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Kobry El-Kobbah,
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OPTIMUM USE OF ASPHALT EMIULSIONS IN SAND-BITUMEN MIXES

A. EL-DESOUKY[*], N. NAGY[**] AND H. AL-JOUF[***]

ABSTRACT

The costs of gravel and crushed stone in Egypt rise as existing sources become exhausted and less suitable supplies have to be exploited. The main objective of this paper is to study the possibility of using emulsions in sand-bitumen mixes used as base layers in desert roads. This objective could be achieved through the selection of the best gradation of sands and optimum emulsion contents. A comprehensive literature review was conducted and the main findings of this review were used to formulate the research plan and testing program. The experimental investigation included the design of 15 sand-bitumen mixes using five different sand gradations with three different powder percentages. The testing program included testing of Marshall specimens for their density, stability and flow. Air voids and voids in mineral aggregates were then calculated. Based on the results of the work presented in this paper, asphalt emulsions could be used successfully in sand-bitumen mixes as a base course of desert roads. This may reduce costs of construction aggregates and transportation of construction materials. On the other hand, some sand-bitumen mixes prepared using asphalt emulsions resulted in high stability values of 695Kg. Mixes like these may even be used as a surface layer in low-volume roads.

Key Words: Asphalt Emulsions, Sand-Bitumen and Mix Design.

INTRODUCTION AND BACKGROUND

Sand in Egypt is the most prevailing available material for construction. It is suggested that economic benefit could be derived from the rational use of stabilized sand in road construction. In recent years, considerable research has been conducted in the construction of pavement layers incorporating asphalt emulsions. Development of improved stabilizing techniques has enabled both effective and economical stabilization of marginal quality pavement materials.

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* Assoc. Prof., Dept. of Civil Engineering, Military Technical College, Cairo, Egypt.
** Lecturer, Dept. of Civil Engineering, Military Technical College, Cairo, Egypt.
*** Libyan Armed Forces.

The main objective of this paper is to provide guidelines to the design of sand bitumen mixes using emulsions. This may be achieved though studying the effect of sand gradations and percent of powders on the basic properties of sand bitumen mixes. For each sand gradation, the optimum emulsion content is to be obtained.

PRIVIOUS RESEARCH WORK

Jostein (1983) dealt with the use of cold bitumen stabilized base courses in Norway. The first cold mix project in Norway was carried out in 1983. Since then, the volume has increased steadily to approximately 1.5 millions m² of milling stabilization and 50,000-100,000 tons of plant mixed materials per year now [1].

International Slurry Surface Association (ISSA) (2010) recommended that emulsified asphalt could be used successfully in slurry seal. The publication provided a performance guideline for the use of emulsified asphalt slurry seal. [2].

A Dedimila and Oti (1987) conducted an experimental study to investigate the possibility of using stabilized laterite as a base course of roads. They concluded that stabilized laterite could be used if adequate amount of MC-3000 cutback bitumen is added [3].

Khedr et al. (2010) studied the construction of Ajdabiya-Jalo Road of a total length of 252 km. The road was constructed in 1978 between the coastal highway and Sahara desert, which is located in southern part of Libya. Sand bitumen was prepared in situ and was used as a base layer in this road. As a typical road, this road was planned to serve for 20 years. After having over 30 years of service, some sections of the road are stressed considerably specially from 85 km to 130 km on sebkha subgrade. The other part of the road constructed on sand subgrade was still found in a good condition. It would be useful to characterize this sand bitumen base mix which proved successful to serve as a base layer in desert roads. The successful practical use of this mix should be evaluated through investigating the pavement surface conditions and determining the possible causes of failure at some highway sections [4].

Anderson and Thompson (1995) studied the properties of emulsion aggregate mixtures that contribute to the observed performance of Emulsion Asphalt Mixtures pavements as base or surface course on low-volume roads, using laboratory testing. They concluded that Emulsion Asphalt Mixtures properties improve as moisture loss increase. The magnitude of Emulsion Asphalt Mixtures shear strength is slightly improved over the untreated granular material. Dense graded Emulsion Asphalt Mixtures should be used if higher shear strength is desired. In addition rutting potential is improved with increased moisture loss [5].

