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A Review on Modification of Bitumen for Flexible Pavement

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Abstract: ***A focus on National and International status review reveals that vast infrastructural development has to be focused only with the available materials. Since, construction materials are in the stage of extinction, we have to make use of the waste materials ensuring its suitability to safeguard the environment. Man for all his daily requirements has to travel from one place to another, mostly by road transport. Bitumen, a road making material is a source from petroleum refineries as a by-product. Oil is a non renewable resource, thus the bitumen's availability in the near future is also in the verge of annihilation. Owing to this, bitumen has to be partially replaced with other possible modifiers. This paper gives an idea of different modifiers that have been used by researchers and the plausible impact of the modifiers on the strength and durability of the bitumen. Modifiers like Low Density PolyEthylene(LDPE), High Density Poly Ethylene(HDPE), Nano clay, Rubber, Polypropylene, Nano Montmorillonite, Nano silica, flyash, Styrene Butadiene Styrene(SBS), Cloisite, Nanofil, Evotherm, Cecabase Rt and Crumb Rubber are used. Binder percentages used by authors are similar to some extent but modifiers percentages vary extensively. From the literatures, it is suggested that the optimum percentage of modification only yields better results. Though availability of the modifiers plays a main role, it must be chosen based on the soil conditions and climatic conditions to meet the specific requirements of the desired pavement life.***

Keywords: ***Bitumen Modifiers, Nanoclay, Montmorillonite, Polymer, Rubber, Nanosilica, Flyash, Cloisite, Nanofill, CNT***

I. INTRODUCTION

Modification of construction materials is the need of the hour. Instead of using all available bitumen source let us focus on modifying the bitumen partially and analyse modified bitumen's strength and durability. If strength and durability are enhanced without affecting the environment then modification of bitumen is preferred. Also, with economic point of view there will be huge reduction in cost if bitumen is partially replaced with other modifiers for improved performance. Hence, the objective of this paper is to analyze different modifiers of bitumen.

II. MATERIALS

A. Bitumen

Bitumen is derived as a by-product from distillation of crude oil process and hence may not obtain desired properties in all cases. To arrive at our required properties, the bitumen is enhanced by carefully selecting the compatible modifiers.

B. Polymer

The polymers are thrown after its usage as waste on the motherland which clogs infiltration of rainwater due to its non biodegradability. Approximately, 70% of the plastic produced goes as waste very often like one time use example carry bags, etc., As per Central Pollution Control Board reports, in India 15342 tonnes/day of waste plastics are generated and it is 5.6 million tonnes per annum. So, many types of polymer like LDPE, HDPE and Polypropylene are tried in bitumen. This polymer addition safeguard the bituminous mix and the under layers by preventing the percolation of water.

C. Rubber

Over usage of tyres leads to its malfunctioning hence tyres are thrown out in environment polluting the land because of the stabilizer and fire retardant contents added in tyres. If burnt they emit methane gases. Globally, per annum 15 million tonnes of waste tyres are generated out of which India contributes to 1 million tonne. Apart from own generation, reports states that from January to

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March 2016 about 70,000 tonnes of waste tyres have been imported to India. So, we have to technically make use of those tyres for our needs without affecting the environment.

D. Clay and Nanoclay

Clays are minerals, occurring naturally and subject to variability in constituent materials. Naturally available clay is converted to nano size to attain high surface area to stick to the bitumen and bind the aggregates together with it. The nano clay modification yields multifolds of profit even when added in small quantity.

