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Experimental Investigation on Bituminous Pavement Using Construction Demolition Waste and Plastic Waste

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Abstract

Objectives: To develop an optimum bituminous mix by studying the properties of construction demolition waste aggregate (CDWA) and plastic waste as a partial replacement of natural coarse aggregate and bitumen. The performance and strength of the conventional bituminous mix and modified bituminous mix were studied using marshall stability test. **Methods:** Construction demolition waste aggregate (CDWA) is produced by crushing and screening old concrete from construction demolition waste, which is then used as a replacement for natural aggregates in pavement construction. This method helps reduce the need for new aggregate materials and conserves natural resources. The plastic waste is melted and blended with asphalt to create a more durable and weather-resistant material. This method reduces the amount of plastic waste in landfills and provides a sustainable solution for pavement construction. **Findings:** Based on the research, the optimum mix proportion of bituminous mix is found as 10% plastic waste blended with 15% construction demolition waste aggregate. The results of marshall stability test have shown significant increase in strength of pavement mixes by adding construction demolition waste and plastic waste. **Novelty:** The novelty of this study lies in its approach to addressing two major environmental issues simultaneously: waste management and sustainable construction practices. The study proposes a solution to reduce the amount of natural resources such as natural coarse aggregate and bitumen by blending alternate recyclable waste materials such as construction demolition waste aggregate and plastic waste shredded from waste bottles.

Keywords: Bitumen; Plastic waste; Natural coarse aggregate (NCA); Construction Demolition waste aggregate (CDWA); Marshall stability

1 Introduction

As the world becomes more environmentally conscious, there is a growing need for sustainable solutions in the construction industry. One approach to addressing this issue is the use of waste materials in pavement construction. Construction demolition waste aggregate (CDWA) and plastic waste are two significant sources of waste materials that can be utilized in pavement construction. Recent studies have shown that the use of construction demolition waste aggregate (CDWA) and waste plastic in bitumen can enhance the mechanical properties of pavements, leading to improved durability and performance. However, there is still a lack of research on the optimal mix designs and construction practices that can ensure the long-term performance of pavements by using these waste resource materials[1,2].

Therefore, this study aims to fill this research gap by developing optimized mix designs and construction practices that can maximize the benefits of using CDWA and plastic waste in pavement construction while ensuring the performance of the pavement. The study's findings will provide valuable insights into the potential benefits of using waste materials in pavement construction, while also addressing the environmental issues associated with waste management in the construction industry.[3,4].

Fig 1. Shredded Plastic waste

2 Literature Study & Methodology

2.1 Literature Study

F.A.N. Silva, M.T.A. Silva, J.M.P.Q. Delgado, A.C. Azevedo, G.F.C. Pereira, investigated use of Construction and demolition waste as raw material in pavements layers. The characteristics of waste materials were evaluated and the various test methods to assess the performance of the materials is discussed[1].

Arpan Ray, Radhikesh Prasad Nanda and Pronab Roy, focused on use of Construction demolition waste in road construction and the results shown the recycled aggregate shown better performance then natural aggregates[2].

Deb, P., Singh, K.L., studied the mechanical performance of cold mix asphalt using Construction demolition waste as filler by adding 1 to 3 % cement. The results reflected significant improvement in moisture susceptibility and stiffness of the bituminous mix[3].

Arjita Biswasand Sandeep Potnis, revealed the performance of plastic bituminous roads and it is found as it is performed better in early deterioration as compared to normal bituminous roads[4].

Johnson Kwabena Appiah, Victor Nana Berko-Boateng, Trinity Ama Tagbor, investigated use of waste plastic materials such as High-density polyethylene and polypropylene polymer in bituminous mix and it showed profound effect on homogeneity and compatibility for road construction compared to conventional bitumen mix[5].

2.2 Process

2.2.1. Dry process

The initial step of this process entails heating small aggregates to a temperature of 170°C in the hot mix plant. Once the aggregates are heated, an equal amount of shredded plastic waste is added to the mixture. Afterward, the bitumen is heated to a temperature of 160°C, and the previously prepared mixture of plastic-coated aggregate is added to the heated bitumen. The resulting mixture is then mixed thoroughly prior to being laid. Finally, the road is laid once the mixture is ready[4,5].