MATERIAL CHARACTERIZATION

General

Five different sand aggregates referred to as (grad1, grad2, grad3, grad4, and grad5) and powder were used for sand bitumen mixtures to select the best sand gradation to be used in sand bitumen mixes using asphalt emulsions. Figure (1) shows the research plan to achieve the objectives of this study.

Sand Gradations

Sieve analysis is performed to determine the different gradations of sand used in sand bitumen mixture using asphalt emulsions [6]. Figure (2) show a summary of particle size distribution for all sand gradations.

Specific Gravity

Specific gravities of different sands were determined in the laboratory. Table (1) presents the results of specific gravity for the sand types used in this study. The specific gravities range between 2.6 for grad4 to 2.8 for grad2. For most gradations (all except grad2) the specific gravity ranges between 2.6 - 2.66.

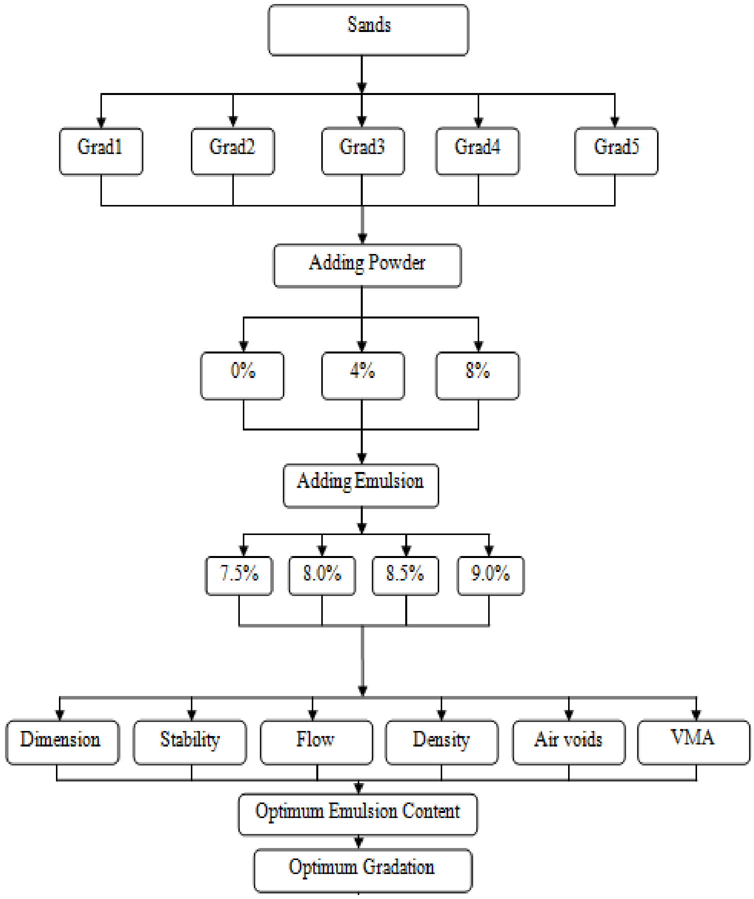

Figure (1): Research plan.

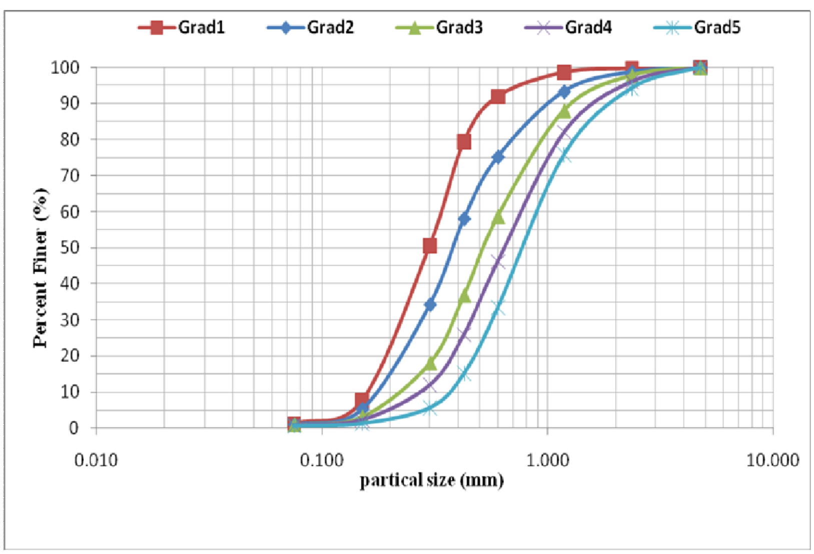

Figure (2): Particle size distribution for all graduations.

