International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Study on Performance of Polymer-Coated Aggregates in Bituminous Pavement Construction

JAMI AJAY KUMAR[1], Dr. G. TABITHA[2]

[1]M.Tech Scholar (Transportation Engineering), Department of Civil Engineering, Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

[2]Associate Professor, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

Abstract

The present study investigates the use of waste-polymer-coated aggregates in bituminous pavement construction through laboratory characterization of aggregates and Marshall evaluation of a dense bituminous mixture prepared with VG-30 bitumen. The experimental programme described in the project report includes comparison of conventional and coated aggregates using mechanical and physical tests, together with Marshall stability, flow and volumetric measurements. The report records an abrasion-test series for coating proportions of 0%, 5%, 5.5%, 6% and 8%, in which the Los Angeles abrasion value decreases from 18.80% for the uncoated aggregate to 8.80%, 9.20%, 10.60% and 7.60%, respectively. A separate results discussion describes coating levels of 0.5%, 1% and 2% for aggregates from different sources and reports reductions in abrasion, crushing and water-absorption values. The Marshall trial data at 8.0%, 8.5% and 9.0% bitumen contents show stability values of 2580, 2627 and 2410 kg, respectively, with the maximum recorded value at 8.5% binder content. However, the project report states that the final polymer-coated dense bituminous mix did not satisfy the cited IRC requirements. The findings therefore indicate potential improvements in selected aggregate properties, but do not establish compliance or field durability of the complete mix. Inconsistencies in the reported polymer dosage series and incomplete optimum-bitumen-content calculations are identified as limitations requiring verification.

Keywords—*Polymer-coated aggregates, waste plastic, flexible pavement, VG-30 bitumen, Marshall stability, aggregate abrasion, sustainable pavement.*

1. INTRODUCTION

Flexible pavements are widely used in highway and urban-road networks because they can be constructed using locally available aggregates and bituminous binders. Their service performance depends on aggregate strength, toughness, abrasion resistance, shape, moisture susceptibility, binder characteristics, gradation, compaction and traffic loading. Repeated wheel loads and environmental exposure can contribute to rutting, cracking, stripping, raveling and surface deterioration. The quality of the aggregate skeleton is particularly important because aggregates form the principal load-carrying framework of a bituminous mixture.

The increasing generation of waste plastic has created a persistent solid-waste management challenge. One approach discussed in pavement engineering is the dry process, in which selected waste plastic is softened and applied to heated aggregates before the addition of bitumen. The resulting polymer-coated aggregate (PCA) has a modified surface that may influence aggregate abrasion, impact and crushing resistance, water absorption, and aggregate–binder interaction. Reuse of suitable plastic waste in road materials may provide a productive waste-management route, provided that the material and construction process satisfy engineering and environmental requirements.

The project investigated conventional and polymer-coated aggregates and used VG-30 bitumen in Marshall mix design. The stated objectives were to evaluate hardness, toughness, crushing and abrasion resistance; design a dense bituminous mix; determine optimum bitumen content; and consider the economics of the proposed material. The present paper consolidates the reported experimental findings, with emphasis on measured aggregate properties and Marshall performance, while retaining limitations and inconsistencies found in the source report.

2. BACKGROUND AND RESEARCH NEED

The literature reviewed in the project indicates that plastic waste has been incorporated into asphalt mixtures through wet and dry processes. Previous investigations cited in the report discuss improvements in aggregate–binder adhesion, moisture resistance, Marshall stability and deformation resistance, although performance depends on polymer type, dosage, particle size, heating conditions and method of incorporation. The literature also identifies unresolved issues associated with compatibility, production emissions, potential microplastic release, recyclability and the need for long-term field validation.

The project identifies a need to examine plastic coating as a treatment of the aggregate surface rather than considering only direct modification of bitumen. It also highlights the need to compare conventional and coated aggregate properties and to connect aggregate characterization with the Marshall properties of the resulting mixture. The contribution of the present work is therefore an experimental assessment of PCA properties and a preliminary Marshall mix evaluation using VG-30 binder.

The source report contains two distinct descriptions of polymer dosage. The abstract and an abrasion-test table use 0%, 5%, 5.5%, 6% and 8%, whereas the Chapter 4 narrative describes results for 0.5%, 1% and 2% coating and different aggregate sources. These series are not assumed to be equivalent in this paper. Both are reported with their stated context, and the inconsistency is treated as a limitation requiring confirmation from original laboratory records.

