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Analysis of Physical Properties of Polyethylene Terephthalate Coated Aggregates Used in Bituminous Concrete Mixes

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Abstract

The main cause of climate change that the world has been facing for several years is burning of plastic waste in open air. To contribute to solution of this problem, an investigation was carried out with utilization of plastic waste in bituminous mixtures used in flexible pavement.With varied amounts of Polyethylene Terephthalate (0%, 6%, 6.5%, 7%, 7.5%, and 8%) of asphalt content, variousdesirable properties of aggregates required for bituminous mix such as hardness, toughness, abrasion resistance, bitumen adhesion, crushing strength, stripping, soundness and water absorptionwere assessed. The physical properties of this composite material show improvement in hardness, toughness, abrasion resistant, resistant to weathering action, water resistant and bitumen binding ability. In order to safely dispose of this non-biodegradable trash and improve the physical qualities of aggregates, using waste plastic bottle (PET) in flexible pavements is an environmentally responsible approach.

Keywords: Waste plastic, physical properties, bituminous mixes, polyethylene terephthalate, composite material

INTRODUCTION

To facilitate the movement of people and goods, humans have recourse to several means of movement, including the land route which is the most used. The construction of these infrastructures sometimes has a somewhat high financial value. Improvement in use of waste plastic in bituminous mixes to construct flexible pavements is still in its infancy but has been applied to a number of roadways.This procedure presents many advantages, on the life of the roads, on the cost of realization, participates in the reduction of the pollution on the atmosphere by using the plastic wastes which are very often burned in the open air, which negatively impact on the climate.

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This study highlights the progress made in the use of plastic waste for plastic roads. The rapid pace of urbanization and improvement has led to the expansion of the plastic waste era. Disposal of plastic waste is difficult due to non- biodegradable in nature, it stays in condition for some time and disposing of plastic wasters to landfill is dangerous as harmful chemicals filter into dirt and waste. There is rapid growing inindustrialization and urbanization due to increase in population. India is also a developing country, the inhabitants of the villages started to migrate to the cities, which create a large amount of solid waste on a daily basis, which leads to environmental problems for the cities. Furthermore, a few Indian states have coastal regions where recreational activities by the sea

produce plastic garbage. Proper disposal of such material that has been gathered outdoors of villages and towns, creating unsanitary and disorderly circumstances that have an impact on people's health and may lead to landfill issues that have serious negative effects on the environment and contaminate groundwater [1-3].

Waste plastic may be used in flexible by two processes. First one is wet processin which waste plastic incorporated in bitumen and second one is dry process in which coating of waste plastic is done over coarse aggregate prier using in bituminous mixes. To control the desired properties of bitumen amount of plastic is less in wet process as compared to dry process [4]. The quality and quantity of plastic affect the bituminous mixtures' volumetric and mechanical qualities. Increased intermolecular interaction between bitumen and plastic-coated aggregate enhances bituminous mixes' mechanical characteristics, including stability, indirect tensile strength, and rutting resistance [5–7]. Durability of flexible pavement can be improved with incorporating waste plastic via dry process [8–10].Better rutting performance and a decrease in the optimal bitumen percentage show that adding PET enhances dense bituminous macadam mixes. This technique has positive effects on the environment [11]. To minimize the risk to which the population in permanent contact with this plastic waste is exposed, efforts must be made taking into account the use of renewable raw materials for innovative products to recent technological developments. The current research is focusing on sustainablesolution of plastic waste in order to reduce environmental losses.

MATERIALS

Bitumen

The bitumen sample for the current investigation of VG-30 grade was obtained from the Indian Oil Corporation Ltd., Panipat Refinery in Haryana, India. Test results of bitumen are as given in Table 1.

Table 1. Bitumen Properties [12].

Sr. No	Property	Observed value	Desired value
1.	Penetration Value (mm) [13]	49	Min. 45
2.	Softening Point (°C) [14]	51	Min. 47
3.	Ductility at 27 °C (cm) [15]	52	Min. 40
4.	Specific Gravity at 27 °C [16]	1.01	-

Aggregates

Mechanical and volumetric properties of bituminous mixture are affected by quality of aggregates used. Table 2 compiles the test findings.

Table 2. Properties of Coarse Aggregates [17].