2.2.2 Wet process

In this particular process, plastic waste is mixed directly with hot bitumen at a temperature of 160°C. The resulting mixture is then stirred mechanically and includes external stabilizers. Proper cooling is also necessary for this process. However, it is not a widely used method due to the significant investment required for larger plants, as well as the need for additional funds[4,5].

2.3 Materials

2.3.1 Bitumen

The bitumen of grade 80/100 obtained from local road contractor was used for the study.

2.3.2 Plastic

For the present study plastic waste such as carry bags, water bottles, milk packets, glasses, cups, etc will be used as a modifier. The plastic wastes are collected and it is shredded in small piece and then it is added with bitumen and aggregate at a temperature of 160 to 170 °C.

2.3.3 Aggregate

Natural Coarse aggregate (NCA) of size 10 mm, 12 mm, 16 mm, 20 mm and 25 mm and construction demolition waste aggregate of size similar to natural coarse aggregated were used for investigation.

3 Results and Discussion

3.1 Test Results on Aggregate

The properties of natural coarse aggregate and Construction demolition waste aggregate were tested based on IS codal provisions of IS 2386 (Part IV):1963, and it was observed that test results of both the aggregates were satisfied the codal recommendations.

The results show that the specific gravity of NCA and CDWA is 2.7 & 2.5, which is within the permissible range of 2.5 to 3.0 as per BIS. The Los Angeles abrasion test result for NCA is 21.89% and CDWA is 27.86%, which is also within the permissible limit of less than 30% for wearing course. The water absorption value for NCA is 0.5%, which falls within the range of 0.1% to 2.0% as per IS 2386 (Part 3):1963. Similarly, the results for aggregate crushing and impact value for NCA and CDWA are also within the permissible limits for wearing course[1,2,6].

3.1.1 Moisture absorption test

This test is performed to decide the degree to which the aggregates retain moisture. Higher the amount of water absorption in aggregate leads to poor binding of asphalt with aggregate and it creates water logging. Aggregates with higher water absorption and high porous in nature are generally unsuitable pavement construction unless they are found to be acceptable based on strength, impact and hardness tests.

3.1.2 Los Angeles abrasion value test

This test is performed to measure the aggregate is sufficiently hard to withstand abrasion. This is done by blending the aggregate sample along with steel balls inside a pivoting drum. The drum is allowed to rotate at a rate of 30 rpm – 33 rpm until 500 upsets had been finished. The blended resultant mass was allowed to pass on 1.70 mm sieve and the passing fraction ought to be under 30 % of total mass.

3.1.3 Aggregate impact value test

This test is done to measure the resistance of aggregate to sudden impact or shock. The aggregate sample is allowed to subject to a sudden impact falling load of 14 kg pound 15 times from a height of fall of 38 cm. The resultant powdered mass will be sieved in a 2.36 mm sieve and the % of mass that winds up plainly powdered in 2.36 mm sieve should not be more than 30 % for aggregates used in wearing surface.

3.1.4 Aggregate Crushing Value test

It is the relative measure of resistance of aggregate to crushing under the gradually applied compressive load and it would give a more extended administration life span to the road. It is recommended that aggregate with crushing value of 30 % - 35 % should be preferred for making wearing surface.

Table 1. Test Results of Natural coarse aggregate (NCA) and Construction Demolition Waste aggregate (CDWA)

S. No.	Name of test	Natural Coarse Aggregate (NCA)	Construction Waste Aggregate (CWA)	Permissible Range as per IS
1	Specific gravity	2.7	2.5	2.5 – 3.0
2	Los Angeles abrasion test	21.89%	27.86%	Less than 30% for wearing course IS 2386 (Part 4):1963
3	Water absorption value test	0.5%	3.4%	0.1% - 2.0% IS 2386 (Part 3):1963
4	Aggregate Crushing test	18.86%	22.63%	Less than 30% for wearing course IS 2386 (Part 4):1963
5	Aggregate Impact test	16.60%	20.40%	Less than 30% for wearing course IS 2386 (Part 4):1963

