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Preparation and Evaluation of Some Asphalt and Polymeric Asphalt Emulsions as Sand Fixators

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SEVEN DIFFERENT bitumen emulsions (50% active material) were prepared to be used as soil stabilizers. These emulsions were; a) Bit. 1 prepared by emulsifying bitumen of penetration 180/200 (Product of Amria Petroleum Company) by a polymeric emulsifier Carpobol 2691 (Product of BFGoodrich Chemical Europe, N.V. BELGIUM); b) Bit.2 prepared by modifying Bit. 1 with 5% w/w Quasr El-Sagha (Fayoum) bentonitic clay; c) Bit.3-Bit.6 prepared by modifying Bit.1 with the emulsified polymers (50% active material) polystyrene acrylate, polyvinyl acetate butyl acrylate, polyacrylic potassium acrylate and mixture of polystyrene acrylate and polyacrylic potassium acrylate (1:1), respectively, and d) Bit.7 prepared by modifying Bit. 1 with (50% active material) butadiene-styrene emulsion. In all cases, the ratio of bitumen: polymer or bitumen: latex were 2:1.

Wind tunnel tests were performed on wind blown sand (particles 20-200μ were > 85%) from El-Obour area on Cairo-Ismailia Desert Road (to simulate sands of Khanka dunes, Eastern Nile Delta). The study included the effect of: 1) application rate of the stabilizer: two rates were examined, *i.e.* 75 and 150 g active material/m^2 soil, 2) covered area: examined stabilizers were sprayed on wetted sand in strips to assemble four different covering percentages, *i.e.* 100%, 66.7%, 50.0% and 33.3%, and 3) wind speed: two different wind speeds to suit both the M.S.W.S. (mean scalar wind speed) on the different locations of A.R. Egypt and IS (the average size of the particles dominant in the wind sand flow in Egyptian deserts) were studied. These are 4m sec^{-1}, *i.e.* 14.4 km hr^{-1} and 8m sec^{-1}, *i.e.* 28.8 km hr^{-1}.

Stability of untreated sand is very low. Examined bitumen emulsions differ in their stabilizing effect against wind erosion by varying degrees. Higher concentrations yield higher stability. Complete covering of sand surface with examined stabilizers prevent wind erosion. With partial covering, soil loss decreases by increasing the mulched area of the sand. Mulching 1/3 of the sand surface with soil stabilizers reduce wind erosion by 80 to 90 %. The effectiveness of the examined stabilizers could be descendingly arranged as follow:

Bit.3 > Bit.4 ≥ Bit.6 > Bit.5≥ Bit.2 >Bit.7 > Bit. 1

It will be a matter of economics to decide which treatment (material, application rate and covering percentage) is the most efficient and economically justified for the needed control of wind erosion. With this respect, the locally prepared bitumen emulsion (Bit.2) seems to be preferable even if its application rate is doubled. Production of cheaper polymers is of great importance.

Keywords: Erosion control, Sand stabilizers, Emulsified asphalts, Polymerized and rubberized bitumen emulsions, Wind tunnel tests.

The problems of wind erosion and dune encroachment in several areas in Egypt and other arid and semi-arid countries are considered to be a real threat which not only affect the agricultural potentialities of the Arable land, but also causes severe losses to human habitation, conununication, transportation, irrigation, and drainage constructions and manpower productivity (Babaev,1980; Zonn,1981 and Moneir, 1983). Hence, fixation of shifting sands and stabilization of soil surface is of vital importance.

Of the techniques, which were used to stabilize structureless soil and sand dunes- at least for a period sufficient to establish vegetation cover-is the use of chemicals such as polymers and bitumen (asphalt) emulsions, *i.e.* chemical soil stabilization; (Armbrust & Dickerson, 1971; Armbrust & Lyles, 1975; El-Hady, 1979, 1982, 1999 & 2000; Wahba, 1980; El-Hady & Hanna, 1983, 1987 & 1988; El-Hady *et al.*,1988, 2000 & 2001a and b; Draz *et al.*, 1988 and 1989; El-Hady & Draz, 1999 a and b; El-Hadidy *et al.*, 1997 and El-Hady & El-Hadidy, 1998).