Sr. no	Property	Test	Observed Values	Specification
1.	Cleanliness	Sieve Size Analysis [18]	0.8	% passing through 0.075 mm sieve(Max. 5)
2.	Particle Shape	Flakiness and Elongation Indices (Combined) [18]	23.71%	Max 35%
3.	Strength	Los Angeles Abrasion Value [19]	21.32%	Max 30%
		Aggregate Impact Value [19]	18.87%	Max 24%
4.	Durability	Soundness: Sodium Sulphate [20]	6.39%	Max 12%
5.	Water Absorption	Water Absorption [21]	1.21%	Max 2%
6.	Stripping	Stripping Test [22]	Retained Coating 96%	Retained Coating 95% Min.
7.	Density	Specific Gravity [21]	2.690	2.5-3.0

Waste Plastic

To provide adequate coating over aggregates, the plastic bottles were cutting in uniform size of 600µ - 2.36mm. Table 3 lists the properties of waste plastic.

Table 3. Characteristics of PET

Sr. No.	Property	Value
1.	Size	600µ - 2.36mm
2.	Density (gm/cc)	1.29
3.	Melting Temperature (°C)	170 -180

METHODOLOGY

As per the MoRT&H, 2013 standards displayed in Table 4, the bitumen concentration was fixed at 5.2%, which is the minimum required for bituminous concrete mixes of Grade I.The physical characteristics of natural aggregates and aggregates modified with waste plastic, which are needed for bituminous concrete mixes, were evaluated. According to IRC, SP-98, 2013 Specifications, dose of waste plastic was chosen as 6% to 8% (with an increment of 0.5%) to examine the physical properties of aggregates [3]. which recommends using 6% to 8% of bitumen content. Once the aggregates reached a temperature of 170 °C, waste plastic was sprayed. Aggregates were cooled to room temperature prior to testing.

Table 4. Compositions of Bituminous Concrete Layers [17].

Grading	I
Nominal Size of Aggregates	19 mm
Thickness of Layer	50 mm
Sieve Size (mm)	Cumulative %age(Weight of Total Aggregates Passing)
26.5	100
19	90 – 100
13.2	59 – 79
9.5	52 – 72
4.75	35 – 55
2.36	28 – 44
1.18	20 – 34
0.6	15 – 27
0.3	10 – 20
0.15	5 – 13
0.075	2 – 8
Percentage of Bitumen Content	Min 5.2

RESULTS AND DISCUSSIONS

Los Angles Abrasion Value

Los Angles Abrasion value is commonly used to find the quality of aggregates used in flexible pavement, especially to know the hardness of aggregates. With an increment of PET content there is a decrease in aggregate abrasion value, which indicates that the aggregates hardness value improved as shown in Figure 1. In comparison to ordinary aggregates, the aggregates hardness value was 17.36% higher at 8% PET content.

Aggregate Impact Value

An aggregate's ability to withstand repeated stress fractures is evaluated using the impact value test. It is clear from Figure 2 that coating of PET improves toughnessof aggregate.Moreover,aggregates of poor quality can be made useful in flexible pavement by coating with PET. Toughness of aggregate was 14.69% moreat 8% PET content with respect to natural aggregates.

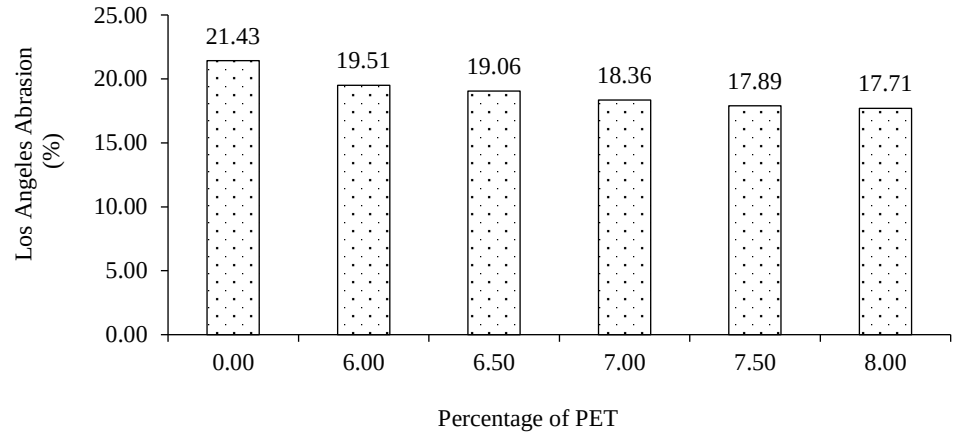

Figure 1. Los angles abrasion value.

