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Use of Fly Ash Plastic Waste composite in Bituminous Concrete Mixes of Flexible Pavement

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***Abstract*:** *The present paper deals with the use of fly ash with plastic waste in combination in the Bituminous Concrete mixes of flexible pavement. Now–a-days plastic waste and fly ash are readily available waste materials. By virtue of their useful characteristics they can be used in bituminous mixes of flexible pavement construction. The plastic will be responsible for improving some properties of the bituminous mix and at the same time will solve the environmental problems related to its disposal as well. Fly ash is finely divided remains, obtained as a result of combustion of pulverized coal. It can be used as economical mineral filler in bituminous concrete of flexible pavements and other asphalt paving applications. Thermo Gravimetric Analysis (TGA) will reflect the thermal degradation behavior of plastic waste. Test specimen were prepared using different percentages of plastic content ranging from 0.2% to 1.0% with an increment of 0.2% by weight of total mix. Test results showed that the optimum plastic content comes out to 0.8% by weight of total mix and the optimum bitumen content for fly ash as filler was 5.2% and fly ash-plastic composite was 5.3%. Samples were prepared using optimum plastic content (0.8%) and optimum bitumen content by weight of total mix. Bituminous concrete samples containing fly ash and fly ash-plastic composite were prepared in laboratory and marked as BC-X and BC-Y respectively. These samples of bituminous concrete were undergone to various performance tests such as indirect tensile strength (ITS), indirect tensile strength ratio (TSR), static creep and resilient modulus at varied temperatures and rutting resistance by wheel tracking test. From results it was observed that indirect tensile strength ratio (TSR) of BC-Y was 10% higher as compared to BC-X mix indicating better resistant against moisture damage. Static creep test showed that the permanent deformation of BC-Y was higher as compared to BC-X at both the temperature 35°C and 45°C but amount of recovery was higher for BC-Y than BC-X mix. Resilient modulus of BC-Y mix was higher than BC-X mix at both the temperature 35°C and 45°C. Higher values of resilient modulus indicate their high strength and support to reduce rutting behavior of mix. It was also observed that average rut depth of BC-Y mix was 15.85% lower than BC-X mix. These results show that Bituminous Concrete containing fly ash-plastic composite is a suitable substitute to traditional filler and is acceptable material for bituminous concrete of flexible pavement construction.*

Keywords: *Bituminous Concrete, indirect tensile strength (ITS), resilient modulus, fly ash-plastic composite, Marshall Stability.*

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I. INTRODUCTION

In present scenario due to vast development of road infrastructure the good quality of virgin aggregates inclusive of traditional fillers like lime , cement etc. are depleting at very fast rate compelling to explore the use of waste mineral materials like fly ash as filler. At present about 100 thermal powers are in operation and are responsible for producing about 170 million tons of ash annually. As a common practice these ashes are dumped in the vicinity of available land adjoining to thermal power plants and are responsible for adverse affect to the environment besides overshadowing useful lands. In 2011 Chandra et al have assessed that the production of ash by 2030 will reach around 600 million tons. Studies have revealed (Chandra et al, 2011) that the scope of using these ashes and other waste materials in highway sector are very much on cards as their effect on performance proves to be technically, economically and environmentally viable and acceptable and are with in the prescribed norms and specifications. As per Kumar et al in 2008, and Jain et al in 2011 the waste materials like fly ash and plastic waste can be conveniently used in the bituminous mixes of flexible pavement construction due to their supportive and pavement friendly characteristics. The plastic will be responsible for improving some properties of the bituminous mix and at the same time will solve the environmental problems related to its disposal as well. Fly ash is finely divided remains, obtained as a result of combustion of pulverized coal. It can be used as an economical mineral filler in bituminous concrete of flexible pavements and other asphalt paving applications.

The continuous global increase in coal use is responsible for greater production of fly ash. Studies reveal that coal fly ash has been successfully used as mineral admixture in Portland cement and cement concretes and as cost effective mineral filler in bituminous concrete of pavements. The benefits of using waste materials like fly ash and plastic waste are listed below-

1. Considerable reduction in the use of natural raw materials.
2. Responsible for industrial sustainability.
3. Solves the deposal problems of wastes as these are utilized in construction activities.
4. Plastic will improve some properties of bituminous mixes used for paving roads.

