The Egyptian International Journal of Engineering Sciences and Technology

ISSN:1687-1006

Vol. 21 (October 2016) 19–23

http://www.eijest.zu.edu.eg

Using Cement By-Pass Dust and Fine Dune Sands in Semi-Flexible Pavement Applications

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ARTICLE INFO

Article history:
Received: 5 April 2016
Received in revised form: 11 June 2016 and 18 July 2016
Accepted: 21 July 2016
Available online: 22 July 2016

Keywords:
Cement by-pass dust
Fine dune sands
Grout
Semi-flexible mixtures

ABSTRACT

In many countries around the world, grout is used to produce semi-flexible pavement mixtures. Grout is formed by mixing cement with water. Additives such as fine silica sand, silica fume, fly ash, and plasticizer are used in grout production to improve the workability and mechanical properties of the grout. In Egypt, fine dune sands and cement by-pass dust are abundantly available. This study aims at evaluating the suitability of using fine dune sands and cement by-pass dust to replace Portland cement in producing grout mixes suitable for semi-flexible pavement applications. To achieve the study objective, three groups of grout mixes were investigated; The first group is control mix using ordinary Portland cement only. The second group composed of ordinary Portland cement with fine sand. The last group composed of ordinary Portland cement with cement by-pass dust. The percentage of water needed for mixing was determined using Marsh funnel. Volumetric properties of grout mixes were then determined. Unconfined compressive strength and indirect tensile strength tests were conducted on samples casted from these mixes at 7 and 28 days of curing to define their mechanical properties. It was found that Replacing 25% of the cement with fine sand dune achieved good viscosity and high compressive and tensile strength, and offered cost savings compared to the control mix. While using of cement by-pass dust resulted in reducing the strength of grout mixes.

1. INTRODUCTION

Semi-flexible pavement (SFP) is formed from open-graded (porous) asphalt concrete mixture containing 25 to 35 percent voids filled with cement slurry grout. The two materials are produced and placed separately [1]. This new type of pavement has high resistant to permanent deformation (rutting) [2]. The SFP is generally laid as 2 inch thickness surface layer. The open graded asphalt mixture is placed with standard paver. After placing, the pavement surface is smoothed with a small steel wheel roller, generally a 3-ton maximum. Compaction of the open graded asphalt mixture will adversely decrease the voids and binder grout penetration [3]. SFP has many applications including bus stations, port pavements, industrial and warehouse floors, airport platforms, taxiways and runways, brake and acceleration strips

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at traffic lights and bridge deck overlays [4, 5, and 6]. SFP has been used in different areas in the world, including Europe, Africa, the South Pacific, the Far East, Malaysia and North America [7]. However, SFP has not been used in Egypt yet. There are many benefits of using SFP including: improve fuel and oil resistance, create flexible pavement compared to Portland cement concrete pavement (PCCP), reducing constructions efforts, costs and eliminate the need to joints compared to PCCP, prevent rutting, and reduce life cycle costs compared to both flexible and rigid pavements[4, 5, 8].

Both of fine dune sands (FDS) as natural source and cement by-pass dust (CBPD) as cement industrial waste material are abundantly available in Egypt. They have negative effects on the environment. Fine dune sands threaten the communities living in the desert areas. Most notably, covering the main roads between communities and thus affect the travelling between such communities in addition to covering their vegetation and in some cases their own homes and utilities [9]. On the other hand, the cement by-pass dust causes problems to human health and environmental pollution. CBPD is a by-product of the manufacture of Portland cement; it is formed of a very fine industrial waste material that has a wide range of particle sizes ranging from less than 20 to 100 micron in diameter, and 2500 cm/gm surface area [**10**]. The cement by-pass dust is collected from the lower cement flues of cement factory into closed vehicles and is then transporting to the stockpile area.

This study aims at evaluating the suitability of using fine dune sands and cement by-pass dust to replace Portland cement concrete in producing grout mixes suitable to be used in semi-flexible pavement applications. To achieve the study objectives, groups of grout samples were created using different proportions of DBPD and OPC as well as FDS and OPC. It is aimed at producing the grout without any plasticizer, fly ash, or silica fume to reduce the cost in Egypt.

