International Journal of Early Childhood Special Education (INT-JECSE)
DOI: 10.48047/intjecse/v12i2.201142 ISSN: 1308-5581 Vol 12, Issue 02 2020

EXPLORING THE INFLUENCE OF POLYVINYL CHLORIDE (PVC) ON THE BEHAVIOR OF BITUMINOUS CONCRETE MIXTURES

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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 and 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 strength properties of coarse aggregates and Marshall Design properties of bituminous mixes according to the test procedure specified by AASHTO. Some of the measured properties of bituminous mix with bitumen-PVC binder used in this study were within the acceptable recommended limits. On the basis of experimental results of this investigation, it is concluded that the dense graded bituminous mixes with bitumen containing PVC up to 10% can be used for bituminous pavement construction in warmer region from the stand point 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 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

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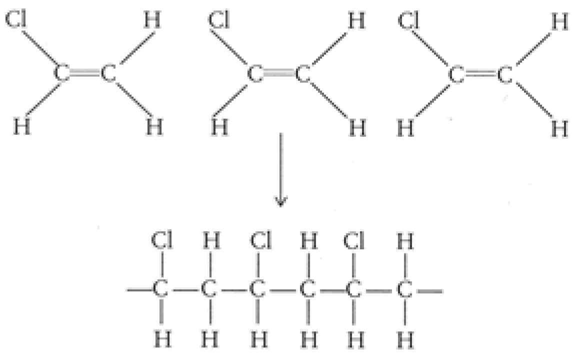
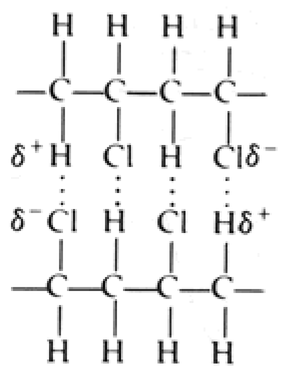
has been tried in possible development of sustainable bituminous paving mixes to improve the pavement performance.

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



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:



PVC

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

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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, 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.

1.1.EVOLUATION OF MIX DESIGN

In this investigation, waste polyethylene and PVC as the sort of polymers 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 amount of waste polyethylene and PVC is increasing day by day as the availability of these two wastes is enormous. More or less all the solid waste is being mixed with Municipal Solid Waste over land area after some nominal sorting and thus thrown over the land area named landfill. Since the plastic, polyethylene and PVC is non-biodegradable, it remains at the site for uncertain time causing the appreciable amount of waste increase into the landfill, ultimately increasing amount of cost for waste disposal. Since the present disposal method is either by land filling or by incineration, the waste plastic is owed dispose likely that causing adverse impact on the environment. To encounter this trend, considerable effort is being put into recycling waste, turning it into re-usable by products. Waste polyethylene and PVC derived from local market, household wastes the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. domestic and commercial uses. Waste polyethylene and PVC on heating melt at around 100°C to 260°C. Moreover, the molten polyethylene and PVC has a binding property. Hence, the molten polyethylene and PVC materials can be used as a binder and they can be mixed with binder like bitumen to enhance their binding property. These two may be a good modifier for the bitumen, used for road construction. Many investigations have found that the strength of the paving mixes can be enhanced by the use of a binder formed by modifying available bitumen with certain additives like Sulphur and organic polymer. The modified polymers also improve temperature susceptibility and viscosity characteristics. Modified bitumen containing 10% waste polyethylene can be used in the road construction particularly in the warmer region Low-density polyethylene carry bags collected from domestic solid waste can be used as the modification of 80/100 paving grade bitumen Bitumen can be mixed with waste polyethylene terephthalate which acts as additives

Moreover, a comparative performance has also been investigated using 8% and 15% waste plastic/polymer by wt. of bitumen with conventional bituminous concrete mixes prepared with 60/70 penetration grade bitumen

1.2.CLASSIFICATION OF BITUMINOUS MIXTURES:

A bituminous mixture is a combination of bituminous materials (as binders), properly graded aggregates and additives. Bituminous mixtures used in pavement applications are classified either by their methods of production or by their composition and characteristics. By the method of production, bituminous mixtures can be classified into Hotmix asphalt (HMA), Cold-laid plant mix, Mixed-in-