Modifying bitumen emulsions to meet the required performance standards for soil stabilizers is of great importance. This has created a need for developing the conventional bitumen emulsions. Many types of polymers are used to modify bitumen emulsions to achieve a wider performance range for bitumen bound materials (Wardlow &Shuler. 1992 and Newcomb *et al.* 1992).

The aim of the present study is to prepare effective and cheap bitumen emulsions to be used for soil stabilization. Better selection of the suitable bitumen and the proper emulsifier is a must. Modification of the prepared bitumen emulsions to be more efficient has to be considered. With this respect. bitumen of penetration 180/200 was emulsified by a polymeric emulsifier Carpobol 2691. A bentonitic clay was used in combination with the emulsifier. Some locally produced emulsified polymers and latex were examined as modifiers. The prepared bitumen emulsions were evaluated as stabilizers for dune sands using the wind tunnel technique.

Material and Methods

Materials

Wind blown sand

Wind blown sand from El-Obour area on Cairo-Ismailia Desert Road (to simulate sands of Khanka dunes. Eastern Nile Delta) was examined. Sand fraction equals to 98-99%. The mechanical composition of sand fraction as determined by sieving technique on a standard set of sieves is given in Table 1. Mechanical analysis of such sand shows that more than 85% of the particles lie in the size class of fine sand, *i.e.* 20-200μ in diameter.

TABLE 1. Mechanical composition of sand fraction of wind blown sand from El-Obour area (Khanka dunes).

Fraction	Size of particles μ	%
Fin sand	20-50	40.6
	50-100	28.3
	100-200	18.6
	200-500	7.3
Coarse sand	>500	4.1
Ca Co_3*		0.1

*determined in a separate sample (Black, 1982).
IS (average size of the particles) = 0.14 mm

Locally prepared bitumen emulsions

a. Materials used: Seven different bitumen emulsions (50% active material) were prepared to be used as soil stabilizers. Bitumen of penetration (180/200) production of Amria Petroleum Company was chosen for: a) its easiness of emulsification (Ezzat, 1985), b) its high content of oils and resins which raises its compatibility with either emulsified polymers or latex emulsions (Newcomb *et al.*, 1992) and c) easiness of its emulsions to penetrate soil surface and to form stable structural units without adverse effects on soil penetrability to air, water and fertilizers solutions (Abou Zeid,1984). Polymeric emulsifier Carpobol 2691 production of Ensol Engineering Solutions Group was used to prepare bitumen emulsion (Bit. 1). The physical and chemical properties of the emulsifier are shown in Table 2. The easiness of preparation and the relatively low cost of both materials were the reasons of prefering Quasr El- Sagha, El-Fayoum Governorate; bentonitic clay produced by Sinai Manganese Company was chosen as a modifier for (Bit.1) to produce (Bit.2).

TABLE 2. Some physical and chemical properties of the emulsifier Carpobol 2691.

Property	Value
- Form	White power
- Ignition temperature	520 C
- Solubility/ miscibility with water	Dispersible
- pH value (10g/1) at 20 C	2.5-3
- Chemical characterization	Cross linked acrylic polymer

Chemical composition and mineralogical data of the clay were given elsewhere (El-Hady and El-Sherif,1986-a). Five different polymers or latex emulsions were also examined as modifiers for Bit. 1 to produce Bits. 3-7. Their main constituents and properties are presented in Table 3.

Polyvinyl acetate butyl acrylate emulsion is produced by Hochest Orient Company, Cairo. The rest are produced by one of the polymer factories, at 10^{th} of Ramadan City under the supervision of Egyptian Petroleum Research Institute (EPRI), (Ghaly, 1998 and Ghaly & El-Hady, 1998).

b- Method of preparation: Bitumen emulsions (50% active material) were prepared as follows:

Bit. 1: Water was warmed up to 70°C. The emulsifier (5% by weight) was added while stirring, followed by hot bitumen (135°C). Stirring was continued until the emulsion became completely homogeneous.

TABLE 3. The main constituents and properties of the examined modifiers.