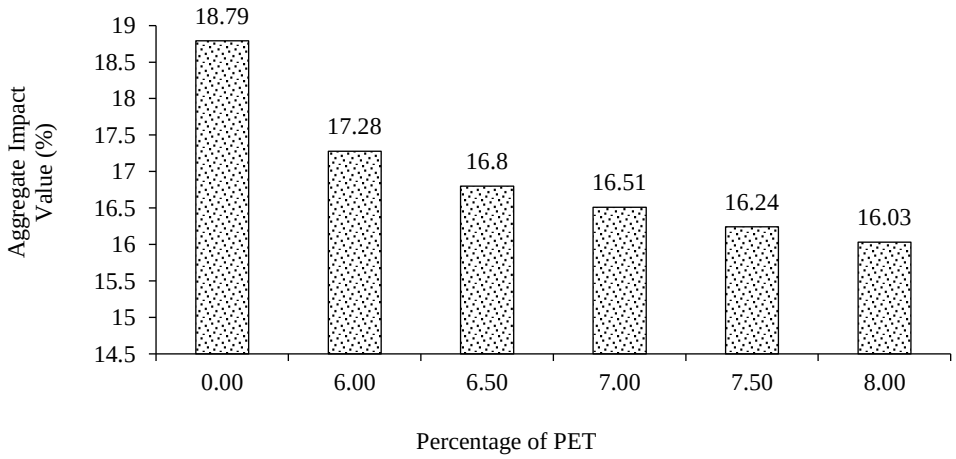

Figure 2. Aggregate impact value.

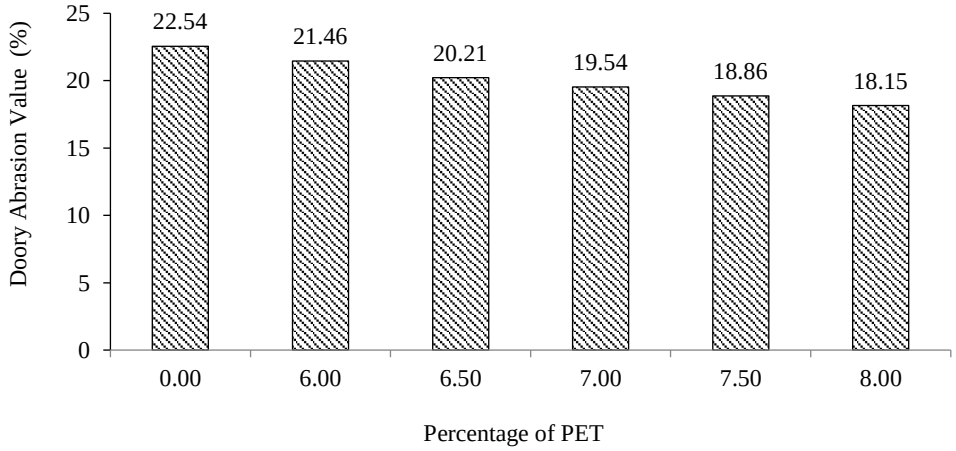

Figure 3. Dorry abrasion value.

DORRY ABRASION VALUE

Dorry abrasion value of aggregates at various PET levels shown in Figure 3 and decreases as PET content increases. This decay in abrasion value shows how adding PET enhances the aggregates resistance to abrasion. Comparing aggregates with an 8% PET covering to conventional aggregates, the abrasion resistance of the aggregates is 19.48% higher.

Bitumen Extraction

To ascertain bitumen extraction from aggregate [23]. this test is conducted. When waste plastic coated aggregate is used instead of conventional aggregates, the results as shown in Figure 4 demonstrate that bitumen removal was less showing more bonding strength.

Crushing Strength Value

The resistance to crushing when a gradually applied compressive load is applied is indicated by the aggregate crushing value. Figure 5 makes it evident that a PET covering increases resistance to crushing strength. The application of plastic coating improves aggregate quality. Furthermore, covering weak aggregates with scrap plastic can enhance their quality. Comparing this to traditional aggregates, the crushing strength value at 8% PET concentration was 24.31% greater.