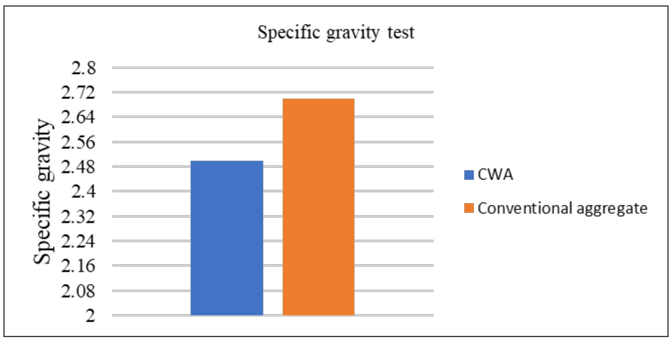


Fig 2. Specific gravity of Natural coarse aggregate (NCA) and Construction Demolition Waste aggregate (CDWA)

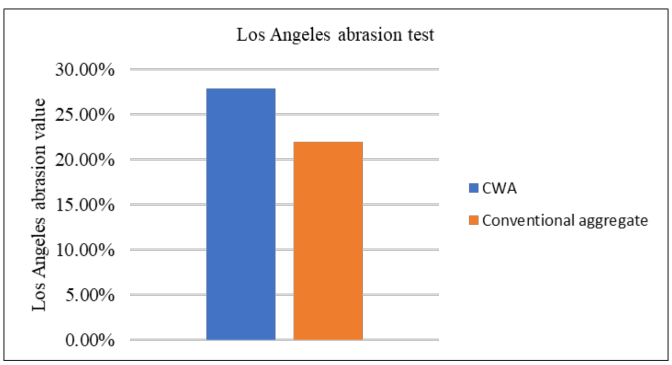


Fig 3. Abrasion value of Natural coarse aggregate (NCA) and Construction Demolition Waste aggregate (CDWA)

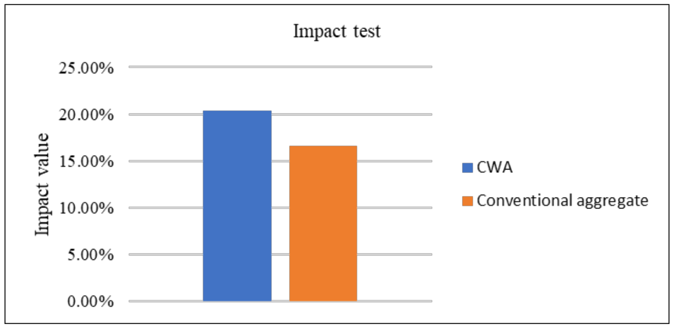


Fig 4. Impact value of Natural coarse aggregate(NCA) and Construction Demolition Waste aggregate (CDWA)

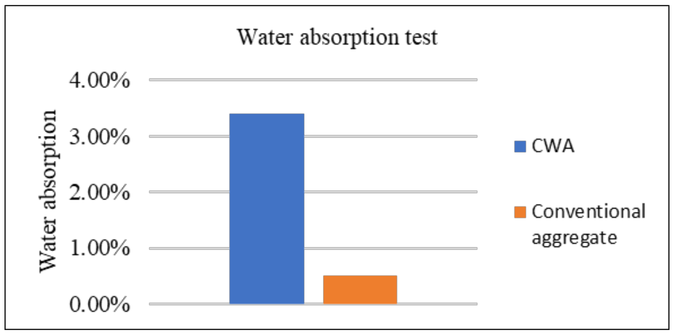


Fig 5. Water absorption of Natural coarse aggregate(NCA) and Construction Demolition Waste aggregate (CDWA)