Main constituents And properties	Prepared bitumen emulsions				
	Bit. 3	Bit.4	Bit.5	Bit.6	Bit.7
Main constituents of the modifier	Styrene acrylic Copolymer	Polyvinyle acetate Butyl acrylate emulsion	Polyacrylic K acrylate	Styrene acrylic copolymer+ polyacrylic K acrylate (1:1)	Butadien styrene 24/76 (latex emulsion)
Main properties of the modifier:					
- Physical appearance	Milky white	Milky white	Milky white	Milky white	Milky white
-Total solid weight%	50 ±1	50 ±1	50 ±1	50 ±1	50 ±1
- pH (1:1)	8-10	4-5	9 – 10	8.5 – 10	9 –10
-Viscosity, 30°c by Brookfield RVT, Sp. 3; 20 rpm (poise)	10-30	15-45	5 –10	7.5 –20	5 –10
- Particle size (u)	0.5 - 1	0.5 - 3	0.5 - 1	0.5 -1	0.5 -2

Bit. 2: Both the emulsifier (5% by weight) and the bentonitic clay (5% by weight) were added to hot water (70°C) while stirring . Hot bitumen (135°C) was added while stirring until the emulsion became completely homogeneous.

Bit. 3 to Bit. 7: The emulsified polymers and latex (50% active material) were added to the emulsified bitumen (50% active material) just after the emulsification of bitumen, taking into consideration that bitumen-polymer ratio was 2:1. Stirring was continued until the emulsions became completely homogeneous (Sitz *et al.*, 1991).

Wind tunnel evaluation for the prepared emulsions

1.The used wind tunnel

Tests were performed on sand material in a wind tunnel of 5.0 m long. Its tube is 3.5 m long with a cross sectional area of 0.135 m^2 (45 m width x 30 cm height). The ventilator (blower) initiating the wind movement was fixed at one end of the tunnel. Wind speed can be adjusted from 0 to 120 km hr^{-1} using the damper. The tray of tested sand (0.35m length x 0.35m width x 0.04m height) is placed inside the wind tunnel at a distance of 3 m away from the blower. Figure1 illustrates the wind tunnel that was used.

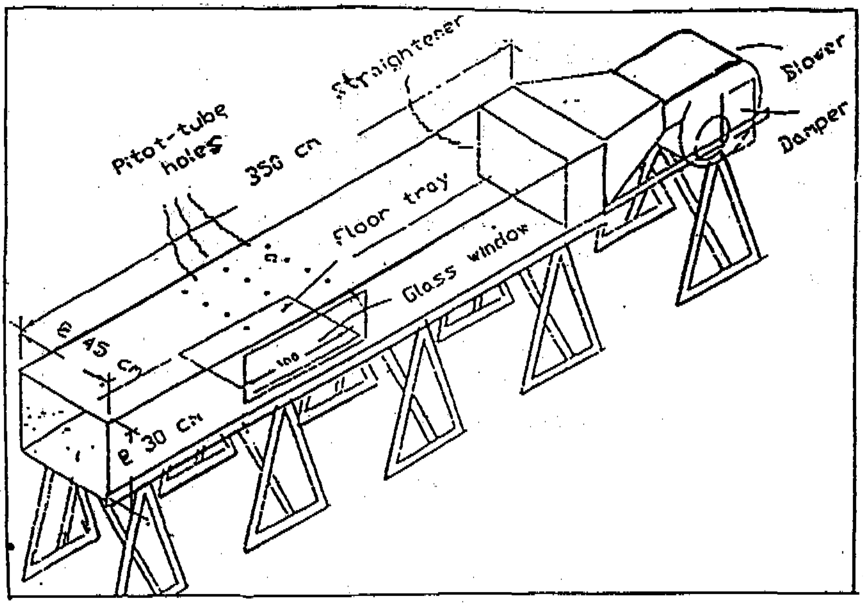

Fig. 1. Wind tunnel used in the evaluation of soil stabilizers.

2. Stabilization of sand

The sand was packed into the trays to a bulk density of 1.6 g cm^{-3} to assemble the dune. Amount of sand for each tray was 10.0 kg. Water was sprayed on sand surface at the rate of 1 l m^{-2} sand (initial moisture) using a hand-held spray bottle and left for two hours to reach equilibrium. Diluted stabilizers (emulsions) were sprayed on wetted sand in strips at a rate of 1 l m^{-2} sand taking into consideration the application rate of examined material (75 and 150 g active material m^{-2} sand) and covering percentage (33.3, 50.0, 66.7 and 100% of the sand surface). Trays were left to dry in the air.

