THE USE OF "UREA-FORMALDEHYDE RESIN" IN STABILIZING FINE TO MEDIUM SANDS

استخدام راتينج اليوريا فورمالدهايد لتثبيت الرمال الناعمة والمتوسطة

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ملخص : اجريت الابحاث على مدى سنوات عديدة لدراسة امكانية استخدام المواد الراتنجية لتحسين الخواص المختلفة للتربة الطبيعية ومنها التماسك والصمود للماء وقوة الشد وخواص أخرى تتميز بها المواد الراتنجية .

واستخدمت فى هذا البحث مادة اليوريا فورمالدهايد لتثبيت وتحسين خواص عينات من الرمل ماخوذة من الصحراء ومن شاطىء البحر . وقد كانت نتائج التجارب مرضية حيث انه امكن الحصول على مقاومة للضغط تزيد عن ٤٠ كيلوجرام/سم٢ ، بعد سبعة ايام باضافة ٥ر٧ ٪ بالوزن من اليوريا فورمالدهايد الى الرمل ، مما يسمح باستعمال هذا الرمل المثبت لتحمل حركة المرور الثقيل وفقا لمواصفات الجمعية الامريكية للطرق والنقل (AASHTO) كذلك ظهر تحسن ملحوظ لخواص أخرى للتربة مثل مقاومة البرى وامتصاص الماء ومعامل الكسر .

Abstract: For several years various investigations have studied the possibility of using resinous materials to improve the properties of natural soils. The improvement may be through increasing bonding, waterproofing, tensile strength and other properties of the polymeric materials.

The urea-formaldehyde resin was used in this paper, as a soil stabilizing agent, to improve the characteristics of desert and beach sands. The results are encouraging since the addition of about 5.7% of urea formaldehyde increases the compressive strength of the sand to more than 40 kg/cm^2 after 7-days air curing time which enables the sands to carry heavy traffic according to AASHTO specifications. In addition, the abrasion resistance, water absorption and modulus of rupture have been improved.

1. INTRODUCTION

In a flexible pavement, the bituminous concrete and its under courses distribute loads downwards to the subgrade soil. Additional strength in the subgrade soil can lead to a prolonged pavement lifetime. Stabilization which is a treatment of soil to improve its strength, works primarily towards this end. Different materials are used for soil stabilization such as lime, cement, bitumen and chlorides with different degrees of success.

Recently many investigations are done to study the possibility of using polymers to modify the properties of some types of soils. Polymeric materials possess outstanding tensile strength, chemical inertness, good adhesion to other materials and other valuable properties which draw considerable attention for their use in soil stabilization.

A number of polymeric materials were used in the Soviet Union as "structure forming agents" suitable for creating highly water resistant and mechanically strong soil structures to control erosion by wind and water on farm lands under cultivation (7). Japanese used polymeric materials in road construction and bridge deck overlays for the negligible permeability and high strength of the mixture (3). In Germany, the sand bed underneath a pier of a railway bridge was injected with urea-formaldehyde resin to increase the compressive strength (1). Sand of Maadi-desert near Cairo has been stabilized using polymeric materials which resulted in improvement of its absorption and strength properties (1).

The aim of this apper is to study more thoroughly the possibility of using the available local "Urea Formaldehyde resin" to stabilize different types of sands: "desert sand", "uncleaned beach sand" and "washed beach sand". The investigation includes the effect of the amount of urea-formaldehyde and time of air curing on sand properties such as compressive strength, flexural strength, water absorption and abrasion resistance.

2. MATERIALS AND TESTING PROGRAMME

Generally the chemical composition of sand determines the type of polymer to be used. The best type of resin to be used for sand stabilization is that containing a high percent of silicon oxide (SiO_2).

2.1 Sands

Three different types of sands were used. They are:

Sand I : Obtained at one meter depth from Cairo-Ismailia desert road at 54 km around the 10th of Ramadan city.

Sand II : Obtained from Gamasa beach to represent beach sand with salts and chlorides.

Sand III: Represents sand from Gamasa beach after washing with tap water.