Stripping

The stripping occurs because some aggregates have a stronger affinity for water than bituminous binder, and this displacement is a result of the physico-chemical processes at work in the system. Figure 6 makes it evident that bitumen retention increases as PET content increases. This suggests that the mixture is more resistant to water. This might be because plastic garbage binds better than aggregates.

Soundness

The soundness test is used to determine how resistant aggregate is to weathering action.It is clear from the Figure 7 that soundness value of aggregates decreases with increase in PET content and there is no weight loss at 8% PET content, This demonstrates how the aggregate's quality has improve.

Water Absorption

It is observed that the absorption of water decreased with the coating of plastic over the aggregate as shown in Figure 8. This demonstrates how the plastic coating reduces the voids. Therefore, covering aggregates with waste plastic (PET) can enhance their quality.

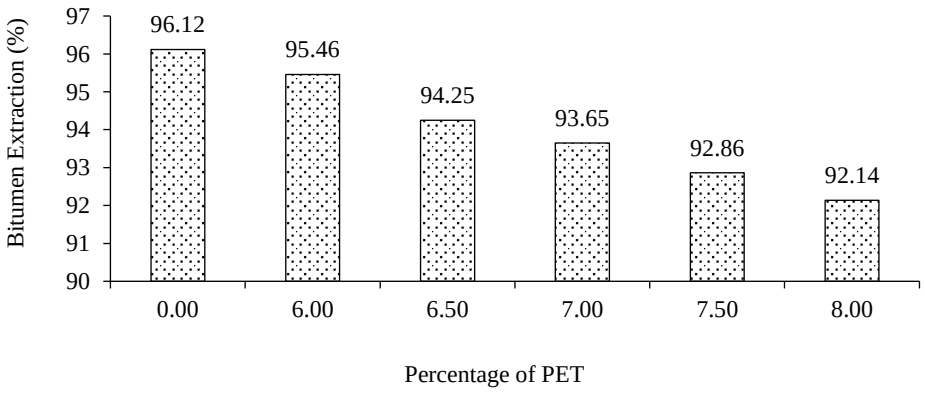

Figure 4. Bitumen extraction.

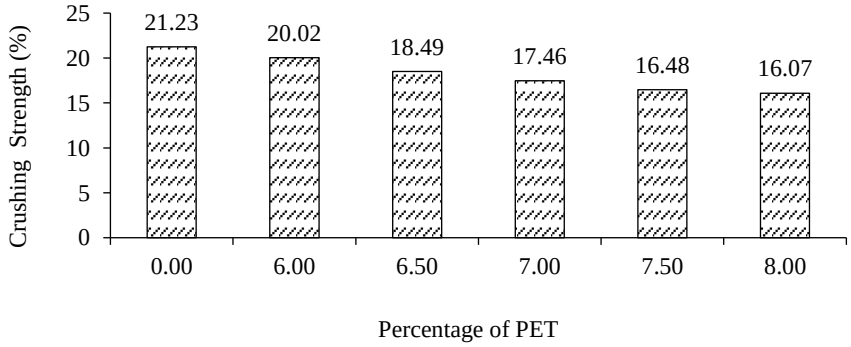

Figure 5. Crushing strength value.

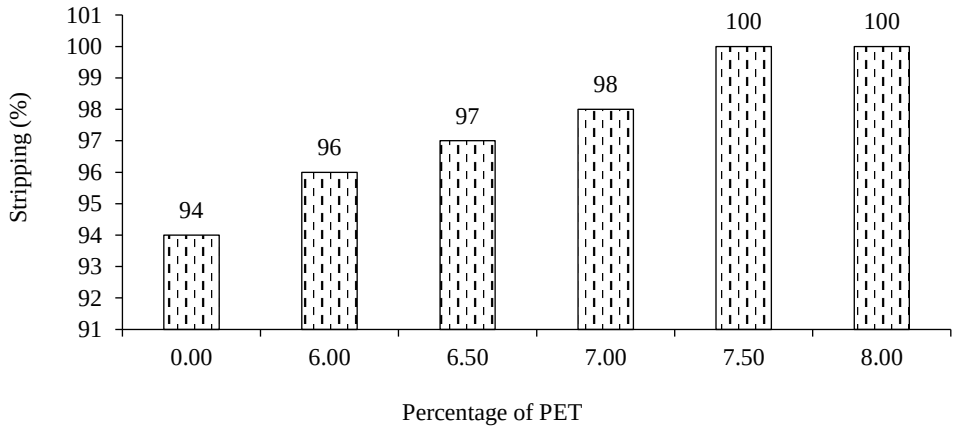

Figure 6. Stripping value.