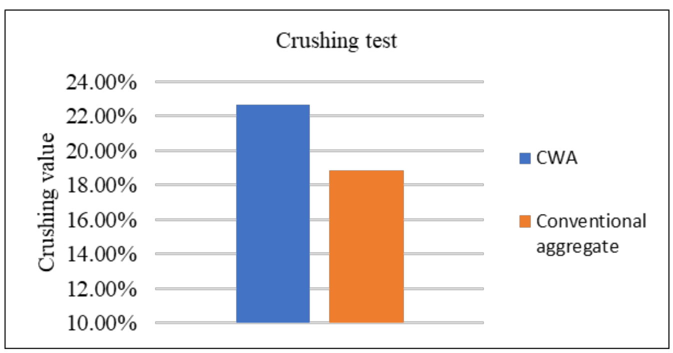


Fig 6. Crushing value of Natural coarse aggregate (NCA) andConstruction Demolition Waste aggregate (CDWA)

3.2 Test Results on Bitumen

The properties of conventional bitumen and modified bitumen were studied by adding 8%, 10% and 12% of plastic waste. The test was carried out based on the codal provisions of IS 1201-1220: 1970 Test on bitumen.

The table presents the results of various tests conducted on bitumen with different percentages of plastic (8%, 10%, and 12%) added to it, compared to normal bitumen. The specific gravity of bitumen increases with an increase in the percentage of plastic waste, with the highest value of 1.05 recorded for 12% plastic in bitumen. The penetration test shows a decrease in the value of penetration with an increase in the percentage of plastic, indicating that the bitumen becomes harder as more plastic is added to it. The softening point, on the other hand, increases with an increase in the percentage of plastic, indicating that the bitumen becomes more resistant to softening at higher temperatures. Finally, the ductility of the bitumen decreases significantly as the percentage of plastic increases, with the value dropping from 85 cm for normal bitumen to 15 cm for bitumen with 12% plastic. Overall, the results suggest that the addition of plastic to bitumen can alter its physical properties, with potential impacts on its performance in construction applications [4].

3.2.1 Ductility test

This test is done to measure the adhesive property of bitumen. The standard of this test is that the ductility of a bituminous material is measured by allow the specimen to undergo plastic before breaking and the elongation of the specimen will be measured in cm.

3.2.2 Determination of softening point

The softening point is the temperature at which the bitumen attains a specific level of softening under determined state of test. The test was carried out in Ring and Ball test apparatus. It is found that the softening point increases by adding more amount of plastic waste to the bitumen. Higher the rate of plastic waste added, higher is the benefit of softening point.

3.2.3 Specific gravity test

The specific gravity of given bituminous sample is measured by preparing a specimen in semi solid or solid state and by weighing in air and water.

3.2.4 Penetration Test

The penetration test is done to measure the hardness or softness of a bitumen by measuring the depth in millimeter. The standard loaded needle is applied vertically in five seconds in the prepared bitumen mix and the depth of penetration was recorded. It was observed higher the plastic waste in bitumen diminishing the value of penetration.

Table 2. Test Results of Conventional bitumen and Modified bitumen with addition 8%, 10% and 12% plastic waste

S. No.	Name of test	Conventional bitumen	8% Plastic waste in bitumen	10% Plastic waste in bitumen	12% Plastic waste in bitumen	IS Codal Provisions
1	Specific gravity	1.01	1.02	1.03	1.05	0.97 – 1.02 IS 1202:1978
2	Penetration test (0.1 mm)	55	26	19	13	20 – 225 IS 1203:1978
3	Softening point (°C)	51	86	92	90	35° to 70° IS 1205:1978
4	Ductility (cm)	85	38	29	15	5 to 100 cm IS 1208:1978

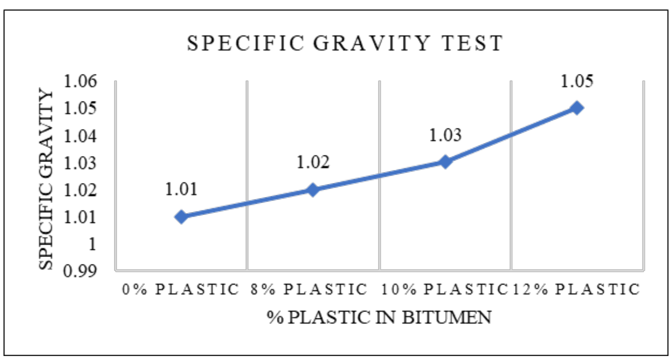


Fig 7. Specific gravity of Conventional bitumen and Modified bitumen with 8%, 10% and 12% plastic waste