2. Experimental Program

The experimental program consisted of material selection, casting, curing and testing of specimens. The selected grouting materials are OPC, FDS and CBPD. The specific gravity of OPC, FDS and CBPD are 3.10, 2.66 and 2.84, respectively. The gradations of these materials are shown in Table (1).

Table 1. Gradation of grout materials, (% passing)

Sieve No.	OPC	FDS	CBPD
No. 40	-	100	-
No. 60	-	99	-
No. 100	-	2.9	100
No. 200	100	0.3	91

The grout mixtures were designed in three main groups, defined as G1, G2 and G3. The first cement grout group (G1) contains 100% of OPC, which is the control mix. The second grout mixtures group (G2a, G2band G2c) contains 25%, 50% and 75% of CBPD as a replacement to OPC, while the third group (G3a, G3b and G3c) contains 25%, 50% and 75% of FDS as a replacement to OPC. The mix details of grout mixtures are presented in Table (2).

Table 2: Grout mixture proportions (dry material).

Mix code	Composition, % (by weight)		
	OPC	FDS	CBPD
G1	100	0	0
G2a	75	0	25
G2b	50	0	50
G2c	25	0	75
G3a	75	25	0
G3b	50	50	0
G3c	25	75	0

The water content required for grout mixing was determined to achieve the acceptable grout viscosity value. For this purpose Marsh funnel was used. The acceptance criterion for the grout viscosity is within range of 7.0 to 9.0 seconds [1], measured immediately after mixing. For comparison, water has a Marsh flow cone viscosity of 6.0 seconds. Viscosity value of about 8.5 sec was considered acceptable in this study. Figure (3) shows the dimensions of the used marsh flow cone [1]. After mixing the dry materials with the determined water content, grout liquid density was calculated for each grout mixture. Also, the viscosity of grout mixes were measured and recorded for three hours after mixing to illustrate the effect of the time between mixing and placing on the viscosity.

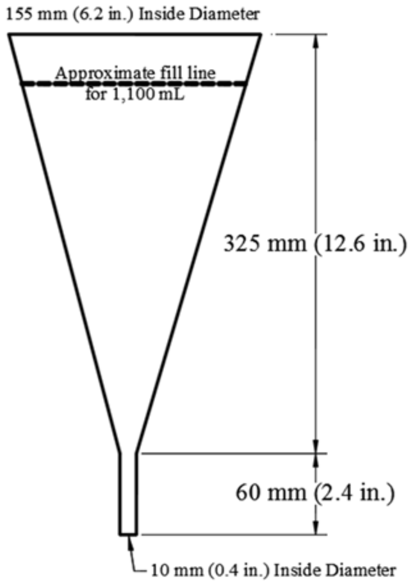


Fig. 1: Marsh flow cone (Marsh Funnel)

Cubes5×5×5 cm samples and cylindrical samples of 5 cm diameter and 10 cm height were casted. Specific gravity for the hardened groutwas determined after 24 hours from casting the samples. The unconfined compressive test was applied on cubic samples of hardened grout in order to determine their compressive strengths. Cylindrical samples were tested by indirect tensile test to define their tensile strengths. All samples have been tested after curing in water for 7 and 28 days.

3. Summary of Results

Percent of water content required to achieve adequate grout viscosity (based on 8.5 sec flow value measured using Marsh funnel) is very important to insure good penetration for grout into the porous asphalt skeleton. Table (3) illustrates the percentages of water content required for liquefying the investigated grout mixes. The table shows that percent of water content varied between 0.24 and 0.51. Replacing the cement with CBPD caused incensement in the amount of needed water, while replacing cement with FDS caused reduction in the amount of water needed to keep the viscosity of the grout. The minimum amount of water was achieved for samples with 75% FDS, whereas the maximum value was achieved for samples with 50% cement dust. This may be due to the nature of the filler and the high surface area of the cement dust compared to the dune sand.

