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DEVELOPMENT OF FLEXIBLE PAVEMENTS OVER EXPANSIVE SOILS , ALTERNATIVE MATERIALS USED TO IMPROVE THE SUBGRADE AS WELL AS THE BITUMINOUS LAYER

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Abstract:

Waste PVC that has been used previously as mineral water bottles, pipes, electrical fittings etc. are biologically non-degradable and posed an ominous environmental problem which led to severe environmental impact. But molten PVC has a binding property which can be reused with bitumen to reduce the cost of bituminous mix. At the same time the recycling of waste PVC save disposal sites to reduce the amount of inert drawn from quarries which often lead to environmental problems. This paper describes the investigation of the properties of bitumen mixed with PVC (2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% by the weight of bitumen) at optimum bitumen content and to check the design criteria of bituminous mixes using this bitumen-PVC binder The investigation concentrated on the test of modified binder properties and Marshall Mix design was used, first to determine the optimum binder content and then further to test the modified mixture properties. The tests include the determination of unit weight, stability, flow and voids characteristics. Some of the measured properties of asphalt mixture with the modifier used in this study were within the acceptable recommended limits. On the basis of experimental results, it is concluded that the asphalt mixtures with waste polyethylene modifier up to 10% and waste PVC modifier up to 7.5% can be used for flexible pavement construction in a warmer region from the standpoint of stability, stiffness and voids characteristics.

INTRODUCTION

the forefront invention of Polyethylene and Polyvinyl chloride (PVC), it has been spasmodically used in every

possible purpose which is biologically non-degradable and has a blimp environmental problem leading astringent environmental impact. Nevertheless, for such property of sustainability the polyethylene and PVC have been reused in the field of transportation engineering for enhancing the property of asphalt binder, since for having a desirable binding property. At the same time the recycling of waste polyethylene and PVC can save disposal sites and reduce the amount of inert drawn from quarries. In this investigation, waste polyethylene and PVC as the sort of polymer is used to investigate the potential prospects to enhance asphalt mixture properties and to check the design criteria of asphalt mixture using this two modifier at optimum binder content. The investigation concentrated on the test of modified binder properties and Marshall mix design was used, first to determine the optimum binder content and then further to test the modified mixture properties. The tests include the determination of unit weight, stability, flow and voids characteristics. Some of the measured properties of asphalt mixture with the modifier used in this study were within the acceptable recommended limits. The purpose of this project is to investigate the possibility of using Polyethylene Terephthalate as polymer additives in Bituminous Mix. In many construction sites, aggregates in different size fractions are not easily available, necessitating their procurement from long distances thereby causing exorbitant increase in cost of construction. On the other hand, 70 % of the total power generation in India is due to coal based thermal power plant that also contributes about 112 million tons of coal ash as by-product waste in every year from 120 coal based thermal power plants (2010–11 data). Such a huge quantity of this type of waste material does pose challenging problems, in the form of land usage, health hazards and environmental dangers. Hence to suppress the said problems related to these materials, a good number of studies have been attempted to utilize them in a productive way which will satisfy the needs of the society. This particular work is an attempt to utilize these waste materials to some extent by replacing the filler and some fractions of fine aggregates in bituminous paving mixes. In order to enhance the properties of the paving mixes, their modification

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with different types of fibers is also done. In order to offset the possible drawbacks of using the coal ashes, unlike conventional fibers, naturally, locally and abundantly available sisal fiber has been tried in possible development of sustainable bituminous paving mixes to improve the pavement performance.

Ali et al. observed through an experimental study on the outcome of fly ash on the mechanical properties of bituminous mixtures, that fly ash as mineral filler can be used to increase resilient modulus characteristics and stripping resistance. Results of a limited field study showed that 3 months after placement, metal concentrations in soils were not substantially altered. Colonna et al. studied the feasibility of bottom ash for HMA (Hot Mix Asphalt) mix used in the intermediate courses of flexible pavements. Their results show that the mixtures perform better when 15 % of bottom ash was added to the mixture in replacement of correspond amount of sand. Kar studied the effect of sisal fiber on SMA (Stone Matrix Asphalt) and bituminous concrete (BC) mixtures and he concluded that the optimum bitumen contents for BC and SMA mixes were 5 % and 5.2 % respectively whereas optimum fiber content for each mix was 0.3 %. From the scanty literature available, it is observed that there is no study on utilization of bottom ash and fly ash together in the same bituminous mix and the use of a natural fiber in SMA and BC mixes. In the present study, dense graded bituminous mix specimens were prepared using natural aggregate as coarse aggregates, bottom ash as partial replacement of fine aggregates and fly ash as mineral filler with sisal fiber as a stabilizing additive. Design of the mixtures was done as per Marshall procedure. For characterization of the mixes, various tests such as indirect tensile strength (ITS) and moisture susceptibility test in terms of tensile strength ratio (TSR) and retained stability were taken up.