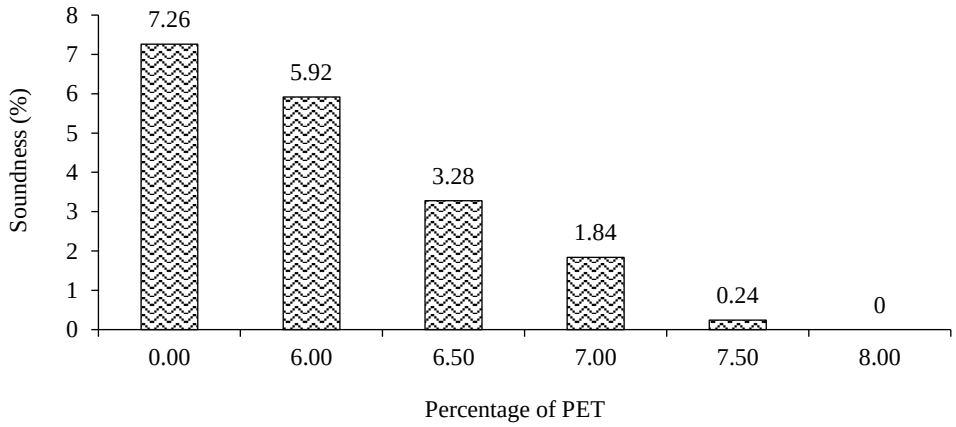

Figure 7. Soundness value.

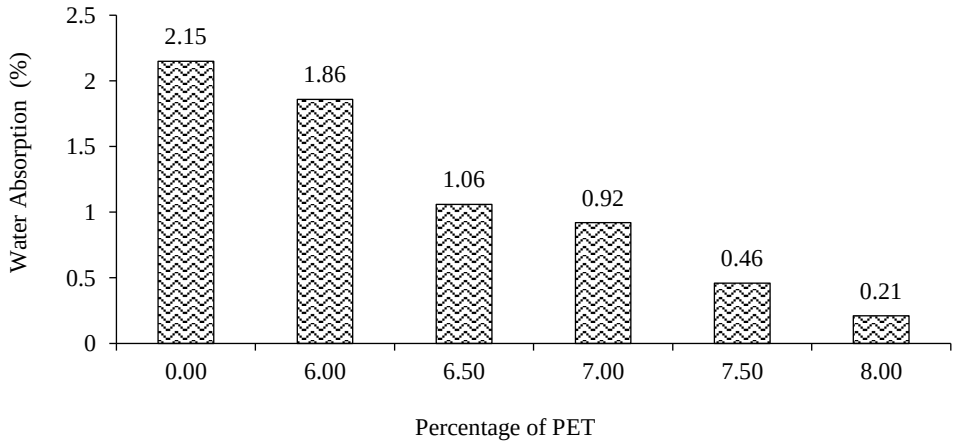

Figure 8. Water absorption value.

CONCLUSIONS

The main findings derived from the research are:

1. When compared to ordinary aggregates, it has been found that the hardness value of PET coated aggregates is continuously improving and is 17.36% greater at 8% PET content.
2. It is observed that the impact value for waste plastic coated aggregate improves the quality of aggregates. Rate of improvement in quality is low after 7% PET content.

3. Gradually applying a PET layer on aggregates boosts their resistance to abrasion, which can be improved up to 19.48% with addition of 8% PET content.
4. Applying a layer of recycled plastic (PET) to aggregates can enhance their binding qualities.
5. Coating aggregate with PET increases its crushing strength, which helps to construct higher-quality flexible pavement.
6. Stripping resistance of aggregates can be ameliorated by covering them with discarded plastic..
7. Coating aggregates with discarded plastic can increase their weathering resistance by up to 100%.
8. The water absorption value reduces with coating of aggregate with waste plastic i.e. water resistance of porous aggregates can be improved.
9. The guidelines suggested in IRC: SP: 98-2013 can be followed for preparing of bituminous concrete mixes.

