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Abstract. A composite pavement known as semi rigid wearing course is made by incorporating high workability fluid grout into a high porosity of porous asphalt skeleton. This fluid grout is particularly designed to have the consistency workability of water with high early and 28 – day strength. It is critical to maintain its high fluidity so it can flow through air voids while simultaneously generate high compressive strength with minimal porosity. The aim of this study is to investigate the influence of a known pozzolanic material towards the properties of fluid grout. A wide range of mix trials was formulated with various proportions of chemical and mineral admixtures. The fresh and hardened grout underwent flow cone and compressive test for its workability and strength determination respectively. The results obtained show that the combination of a known pozzolanic material and a known chemical admixture is possible to improve the fluidity of grout and strength when suitable and conducive mix proportions attained.

1. Introduction

A composite pavement known as semi rigid wearing course is made by incorporating high workability fluid grout into a highly porosity asphalt skeleton. This type of fluid grout is specially designed to have water-consistency workability with a high early and 28-day strength. This is in accordance to the standard set by Road Engineering Association of Malaysia (REAM). The properties of fresh fluid grout is crucial to ensure that the grout fills up small pores and voids in the porous asphalt skeleton, concurrently generate high compressive strength to effectively bond the two composition together with minimal porosity. High strength grout should also be able to withstand high compressive and static loads to maintain the stability of a structure. Besides that, the improvement of porous skeleton matrices also contributes to the function of impermeability to fluid grout, capable of giving it a better chemical resistance [1].

Research has shown that not only Portland cement is used to produce high compressive strength grout but also a mixture between Portland cement and supplementary cementitious materials (SCMs) is possible. SCMs that have been widely used in grout/concrete includes the pozzolanic materials such as fly ash (class F and class C), silica fume (SF), slag and metakaolin. These pozzolanic materials are

able to improve packing capacity at the interface, hence creating a tighter pore structure of the composite materials and produce high strength concrete/fluid grout of varying magnitude. This reflects the extent to which each addition is chemically active during the hydration process and therefore the extent to which they contribute to or modify the structure and properties of the hardened paste [2].
This paper aim to investigate the mechanical properties of fluid grout for the preparation of semi rigid wearing course. Workability and compressive strength analysis was performed on fresh and hardened grout using its specified testing machine.

2. Materials

2.1. Cementitious Binder

Cementitious binders used in this research were the ordinary Portland cement (OPC) type 1 and SF and in comply with BS EN196 and ASTM C1240-03a respectively. This study investigated the effect of SF replacement towards workability and strength of fluid grout within the range of 0% to 10% for the application in semi rigid pavement.

2.2. Chemical Admixture

Superplasticizer (SP) or also known as high-range-water-reducer (HRWR) has been introduced to the mineral admixtures to promote high-workability fluid grout. The selected SP was supplied by Fosroc and in comply with BS 5075 Part 3 and ASTM C494 Type F. The recommended dosages were in between 0.7% to 2.0% from the total mixture [3]. Excessive usage of SP will cause segregation and bleeding to the hardened grout [4][5].

2.3. Water/binder Ratio

Water to binder (w/b) ratio is known to be the weight of water to the weight of cement used in concrete mix. According to BS EN447 stated, concrete/grout complying with the standard will normally have a water w/b ratio below than 0.4. As such, the suggested w/b ratio were in the range of 0.30 to 0.36. With the aid of SP, which acts as a water removal agent, the final grout strength will help in the quality of concrete produced. This is also in agreement with Alsadey (2012) who claimed that SP is used to increase the workability without changing the w/b ratio.

3. Experimental Methods

3.1. Fluid Grout Mixture and Proportions

Table 1 shows the fluid grout mix design composition for various percentages of cement replacement and w/b ratio. The influence between various percentages of SF and w/b ratio towards the compressive strength and workability of fluid grout were studied and deliberated in accordance to the REAM Standard.

Table 1. Fluid Grout Mixture Proportions of Portland Cement and Silica Fume

Mix	Mix Component			
	OPC	SF	SP	w/b ratio
1	100%	0%	1%	30%
2	95%	5%		
3	90%	10%		
4	100%	0%	1%	33%
5	95%	5%		
6	90%	10%		
7	100%	0%	1%	36%
8	95%	5%		
9	90%	10%		

3.2. Grout Preparation and Curing

The fluid grout compositions were mixed in accordance to ASTM C305-99: Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency. The fresh fluid grout will undergo the flow cone test which the dimension used is in comply with REAM standard.

The hardened cubes on the other hand were prepared and tested in accordance to BS 1881: Part 116:1983. Steel mold cubes with the size of 50 mm x 50 mm x 50 mm for compressive strength test should be prepared before casting. The hardened cubes were then removed from the mold and placed in the curing tank for 3,7 and 28 days.