Studies revealed that many researchers have given their own outcomes on use of fly ash and plastic wastes in bituminous mixes of flexible pavement construction. The details are listed below in table no-1.

Table-1 Details of use of fly ash and plastic wastes in bituminous mixes

Researchers	Year	Performance study	Outcome
Fly ash			
Swaminathan et al	1968	Use of fly ash in bituminous road surfacing.	Acceptable for low volume traffic.
Kandhal	1993	Critical review on use of fly ash in bituminous road construction.	Satisfactory performance
Kavussi & Hicks	1997	Study on viscosity of fly ash and bituminous mixture.	Increase in fly ash content up to 6% yields considerable improvement in fatigue life of mixes.
Kumar et al, Tapkin et al	2008	Laboratory study on use of fly ash in bituminous mixes.	Fly ash can be used effectively as a filler replacement in dense graded bituminous wearing course.
Sharma et al,	2011	Use of fly ash in bituminous road construction.	Satisfactory performance
Plastic waste			
Vasudevan et al	2006	Use of Plastic coated aggregate in bituminous mixes of flexible pavement.	Performance improved
Verma S.S.	2008	Use of plastic waste in bituminous mixes.	Performance improved
Sangita et al	2011	Use of waste polymer as modifier in bituminous concrete.	Performance improved
Jain et al	2012	Use of waste polymeric packaging materials in bituminous concrete.	Performance improved

The use of plastic will increase the melting point of the bitumen and hence improvement in properties of bituminous mixes. This will result in increased life of roads. As a result of the facts mentioned above by the various researchers and the problem associated with the disposal of fly ash and plastic waste, a study on use of these wastes was planned. A composite named fly ash-plastic composite was prepared by blending fly ash and plastic waste in suitable proportion. Bituminous mix characteristics are mainly dependent on properties of bitumen and aggregates that forms the paving mix. The mineral filler plays an integral part and is very important for modifying the mix characteristics. All properties of the bituminous mix like optimum bitumen content, air voids etc. The basic objective of the study is to evaluate the mechanistic properties of bituminous concrete mix using the composite of fly ash and plastic waste.

II. MATERIALS USED

Plastic waste in the shredded form size ranging from 2-8 mm was selected for the present study. Properties of shredded plastic waste are laid in the table given below-

Table-2 Properties of shredded plastic waste

Properties	Test	Value
Initial Decomposition Temperature	TGA Curve	392°C
Melting Point	DSC Curve	125°C
Plastic type	Grinded waste thin plastic packaging bags	
Plastic material	Low density Polyethylene (LDPE)	
Density (gm/cm3)	0.92	

2.1. Waste plastic: In India 330 Million People depending on Plastic bags. India ranks III in the world in the consumption of plastics. It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. 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 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.

Table -3 - Thermal Behavior of Polymers

Polymer	Solubility		Softening Temp. in °C	Product reported	Decomposition Temp. in °C	Product reported	Ignition Temp. range in °C	Product reported
	Water	EPT*						
PE	Nil	Nil	100-120	No Gas	270-350	CH4.C2H6	>700	CO, CO2
PP	Nil	Nil	140-160	No Gas	270-300	C2H6	>700	CO, CO2
PS	Nil	Nil	110-140	No Gas	300-350	C6H6	>700	CO, CO2

2.2. Fly ash: Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric bag houses. Fly ash is most commonly used as a pozzolana in Portland cement concrete applications. Pozzolanas are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. The unique spherical shape and particle size distribution of fly ash make it good mineral filler in hot mix asphalt (HMA) applications and improves the fluidity of flowable fill and grout. The consistency and abundance of fly ash in many areas present unique opportunities for use in structural fills and other highway applications. There are three types of fly ashes, namely, fly ash, bottom ash and pond ash. Fly ash and bottom ash when transported and disposed to the pond it is termed as pond ash.