REFERENCES

1. Prasad KVR, Mahendra SP, Kumar NS, Rakesh SG, Vijay V, Likith T, Yogesh BP. Study on utilization of waste plastic in bituminous mixes for road construction. In: Proceedings of the international conference on futuristic innovations and developments in civil engineering. 2013; pp 198–203.
2. Ranadive MS, Hadole HP, Padamwar SV. Performance of stone matrix asphalt and asphaltic concrete using modifiers. J Mater Civ Eng. 2018; 30(1):1–9.
3. IRC: SP 98. Guidelines for the use of waste plastic in hot bituminous mixes (dry process) in wearing courses. 1st ed. Indian Road Congress. 2013; New Delhi, India.
4. Sangita, KhanTA, Sabina, Sharma DK. Effect of waste polymer modifier on the properties of bituminous concrete mixes. Constr Build Mater. 2011; 25: 3841–3848.
5. Ahmadinia E, Zargar M, Karim MR, Abdelaziz M, Shafig P. Using waste plastic bottles as additive for stone mastic asphalt. Constr Build Mater. 2011; 32: 4844–4849.
6. Ahmadinia E, Zargar M, Karim MR, Abdelaziz M, Ahmadinia E. Performance evaluation of utilization of waste polyethylene terephthalate (PET) in stone mastic asphalt. Constr Build Mater. 2012; 36: 984–989.
7. Bindu CS, Beena KS. Waste plastic as a stabilizing additive in stone mastic asphalt. Int J Eng Technol. 2010; 2(6):379–387.
8. Modarres A, Hamidreza HH. Effect of waste plastic bottles on the stiffness and fatigue properties of modified asphalt mixes. Constr Build Mater. 2014; 61:8–15.
9. Rahman WMNWA, Wahab AFAW. Green pavement using recycled polyethylene terephthalate (PET) as partial fine aggregate replacement in modified asphalt. Constr Build Mater. 2013; 53:124–128.
10. Shankar AUR, Lekha BM, Sarang G, Abhishek P. Performance and fatigue behaviour of semi dense bituminous concrete using waste plastics as modifier. Indian Highways. 2010; 42(7):17–26.
11. Saini M, Aggarwal P, Chouhan S. Effects of Adding Polyethylene Terephthalate (PET) to Dense Bituminous Macadam Mixes Using the Dry Process. Recent Developments in Water Resources and Transportation Engineering. Lecture Notes in Civil Engineering. 2023; 353: 265-275.
12. IS: 73. Paving bitumen specification. 2nd ed. Bureau of Indian Standards. 1992; New Delhi, India
13. 12. IS: 1203. Determination of penetration. 1st revision. Bureau of Indian Standards. 1978; New Delhi, India
14. IS: 1205. Determination of softening point. 1st revision. Bureau of Indian Standards. 1978; New Delhi, India
15. IS: 1208. Determination of ductility. 1st revision. Bureau of Indian Standards. 1978; New Delhi, India
16. IS: 1202. Determination of specific gravity. 1st revision. Bureau of Indian Standards. 1978; New Delhi, India
17. MoRT&H. Specification for road and bridge works. Indian Roads Congress. 2013; V - Revision, New Delhi, India

18. IS: 2386. Methods of test of aggregates for concrete. Part-I, particle size and shape. 1st ed. Bureau of Indian Standards. 1963; New Delhi, India
19. IS: 2386. Methods of test of aggregates for concrete. Part-IV, Los Angles Abrasion value and aggregate impact value. 1st ed. Bureau of Indian Standards. 1963; New Delhi, India
20. IS: 2386. Methods of test of aggregates for concrete. Part-V, soundness, 1st ed. Bureau of Indian Standards. 1963; New Delhi, India
21. IS: 2386. Methods of test of aggregates for concrete. Part-III, water absorption. 1st ed. Bureau of Indian Standards. 1963; New Delhi, India
22. IS: 6241. Method of test for determination of stripping value of road aggregates. Bureau of Indian Standards. 1971; New Delhi, India
23. IRC: SP 11. Determination of binder content for asphalt mix. 2nd ed. Indian Road Congress. 1988; New Delhi, India.

