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Comparative evaluation of designing asphalt treated base mixture with composite aggregate types

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HIGHLIGHTS

- Composite aggregates is effective way to solve aggregate shortage in mixture design.
- Effective density should be used in the mixture design with composite aggregates.
- Composite aggregate changes volumetric properties of composite asphalt mixtures.
- Alkaline coarse aggregates improve mechanical properties of asphalt treated base.
- Mixture with composite of basalt and limestone has better moisture resistance.

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ABSTRACT

This study aims at investigating the possibility of using basalt, limestone and andesite aggregates combinations in asphalt treated base mixture. Rapid developing of asphalt pavement construction results in the lack of high quality aggregates and environmental damage. Using the composite aggregates in asphalt mixtures is an effective way to solve problems of aggregate shortage and minimize the environmental depredation.

Two types of composition methods, Coarse-Fine (C-F) composition method and Coarse-Coarse (C-C) composition method, were proposed and studied. Effective density was used in the mixture design to improve the accuracy on using composite aggregate. Research results illustrate that composite aggregate will change the volumetric properties of composite asphalt mixtures. The incorporation of alkaline coarse aggregates or surface roughness coarse aggregates on the aggregate can improve the mechanical properties of asphalt treated base. Asphalt mixture with composite of basalt and limestone aggregates can significantly enhance the moisture resistance property. Changing the types of coarse aggregates will result in more variables than changing the fine aggregates types.

1. Introductions

Asphalt concrete pavement has the advantages of fast laying, easy maintenance and comfortable driving. So more than 90% of highways are asphalt concrete pavement world widely. Mineral aggregates, which play an important role in the structure of asphalt pavement, consist more than 90% by weight in asphalt concrete [1,2]. Therefore with the developing of asphalt pavement construction, lots of high quality aggregate has been mined. This situation leads to the lack of high quality aggregates and environmental damage [3–5]. Using the composite aggregate in asphalt mixtures can effectively alleviate the aggregate shortage and minimize the environmental depredation.

Composite aggregate design is a newly developed method that prepares asphalt mixture by combining two or more types of aggregate, instead of using only one kind of aggregate in the traditional asphalt mixture [6,7]. Research on composite aggregate design in asphalt treated base is relatively rare [8,9]. The research of composite aggregate is mainly concentrated in the asphalt mixtures with the largest nominal particle size less than 20 mm [10].

Traditionally, basalt, andesite and limestone aggregates are the three most widely used aggregates in asphalt pavement. They are used individually in asphalt pavement design to ensure homogeneous mixing and stable skeleton structures [11].

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Basalt is a mafic extrusive rock. It is the most widespread of all igneous rocks, and comprises more than 90% of all volcanic rocks. It has relatively low silica content. Andesite is an extrusive rock intermediate in composition between rhyolite and basalt. It is the volcanic equivalent of diorite. It can be used as aggregate and filler in the construction and pavement industries, but is not an ideal concrete aggregate because of its high silica content.

Limestone is a very common sedimentary rock and composes half of Calcium oxide (also called lime, CaO). Limestone is popularly used for roads, building construction and cement manufacture, due to its characteristics of long-lasting and stands up well to exposure. However, though the limestone used for construction is good for humid climates [12,13], it is vulnerable to acids, making acid rain a problem when it occurs in places where limestone is used extensively. The acids in the water can result in seriously problem on limestone based pavements.

The feasibility of using composite aggregate in asphalt mixture has been well evaluated in literatures. Results showed that using composite aggregate in asphalt mixture properly, can improve the mechanical characteristics [14,15]. On the one hand, the chemical composition of aggregates has a great influence on asphalt mixture. Using Limestone fine aggregates in Basalt asphalt concretes can provide a better performance of moisture stability, as well as deformation and crack resistance [16]. On the other hand, the coarse aggregate's shape and texture are also play an important role in asphalt concretes. Aggregate's angularity determines whether the hot mix asphalt (HMA) mixture has a good stable ripple structure. More needle-like content in aggregate will destroy the structure of the asphalt mixture [17].