3. Measuring sand loss due to wind movement

The trays were placed inside the wind tunnel. Two different wind speeds-to assemble wind speeds on the different locations of A.R. Egypt were examined. These are 4 m sec^{-1}, *i.e.* 14.4 km hr^{-1} and 8 m sec^{-1}, *i.e.* 28.8 km hr^{-1}. The choice of such wind speeds suits two main reasons. First, the highest value of M.S.W.S. (mean scalar wind speed) measured for winds blown on Egypt at Mersa Matrouh is 6.1 m sec^{-1} (Moneir, 1983) and second, the IS (the average size of the particles) dominant in the wind sand flow in Egyptian and Lybian deserts is 0.25 mm (Bagnold, 1954) which needs winds up to $\simeq$ 7 m sec^{-1} to be initially transported (Zakirov, 1982). Sand loss from the trays after each run was estimated by weighing. Sand lost was converted to a g m^{-2} basis.

Results and Discussion

As previously mentioned, amounts of sand packed into the trays to a bulk density of 1.6g cm^{-3} were 10.0 kg sand for each tray. The dried trays were placed inside the wind tunnel and subjected to two different wind speeds (4 m sec^{-1} and 8 m sec^{-1}). Loss from the untreated trays was amounted to 1.305 and 2.090 kg / tray under the mentioned wind speeds, respectively. This means that trays of untreated sand when subjected to wind speed of 4 m sec^{-1} lose nearly 13% of their sand. Relevant value for wind speed of 8 m sec^{-1} was 20.9 %. Such values refer to the high erodibility of sand and the great need for stabilization to reduce this loss to the lowest possible amounts.

Table 4 presents the amounts of sand loss as g/m^2 soil when various percentages (33.3, 50.0, 66.7 and 100%) of soil surface were mulched with two application rates of each stabilizer (75 and 150 g active material/m^2 soil) and subjected to two different wind speeds (4 and 8 m sec^{-1}). Soil loss ratio, *i.e.* amounts of sand lost (g /m^2 soil) after the treatment /amount of sand lost (g/m^2 soil) before the treatment (non mulched soil) are shown in Table 5, taking into consideration that such ratio for the untreated sand equals to 1.

TABLE 4. Soil loss (g/m^2 soil) when various percentages of soil surfaces were mulched with soil stabilizers and subjected to wind speeds.

Treatments		Wind speed 4 m /sec				Wind speed 8 m / sec			
		Covering percentage							
Examined Material	Application Rate (active material)	100%	66.7%	50.0%	33.3%	100.0%	66.7%	50.0%	33.3%
Bit.1	75 g / m^2	0	889	1330	1553	0	1696	2434	3140
	150 g / m^2	0	668	844	1016	0	1177	1216	1886
Bit.2	75 g / m^2	0	836	1271	1462	0	1635	2318	3072
	150 g/ m^2	0	594	765	963	0	1079	1141	1791
Bit.3	75 g / m^2	0	696	1135	1291	0	1393	2142	2930
	150 g/ m^2	0	478	700	867	0	937	1004	1682
Bit.4	75 g / m^2	0	739	1191	1399	0	1449	2188	2969
	150 g/ m^2	0	530	726	911	0	988	1034	1714
Bit.5	75 g / m^2	0	812	1261	1450	0	1601	2298	3051
	150 g/ m^2	0	587	768	961	0	1044	1099	1786
Bit.6	75 g / m^2	0	759	1211	1397	0	1517	2234	2974
	150 g/ m^2	0	542	753	925	0	994	1042	1739
Bit.7	75 g / m^2	0	861	1296	1496	0	1676	2410	3112
	150 g/ m^2	0	633	815	1000	0	1151	1182	1836

*Soil loss with no cover equals to 9800 and 15675 g/m^2 soil when subjected to wind speeds of 4sec^{-1} and 8m Sec^{-1}, respectively.

*Each value is the mean of two runs.