Grain-size distribution of the three types of sands is given in Figure (1), while the chemical analysis of these sands is given in Table (1).

2.2 Urea-Formaldehyde

Urea- formaldehyde resin is classified as a thermoset material. The high degrees of cross linking are used to impart high rigidity and dimensional stability under conditions of heat and stress. Most mechanical properties depend on and vary considerably with molecular weight. The Urea-Formaldehyde polymer is generally characterized by :

- High rigidity and high resistance to deformation.
- modulus of elasticity (the resistance to deformation as measured by the initial stress divided by ($\Delta L/L$) ranges from 6.895×10^5 to 3.448×10^6 KN/m^2 (100000 - 5000000 psi).
- tensile strength ranges from 34475 to 82740 KN/m^2 (5000-12000 psi).
- Very small elongation (0.5 to 3 %).
- amorphous polymer with high chain rigidity as achieved by extensive cross linking.
- It can bond and link sand mineral particles and becomes insoluble after the reaction is completed
- it resists the biochemical decomposition.

The Urea-Formaldehyde used in this work is produced by "El-Nasr Company for particle Board and Resins" at El-Mansoura, and its characteristics are given in Table (2).

2.3 Testing programme

Three variables were considered in the testing programme. They are :

- Amonunt of Urea-formaldehyde to sand. The following values were taken 2,4,5,6 and 8% by weight.
- Time of air curing of mixtures. Time was divided into 7, 14, 21 and 28 days after preparation.
- Soaking of specimens in water where samples were allowed to soak in water for one day before performing tests.

In addition ammonium chloride was used to accelerate the polymerization process.

For each specimen of the above combinations , the following tests were performed.

1. Compressive strength
2. Flexural strength
3. Water absorption
4. Abrasion resistance.

3. ANALYSIS AND DISCUSSION OF RESULTS

a) Compressive strength

Figures 2 and 3 show test results. It can be seen that :

1. Compressive strength of desert sand increases with the increases of the percentage of added Urea-formaldehyde with a peaking value showing an optimum at 5.7% then it starts to decrease.

2. For beach sand either before or after washing compressive strength increases steadily to the maximum percentage of added Urea-formaldehyde 8%.

3. The compressive strength increases with increasing air curing time.

4. The maximum obtained values of compressive strength, after 28 days for desert sand, beach sand , washed beach sand were found to be 95, 148 and 164 kg/cm^2 respectively which are quite suitable for many structural and road construction uses.

5. Soaking the Urea-formaldehyde treated specimens in water for 24 hours after 28-days air curing time reduces the compressive strength to about 40% of the original value before soaking. This may be due to the long curing time required to complete the polymerization process before soaking.

b) Flexural stregnth.

From Figures 4 and 5, it is clear that :

1. Increasing the percentage of added Urea-formaldehyde (2-8%) resulted in an increase in flexural strength. This increase peaked at 5.7 % for desert sand, while it was steady for beach sand before or after washing with water.

2. The maximum achieved values of modulus of rupture for the desert sand, beach sand and washed sand were 48, 51.5 and 51.5 kg/cm^2 respectively.

3. Soaking of specimens in water for 24 hours after 28 days air curing reduces the flexural strength to about 40-50% due to the incompleteness of polymerization process.

c) Abrasion Resistance

Figures 6 and 7 indicate that the percentage of losses in weight by abrasion decreases with increasing air curing time and by adding Urea-formaldehyde up to 6.7 % for desert sand. 6% for beach sand and 8% for washed sand. After these percentages, the losses reach approximately a steady state giving percentages of wear between 3.5 to 5.5% by weight for all specimens.

The maximum values of abrasion lossses for treated samples ranged from 3 to 5% by weight after 28-days air curing time.

d) Water Absorption.

Figures 8 and 9 show that the percentage of water absorption by weight decreases with:-

1. increasing the percentage of Urea-formaldehyde up to 6.5% for desert and beach sands while it reaches 8% for washed sand.

2. Increasing air curing time.

The mimumum value of the percentage of water absorbed of all types of sands is about 6.5 % by weight. This value was obtained after 28 days air curing time.

