FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 12, N° 1, 2014, pp. 1 - 9
DOI: 10.2298/FUACE1401001S

MARSHALL PROPERTIES OF WASTE POLYMER AND NANOCLAY MODIFIED BITUMEN

UDC 902.65 (497.11)=111

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Abstract. *Polymer modified bitumen is emerging as one of the important construction materials for flexible pavements. The addition of polymers in bitumen improves the deformational stability and durability of bitumen. Also Montmorillonite nanoclay has been successfully used as additive in polymer to significantly improve the thermal stability and mechanical properties. The present study, the effect of waste low density polyethylene (LDPE), polypropylene (PP) obtained from waste carry bag, crumb rubber obtained from Waste tyre (CR)and nanoclay (MMT) on Marshall stability have been evaluated. Waste plastics, whose disposal is a matter of concern can be used successfully to modify the bitumen, these waste polymers are added in 2%, 4% and 6% whereas nanoclay is added in 1,2 and 3 % in 60/70 penetration grade bitumen and its effect on stability and flow of bitumen are evaluated. The result of experimental study shows that there is significant improvement in the Marshall Stability of bitumen due addition of waste polymer and nanoclay.*

Key Words: *Waste Plastic, waste tyre, modified bitumen, Marshall stability*

1. INTRODUCTION

Use of plastic waste in the construction of flexible pavement is gaining importance because of the several reasons. The polymer modified bitumen show better properties for road construction & plastics waste, otherwise considered to be a pollution menace, can find its use in this process and this can help solving the problem of pollution. Thousands of tonnes of waste plastic are produced every year. The amount of waste being recycled is increasing but still not enough to efficiently solve the problem. The aim of this study is to evaluate the performance of waste polymer, LDPE, PP, CR and MMT, LDPE/MMT, PP/MMT blend to modified bitumen and compared their Marshall properties with those of base bitumen.

Received December 22, 2013
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2. Earlier Studies

Some of the studies in done this field during last decade are summarized here. Piotr et al. (2007) based on their study on asphalt concrete modified by waste tyre rubber concluded that asphalt mixture with waste tyre rubber are more resistant to rutting as compared to unmodified bitumen.

Coating of recycled polypropylene on stone aggregate improves impact value, abrasion value and reduces water absorption of aggregate. The Marshall stability parameters also significantly improve. Thus waste polypropylene modified bituminous mixtures are expected to be more durable and more resistant to moisture damage (Sabina et al. 2009).

Praveen Kumar (2009) based on his laboratory study on rheological properties of crumb rubber modified bitumen found that the physical properties like penetration, ductility and softening point are improved due to addition of crumb rubber. It is also found that complex modulus increases with increase in modifier content but the phase angle decreases with increase in modifier. The increase in complex modulus and decrease in phase angle is an indication of higher resistance to deformation as compared to unmodified bitumen. Airey et al. (2002) reported that modified bitumen using crumb rubber showed an improvement in the performance of pavements over the base binders as a result of the interaction of crumb rubber with base binders. Due to this interaction, the viscosity, physical and rheological properties of the modified bitumen are improved.

Hadidy et al. (2009) based on study on the utilization of LDPE in Stone Mastic Asphalt mixtures conclude that Penetration at 25^0C will generally decrease as LDPE content increases, which indicates an improved shear resistance in medium to high temperatures. Due to addition of LDPE ductility values remain at a minimum range as specified by ASTM up to 6% LDPE content. Softening point tend to increase with the addition of LDPE, which indicates improvement in resistance to deformation. Garcı´a et al. (2006) have reported that, a polymer blend composed of EVA (Ethylene Vinyl Acetate) and LDPE quite suitable mainly at high in-service temperatures, showing favorable mechanical properties at temperatures for which neat bitumen undergoes permanent deformation processes. The amount of polymer in the blend should be adjusted, in order to get a proper value of viscosity at the temperatures involved in bitumen application and compaction.

Naskar et al. (2010) reported that the performance of bitumen can be improved by addition of waste plastic. The optimum waste plastic content is found to be 5% by weight based on the thermal stability results. Yue Huang (2007) based on the study on waste material in asphalt pavement concluded that, tyre rubber is used in asphaltic mixture to reduce cracking, improve durability and mitigate noise. Depending on the application, different variable need to be considered when assessing the technical performance of asphalt containing tyre rubber, binder properties in the wet process, and mixture properties in the dry processes. The use of recycled material in pavement asphalt represents a valuable outlet for such material.

