Substitution of Fly Ash as Mineral Filler in Wearing Course of Hot Mix Asphalt

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Abstract. Fly Ash (FA) is one of the sustainable materials to substitute Ordinary Portland Cement (OPC) was found commercialized in construction field but the usage in HMA pavement is limited. Thus, this study is important to promote FA as a sustainable filler instead of using OPC to reduce greenhouse gases. The primary aim is to investigate the Marshall Stability of HMA that incorporating of OPC and FA as filler. In addition, Optimum Bitumen Content (OBC) determination also conducted in this study. Marshall Stability test was conducted based on ASTM 2006 for both mixtures. The parameters gained from the test are the stability, flow, air void in mix (VIM), void filled bitumen (VFB) and stiffness being used to OBC. The OBC for HMA with OPC filler obtained is 5.06% meanwhile for HMA with FA is 4.79%. All Marshall Parameters was complied with of Malaysia Public Work Department (PWD) Standard for both mixtures. The HMA with FA filler give better results for all parameters. Based on OBC percentage, usage of asphalt binder was reduced at 0.29%. Thus, it was more economical if using FA compared with OPC as a filler. Furthermore, HMA with FA filler have better stability and strength as well as lesser deformation with HMA with OPC filler. For the overall, FA have huge potential in substituting other mineral filler to produce better quality of asphalt pavement.

1. Introduction

Developing and using new modified asphalt pavement materials in construction contribute to high-performance pavement to meet the needs of the communities. The change of pavement materials can be rendered directly by applying the modifier to the bitumen and aggregate combinations during the mixing process. A substitution of standard filler material with another suitable material that can be identified or easily found in nature is the most ancient usage of asphalted aggregate mix alteration. This is known as filler substitution [1-9]. The mix design developed must comply all the requirements stated in Standard Specification for Road Works from PWD, Malaysia. Usually, in asphalt aggregate mixtures, stone dust generated during the aggregate crushing is used as filler beside others such as hydrated lime, limestone dust and OPC. Mineral filler is required to fill the airspace between the aggregate particles and thus reduce the airspace by up to 3-5% as specified in the Standard Specification for Road Works from PWD, Malaysia. With the presence of filler, the aggregates lock
into each other and increase the strength of the asphalt mixture. The use of fillers usually increases the passive adhesion between the aggregates and bitumen, which leads to bitumen mixtures with higher water resistance and hence greater durability [2,5]. Fly ash is one of the largest coal-fired thermal power plants waste by-products. Fly ash is not only readily accessible in areas around such sites, it sees no use to cause severe problems in waste disposal. Thus, in this survey, an attempt was made to investigate the use of fly ash, which is typically 0.075 mm long and is regarded by various fundamental technical characteristics as a filler in asphalt pavement [4-6]. The addition of fly ash increases the rheological effects of the mixture of asphalt. These adjustments can be tracked to change asphalt pavements mechanical stability. Fly ash tends to enhance the mixture aging resistance by reducing age-related cracks and thereby increase the durability of the pavement infrastructure. Adding the fly ash increases thermal relaxation and thereby improves thermal cracking resistance and decreases internal thermal tension during the winter months [5]. This research will investigate and compared the OBC for HMA with FS filler and HMA with OPC filler and Marshall Stability for both mixes.

2. Materials and Methods

2.1 Material Preparation
The aggregate used in this research was granite while the bitumen grade used was PEN 60/70. Both of the material was collected from Pens Industries Pvt Ltd, Malaysia quarry. The aggregate gradation followed AC 14 gradation limit [1,7]. The FA grade C used in this research to act as filler and substitute currently used OPC in AC14 mixtures of HMA. The percentage of mineral fillers used was 4% by weight of aggregate for OPC and FA [3,6,8].

2.2 Marshall Stability Test
For determination of Optimum Bitumen Content (OBC), Marshall Stability testing were used. Two set of samples were prepared for HMA with OPC filler and HMA with FA filler. Each set comprise of three samples for each percentage of bitumen contents which were 4.0%, 4.5%, 5%, 5.5% and 6.0% as standard specification by PWD. All the samples with different mineral filler were prepared at a temperature of 160° and compacted at a temperature of 150°. Samples were compacted using Marshall Hammer with 75 blows for each side. The prepared samples will test using Marshall Tester and the result for each samples were recorded. The average result for each bitumen percentage were plotted in Figures 1 to 6. The testing procedure was carried out based on ASTM 2006 [1]. The flow of the research is shown in Figure 1. All the value obtained from the test will then compared with standard specification provided by PWD.

