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Use of waste tyres in road construction

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ABSTRACT -India is a rapid urbanizing country. Due to overall development new roads are being constructed for ever increasing population. Density of vehicular traffic increases day by day. The wear and tear of tires from these vehicles is undoubted. So, a large number of scrap tires are being generated.A large number of waste and worn-out tires are 15-20% each year.

Waste tyres and their accumulation is a global environmental concern; they are not biodegradable, and, globally, an estimated 1.5 billion are generated annually. Waste tyres in landfill and stockpiles are renowned for leaching toxic chemicals into the surrounding environment, acting as breeding grounds for mosquitoes, and fuelling inextinguishable fires.Now-a-days disposal of different wastes produced from different Industries is a great problem. The modified bitumen and granulated or ground rubber or crumb rubber can be used as a portion of the fine stone aggregate. A mixture of hot bitumen and crumb rubber derived from post-consumer waste or scrap tyres.

These tires are discarded indiscriminately or stockpiled. The used tires pose a great threat to human health and environment, since they are non-biodegradable; the waste tire rubber has become a problem of disposal. 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.

I. INTRODUCTION

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.

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So, an attempt to use this waste tire rubber for improving the properties of bitumen by blending it with crumb rubber and ultimately a new method to be introduced to reduce pollution problems and protect our environment.

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.

II. LITERATURE REVIEW

Prof. Justo et al (2002), at the Centre for Transportation Engineering of Bangalore University compare the properties of the modified bitumen with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 percent by weight.

Therefore, the life of the pavement surfacing using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen. Shankar et al (2009), crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures.

Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67 %). Mohd. Imtiyaz (2002) concluded that the mix prepared with modifiers shows: -

Higher resistance to permanent deformation at higher temperature.

HISTORY

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.

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.

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Fig: Scheme of rubberised asphalt production through the "wet process".

PROCESS OF MAKING RUBBERISED BITUMEN

This terminology is related to the system of producing RTR-MB with the original wet process proposed by Charles McDonald in the1960s. The McDonald blend is a Bitumen Rubber blend produced in a blending tank by blending Crumb Rubber and bitumen. This modified binder is then passed to a holding tank, provided with augers to ensure circulation, to allow the reaction of the blend for a sufficient period (generally 45–60 min). The reacted binder is then used for mix production.

Continuous Blending-reaction Systems: This system is similar to the McDonald process of blending; the difference is that CRM and bitumen are continuously blended during the mix production or prepared by hand and then stored in storage tanks for later use. Therefore, it consists of a unique unit with agitators, in which the reaction occurs during the blending.

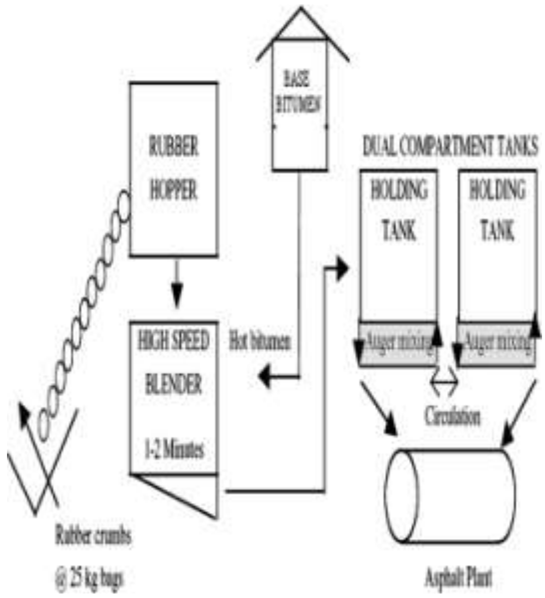

Fig: Schematic diagram of McDonald process

USES OF RUBBERISED BITUMEN

1 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 followed by aggregate application with standard chip spreaders [MCD81]. This process had two distinct construction problems.

First, in order to achieve the desired reaction of the bitumen and crumb rubber in the limited time available in theslurry equipment, it was

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necessary to employ bitumen temperatures of 4500 F (2320 C) and higher.

Second, the thickness of the membrane varied directly with the irregularity of the pavement surface. This resulted in excessive materials in areas such as wheel ruts and insufficient membrane thickness.