4. Results and Discussion

4.1. Fluid Grout

Figure 1 shows the time taken for 3 different w/b ratios with 0% to 10% cement replacement respectively to empty the flow cone. The time taken to empty the cone varies from 11.5 s (high water consistency) up until 181.5 s (very cohesive). It was found that the increment of w/b ratios gave significant changes to the workability of fluid grout when measured using the flow cone test. The results exhibited the disadvantage of replacing OPC with higher percentage SF to the mixture where by revealed a longer time to empty the flow cone. It was found that by replacing OPC with a lower percentage of SF to the mixture generally gave shorter time for the fluid grout to empty the cone.

SP was introduced to the mix composition where it provides the possibility of a better dispersion of cement particles and improves stability through inter-particle repulsive force, thereby improving a higher fluidity [6]. Note that the SP used for this research is fixed to 1% as it could control the possibility of segregation and bleeding.

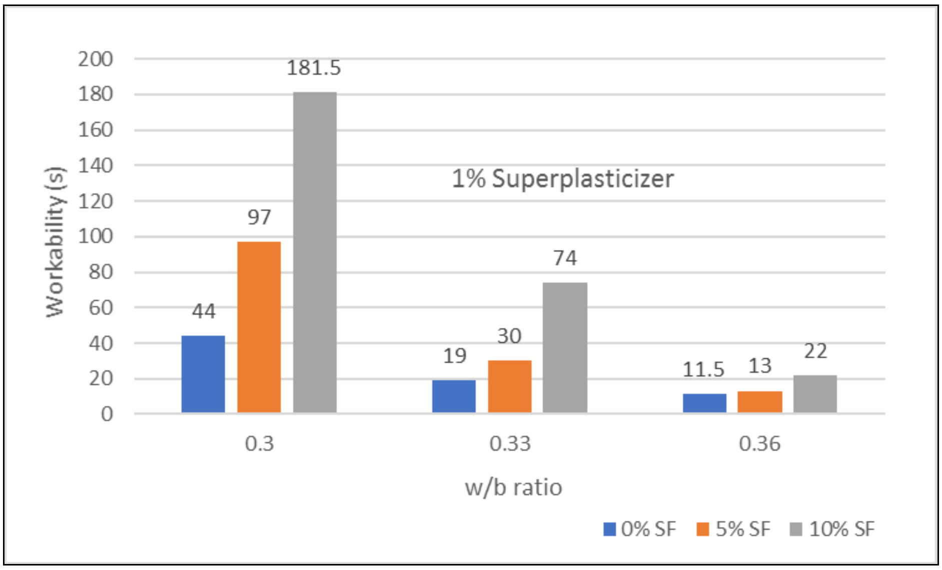

Figure 1. Workability of Fresh Fluid Grout at various w/b ratios and SF dosages.

4.2. Compressive Strength

The grout that is specified by REAM should comply a compressive strength on day 1 and day 28 of 45-50 MPa and 100-105 MPa respectively. This requirement is needed for the purpose of producing semi rigid wearing course.

Figure 2 illustrates the strength development at 0.3 w/b ratio over various percentage of SF replacement. The results achieved prove that higher dosage of SF incorporated into the mix possess higher strength especially on day 28 with 75 MPa compared to the controlled Mix 1 at only 68 MPa. The same pattern was also demonstrated for Mix 2 and Mix 3 from day 1 and maintained until day 28. The enhancement of compressive strength could be attributed to the pozzolanic reaction.

Figure 3 on the hand elucidates the strength development for mixes with 0%, 5% and 10% of SF replacement at 0.36 water to binder ratio on the 1st, 3rd, 7th and 28th day. It was observed that the results obtained for mixes with 0.36 w/b ratio are relatively low compared to those with 0.30 wa/b ratio. Lost of compressive strength from the hardened grout has been observed when the w/b ratio was increased to the mix particularly at 0.36. Bleeding and segregation were observed on the surface of the hardened grout. Although it gave good workability to the mixture however, it shows an underperformed orientation in strength. It can definitely be concluded that high dosage of water could affect the later days strength significantly and other related properties.

A noticeable finding can be highlighted from this study which includes the behaviour of cement replacement itself. The cement replacement by SF plays a vital role in the workability and strength of the fresh and hardened grout. Compared to the control mixes (0% SF), the increment of SF dosages managed to give higher compressive strength especially on the 28th day. It is generally accepted that SF improves pore structure by its small particle size that allow a filler effect to build the bridge between cement grains and the spaces between cement grains and aggregate [7]. This is also in agreement with Neville and Aitcin (1998) which stated that the very fine material was observed to reduce in the porosity of the grout matrix and provides a dense microstructure for microstructure properties improvement thus increasing the strength of the system.

