In order to obtain the mechanical characteristics of **asphalt mixture in micro / meso-scale**, the components of the asphalt mixture, such as aggregates, air-voids and asphalt mastic, were deeply investigated in terms of the following aspects.

Morphology of aggregates The morphological characteristics including sphericity, angularity and texture are the most important parameters of an aggregate and have a decisive influence on interlocking, force transmission and the compaction as well as the performance characteristics of asphalt and concrete mixtures. Therefore, many phenomena (e.g. the fatigue resistance, deformation, low temperature cracking) with an influence on the durability of roads can be linked to morphological characteristics of aggregates. Furthermore, the morphological characteristics are the most important input values for pavement modelling with numerical methods, e.g. DEM. The morphological characteristics of 11 types of aggregates were investigated by X-ray Computed Tomography (XCT) in two-dimension and three-dimension. In order to simulate the polishing process for the road surfacing aggregates, Micro-Deval test (MD) polishing was carried out. The aggregate's morphological properties before and after MD testing were characterized by various parameters calculated from AIMS and XCT. Changes of the aggregates' morphological properties (angularity, sphericity and texture) due to polishing were described with log-normal distribution functions. The correlations between mass loss and change of morphological characteristics were described using multiple regression analyses. The knowledge obtained from these studies represents an important step with regard to the quantitative evaluation of the MD test and the assessment of the polishing resistance of road surfacing aggregate. Furthermore, the results contribute to the further development of DEM approaches and explain the variation of performance characteristics of the roads.

Influence of air-voids on fatigue damage of asphalt mixture Fatigue damage caused by vehicle loads is the main asphalt pavement distress, and it deteriorates the serviceability and strength seriously. In order to evaluate the fatigue damage of asphalt mixture under repeated load, microstructures were detected to investigate the morphology change of internal structures using Digital Image Processing (DIP). Test track was built and cores were drilled to slice into test specimens with different air-voids that can reflect the real internal state of asphalt pavement. Fatigue properties were measured under temperature -10°C, 0°C and 10°C respectively, the frequency of sinusoid load was 0.1 Hz, the minimum value was 0.035 MPa and maximum value was 0.5 MPa. Internal structures of asphalt mixture were scanned by XCT device before and after fatigue damage, thus the relationship between microstructures and fatigue damage was conducted. The results show that microstructural analysis can effectively determine the internal structure change of asphalt mixture. Changing compaction causes different air-voids distributions and morphologies, which have obvious influence on failure state of asphalt mixture. The effect of temperature and initial air-voids on fatigue performance is significant, and fatigue damage presents a linear relation with the complexity of air-voids. Methodology established in this paper provides an effective method for fatigue damage assessment.

Influence of aggregates' spatial characteristics on air-voids in asphalt mixture Air-void significantly affects the strength and durability of asphalt mixture. To better understand the influencing factors of air-voids, a study was carried out, in which one group of specimens with different aggregate gradations were fabricated at the same experimental situations and evaluated at first, and then another group of specimens with the same aggregate gradation were drilled from test track and used to investigate the effect of compaction energy on air-voids. The internal structures were obtained by XCT device, and DIP technology was used to extract and reconstruct the spatial models of aggregates and air-voids based on original CT images. Influence of aggregates and compaction energy on air-voids was studied; the results show that 3D fractal dimension provides a quantitative value of presenting the complexity of microstructures' morphology, it comprehensively reflects the volume, shape and distribution of aggregates and air-voids; aggregates' angularity has a significant effect on air-voids, and compaction energy causes different characteristics of air-voids as well. Methodologies developed in this study are effective to evaluate the influence of aggregate particles on air-voids.