Fig -1: Rubberised bitumen applied as a slurry seal

2 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.

For these seal coat type application projects, a boot truck distributor was used to apply the AR. In these early applications the ground tyre rubber was introduced into the top of the boot lorry and mixed by rocking the lorry forward and backward. Even with this rather primitive early technology it was possible to construct the first full scale ADOT field experiment in 1972 using AR as a seal coat or Stress Absorbing Membrane (SAM), as well as an interlayer under a hot mix asphalt (HMA) surfacing. The interlayer application is typically referred to as a Stress Absorbing Membrane Interlayer (SAMI).

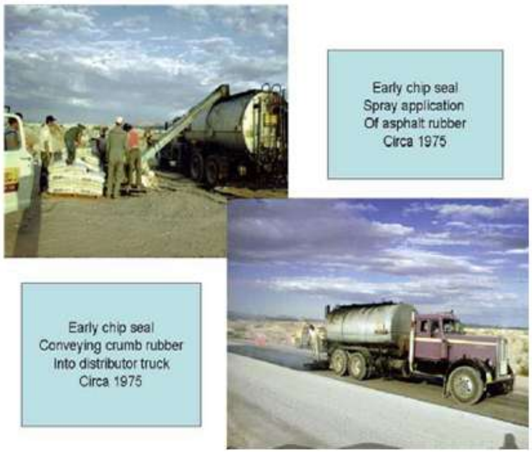

Fig -2: Crumb rubber chip seal

Sieve	Percent Passing
2 mm, #10	100
1.18 mm, #16	65-100
600 µm, #30	20-100
300 µm, #50	0-45
75 µm, #200	0-5

Table -1: Ground Tyre Rubber Gradation.

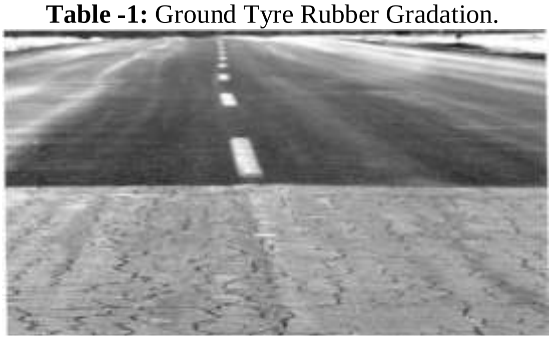

Fig: Rubberised bitumen chip seal applied to badly cracked pavement.

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3. Rubberised Bitumen Mix Construction:

Construction of an AR pavement involves first mixing and fully reacting the crumb rubber with the hot bitumen as **Fig -5:** Crumb rubber required by specification. Typically, 20 percent ground tyre rubber that meets the gradation shown in Table 1 and is added to the hot base bitumen. The bitumen needs to have a temperature of about 177^{O}C (about 350^{O}F) before being put into the blending unit, that heats the bitumen to 191^{0}C to 218^{O}C (375^{O}F to 425^{O}F) just prior to adding the rubber particles. The rubber and bitumen are mixed for at least one hour. After reaction, the rubberised bitumen mixture is kept at a temperature of between 163^{O}C and 191^{O}C (325°F and 375^{O}F) until it is introduced into the mixing plant Samples of the rubber, base bitumen, and AR mixture are taken and tested accordingly. The ARFC, which typically has one percent lime added to the mix, is placed with a conventional laydown machine and immediately rolled with a steel wheel roller.

5. Why is Rubberised Bitumen a Best Practice?

1. It is a less expensive application when used as a thin top course over failed pavement that would otherwise need replacement (California & Arizona studies).
2. It is less expensive to maintain per lane-kilo meter (lane mile) in years 6 through 15 of pavement life over conventional pavements, and the same in years 1 through 5 (Arizona & California studies).
3. It significantly reduces noise as opposed to concrete pavements, and also is quieter than bituminous pavements; rubber bitumen makes urban environments more habitable (Arizona DOT studies).
4. It significantly improves wet surface traffic safety (Texas DOT studies).
5. It creates less of a "heat island" effect than with concrete pavement at surface (Arizona State University studies).
6. It provides better surface road drainage when used in an Open Grade Friction Course (Texas & Arizona studies), and
7. It is a hugely beneficial use for post-consumer waste tyre materials, using about 1,000 waste passenger tyres per lane mile (about 621 waste passenger tyres per lane-kilometer).