Table (1): Results of bulk specific gravity.

Type	Grad1	Grad2	Grad3	Grad4	Grad5
Bulk specific gravity	2.61	2.80	2.66	2.60	2.64

TESTING PROGRAM

The experimental program included tests to determine bulk density, maximum density, air voids, voids in mineral aggregate, and Marshall stability and flow. Based on their gradations as illustrated in Figure (2), five sand soils were selected to be used in this study. Gradations have been identified to all types of soil. Sand gradations are classified from fine to coarse, they were denoted as Grad1, Grad2, Grad3, Grad4, Grad5, respectively. Powder, Calcium Carbonate, was obtained from El-Gayar Quarry (Cairo) and added to sands with three different ratios of 0 %, 4 %, and 8 % by weight to obtain 15 different sand types. These sands were then used to prepare sand-bitumen mixtures. Figure (1) shows a schematic diagram illustrating the laboratory program conducted in this research. Sand bitumen mixtures were prepared using Marshall Mix Design. The emulsion used in this study is anionic [7-9]. Four emulsion ratios were used and mixed with each sand type to prepare sand-bitumen mixtures. These ratios were 7.5 %, 8 %, 8.5 %, and 9 %. For each mixture, 12 Marshall specimens were prepared (three of each emulsion percent). After completion of sample preparations, all Marshall specimens were measured for their dimensions. Similar to the traditional Marshall mix design procedures, specimens were tested for their density, stability and flow while air voids (AV) and voids in mineral aggregates (VWA) were calculated. The Marshall test was conducted at room temperature without specimen conditioning. Based on mix design, optimum emulsion content (EC) for each sand gradation was obtained. Accordingly, recommendation regarding optimum use of sand-bitumen might be concluded.

RESULTS AND ANALYSIS OF THE TESTING PROGRAM

Results of Bulk Relative Density

Before performing any test all sample dimensions were measured and specimens were labeled into groups. Table (2) introduces the density of all specimens based on the percent of powder used in the mixture [10]. For no powder, density value changed from 1.66 for Grad1 with 7.5% emulsion to the highest value of 1.86 for Grad4 and 8% emulsion. The density ranges were 1.72-1.92 gm/cm^3 and 1.92-1.97gm/cm^3 for 4% and 8% powder percents, respectively. Clearly, as the sand gradation got coarser, the density increased. On the other hand, for most studied cases, it was found that the density increased as the percent of powder added to the sand increased from 0% to 4%. These increases were followed by reduction in densities as the powder percent increased from 4% to 8%. This may lead to a conclusion that there were an optimum powder percent at which the maximum density exists. Beyond this percent, any increase in powder may cause loss of sand particle-to-particle interlock and in turn reduces the density of the mix.

Table (2): Result of bulk density.

Gradation	EC (%)	BD (gm/cm^3)		
		No powder	4% powder	8% powder
Grad1	7.5	1.66	1.85	1.69
	8.0	1.68	1.85	1.71
	8.5	1.69	1.83	1.74
	9.0	1.75	1.86	1.81
Grad2	7.5	1.81	1.83	1.71
	8.0	1.75	1.80	1.72
	8.5	1.80	1.91	1.74
	9.0	1.80	1.90	1.75
Grad3	7.5	1.75	1.73	1.78
	8.0	1.73	1.73	1.75
	8.5	1.74	1.72	1.76
	9.0	1.75	1.77	1.73
Grad4	7.5	1.85	1.90	1.97
	8.0	1.86	1.86	1.91
	8.5	1.84	1.87	1.96
	9.0	1.78	1.84	1.97
Grad5	7.5	1.85	1.93	1.92
	8.0	1.78	1.94	1.92
	8.5	1.82	1.92	1.93
	9.0	1.78	1.93	1.92

Marshall Test Results (Stability and Flow)

Marshall Mix Design Procedures [7-9, 11] was used in this paper for two purposes. The first is to design the mixes of different cold sand bitumen i.e., to select the optimum emulsion content for each sand gradation. The second is to empirically evaluate the behavior of these different cold sand bitumen mixes. The results of stability are as stated in Table (3).

