stability characters of BC mix.
To study strength characteristics of waste plastics.
To study strength characteristics of BC mix.

4. TESTS

4.1 TEST ON BITUMEN

The following are the tests on the bitumen:

4.1.1 penetration test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle would penetrate vertically in 5 seconds. A grade of 60/70 bitumen means the penetration value is in the range 60 to 70 at standard test conditions. In this study, the penetration test was carried out on each sample of bitumen products where obtained data are analysed to establish the rubber powder percentage corresponding to a better penetration value. The materials used to carry out the test are standard needle, penetrometer apparatus, cans, heater, water, thermometer, kerosene, glycerin

Table 4.1: Test result of penetration value of bitumen vs Penetration Value (mm) modified Bitumen.

S. No	Penetration Value (mm) Plain Bitumen	Penetration Value (mm) Modified Bitumen (10% Plastic Replaced)
1	79	67
2	63	49

Source (Manju et al. 2017)

4.1.2 softening point test

The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of this test.

The test is conducted by ring and ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5C / minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

Table 4.2: Test result of softening point of bitumen and modified bitumen (bitumen replaced by plastic)

Sample No	Softening point(0C) (plain bitumen	Softening point(0C) 10% bitumen replaced by plastic
1	69.2	80.7
2	70	81.2

Source (Manju et al. 2017)

4.1.3 standard elastic recovery test

Standard elastic recovery (ER) test was used for measuring the tensile property of the modified bitumen, this such test was intended to optimize the dose of polymeric additive in the bitumen along with accessing their quality in laboratory as per standard specification. The ER of modified bitumen was evaluated by comparing recovery of thread after conditioning for one hour at standard temperature and the specimen was elongated up to 10 cm deformation in ductility machine and then cut off at the middle of the sample and left for an hour in 15°C water to measure its recovery. This was intended to assess degree of bitumen enrichment by polymeric additives.

4.1.4 Viscosity test:

This test determines the dynamic viscosity of the bitumen. The viscosity is greatly influenced by temperature under which it is spread into the voids and it coats the aggregates. In this study, the viscosity test is carried out in order to establish the practical percentage at which bitumen product would provide better viscosity. Materials used are viscometer, thermometer, brookfield, glycerin, graduated cylinder, stopwatch. Some of these tools are shown in Fig. 7. The viscometer with bitumen samples should be plugged into the voltage source to raise the temperature up to 600C.

5. Analysis of Results .

5.1 PENETRATION TEST RESULTS

The comparison was done between ordinary bitumen and bitumen product with 0%, 5%, 10%, 15%, and 20% of tires rubber waste. From the results shown in Table 1 and Table 2, it can be seen that the penetration value for ordinary bitumen was 65.43 mm, while the penetration value for bitumen product was gradually decreasing with an increase of rubber waste. It is worth to note that the lower penetration value means the higher strength of bitumen which makes a harder grade of asphalt and offers additional strength to the road structure. The addition of tire waste into bitumen improved the penetration properties by increasing its hardness

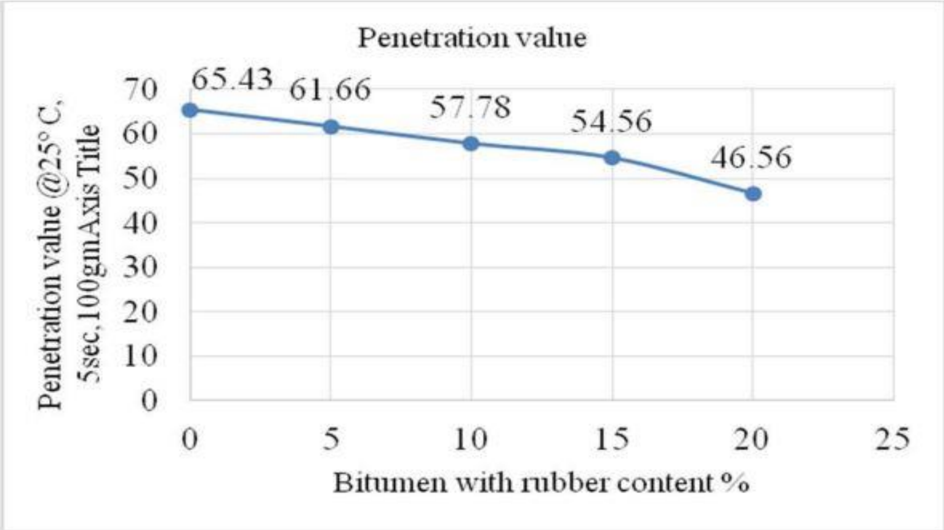

FIG 5.1 source"Use and Influence of Tire Rubber Waste Powder in Bitumen Product." Journal of Engineering, Project, and Production Management

5.2 SOFTENING POINT TEST RESULTS

The results illustrated in Table 3 and Table 4 show that the softening point for ordinary bitumen found is 49.350C, while the addition of tire rubber waste adversely affected the temperature by increasing the softening point. Fig. 9 shows the variation of softening temperature with % of tire rubber waste. As for the penetration, the addition of tire rubber waste in bitumen improved the softening property of bitumen.