Polyvinylchloride (PVC) [-(-CH_2-CHCl-)n-] is one of the three most important polymers currently used worldwide. This is because PVC is one of the cheapest polymers to make and has a large range of properties so can be used to make hundreds of products. PVC is formed by the polymerization of vinyl chloride (chloromethane) monomer units

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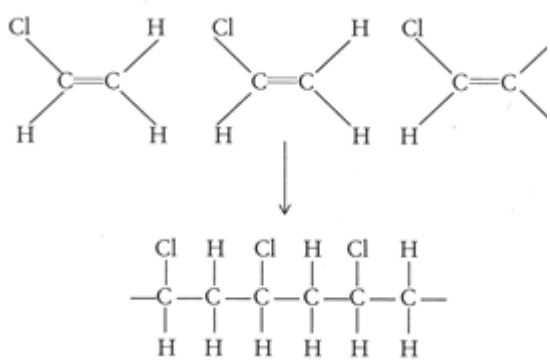
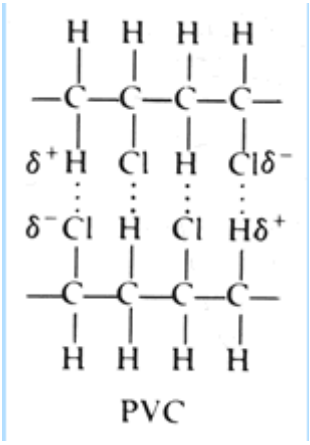


PVC consists of polar molecules which are attracted to each other by dipole-dipole interactions due to electrostatic attractions of a chlorine atom in one molecule to a hydrogen atom in another atom:



Polyvinyl chloride (PVC) is a popular thermoplastic that contains high levels of chlorine which can reach up to 57%. Carbon, which is derived from oil or gas is also used in its fabrication. It is an odorless and solid plastic that is white, brittle and can also be found on the market in the form of pellets or white powder. PVC resin is often supplied in the powder forms and its high resistance to oxidation and degradation make it possible to store the material for long periods. Some authors/activists that oppose the manufacturers of PVC often refer to it as the "Poison Plastic" due to the toxic pollutants it might release. When plasticizers are added it becomes softer and more flexible.

Uses of PVC:

PVC is predominant in the construction industry due to its low production cost, malleability, and light weight. It is used as a replacement for metal in many applications where corrosion can compromise functionality and escalate maintenance costs. Many of the world's pipes are made from PVC and these are used in industrial and municipal applications. It is also used to make pipe fitting and pipe conduits. It does not have to be welded and can be connected with the use of joints, solvent cement and special glues--key points that highlight its installation flexibility. The material is also present in the electrical components such as electrical insulation, wires, and cable coatings.

In the healthcare industry, it is used to make feeding tubes, blood bags,

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intravenous (IV) bags, parts of dialysis devices and many other items. This is only possible when phthalates are added to it. Phthalates are used as plasticizers to produce flexible grades of PVC (and other plastics), thus making it better suited for the aforementioned applications due to improved performance characteristics.

Common consumer products such as raincoats, plastic bags, toys, credit cards, hoses, doors and window frames and shower curtains are also made from PVC. This is not an exhaustive list of the many products that can be found around the household with PVC as its main constituent.

Advantages of PVC:

As mentioned earlier, PVC is a low-cost material that is lightweight and as such, is easy to handle and install. Compared to other types of polymers, its manufacturing process is not limited to the use of crude oil or natural gas. Some use this point to argue that it a sustainable plastic since these forms of energy are known to be nonrenewable.

PVC is also a durable material and is not affected by corrosion or other forms of degradation. It can easily be converted into different forms making its use across various industries an evident advantage. Being a thermoplastic it can be recycled and converted into new products for different industries, but this is not an easy process due to the many formulations used to manufacture PVC.