III. REVIEW

A. Polymer

Polymer of both types plastomeric and elastomeric can be used in bitumen. Bitumen has numerous uses as paving, maintaining like filling, patchwork, recycle and slurry seal. Polymer adapts itself to blend with bitumen for all these uses. Shiva Prasad K et al.,(2012) suggested that first bitumen has to be heated to 260° to 280°C then the waste plastics must be added to it, if not then the blend will not be properly mixed. But if so happens the bitumen may catch fire since it reaches its fire point and also loss in weight of bitumen also may occur. Yazdani et al.,(2012) used polypropylene plastomer, Styrene Butadiene Styrene elastomer and Nanoclay. Compressive strength and softening point of modified bitumen increased by 55%. Among the various percentages tried, it was concluded that at PP 5%, SBS 3% and NC 1.5% has given an optimized result in enhancing the properties Avula Vamshi(2013) found that the stripping value of 10% plastic modified bitumen is nil as compared to virgin bitumen of 0.4%. Also there is a material cost reduction of 7.99% when plastic waste is used in the road. Modified bitumen decreases the penetration when compared with the plain bitumen. S. Rajasekaran et al.,(2013) concluded that the thermal analysis using Thermal gravimetric analysis shows that polymer like Polyethylene, polypropylene and polystyrene softens from 130°C to 140°C without evolution of gas. It is safe if molten waste plastic is used below 150°C. Also the increasing order of strength is poly styrene, poly ethylene and poly propylene for the modified bituminous block. Sandhya Dixit et al., (2013) in their paper suggested that maximum 0.6% of plastic fibre modification only yielded satisfactory results. Marshal stability values increases with binder content of 5.4%. Shweta N. Rokdey et al., (2015) published that the waste plastics are mixed with hot bitumen at 160°C. Plastic modification of bitumen increased the melting point of the binder. They used thermosets, elastomers and thermoplastics as modifiers. They also absorbed that the polymer will not be leached out of bitumen. al., (2015) proved that 9% of LDPE by weight of the bitumen to be an effective proportion of binder. They achieved 32.5% increase in the stability value comparing with neat bitumen. Voids in mineral aggregates were 5%. Air voids calculated were up to 66.7% Yash Menaria et al., (2015) in their study found that waste plastic of 8% is the optimum amount to be added to modify the bitumen. They suggested that plastic roads can also be laid with areas having high tempeature like 50°C. The optimum binder content was found to be 4.5%. Dry process is followed in this work. Amit kumar Sahu et al., (2016) studied the bitumen modification and suggested that polymer have wonderful adhesion property and hence there is nil stripping value for about 72 hours againt 5% of stripping in conventional bitumen for 24 hours itself. Moisture absorption of polymer modified bitumen coated aggregates is found to be 0.12% for 10% of plastics; the value for conventionl bitumen is 4%. Mehdi Karimi Cheshmehgol et al., (2016), prepared specimens with LDPE from 2 to 14%. They stated that indirect tensile strength for unconditioned specimens increase by 15.2%, and for conditioned specimens it is 23% increase. Tensile Strength Ratio is 88% for undified sample and with 10% LDPE modification it is 94%. Minakshi Singhal et al., (2016) calculated that total material cost when bitumen is modified with waste plastic (6%) is reduced by 7.99% and the marshall stability value achieved is 1161kg. When plastic content is increased then the ductility and penetration value decreased and softening point value increased.

B. Rubber

Rubber is obtained from waste tires which cannot be used in vehicles. Since we go for waste material utilization our material cost decreases and also we pave the way for cleaning of environment. Both natural rubber and crumb rubber can be used for modification. It is used in powder form. Rubber adsorbs bitumen's aromatic oil and hence gets close each other. Rajesh kumar et al.,(2014) modified the bitumen with 10% crumb rubber and found that both with unmodified and modified bitumen the optimum content of HDPE is 8% which yields better stability values in Marshall stability test. It is finalized in their work that 6% is optimum binder content.

Krishnapriya M. G., (2015) studied the performance of Natural Rubber modified mixes. She found that 5% is the optimum binder content. Fatigue life increased the resilient modulus at the rest period of 0.9 sec. Natural rubber modified bitumen has excellent rutting resistance. Yuqiao et al., (2016) viewed that 8% waste poly ethylene modifier is best in penetration compared to the same

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percentage of the compound waste poly ethylene and waste crumb rubber. The softening point at 8% was increased for Waste poly ethylene but the ductility is less. The waste crumb rubber has low temperature resistance. Prakash Somani et al., (2016) got 6% as optimum bitumen content since in it they achieved Marshal stability value as 945 kg. Beyond 6% of binder the stability value decreases. Then the modification of 8% LDPE and 12% Crumb rubber yielded a marshal stability of 1250 kg. The corresponding flow value is 3.86 mm. Mnjunath. K.R. et al., (2014) added 0.3% and 0.4% of Evotherm and Cecabase RT additive to base bitumen. Maximum stability is achieved at 130°C temperature and stability values increased upto 24% for Evotherm and 22% for cecabase of grade 2.