Fig -6: Rubberised bitumen construction**.**

III. METHODOLOGY

For this research work aggregate, bitumen and crumb of scrap tyre was used. Different properties of bitumen and aggregate have been tested. Then prepare different mixes of bitumen and crumb of waste tire rubber with varying proportions by using wet process.

The percentage weight of crumb tyre rubber replaces for percentage weight of bitumen taken for test. The feasibility of different mixes of bitumen and crumb tirerubber with varying proportions with aggregate has been tested.

IV. RESULTS

Marshall Stability test has been preparing for bituminous mix design, for this research project the size of aggregate used as follows.

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Table No. 1: Mix Proportion

Material	Sieve size mm	Wt. in kg.
Aggregate	40 – 19	74.10 gm.
	19 – 13	347.1 gm.
	13 – 6	260.00 gm.
	6 – 0	559.00 gm.
Bitumen		59.8 gm.
	Total	1300 gm.

Table No. 2: Physical properties of aggregate & filler used

Sr. No	Aggregate tests	Test results obtained			
1	Crushing value (%)	24.8			
2	Impact value (%)	20.8			
3	Los Angeles abrasion value (%)	32			
	Sieved size mm	**40-19**	**19-13**	**13-6**	**6-0**
4	Specific gravity	2.68	2.65	2.63	2.62
5	Water absorption	0.93	0.75	0.68	-----

Table No.3: Physical properties of ground waste tire rubber

Properties	Measured value
Specific gravity	0.94
Unit weight g/cm^3	0.69
Absorption %	1.8
Fineness modulus	3.78

Table No. 4: The properties of the bitumen without rubber content

Sr. No.	Penetration test @27^{0}C, 5S,100gm	Softening point @ ring test	Ductility(cms) @27^{0}C, 5cm/ min	Viscosity (sec) @ Viscomet by ball stopper	Specific gravity Reading (G)

1.	60-70 grade	60 ^{0}C	73	26	1.036

Table No. 5: Details of sample constitution and percent constituents

Sample constitution	**Sample preparation**	**% constituent by wt. of bitumen**
60/70 grade bitumen + 0.2-1 mm particle size of crumb rubber	Wet process	5%
		10%
		15%
		20%
		25%
		30%

Table No. 6: Properties of bitumen by varying % of rubber

Properties	**60/70 grade bitumen**	**Bitumen with rubber content %**					
		5	**10**	**15**	**20**	**25**	**30**
Penetration value @ 25^{0}C, 5 S, 100 gm	65.6	59.3	56.3	45.6	35.3	27.2	21.6
Softening Point(^{0}C) @ ring ball test	57	62	62	65	72.5	77.5	83
Ductility test (cms)@ 27 ^{0}C, 5 cm/min	73	61	55	41.6	21.8	14.3	12.7
Viscosity test@ 27^{0}C(sec)	26	22.5	20	17	15.5	11.5	9
Specific Gravity	1.036	1.180	1.24	1.46	1.70	2.0	**1.26**

3. Marshall stability test

IRC Recommendation for modified blended bitumen

%of rubber	Wt. sample o f (gm)		Bulk specific gravity (g/cc)	% air voids (Vv)	VMA	VFB	Marshall stability (kg)	Flow value (mm)
	Air	water						
0	1257	773	2.56	4.12	15.49	73.40	1190.56	3.3
5	1274	787	2.58	4.08	14.13	71.12	1051	3.0
10	1278	798	2.60	4.41	14.05	68.64	912.8	2.9
15	1269	790	2.63	4.36	12.64	65.30	843.8	3.6
20	1284	791	2.60	5.10	12.73	58.00	715.9	2.7
25	1270	789	2.63	5.05	10.81	53.28	652.9	2.9
30	1268	793	2.64	6.06	11.43	46.98	550.6	2.6

Bitumen Grade – 60/70

Test property	**Specified value**
Marshall Stability kg.	340 (minimum)
Flow value (mm)	2.5 – 4
Air voids in total mix Vv %	3 to 5
Voids filled with bitumen VFB %	**65** o 85

Conclusion

1) The values of Marshall Stability are consistent for all rubber percentage reading.