3. MATERIALS AND EXPERIMENTAL PROGRAMME

3.1 Materials

The materials identified in the project are coarse aggregates of 10 mm and 20 mm nominal sizes, VG-30 grade bitumen, processed waste-plastic clinkers and mineral filler. The plastic clinkers are described as having a particle diameter below 5 mm. The project describes the use of the dry coating process: aggregates are heated, processed plastic is applied to their surfaces, and the coated particles are allowed to cool before use in the bituminous mixture.

The plastic-clinker property table reports a density of 0.92 g/cc, surface hardness SD48, tensile strength of 10 MPa, flexural modulus of 0.25 GPa, maximum operating temperature of 50°, water absorption of 0.01%, and melting temperature of 220–260°C. The report does not provide a sufficiently detailed material identification or test-standard description for all these entries; accordingly, they are reproduced as reported and should be independently verified before use in design.

Table 1. Properties of waste-plastic clinkers reported in the project

Property	Reported value
Density	0.92 g/cc
Surface hardness	SD48
Tensile strength	10 MPa
Flexural modulus	0.25 GPa
Maximum operating temperature	50° (unit not specified)
Water absorption	0.01%
Melting temperature	220–260°C

3.2 Aggregate coating and tests

Conventional aggregates and polymer-coated aggregates were evaluated through tests listed in the report, including aggregate impact, crushing, flakiness and elongation, Los Angeles abrasion, water absorption and specific gravity. The report also refers to soundness and stripping-related evaluation. The coating proportions stated in the abstract are 0%, 5%, 5.5%, 6% and 8%; however, the results chapter separately discusses 0.5%, 1% and 2% coating. The paper preserves these source distinctions rather than merging the datasets.

The Los Angeles abrasion table provides a complete set of values for the five dosage levels. The reported abrasion values are 18.80%, 8.80%, 9.20%, 10.60% and 7.60%, respectively. These values are transcribed directly from the report. The non-monotonic sequence between 5% and 6% and the unusually large

reduction between the uncoated and coated samples should be checked against laboratory worksheets and sample identification.

Table 2. Los Angeles abrasion test results for the reported polymer-coating series

Polymer coating (%)	0	5	5.5	6	8
Los Angeles abrasion value (%)	18.80	8.80	9.20	10.60	7.60

In the separate Chapter 4 narrative, the Poochampatty aggregate is reported to have a plain-aggregate abrasion value of 37%, decreasing to 34.10%, 32.00% and 29.40% at 0.5%, 1% and 2% polymer coating. Its crushing value is reported to decrease to 23.19%, 21.30% and 20.00%, while water absorption decreases to 0.48%, 0.45% and 0.36%. For Thiruvathavur quarry aggregate, the report gives abrasion values of 24.20%, 23.10% and 20.00%, and impact values of 20.40%, 14.30% and 12.00%, at the same three dosage levels. Because the complete corresponding raw-data tables are not consistently available in the report, these values are discussed narratively and are not combined with Table 2.

3.3 VG-30 bitumen and Marshall mix design

VG-30 grade bitumen was used as the binder. The report identifies ductility, softening-point and penetration tests for binder characterization. Marshall specimens were prepared using aggregate, filler and VG-30 bitumen. The reported procedure specifies approximately 1200 g of aggregate and filler, heating of aggregates to 175–190°C, heating of bitumen to 121–125°C, mixing at 154–160°C and compaction using 75 blows on each face. Specimens were conditioned in a 60°C water bath for 30–40 minutes and loaded at 50.8 mm/min until failure. Marshall stability was recorded in kilograms and flow was recorded as deformation units.

Three binder contents—8.0%, 8.5% and 9.0%—were examined in the Marshall trial. The report presents specimen dimensions, masses, bulk volume, bulk specific gravity, maximum specific gravity and corrected stability. The stability values shown are 2580, 2627 and 2410 kg, respectively. The report also describes optimum binder content as the average of binder contents corresponding to maximum stability, maximum bulk specific gravity and 4% air voids. However, the corresponding Table 10 is not populated with readable numerical values, and a final OBC value cannot be independently reconstructed from the supplied report.