FE Simulation of asphalt compression behavior in microscale The microscale FE models of asphalt mixtures with heterogeneously internal structures were constructed to simulate the asphalt compression behavior. Experimental investigations have implied that morphological properties of aggregate have a great impact on the performance of asphalt mixtures. In this study, the microstructural model of asphalt mixture was reconstructed based on XCT scans, thus maintaining the original morphology of the aggregate. Then the angularity of the aggregate was decreased artificially while the other features of the asphalt mixture remained constant. Based on these microstructures three dimensional FEM with different aggregate angularities were created followed by a simulation of a uniaxial compression test. The relationship between aggregate angularity and mechanical responses of the asphalt mixture, such as load-carrying capacity, creep deformation of the asphalt mastic, damage behavior and energy dissipation were investigated. The computational results indicate that the aggregate angularity significantly affects the mechanical responses of the asphalt mixture; some initial relationships were set up with high degrees of determination.

Polishing behavior of road surfacing aggregate The exact mechanisms as to how petrographic properties of aggregate influence the polishing behavior quantitatively were identified. Since the aggregate is composed of the different rock-forming minerals, the analyses conducted in this research focused not only on the aggregate but also on crystals/minerals. The hardest and most abundant rock-forming minerals found on earth – quartz and feldspar – were investigated with polishing tests with the Aachen Polishing Machine (APM) on granite aggregates from four sources which exhibit different mineralogical properties. Changes of the aggregate texture and minerals were studied based on texture measurements and skid resistance measurements obtained by means of the Pendulum Test and the Wehner/Schulze device. The influences of mineral composition and crystal size on the changes of the micro-texture and skid resistance of the aggregates were determined by comparing the four granites. The polishing and wearing behavior of quartz and various feldspars (albite, microcline and plagioclase) were characterized quantitatively by means of a spectral analysis and abrasion analysis. The results show that aggregates with almost identical polishing resistances may exhibit different wearing resistances. When choosing an aggregate for a road surface one must take into consideration that a low wearing resistance can lead to higher fine dust emissions.

Wearing behavior of road surfacing aggregate The amount of urban dust and especially the particulate matter (PM) production is closely related to the wearing resistance of the aggregates on the road surface. The APM was used to conduct wearing tests. The obtained results were analyzed with a rubber-road wearing model. Based on the spectral analysis of the texture, the wave length coinciding with the most wear of the specimen surface was identified. Findings show that the decrease of skid resistance can be ascribed to changes in the micro-texture up to 62.8 µm in the polishing test with the APM procedure. The final friction after polishing tests exhibits a positive correlation with the average hardness of the aggregate and the mass percentage of non-fissile mineral. A positive interdependence is observed for the quartz content whilst the calcite content exhibited a negative one. The average height induced by polishing is selected to determine and quantify the abrasion of aggregate. The results show a directly proportional relationship between the abrasion and the contact pressure.

The conclusions from these studies are capable of offering useful information for the tire-pavement interaction model in macroscale.

Development of Semi-Analytical Finite Element Method To effectively investigate the mechanical performance of asphalt pavements in macroscale, software named SAFEM with a user friendly graphical user interface (GUI) was developed. This FE code is able to verify the results derived from the macro-model. It is based on the semi-analytical finite element method, which is a three-dimensional FE algorithm that only requires a two-dimensional mesh by incorporating the Fourier series in the third dimension. SAFEM is able to analyze static and dynamic responses of asphalt pavements under stationary or moving loads. Besides linear elasticity, a viscoelastic material model for asphalt layers has also been integrated. Verification was carried out to test and explore the functionality of the software package. The study shows that SAFEM is an accurate tool for the fast prediction of asphalt pavement responses, such as the surface deflection and the strain/stress at response points.

Coupling method between the micro-model and macro-model The sequentially coupled numerical investigation of micro- and macro-model is realized by a programed interface, which organizes the exchange of required input and output data of the separate model. A moving load is applied on the macro-model of asphalt pavement. The micro-model of asphalt mixture is assumed in the loading path. The locations of nodes on the external surface of the micro-model are able to be determined in the macro-model. Thereafter the displacements from these locations in the macro-model are computed. As output of the macro-model, these displacements are transferred as input boundary conditions which are applied on the corresponding nodes on the external surface of the micro-model. The influence of the traffic loads on the internal structure of the asphalt mixture can thus be comprehensively investigated.