TABLE 5. Soil loss ratio when various percentages of soil surfaces were mulched with soil stabilizers and subjected to different wind.

Treatments		Wind Speed 4m/sec				Wind Speed 8m/sec			
		Covering percentage							
Examined Material	Application Rate (active material)	100%	66.7%	50.0%	33.3%	100.0%	66.7%	50.0%	33.3%
Bit.1	75 g / m²	0	0.091	0.136	0.158	0	0.108	0.155	0.200
	150 g / m²	0	0.068	0.086	0.104	0	0.075	0.078	0.120
Bit.2	75 g / m²	0	0.085	0.130	0.149	0	0.104	0.148	0.196
	150 g/ m²	0	0.061	0.078	0.098	0	0.069	0.073	0.114
Bit.3	75 g / m²	0	0.071	0.116	0.132	0	0.089	0.137	0.187
	150 g/ m²	0	0.049	0.071	0.088	0	0.060	0.064	0.107
Bit.4	75 g / m²	0	0.075	0.122	0.143	0	0.092	0.140	0.189
	150 g/ m²	0	0.054	0.074	0.093	0	0.063	0.066	0.109
Bit.5	75 g / m²	0	0.083	0.129	0.148	0	0.102	0.147	0.195
	150 g/ m²	0	0.060	0.078	0.098	0	0.067	0.070	0.114
Bit.6	75 g / m²	0	0.077	0.124	0.143	0	0.097	0.143	0.190
	150 g/ m²	0	0.055	0.075	0.094	0	0.063	0.066	0.111
Bit.7	75 g / m²	0	0.088	0.132	0.153	0	0.107	0.154	0.199
	150 g/ m²	0	0.065	0.083	0.102	0	0.073	0.075	0.117

*Soil loss ratio for sand with no cover equals to 1.

Data show that complete mulching of sand surface, even with the low application rate of examined stabilizers, and under the highest wind speed (8m sec^{-1}) completely prevent soil erodibility. Soil loss under such conditions will be equal to zero.

With partial covering, soil loss increases by decreasing the mulched area of sand or increasing wind speed from 4m sec^{-1} to 8 m sec^{-1}. On the other hand, examined emulsions differ in their stabilizing effect against wind erosion by varying degrees. Higher application rates, yield higher stability, *i.e.* lower sand loss under all investigated covering ratios (2/3, 1/2 and 1/3 the area of sand) and the two studied wind speeds (4 and 8 m sec^{-1}).

The multiple regression analysis (Snedecor and Cochran, 1980) was used to evaluate the interaction between any one of the factors affecting soil loss, *i.e.* wind speed (WS), application rate of the stabilizer (AR), and covering percentage with the stabilizer (CP) from one side and the soil loss ratio (SL) from the other side. The regression equations and the multiple correlation coefficients are given in Table 6. It is worthy to mention that all the interactions were highly significant.

TABLE 6. Multiple correlation coefficients and regression equations for the relations between factors affecting soil loss (wind speed, application rate of the stabilizer and covering percentage) and the soil loss ratio.

Examined stabilizer	Regression equation*	Multiple correlation
Bit. 1	(SL) = 0.7493 + 0.0026 (WS) – 0.0029 (AR) – 0.0052 (CP)	0.8822 **
Bit. 2	(SL) = 0.7443 + 0.0029 (WS) – 0.0029 (AR) – 0.0052 (CP)	0.8795 **
Bit. 3	(SL) = 0.7343 + 0.0033 (WS) – 0.0030 (AR) – 0.0051 (CP)	0.8730 **
Bit. 4	(SL) = 0.7405 + 0.0027 (WS) – 0.0029 (AR) – 0.0051 (CP)	0.8757 **
Bit. 5	(SL) = 0.7443 + 0.0028 (WS) – 0.0029 (AR) – 0.0052 (CP)	0.8790 **
Bit. 6	(SL) = 0.7410 + 0.0028(WS) – 0.0029 (AR) – 0.0051 (CP)	0.8768 **
Bit. 7	(SL) = 0.7464+ 0.0028 (WS) – 0.0029 (AR) – 0.0052 (CP)	0.8810 **

* (SL) = Soil loss Ratio, (WS) = Wind speed m sce^{-1}, (CP) = Covering percentage. (AR)=Application rate g (active material)/m^2 soil l.