4. THE MECHANISM OF POLYMERIZATION

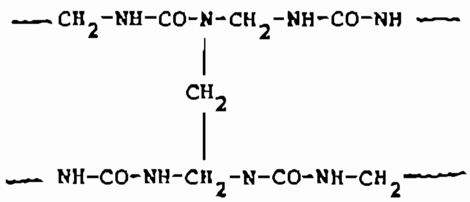
Polymers are macro molecules built up by the linking together of large numbers of much smaller molecules. The small molecules which combine with each other to form polymer molecules are termed "monomers" . The reaction by which they combine is termed "polymerization". Polymers are classified as linear, branched or cross linked polymers depending on the structure shape of the polymer molecules.

Urea-formaldehyde has an excessive rigidity due to extensive cross-linking which leads to an inability to crystallize. Urea-formaldehyde shows the characteristics of highly viscous liquids.

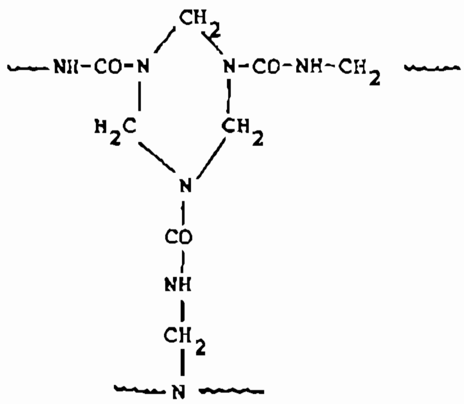
The polymerization of Urea-formaldehyde under mildly basic conditions yields methyol derivatives such as mono- and di-methylolurea (XIX).

$HOCH_2\text{-}NH\text{-}CO\text{-}NH_2$ (XIXa) $HOCH_2\text{-}NH\text{-}CO\text{-}NH\text{-}CH_2OH$ (XIXb)

which are then polymerized to network structures under neutral or slightly acid conditions. The nature of the cross linking reaction is out of the scope of this paper. Cross linking reactions via both linear (XX) and cyclic (XXI) may take the form(6):



linear (XX)



cyclic (XXI)

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the test results and above analysis, the following conclusions could be drawn.

1. Adding 5.7% Urea-formaldehyde by weight to medium size desert sand gives about 90 Kg/cm^2 compressive strength after 28 days curing time. The same amount enables the beach fine sand to withstand 130 kg/cm^2 compressive stress after 28 days curing time. All these values largely exceed the AASHTO specifications for portland cement stabilization (40 kg/cm^2) for

low and medium traffic. This means that Urea-formaldehyde treated sands will satisfy the AASHTO requirements with higher factor of safety for all types of tested fine and medium sands.

2. Washing the beach sand with tap water increases the pH value. The higher the pH value, above 7, for the treated sands the higher the compressive and flexural strengths. This may be attributed to the higher bond developed between slightly acidic Urea-formaldehyde (pH = 6.8) and the alkalinity of sandy materials.

3. Compressive strength of sands treated with Urea-formaldehyde increases with the increase of curing time in air.

4. Abrasion losses reach a minimum value (3%) by adding 5.7 - 6 % Urea-formaldehyde to sand by weight for all types of fine or medium sands. The abrasion losses may be decreased also by increasing air curing time. The same percentage of Urea-formaldehyde may decrease the ability of specimens for water absorption to its minimum value (6% by weight).

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Table 1: Chemical Analysis of Sands:

Chemical Composition		Oxide		% age		
				Sand I	Sand II	Sand III
Chemical Composition	Soluble Salts Content	Chloride$^-$	Cl^-	0.18	0.30	0.15
		Sulphate^{--}	SO_4^{--}	0.12	0.20	0.10
		Sodium$^+$	Na^+	0.00	0.05	0.00
		Potassium$^+$	K^+	0.00	0.02	0.00
	Oxide Content	Silicon Oxide	SiO_2	91.97	84.28	87.80
		Aluminium Oxide	Al_2O_3	1.52	5.62	4.20
		Ferric Oxide	Fe_2O_3	1.63	1.97	1.82
		Titanium Oxide	TiO_2	0.33	0.42	0.22
		Calcium Oxide	CaO	1.43	2.48	1.76
		Magnesium Oxide	MgO	0.28	0.67	0.48
		Sodium Oxide	Na_2O	0.37	1.62	0.56
		Potassium Oxide	K_2O	0.62	1.16	1.10
		Sulpher Trioxide	SO_3	0.57	0.58	0.56
		L.O.I.		1.25	1.14	1.12
Total				99.97	99.94	99.62
PH Value				7.50	7.80	8.10