4. RESULTS AND DISCUSSION

4.1 Aggregate performance

The abrasion results in Table 2 indicate lower reported mass loss for all coated samples than for the uncoated sample. The lowest abrasion value in this series is 7.60% at 8% coating, compared with 18.80% for the uncoated aggregate. The 5% and 5.5% values are 8.80% and 9.20%, while the 6% value is 10.60%. Thus, the abrasion response is not strictly monotonic across all intermediate dosage levels, although the 8% sample records the lowest value in the tabulated series.

The separate narrative results also describe improvements in abrasion, impact, crushing and water absorption as polymer content increases from 0.5% to 2% for selected aggregate sources. For example, Poochampatty abrasion decreases from 37% to 29.40% at 2% coating, and water absorption decreases from the reported plain-aggregate value of 0.52% to 0.36%. These source-specific findings support the possibility that polymer coating can improve selected aggregate characteristics. They do not, by themselves, demonstrate that all aggregate sources or all coating proportions will meet the relevant MORTH/IRC specifications.

The source report states that a 6% coating level was considered optimum in its aggregate conclusion and later used in preparing a dense bituminous mix. However, the same report also gives the distinct 0.5–2% dosage series in its Chapter 4 narrative. The basis for selecting 6% is therefore not unambiguously linked to the separate source-specific results. This dosage discrepancy should be resolved before the study is used to recommend a design proportion.

4.2 Marshall stability and flow

Table 3 summarizes the Marshall stability trial data. Stability increased from 2580 kg at 8.0% bitumen to 2627 kg at 8.5%, followed by a reduction to 2410 kg at 9.0%. The peak among the three tested binder

contents therefore occurs at 8.5%. The reported specimen bulk specific gravity also increases across the three trial contents, from 2.034 to 2.445 and 2.533. The report lists a maximum specific gravity of 2.652 for the trials.

Table 3. Marshall stability trial results reported for VG-30 bituminous mix

Parameter	8.0% bitumen	8.5% bitumen	9.0% bitumen
Specimen height (mm)	59	65	67
Mass in air (g)	1066	1286	1340
Mass in water (g)	556	673	774
SSD mass (g)	1080	1200	1300
Bulk volume (cc)	524	526	529
Bulk specific gravity of mix	2.034	2.445	2.533
Maximum specific gravity	2.652	2.652	2.652
Marshall stability (kg)	2580	2627	2410

The Marshall flow graph in the project shows an increase in flow from approximately 2.1 at 8.0% bitumen to 3.8 at 8.5% and 4.9 at 9.0%. This indicates increasing deformation at peak load as binder content increases over the tested range. The rise in flow between 8.5% and 9.0%, combined with the decline in stability, suggests that the 9.0% mix may be comparatively more deformable under the Marshall test conditions.

The report includes plots of air voids, voids filled with bitumen (VFB) and bulk specific gravity against bitumen content. These plots are retained as source figures. However, the underlying numerical values for each volumetric parameter are not fully tabulated in the report. As a result, the optimum binder content cannot be independently verified using the three-parameter averaging method described in the methodology.