C. Nanoclay

Jeroen Besamusca(2008) analysed two organic Montmorillonite(MMT) Nanoclay. He claimed that ageing characteristics of bitumen is influenced by the modifiers, which may be due to change in viscous properties because of addition of modifiers. Viscosity is shear rate dependant and must be taken into account than temperature dependant. Saeed et al.,(2009) with the help of Nanofill-15 and Cloisite -15A modified the bitumen at 0.2%, 0.4% and 0.7%. Modified bitumen showed superior performance for dynamic creep than unmodified bitumen. But at low temperature modified bitumen does not show beneficial effect for fatigue test. Cloisite increases the stability by 15% but Nanofill only by 6%. Among the two MMT cloisite-15A performed well compared to Nanofill-15A in resilient modulus test, dynamic creep test, indirect tensile strength test and Fatigue resistance test. Jahromi et al.,(2009) tested specimens at 5 °, 25° and 40° C at loading frequency of 0.5 Hz. Pulse period was 500 ms and recovery time was 1500 ms. 2% to 7% of Nano clay is used to modify. Depending on test temperature and Nanoclay content, for Cloisite-15A stiffness varied from 8% to 40% and Nanofill-15 from 3% to 18%. Creep test at 40° C and 60° C show high pulse for modified mixtures. Van de Ven et al.,(2009) checked the influence of Nano clay modifiers on fresh and aged bitumen with Dynamic Shear Rheometer, penetration and softening point Cloisite Nanoclay increased rutting resistnce, Indirect tensile strength, stiffness for 40/60 penetration bitumen.

Nanofill modifier increased ageing resistance of 70/100 bitumen both in short and long term ageing. S Ghaffarpour(2011) expressed that fatigue resisting parameter improved 1.2 to 1.4 times in unaged condition by adding Cloisite in 7% when comparing with unmodified bitumen. Nanofill modification decreases fatigue life but ageing, exihibits same fatigue life. He also concluded like enhancement of bitumen properties depends on Nanoclay type, clay pretreatment and selection of polymer.

You et al.,(2011) used 2% and 4% by weight of bitumen. Rotational viscosity increased on an average by 41% and 112%. Dynamic shear complex modulus increased by 66% when 2% Nanoclay A is added and by 125% when 4% Nano clay A is added. Similarly, 184% and 196% of dynamic shear modulus is increased with Nanoclay B. Use of both Nano clay(NC) reduced the strain failure rate in tensile strength test.

Ezio et al., (2012) noticed in unaged stage 0.5% blend exihibiting higher Complex shear modulus for any phase angle value with respect to binder of 1% CNT. After Rolling Thin Film Oven Test(RTFO), differences were minimum between unaged and aged but after Pressure ageing vessel the condition reversed like 1% blend was stiffer than 0.5% .

Jun yang et al.,(2013) found that sodium MMT and organophilic MMT can increase ageing resistance and in low temperature, where snow susceptibility is there, these modifications have a higher hand in terms of quality of bitumen.

Lamya et al.,(2013) added 3%,7% and 9% of organic MMT NC(N3 and N4) with bitumen. N3 is having X-Ray diffraction properties equal to 2.28 and N4 equal to 3.8.

In DSR, Complex Shear Modulus increased and phase angle decreased for modified binders compared to unmodified ones. Hence, modified binders have increased resistance to shear deformation.

Ali Jamshidi et al.,(2015) identified that there is a visible difference in the rate of change in rheology of asphalt modified with numerous types and contents of nano materials (2% and 4%). The critical temperature is found to be 64°C for NI44 P2 binder from rutting factor gradient analysis.

Saad Issa Sarsam(2013) tested with silica fumes and Flyash for penetration, softening point, ductility and rheologicl characteristics. Silica is best known for adhesion and nano silica material with high surface area and stiffness modulus decreases the temperature susceptibility. Silica fumes increases viscosity and softening point whereas flyash decreases viscosity and increases softening point.