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place or road mix and Penetration macadam. Hot-mix asphalt is produced in hot asphalt mixing plant (or hot-mix plant) by mixing a properly controlled amount of aggregate with a controlled amount of bitumen at an elevated temperature. The mixing temperature has to be sufficiently high such that the consistency of bitumen is fluid enough for proper mixing and coating the aggregate, but not too high as to avoid excessive stiffening of the asphalt. HMA mixture must be laid and compacted when the mixture is still sufficiently hot so as to have proper workability. They are the most commonly used paving material in surface and binder courses in bituminous pavements. Cold-laid plant mix is produced in a bitumen mixing plant by mixing a controlled amount of aggregate with a controlled amount of liquid bitumen without the application of heat. It is laid and compacted at ambient temperature. Mixed-in-place or road mix is produced by mixing the aggregates with the bitumen binders in the form of emulsion (medium setting or slow setting) in proper proportions on the road surface by means of special road mixing equipment. Penetration macadam is produced by a construction procedure in which layers of coarse and uniform size aggregate are spread on the road and rolled, and sprayed with appropriate amounts of bitumen to penetrate the aggregate. The bituminous material used may be hot bitumen or a rapid setting bitumen emulsion.

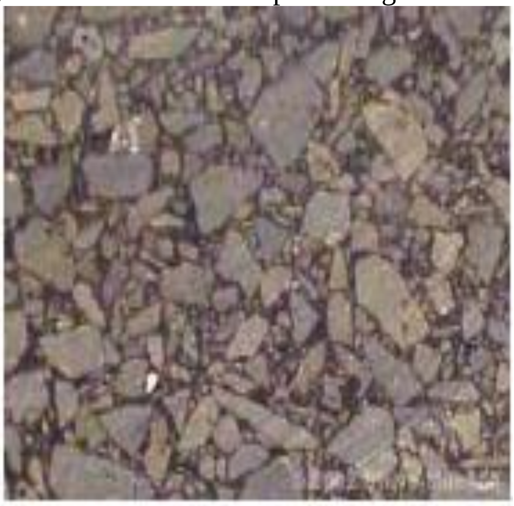

Figure:1.1.Dense graded HMA

Figure:1.2.Open graded HMA

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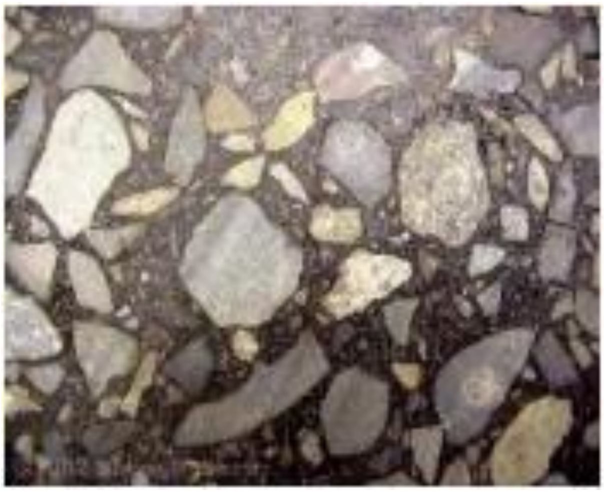

Polymer as an additive bituminous pavements have experienced accelerated deterioration due to traffic growth and climatic conditions. When a load is applied to the surface of a bituminous pavement it deforms. But bitumen, being a viscoelastic material, the majority of the deformation recovers when the load is removed. However, there is a minute amount of irrecoverable viscous deformation which remains in the bitumen and which results in a very small permanent residual strain. Accumulation of millions of these small strains due to axle loading results in the surface rutting familiar on heavily trafficked pavements. Laboratory tests that attempt to measure the rutting resistance, i.e., the resistance to permanent deformation of a bituminous mix, are: the Marshall test, static and dynamic creep tests, wheel-tracking tests, and laboratory test track tests Bitumen with polymers form multiphase systems, which usually contain a phase rich in polymer and a phase rich in bitumen not absorbed by the polymer. The properties of bitumen-polymer blends depend on the concentrations and the type of polymer used.

MATERIALS AND METHODS

Polyethylene:

Polyethylene has been the most popular plastic which has been used so far. 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: 3.1. Polyethylene

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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:3.2. 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.

