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Performance evaluation of porous asphalt with granulated synthetic lightweight aggregate

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Abstract

This paper presents the results of a laboratory study evaluating the mixture characteristics and durability of porous asphalt made with granulated synthetic lightweight aggregate (GSLA). Porous asphalt specimens incorporating 0%, 5%, 10%, 15% and 20% GLSA by volume as a coarse aggregate (retained on a No. 4 sieve) replacement were prepared. Test results indicating that GSLA exhibits well particle shape, lower specific gravity, higher soundness and higher water absorption than conventional crushed stone (CS) does. The mix design results showed that GSLA mixtures have high asphalt absorption due to porous nature of the GLSA as evidenced in scanning electron microscope (SEM) image. Compared with conventional CS mixtures in terms of skid resistance, permeability, particle loss resistance, moisture susceptibility and rutting resistance, the GLSA mixtures perform very favorably. The results show that the mixture of 15% GSLA replacement was determined to be the most suitable mixture.

Keywords: Synthetic lightweight aggregate; Porous asphalt; Performance evaluation; Mixture characteristics; Durability

1. Introduction

Taiwan has a unique geographical environment and topographical characteristics which is characterized by its steep mountains and rapid rivers. Reservoirs which regulate water and generate electric power become very important resources of water and energy supply in Taiwan. However, a large quantity of soil sediment has accumulated in reservoir due to flood scouring, erosion and typhoon induced debris flow. According to the report of statistical data from the Water Resources Agency, Ministry of Economic Affairs [1], around 20% of the 46 main reservoirs have soil deposits problems and the total volume of sediment is approximately 4.7 hundred million cubic meters. Furthermore, there is average sediment of 0.15 hundred million cubic meters increased in each year. Reservoir sediment is not suitable for land filling disposal because of the adverse effect on the environment. Thus, utilization of synthetic lightweight aggregate (SLA) manufactured from reservoir sediment may form an attractive alternative to land filling disposal in Taiwan and reduce the consumption of natural aggregate.

SLA usually is produced from expanded clay, shale, slate or by-products from rotary kiln process and must meet the requirements of ASTM C330. In general, the particle shape of SLA, which is nearly rounded and without any fractured faces, is not suitable for use in hot mix asphalt (HMA). Angular shaped particles which are preferred in HMA exhibit greater interlocking and internal friction, and result in greater mechanical stability than do rounded particles [2]. Recently, a new manufacturing process is developed to produce granulated synthetic lightweight aggregate (GSLA) and enhance the application of SLA in asphalt mixtures.

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GSLA not only has well particle shape and fractured faces, but also benefit from skid resistance. Several US highway agencies have reported that the GSLA used in chip seals has positive results [3,4]. Study also showed that GSLA has excellent potential for being used as 15% by weight of aggregate replacement of mineral aggregates in HMA appearing to be an optimum amount for use [5].

Porous asphalt, which was developed in Europe and has a porous structure, can reduce traffic noise, drain water from the pavement surface and reduce thermal conductivity. However, there is very few research focused on the topic of utilizing the GSLA in porous asphalt. Therefore, the objectives of this study were to evaluate the mixture characteristics and the durability of porous asphalt which used GSLA as coarse aggregate replacement for mixtures.

2. Materials and test methods

2.1. Aggregates and asphalt binder

The coarse GSLA used in this study was produced from sintering fine sediment excavated from reservoirs. A rigid coating of glazing shell on aggregates during burning process was formed to reach lower asphalt absorption and higher strength. After cooling process, the product was made into GSLA by the granulator as illustrated in Fig. 1. River crushed stone (CS) and crusher fines used as mineral filler were obtained from a local aggregate supplier. A styrene–butadiene–styrene (SBS) modified polymer asphalt binder was obtained from a commercial asphalt manufacturer.

2.2. Test program

The aggregate blending procedure of HMA presumes that all aggregates have the same specific gravity. However, when specific gravities of individual aggregates differ significantly (by 0.20 or more) they should be adjusted for specific gravity variation before blending to obtain correct volumetric proportions in the mixture [6]. The GSLA used in this study has a lower specific gravity (1.515) than that of natural CS (2.675). The blending of GSLA as a replacement of coarse CS aggregates was done on the volume basis to maintain the volumetric properties in target gradation. Porous asphalt specimens incorporating 0%, 5%, 10%, 15% and 20% GLSA by volume as a coarse aggregate (retained on a No. 4 sieve) replacement were prepared.

Fig. 1. The photograph of GSLA product.

The test flow chart in this study consisted of three tasks as illustrated in Fig. 2. Task I was to investigate the physical properties of aggregates (GSLA and CS) and asphalt binder. Task II was to perform the gradation design based on a theoretical particle packing method and the mix design of porous asphalt. Task III was to evaluate the mixture characteristics and durability of porous asphalt with and without GSLA. The fractured section of the GSLA mixture was further investigated to identify the microstructure of GSLA and asphalt binder.

2.3. Test methods

2.3.1. Skid resistance

Skid resistance was evaluated based on tests performed in accordance with ASTM E303 procedure. The British pendulum skid resistance device was used to measure the British Pendulum Number (BPN) value of the specimen.

2.3.2. Water permeability

Permeability test was conducted using a constant-head type equipment which developed by the Japan Road Association (JRA) [7]. The coefficient of permeability measured was corrected to a standardized value at 20 °C for the viscosity of the water. A minimum permeability coefficient of 10^{-2} cm/s is usually specified in order to ensure good performance of draining water from the road surface.

2.3.3. Particle loss resistance

The Cantabro test was used to evaluate the resistance to particle loss of the mixtures [8]. This test was carried out in Los Angeles abrasion machine without steel ball. A compacted specimen, unaged or aged, was tumbled inside the steel drum for 300 revolutions at a speed of 30–33 rpm. The specimen is weighed before and after the test, and the percentage loss by weight of original specimen is calculated as the Cantabro abrasion. Aged specimens were conditioned by placing in an oven at 60 °C for 168 h (seven days), and cooled to 25 °C and stored for 4 h prior to testing. The specifications of European require that the percentage loss by weight must be less than 25% for unaged specimens and 30% for aged specimens.

2.3.4. Moisture susceptibility

Moisture produces a loss of adhesion between the asphalt binder and the aggregate surface, and accelerates