Table (3): Summary of Marshall stability test results.

Gradation	EC (%)	Stability (kg) / flow (1/100 in)		
		No powder	4% powder	8% powder
Grad1	7.5	264.27 (11)	406.98 (8)	٥٥٤.٥٩ (16)
	8.0	283.31 (12)	291.26 (12)	٦٨٦.١٦ (17)
	8.5	302.40 (13)	345.23 (16)	٦٧٦.٣٧ (20)
	9.0	257.19 (16)	292.88 (18)	٦٩٥.٩٧ (22)

Grad2	7.5	242.61 (12)	378.64 (16)	٣٩٩.٣٩ (14)
	8.0	203.39 (14)	٣٣٠.٨٩ (17)	٣٥٣.٣٤ (15)
	8.5	228.71 (16)	٣٣٥.٧٨ (18)	٤٣٨.٦٤ (16)
	9.0	263.53 (17)	٢٩٥.٢٧ (20)	٣٨٥.٤٤ (18)
Grad3	7.5	167.43 (12)	237.94 (13)	٤٢٢.٣٨ (12)
	8.0	107.16 (14)	١٩٢.٨٦ (14)	٤٢٥.٤٤ (13)
	8.5	146.50 (16)	١٨٣.٤٥ (16)	٣٥٧.٦٩ (14)
	9.0	151.74 (18)	١٦٧.٧٥ (18)	٣١١.٤٩ (16)
Grad4	7.5	195.68 (12)	277.15 (12)	533.32 (14)
	8.0	162.11 (14)	263.19 (14)	547.82 (11)
	8.5	175.18 (15)	257.26 (16)	430.26 (16)
	9.0	132.39 (16)	250.28 (18)	452.82 (12)
Grad5	7.5	228.02 (14)	222.13 (12)	464.90 (13)
	8.0	172.30 (15)	167.23 (14)	488.15 (13)
	8.5	169.88 (16)	161.41 (16)	459.98 (12)
	9.0	162.42 (19)	153.89 (18)	498.49 (12)

The table shows that, for no powder, Grad1 resulted in the highest stability value of 302.4 kg followed by Grad2 then Grad5. The optimum EC was found to be 7.5% for most cases (3 out of 5). As 4% powder added the sand, the yielded stability values increased. Grad1 yielded again the highest stability value of 406 kg followed by Grad2 then Grad4. The optimum EC was found to be 7.5% for all cases. When 8% powder was added by weight to the sand, stability increased significantly. Again Grad1 yielded the highest stability value of 695.97 kg followed by Grad4 then Grad5. In this case, the optimum EC increased to 9% (for Grad1 and Grad5), 8.5% (for Grad2) and 8% for (Grad3 and Grad4).

Generally, it was found that addition of powder to sands could enhance the stability of emulsified asphalt mixes. However, attention should be paid regarding air voids and performance in presence of water. On the other hand, specifications state that the lower accepted stability for emulsified asphalt content is 500 lb (227 kg) [7-8]. It means that for no powder, Grad3 and Grad4 should be excluded and for 4% powder, Grad5 might be excluded as they resulted in stability values less than 227 kg. For higher powder percents (8%), all sand gradation could be used efficiently based on their stability values.

Taking the results of density into considerations, more attention and analysis should be paid to Grad1 of maximum stability and Grad5 of maximum density (almost as high as Grad4). The flow values for 8% powder shows that Grad1 resulted in higher values compared to Grad5 that yielded flow values less than 16 (1/100 in) [7-8].