Table 3: Different characteristics of investigated grout

Mix code	composition (by weight)				grout properties	
	OPC	FS	CBPD	water	liquid density, gm/cm^3	marsh flow, sec.
G1	0.67	0	0	0.33	1.79	8.5
G2a	0.46	0	0.15	0.39	1.64	8.5
G2b	0.27	0	0.27	0.46	1.54	9.5
G2c	0.12	0	0.37	0.51	1.43	8.5
G3a	0.52	0.17	0	0.31	1.82	8.5
G3b	0.37	0.37	0	0.26	1.92	8.5
G3c	0.19	0.57	0	0.24	1.89	8.5

Figure (2) shows the relation between the needed water content and filler ratio. Analyzing the figure it can be concluded that the increasing of CBPD ratio by 1% leads to increase water content by 2 litres/m^3 grout. While the increasing of FDS ratio by 1% leads to decrease water content by 1.8 litres/m^3 grout.

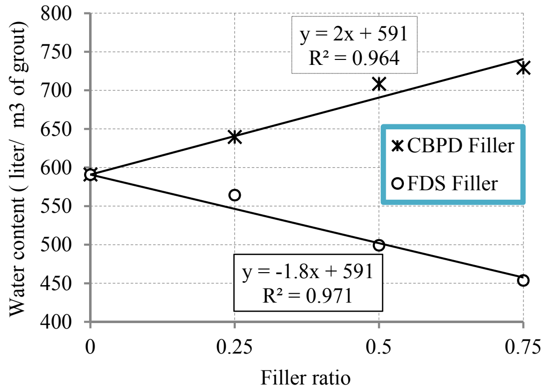


Fig. 2: Required water content

This means using CBPD required additional amounts of water, which can be considered as a disadvantage especially in countries suffering from water resource problems.

In order to determine the maximum allowable time between grout mixing and its application; the viscosity was measured and recorded for 3hours for all investigated grout mixes. Considering the maximum allowable time of flow of 9 seconds, the maximum allowable mixing time was found to be 3, 2.6, 1.6, 1.15, 0.66, 0.62 and 0.28 hr for G3b, G3c, G3a, G2c, G2c, G1 and G2a, respectively. This means that grout mixes containing FDS can be applied to the porous asphalt pavement during period between 1.6 to 3 hrs unless reaching the maximum allowable flow value. While CBPD reaches this maximum flow value in lower time ranges between 0.62 and 1.15 hr. Short mixing time can cause the grout to be rejected if the grout will not be applied to the pavement during this period. This can be considered as an advantage for FDS filler.

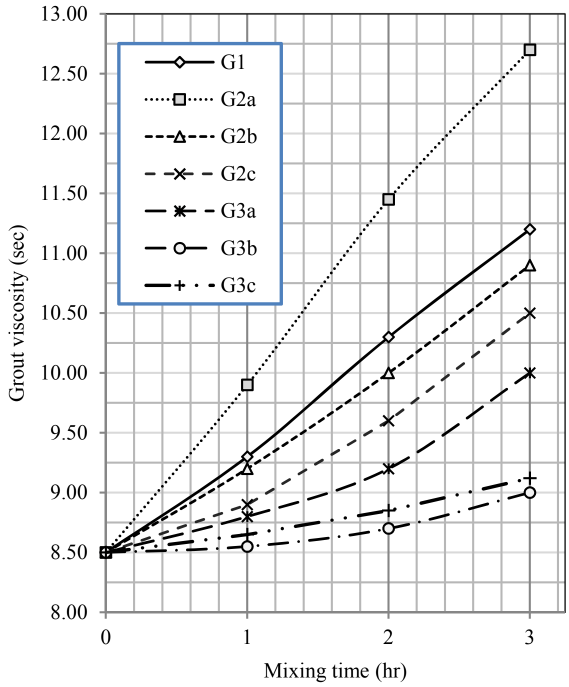
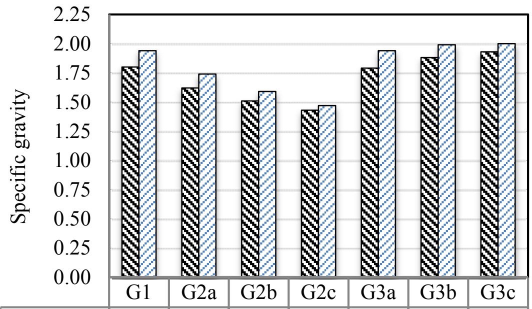


Fig. 3: Effect of mixing time on grout viscosity.