Table 2: Characteristics of Urea-Formaldehyde Resin

Item	Character	Specifications
1	Appearance	Milky white liquid, free from foreign matter.
2	Hydrogen ion Concentration (PH value)	6.8 (at 20 °c)
3	Viscosity	(0.2 - 2.0) poise /20 °c.
4	Non - Volatile matter	45 to 52 %
5	Density (gm/cm^3)	1.26 at 25 °c.
6	Chemical Stability in water	Stable.
7	Gellation time	(20 - 100) min at 35 °c (soon after manufacture)
8	Storage	In plastic containers.
9	Handling	It is very sensitive to (PH) and high temperature.

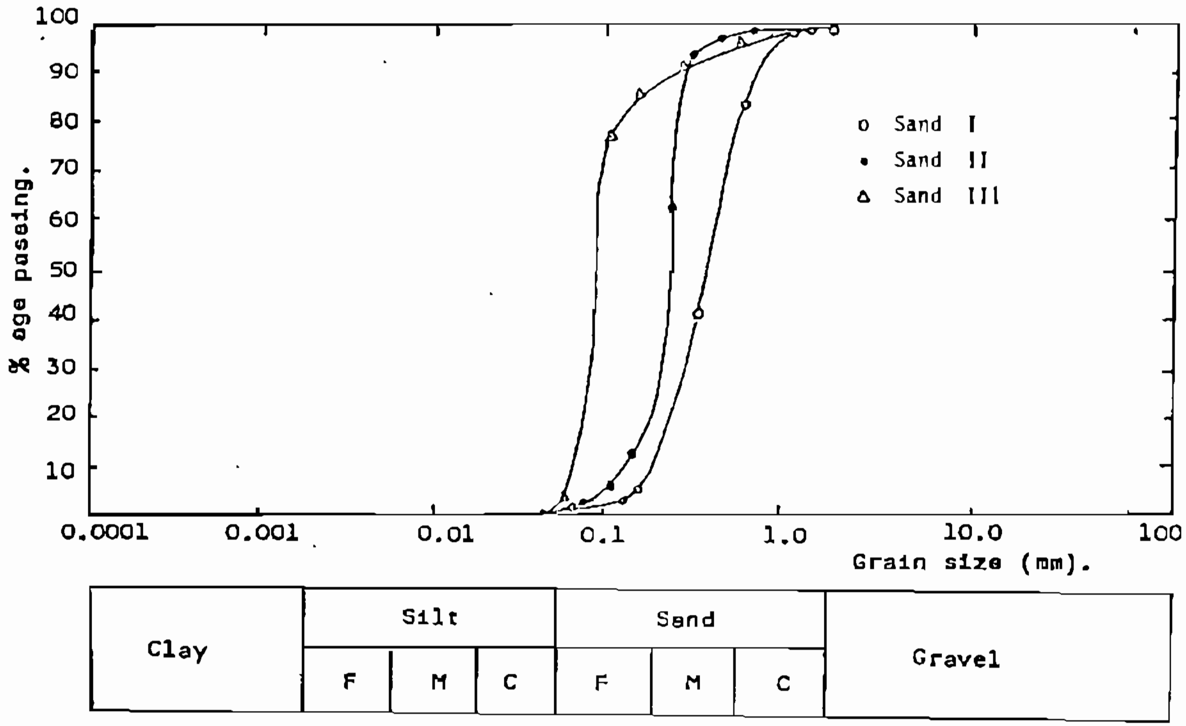

Fig.(1) : Grain size distribution curve for sands.