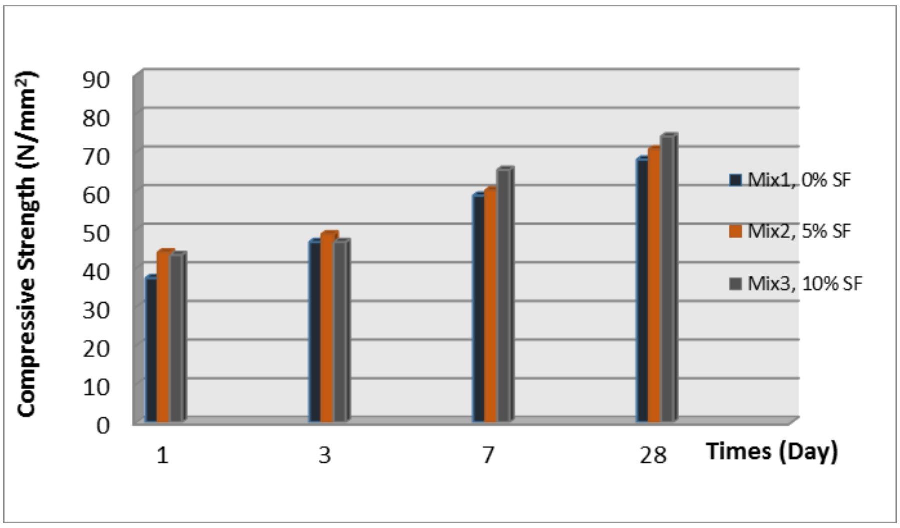

Figure 2. Strength Development at 0.3 w/b ratio over various percentage of SF replacement.

The introduction of SF will slightly lower the strength during the initial period (between day 1 and 3). The presence of SF in the mix composition shows lower strength development in the early days compared to the control mix.

Two types of reactions occur when dealing with pozzolanic materials – primary cement hydration, secondary pozzolanic reaction. The primary cement hydration produces an end product in the form of calcium silicate hydrate (C-S-H) and Calcium hydroxide ($Ca(OH)^2$). The C-S-H is known to determine the strength of the mixture. The secondary reaction focuses on the pozzolanic material, which is the SF. SF undergoes pozzolanic reaction with $Ca(OH)^2$ to produce more of C-S-H gel [9]. The C-S-H gel then leads to an additional reduction in capillary porosity. Eventually, the additional generated C-S-H allows for a further increase in strength to the hardened grout [10]. This explains the reason behind the decrement of strength at early days for mixes that has been incorporated with SF.

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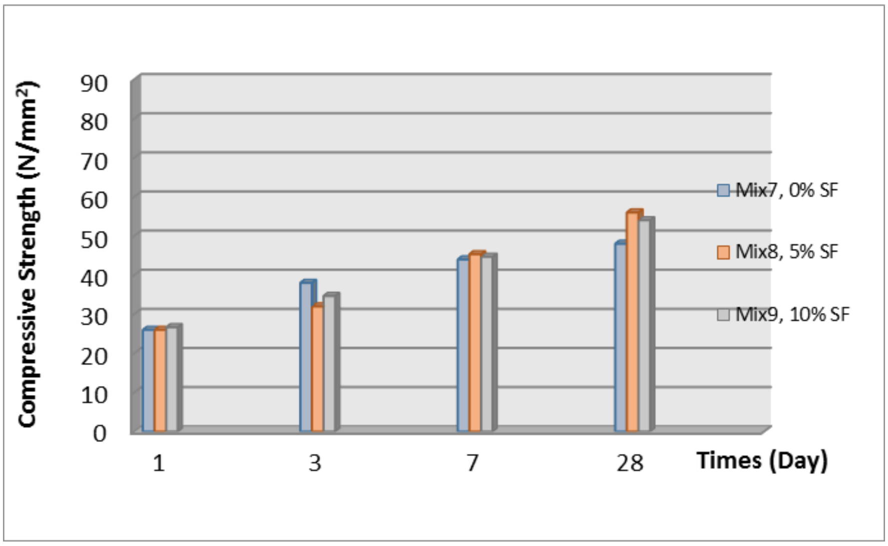

Figure 3. Strength Development at 0.36 w/b ratio over various percentage of SF replacement.

5. Conclusion

This study has concluded that workability of fresh fluid grout and strength of hardened grout is significantly reflected by the increment of w/b ratio and the incorporation of pozzolanic material especially at early and later days.

6. Recommendations

The recommended mixture for this particular set of data for the purpose of semi rigid wearing course production in compliance with REAM requirement probably would be Mix 2 from the 0.3w/b ratio. However

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