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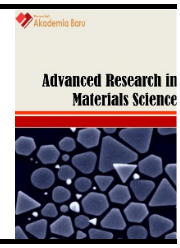

Marshall Properties of Asphalt Mixture Containing Garnet Waste

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ABSTRACT

Waste materials have become increasingly popular for recycling due to high awareness of the environmental impact of waste disposal. Numbers and amounts of waste materials produced increase yearly and Garnet waste is one of the industrial wastes that getting attention among the mining and blasting industries. Garnet is a group of silicate minerals. Its important properties such as angular fractures and relatively high hardness, specific gravity and resistance to degradation combined with its ability to be recycled make it desirable for many industrial applications. This study aims to investigate the potential of using garnet waste as fine aggregate replacement in hot mix asphalt for asphalt pavement. The Garnet was designed to replace up to 25% aggregate in the asphalt mixture of AC14 and compare with granite aggregate as conventional asphalt sample. The Marshall mix design method was undertaken for both mixture types and detailed Marshall properties were compared i.e. volumetric properties, optimum bitumen content, stability and flow. In addition, the Garnet waste was characterized for its size distribution and chemical composition. The results show that the performance of the garnet waste aggregate is within the specification and could be potentially used as aggregates replacement in hot mix asphalt.

1. Introduction

Previous researchers have proven that modified asphalt pavement using waste materials can improve the pavement performance and reduce the waste going to landfill as well as its impact to the environment [6, 3]. One of the waste materials known as “garnet” alludes all the aggregation from the complex silicate minerals, that had analogous lattice crystalline structures and varied chemical composition [4]. Garnets being the waste spin-off of surface treatment operations remain a major environmental concern worldwide [8]. Basically, the angular fractures and hardness properties of garnets together with their ability to be recycled make them advantageous for numerous abrasive functions. Garnets have major industrial uses such as water jet cutting, abrasive

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blasting media, water filtration granules, abrasive powders for antiskid surfaces, etc [5]. Abrasive blasting technique is used to prepare the surfaces for coating and painting [10]. This technique is used for the construction of vessels, ship maintenance and repair activities, Thus, blasting process creates massive quantities of exhausted garnet wastes mixed with surface components for example, paint chips and oil. A recent assessment on a Malaysian shipyard industry revealed that this country imported approximately 2000 million tons of garnets in the year 2013 alone and a large quantity was dumped as waste [8]. In addition, such garnet wastes make a sizable number of ecological and wellbeing dangers for example, when these materials would have entered the waterways throughout surge alternately through runoffs. However, Mior Sani [9] recommended it is safe to be used as subgrade material in road construction. Therefore, this study attempts to evaluate the performance of asphalt concrete with garnet waste as fine aggregate replacement and compared with the conventional dense graded asphalt with granite aggregate.

2. Materials and Methods

This study is designed according to Malaysian Public Works Department Specifications (JKR/SPJ/2008-S4).

2.1 Binder, Aggregate and Gradation

The materials used in this study includes bitumen type 60/70 PEN and aggregate granite type (coarse, fine, and filler size). The aggregates were blended with 2% hydrated lime by weight of the combined aggregates as an anti-stripping agent. Figure 1 shows the dense graded aggregate of asphalt mix with the nominal maximum aggregate size of 14 mm.

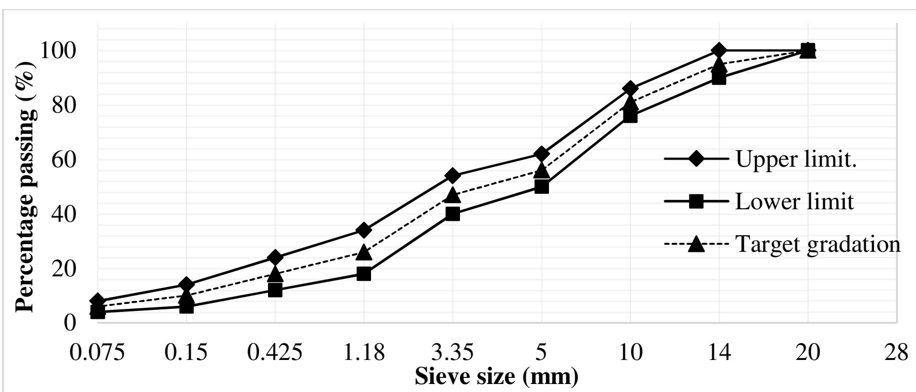


Fig. 1. Particle Size Distribution of Dense Graded Asphalt Mix (AC 14)