Murphy et al. (2003) based on their experimental studies on bitumen modified with recycled polymers reported that, some of the waste polymers showed potential for enhancing the properties of bitumen but other are not. The addition of polyethylene increases the softening point although viscosity value remains low. In this case they showed some tendencies to separate from the bitumen. The addition of polypropylene increased the softening point but viscosity remains same. The blends with low density polyethylene and ethylene vinyl acetate are worthy of further consideration.

TAO Yuan et al. (2008) have carried out study on effect of two different Montmorillonite on rheological properties of bitumen/clay nano composites by dynamic shear rheometer (DSR), their result indicate that both the Montmorillonite modified bitumen exhibit higher complex modulus, lower phase angle than pristine bitumen which means that resistance to rutting at high temperatures of pristine bitumen is improved due to the introduction of Montmorillonite.

3. MATERIALS

3.1 Base bitumen

For present study 60/70 penetration grade bitumen, obtained from Shell Corporation India is used as base material. The physical characteristic of the base bitumen is shown in table 1.

Table 1 Characteristics of base bitumen

1	Penetration, 25 ^{0}C, 100 g, 5 second (dmm)	67
2	Ductility, 25 ^{0}C, 5 cm/min (cm)	>120
3	Softening point (^{0}C)	40
4	Stability (kN)	16.38
5	Flow (mm)	3.05

3.2 Low density polyethylene (LDPE)

Polyethylene belongs to polyolefin of polymers, it is a thermoplastic polymers. Many types of polyethylene exist but, low and linear density and high density polyethylene are the most common. High Density Polyethylene (HDPE) are used when, strength, heat tolerance, stiffness and shrinkage are required. They are commonly used in food packaging, like milk bottles, soft drink bottles, and industrial drums for chemical. Low density polyethylene (LDPE) is used where impact strength, toughness and high elongation are important. Some applications of LDPE include carry bags, bread packaging, sandwich bags, house wares, toys, buckets, wire and cable jacketing, carpet. Fig.1 shows the molecular structure of polyethylene.

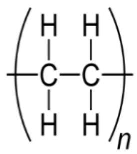

Fig. 1 Molecule of polyethylene

3.3 Polypropylene (PP)

Polypropylene is the lightest known industrial polymer. It is produced by polymerization of propylene. Polypropylene is a stiffer material than polyethylene. Polypropylene has good heat and chemical resistance, resistance to deformation at elevated temperatures, high stiffness, surface hardness and toughness at normal temperatures. The molecular structure of polypropylene is shown in Fig. 2.

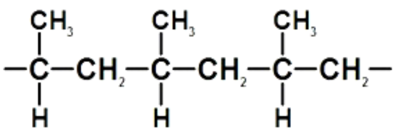

Fig. 2 Molecule of polypropylene

The waste LDPE and PP are obtained from the waste plastic bag in the form of pellets, manufacture by a minor local industry from Aurangabad state of Maharashtra India. Physical characteristics of waste polyethylene and polypropylene used in this study are given in table 2.

Table 2 Properties of waste LDPE and PP

Type of polymer / Properties	Melting Point	Relative density
LDPE	105-112 ^{0}C	0.910-0.916
PP	152-158 ^{0}C	0.866-0.884

3.4 Waste Crumb Rubber (CR)

The rubber used was a sample of reclaimed car tyres. Apart from use as a bitumen modifier, this rubber is also used for playground surfaces and athletic tracks, carpet backing, brake pads, roofing and cattle mats. The sample used was derived from ambient grind. Table 3 contains information provided by the supplier and is an indication of content only.

Table 3 Typical Constituents of Crumb Rubber

Material	Content (%)
Natural rubber	25-50
SBR/Butadiene content	5-30
Carbon black	25-30
Processing agents	20-25
Acetone extraction	3.5-9
Ash content	10
Benzene Extraction	4-6

3.5 Montmorillonite nanoclay (MMT)

The nanoclay technology is a recent development. Raw material for nanoclay is montmorillonite mineral. The commercially available nanoclay content about 98% of montmorillonite. Montmorillonite is type of mineral, which consist of layers of tetrahedral silicate sheet and octahedral hydroxide sheets. MMT have been used for the modification of polymers. Polymer chains can intercalate into the polymer matrix at nanometer-scale. These lead to significant improvement in thermal oxidative degradation of polymer [10]. For the present study Montmorillonite nanoclay is supplied by Crystal Nanoclay Pvt. Ltd. Pune, India.

3.6 Aggregate

Aggregate grading used for Marshall Stability test is shown in the form of grading curve in the figure3. Bitumen content is taken as 5% for all the samples prepared for Marshall test.