2.2.1. Favorable properties of fly ash

- Light weight, lesser pressure on sub-soil
- High shear strength
- Coarser ashes have high CBR value
- Pozzolanic nature, additional strength due to self-hardening
- Amenable to stabilization
- Ease of compaction
- High permeability
- Non plastic
- Faster rate of consolidation and low compressibility
- Can be compacted using vibratory or static roller

Table-4 Engineering properties of Fly ash

Parameter	Range
Specific Gravity	1.90 – 2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9 – 1.6
Optimum moisture content (%)	38.0 – 18.0
Cohesion (KN/m^2)	Negligible
Angle of internal friction (¢)	$30^0 – 40^0$
Coefficient of consolidation C_v (cm^2/sec)	$1.75 \times 10^{-5} – 2.01 \times 10^{-3}$
Compression index C_c	0.05 – 0.4
Permeability (cm/sec)	$8 \times 10^{-6} – 7 \times 10^{-4}$
Particle size distribution (% of materials) Clay size fraction Silt size fraction Sand size fraction Gravel size fraction	 1 – 10 8 – 85 7 – 90 0 – 10
Coefficient of uniformity	3.1 – 10.7

2.2.2. Use of fly ash in Portland cement concrete for applications in highway construction: Fly ash is used in concrete admixtures to enhance the performance of concrete roads and bridges. Portland cement contains about 65 percent lime. Some of this lime becomes free and available during the hydration process. When fly ash is present with free lime, it reacts chemically to form additional cementitious materials, improving many of the properties of the concrete. There are many advantages of incorporating fly ash into a Portland cement concrete which have been demonstrated through extensive research and countless highway and bridge construction projects. Benefits to concrete vary depending on the type of fly ash, proportion used, other mix ingredients, mixing procedure, field conditions and placement. Some of the advantages of fly ash in concrete are mentioned below:

- Higher ultimate strength;
- Improved workability;
- Reduced bleeding;
- Reduced heat of hydration;
- Reduced permeability;
- Increased resistance to sulphate attack;
- Increased resistance to alkali-silica reactivity (ASR);
- Lowered costs;
- Reduced shrinkage; and
- Increased durability.

2.2.3. Use of fly ash in base course for stabilization applications in highway construction: Fly ash and lime can be combined with aggregate to produce a quality stabilized base course. These road bases are referred to as pozzolanic-stabilized mixtures (PSM). Typical fly ash contents may vary from 12 to 14 percent with corresponding lime contents of 3 to 5 percent. Portland cement may also be used in lieu of lime to increase early age strengths. The resulting material is produced, placed, and looks like cement stabilized aggregate base. Pozzolanic stabilized mixture bases have advantages over other base materials which are shown below:

- Use of locally available materials;
- Provides a strong, durable mixture;
- Increased energy efficiency;
- Suitable for using recycled base materials; and
- Can be placed with conventional equipment.

2.2.4. Use of fly ash in soil improvement for applications in highway construction: Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. The properties of soil which can be change by using of fly ash are density, water content, plasticity, strength and compressibility performance of soils, hydraulic conductivity, and so on. Typical applications include: soil stabilization, soil drying, and control of shrink-swell. Fly ash provides the following advantages when used to improve soil conditions:

- Eliminates need for expensive borrow materials;
- Expedites construction by improving excessively wet or unstable sub grade;
- By improving sub grade conditions, promotes cost savings through reduction in the required pavement thickness (as the CBR value increases).
- Can reduce or eliminate the need for more expensive natural aggregates in the pavement cross-section.

2.2.5. Use of fly ash in asphalt pavements for applications in highway construction: Fly ash can be used as mineral filler in hot mixed asphalt (HMA) paving applications to increase its density. Mineral fillers increase the stiffness of the asphalt mortar matrix, improving the resistance of pavements, and the durability of the mix. Fly ash will typically meet mineral filler specifications for gradation, organic impurities, and plasticity. The advantages of fly ash which are mentioned in the following:

- Reduced potential for asphalt stripping due to hydrophobic properties of fly ash;
- Lime in some fly ashes may also reduce stripping; and
- May afford a lower cost than other mineral fillers.