2.2 Garnet

The garnet was collected from southern Johor (Malaysia). The particle size distribution of the garnet after sieving was found less than 1.18 mm as shown in the Figure 2. Therefore, the garnet suits to replace the fine aggregate with approximately 25% from the total aggregate weight.

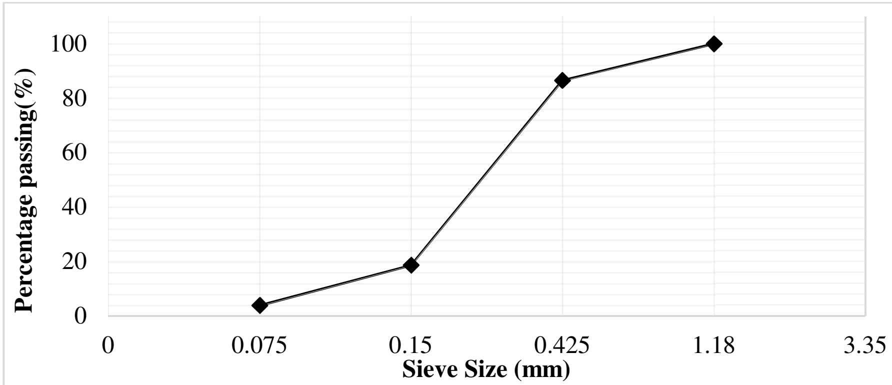


Fig. 2. Particle distribution of garnet waste

In addition, the chemical composition of garnet aggregate was determined using X-ray fluorescence. Figure 3 shows the details chemical composition of the garnet waste. From the figure it can be seen that SiO_2 and Fe_2O_3 are among the highest composition of the garnet particles. This could contribute to the hardness of its physical structure. On the other hand, the physical properties are summarized in Table 1. Overall, for pH this material behaves bases, very high temperature for melted, good hardness, low water absorption and high specific gravity more than normal aggregate.

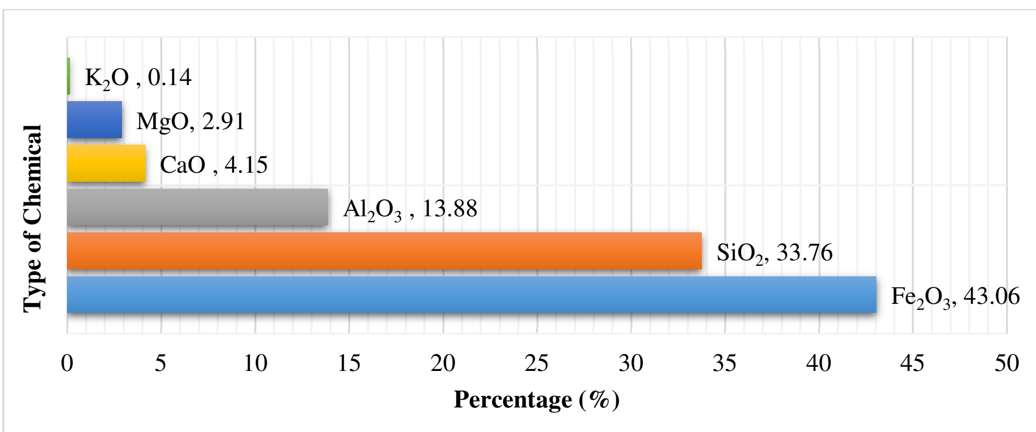


Fig. 3. Chemical composition of garnet waste

Table 1
Garnet physical properties

pH	Melting point	Hardness	Water absorption	Specific gravity
>7	Up to 1250°C	7.5-8.0	6%	2.900