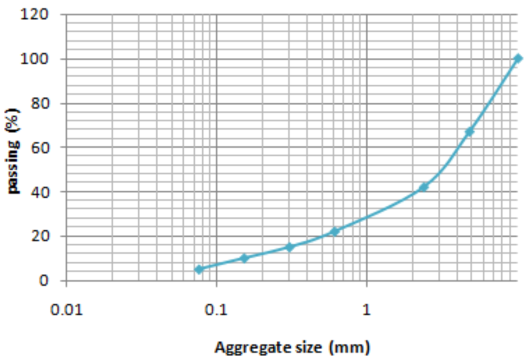

Fig. 3 Aggregate grading

4. EXPERIMENTATION

Waste PE, PP, CR and MMT, LDPE/MMT, PP/MMT modified bitumen are prepared in laboratory by heating bitumen at 200 ^{0}C and additives are mixed in various percentage by weight and stir for one hour. The Marshall Stability test is carried out as per Bureau of Indian standards. Based on waste polymer and MMT concentration sample are given notation which are represented in table 4.

Table 4 Polymer and montmorillonite percentage in bitumen and sample notations

Sample notation	Type of waste polymer	Waste polymer content (%)	Montmorillonite Content (%)
B	-	0	0
L1	LDPE	2	0
L2		4	0
L3		6	0
LM1		4	1
LM2		4	2
LM3		4	3
P1	PP	2	0
P2		4	0
P3		6	0
PM1		4	1
PM2		4	2
PM3		4	3
M1	-	0	1
M2		0	2
M3		0	3
C1	CR	2	0
C2		4	0
C3		6	0

5. RESULT AND DISCUSSIONS

The Marshall Stability test result on waste LDPE and PP modified bitumen shows that with increase in concentration of these additives the stability value increases along with decrease in flow. Hence the Marshal Quotient increases with increase in waste polymer concentration, which is an indication of improvement in the resistance to permanent deformation. The effect of waste LDPE on stability /flow and Marshall Quotient are indicated in fig.4 and fig. 5 respectively. The effect of waste PP on stability /flow and Marshall Quotient are indicated in fig.6 and fig. 7 respectively. In case of CR modified bitumen also stability and Marshall Quotient are increase where as flow decreases but the effect is more pronounced as compare to LDPE and PP modified bitumen. The effect of CR on Marshall stability/flow and Marshall Quotient are indicated in Fig.8 and Fig.9 respectively. Stability of bituminous mix with bitumen modified by 6% of LDPE, PP and CR are increase by 22%, 31% and 48% respectively. It is found that due to addition of these waste polymers in bitumen penetration value decreases and cohesion increases which may lead to improvement in stability of bitumen mixes.

