

Performance Study on Partial Replacement of Bitumen using Waste Polypropylene Cement Bags for Pavement Construction

R. Malathi^{1,a*}, R. Geethamani^{2,b}

¹Department of Civil Engineering, Sri Ramakrishna, Institute of Technology, Coimbatore, Tamilnadu, India

²Department of Civil Engineering, Bannari Amman Institute of Technology, Alathukombai, Sathyamangalam, Tamilnadu, India

^amalub18@gmail.com, ^bgeethamanir@bitsathy.ac.in

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Abstract. Flexible pavement is most commonly used in the bituminous material mix. It consists of different binders such as asphalt or bitumen and other minerals are added and compacted and used together in the lower layer of the pavement. Bituminous pavement surface property changes due to varying weather conditions. In hot climatic conditions, the bitumen becomes soft and during cold conditions it becomes too stiff and brittle in nature. In this study, the main concept is to reuse the waste materials and to promote cost-effective solution and reduce environmental pollution. In this project, waste cement bags (polypropylene) are used to replace a portion of bitumen which is used in road construction. Effect of addition of additive materials on the strength of the pavement was evaluated. Previous studies state that polypropylene emits 60ppm less pollution than bitumen while burning. The used cement waste bag when mixed with bitumen improves the behaviour and mechanical properties as per standard specification. In this experimental work, cement bags are shredded into smaller fragments and heated to 90°C for 30 minutes in a heating mantle till the plastic pieces turned into powder form. On heating, 5 gm of powder was obtained from 20 gm of the used cement bags. This powder was added subsequently to bitumen in 5%, 7%, 9% & 11% for partial replacement of bitumen. Finally, it is inferred that the optimum percentage was 8.2% without the addition of binders or oxidizing agents, for better efficiency.

Introduction

Our country has initiated improved road development depending on the connectivity of various places with an adequate road network. Roadways are more flexible for travel with the choice of time-saving. The movement passengers are easy to select the major channel of transportation. They play a significant role in improving the socio-economic and living conditions of the peoples as well as goods. Roads are planned and designed to provide a good road network connecting all interconnecting road lines. Additional significance that was achieved through road development is increase in employability to a highly potential level. The government sector invested funds to upgrade the existing road by adopting excellent maintenance. Out of the total length of highways available 98% are of flexible type. A lot of researches experimented utilizing waste materials in road construction, but not experimented in the field. Hence the lab scale study has to be transformed to field model, to promote sustainable development.

Plastic is one of the non-biodegradable materials. Plastics now form part of our day today life. The population is changing and drastically increasing every year and also development activities

are improved day by day to meet the current standards. As a result, the production of various plastic waste materials has seen a tremendous increase every day throughout the year all over the world. Increasing the usage of non-biodegradable materials which are not easy to handle and rate of decomposition is too long [8]. Lot of problems are created due to improper disposal of wastes. Though this waste plastic material is useful, improper disposal can create lot of problems. There is no proper method for the disposal of plastics; therefore proper recycling methods should be adopted and encouraged to reduce the plastic waste disposal. Proper steps are to be initiated to apply in the research area with respect to the addition of such waste materials to mix with bitumen to improve their quality, increasing life and reducing the cost of road construction work [9]. The use of polymeric waste in bitumen to improve the properties of binders proves to be very promising. Polypropylene is an excellent material for partial replacement of bitumen. Polypropylene waste originally prepared from Low-Density Polypropylene (LDPP) has been identified to be studied in modified bitumen [10]. When polypropylene is mixed with hot bitumen, it forms an oily surface on the aggregates and the mixture is laid on the road surface just like a normal tar road.

The main objectives of this study area. To analyze the important properties of polypropylene, bitumen and aggregates, b. To prepare liquid and powdered polypropylene materials and compare their characteristics. c. To conduct laboratory tests on molten and powdered polypropylene and compare their properties with bitumen. d. To evaluate the optimum polypropylene percentage, to reduce the quantity of bitumen and thereby reduce the cost of road construction. e. To collect, clean, shred, reprocess by melting and blending with bitumen and test it for efficiency.