3.1.CHARACTERISTICS OF MATERIAL USED IN BITUMINOUS MIX:

There are various types of mineral aggregates which can be used in bituminous mixes. The aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines. These are termed as natural aggregates and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by products such as steel slag, blast furnace slag etc. sometimes used as a component along with other aggregates to enhance the performance characteristics of the mix. Reclaimed bituminous pavement is also an important source of aggregate for bituminous mixes. Aggregates play a very important role in providing strength to asphalt mixtures as they Contribute a greater part in the matrix. SMA contains 70-80 percent coarse aggregate of the total Stone content. The higher proportion of the coarse aggregate in the mixture forms a skeletontype structure providing a better stone-on-stone contact between the coarse aggregate particles resulting in good shear strength and high resistance to rutting as compare to BC.

Bituminous Materials:

The binding material, 80/100 penetration grade bitumen, has been collected from Eastern Refinery, Bangladesh. Routine test as per AASHTO were performed on the bitumen samples to evaluate the bitumen properties were: Specific gravity, Ductility, Flash point & fire point, Penetration, Softening point and Solubility. The properties of bitumen binder, which are presented in Table, were within the specification of penetrating bitumen grade 80/100.

Table:3.1. Properties of used bituminous binder

Properties	Test results
Specific gravity	1.023
Ductility (cm)	115
Flash point (°C)	295
Fire point ((°C)	305
Solubility (%)	97.93
Softening point (°C)	52.5
Penetration (0.1 mm)	83

Aggregates:

In this investigation the crushed black stone was used as a coarse aggregate which were broken into pieces manually in 25.00 mm downgrade. Particles retained on 2.36 mm sieve were regarded as coarse aggregate A fine aggregate portion of the aggregate blend (passes 2.36 mm and retained on 0.075 mm sieve) was taken from coarse sand. Non-plastic sand finer than 0.075 mm sieve was used as mineral filler apparent specific gravity of the filler was 2.63

Table :3.2.Properties of aggregates

Properties	Coarse Aggregate	Fine Aggregate
Bulk specific gravity	2.79	2.46
Apparent specific gravity	2.86	2.66
Water absorption, %	0.81	3.10
Impact Test, %	6	...
Loss Angeles Abrasion, %	12	...

Figure:3.3.Aggregates

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Gradation of Aggregates:

Construction aggregate, or simply "*aggregate*", is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete. In order to investigate the behavior of the asphalt concrete mix modified with additives, a continuously graded aggregate of bituminous macadam is needed. In the continuously graded bituminous macadam, in order to obtain a dense mix with a controlled optimum air void The gradation of aggregates in asphalt mixes in the present investigation is shown in Figure content, the uniform gradation of the aggregate blend is required, hence to construct a stable and durable flexible Construction aggregate, or simply "aggregate", is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete.

Figure:3.4. Gradation of Aggregates

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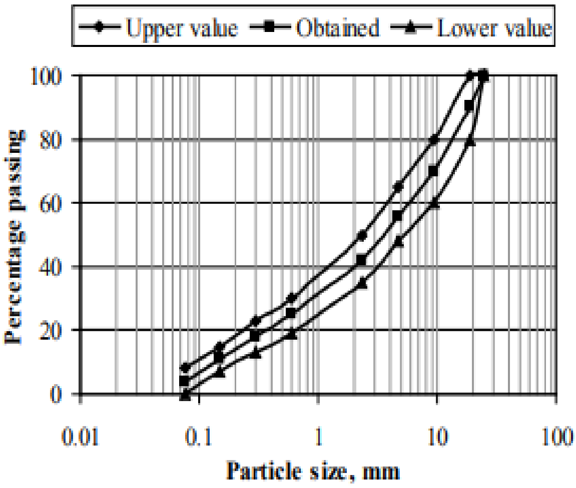

Figure: 3.5..Grain size distribution of aggregate gradation

Sieve mm	% passing by wt		Cumulative retain %	Individual retain %	% of C.A, F.A & M.F	Individual wt. for 1200 gm
	Specification	Blend				
25.0	100	100	00	00	C.A = 58%	00
19.0	80-100	90	10	10		120
9.50	60-80	70	30	20		240
4.75	48-65	56	44	14		168
2.36	35-50	42	58	14		168
0.60	19-30	25	75	17	F.A = 38%	204
0.30	13-23	18	82	07		84
0.15	7-15	11	89	07		84
0.075	0-8	4	96	07		84

types of binders (VG-30 and PMB-40) are used to prepare the bituminous mixture specimens. These were tested for their physical properties and test values satisfied all the requirements of paving grade bitumen specified in IS: 73 -2006 and IS: 15462 -2004. Crushed stone aggregates (coarse, fine and filler) from Ganga basin of Hardwar district in the state of Uttarakhand were used to prepare the bituminous mixture specimens. Maximum size and aggregate grading are directly controlled by the specification s (MORTH - 2001). Three aggregate gradations for each mix as described below were selected:

Gradation U: Upper limit of gradation range. The nominal size of this gradation is 9.5 mm for BC and 19 mm for DBM mix.

Gradation M: Midpoint of gradation range. The nominal size of this gradation is 13 mm for BC and 26.5 mm for DBM mix.

Gradation L: The lower limits of gradation range. The nominal size of this gradation is 13 mm for BC and 26.5 mm for DBM mix.

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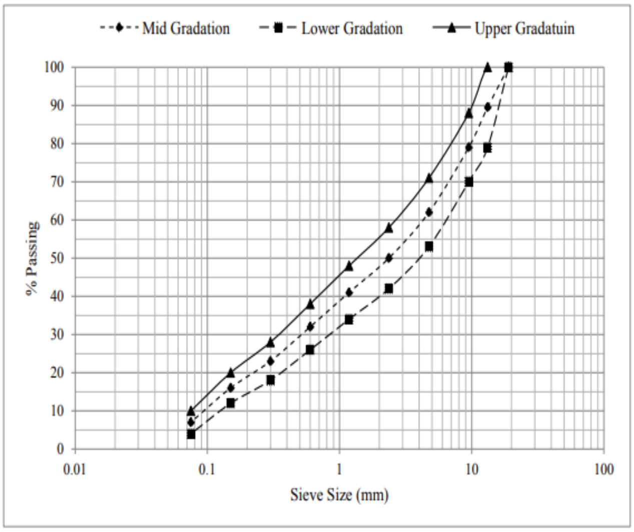
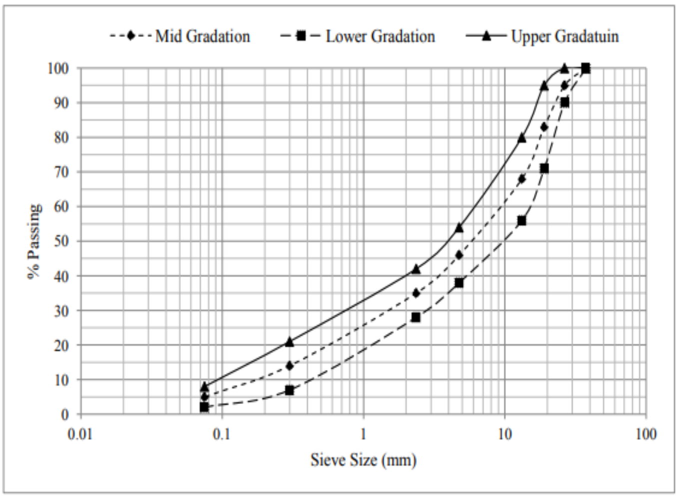
the aggregate size distribution of three grading for two mixes used in the present study. The notation B and D are used to describe BC and DBM mixes and U, M and L describe upper, middle and lower gradation in a mix respectively



Graph:3.1. Aggregate Gradation of Bituminous Concrete (BC) mix



Graph:3.2.Aggregate Gradation of Dense Bituminous Macadam (DBM) Mix

Preparation of Marshall Specimen:

To investigate the Marshall stability of asphalt mixes with polyethylene and PVC, specimens of 101.6 mm diameter and approximately 63.5 mm thickness were prepared. The test procedure introduced by Bruce Marshall and developed by the U.S corps of engineers has been followed in the laboratory investigations. Initially about 1200 g of aggregates was taken to prepare the specimen of 101.6 mm (4 inch) diameter and 63.5 mm (2.5 inch) thick for pure bitumen and three specimens were prepared for each bitumen content. Five bitumen content was used starting from 4.5% with increment of 0.5% to determine the optimum bitumen content for the pure bitumen and the optimum bitumen content (OBC) was 5.4%. This bitumen content (5.4%) was kept constant for preparing the further specimen, only changing the percentage of polyethylene and PVC content. Then, sixteen bowls for preparing sample was weighted for both polyethylene and PVC. Hot pure bitumen was poured into those bowls. The weight of the bitumen was taken. The polyethylene and PVC were weighted with respect to 2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20% weight of pure bitumen separately. The samples were prepared one after another. At first the bitumen for 2.5% polyethylene and PVC were heated till it fully liquefied separately and was in a state to dissolve polyethylene and PVC. The polyethylene bags and PVC were gradually left in bitumen. The softened form of the polyethylene bags was floating on the hot bitumen. But after continuous stirring by steel spoon it was thoroughly mixed with the bitumen. There was a little change in color. This mother sample is kept for further experiments. Thus,

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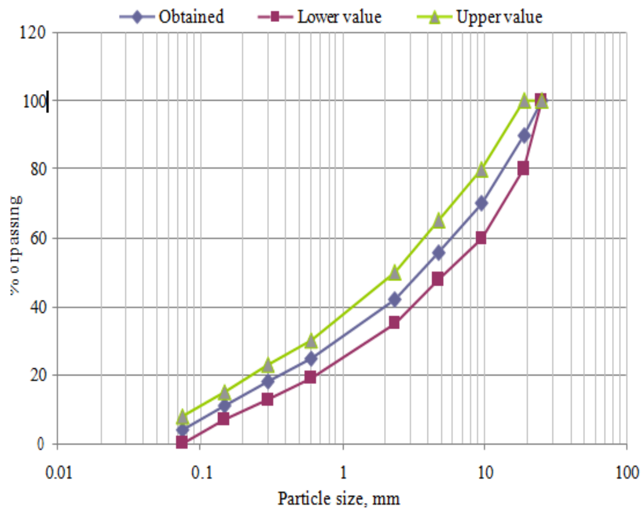
eight samples were prepared with variable polyethylene content and another eight samples were prepared for PVC content. Now, for the preparation of Marshall specimens of 101.6 mm diameter and approximately 63.5 mm thick, about 1200 gms of aggregates of all sizes were weighted and taken in a pan.



Graph:3.3. Grain size distribution of aggregate gradation

The aggregate blend was then heated for four hours in an electric oven maintained at a temperature of 182-188°C (depending on the moisture content of that aggregates). The aggregates were then transferred to a hot mixing bowl and thoroughly mixed.of the dry blended aggregate and the required amount of bitumen (5.4% pure bitumen + various % of polyethylene/PVC content by the weight of bitumen), heated to a steady temperature of 160°C was added. The aggregates and modified bitumen were mixed to yield a mixture having a uniform distribution of modified bitumen. The mould assembly heated in a bath of boiling water was placed on the table and a piece of circular paper of 101.6 mm diameter was placed at the bottom of the mould. The entire bath of mixture was then introduced in the mould and the mixture was vigorously spaded with a hot trowel 15 times around the perimeter and 10 times over the interior. Temperature of the mixture was recorded and the mould assembly with the mixture was placed on the standard compaction pedestal and 50 blows were applied with the 4.5 kg compaction hammer with a free fall of 45.7 cm. The axis of the hammer was kept perpendicular to the base of the mould assembly during compaction. The number of blows for the preparation of the sample was selected corresponding to 690 kN/m2 (100 psi) tyre pressure. The heavy vehicles which move on the road of Bangladesh have tyre pressure in range of 415-485 kN/m2 (60-70 psi). So the assumption of 690 kN/m2 tyre pressure seems to be safe and appropriate. The collar of the mould was then removed and the mould with specimen inside was inverted and reset on the base plate. The extension collar was placed in position and 50 blows were applied on the face of specimen with the compaction hammer. The sample was then cooled for about 10 minutes and extruded from the mould with the help of a hydraulic jack. The specimen was then transferred to a smooth flat surface and allowed to stand overnight at room temperature. The same procedure was adopted to prepare specimens of all percentage of polyethylene and PVC content