**Significant at 1% level.

When covering 33.3% of sand area with the lowest application rate of examined stabilizers, *i.e.*75 g (active material) /m^2 sand and subjecting the trays to 4m sec^{-1} winds, sand loss ranged between 13.2 and 15.8 % with an average of 14.7 ± 0.83 % that of non mulched sand. Relevant values for 8 m Sec^{-1} winds were 18.7% and 20.0% with an average of 19.4 ± 0.51%. Doubling the application rates of the stabilizers to be 150 g (active material) /m^2 sand lowered the amounts of lost sand to be 8.8 to 10.4% with an average of 9.7 ± 0.55% and 10.7 to 12.0 % with an average of 11.3 ± 0.45% under 4 and 8 m sec^{-1} winds, respectively. Obtained results are in good agreement with those of Fryrear (1985 and 1989), El-Hadidy *et al.*, (1997) and El-Hady & El-Hadidy (1998) who noticed that soil loss would be reduced 80 percent if 30 percent of the sand surface was protected with stable soil aggregates larger than the maximum size that can be transported by wind. With this respect, examined stabilizers could be descendingly arranged according to their stabilizing effect as follows:

Bit.3 > Bit.4 ≥ Bit.6 > Bit.5 ≥ Bit.2 > Bit.7 > Bit.1.

The effectiveness of examined stabilizers on improving mechanical strength and increasing stability of sand depends upon their ability to penetrate soil structural units as well as their ability to form stable interparticle bonds. Data obtained by El-Hady *et al.* (2001) using the same stabilizers and applying different laboratory measurements to assess the stable adhesive bonds between sand particles in both the dry and wet conditions, *i.e.* unconfined compressive strength and penetration resistance (El-Hady *et al.*, 1986), the most stable dry structural units > 0.84 mm in diameter (El-Hady,1982) and wind erosion parameter (El-Hady and El-Sherif, 1986-b); the distribution of water stable structural units (Hartman and Verblancke, 1980); erosion index (Vandvelde *et al.*, 1974) and structure coefficient (El-Shafei and Ragab, 1976) stood with our results and may explain the differences in the effects of studied stabilizers, on one hand, and that both methods (wind tunnel test and laboratory measurements) could be used to evaluate sand stabilizers against erosive winds, on the other hand.

When mulching 1/3 of the sand surface with the lowest application rate of the examined stabilizers, quantities of materials needed to protect one hectar (10000 m^2) of sand dunes against wind erosion are 500kg of either Bit.l, or Bit.2 (50% active material). Preparation of Bit.2 needs also 25 kg bentonitic clay. For Bits.3, 4, 5 and 7, needed materials to protect the same area are 333.3 kg of Bit.l and 166.7 kg from each of the examined polymers styrene acrylic copolymer to prepare Bit.3, polyvinyl acetate butyl acrylate emulsion to prepare Bit.4, polyacrylic potassium acrylate, to prepare Bit.5 and latex emulsion (Butadiene styrene 24/76) to prepare Bit.7, all of them are 50% active material. With respect to Bit.6-besides 333.3 kg of Bit. l-needed polymers are 83.33 kg from each of the polymers styrene acrylic co-polymer and polyacrylic potassium acrylate (50% active material).

Taking into consideration that the preparation costs of bitumen emulsions (50% active material) are about 300 L.E. / ton compared with 2000-4000 L.E/ton for the examined polymers, locally prepared bitumen emulsions (such as Bit. 1 or Bit.2) seem to be preferable even if their application rates are doubled. Production of cheaper polymers to be used as modifiers for bitumen emulsions is of great importance.

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تحضير وتقييم بعض المستحلبات الأسفلتية والمستحلبات الأسفلتية المحسنه بالبوليمرات لاستخدامها كمثبتات للرمال

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تم تحضير عدة مستحلبات بتومينية (٥٠٪ مادة فعالة) لاستخدامها كمثبتات للأراضى وهى:

(أ) مستحلب بتيوميني رقم ١ محضر من بتيومين ذو درجة غرز ١٨٠/٢٠٠ انتاج شركة العامرية للبترول والمادة المستحلبة البوليمرية كاربوبول ٢٦٩١ انتاج BFGoodrich Chemical Europe, N.V.