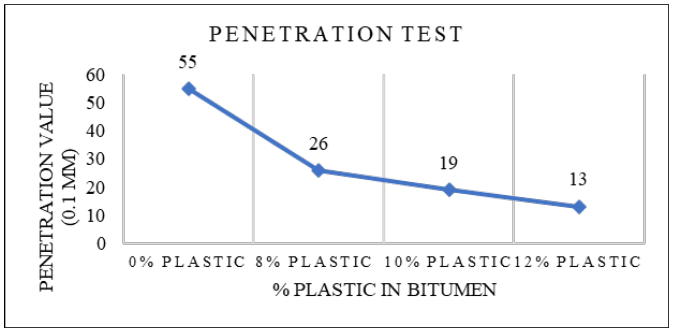


Fig 8. Penetration value of Conventional bitumen and Modified bitumen with 8%, 10% and 12% plastic waste

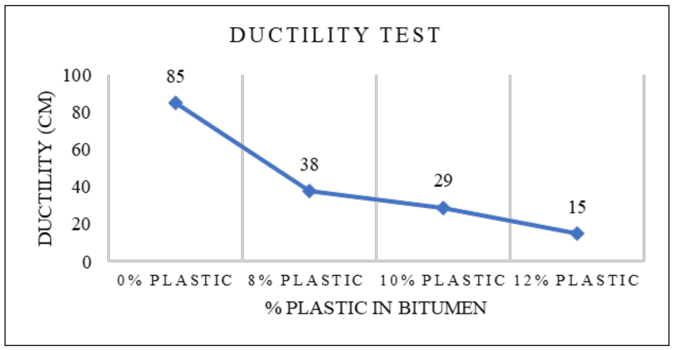


Fig 9. Ductility value of Conventional bitumen and Modified bitumen with 8%, 10% and 12% plastic waste

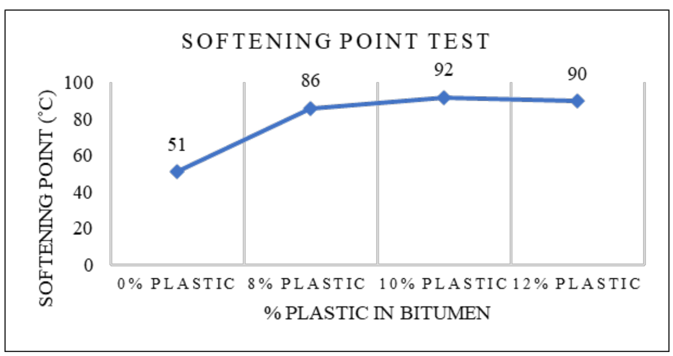


Fig 10. Softening point of Conventional bitumen and Modified bitumen with 8%, 10% and 12% plastic waste

3.3 Test Results on Bitumen mixes

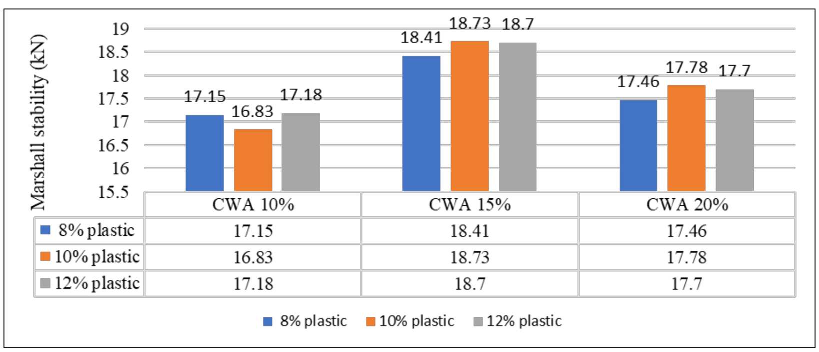
3.3.1 Marshall Stability and Flow Value test