Air Voids

Table (4) presents a summary for results of air voids for the 15 studied mixes [7-8]. Generally, Grad1 yielded higher AV values compared to Grad5. The table shows that, for no powder, the percent of AV (at the same EC that yielded the highest stability values) is highest for Grad1 (27.16%) against 22.27% for Grad5. For 4% powder, Grad1 yielded AV value of 26% against 23.65% for Grad5. Finally, for 8% powder, the AV values are 26.42% and 26%

respectively for Grad1 and Grad5. Based on the EC that yielded the highest density values, same conclusion may be obtained where the percent of AV (at the same EC that yielded the highest density values) is highest for Grad1 compared to that for Grad5. AV values for Grad1 were 27.16%, 23.77%, and 26.42% for 0%, 4%, and 6% powder, respectively. For Grad5, the percent of AV decreased to 22.27%, 22.71%, and 26% respectively.

Table (4): Results of calculated air voids.

Gradation	EC (%)	Air voids (%)		
		No powder	4% powder	8% powder
Grad1	7.5	29.0	26.00	32.94
	8.0	27.90	25.40	31.60
	8.5	27.16	25.31	29.84
	9.0	23.91	23.77	26.42
Grad2	7.5	21.65	25.31	33.90
	8.0	23.58	25.95	31.70
	8.5	20.70	21.07	30.40
	9.0	20.35	20.83	29.40
Grad3	7.5	22.27	23.65	30.70
	8.0	24.58	22.71	31.35
	8.5	22.22	22.89	30.40
	9.0	23.61	21.86	30.80
Grad4	7.5	21.71	26.07	27.80
	8.0	22.00	27.06	27.00
	8.5	21.85	26.10	26.10
	9.0	17.88	26.69	26.40
Grad5	7.5	22.27	23.65	27.80
	8.0	24.58	22.71	27.00
	8.5	22.22	22.89	26.00
	9.0	23.61	21.86	26.00

Voids in Mineral Aggregates

Table (5) presents a summary for results of VMA for the 15 studied mixes [7-8]. The table shows that, VMA decreased as the percent of powder increased from 0% to 4%. Then it increased again when the percent of powder more increased to 8% for Grad1, Grad2, and Grad3. For Grad4 and Grad5, VMA decreased as percent of powder increased. Consequently, there may be a critical powder percent at which the maximum VMA may exist.

Table (5): Results of calculated voids in mineral aggregates.

Gradation	EC	VMA (%)

	(%)	No powder	4% powder	8% powder
Grad1	7.5	41.17	34.43	40.11
	8.0	40.80	34.79	39.72
	8.5	40.75	35.84	39.0
	9.0	38.98	35.15	36.89
Grad2	7.5	34.18	32.40	40.09
	8.0	34.18	33.12	40.06
	8.5	35.25	34.19	39.70
	9.0	37.7	35.6	39.60
Grad3	7.5	38.88	35.91	38.10
	8.0	41.51	36.26	39.50
	8.5	40.53	37.26	39.40
	9.0	42.15	37.28	40.80
Grad4	7.5	36.58	35.88	32.70
	8.0	37.27	37.27	33.10
	8.5	37.61	33.80	33.15
	9.0	37.95	34.51	33.80
Grad5	7.5	39.14	39.84	38.10
	8.0	40.17	40.17	39.47
	8.5	40.15	40.83	39.46
	9.0	40.13	39.45	40.82

CONCLUSIONS

Based on the results of the work presented in this paper, the following can be concluded:

1. Asphalt emulsions could be used successfully in sand-bitumen mixes for base courses of desert roads.
2. Sand gradations in A.R.E. may be used successfully in sand bitumen mixes.
3. Sand-bitumen mixes prepared using asphalt emulsions may reduce costs of construction aggregates and transportation of construction materials.
4. Sand-bitumen mixes prepared using asphalt emulsions resulted in high stability values up to 695 kg.
5. The optimum asphalt emulsion content is found to be 9% for the sand gradations used in this study.
6. Powder (filler) percent of 8% increased the obtained stability of sand-bitumen mixes prepared using asphalt emulsions.
7. Fine sands with powder percent of 8% could increase the stability of mix.
8. It is recommended to study the effect of submersing in water on the properties of sand bitumen mixes using asphalt emulsions.

9. It is recommended to study the effect of higher temperature on the behavior of sand-bitumen mixes using asphalt emulsions.

10. More research is needed to evaluate the ability of sand-bitumen mixes to act as a surface layer in low traffic volume roads (minor roads) and temporary roads.

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