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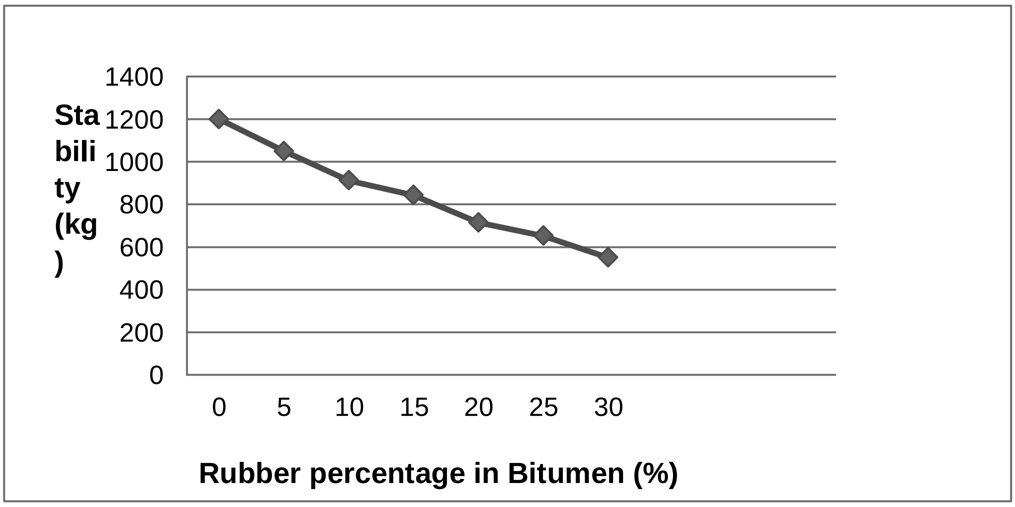
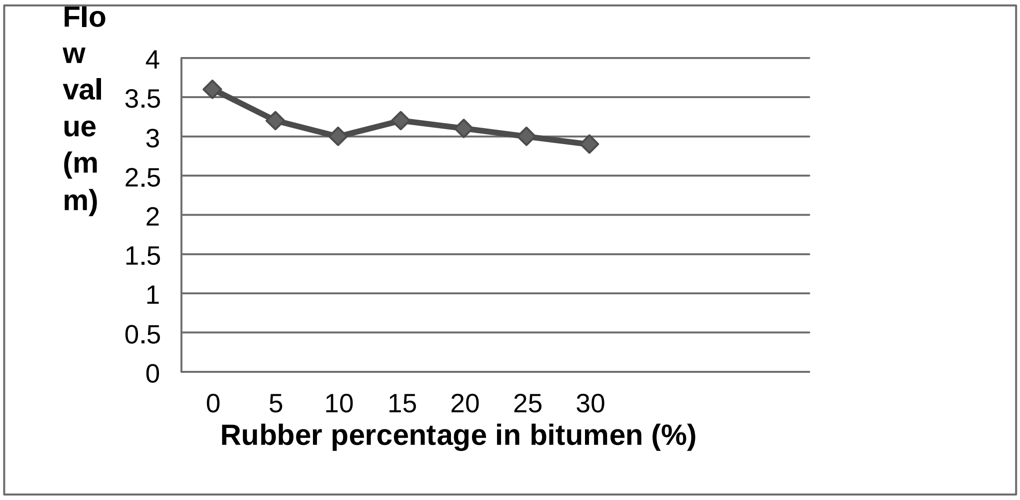


Graph No.1 Percentage of Rubber in Bituminous Concrete Vs Marshall Stability.

2) The values of flow value are consistent for all rubber percentage reading.



Graph No.2: Percentage of Rubber in Bituminous Concrete Vs flow value

3) The values of air voids in total mix are consistent up to 15% of addition of rubber.

