# Abstract

The skid resistance of pavement surfaces is a crucial factor in road safety, particularly in wet conditions. The texture of the pavement surface, including macrotexture and microtexture, plays a significant role in controlling skid resistance. This study aims to investigate how the mineralogical and morphological properties of coarse aggregates affect the macrotexture and microtexture of bituminous pavement surfaces, and subsequently impact initial and long-term skid resistance. Additionally, the study proposes image-based indicators for microtexture and macrotexture that can predict the initial skid resistance of a bituminous pavement surface a few months after construction.

Aggregate samples were collected from fourteen quarries in West Bengal and neighboring states in India. The mineralogical parameters of these aggregates were analyzed using optical microscopy, SEM, and SEM EBSD techniques. The study evaluated the influence of these mineralogical parameters on microtexture and microtexture deterioration, using Polished Stone Value (PSV) and polishing resistance as indicators. Image-based indices for macrotexture and microtexture were identified through statistical and transform-based analyses on aggregate images. These indices were compared with direct indicators of microtexture and macrotexture. Based on the outcomes of image processing, shape, angularity, and surface texture indicators were proposed to predict the initial skid resistance of the pavement surface. Two models were developed: one for predicting skid resistance based on aggregate properties for pavements yet to be constructed, and another for predicting skid resistance based on pavement surface macrotexture for already constructed pavements. Skid resistance data was collected from eleven pavement sections constructed using the investigated aggregates and mixes to develop these models. The skid resistance data (SR50) was measured using Skiddometer BV 11, a continuous friction measuring equipment, at a test speed of 50 km/h with a 1mm water film thickness on the pavement surface after about three to six months of construction.

The study evaluated the polishing behavior of aggregates through accelerated polishing tests, measuring the British Pendulum Number (BPN) and PSV according to BSEN-1097-8. Results showed that granites and igneous aggregates exhibited good resistance to polishing, while aggregates with altered minerals showed poor polishing resistance. Correlation analysis indicated that mineralogical parameters such as Relative Hardness (RHD), Differential Hardness (DH), and degree of alteration (DA) influenced microtexture deterioration (i.e., degree of polishing) and PSV. Aggregates with a higher proportion of fine grains demonstrated greater resistance to polishing. Statistical analysis revealed that a wide variation in grain size positively contributed to resistance against polishing.

Various image texture analysis methods were evaluated to identify a reliable indicator of aggregate surface microtexture. These methods included traditional statistical approaches like the grey-level intensity histogram method and Grey Level Co-occurrence Matrix (GLCM), as well as transform-based wavelet texture analysis. Grey-scale SEM images of aggregates captured before and after accelerated polishing were used for image analysis. Correlation analysis indicated that the wavelet-based surface texture index (STI) provided a more accurate quantification of microtexture compared to statistical methods.

To quantify aggregate parameters affecting pavement macrotexture, image processing techniques were applied to images of individual aggregate particles. The roundness of the aggregates, derived from aggregate images, was considered as the shape index (SI). The roundness was determined as the ratio of the maximum inscribed circle radius to the minimum circumscribed circle radius for each aggregate particle. The boundary coordination points of the aggregate image were detected using the Voronoi diagram concept and Welzl algorithm to find the inscribed circle and circumscribed circle, respectively. The angularity index (AI) was obtained through the differential radial distance method, measuring the length of the line connecting the particle center to its boundary points. Additionally, the Weibull cumulative distribution function was used to describe the gradation characteristics of asphalt

mixes, with shape parameter (α) and scale parameter (β) effectively differentiating between dense graded and gap-graded mixes. The study showed that by combining these parameters with microtexture, accurate prediction of initial skid resistance before pavement construction was possible.

To determine the skid resistance of newly constructed pavements, this study suggests using the Surface Macrotexture Index (SMI) as an indicator of pavement surface macrotexture. The SMI can be obtained by analyzing pavement surface images taken at a constant traffic speed, offering a simple and cost-effective method to measure macrotexture using images collected during normal traffic conditions. In order to compare the SMI with commonly used macrotexture indices, the study gathered macrotexture data, such as Mean Texture Depth (MTD) from the sand-path test and Mean Profile Depth (MPD) from laser-sensor-based measurements, at the image locations of pavements constructed with commonly used surface course mixes in India. By applying wavelet transform-based image texture analysis, the study compared the SMI derived from this analysis to the MTD and MPD data, showcasing its accuracy as an indicator of pavement surface macrotexture. To address outliers in the SMI data resulting from isolated spots with dirt, pavement markings, or wet surfaces, an unsupervised machine learning algorithm was proposed to identify and replace these outliers. Reliable relationships were established between the proposed SMI and MTD/MPD, enabling predictions of the commonly used pavement surface construction quality measure (MTD) and the network-level skid resistance indicator (MPD).

The study further proposed statistical models for predicting the initial skid resistance (SR50). The analysis revealed that macrotexture parameters play a more significant role than microtexture parameters in determining SR50, which can be attributed to the test conditions under which the skid resistance values were measured. The macrotexture component dominates skid resistance on wet pavement surfaces and at relatively higher test speeds.

In summary, this research emphasizes the impact of aggregate mineralogical and morphological properties on microtexture and macrotexture, and subsequently on the initial and long-term skid resistance of pavement surfaces. The proposed image-based indices offer a promising tool for predicting skid resistance and identifying factors that influence pavement performance. These findings can contribute to the development of improved pavement design and maintenance strategies, enhancing skid resistance and improving road safety.