Review of Literature

Waste Plastic

Waste Plastic is used in partial replacement of bitumen in the form of aggregate or binder. The stability of pavement construction was developed using the addition of waste plastic materials. It enhanced the strength and life of the structures. Similarly, if a bitumen concrete blend is mixed with a waste of polypropylene materials it gives a better result when compared to plain bitumen. At the same time, the waste reduction also to be accounted for reduction in pollution. Utilization of waste plastic used in the road construction provides better resistance of water and in turn reduces the failure of bitumen segregation from pavement structures [8]. Newly the road network patterns were introduced in many places for the integrated development of Rural and Arterial road network for socio-economic growth. In the current scenario, reuse or recycling of waste materials is growing among the public. Utilization of polythene or polypropylene bags for replacement in bitumen blended work is promoted, since good results are obtained with replacement. Marshall Stability tests were found to be the formation of deformation variations to study the failure occurring in the road pavement due to poor material mixing and binder occurs. This in turn decreases the possibilities of potholes formation in the pavement structure. The result shows that the use of a higher percentage of plastic waste to reduce the quantity level of bitumen is 10% [9]. Studies were made to analyse the strength performance by using replacement materials with different mixing percentage. Plastic replaced by tar road showed good performance for heavy traffic and showed better binding results in various climatic conditions [10]. Asphalt type roads were also used in the waste plastic materials by both wet and dry methods. Bitumen replacement percentage varied between 5-10% by weight of bitumen. In addition waste plastic in the modified bitumen methods, improved the endurance limit of pavement performance with marginal saving in bitumen usage [11]. Different types of plastic materials also were studied in research work namely High-density polyethylene (HDPE), Low-Density Polypropylene (LDPP) and

Polypropylene (PP). The above specified materials were added in a conventional type of AC-20 graded bitumen and other grades. Generally, the temperature variation ranged between 160°C–170°C. Because of that when temperature increased after setting the road pavement is hardened or shrank and blended with the bitumen 'in-situ', with a shear mixer [12].

Road Construction Materials:

The research methodology studied has to adopt various tests to investigate results on mixing of aggregate, bitumen and plastic. The test result was done in water absorption, aggregate impact, loss Angeles and aggregate crushing test [IS: 2386 (part 4)-1963] for aggregates and softening point, penetration test and ductility test [IS: 1203-1978] for bitumen. Alternative ways of using waste plastic materials are mixing with the aggregates and a small proportionate ratio blended with polymer in the bitumen. Prepared mixing materials are later tested in the laboratory and the results are obtained. To determine the physical properties and flow characteristics of bitumen, tests such as penetration ring, ball softening point and viscosity tests were performed. When compared to bitumen mix with HDPE PMBs up to 3% concentration of polymer in bitumen softening temperature point has been increased gradually. Likewise, the viscosity test showed that the results were increment in concentration of polymer with increase in the viscosity variation [13]. Proposed durability of the roads laid with shredded plastic waste is much more compared asphalted with the conventional mix proportion. While considering a National highway road in the past 4 to 5 years it's claimed that plastic-bitumen roads were used in replacement of conventional roads in the last 10 years. It shows that waste plastics such as high-density polyethylene are made in the form of powder; 3 to 4 % is used to increase the durability of the road. In addition hot bitumen was mixed with varying proportions of 0 to 12%. It was inferred that the values of penetration and ductility have decreased with an increase in the proportion of plastic additives upto 12 % by weight. The softening point was increased in the proportion of plastic additives upto 8 % by weight [14].

Range of Material Testing Values:

Asphalt pavement construction, laminated in hot bitumen is coated over stone aggregates and is laid and rolled in the pavement layer. Mixing of bituminous and recycled plastic waste is mainly done with the low-density polyethylene for the replacement of 30%. Aggregates are chosen based on a standard specification of 2.36 - 5mm aggregates and showed 250% increase in the strength of Marshall Stability. At the same time mix density was reduced to 16% [15]. Waste plastic is heated, grounded and made into powder form and mixed with 4 % plastics in bitumen [16]. The cost of the material was reduced by 7.99% with the addition of plastic to bitumen between the ranges of 5% to 10% [17]. Two percent of polymer composition added with AC-10 bitumen and it's produced AC-20 bitumen. Properties studies that helped to improve the marshal stability, design stability and other desirable properties were observed [18]. Alternative methods of waste disposal packing materials were collected from domestics and industrial. This technology has been used by many researchers because they reviewed variety of research studiosto choose the most effective and efficient technology. Collection and utilisation of waste materials created a pathway to eco-friendly environment. The usage of polymer depends on the equivalent amount of bitumen quantity to reduce the road construction cost [19]. In India, Network systems are adopted more efficiently implanted in a large level of the movement mostly inroads. Apart from the passenger, the freight moves on the roads network. Studied based 65% of freight and 85% of passenger traffic used as roads for their movement. Strength parameter increased in plastic waste when compared to conventional and replacement of bituminous mixes in plastic studies. Good results were produced in the replacement of plastic in the bituminous mixes [20]. According to reviewed result the