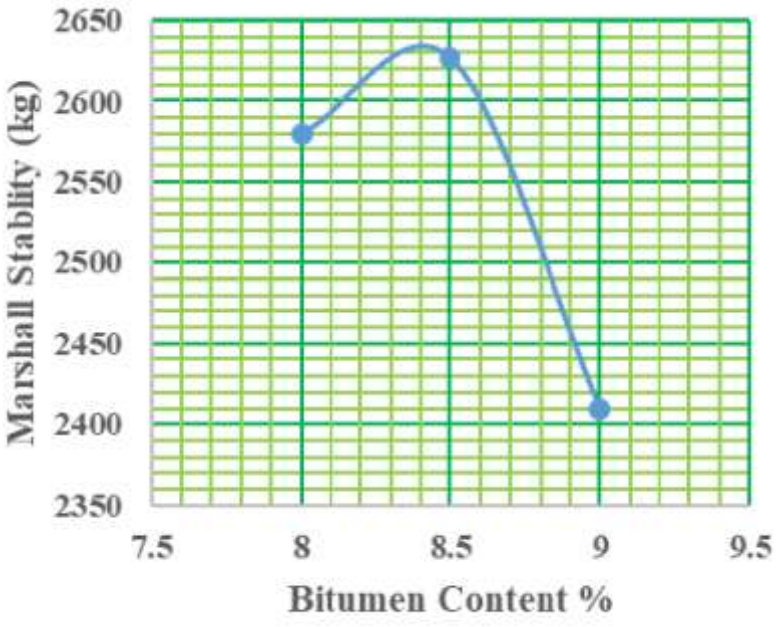


Fig. 1. Variation of Marshall stability with bitumen content

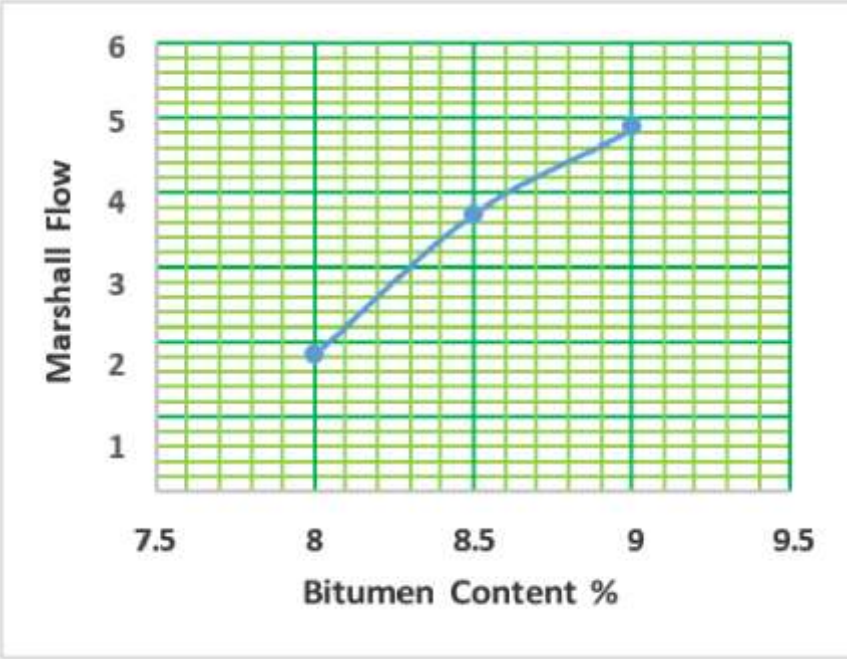


Fig. 2. Variation of Marshall flow with bitumen content

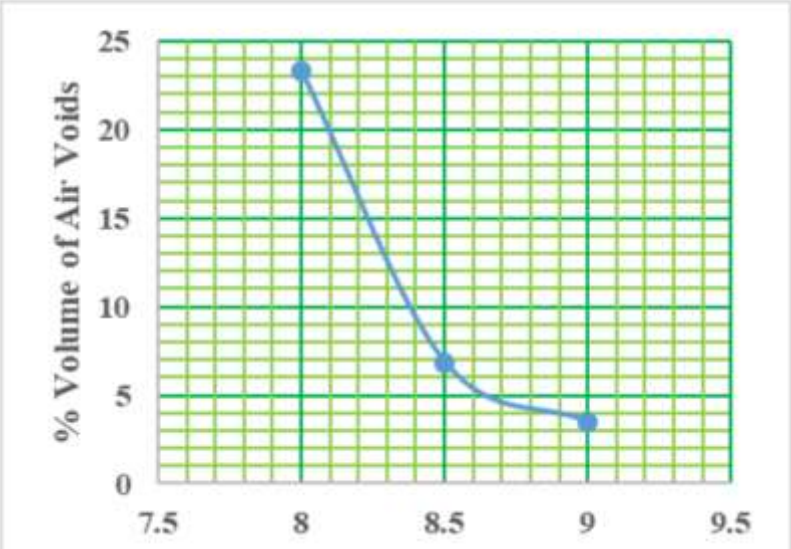


Fig. 3. Variation of air-void content with bitumen content

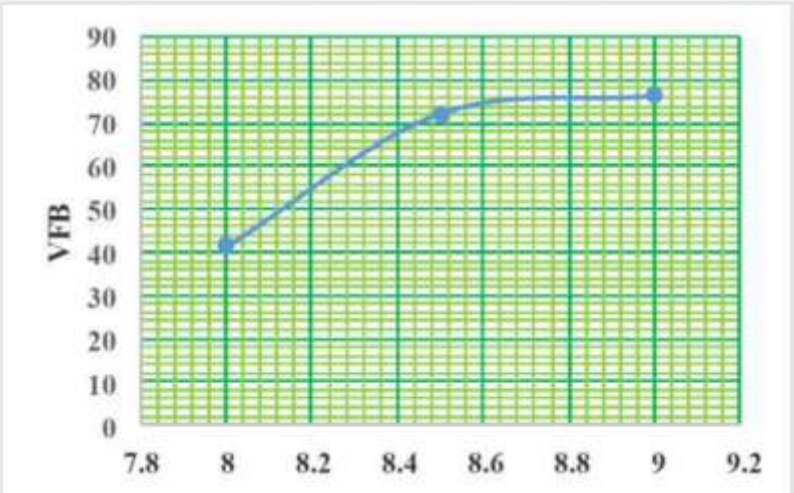


Fig. 4. Variation of voids filled with bitumen (VFB) with bitumen content

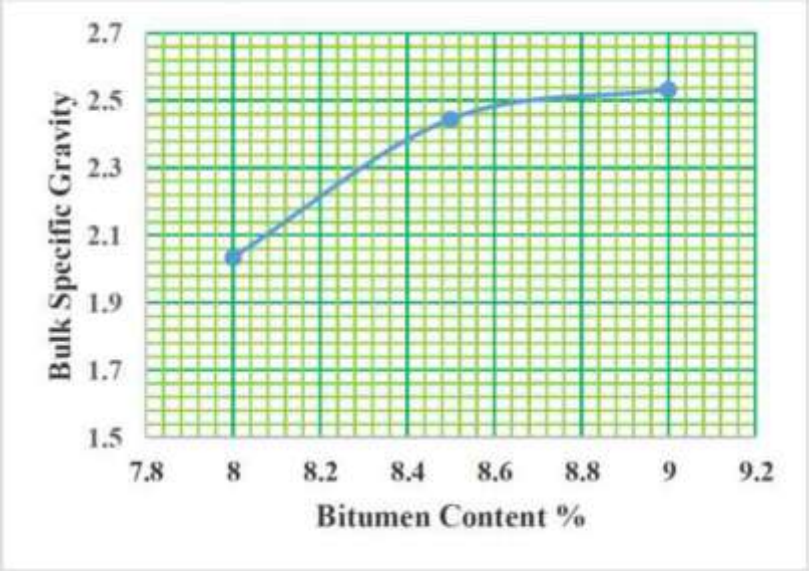


Fig. No.: 6 Bitumen content vs Bulk Specific Gravity

Fig. 5. Variation of bulk specific gravity with bitumen content

4.3 Comparison with specification and engineering implications

The project report includes a comparison table against IRC/MORTH requirements and cites IRC 94-1966 specifications for the Marshall mix. It subsequently states that the dense bituminous mix prepared using the selected polymer-coated aggregates did not satisfy the prescribed IRC conditions. This is a central result and should not be obscured by the improvements observed in individual aggregate tests. Improved aggregate abrasion or impact resistance does not automatically guarantee acceptable mixture-level stability, flow, air voids, VMA, VFB or other design requirements.

The report further indicates that plastic incorporation may reduce pavement construction cost. Nevertheless, no detailed bill of quantities, unit-rate schedule, cost comparison, sensitivity analysis or life-cycle cost calculation is provided in the supplied report. Consequently, the economic benefit remains a qualitative observation rather than a quantified outcome. Similarly, no field trial, wheel-tracking test, moisture-conditioned mixture test or long-term durability assessment is reported in the experimental results presented here.