Fly ash used in the study was obtained from NTPC Ltd. Tanda (U.P.) India. The various properties of fly ash like bulk density, specific gravity, water absorption etc. were obtained by performing specified tests and the results are laid down in table-3 below-

Table-5 Properties of fly ash

Properties	Test	Value
Bulk Density in gm/cm³	IS: 2386-III-1963	1.22
Specific Gravity	IS: 2386-III-1963	2.2
Water absorption (%)	IS: 2386-III-1963	1.52
Fineness modulus	IS: 2720-IV-1985	2.42
Methylene blue	IS: 2720-XXIV-1976	0.56
Plasticity Index	IS: 2720-V-1985	Non plastic

The bitumen VG-30 grade paving bitumen of Indian Oil Mathura refinery was used in the study. The physical properties of bitumen are shown in table-4 below-

Table-6 Physical properties of bitumen (VG-30)

Properties	Test	Value	Specification IS-73-2006
Penetration(100gram, 5seconds at 25°C) (1/10th of mm)	IS 1203-1978	60	50-70
Softening point, °C(Ring and Ball Apparatus)	IS 1205-1978	48	46-54
Ductility at 27°C(5cm/ minute pull) cm	IS 1208-1978	77	>75
Specific gravity at 27°C	IS 1203-1978	1.02	>0.99
Viscosity at 60°C , poise	IS 1206-1978	2452	>2400
Viscosity at 135°C, cSt	IS 1206-1978	362	>350
Flash Point Test °C	IS 1209-1978	305	
Fire Point Test °C	IS 1209-1978	315	

The mineral aggregate (granite) was taken from local supplier and its physical properties are shown in table-5 below-

Table-7 Physical properties of mineral aggregate(granite)

Properties	Test	Value	MORTH 2001Specification
Impact value	IS 2386-IV-1963	9.84	Max 30
Crushing Value	IS 2386-IV-1963	11.45	Max 30
Specific gravity	IS 2386-III-1963	2.65	2.5-3.0
Flakiness & Elongation index combined	IS 2386-I-1963	24	Max 30
Water absorption	IS 2386-III-1963	0.87	Max 2
Stripping value (%)	IS 6241-1971	98	Minimum retained coating 95

III. DESIGN OF MIX AND PROCEDURE

Grading of aggregate was adopted as per specification of Ministry of road transport and highway (MORTH, 2001) for 50 mm thick bituminous concrete as shown below in table no- 8 below-

Table-8 Gradation of Aggregates for bituminous concrete mixes

IS sieve size in mm	Cumulative % by weight of total aggregate passing	
	Gradation Specified	Gradation Adopted
26.5	100	100
19.0	90-100	95
13.2	59-79	69
9.5	52-72	62

4.75	35-55	44
2.36	28-44	34
1.18	20-34	28
0.6	15-27	21
0.3	10-20	14
0.15	5-13	9
0.075	2-8	5

The gradation curve of aggregate is shown below in Fig-1.