FIG5.2 source"Use and Influence of Tire Rubber Waste Powder in Bitumen Product." Journal of Engineering, Project, and Production Management

5.3 VISCOSITY TEST RESULTS

With regards to the viscosity, results illustrated in Table 5 and Table 6 show that the viscosity value in seconds at 600C for 50 ml of ordinary bitumen was 124 sec. The addition of rubber waste in ordinary bitumen adversely affected the flow of bitumen by increasing the viscosity The Fig shows the variation of viscosity in seconds with increase in % of tire rubber waste. The increase of viscosity value shows how the bitumen product sticks with the aggregates when used in asphalt preparation.

FIG5.3 source"Use and Influence of Tire Rubber Waste Powder in Bitumen Product." Journal of Engineering, Project, and Production Management

5.4 COST ESTIMATIONS OF THE BITUMEN PRODUCT AND OTHER ADVANTAGES

The calculated cost of bitumen product shows a decrease of around 13,600RwF - 15,870RwF (around 20USD). This would mean that the replacement of bitumen by 5% of rubber wastes can reduce the cost of 500m3 bitumen by 5.3%. Therefore, for a big quantity of works with bitumen application, the reduction of used bitumen as well as the decrease of tire rubber waste in the nature would be important.

6. EFFECT OF HIGH TEMPERATURE STORAGE STABILITY ON POLYMERIC WASTES ADDED BITUMEN

To quantify the compatibility between waste materials and the bitumen during mixing and the resistance against separation of the wastes from bitumen in the conditioned samples, a stability test has been executed. Results of the same are analyzed in terms of differences of softening point value against the added percentages of wastes with bitumen. Bitumen loses its homogeneity after conditioning at 163°C for 48 h because the differences in the softening point values of the conditioned samples are increased beyond 2.5°C for addition of all types of modifying agents more than 1% by weight indicate less compatibility (phase separation) with bitumen except PC and PMP. Significant compatibility has been observed for PC up to 3% by weight while insignificant compatibility spotted for PMP more than 0.5% by weight with base bitumen. Further chemical study of such polymeric modifiers revealed that the content of aliphatic C-H in the PB, PMP, and MP possibly enhances the hydrocarbon branches of the base bitumen, resulting in stiffer binder, while carbon black present in the TRA shows the same effect for its higher dosages also. Again, increased concentration of asphaltene in the blend with the higher dosages of polymeric modifiers in the bituminous blend caused a less compatible bitumen matrix.

6.1 ADVANTAGES AND DISADVANTAGES

Advantages

Environmental: Discarded tires provide the source for the rubber granules used in rubber asphalt. It is estimated that the annual amount of rubber available from discarded tires is lakh tons, an amount sufficient to modify the pavements on 4000 kilometer of two-lane.

De-icing: Rubber asphalt pavements have been reported to keep themselves de-iced. The patent holder claims de-icing occurs by compression of protruding rubber granules which sufficiently deform the pavement under the weight of traffic. This causes fracture of the ice layer formation. Following this, wind created by passing vehicles clears the ice from the roadway.

Noise Reduction: Reductions of up to 10 dB in noise level in comparison with noise levels of conventional pavement surfaces have been reported.

Skid Resistance: The surface texture and protruding rubber granules are reported to give the pavement improved skid resistance during dry, wet, and icy conditions. Measurements have shown a reduction in stopping distance averaging 25% under icy road conditions.

Hydroplaning and Water Spray: The high content of coarse aggregate in this product results in a coarse surface texture with good surface drainage, which reportedly eliminates hydroplaning and reduces water spray.

Sanding and Salting:

With improved skid resistance and deicing characteristics, the need for sanding and salting
Would be greatly reduced. This would result in a reduction of maintenance costs and corrosive damage to vehicles.

Increases the drainage properties of road pavement.

There is a no compression takes place due to continuous loading of traffic.

Vibration attenuation property will be increase.

Disadvantages

Cleaning process-

Toxics present in the co-mingled tyre waste would start leaching.

During the road laying process-

In the presence of chlorine will release noxious HCL gas.

After the road laying-

It is opined that the first rain will trigger leaching. As the rubber will merely form a sticky layer, (mechanical abrasion).

The components of the road, once it has been laid, are not inert.

6.2 SIGNIFICANCE AND SCOPE

Significance

A certain proportion of waste tyres are reused as treads or are reclaimed for other forms of reuse/recycling. Waste tyres can be used in cement kilns as an alternative fuel, or in the production of electricity, despite the fact that the incineration of tyres, which is an undesirable option, can not be achieved without pollution and contribution to climate change.In addition to these general non-civil engineering applications, several studies have been carried out in order to examine the feasibility of the addition of these wastes in cement and asphalt concrete as well as in geotechnical works, where tyres take the place of conventional construction materials such as fills or aggregates. The design engineer is