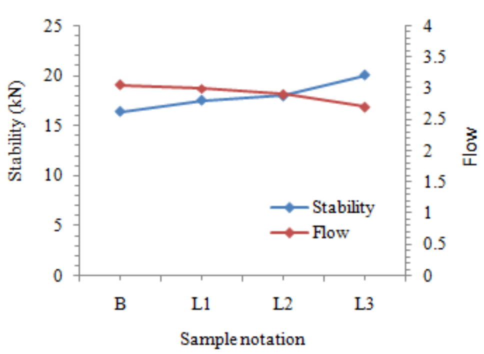

Fig. 4 Effect of LDPE on stability and flow

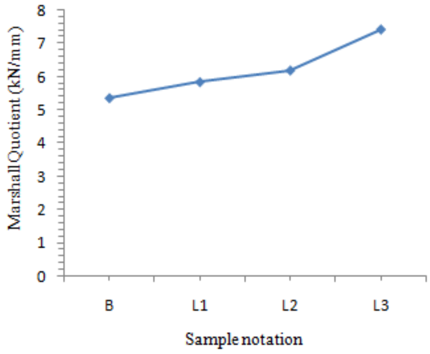

Fig. 5 Effect of LDPE on Marshall Quotient

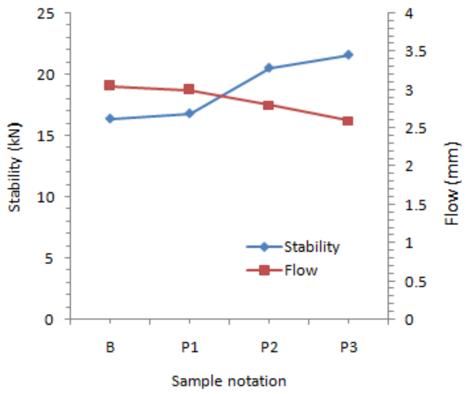

Fig. 6 Effect of PP on stability and flow

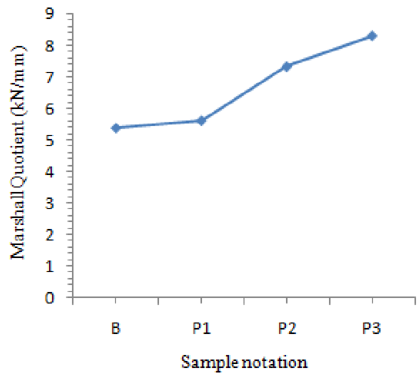

Fig. 7 Effect of PP on Marshall Quotient

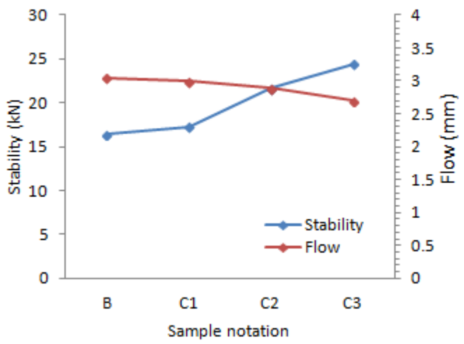

Fig. 8 Effect of CR on stability and flow

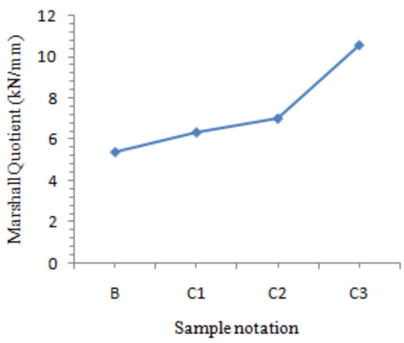

Fig. 9 Effect of CR on Marshall Quotient

The effect of MMT on the stability/flow and Marshall Quotient are represented in fig.10 and fig.11 respectively. Form the laboratory test it is seem the addition of MMT in small percentage in bitumen significantly improve the Marshall properties. The stability of bituminous mix with the bitumen modified by 3% of MMT has stability of 20kN approximately as compared to 16.38 kN of neat bitumen. The effect of LDPE and MMT combined as additive on stability/flow and Marshall Quotient are shown in fig.12 and fig. 13 respectively. The effect of PP and MMT combined as additive on stability/flow and Marshall Quotient are shown in fig.14 and fig. 15 respectively. in case of LDPE/MMT, PP/MMT modified bitumen concrete maximum stability was observed at 4% waste polymer (LDPE and PP) with 1% of MMT content, there after stability decreases with increase inn MMT concentration. For the higher concentration of MMT slight decrease in stability is observed that may be due to the reduction of cohesion of binder due to clay (MMT) content. Presence of MMT in PP and LDPE modified bitumen can improve the high temperature storage stability of PP modified bitumen (Saeed Sadeghpour et al. 2010).