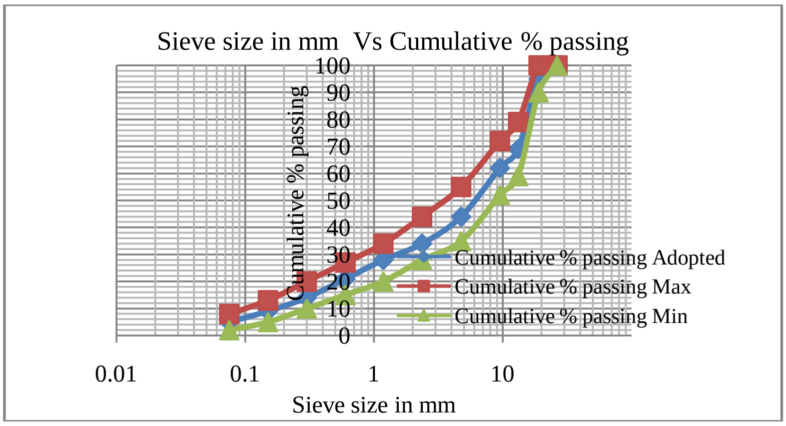

Fig-1 Gradation Curve of Aggregate

Adopted grading aggregate was heated to 160°C in a pan and requisite amount of heated bitumen was then added and mixed properly as per prescribed norms and specifications in order to obtain bituminous concrete mixes. In case of preparation of bituminous mix with waste plastic the suitable dosage of plastic waste was added to heated fly ash and mixed for 8-10 minutes and then added to heated aggregate at 160°C and mixed for 5 minutes. Test specimen were prepared using different percentages of plastic content ranging from 0.2% to 1.0% with an increment of 0.2% by weight of total mix. From the test results the optimum plastic content was found to be 0.8% of total bituminous mix by weight. Samples were prepared using optimum plastic content (0.8%) and optimum bitumen content by weight of total mix. Bituminous concrete samples containing fly ash and fly ash-plastic composite were prepared in laboratory and marked as BC-X and BC-Y respectively. Test samples were prepared by adopting Marshall Method (ASTM D 1559) by applying 75 blows on both faces.

Table-9 Properties of designed bituminous concrete mixes with various % of plastic waste

Properties	**Method**	**Plastic waste percentage**				
		0	0.2	0.4	0.8	1.0
Bulk density gm/cm³	ASTMD 2726	2.35	2.36	2.38	2.37	2.34
Air voids %	ASTMD 3203	5.32	5.10	4.7	4.8	5.30
Marshall Stability Kg, 60°C	ASTMD 1559	1282	1180	1350	1502	1290
Marshall Flow mm, 60°C	ASTMD 1559	3.75	3.50	3.8	4.25	3.75
Marshall Quotient Kg/mm	Stability/ Flow	342	337	355	353	344

The various properties of the designed bituminous concrete mixes (BG-X and BC-Y) are laid in the table below-

Table-10 Properties of designed bituminous concrete mix

Properties	**Method**	**BC-X**	**BC-Y**
Bulk density gm/cm³	ASTMD 2726	2.345	2.358
Air voids %	ASTMD 3203	5.12	4.62
Bitumen content %	ASTMD 3203	5.2	5.3
Marshall Stability Kg, 60°C	ASTMD 1559	1282	1502
Voids in mineral aggregate(VMA)	ASTMD 1559	17.0	16.5
Voids filled with bitumen(VFB)	ASTMD 1559	70	72
Marshall Flow mm, 60°C	ASTMD 1559	3.75	4.25
Marshall Quotient Kg/mm	Stability/ Flow	342	353
Un-conditioned Indirect tensile strength, Kg/ cm²	ASTMD 4867	9.76	12.32
Conditioned Indirect tensile strength, Kg/ cm²	ASTMD 4867	8.25	11.56
Tensile strength ratio (TSR) %	ASTMD 4867	80	88
Stiffness modulus MPa, 35 °C	ASTMD 4123	2905	4506
Retained stability (SR) %	IRC:SP: 53-2002	78.16	84

IV. EXPERIMENTAL INVESTIGATIONS

For performing various tests the details of procedure are given below-

4.1. 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) $= \frac{2P}{\pi t d}$ ---- Equation 1

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, equation 2.

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

Where, Stc is average indirect tensile strength of conditioned specimen and Stuc is indirect tensile strength of un-conditioned specimen. Results of tensile strength and TSR are plotted in fig-2 as shown below-

Table-11 Indirect tensile strength (ITS) and TSR

Specimens	% Plastic	ITS (Stuc), Unconditioned (Kg/cm²)	ITS (Stc) Conditioned (Kg/cm²)	TSR $= 100 * \frac{Stc}{Stuc}$
BC-X	0	9.76	8.25	84.53
BC-Y (Fly ash-plastic composite)	0.8	12.32	11.56	93.83