![Flowchart of marshall stability test.](image)

**Figure 1.** Flowchart of marshall stability test.
2.3 Optimum Bitumen Content (OBC)
From the Marshall plotted graph, OBC percentage was determined from average value obtained from Figures 2 to 6 by using the following criteria [7,9]:

i. % Bitumen Content for Density at the peak curve
ii. % Bitumen Content for Stability at the peak curve
iii. % Bitumen Content for 4.0% Void In Mix (VIM)
iv. % Bitumen Content for 75.0% Void Filled Bitumen (VFB)
v. % Bitumen Content for 4mm Flow Value.

3. Results and Discussions
Marshall Stability test results discovered the OBC was in the different values in HMA with different mineral fillers. OBC obtained from the Figure 2 to 6 for HMA with OPC filler was 5.06% meanwhile for HMA with FA filler was 4.79%. It shows that, the substitution of FA as filler has reduce the usage of bitumen in the HMA Mixtures by 0.29%. The result was parallel with the studied by Mistry and Roy [3], where the percentage of OBC also reduce in adding FA in the filler compared to the Hydrated lime filler. The range of all parameters which were Stability, VIM, VFB, Flow and Stiffness for both mixtures are meet the requirement set by PWD, Malaysia for both samples shown in Table 1. The test and analysis parameter for HMA with OPC & FA filler shown in Table 1. For comparison between the results, HMA with FA filler shows higher stability and stiffness compared to the HMA with OPC filler as shown in Figures 6 and 7. Where the stability HMA with FA filler give better stability compared to HMA with hydrated lime filler [3]. By substituted mineral filler with FA, it can improve the rheological properties of the asphalt mixtures. Thus, improve the mechanical stability of asphalt pavements [8,10].

Table 1. Test and analysis parameter for HMA with OPC and FA filler.

|                  | % OBC | Density (g/cm³) | Stiffness (kN/mm) | Stability (kN) | Flow (mm) | VIM (%) | VFB (%) |
|------------------|-------|-----------------|-------------------|----------------|-----------|---------|--------|
| HMA with OPC     | 5.06  | 2.32            | 3.53              | 13.838         | 3.92      | 4.23    | 70.39  |
| Filler           |       |                 |                   |                |           |         |        |
| HMA with FA      | 4.79  | 2.39            | 4.26              | 15.932         | 3.74      | 3.95    | 76.31  |
| Filler           |       |                 |                   |                |           |         |        |
| Standard         |       |                 |                   |                |           |         |        |
| Specification    | 4% - 6% |               | > 2kN/mm          | > 8kN          | 2.0 – 4.0 | 3.0 – 5.0 | 70 – 80% |
| PWD, Malaysia    |       |                 |                   |                |           |         |        |

Furthermore, VIM and VFB also shows higher percentage for HMA with FA filler compared to the HMA with OPC filler as shown in Figures 3 and 4. FA shown better performance in filling the air void in HMA and better performance in filling the void in aggregate filled with bitumen resulting lesser deformation compared to OPC filler mix [3]. In addition, by having adequate void in FA mix will help to establish adequate film thickness without unnecessary asphalt bleeding of flushing [2]. Besides, flow value in Figure 5 reflect the plasticity and flexibility properties of both mixtures. HMA with FA shown less deformation compared to HMA with OPC [10]. On the other hand, denser samples of HMA with FA as shown in Figure 2 were contributed to the improvement of properties such as flow, stability & stiffness.
Figure 2. Density vs % Bitumen Content for HMA with OPC and FA filler.

Figure 3. VIM vs % Bitumen Content for HMA with OPC and FA filler.
**Figure 4.** VFB vs % Bitumen Content for HMA with OPC and FA filler.

**Figure 5.** Flow vs % Bitumen Content for HMA with OPC and FA filler.

**Figure 6.** Stability vs % Bitumen Content for HMA with OPC and FA filler.
4. Conclusions
From this research, it revealed that the huge potential of FA to be used as substitution for OPC and others mineral filler. The following conclusion can be made from investigation carried out:

i. Both mixtures meet the requirement by PWD, Malaysia for Marshall Stability Test. However, others parameter still needs further investigation for the mixture used in construction.

ii. By substituting OPC with FA filler, it can reduce the usage of asphalt binder. Thus, it was considered economical.

iii. HMA with FA Filler have better strength with lesser deformation compared with HMA with OPC filler. With this improvement, it will increase the quality of asphalt pavement.

iv. Since the FA was a by-product and always being dumped, it can be used as filler and contribute to global sustainability.

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