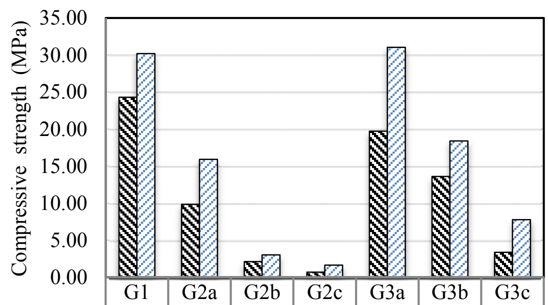
After hardening of grout specimens, specific gravities were determined. Figure (4) shows the bulk and apparent specific gravities of the hardened grout specimens. Maximum values were noted for specimens including FDS, while increasing of CBPD in grout caused reduction in the specific gravities. This may be due to the high value of water content that was required to liquefy the grout samples containing CBPD; which evaporated during the curing process, and caused increase in the air voids in the specimen when hardened.



	G1	G2a	G2b	G2c	G3a	G3b	G3c
Bulk	1.80	1.62	1.51	1.43	1.79	1.88	1.93
Apperent	1.94	1.74	1.59	1.47	1.94	1.99	2.00

Fig. 4: Specific gravities of the hardened grouts

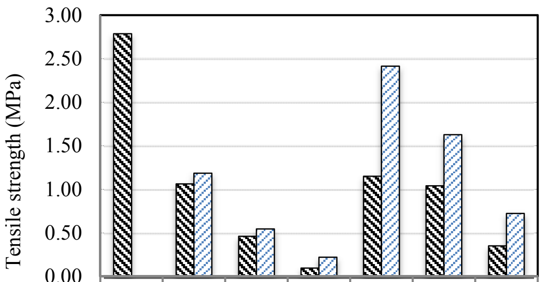
The mechanical properties of the grout (compressive and tensile strength) are major factors that would control the selection of the grout material as well as its price. Compressive and tensile strengths for tested grout materials at 7 and 28 days of curing are presented in Figures (5 and 6) respectively. Figure (5) shows that the grout material G1 had the highest values of compressive strength after 7 days of curing. This value is 24.3 MPa. The grout material G3a had the highest value of compressive strength (31.04 MPa) after 28 days of curing. On the other hand, the grout material G2c had the lowest compressive strength value. The results show that the grout materials composed of FDS with OPC achieved higher compressive strengths compared with the identical grout materials containing CBPD instead of FDS.



	G1	G2a	G2b	G2c	G3a	G3b	G3c
7 days	24.30	9.85	2.10	0.69	19.72	13.60	3.37
28 days	30.19	15.91	3.01	1.64	31.04	18.41	7.76

Fig. 5: Unconfined compressive strength of the hardened grouts at 7 and 28 days

Figure (6) shows that the grout material G1 had the highest value of tensile strength after 7 days of curing. This value is 2.79 MPa. The grout material G3a had the highest values after 28 days of curing; 2.41 MPa tensile strength. On the other hand, the grout material G2c had the lowest tensile strength value. The results show that the grout materials composed of FDS and OPC achieved higher tensile strengths compared with the identical grout materials containing CBPD instead of FDS.



	G1	G2a	G2b	G2c	G3a	G3b	G3c
7 days	2.79	1.06	0.46	0.10	1.15	1.04	0.35
28 days	0.00	1.19	0.54	0.22	2.41	1.63	0.72

Fig. 6: Indirect tensile strength of the hardened grouts at 7 and 28 days

Based on the results two grout types are selected for porous asphalt mix grouting. The first selected grout material is G1 because of the higher values of the strengths for the early curing period (7 days). The second selected grout material is G3a due to its high compressive and tensile strength, at lower price compared to G1.

4. Conclusions and Recommendations

From analysing the study results, it can be concluded as follows:

- Using fine dune sands (FDS) requires less amount of mixing water when compared to cement by-pass dust (CBPD).
- Replacing 25% of the cement with fine dune sands resulted in a grout mix, with good viscosity and high compressive and tensile strength, and offered cost savings.
- Cement by-pass dust is not recommended as a grout filler material when compared to fine dune sands.
- The following stage of the research is to apply the best grouts to open graded asphalt mixture, to evaluate the mechanical strength of semi flexible pavement in the laboratory, as a step towards promoting its use in Egypt.

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