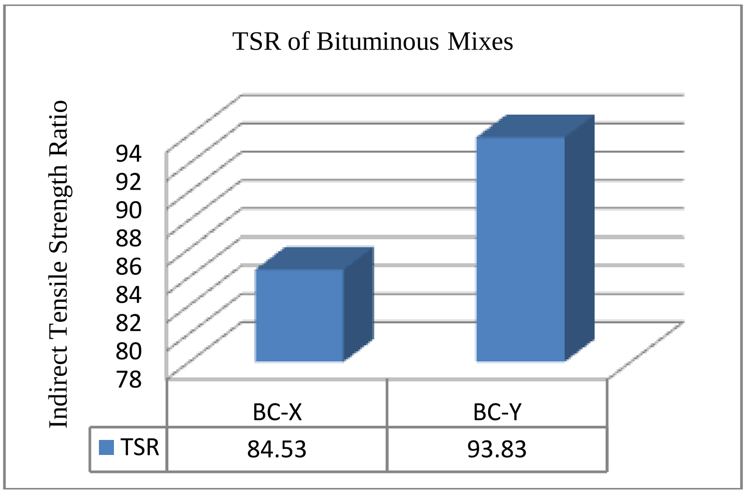

Fig-2 Indirect tensile strength ratio (TSR)

Table-12 Stability values of unconditioned and conditioned Marshal samples & Stability Retention(SR)

Descriptions	Marshall Stability value (Kg)		Stability Retention(SR) SR= 100* S1/ S2
	Unconditioned S1	Conditioned S2	
BC-X Conventional Mix .(without plastic) at optimum bitumen content of 5.2 %	1282	1002	78.16
BC-Y (Fly ash-plastic composite with 0.8% plastic) optimum bitumen content of 5.3 %	1502	1262	84.02

4.2. Resistance to deformation: The resistance to deformation at high temperatures can be assessed by performing rutting and static creep tests.

4.2.1. Rut depth study: To assess the rutting resistance of the bituminous concrete mixes tests were performed by using Wheel Tracking Device (WTD). It is a destructive test and has a feature of direct contact between the loaded wheel and rectangular test samples. The test was conducted on rectangular sample having dimension 300x300x50 mm at optimum bitumen content containing fly ash and fly ash-plastic waste composite as filler material. The test was performed as per specifications of BS: 598-1998. In this test 20000 passes were applied on test sample at 45°C and resulting rut depth was measured. The rut depths of different bituminous mixes are plotted in figure below and also the rut depth in different cycle range is shown in table below.

Table-13 Rutting in bituminous concrete mixes

Composition / Samples	Rutting in mm at 45°C for different cycle range		
	0-5000	5000-10000	10000-20000
BC-X	2.75	3.25	4.0
BC-Y	2.25	3.20	3.15