LITERATURE REVIEW

Punith, V. S. and Veeraragavan, A,: (2010) Possible purpose which is biologically non-degradable and has a blimp environmental problem leading astringent environmental impact Nevertheless, for such property of sustainability the polyethylene and PVC have been reused in the field of transportation engineering for enhancing the property of asphalt binder, since for having a desirable binding property. At the same time the recycling of waste polyethylene and PVC can save disposal sites and reduce the amount of inert drawn from quarries. In this investigation, waste polyethylene and PVC as the sort of polymer is used to investigate the potential prospects to enhance asphalt mixture properties and to check the design criteria of asphalt mixture using this two modifier at optimum binder content. The investigation concentrated on the test of

modified binder properties and Marshall Mix design was used, first to determine the optimum binder content and then further to test the modified mixture properties.

Sabina, Tabrez A Khan, Sangita, (2009) Preparation of bituminous mixes, commonly aggregates, inform of coarse, fine and filler fractions are used. In many locations, the aggregates in different size fractions are not easily available, use of which needs procurement from long distances and hence increases the cost exorbitantly. On the other hand, a number of coal-based thermal power plants have been set up to somewhat cater to the power supply requirement. It is reported that around 120 Million Tons of ashes are producing from forty major thermal power plants per year in India.

The Asphalt Institute (1984), The proportion as well as the properties of the components (binder, aggregate and additive) into the design mix of Asphalt concrete greatly depends on its performance. Among them, the binder is of relatively more important which can be normal penetration grade bitumen as well as it can be modified by adding an optimum proportion of different additives. Recently, many studies have been attempted by adding different materials as an additive to improve the mechanical and physical properties of asphalt concrete. Polymers are one of these additives. Bitumen can be improved by the addition of polymers in stiffness and the temperature susceptibility point of view The rutting resistance of the mixture has been observed to be increased by the improvement of stiffness in hot climates and the stiffness enhancement allows the use of relatively softer base bitumen, which sequentially, provides a better low temperature performance.

M. A. Sobhan, S. A. Mofiz (2001) The vast quantities of plastic waste resulting from the different types and sizes of bottles which are used to contain all types of liquid products such as municipal solid waste is increasing in the last years due to increase in population, development activities and changes in life style. Thus disposal of plastic waste is a menace and becomes a serious problem globally due to their no biodegradability and unaesthetic view. This paper focused on Marshall test and index of retained strength to determine the properties of plastic waste particles

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such as (size, thickness, and percent of content) which provide the ultimate performance of hot mix asphalt.

Sobhan, M. A. and Zakaria,M. (2001). The costliest and highest types of flexible pavement layer used are bituminous concrete or asphalt concrete. To satisfy the design requirements of stability and durability the bituminous mixes should be designed effectively. The ingredients of the mixture include dense grading of coarse aggregates, fine aggregates, fillers and bitumen binder. In this Study an attempt was made to find the effect of filler on the behavior of bituminous mixes. Fillers play an important role in the filling of voids and hence change the physical and chemical properties. Thus their effect is of utter importance. Bitumen in combination with filler forms mastic.

Catt, OV, (2004). As the traffic demand is growing at a rapid rate along with the increase in the axle loads, it is necessary to improve the highway paving materials. The main objective of highway authorities is to provide safe, smooth, imperishable, and economical pavements that are capable of carrying the anticipated loads.

Hinislioglu, S and Agar, E, (2004). studied the Effect of Fillers on Bituminous Mixes. To satisfy the design requirements of stability and durability the bituminous mixes should be designed effectively. The ingredients of the mixture include dense grading of coarse aggregates, fine aggregates, fillers and bitumen binder. In this Study an attempt was made to find the effect of filler on the behavior of bituminous mixes. Fillers play an important role in the filling of voids and hence change the physical and chemical properties. Thus their effect is of utter importance. Bitumen in combination with filler forms mastic. This mastic can be seen as a constituent of mixture of asphalt that holds the aggregates together.