marshal stability test obtained optimum use of plastic up to 10% by maintaining a softening temperature of around 130 - 180°C and because of good binding properties, it is used as a good binder for road construction work[21]. Suggestions were made to use the bitumen with optimum replacement waste bag materials.

Methods and Materials

The recycling process involves five steps namely collection, cleaning, shredding, reprocessing by melting and blending with bitumen.

The first step includes collection of waste polypropylene cement bags from construction site. The waste cement bags are then cleansed and immersed in detergent dissolved water to remove dirt and suspended impurities. Then these bags were dried to remove moisture from them. These bags were cut down into small pieces. The shredded pieces were taken in appropriate amount and melted till liquid form is attained with the help of heating mantle. The molten liquid was added to bitumen in desired percentage to determine the optimum polypropylene content by conduct various test such as Penetration test, Ductility test, Marshall Stability test & Centrifugal Extraction test. On heating polypropylene bags in the heating mantle, it is converted into a molten state. But if heated further, it gets converted into powdered form. Liquid forms of polypropylene bags were used in many researches to identify the possibility of partial replacement using additive materials of oxidant agent and others. Powdered form of polypropylene bags without using additive agents is concentrated more in this study.

Bitumen

Bitumen is collected from petroleum products and is a more consistent viscous material. Different grades of bitumen were used for road work. Before using bitumen, the grade has to be analysed and the best has to be used for road construction. Bitumen is the heaviest fraction obtained from the fractional distillation of crude oil. The primary use of bitumen is for road construction. Bitumen is highly adhesive, which keeps the aggregate in the road mix bound together greater than 50mm wide and several deep conditions are considered. Pavement cracks are formed due to changes in weathering seasons, thus forming improper bitumen mixing and uneven soil surface nature. Finally, the results occurred in irregular swelling and heaving. Soil stability is one of the criteria to decide to mix bituminous materials. The instability of soils may develop more damage in the pavement structure.

Polypropylene

Polypropylene, a thermoplastic, is formed by the polymerization of propylene using an appropriate catalyst. It belongs to a group of polyolefins and is partially crystalline and non-polar. It can resist the actions of organic solvents, salts, acids and alkalis. Due to its mineral composition, it is highly resistant to water.

Materials Testing

Waste Polypropylene

The first step includes the collection of waste polypropylene cement bags from the construction site. The waste cement bags are then cleansed by immersing them in detergent dissolved water to remove dirt and suspended impurities. Then these bags were dried to remove moisture from them. These bags were cut down into small pieces. The shredded pieces were taken in an appropriate amount and melted till liquid form is attained with the help of a heating mantle. The molten liquid was added to bitumen in the desired percentage to determine the optimum polypropylene content

by conducting various tests such as Penetration test, Ductility test, Marshall Stability test & Centrifugal Extraction test.

Ductility Test is used to determine the extent to which a material can withstand plastic deformation without rupture. It gives a measure of the adhesive property of bitumen and its ability to stretch. The bitumen is added with waste polypropylene in successive ratios to obtain the optimum value. Penetration Test, in this test, a standard penetration needle is allowed to penetrate a standard bitumen sample for 5 seconds and the value is expressed as 1/10 of mm. It determines the hardness or softness of bitumen by measuring the depth in mm.