Farhad Zafari et al.,(2014) seen through their investigation that after addition of 6% Nano silica penetration decreased, softening point increased and ductility decreased. It might be because of high surface area absorbing more binder. Among various percentages 2%, 4% and 6%, it was the 6% Nanosilica that lead the bitumen not to age soon.

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Table – I
Percentage of modifiers by different authors

Author	Percentage of Modifiers	Type of Modifier
Zhanping You	2, 4	Nano montmorillonite
Saeed Ghaffarpour Jahromi	2,4,7	Montmorillonite
Van de ven	3,6 6	Cloisite Nanofil
Lamya	3,7,9	Organic MMT
Ghaffarpour	2,4,7 2,4,7	Cloisite-15A Nanofil-15
Ezio Santagata	0.1,0.5,1	Carbon Nano Tubes
Farhad zafari	2,4,6	Nano silica
Ali Jamshidi	2,4 4,6	Polymer Nanosilica
Sandhya Dixit	0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9	Plastic bag Fibres
Yuqiao Yang	1,2,3,4,5,6,7,8,9	Waste poly ethylene, Waste Crumb Rubber
Saad Issa sarsam	3,6,9,12	Flyash
	1,2,3,4	Silica Fumes
Avula Vamshi	10	Plastic waste
Mehdi Karimi Cheshmehgol	2,4,6,8,10,12,14	LDPE
Prakash somani	4,6,8	LDPE
	2,4,6	Crumb Rubber
Minakshi Shingal	1,2,3,5,10	Waste Plastic
S.Ghaffarpour Jahromi	7	Nanofil-15 Cloisite-15A
Shiva Prasad	2,4,6,8,10,12	Poly Ethylene Terapthalate,LDPE, HDPE
S Rajasekaran	5,10,20,25	Polyethylene(PE), PolyPropylene(PP), Polystyrene(PS)
Yash Menaria	6,8,10,12,14,	PE,PP,PS
Rao	5,7,9,11	PE
Shwetha Rokdey	10,20,30,40	Waste Plastic
Amit kumar Sahu	1,2,3,5,10	Crumb Rubber
Rajeshkumar	6,8,10	HDPE
Manjunath	0.3, 0.4 0.3, 0.4	Evotherm Cecabase Rt
Krishnapriya	2	Natural Rubber
Jeroen Besamusca	3,6	Organic MMT

IV. CONCLUSION

A. From The Literatures On Modification Of Bitumen Using Waste Polymer And Rubber The Following Conclusions Were Drawn

1) Modifiers enhance the water proof quality of bitumen.

2) The objective is that at working condition of the pavement bitumen should be less temperature susceptible and at construction condition workability must be maintained and modifiers does this magically.

3) Cost of modified binder is reduced when compared with conventional binder

4) Modified binders possess increased stability and durability compared to neat binders.

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5) Modifiers improve the thermal stability From the literatures on modification of bitumen, using materials like clay the following conclusions were drawn
6) Bitumen is an organic material it undergoes ageing when it comes in contact with UV light and oxygen but ageing resistance is achieved by modifying with Nano clay
7) The prediction of permanent deformation based on complex shear modulus and phase angle shows improvement for Cloisite properties but not much difference using Nanofill.

B. From these total Literatures on Modification of Bitumen The Following Conclusions Were Drawn

1) Mixing of the additives in particular speed for certain time period plays a significant role in quality achievement.
2) Many researchers have concentrated on Penetration, softening point, viscosity test and marshal stability test before and after modification which yields a fast result about the properties.
3) Rutting in short term, Fatigue in long term and water susceptibility during all period are areas to be concentrated and hence advanced research is carried out in this only by few researchers, it needs to be still more focussed.
4) Also, modification in the field has to be checked even after all lab tests have been done. Since live traffic and environment conditions for at least a minimum width and length poses the real time challenges.
5) The percentage of modifiers addition must not be too high since it decreases the quality.
6) Proper selection of modifiers with required quantity based on neat bitumen revolutionizes the road pavement with increased strength, durability and reduced cost.