RESULTS

The population of our country is increasing rapidly and due to it plastic waste is also increasing day to day due to urbanization, development activities and changes in life style, which leading extensive environment pollution. Thus disposal of waste plastic is a threat and become a serious problem globally due to their non-biodegradability and anaesthetic view. Since these are not disposed scientifically & possibility to create ground and water pollution. This waste plastic partially replaced the conventional material to improve desired mechanical characteristics of road mix. In the present paper developed techniques to use plastic waste for construction purpose of roads and flexible pavements has reviewed. In conventional road making process bitumen is used as binder. Such bitumen can be modified with plastic waste pieces and bitumen mix is made, which can be used as a top layer coat of flexible pavement. This waste plastic modified bitumen mix show better binding property, stability, stiffness, density and extra resistant to water The use of waste plastics in road

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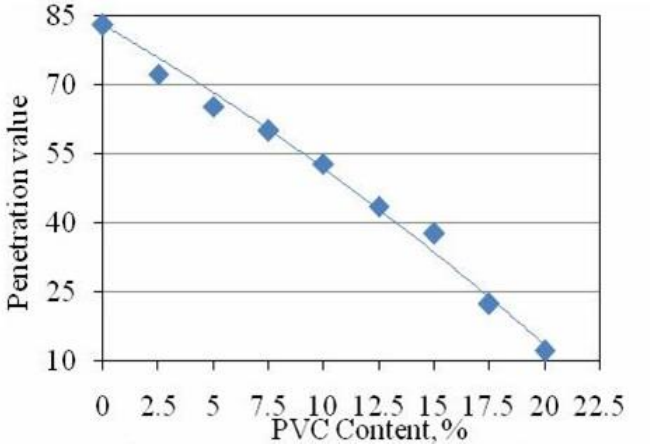
construction is gaining importance these days because plastic roads perform better than ordinary ones and the plastic waste considered to be a pollution menace, can find its use. Studies reported in the used of re-cycled plastic, mainly polyethylene, in the manufacture of blended indicated reduced permanent 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 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.

Marshall stability:

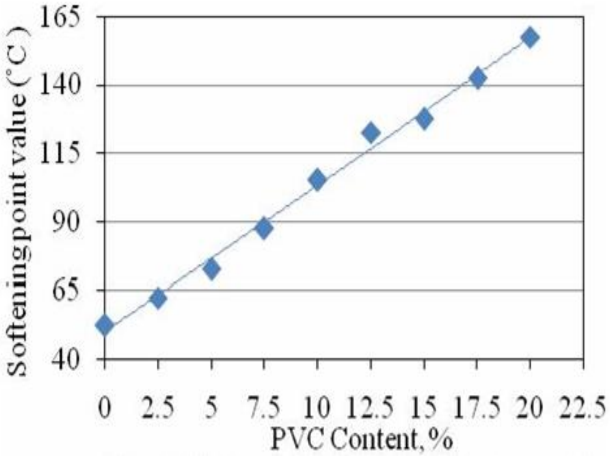
It is seen from that using of coal ash in PVC mix is not satisfactory with respect to stability value, when compared with conventional mix. The maximum stability value of 11.83 kN was achieved when 14% of coal ash by weight of the mix was mixed for preparing PVC samples For determination of optimum bitumen 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:4.1.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.

DOI: 10.48047/intjecse/v12i2.201142 ISSN: 1308-5581 Vol 12, Issue 02 2020



Graph:4.2. 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. Indirect tensile strength (ITS) = $2P$ Where, P is load(Kg), d is the diameter in cm of the specimen, t is the thickness of the specimen in cm. The tensile strength ratio(TSR) was calculated by following relation,

Tensile strength ratio (TSR) = 100 $*$ $Stc\ Stuc$ ---- Equation 2

Where, Stc is average indirect tensile strength of conditioned specimen and Stuc is indirect tensile strength of un-conditioned specimen.

Table:4.1.Indirect tensile strength (ITS) and TSR

Specimens	% Plastic	ITS (Stuc), Unconditioned (Kg/cm²)	ITS (Stc) Conditioned (Kg/cm²)	TSR = ????* ??????
BC-X	**0**	**9.76**	**8.25**	**84.53**
BC-Y	**0.8**	**12.32**	**11.56**	**93.83**