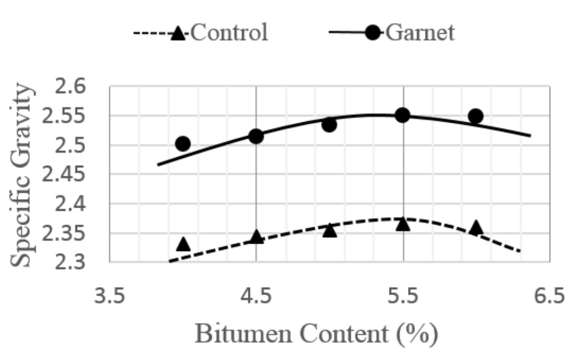
2.3 Mix Preparation and Marshall Test

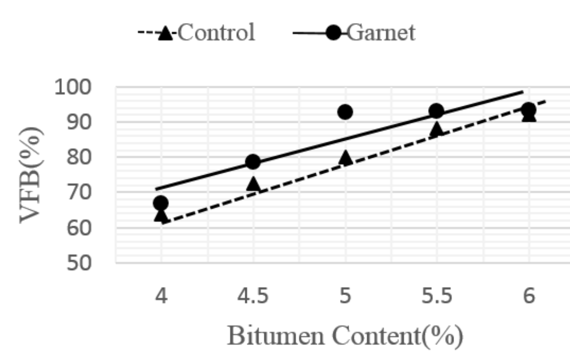
In this study, two groups of samples were prepared, one as conventional asphalt and second was modified asphalt with 25% garnet as fine aggregate. The Marshall mix design method was conducted by preparing the compacted samples within the range of bitumen content 4-6% at 0.5% increment.

The aggregate and bitumen were heated prior to mixing and compaction at the temperature of 175° and 190°C respectively. The loose mixes were compacted at 75 blows using standard Marshall hammer and allowed to cool overnight. The samples were then extruded from the mold and tested for specific gravity and Marshall stability tests to determine the volumetric properties and stiffness. The specific gravity and the stability tests were conducted according to (ASTM D2726) and (ASTM D6927) respectively. For the stability test, the samples were conditioned in the water bath at 60°C for 40 minutes. The load was applied to the sample by means of the constant rate of movement of 50.8 mm/min until the maximum load was reached and the load decreases. The load and flow values at peak were recorded for the stiffness.

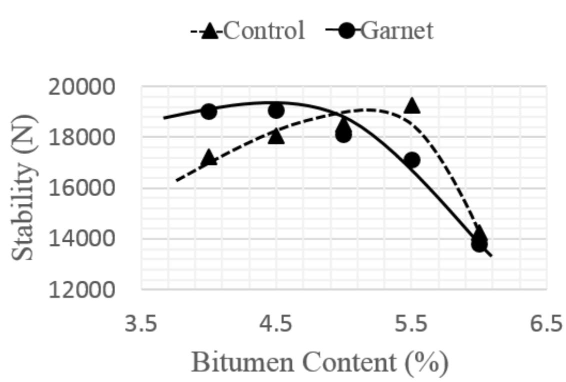
3. Results and Discussion

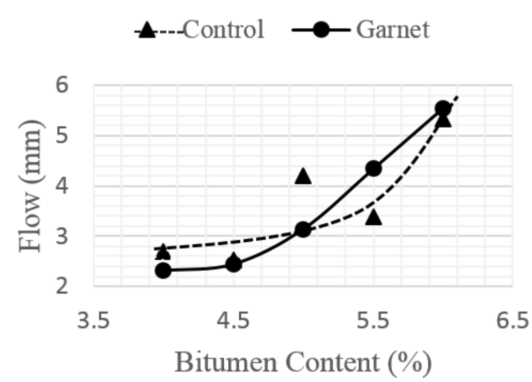
Figure 4 shows the detailed plots of Marshall properties with increased percentages of bitumen from the Marshall mix design. The optimum binder content from the data was determined based on the design requirements according to specification (JKR/SPJ/2008-S4). Two groups of samples (conventional asphalt mix as control sample and mix with 25% waste garnet) were prepared for comparison.