MATERIALS AND METHODS

In this investigation, polyethylene and PVC used as modifier on asphalt mixtures To evaluate the performance of polyethylene and PVC on hot asphalt mixtures crushed black stone that are collected from Panchagarh, India used as coarse aggregate. Fine aggregate portion of the aggregate blend was taken from Domar sand which is collected from the northern part of Bangladesh. The fines from sand and stone dust finer

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than 0.075 mm were used as filler material in this study. A considerable amount of stone dust is produced during crushing and some stone dust remains in crushed stone. These are mixed with fine sand for proper utilization of stone dust. Design of bituminous mixes For determination of optimum bitumen content (OBC), Marshall Specimen was prepared by adding bitumen (4, 4.5, 5.0, 5.5 and 6.0% by weight of aggregate) into hot aggregate. Then, bulk density, Marshall Stability, flow and volumetric properties [air voids, voids filled with bitumen (VFB), and voids in mineral aggregates (VMA)] were determined for fresh bitumen. OBC for fresh bituminous mix was 5.4% (by the weight of aggregate). Further, Marshall Samples at OBC were cast using waste PVC (2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20% by weight of OBC) to determine bulk density and strength properties of the bitumen-PVC binder The use of waste plastics in road construction is gaining importance these days because plastic roads perform better than ordinary ones and the plastic waste considered to be a pollution menace, can find its use. Studies reported in the used of re-cycled plastic, mainly polyethylene, in the manufacture of blended indicated reduced permanent deformation in the form of rutting and reduced low – temperature cracking of the pavement surfacing. Plastic is a very resourceful material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Plastic is a non-biodegradable material and researchers found that the material can remain on earth for 4500 years without degradation. Several studies have proven the health hazard caused by improper disposal of plastic waste. This paper investigates the effective use of waste plastic for coating the aggregates of the bituminous mix to improve its performance characteristics and to design an optimum bituminous mix. Recycled polythene carry bags were shredded into small sizes and mix with aggregates of the bituminous mix at specified temperature. Bituminous mixes were prepared with 60/70 bitumen and plastic coated aggregates/ordinary aggregates with cement as a filler material. Marshall Method is adopted for the mix deign.

Polyethylene:

Polyethylene has been the most popular plastic which has been used so far.

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Moreover, it is a semi-crystalline polymeric material having a well fatigue, wearing as well as chemical resistance and a wide range of properties. This polyethylene is available in local markets in Bangladesh in the form of a bag with various colors. In this investigation, white color of low density polyethylene bags were used which were collected from local market and domestic wastes. This polyethylene was then cleaned properly and shredded to form the size of the particle 2-3 mm for the preparation of the recycled polyethylene. Specific gravity and melting temperature of the polyethylene used in this investigation were 0.94 and 115°C

Figure: Polyethylene

Polyvinyl Chloride (PVC):

Polyvinyl chloride (PVC), a thermoplastic material, has widely been used in construction works for being cheap, durable and easy workability. For the present study, waste PVC was collected from domestic waste, mineral water bottles, credit cards, toys, pipes and gutters, electrical fittings, furniture, folders and pens, medical disposables etc. and then cleaned properly for the preparation of recycled PVC. This waste PVC was then shredded in a shredding machine to form the size of the particle is about 2-3 mm. The specific gravity of the waste PVC used in this study was 1.25.

Figure: Polyvinyl Chloride

PVC's abrasion resistance, light weight, good mechanical strength and toughness are key technical advantages for its use in building and construction applications PVC can be cut, shaped, welded and joined easily in a variety of styles. Its light weight reduces manual handling difficulties.

The optimum dose is around 0.4- 0.5 % by weight of bituminous mix and 6-8% by weight of bitumen. Bituminous Concrete (BC) is a composite material mostly used in construction projects like

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road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted. The role of waste plastic bags in the mix was studied for various engineering properties by preparing Marshall samples of BC mixtures with and without polymer. Marshall properties such as stability, flow value, unit weight, air voids were used to determine optimum polythene content for the given grade of bitumen. Thin plastic bags are mainly composed of low density Polyethylene (LDPE) and it's commonly used for packaging, protecting and many other applications. Waste Plastic Bags as one form of polymers were used to investigate the potential prospects to enhance asphalt mixture properties. Thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130- 180°C. Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

Parameters used in the study

All the Marshall propeties properties were calculated The concern equation and other formulae used in calculations are given below.

