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Machine-Learning Prediction of Marshall Mix-Design Properties and Mechanical Characterization of DCR-Treated Asphaltic Concrete

[IIUM Engineering Journal](#) • Article • 2026 • DOI: 10.31436/ijumej.v27i3.4533 [Kamaruzaman, Nur Atikah](#)^a; [Wan Azahar, Wan Nur Aifa](#)^a [Nadimalla, Altamashuddin Khan](#)^{a, e}; [Kasim, Norhidayu](#)^a; [Masjuki, Siti Aliyyah](#)^a; [+3 authors](#)^a Department of Civil Engineering, Kulliyah of Engineering, International Islamic University Malaysia, Jalan Gombak, Kuala Lumpur, 53100, Malaysia[Show all information](#)

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Abstract

Marshall mix design remains the dominant empirical framework for proportioning hot-mix asphalt, and coconut-derived by-products such as Desiccated Coconut Residue (DCR) have attracted interest as sustainable bitumen modifiers. Determining the optimum bitumen content (OBC) and characterizing mechanical performance is laboratory-intensive, which motivates data-driven prediction. This study evaluated whether regression models can predict six Marshall responses for DCR-modified asphalt concrete and characterized the mechanical performance of the modified mixtures at their respective OBC. Thirty averaged Marshall records covering bitumen contents of 4–6%, two gradations (AC14, AC20), and three treatments (Control, untreated DCR, treated DCR) were modeled using eight algorithms and a quadratic response-surface baseline. Models were assessed by

pooled out-of-fold prediction under random K-fold, leave-one-mixture-out, and leave-one-bitumen-level-out validation. For the AC14 mixtures, OBC values were 5.30% (Control), 4.95% (untreated), and 5.10% (treated); resilient modulus, indirect tensile strength (ITS), tensile strength ratio (TSR), and dynamic creep were measured for each mixture prepared at its own OBC. Pooled out-of-fold R^2 reached 0.89 for voids filled with bitumen, 0.88 for air voids, 0.83 for bulk density, 0.81 for voids in mineral aggregate, 0.53 for flow, and 0.49 for stability. The quadratic response surface matched or exceeded the machine-learning models on four of six responses. Under leave-one-mixture-out validation, R^2 became negative for most responses, whereas leave-one-bitumen-level-out validation retained R^2 of 0.47–0.91. The models are therefore interpolation tools within the tested design space rather than general predictors. The untreated mixture required the lowest binder content, and the treated mixture recorded the highest dry ITS (1,148.7 kPa) and TSR (50.3%), although all mixtures fell below common TSR acceptance limits despite the hydrated-lime filler. Copyright © 2026 IIUM Press This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License. <https://creativecommons.org/licenses/by-nc/4.0/>

Author keywords

Asphalt mixture; Cross-validation; Desiccated coconut residue; Indirect tensile strength; Machine learning; Marshall mix design; Response surface

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