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Experimental Performance On Optimum Utilization of Polyethylene Terephthalate (PET) Resin In Flexible Pavement-A Review

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Abstract: *This studyrepresents the Experimental Performance on Optimum Utilization of Polyethylene Terephthalate (PET) Resin In Flexible Pavement. As we know, Good transportation is the important infrastructure for our nation development. Road is the greatest mode of transportation in India. And it is essential to achieve economy in the construction of roads. Along with the economy, quality is also an important factor to be considered. On the other hand the domestic wastage and industrial wastage disposal is a big problem. Especially the plastic which creates many environmental problems cannot be decomposable in nature. It is generally recycled and reused. The present investigation is to utilize the plastic waste in the form of reinforcement in road construction in order to increase its performance. There are many ways to achieve economy and quality in roads. it is used in flexible pavement for stabilization, to reduce the thickness of pavement. It includes ecofriendly road construction, waste management, development of innovative material for construction of flexible pavement.This topic provides the summary of the study on the utilization of polyethylene terephthalate (PET) resin in road construction. Data from researcher show that, PET can improve some properties of modified asphalt mixture having considered the economic and environmental prudent angles, utilization of PET as an additive to asphalt mixture is suitable to use for flexible road pavement.*

Keywords: *Polyethylene Terephthalate (PET), Experimental Performance, Flexible Pavement, Modified Bitumen, etc.*

1. INTRODUCTION

Roads are very important national investment and require maintenance to keep them in a satisfactory condition and ensure safe passage at an appropriate speed and with low road user cost. Road is a way of communication using a stabilized base other than rails or air strips open to public traffic, primarily the road is used for vehicles running on their own wheel loads. The road should be constructed for development and progress of our country. Road also constructed for connecting different capital of states, large industrial & tourist centers, different states & cities with each other for the purpose of transporting peoples, goods, tools, equipment, machinery etc.

A road is well designed, well-constructed and well maintained is essential for agricultural, commercial, industrial and cultural progress i.e. for overall development of country. In the road foundation or pavement, various types of defects are occurs like un-stability, pot holes etc. due to improper proportion of materials, inadequate thickness of pavement & separation or settlement of any layer or any reason then this defect can be overcome by using various Geo-synthetic materials in road pavement to improves such defects this is our actually study as mentioned above. Geo-synthetics can be defined as the manmade or natural fiber, which is used in construction. They are made up of natural fibers or synthetic fibers, which are weaved or bonded with partial melting, needle punching or the addition of chemical agents Generally, the Geo-synthetics are made of Polymer based - Polypropylene, PVC, Polyester, Polyethylene, Polyamide, PET High-Strength Woven Polyester Geo-textiles. Many plastics common to everyday life are found in geo-synthetics. The most common geo-synthetics are polyolefin and polyester, rubber, fiberglass, and natural materials are used. The function of Geo-synthetics is used as a separator, filter, drainage, and reinforcement, protection, as a liquid and gas barrier. It can be also used in construction of road, retaining wall, railway embankment, earthen dam etc.

Polyethylene terephthalate is commonly known as PET or beverages plastic bottle. The PET the most common thermoplastic polymer resin of the polyester family is used in fibers for textile, containers, thermoforming for manufacturing, and in combination with glass fiber for engineering resins. The majority of the world's PET production is for synthetic fibers in excess of 60%, with bottle production accounting for about 30% of global demand. In the context of textile applications, PET is referred to by its common name, polyester, whereas the acronym PET is generally used in relation to packaging. Polyester makes up about 18% of world polymer production and is the fourth most.

Plastics are regularly utilized substances which play an essential part in practically every part of our lives. The increasing of plastic waste throughout the world need appropriate end-of-life management. Most amount of plastics can be found in containers and packaging (i.e. bottles, cup, etc.) and also can be found in disposable good (e.g. medical device) and durables (e.g. furniture, building materials, tires, etc.). Compared to other materials, plastics always be selected because of their properties such as easy processing, low density, good chemical resistance, good mechanical properties, good electrical insulating properties, low cost and good thermal properties. There are two main field directions of plastic application for post-production and post-consumer which are used as material recycling of waste polymer and used as alternative fuel in power plants.

This research showcases an environmental friendly way of utilizing this waste for road construction.

2. MATERIALS

1. Bitumen

2. PET Resin

BITUMEN : Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar. The desirable properties of bitumen depend on the mix type and construction.