Marshall Stability Test

Marshall Stability is an important testing for pavement construction to evaluate the performance prediction measure conducted on the bituminous mix. It measures the maximum load sustained by the bituminous material at a standard loading rate 50.8mm/minute. It is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The procedure consists of the determination of properties of mix, flow analysis and optimum bitumen content. The experiment was carried out using Marshall Stability Apparatus [1].

Los Angeles Abrasion Test

Los Angeles Abrasion test on aggregate is used to measure toughness and abrasion resistance and also studied the degradation of aggregate value which is subjected to analyzed graded percentage. Increasing the wheel load or rubbing actions that are affecting pavement structure. This experiment results to evaluate the suitability of stone aggregate in pavement work which relates to the quality of aggregates. This test is carried out by AASHTO T 96 or ASTM C 131: A steel ball is used to measure the strengthening of aggregate crushing values. Quality of aggregate acceptable limits for the bituminous road should not be less than 30 percent [4][5].

Aggregate Impact Test

The aggregate impact test is used to measure resistance to the impact of fracture under the heavy wheel load action. Aggregates percentage losses determined passing through 2.36mm sieve and 15 blows of standard hammer drop. The test performance can be determined within a short duration. It is easy to work and handle equipment and transfer to the construction field. Find properties of aggregates that could be considered the resistance to crushing of aggregates. The percentage of crushing is increased due to varying the load. Toughness values of aggregate are measured to find indirect information of the compressive strength [5][6][7].

Addition of Polypropylene to Bitumen and other Aggregates

Polypropylene in liquid form

After collecting the samples during heating process on every sample 20gms of polypropylene is collected 10ml in molten state materials in a single process. To increase the binding property between polypropylene and bitumen, a strong oxidizing agent and binder agent is needed. The trial proved effective but on re-heating for further addition of liquid polypropylene, the plastic began to segregate from bitumen. This led to the use of fresh bitumen and resulted in the wastage of bitumen. Heating time should not be less than 20 minutes.

Polypropylene in powdered form without using an oxidizing and binding agent

On heating polypropylene bags in the heating mantle, it is converted into a molten state. But if it is heated further, it gets converted into powdered form. Thus powdered waste binds well with bitumen and can be re-used for successive addition for conducting a test to find out the optimum bitumen content. But this resulted in a decrease in quantity. On heating 20gms of polypropylene

wastes, get collects 5gms of powder polypropylene. The heating time of the polypropylene wastes is not exceeding 35 minutes.

Experiment was carried in two trials, since it was easier, more economical and it does not require the use of strong oxidizing agents and binder agents for proper blending. The bitumen was added with 5%, 7%, 9% & 11% of polypropylene powder to determine the optimum polypropylene ratio. Powdered form of Waste polypropylene bag materials is shown in Fig.1.



Figure 1. Powdered form Waste Cement bag

Result and Discussion

Material Properties

Properties of Polypropylene

Polypropylene is a tough, rigid and crystalline thermoplastic produced from propene or propylene monomer. It is a linear hydrocarbon resin and also it has the lowest density among plastic [15]. List of physical and chemical properties of polypropylene are listed in Table 1.

Table 1. Physical Properties of Polypropylene

S.No	Parameters	Values
1.	Tenacity	3.5 – 8 gm/denier
2.	Density	0.91 gm/cubic centimetre
3.	Elasticity	Very good
4.	Moisture regain	0
5.	Melting Point	170°C
6.	Resistance to heat	Moderate
7.	Elongation at break	10 – 45 %

The density of Polypropylene ranges between 0.895 – 0.92 g/cm³. Young's modulus lies between 1300 – 1800 N/mm². It has a melting point of 170°C and becomes brittle below 0°C. The glass structure of the quenched glass largely depends on the proportions of silica and aluminium along with calcium and magnesium. ASTM standard values of specific gravity of bitumen ranges were taken from codal provision. The same physical parameters of specific gravity of 0.905 and bulk density 520 - 620 kg/m³ were observed by the mixing of polypropylene bags. The chemical properties were analyzed in the experiment and the results were observed. The waste polypropylene materials do not affect the road pavement in the future, since; it has more corrosion resistance and high acid resistance. No bleaching of the pavement due to the presence of materials

within the range of temperature 65°C. Increase in temperature may lead to bleaching of road pavement. The above readings were observed within the range specified by researchers [5].