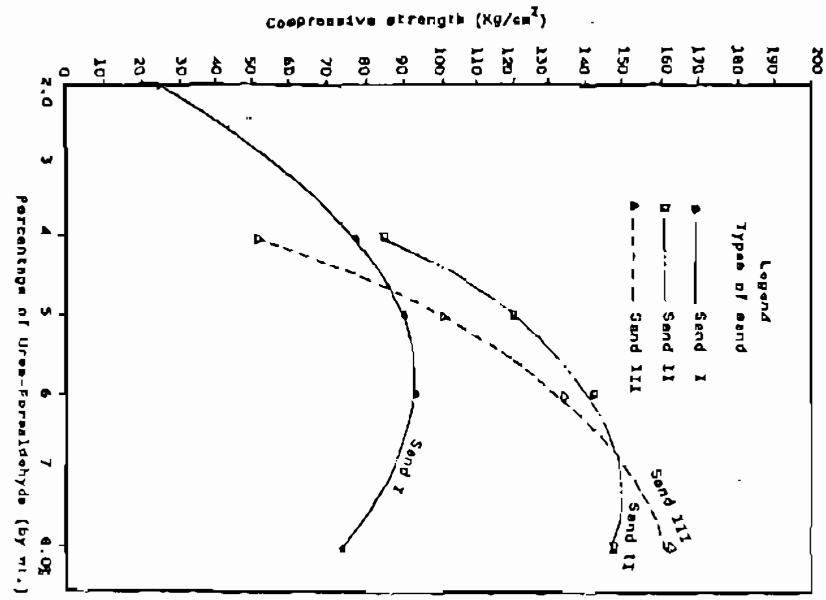

Fig.(2): Relationship between compressive strength at 28 days (Kg/cm²) and percentage of Urea-Formaldehyde (by wt.) for all sands.

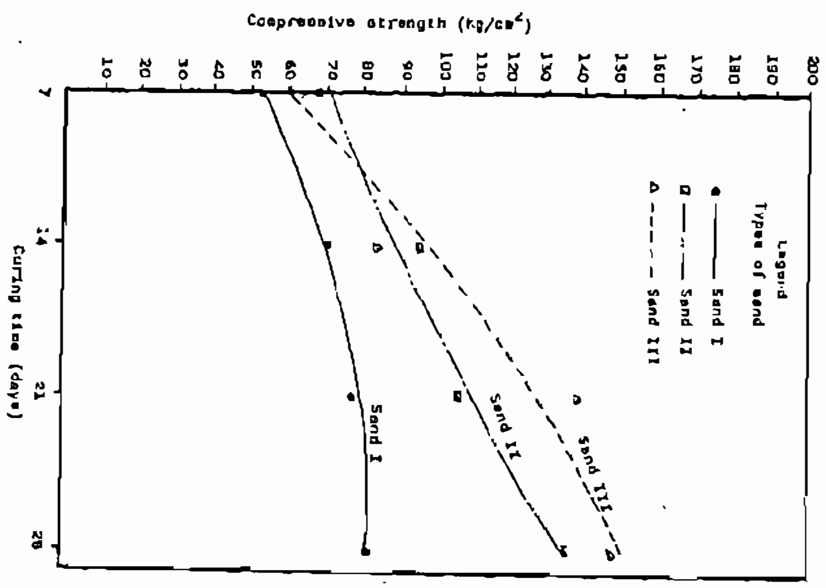

Fig.(3): Relationship between compressive strength (Kg/cm²) and curing time (days) for all sands at 6% Urea-Formaldehyde.