Marshall Stability of a sample is the ultimate load required to cause failure when the bitumen mix sample is preheated to a temperature of 160 to 170°C in the test assembly. Strain measuring devices were used to measure the load and flow value of the sample mix and it fixed at a consistent strain of 5 cm for every moment. To measure the deformation of the sample, dial gauges were used and at the time the stability value will be higher. The deformation at the cracking point communicated in units of 0.25 mm is known as the Marshall flow value of the sample.

The table shows the results of various trials conducted on bituminous mix blended with construction demolition waste aggregates with different percentages of plastic waste (8%, 10%, and 12%). The bitumen and plastic waste are heated to a temperature of 160°C. The tests include weight in air, weight in water, saturated (SSD) weight, volume, density, Marshall value, and flow value. The results show that as the percentage of plastic content increases, the Marshall value and flow value also increase, indicating an increase in the strength and stability of the aggregate. Additionally, the density of the aggregate decreases slightly as the plastic content increases. However, the average density of the aggregate with plastic content is still within the acceptable range. Overall, the results suggest that the addition of plastic waste to construction demolition waste aggregates can potentially enhance their mechanical properties, making them suitable for various construction applications[3,4].

Table 3. Test Results of Modified Bitumen mix with addition of 8%, 10% and 12% plastic waste and 10%, 15%, 20% construction demolition waste aggregateby Marshall stability test

Plastic waste (in %)	Construction demolition waste aggregates (in %)	Weight in Air (g)	Weight in water (g)	Saturated (SSD) weight(g)	Volume (cc)	Density (g/cc)	Marshall Value (kN)	Flow value (mm)
8%		1116	638	1120	482	2.315	17.15	2.58
10%	10%	1118	638	1121	483	2.315	16.83	2.56
12%		1115	641	1122	481	2.318	17.18	2.59
Average:						**2.316**	**17.05**	**2.57**
8%		1160	676	1167	491	2.363	18.41	3.13
10%	15%	1150	670	1156	486	2.366	18.73	3.37
12%		1158	766	1256	490	2.363	18.7	3.26
Average:						**2.364**	**18.62**	**3.25**
8%		1250	720	1252	532	2.35	17.46	2.76
10%	20%	1252	723	1254	531	2.358	17.78	2.96
12%		1248	725	1255	530	2.355	17.7	2.91
Average:						**2.354**	**17.65**	**2.87**



	CWA 10%	CWA 15%	CWA 20%
8% plastic	17.15	18.41	17.46
10% plastic	16.83	18.73	17.78
12% plastic	17.18	18.7	17.7

Fig 11. Marshall Stability value of Modified bitumen mixes with 8%, 10%, 12% plastic waste and 10%, 15% and 20% of construction demolition waste aggregates

The table shows the results of various tests conducted on conventional bitumen mix, including Marshall value and flow value. Three trails were conducted, and the results indicate that the Marshall value ranged from 17.72 kN to 17.77 kN, with an average of 17.74 kN. Similarly, the flow value ranged from 2.22 mm to 2.24 mm, with an average of 2.23 mm.

Table 4. Test Results on Conventional Bitumen mix with no addition of plastic waste and construction demolition waste aggregate

Specimen	Marshall value (kN)	Flow value (in mm)
Trail 1	17.75	2.24
Trail 2	17.72	2.23
Trail 3	17.77	2.22
Average	17.74	2.23