Table 2. Chemical Properties of Polypropylene

S.No	Parameters	Values
1.	Acid	Highly resistant
2.	Base	No effect
3.	Effect of Bleaching	No effect under 65°C
4.	Organic Solvent	No effect
5.	Protection against light	Looses energy
6.	Protection against Mildew	Good

When compared to bitumen the waste polypropylene cement bags can be used for the road construction in the pavement top layers. This work was initiated to improve the wastage reduction of polypropylene materials as well as to promote the cost-effective methods for the road construction work. The physical and chemical properties were satisfied and were found to be similar to conventional bituminous materials.

Properties and Function of Coarse Aggregate

In the road pavement structure, the main function of construction work is coarse aggregate. It has to withstand the stresses due to the wheel loads. The different layers of the pavement are formed using different sizes of coarse aggregate. The different pavement layer is to distribute wheel load magnitude as the bottom-most layer. So that, the wearing surface of the pavement may use any type of materials and mixes with the stone aggregate. Hence it is an important aspect to study the strength of coarse aggregate also. Coarse aggregate testing values are shown in the below table no. 4.2.

Table 3. Properties of Coarse Aggregate Values

S.No	Test	Values
1.	Impact Value Test	17.28 %
2.	Crushing Value	28.33 %
3.	Abrasion Test	14.4 %

Table 3 shows the strength parameters studies of coarse aggregate materials. All the testing values are within the limits. In general, for the convention road pavement construction the impact Value test, Crushing and abrasion tests are less than 30%, 30% and 40% respectively. The standard values of coarse aggregates testing values are obtained in the work. Hence, this result was correlated to the present study. Herewith, further studies of the pavement construction are partial replacement of Waste Polypropylene cement bag in the conventional pavement materials.

Properties and Function of Marshall Stability:

Marshall Stability is determined to study the maximum load-carrying capacity of road pavement with standard temperature as 60 degrees centigrade when applied the load for given specified material test condition [1]. Marshall Stability is the resistance of deformation of pavement structures for applied load values. Generally, the load is applied at the constant rate of deformation

51mm per minute to varying from time to time. The test was done to determine the density and compactness of road pavement structures.

Properties and Function of Centrifugal Extractor:

Centrifugal Extractor is used to find the bitumen percentage in bituminous paving mixtures. The same working principles were used in the alternate materials of waste Polypropylene cement bag materials. This experiment working procedure was used to suggest the aggregate weight in the pavement construction [2][3]. The Centrifugal Extractor is used to mix two substances as Waste cements bag material and bitumen. The mix generates a continuous extraction from one liquid phase point into another liquid phase solvent. The property studies results were taken with different proportionate replacement of cement bag materials such as 5% to 11%. The optimum ratio from the graph was inferred as 9%, which indicates that the bitumen bounded more strongly with the aggregates which resulted in a heavier weight.

Properties and Function of Ductility Values:

The ductility of bitumen materials is used to find out adhesive properties. Poorly graded bitumen used in the road works forms deformation or longitudinal cracking under traffic load conditions. The ability of stretch of bitumen and sticking properties were carried out. It is expressed in the distance in centimetre to which it elongates before breaking the specimens. The pull rate of bitumen is 50mm per minute at the maintained temperature of 27 degrees centigrade. The pavement road surface melts during the summer season due to increasing temperature. Variation in temperature affected the road life and as well as the public life. In this experiment, the result was observed the maximum ductility point was 77cm for the replacement value of 5%. The permissible point of the ductility test was found to be less than 75cm.

Properties and Function of Penetration Values

The penetration test is determining the grade of bitumen in different viscosity. The penetration test of bitumen is carried out on the relationship between temperature and stiffness. Characterization of waste cement bag materials has to be carried out to perform the penetration test values. Penetrating Grade Bitumen was found that the standard bitumen with mixing replacement of waste bag for road construction. The optimum range of replacement used is 5%, which shows that the bitumen mix is most permeable at this percentage. For the road construction, the penetration values were taken as in the ranges of 60-70cm.