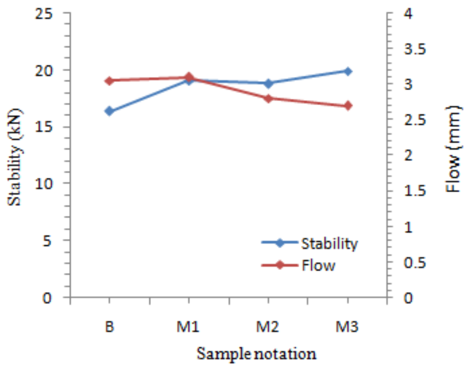

Fig. 10 Effect of MMT on stability and flow

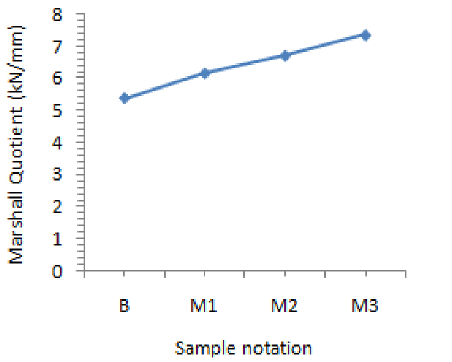

Fig. 11 Effect of MMT on Marshall Quotient

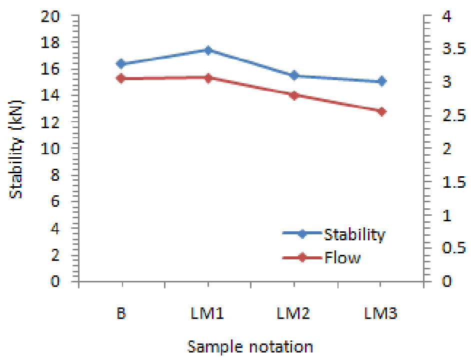

Fig. 12 Effect of LDPE /MMT on stability and flow

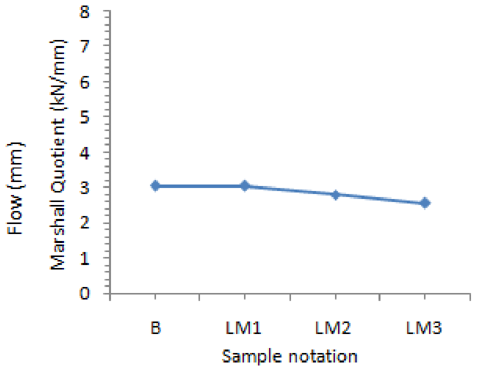

Fig. 13 Effect of LDPE/MMT on Marshall Quotient

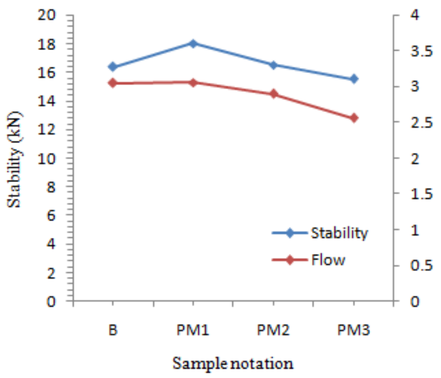

Fig. 14 Effect of PP/MMT on stability and flow

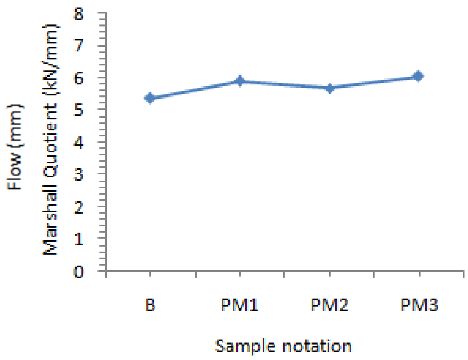

Fig. 15 Effect of PP/MMT on Marshall Quotient

6. Conclusions

The observations brought out through the experimental studies on neat bitumen and bitumen modified by waste polymer and nanoclay has been summarized as below.

The bituminous concrete with bitumen modified by waste LDPE, PP and CR show appreciable improvement in the Marshal properties. Stability increases and flow decreases and hence the Marshall quotient increases, which is indication of improved resistance to rutting. Thus the use waste polymer could be a good alternative to the virgin polymer for bitumen modification, as it will economical and solve the problem of waste disposal to some extent.

The bitumen modified with MMT also show appreciable improvement in physical and strength properties, the bitumen modified with 4% of LDPE/PP and various percentages (1%, 2% and 3%) of MMT shows small improvement. The highest stability value is observed at 1% MMT. These waste polymers could be good alternative to the virgin polymer for modification of bitumen.

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MARŠALOVA SVOJSTVA BITUMENA MODIFIKOVANOG OTPADNIM POLIMEROM I NANO-GLINOM

Bitumen modifikovan polimerom se javlja kao jedan od važnih materijala za izradu fleksibilnih zastora puteva. Dodavanje polimera u bitumen poboljšava deformacionu stabilinost i trajnost bitumena. Takođe montmorilonitska nano-glina se uspešno koristi kao aditiv u polimerima gde značajno poboljšava stabilnost i mehanička svojstva. Ova studija se bavi efektima otpadnog polietilena male gustine (LDPE) i polipropilena (PP) dobijenih iz otpadnih plastičnih kesa, granulisane gume dobijene od starih guma (CR) i nano-gline (MMT) na Maršalovu stabilnost. Otpadna plastika, čije je odlaganje problematično, može se uspešno koristiti za modifikaciju bitumena, i ti otpadni polimeri se dodaju u iznosu od 2%, 4% i 6% dok se nano-glina dodaje u procentima od 1,2 i 3% u bitumen koji ima svojstva prodora 60/70 i procenjen je njen uticaj na stablinost i tečenje bitumena. Rezultati eksperimentalnih studija pokazuju da postoji značajno poboljšanje Maršalove stabilinosti bitumena usled dodavanja otpadnih polimera i nano-gline.

Ključne reči: *Otpadna plastika, otpadna guma, modifikovani bitumen, Maršalova stabilnost*