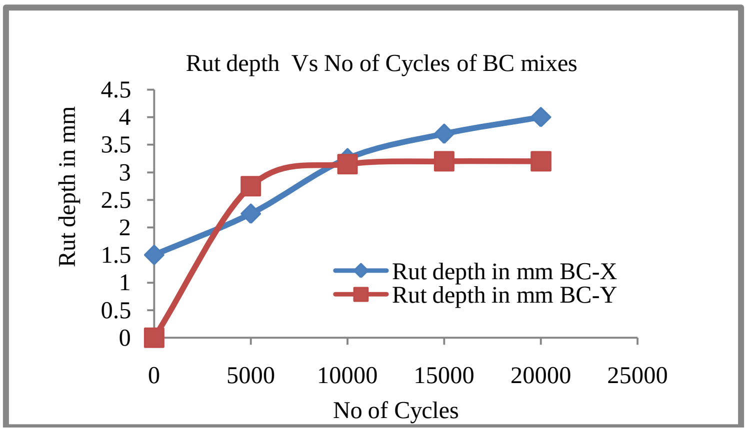

Fig 3 Rut depth Vs No of Cycles of BC mixes

4.2.2. Static Creep Test: It is conducted by applying a static load to a sample and measuring the permanent deformation of the sample after removal of load. The test is used to determine the permanent deformation of bituminous concrete mixes. The observed permanent deformation of the bituminous mixes was then correlated with rutting potential. Under a uni-axial static loading the creep deformation of a cylindrical specimen was measured as a function of time and sample dimensions under the standardized test condition. After initial elastic response, the creep portion of the response curve ultimately becomes linear, forming constant slope. After removal of applied stress the elastic deformation recovers followed by time dependent recoverable elastic deformations, the residual strain which remains after complete elastic recovery is the non recoverable permanent deformation. Permanent deformation risks are greater under heavy loading and high temperature. To analyze the same the following test parameters were selected-
Uni-axial load = 100 KPa
Temperature = 35°C and 45°C
Load duration = 3600 sec
Unloading duration = 2000 sec
The values of permanent deformation, percentage recovery and creep modulus of creep test are shown in table below. The creep deformation obtained during test at 35°C temperature is shown in Fig-4.

Table-14 Test results of Static creep

Temperature (°C)	Samples	Total deformation (mm)	Permanent deformation (mm)	Recovery (%)	Modulus (MPa)
35°C	BC-X	0.25	0.13	52.00	13.60
	BC-Y	0.26	0.18	69.23	14.30
45°C	BC-X	0.20	0.08	40.00	15.40
	BC-Y	0.21	0.11	52.38	15.80

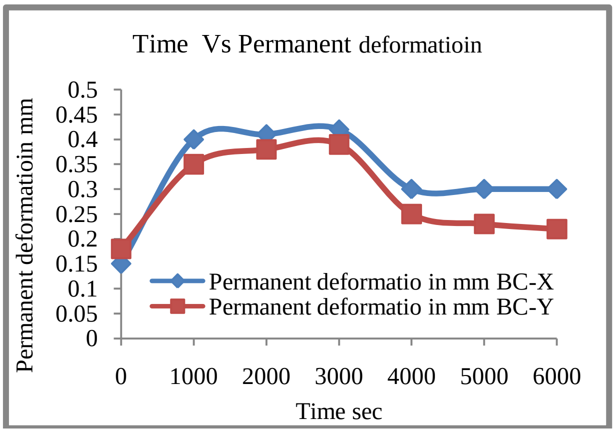

Fig-4 Static creep test of different BC mixes at 35°C

4.3. Resilient Modulus (MR) Test: It is one of the most important mechanistic properties of bituminous mixes. The repeated loading indirect tensile strength test was performed as per ASTM D4123 on compacted bituminous mix containing fly ash-plastic waste composite material as filler in order to find resilient modulus values at different temperatures. The test was conducted by applying a compressive load in the form of haversine wave at 25°C, 35°C and 45°C for two Bituminous mixes (BC-X and BC-Y). The samples were conditioned for 5 hour in environmental chamber at given temperature and then subjected to repeated loading pulse width of 100 ms, and pulse repletion of 100 ms. The results are plotted inFig-5.