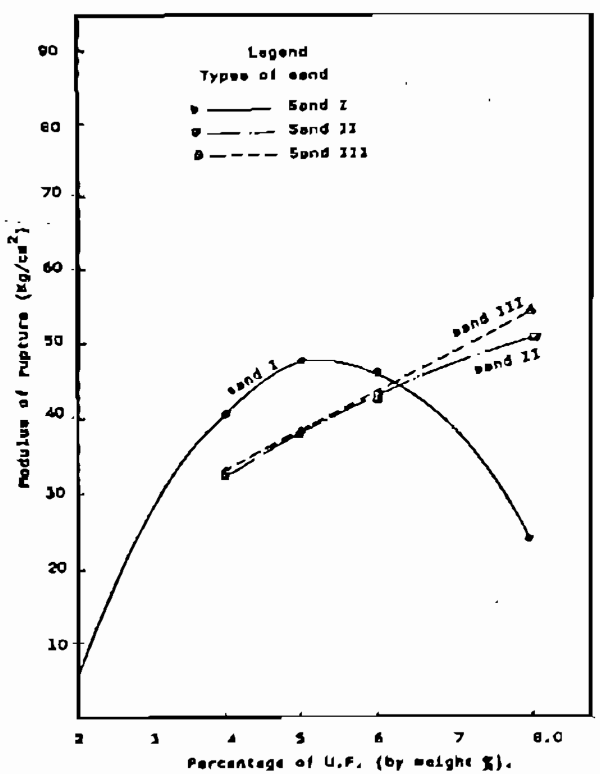

Fig.(4): Relationship between modulus of rupture (Kg/cm^2) at 28 days and percentage of U.F. for all sands.

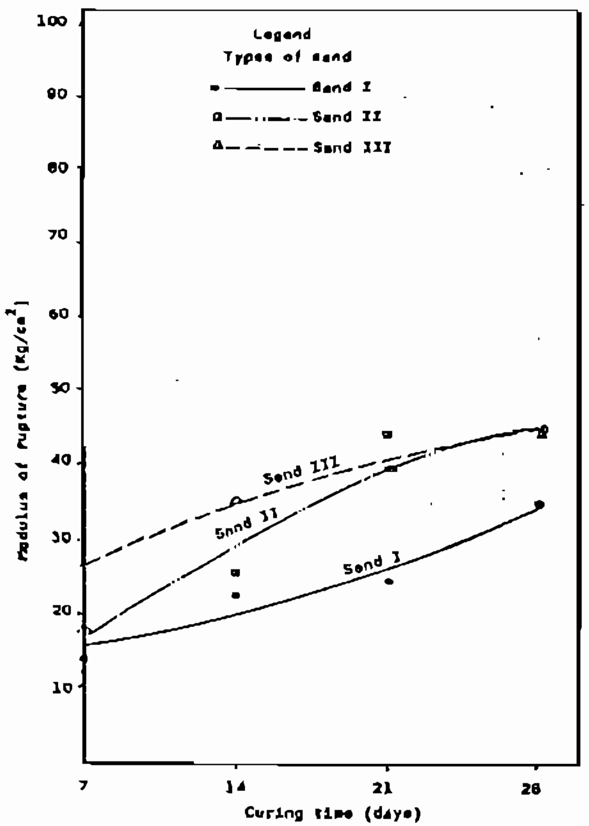

Fig.(5): Relationship between modulus of rupture (Kg/cm^2) and curing time (days) for all sands at 6% U.F.

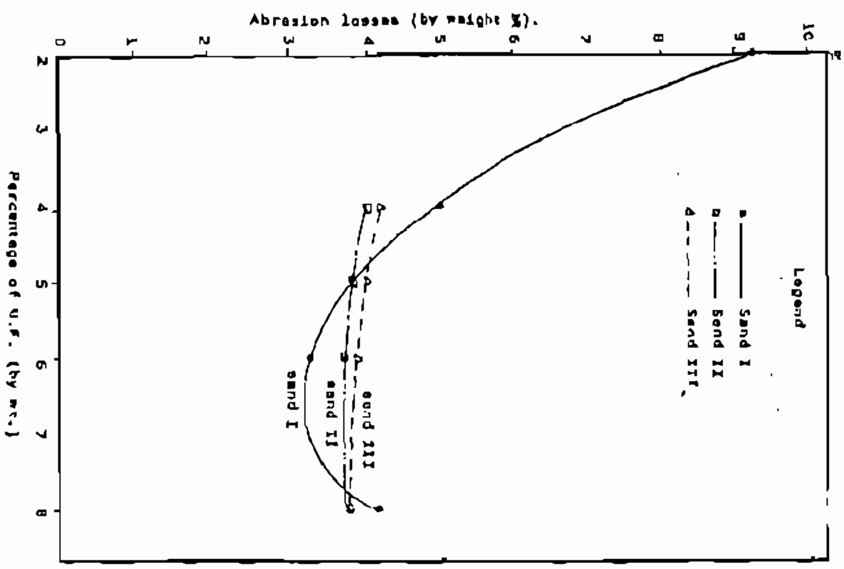

Fig.(6): Relationship between abrasion losses (by weight %) after 28 days and percentage of U.F. for all sands.