Wu et al. discussed the gneiss-limestone composite aggregates. The research showed that the alkalinity of limestone aggregates can enhance the moisture stability of gneiss based asphalt mixture [18,19]. The use of limestone fine aggregate in gneiss based asphalt concretes can also improve the mechanical properties [20]. Xie et al. studied the use of limestone fine aggregates in granite asphalt concretes. Their study focused on moisture stability and fatigue properties and how to improve these properties by optimizing the replacement percentage of fine aggregate by limestone. Results showed that using limestone fine aggregate and active or powders can effectively improve the moisture stability of asphalt mixture [21,22].

Huang et al. discussed the composite aggregates in Stone Matrix Asphalt (SMA). They compared three kinds of aggregates which are Limestone, basalt and dolerite [23]. Results showed that the performance characteristics of three aggregates are different and the traffic resulted forces are also different based on molding analysis. The compactibility of the asphalt mixture using limestone aggregate is the best and its porosity is the lowest. The road performance of limestone SMA asphalt mixture is especially excellent in moisture stability and rutting resistance. However, the composite aggregate methods used in the literatures were designed with volumetric ratio. The influence of density differential was underestimate or even ignored, which consequently reduced the accuracy of research results [24–26].

In this research, effective density is first introduced to for designing asphalt mixture with composite aggregate. Three widely used aggregates, including basalt, andesite and limestone aggregates, are detailed studied by coarse-coarse aggregate composite method and coarse-fine aggregate composition methods. Both volumetric and mechanical properties are studied to evaluate the aggregate size dependence and density dependence during composite aggregation design.

2. Materials

2.1. Aggregates

Three types of aggregates, basalt, limestone and andesite, were used in this research. The basalt and limestone aggregate materials were obtained from Xilin Hot in Inner Mongolia, while the andesite aggregate was obtained from a quarry in Hubei province in China. Table 1 compares the chemical compositions from X-ray Fluorescence analysis.

Naturally occurring aggregates of basalt, limestone and andesite are a mixture minerals with an orderly internal structure and a chemical composition that ranges within narrow limits, which is depending on origin. Table 1 shows that half of the chemical composition in basalt and andesite is SiO2, indicating these two types of aggregate are acid aggregate. While in limestone, the CaO consist more than fifty percent, making it as Alkali aggregate. Table 2 compares the basic engineering properties of three aggregates. They are all within the Chinese specification requirements.

As Fig. 1 shows, thin sections of investigated aggregates were first prepared to mineralogy analysis. Slices of aggregate are glued to a glass carrier and ground down to a thickness of less than 0.03 mm.

Fig. 2 Images of the investigated aggregates from optical microscope (Basalt: A-×200, B-×200; Limestone: C-×50, D-×100; Andesite: E-×100, F-×100) compares the optical microscopy analysis from specimens in Fig. 1. Graph A and B indicates that basalt consisted with porphyritic texture, including large olivine phenocrysts, small laths of plagioclase feldspar and volcanic glass. The limestone is present in a gray color and is composed of angular fragments of calcite and quartz, as graph C and D present. The used andesite in this research is composed of Amphibole and intermediate plagioclase feldspar. In graph E and F, the black phenocrysts are hornblende, the white crystals are plagioclase. The grayish areas between the phenocrysts display some tiny mineral crystals.

2.2. Bitumen binder and filler

Pen 80/100 bitumen binder was used in this research and its content is 3.7% in the asphalt mixture. Its characteristics were concluded in Table 3. Table 4 presents the features of the used filler in this research.

Table 1
Chemical composition in the investigated aggregates.

Composition [%]	MgO	Al_2O_3	SiO_2	CaO	Na_2O	Fe_2O_3	K_2O	loss
Basalt	4.34	18.65	46.54	7.73	3.87	11.52	2.25	1.27
Andesite	3.98	15.25	59.34	7.42	3.26	5.67	1.35	2.33
Limestone	2.36	0.85	0.86	52.02	0.04	0.12	0.03	42.93

Table 2
The basic engineering properties of the researched aggregate.

Parameter measured	Basalt	Andesite	Limestone	Requirements
Los Angeles abrasion (%)	10.2	10.9	11.5	≤28
Aggregate Crushing Value (%)	9.1	9.3	9.7	≤26
Flakiness and elongation (%)	13.2	8.5	10.5	≤18
Fine aggregate angularity (%)	42	36	42	≥30
Sand equivalent (%)	68.5	80.4	74.2	≥60