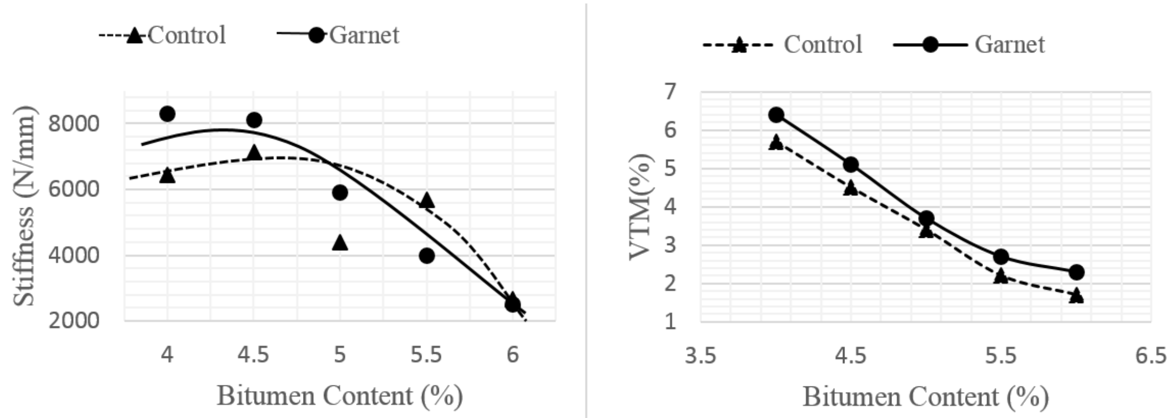


(a) Specific Gravity (b) Voids filled with bitumen, VFB





(c) Stability (N) (e) Flow (mm)



(f) Stiffness (N/mm) (g) Voids in total mix VTM

Fig. 4. Plot of Marshall Properties for the control and 25% garnet samples

Table 3 summarizes the results of verification for the Marshall properties. From the curves the optimum bitumen content was calculated and the result shows that, sample with garnet waste requires less bitumen content (4.8%) compared to the conventional sample with granite aggregate (5%). In addition, the replacement of garnet increases the specific gravity, voids filled with bitumen, VFB and voids in total mix, VTM percentage of the mix. On the other hand, the result also shows increment in the Marshall stability and less flow with the addition of garnet. This finding suggested that mixtures produced with garnet were stiffer than mixtures with granite aggregate. In other words, the garnet could stiffen the asphalt mixture and provides better resistance against permanent deformation. Both stiffness values comply with the specification of more than 2000 N/mm. The relatively high value in stiffness is due partly to a higher garnet specific gravity compared to the granite aggregate.

Table 3
Results of Marshall Properties and Optimum Bitumen Content

Properties	**Results**		**Specification (JKR/SPJ/2008-S4)**
	Control	25% Garnet	
Stability (N)	18502	19000	>8000
Flow (mm)	4.2	2.9	2.0-4.0
Stiffness (N/mm)	4405	6551	>2000
Voids in total mix, VTM (%)	3.4	4.1	3.0-5.0
Voids filled with bitumen, VFB (%)	80.2	85.0	70-80
Optimum Bitumen Content (%)	5.0	4.8	4-6

4. Conclusion

This paper presents the feasibility of using waste garnets at 25% percentage as fine aggregate replacement in asphalt mixture. The results show that samples with garnet need less quantity of binder than the control samples. In addition, asphalt mixture produced with garnet has better stability compared to mixture made with 100% granite aggregate. Higher stability could reduce the potential of the mixture to deform permanently under loading.

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