Bulk specific gravity of aggregate (G_{sb})

$$G_{sb} = [\frac{M_{agg}}{Volume\ of\ (mass\ of\ agg+air\ void\ in\ mix+absoeved\ bitumen)}]$$

Where Magg = Mass of aggregate

Effective specific gravity of aggregate (Gse)

$$G_{se} = [\frac{M_{agg}}{Volume\ of\ (mass\ of\ agg+air\ void\ in\ mix)}]$$

Or, $$Gse = [\frac{(M_{mix}-M_b)}{(\frac{M_{mix}}{G_{mm}}-\frac{M_b}{G_b})}]$$

Where, Magg = mass of aggregate

Mb = mass of bitumen used in mix

Gb= specific gravity of bitumen

3. Apparent specific gravity (Ga)

$$Ga = [\frac{M_{agg}}{Volume\ of\ aggregate}]$$

Theoretical maximum specific gravity of mix (Gmm)

$$Gmm = [\frac{M_{mix}}{Volume\ of\ (mix-air\ void)}]$$

5. Bulk specific gravity of mix (Gmb)

$$Gmb = [\frac{M_{mix}}{Bulk\ volume\ of\ mix}]$$

6. Air voids (VA)

$$VA = 1 - \frac{G_{mb}}{G_{mm}} \times 100$$

7. Voids in mineral aggregates (VMA)

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$$VMA = [1 - \frac{G_{mb}}{G_{mm}} \times P_s] \times 100$$

Where, Ps = percentage of aggregate present by total mass of mix

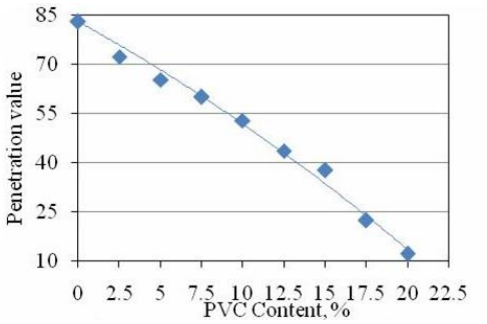
8. Voids filled with bitumen (VFB)

$$VFB = \frac{VMA - VA}{VMA} \times 100$$

Effect of coal ash (Bottom ash and Fly ash) on DBM mix At the initial stage of experiment bottom ash and fly ash was used as fine replacement in DBM mix. In this experiment the total coal ash content is taken as 35% by weight of the total mix, from which the percentage of fly ash as mineral filler is fixed, i.e. 5% of weight of the mix.

Marshall stability:

It is seen from that using of coal ash in PVC mix is not satisfactory with respect to stability value, when compared with conventional mix. The maximum stability value of 11.83 kN was achieved when 14% of coal ash by weight of the mix was mixed for preparing PVC samples For determination of optimum bitumen content (OBC), Marshall Specimen was prepared by adding bitumen (4, 4.5, 5.0, 5.5 and 6.0% by weight of aggregate) into hot aggregate. Then, bulk density, Marshall Stability, flow and volumetric properties [air voids, voids filled with bitumen (VFB), and voids in mineral aggregates (VMA)] were determined for fresh bitumen. OBC for fresh bituminous mix was 5.4% (by the weight of aggregate). Further, Marshall Samples at OBC were cast using waste PVC (2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20% by weight of OBC) to determine bulk density and strength properties of the bitumen-PVC binder.



Graph: Variation of Stability value with bitumen content at different PVC content

It was seen from the flow value vs bitumen content graph shown in that with increase in bitumen content and PVC content the flow value increase. But with 14% PVC content by weight of mix the flow value decrease as compare to the conventional mix.

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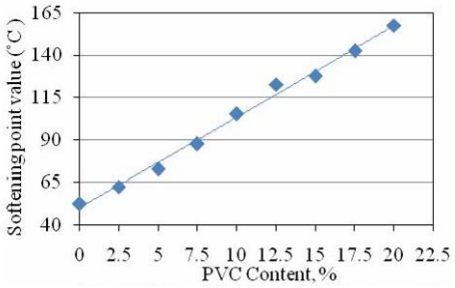
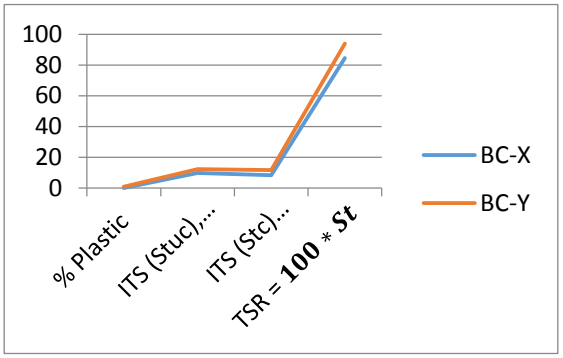


Graph: Variation of Flow value with bitumen content at different PVC content

Indirect tensile strength test:

This test is useful in determining the resistance of bituminous mix against cracking and sensitivity of mixture to moisture damage as well. To assess whether the coating of bitumen binder and aggregate is susceptible to moisture damage tensile strength is determined according to ASTM D 4867. Tensile strength ratio (TSR) is defined as the ratio of average indirect tensile strength of conditioned specimens to the indirect tensile strength of un-conditioned specimens. The test sample were prepared as per prescribed norms by maintaining suitable air voids about 7% . The specimens when placed in water bath maintained at a temperature of 60°C for 24 hours and then placed in water chamber maintained at 25°C for 1 hour are termed as conditioned specimens. On the other hand when the samples are placed in water bath maintained at 25°C for 30 minutes are termed as un-conditioned specimens. Both conditioned and un-conditioned specimens were tested for their tensile strength. The load at failure of specimen was recorded and the indirect tensile strength (ITS) was calculated from the following equation no-1.



Graph: Indirect tensile strength (ITS) and TSR variations

Voids in Mineral Aggregate (VMA)

From the observation of PVC vs bitumen content graph in Figure, it is clear that with increase in bitumen content voids in mineral aggregate decrease rapidly first and then increases steadily.

PVC %	bitumen content %
0	4.5
14	5
26	5.5

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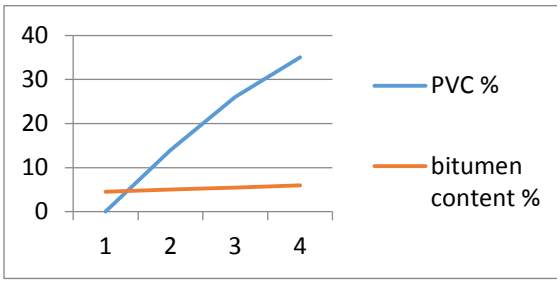
35	6

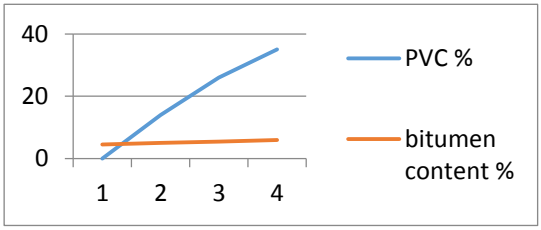


Graph: Variation of PVC value with bitumen content at different coal ash content

PVC with Bitumen:

It is observing from the PVC and bitumen content graph that VFB increase rapidly with increase in bitumen and coal ash content.

PVC %	bitumen content %
0	4.5
14	5
26	5.5
35	6



Graph: Variation of VFC value with bitumen content Ash content

Effect of Sisal fiber and Coal ash (Bottom ash and Fly ash) on DBM mix

From the above Marshall property of PVC mix that is prepared with coal ash, it is observed that, coal ash cannot deliver satisfactory result when used alone. The stability and flow values are not within the specification made for PVC mix. Therefore the Marshall propeties study is done by using coal ash and sisal fiber as an additive. The percentage of coal ash is taken as 14% as it shown better result than other coal ash content. The fiber content varied from 0% to 26% with 35 % increment, along with fiber length ranging from 5mm, 10mm, 15mm, and 20mm.

CONCLUSIONS

The Marshall Stability which is a strength parameter has shown increasing trend with a maximum increase percent of 35.20% as compared to Conventional mix when modified with 4.5 % Polythene Waste. It is observed that Marshall Stability value increases with polythene content up to 4.5 % and thereafter decreases. Thus the use of higher percentage of waste polythene is not preferable. While talking to environmental pollution due to these

non-biodegradable plastics waste where disposal of such materials has become a serious problem, its use in construction of flexible pavement will give a better place for their burying and thus solving the problem of their disposal on one hand and providing a better flexible pavement with improved performance on other hand. The properties of aggregates which mainly cause rutting action are improved using plastic coated aggregates. Considerable increase in Marshall Stability value & the optimum bitumen content is also reduced. On the basis of experimental results of this investigation, the following conclusions are drawn:

The scrap PVC available from domestic and other waste can be utilized to modify the bitumen to obtain high strength mixes and to get better adhesion properties of bitumen.

The recommended proportion of the PVC modifier is up to 10% by the weight of bitumen content can be used for construction of road in hot climate where low penetration grade bitumen is used. The result found in this study are encouraging, however, further investigation is required to investigate the application of current mix design methods for bituminous mixture containing waste PVC.

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