Partial Replacement of Waste Polypropylene:

Marshall Stability when observed that the optimum ratio is 8.2%, which gives the load failure at 25kN. If any ratio above 7% is selected, the load was found to be less than 22kN. The waste polypropylene materials used in Pavement construction with a load limit is less than 25K. The minimum load condition should affect the pavement structure due to incremental load conditions. Since the optimum values differ for each type, to find a common ratio suitable to meet the demands of the tests.

Table 4. Percentage of Partial replacement of Polypropylene

S.No	% of Polypropylene	Load @ failure(kN)
Marshall Stability		
1	8	25
2	8.2	25.2
3	8.4	24.3
S.No	% of Polypropylene	Weight of the aggregate
Centrifugal Extractor		
1	8	843.5
2	8.2	845.2
3	8.4	844.1
Ductility Test		
S.No	% of Polypropylene	Ductility (cm)
1	8	77
2	8.2	76.7
3	8.4	75.5
Penetration Values		
S.No	% of Polypropylene	Penetration Value(cm)
1	8	67
2	8.2	66.45
3	8.4	65.9

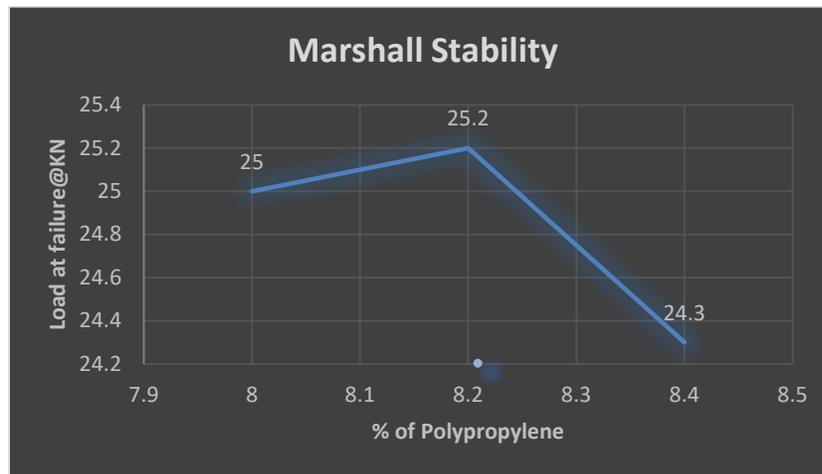


Fig. 1. Optimum Values of Marshall Stability.

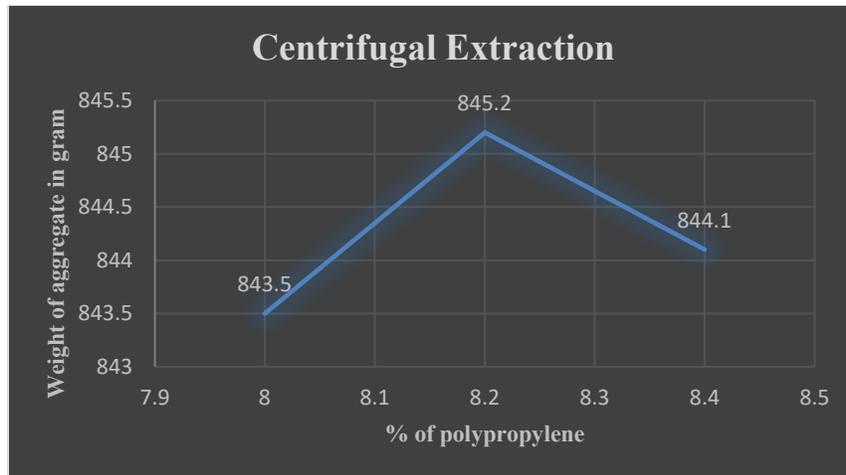


Fig.2.Optimum Values of Centrifugal Extractor.

