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International Journal of Pavement Research and Technology xxx (2017) xxx–xxx

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# Analysis of coarse aggregate performance based on the modified Micro Deval abrasion test

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Received 9 September 2016; received in revised form 13 June 2017; accepted 12 October 2017

**Abstract**

The anti-abrasion property of aggregate significantly affects the performance of the pavement. In this research, the quartzite and gneiss which were produced in Lincheng County, Xingtai City, Hebei Province were selected as test samples. According to the American Society for Testing and Materials standard, the Micro-Deval abrasion test was taken every 1000 rotation times until 20,000 times, and the change trend of the Micro-Deval abrasion value was obtained. Results showed that the abrasion values were in the exponential growth rate rather than linear rate. Their R-Square coefficient was 0.99142 and 0.99916 respectively. The gravel information such as area, roundness, diameter, perimeter and so on were calculated and analyzed by Image-Pro Plus software, which provided a rapid way for the 2D morphology characteristics analysis of the coarse aggregate.


*Keywords:* Micro-Deval abrasion test; Coarse aggregate; Anti-abrasion property; Abrasion values

## 1. Introduction

The rapid development of highway brought us efficient and convenient life, but at the same time more and more traffic accidents happened. A lot of research data showed that the moisturized road accidents were closely related to the anti-abrasion property of pavement [1]. There were many factors that affect the skid resistance performance of asphalt pavement. It mainly included the stone properties and particle size distribution. They could also affect the microstructure and macrostructure of pavement. The abrasion value of aggregate was one of the main factors that affect the microstructure of pavement. It was also an important reference index in pavement design. The physical and mechanical properties of coarse aggregates were directly related to the skid resistance performance of pavement. It was required that the coarse aggregates used in the pavement had high abrasion resistance ability that could resist the impact of driving, crushing and abrasion. Therefore, it was necessary to carry out a detailed research work on the skid resistance performance of the aggregate, so as to better determine the real property of the aggregate.

Aggregate is widely used in civil engineering and road engineering. It existed as skeletons that will fill in the asphalt mixture, including the rubble, gravel and machine-made sand, crushed stone, sand and so on [2]. According to the test methods of Aggregate for Highway Engineering (JTG E42-2005) published by Ministry of

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Peer review under responsibility of Chinese Society of Pavement Engineering.

https://doi.org/10.1016/j.ijprt.2017.10.007
1996-6814/

Please cite this article in press as: J. Wu et al., Analysis of coarse aggregate performance based on the modified Micro Deval abrasion test, Int. J. Pavement Res. Technol. (2017), https://doi.org/10.1016/j.ijprt.2017.10.007

Communications of the PRC, coarse aggregate referred to gravel, crushed gravel, screening gravel, slag and so on. The particle size was greater than 2.36 mm in the asphalt mixture. The researchers in different countries used different technical indexes and test methods to measure abrasion value, such as Deval abrasion method, Los Angeles abrasion method and Dorry integrate test. Due to the impact value, Dorian abrasion value and Los Angeles abrasion value had a strong correlation, the coarse aggregate abrasion value was widely used in China as one of the most important mechanical indexes of road building and designing, to reflect the rutting resistance, abrasion resistance and durability of asphalt concrete pavement. However, this method had its own defects when the Los Angeles abrasion value was only used in the test. Los Angeles abrasion test obtained aggregate abrasion value in dry condition considering the impact of steel ball and the aggregate. It could identify the property of impact resistance, edge shear and friction resistance, rather than pure abrasion [3]. The abrasion mode couldn't truly reflect the abrasion resistance ability of aggregate. It could indirectly reflect the abrasion effect between tires and pavement. The dry condition was not consistent with the actual environment of the aggregate. It had been proved that water was one of the main reasons for the failure of asphalt concrete pavement. Water could invade the interface between aggregate and asphalt which led to the loss of adhesion and the loss of asphalt concrete pavement [4]. It was difficult to avoid water during the pavement service due to the rain soaked, snow and ice melt and so on. Thus, it was necessary to conduct research on the anti-friction performance of aggregate in moisturized condition.

There were different test conditions and results between Micro-Deval abrasion test and Los Angeles abrasion test although they were both abrasion tests. It meant that they couldn't replace each other and needed to be selectively used in a certain range [3]. Compared to the Test Methods of Aggregate for Highway Engineering (JTJ 058-2000), the biggest difference in ASTM D6928-10 was the moisturized environment of aggregate abrasion testing. Compared to several other measurements of aggregate performance test, Micro-Deval abrasion test could better reflect the anti-abrasion properties of gravel which could be used to study the properties of some rocks that have been weakened in the moisturized condition. Richard et al. (1997) considered that Los Angeles abrasion test was not very good to distinguish the materials because it was easily broken in moisturized condition and cannot establish a good relationship with the service performance of the aggregate. But the Deval abrasion test can distinguish properly aggregates [5]. Cooley et al. (2002) described the durability of stone according to Deval abrasion test results, and found that this test can distinguish different kinds of rocks efficiently even though they had the same performance. Their test results were different due to the different mineral composition [6]. Takarli (2009) got the relationship between the wear coefficient and mineral composition of rock using the modified Deval test. It showed that there was a close relationship between the main mineral composition and the wear resistance of the rock [7]. Wang et al. (2015) selected 48 particles from each type of aggregate and used the Aggregate Imaging System (AIMS) and X-ray Computed Tomography (XCT) equipment to capture the changes in their morphological characteristics, including sphericity, angularity and texture, established a correlation between the Micro-Deval test results and their morphological properties for 11 different aggregates [8]. Ivan Deiros et al. (2016) adopted discrete element method (DEM) simulations of Micro-Deval attrition test to detect the different loading and wearing mechanisms and quantify the amount of friction work [9].

Thus, Micro-Deval abrasion test had its own advantages in the measurement of anti-abrasion property of aggregate. It could distinguish aggregate performance in the moisturized condition better. It was helpful to better evaluate the material service performance in the practical application such as road engineering, civil engineering and so on. According to the standard of American Society for Testing and Materials (ASTM), we adopted modified Micro-Deval abrasion test and analyzed the anti-abrasion performance of aggregate in moisturized condition, and obtained the shape characteristics of gravel and sand. It provided a new method to analyze the aggregate's physical properties and morphological characteristics.

## 2. The principle and process of Micro-Deval abrasion test

Micro-Deval abrasion test was a method to measure the gravel durability which was proposed in the 1960s in France. It evaluated the anti-abrasion resistance and durability of aggregate by measuring the mass change in the aggregate using steel ball in water. Many aggregates could be scuffed easily in a moisturized condition than in a dry condition. Compared to other tests (such as the Los Angeles abrasion test), it could reflect the anti-abrasion performance of aggregate better and had a higher discrimination. It could also simulate the physical weathering process of rocks in moisturized condition.

In this research, the Micro-Deval abrasion testing machine was chosen to do the test according to the standard of ASTM D6928-10 [10], as shown in Fig. 1. The steel ball was used to abrade the aggregate, and the diameter of each ball was 10.0 mm and its mass was 4.15 g. Before experiments, the selected gravel was put into water for 1 h, then the soaked rock, 2 L water and 5000 g steel ball were put together in the jars, rotating at the speed of 30–33 rpm. A test measurement was taken every 1000 rotation times. After the test was completed, the steel balls were removed from the aggregates immediately by moisturized method without losing any material, filtering out the gravels whose grain size was smaller than 1.18 mm. The gravels were dried in the convection oven at a constant temperature of 105 ± 5 °C until a constant quality was obtained.

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