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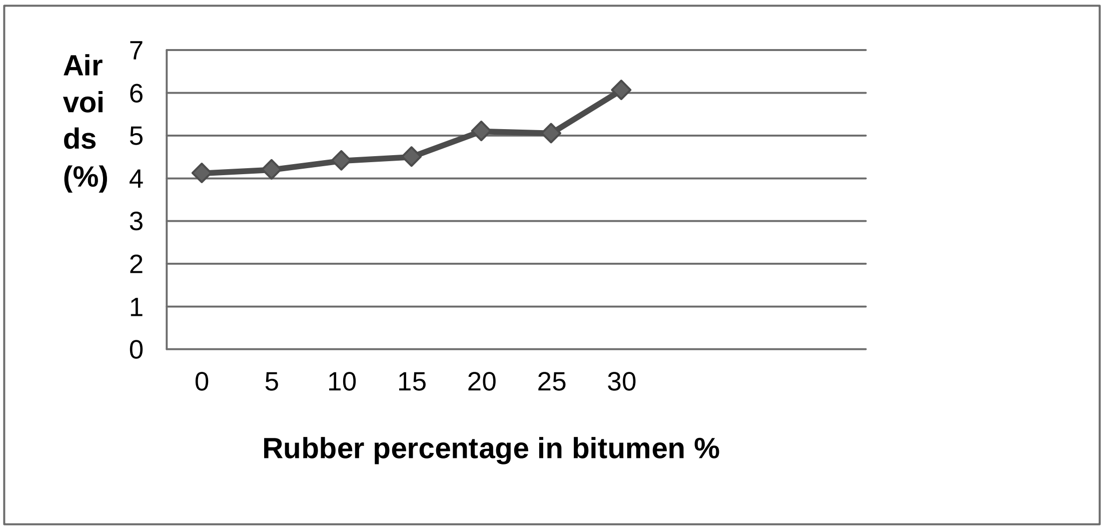
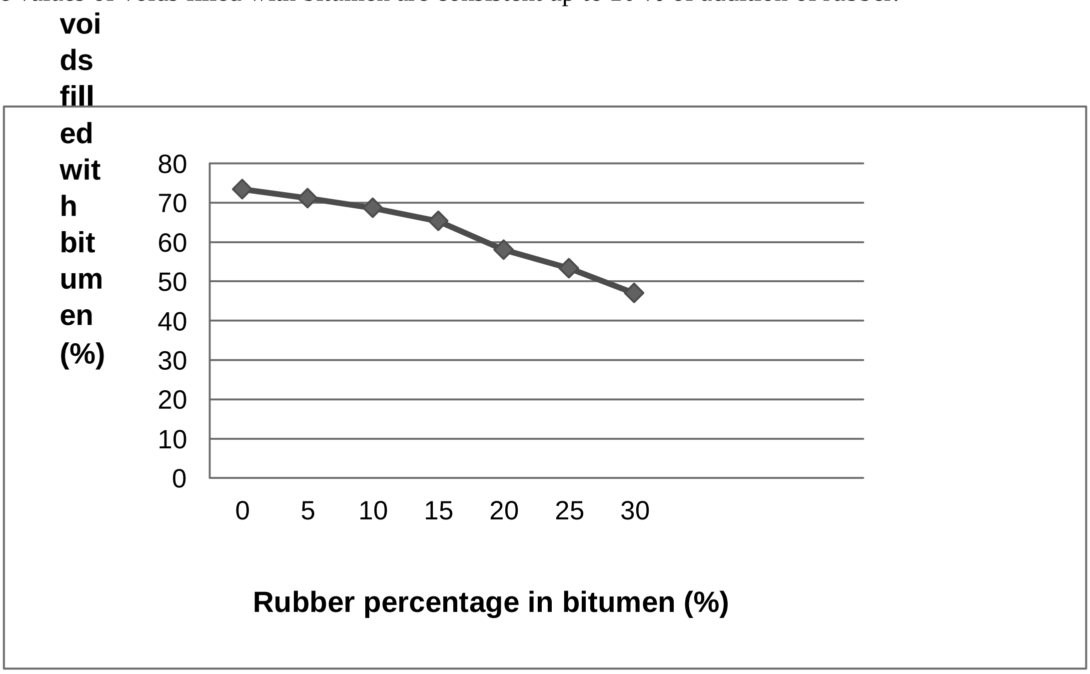


Graph No.3: Percentage of Rubber in Bituminous Concrete Vs Air Voids (Vv)

4) The values of voids filled with bitumen are consistent up to 10 % of addition of rubber.



Graph No.4 Percentage of Rubber in Bituminous Concrete Vs voids filled with bitumen (VFB)

V. CONCLUSIONS

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.

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