V. List of symbols and Abbreviations

LDPE – Low Density Poly Ethylene LDPE
HDPE – High Density Poly Ethylene
SBS – Styrene Butadiene Styrene
MMT – Montmorillonite
CNT – Carbon Nano Tubes
PS – Polystyrene
UV – Ultra Violet
RTFO – Rolling Thin Film Oven
DSR – Dynamic Shear Rheometer
PP – Poly Propylene
PE – Poly Ethylene
NC – Nano Clay

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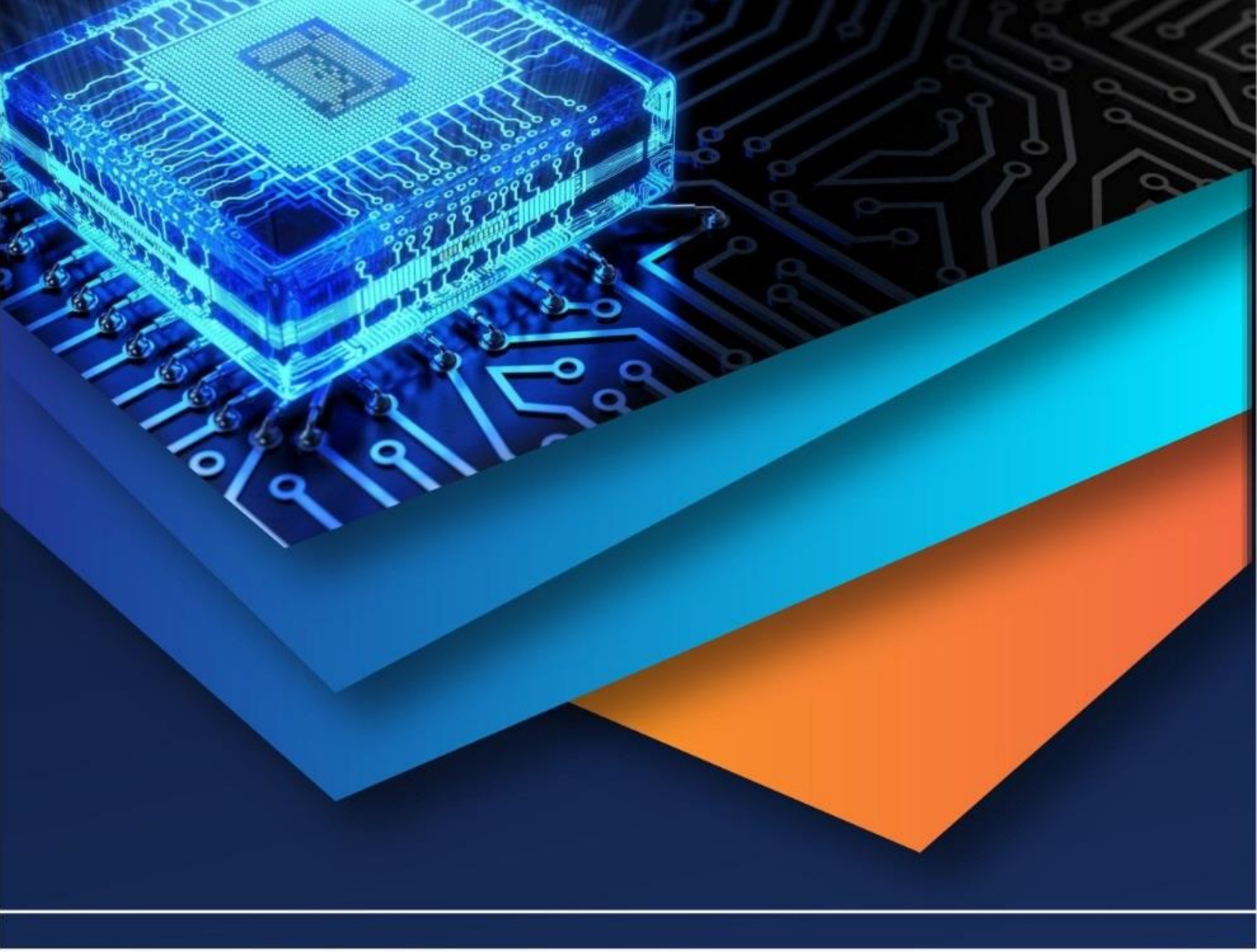

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