responsible for determining the appropriateness of using scrap tyres in a particular application and for selecting applicable tests and
232 Sustainability of construction materialsusing scrap tyres in a particular application and for selecting applicable tests and
specifications to facilitate construction and environmental protection.Recent trends in Europe and worldwide have seen tyres used in many applica-tions: as coatings, as a means for preventing soils from sliding, for sea embankments,as a means for inhibiting erosion near sea, as artificial reefs in marine environ-ments, for temporary and heavy-load roads, as off-shore breakwaters, in retainingwalls, as sound barriers, in drainage culvert beds, for riverbank and coastalstabilisation, as bridge abutment fill, in tram-rail beds, for thermal insulation andinsulating backfill to limit heat loss from buildings, for insulation to limit frostpenetration beneath roads, as porous bitumen additives, as a means of absorbing seismic waves and for slope stabilisation (http://www.etra.eu.com).The addition of rubber in a wide range of applications in civil engineering isbased upon the unique characteristics of tyre rubber as listed below:
1 High durability constituents of tyres, such as carbon black and antioxidants,enhance the resistance to wear, chemical decomposition and sunlight.
2 Moisture absorption – they are relatively impervious to absorption.
3 Low compacted dry density and thermal conductivity – a tyre is a poor thermal conductor so they are a better thermal insulator than soil or aggregates. 4 High hydraulic conductivity.
5 High compressibility, enough to absorb vibrations.
6 Low acoustic insulation.
Finally, reuse of tyre rubber in the applications mentioned above can lead to the achievement of an environmental goal, which is the protection of the environment by recycling this kind of solid waste. At the same time, the use of large volumes of waste tyres as a substitute for natural aggregates (sand, gravel, etc.) represents a great advantage from the point of view of sustainability in construction, while the tyre mountain would cease to exist.

Scope:

Nowadays, the disposing of rubber wastes has become a vast problem. Crumb rubber is a material produced by shredding and commutating used tires. Approximately 60 percent of waste tyres are disposed of via urban and rural areas. This causes various environmental problems including air pollution (due to burning of tyres) and aesthetic pollution which causes severe health related issues These are a biotic, disposable product due to which these materials pose environmental pollution. In recent years, by-products of rubber wastes are being used in road construction with great interest in many developing countries. The selection of these materials in road construction is based on technical, economic, and ecological criteria and is giving a fruit. Every year millions of tons of rubber waste are produce in India. Utilizing these materials in highway road construction, the pollution and disposal problems can be successfully be reduced. Minding the bulk ruse of these wastes in India, it was thought necessary to examine these materials and to develop specifications to increase the use of rubber wastes in road making, in which higher economic returns may be possible. These materials should be used in road construction in each and every part of our country. The w aste tyres can be used in the form of aggregate which on mixing with various bitumen in suitable size. This reduces the pollution occurred due to waste tyres as well as minimizes the use of natural aggregate, which help in reducing global warming as well as health problems.

7. CASE STUDY

Laboratory studies were carried out at the Centre for Transportation Engineering of Bangalore University, in which the plastic was used as an additive with heated bitumen and different proportions (ranging from zero to 12% by weight of bitumen) The results of the laboratory investigations indicated that, the addition of processed plastic of about 8.8% by weight of bitumen, helps in substantially improving the stability, strength, fatigue life and other desirable properties of bituminous concrete mix, even under adverse water-logging conditions. The additions of 8.0% by weight of processed plastic for the preparation of modified bitumen results in a saving of 0.4% bitumen by weight of the mix or about 9.6% bitumen per cubic meter of BC mix.

In Tamil Nadu, length of roads around 1000 m in various stretches were constructed using waste plastic as an additive in bituminous mix under the scheme “1000 Km Plastic Tar Road”, and found that, the performance of all the road stretches are satisfactory.

In Karnataka, the performance of the road stretches constructed using waster plastic is also found to be satisfactory.

8. CONCLUSIONS

The main objective of this study was to investigate the use and influence of tire rubber waste powder in bitumen products. It was confirmed that the quantity of rubber waste was increasing in nature due to the development of tire manufacturing industries and challenges regarding the respective waste disposal. Also, it was observed that while the application of bitumen in construction was increasing, the bitumen cost was not much affordable. While available studies have been considering rubber waste as aggregates and in addition to bitumen, this study used rubber waste powder as partial replacement to bitumen and checked properties of the modified bitumen. The penetration, viscosity and softening tests were conducted with ordinary and bitumen products with a replacement of 0%, 5%, 10%, 15%, and 20% by respective rubber waste. The established test results were in line with standards values. For the used bitumen of 60/70 grade, the study observed that penetration values were decreasing with an increase of % of rubber waste, and the standard value was achieved at 5% of replacement. Therefore, it was recommended that the replacement should be limited to 5% by weight of bitumen, in order to achieve the same grade. Regarding the cost estimation of bitumen, a cost reduction of around 5.3% was realized. Based on all those results, It is concluded that the application with the replacement of rubber waste powder in bitumen product would contribute not only to the gradual reduction of the quantity of respective waste in the environment, but also in some measures influence on the bitumen material affordability. The use of tire rubber waste powder can also improve the performance of bituminous flexible pavement. In order to protect the environment against inhuman gases from the burning of tire rubber waste, the use of incineration burning method is recommended. Finally, further studies either using other grades of bitumen than 60/70 or checking other bitumen properties like strength, durability,

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