5. CONCLUSIONS

The following conclusions are drawn strictly from the experimental information documented in the project report:

1. Polymer coating was successfully applied to aggregate surfaces using the dry process described in the project.
2. The reported abrasion-test series (0–8% coating) shows lower Los Angeles abrasion values for coated aggregates than for the uncoated sample; the lowest reported value is 7.60% at 8% coating.
3. The separate source-specific results in the report describe reductions in abrasion, crushing, impact and water-absorption values at coating levels of 0.5%, 1% and 2%. These data indicate potential improvements in selected aggregate properties, but they represent a separate dosage series and should not be merged with the 0–8% table.
4. For the three Marshall binder contents tested, the maximum reported stability is 2627 kg at 8.5% bitumen. Stability decreases to 2410 kg at 9.0%, while the plotted flow value increases with binder content.
5. The optimum bitumen content cannot be independently confirmed because the numerical contents of the OBC parameter table are not available in readable form in the report.
6. Most importantly, the project report states that the final dense bituminous mix prepared with the selected polymer-coated aggregates did not satisfy the cited IRC requirements. The present findings therefore do not establish specification-compliant pavement mix performance.

REFERENCES

[1] H. Laldintluanga, Zorinkima, and R. Ramhmachhuani, “Enhancing the durability of bituminous concrete using plastic waste on soft rock aggregates,” Polymers, vol. 18, no. 7, Art. no. 813, 2026, doi: 10.3390/polym18070813.

[2] X. Wu, E. Jusli, W. Anggraini, R. P. Jaya, and X. Zhang, “Performance and environmental impacts of waste plastic-modified asphalt pavement: A comprehensive review,” Cleaner Materials, vol. 18, Art. no. 100357, 2025, doi: 10.1016/j.clema.2025.100357.

[3] O. Matre, V. Dhanuskar, and P. Sawarkar, “Utilization of waste plastics in road construction: Enhancing aggregate and bitumen properties for sustainable pavement development,” Advances in Transdisciplinary Engineering, 2025, doi: 10.3233/ATDE251274.

[4] M. L. Pallavi, S. Dey, G. T. N. Veerendra, S. S. A. B. Padavala, and A. V. P. Manoj, “Optimizing the bituminous pavement constructions with waste plastic materials improved the road constructions performance and their future applications,” AI in Civil Engineering, vol. 3, Art. no. 16, 2024, doi: 10.1007/s43503-024-00035-5.

[5] R. P. Ashish, P. Kumar, S. Sreeram, A. Xu, X. Chandrasekar, P. Jagadeesh, A. Adwani, and R. K. Padhan, “Closing the loop: Harnessing waste plastics for sustainable asphalt mixtures—A comprehensive review,” Construction and Building Materials, vol. 400, Art. no. 132858, 2023, doi: 10.1016/j.conbuildmat.2023.132858.

[6] R. Xiao, Z. Shen, P. Polaczyk, and B. Huang, “Thermodynamic properties of aggregate coated by different types of waste plastic: Adhesion and moisture resistance of asphalt-aggregate systems,” Journal of Materials in Civil Engineering, vol. 35, no. 8, 2023, doi: 10.1061/JMCEE7.MTENG-15679.

[7] M. A. Rabby, M. Alam, T. K. Ray, and J. Bari, “Reusing waste plastics in aggregate for road construction,” in Proc. Int. Airfield and Highway Pavements Conf., 2023, doi: 10.1061/9780784484906.012.

[8] A. Noor and M. A. U. Rehman, “A mini-review on the use of plastic waste as a modifier of the bituminous mix for flexible pavement,” Cleaner Materials, vol. 4, Art. no. 100059, 2022, doi: 10.1016/j.clema.2022.100059.

[9] S. Karmakar and T. K. Roy, “Influence of plastic waste on chemical and mechanical properties of modified bitumen used in the bituminous mix for flexible pavement,” Journal of Materials in Civil Engineering, vol. 33, no. 2, Art. no. 04020440, 2021, doi: 10.1061/(ASCE)MT.1943-5533.0003545.

[10] S. L. Hake, R. M. Damgir, and P. R. Awsarmal, “Utilization of plastic waste in bitumen mixes for flexible pavement,” Transportation Research Procedia, vol. 48, pp. 3779–3785, 2020, doi: 10.1016/j.trpro.2020.08.041.

[11] S. G. Dhundalwar, A. Moon, V. C. Patle, and S. K. Jaiswal, “Use of plastic waste in bituminous road construction,” pp. 3637–3644, 2017.

[12] P. Singh and R. R. K. Yadav, “Effect of plastic waste on properties of road aggregate,” IJIRST—International Journal of Innovative Research in Science and Technology, vol. 2, no. 11, pp. 2012–2015, 2016.