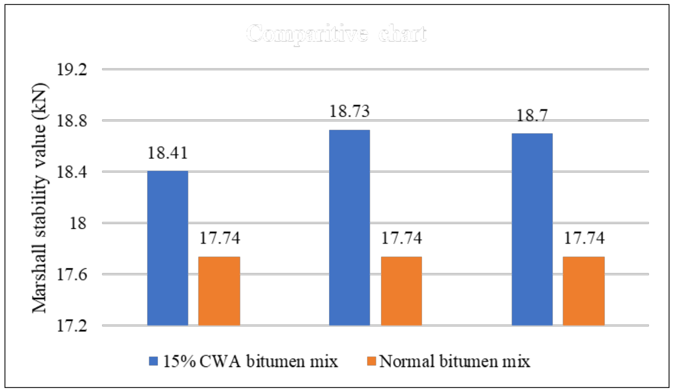


Fig 12. Comparison of Marshall Stability value of Conventional bitumen mix with Modified bitumen mixes with 8%, 10%, 12% plastic waste and 15% of construction demolition waste aggregates

4 Conclusion

Based on the experimental investigation, it can be concluded that he utilization of construction demolition waste aggregate (CDWA) and plastic waste in pavement construction has proven to be a sustainable and cost-effective approach to improving road quality and durability while reducing environmental impact.

- The objective of developing optimized mix designs and construction practices has been achieved through experimental investigation by adding of 10%, 15%, and 20% of construction demolition waste aggregate (CDWA) as partial replacement of natural coarse aggregate (NCA) and addition of 8%, 10% and 12% of plastic waste in bitumen.
- The optimum mix proportion of bituminous mix is found as 10% plastic waste blended with 15% construction demolition waste aggregate.
- The average Marshall stability value of the modified bitumen mix with the addition of 8%, 10% and 12% plastic waste and 10% construction demolition waste aggregate is 18.62 kN, which is higher than the average Marshall stability value of the conventional bitumen mix 17.74 kN.
- The usage of construction demolition waste aggregate also proves to be economical as it has a lower price range than natural coarse aggregate.
- Furthermore, the addition of plastic waste in bitumen mix helps in increasing the softening point of the bitumen, which reduces bleeding of roads during high temperatures. Moreover, the higher addition of plastic waste in bitumen mix reduces the penetration value of bitumen and improves the permeability of bituminous roads, thereby increasing their lifespan.
- In conclusion, the usage of construction demolition waste aggregate and plastic waste in bituminous mixes is a sustainable and cost-effective approach that can improve the quality and durability of roads.
- Further research can be conducted on the optimization of the percentage of plastic waste and construction demolition waste aggregate to achieve maximum benefits. The method can also be recommended for adoption in road-laying projects to promote sustainability and reduce the environmental impact of road construction.

References

1) Silva FAN, Silva MTA, Delgado JMPQ, Azevedo AC, Pereira GFC. Arpan Ray, Radhikesh Prasad Nanda and Pronab Roy, Use of C&D Waste in Road Construction: A critical review. *IOP Conf Series: Materials Science and Engineering*. 2021;21(1). Available from: https://doi.org/10.7764/RDLC.21.1.184.
2) Ray A, Nanda RP, Roy P. Use of C&D Waste in Road Construction: A critical review. *IOP Conference Series: Materials Science and Engineering*. 2021;1116(1):012159. Available from: https://doi.org/10.1088/1757-899X/1116/1/012159.
3) Deb P, Singh KL. Experimental Investigation on the Mechanical Performance of Cold Mix Asphalt Using Construction Demolition Waste as Filler. *International Journal of Pavement Research and Technology*. 2022. Available from: https://doi.org/10.1007/s42947-022-00216-4.
4) Biswasand A, Potnis S. Plastic Bituminous Roads: A Sustainable Technology - For Better Handling Distresses. *European Journal of Engineering and Technology Research*. 2022;7:63–69. Available from: http://dx.doi.org/10.24018/ejers.2022.7.1.2695.
5) Kwabena J, Appiah. Use of waste plastic materials for road construction in Ghana. *Case Studies in Construction Materials*. 2017;6. Available from: https://doi.org/10.1016/j.cscm.2016.11.001.
6) Agrawal N, Gulzar P, Yadav N, Padmamalika K, Hazra. Beneficial Reuse and Recycling of Plastic Wastes in Construction of Roads: A Review. *Indian Journal of Advances in Chemical Science*. 2021;9(4). Available from: https://doi.org/10.22607/IJACS.2021.904029.