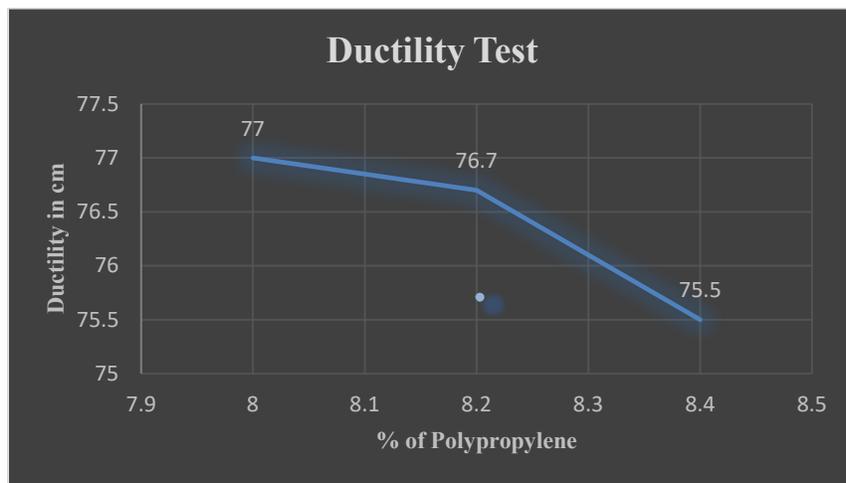


Fig.3.Optimum Values of Ductility Test

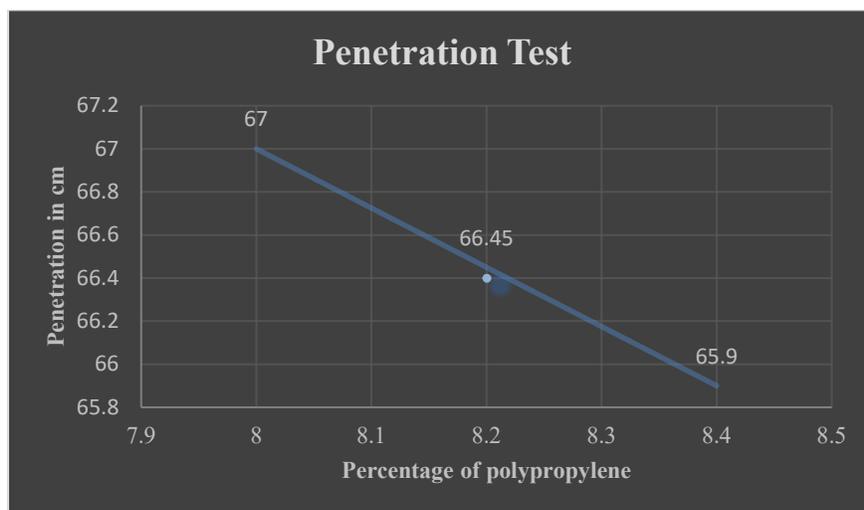


Fig.4.Optimum Values of Penetration Values

The ductility value if greater than 75cm for road construction it may harden more compared to the nature work. Penetration test values must lie between the ranges 60-70cm. The centrifugal extractor gives an optimum ratio of 9%. To satisfy all of the above criteria, the optimum temperature lies around the replacement of 8%. The result was carried out testing the values at 8 %, 8.2 % and 8.4%. The common optimum ratio was found after interpreting the data from the figures 1, 2, 3 and 4.

The peak values for both Marshall Stability and Centrifugal Extraction (most relevant) @ 8.2%, within limit values for Penetration and ductility. It was inferred that the optimum value of polypropylene that can be added for road construction is 8.2%.

Conclusion

In this study, the properties of conventional bituminous mixes were analyzed. Based on that the evaluation strength of the flexible pavement was to be carried out. The waste plastic cement bag has been used in the powder. The end product of cement bags was shredded into smaller fragments and heated to 90°C for 30 minutes using a heating mantle. After heating the samples for every 20gm of plastic waste samples, 5gm of powder was obtained. The various mixes of partial replacements of waste plastic cement bag materials were analyzed for 5%, 7%, 9% and 11% in the bitumen. Based on the tests conducted for the different proportions, the optimum ratio of polypropylene was found to vary from 8% to 9% without adding any oxidant agent. Finally, in the modified bitumen, the optimum replacement of bitumen was found to be 8.2% without the addition of binders or oxidizing agent. Results showed that Marshall Stability, centrifugal extractor, Ductility and penetration test of bitumen by using 8.2% partial replacements of waste plastic cement bag materials used in road construction was found to be most effective and efficient. This method was aimed to reduce the materials cost as well reduce pollution to the environment. The reuse and recycling of waste materials will promote sustainable development in the future.

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