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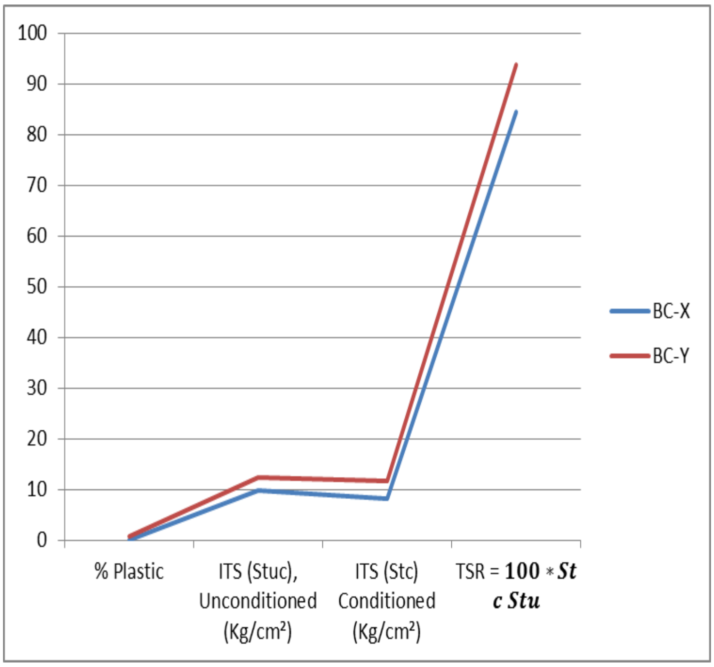


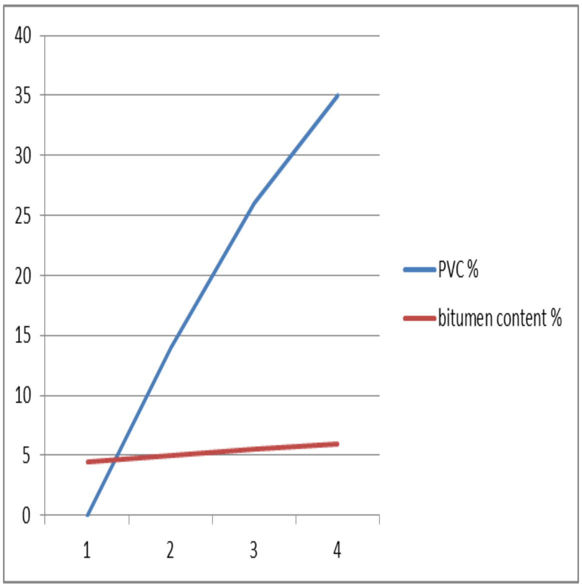
Graph:4.3. Indirect tensile strength (ITS) and TSR variations

It is observed from the graph shown in that with increase in coal ash the air void increases. By taking 14% coal ash by weight of the mix, the air void is fairly near to the conventional mix, which means coal ash can be used with some modification to achieve optimum properties than conventional mix. From the Unit weight and bitumen content graph shown in it is observed that with increase in coal ash content the unit weight of PVC a lighter material cause the decrease of unit weight.

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
35	6

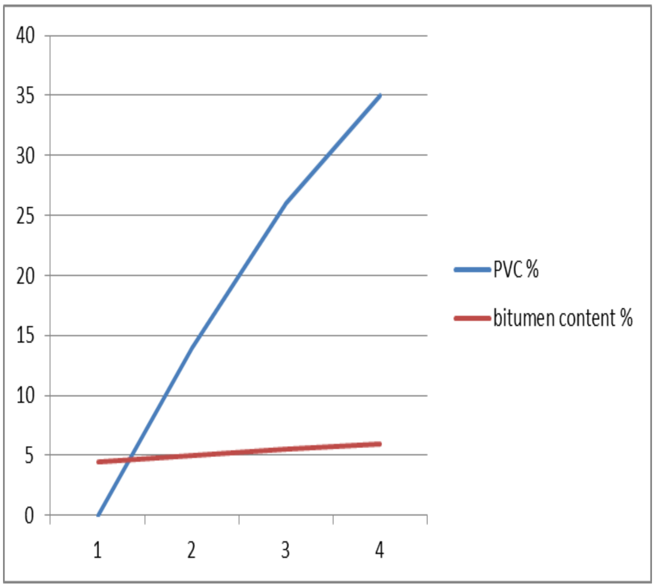


Graph:4.4.Variation of PVC value with bitumen content at different coal ash content

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:4.5. Variation of VFC value with bitumen content Ash content

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

DOI: 10.48047/intjecse/v12i2.201142 ISSN: 1308-5581 Vol 12, Issue 02 2020

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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