Fig 1: *Bitumen*

3. POLYETHYLENE TEREPHTHELATE (PET)

PET is the most used thermoplastic polyester. PET is an acronym for polyethylene terephthalate, which is a long-chain polymer belonging to the generic group of polyesters. Polyethylene terephthalate (PET) is a semi-crystalline, thermoplastic polyester . PET is one of the polyesters which formed by a polymerization reaction between an acid and alcohol . PET is a polymer which easy to handle and also durable and strong, has low gas permeability, thermally stable and chemically . With it good properties, PET was used widely in the form of the automobile part, lighting product, food packaging, electronics, sports tools, x-ray sheets, house ware, textile, power tools and photographic applications . There are 60% of PET productions in term of bottles synthetic fibers.

PET can be used as an additive to the bituminous mixture in road construction which acts as the modifier for asphalt, and this can solve the waste PET recycling problem . This initiative can increase lifespan and improve the engineering properties of modified materials.

Fig 2: *Polyethylene Terephthalate (PET)*

Table 1: *Properties of Bitumen and PET Resin*

Sr.no.	Properties	Bitumen	Pet resin
1.	Density	1.01 to 1.06	1.38
2.	Young modulus	2000 MPa	2800 MPa
3.	Specific gravity	0.97 to 1.02	More than 1.1
4.	Melting point	120°C	More than 250°C
5.	Boiling point	More than 538°C	More than 350°C
6.	Solubility	None in water	None in water

Sources of PET Wastes

Waste PET source can be subdivided into three which are foils, bottle, and cord from tires. Foils have two small problems with material recycling which is related to utilization of additive in production and molecular weight of PET. The bottle also has the same problem with foils, and it also has another one problem which is impurities problem. The cord from tires has big material recycling problem which is pollution of ground tire rubber and metals. Most of this waste is used as alternative fuel.

4. LITERATURE REVIEW

A. F. Ahmad, A. R. Razali, I. S. M. Razelan (2004**)**-The quantity of plastics used throughout the world is increasing every year. Municipal solid wastes (MSW), manufacturing processes and service industries produce a lot of waste plastic materials. The increasing awareness among consumers about the environment has contributed to the concerns over disposal of generated wastes. The growing number of plastic materials every year and limited landfill conditions causes many alternatives exist for the disposal of plastic waste. This paper provides a summary of the study on the utilization of polyethylene terephthalate (PET) in road construction. Data from researcher show that PET can improve some properties of modified asphalt mixture. Having considered the economic and environmental prudent angles, utilization of PET as an additive to asphalt mixture is suitable to be used for road pavement.

Dhirar Taha Mohammed, Zaid Hazim Hussein (2014)-This research investigates the ability of improving the performance of asphalt mixtures using PET obtained from plastic waste in Mosul landfills. Five different percentages of PET by weight of asphalt binder were added using wet process. Marshall test, moisture susceptibility and durability test known as Cantabro Loss were conducted on unmodified and modified asphalt mixtures. The experimental results showed that the optimum polymer content of PET was 4%. The addition of this percentage of polymer caused an increase of the Marshall stability by 36.09 % for PET modified mixtures, while the flow values reduced slightly. Also the addition of this percentage of polymer led to an improvement in the durability and resistance of asphalt mixture to moisture damage.

Swaptik Chowdhury, Aastha Tashkant Maniar, and Om. Suganya-This paper presents the work on synthetic fiber Polyethene terephthalate (PET) as alternative construction entity. As plastic is non biodegradable, its disposal has been a problem. Recently, PET fibers were proposed to be used as either reinforcement in concretes or being casted as blocks. And recent studies show that they can be accepted as successful building materials. PET fiber reinforced concrete offer less compression strength and flexural rigidity than conventional concrete but it offers high ductility thereby increasing deforming capability of the concrete. Also, it reduces the density of the reinforced concrete thus aiding in light weight materials production. This paper also presents the study on some other innovative ideas like PET panels and mattress or direct use of PET bottles for construction of nonloadbearing walls with suitable fillers.

Adebayo Olatunbosun Sojobi, Stephen Emeka Nwobodo and Oluwasegun James Aladegboye(2015)-This research sheds light on the concept of eco-friendly road construction which comprises eco-design, eco-extraction, eco-manufacturing, eco-construction, eco-rehabilitation, eco-maintenance, eco-demolition, and socioeconomic empowerment. It also revealed the challenges being faced in its adoption and the benefits derivable from its application. Furthermore, the effects of recycling PET plastic bottle wastes produced in North Central Nigeria in bituminous asphaltic concrete (BAC) used in flexible pavement construction were also evaluated. The mix design consists of 60/70 penetration-grade asphaltic concrete (5%), 68% coarse aggregate, 6% fine aggregate, and 21% filler using the dry process at 170°C. The optimum bitumen content (OBC) for conventional BAC was obtained as 4% by weight of total aggregates and filler. Polymer-coated aggregate (PCA)-modified BAC seems preferable because it has the potential to utilize more plastic wastes with a higher optimum plastic content (OPC) of 16.7% by weight of total aggregates and filler.