(ب) مستحلب بتيوميني رقم ٢ محضر بتعديل المستحلب رقم ١ باضافة طين بنتونيت قصر الصاغة بالفيوم بمعدل ٥٪ وزنا.

(ج) المستحلبات ٣و٤و٥و٦ حضرت بتعديل المستحلب البتيوميني رقم ١ بالمستحلبات البوليمرية (٥٠٪ مادة فعالة) بولى ستيرين أكريلات- بولى أكريلك بوتاسيوم أكريلات - خليط من بولى ستيرين أكريلات وبولى أكريلك بوتاسيوم أكريلات بنسبة ١:١.

(د)المستحلب البتيوميني رقم ٧ حضر بتعديل المستحلب البتيوميتى رقم ١ بإضافة مستحلب المطاط (بيوتا دايين ستايرين) ٥٠٪ مادة فعالة.

فى جميع الأحوال كانت نسبة مستحلب البتيومين: مستحلب البوليمرات أو مستحلب المطاط كنسبة ١:٢.

اختيرت للدراسة رمال كثبان العبور على طريق مصر الإسماعيلية الصحراوى كمثال لكثبان الخانكة بشرق الدلتا.

قيمت كفاءة المثبتات المحضرة بتقدير كمية الرمل المفقود بالجرام /م٢ من سطح الرمل بعد تغطية نسب مختلفة منه (١٠٠،

٧. ٦٦، ٥٠، ٣. ٣٣٪) بالمواد المثبتة بمعدلين إضافة[٧٥، ١٥٠جم (مادة نشطة)/م٢] وتعريض الرمال للرياح فى نفق هوائى بسرعتين (٤. ٨ متر/ثانية أى ما يوازى ٤ . ١٤، ٨ . ٢٨ كم/ساعة على الترتيب) علما بأن اختيار هاتين السرعتين يتوافق مع كل من السرعة المتوسطة للرياح على مناطق مختلفة من جمهورية مصر العربية والقطر المتوسط للحبيبات السائدة فى الرمال السافية بالصحارى المصرية.

تشير النتائج المتحصل عليها إلى:

١- ثبات بناء الرمل الغيرمعامل ضعيف جدا قد يصل إلى الصفر.

٢-التأثير المثبت للمستحلبات المحضرة واضح ويختلف من مستحلب إلى أخر وكلما زاد معدل إضافة المستحلب زادت كفاءته على التثبيت.

٣- تحسين خواص المستحلب البتيوميني رقم ١ بإضافة طين البنتونيت له لانتاج بتيومين رقم ٢ أو اضافة المستحلبات البوليميرية له لانتاج المستحلبات البتيومينية المحسنة رقم ٣و٤و٥و٦و٧ يزيد من كفاءته على التثبيت.

٤- التغطية الكاملة لسطح الرمل بالمستحلبات المختبرة تمنع الانجراف بالرياح أما فى حالة التغطية الجزئية لسطح الرمل يقل فقد الرمل بزيادة المساحة المغطاه.

٥- تغطية ١/٣ سطح الرمال بالمثبتات تحت الدراسة يقلل الانجراف بالرياح بمقدار ٨٠-٩٠٪.

٦- يمكن ترتيب المستحلبات المحضرة تبعا لكفاءتها على التثبيت تنازليا كالأتى:
بتيومين ٣> بتيومين ٤ ≤بتيومين ٦ > بتيومين ٥≤ بتيومين ٢ بتيومين ٧ > بتيومين ١.

يتوقف استخدام أى من المثبتات المحضرة واختيار أفضل معدل إضافة وأفضل نسبة تغطية على الجدوى الاقتصادية ومدى الحاجة إلى ضبط الانجراف فى المنطقة. فى هذا المجال فإن المستحلب البتيوميني رقم ٢ يبدو أنه هو الأفضل حتى ولو ضوعف معدل إضافته كما أنه أقل تكلفه.

إنتاج بوليمرات منخفضة التكاليف لاستخدامها كمثبتات للرمال أو كمحسنات لخواص المستحلبات البتيومينيه يعد من الأهمية.