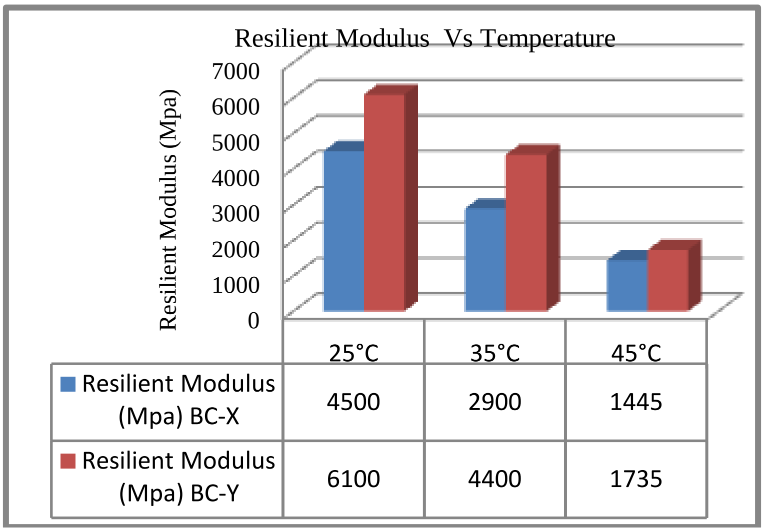

Fig-5 Resilient Modulus of different BC Mixes at various temperatures

V. DISCUSSION OF TEST RESULTS

- The particle size of shredded plastic is in the range of 2-8 mm which lies in the conformity of findings of earlier researchers. The melting temperature of plastic waste is around 125°C which melts at the heating temperature of the aggregates and fly ash. The decomposition temperature of plastic waste is 392°C, where the chemical properties of plastic waste changes. Therefore plastic waste can be conveniently used from temperature range of 120-180 °C. Test results on fly ash as shown in table 5 indicate that fly ash was non plastic. A lower value of methylene blue indicates lesser amount of clay and organic material in the fly ash. As shown in table-5 the optimum bitumen content was 5.2% for fly ash and 5.3% for fly ash-plastic waste composite by weight of aggregate.
- The damage caused by ingress of water is generally assessed by TSR value. The value of TSR of BC-X and BC-Y were recorded as 84.53% and 93.83%. Bituminous concrete with fly ash-plastic waste composite filler has tensile strength ratio 11% higher as compared to only fly ash (BC-X) indicates better resistance to moisture damage. On the basis of results obtained the bituminous concrete containing plastic waste composite as filler can be used in high rainfall locations.
- Rutting plays very important role for design and performance study of bituminous concrete mixes. As shown in fig-3 the observed rut depth values of bituminous concrete mixes are in the range of 3.15 to 4.0 mm using VG-30 bitumen binder with fly ash and fly ash- plastic waste composite as filler. Test results plotted in Fig-3 shows that higher resistance to rutting was observed when fly ash- plastic waste composite was used. It was also observed

that rate of rutting was on lower side for bituminous concrete mixes containing fly ash- plastic waste composite as shown in table-13.

- The value of creep modulus is higher for bituminous concrete mix containing fly ash- plastic waste composite. The value of permanent deformation was more in Bituminous concrete containing fly ash- plastic waste composite but at the same time percentage recovery was high for fly ash- plastic waste composite.
- Resilient modulus is the measure of pavement response in forms of dynamic stress and corresponding strains. The plot of data in Fig-5 show that use of fly ash- plastic waste composite as filler has improved the diametric resilient modulus of the mixes in comparison of BC mixes with fly ash at all temperatures. The value of 1735 MPa was observed for BC mix containing fly ash- plastic waste composite at 45°C as compared to 1445 MPa without plastic waste. The average value of resilient modulus at 35°C was increased from 2900MPa to 4400 MPa upon addition of composite material as filler in BC mixes. The values of resilient modulus at 45°C are very high and are responsible for reduced rutting behavior of BC mixes when tested by wheel tracking test at same temperature.
- The combined effect of pozzolanic property of fly ash and elastic property of plastic waste contribute to high value of modulus of resilient at 35°C and 45°C, resulting in overall improved performance of bituminous concrete mixes.

VI. CONCLUSION

On the basis of study and experimental investigations the following conclusions can be drawn-

1. Fly ash can be used as mineral filler in bituminous concrete mix. By coating of fly ash with plastic waste the properties of bituminous concrete mixes can be further enhanced.
2. The tensile strength ratio (TSR) value for BC-Y is 10% higher as compared to BC-X, clearly implies that there was an improvement in the moisture sensitivity of BC mix .
3. The value of modulus of resilient at 35°C and 45°C for BC-Y is 51.72 %and 20.07 % higher than the mix BC-X. The reason behind it may be due to decrease in air voids thus provide a denser and stiffer mix. Therefore use of the fly ash-plastic waste composite was responsible to increase the indirect tensile strength of the bituminous mix. The value of modulus of resilient at 35°C and 45°C was also increased due to incorporation of fly ash-plastic waste composite.
4. It was observed that fly ash-plastic waste composite reduced rutting in bituminous concrete mix during wheel track testing. The creep modulus and creep recovery was also improved due to introduction of fly ash-plastic waste composite in bituminous concrete mixes.

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