Hakeem Jan1, Mohamad Yusri Aman, Sheraz Khan, and Fazal Karim (2016)**-** This study focuses on evaluating

the resistance of polymer modified asphalt mixes and the role played by asphalt in the realm of construction is undeniably important. Addition of polymers(PB) as additives to asphalt helps to improve the strength and water repellentproperty of the mix and as well as helps environment in various ways and at the same time, analyzing its lower maintenance activities and service life is most important. The use of inexpensive polymers, in this case, waste polymers has without any doubt proven to be the most convenient way of reducing the cost of construction and at the same time maintaining quality. The results indicate that the inclusion of Polyethylene Terephthalate (PET) had a particularly substantial effect on the properties of asphalt.

M. Sulyman, J. Haponiuk, and K. Formela (2017)- In general, the quantity of plastics of all types consumed annually all over the world has been growing in a phenomenal way. The manufacturing processes, service industries and municipal solid wastes (MSW) generate numerous waste plastic materials. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of the generated wastes. This paper provides a summary of experimental efforts on the utilization of poly (ethylene terephthalate) (PET) in civil engineering projects, mainly in road pavement, cements and concretes. Presented data indicate that use of waste PET for modification of asphalt, cement and concretes improved their selected properties, which makes economical this approach. Furthermore, using of waste PET in building materials reduce usage of new polymeric materials, which has significant effect on environment pollution (e.g. emission of carbon dioxide, waste disposal problems, etc.)

5. MODIFIED BITUMEN

Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction.

The advantages of using modified bitumen are as follows;

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking.

6. EXPERIMENTAL TESTS ON MODIFIED BITUMEN

1. Penetration test
2. Ductility test
3.Flash and Fire point test
4. Softening point test
5. Specific gravity test
6. Viscosity test

7. PENETRATION TEST

Penetration of a bituminous material is the distance in tenths of millimeter thatstandard needle will penetrate vertically into a sample under standard conditionsoftemperature, load and time.

Table 2: *Penetration Test Performance*

Sr.no	Reading	Sample(4%)			Sample(8%)			Sample(12%)		
		1	2	3	1	2	3	1	2	3
1.	Dial initial Reading.	0	0	0	0	0	0	0	0	0
2.	Final Reading.	30.2	29.9	30	29.6	29.7	30.1	29.5	29.7	29.4
3.	Penetration value.	30.03 mm			29.8 mm			29.53 mm		

The permissible limit for penetration test is 35mm.
Result: The Penetration test value is given by modified bitumen sample is 29.53 mm.

8. DUCTILITY TEST:

The ductility of bituminous material is the distance in centimeters to which it will elongate before breaking when a briquette specimen of the materials is pulled at a specified speed and at specified temperature.

Table 3: *Ductility Test Performance*

DUCTILITY VALUE	Briquette number (4%)		Briquette number (8%)		Briquette number (12%)	
	1	2	1	2	1	2
	47.3	48.1	46.7	45.2	43.1	43.6
	47.5cm		45.95cm		43.35cm	

As we increase the percentage of PET content in the bitumen the ductility value goes on decreasing. The standard minimum value for the ductility test is 40cm.

9. FLASH AND FIRE POINT TEST (IS: 1209 – 1978)

Flash Point– The flash point of a material is the lowest temperature at which the application of test flame causes the vapours from the material to momentarily catch fire in the form of a flash under specified conditions of the test.

Fire Point – The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test.

Table 4: *Flash and Fire point Test Performance*

Modified bitumen(%)	Fire point (*C)	Flash point (*C)
4%	167*C	172*C
8%	175*C	187*C
12%	190*C	210*C

The permissible limit of fire point = 175*C

The permissible limit of flash point (Degree Celsius)= 185+5/185-5

RESULT:

- The maximum fire point for modified bitumen =190 Degree Celsius
- The maximum flash point for modified bitumen = 210Degree Celsius

10. CONCLUSION

The performance of polyethylene Terephthalate(PET) on the basis of experiment result higher resistance to permanent deformation and higher resistance to rutting. It appears that polyethylene Terephthalate (PET) decreases the consistency and increases the resistance of the material to temperature changes while the resistance to flow also increases. It may be inferred that PET-modified bituminous binders provide better resistance against permanent deformations due to their higher complex shear modulus and lower phase angle as compared to conventional binder. It also contributes to recirculation of plastic wastes as well as to the protection of the environment.

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