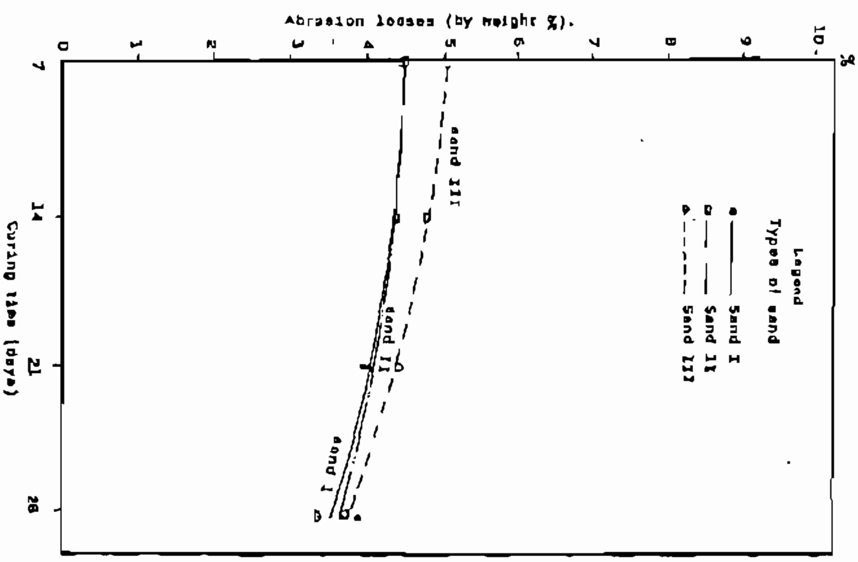

Fig.(7): Relationship between abrasion losses (by weight %) and curing time for all sands for 6% U.F.

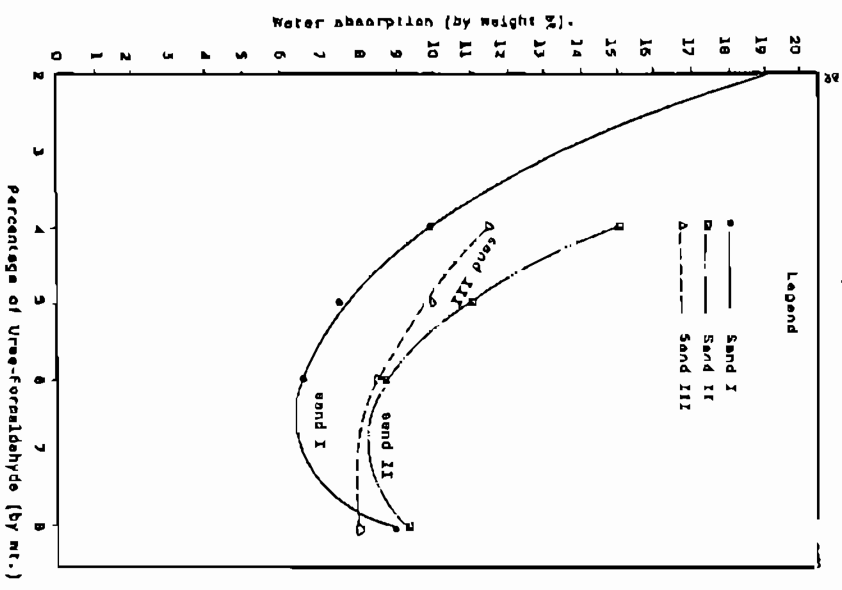

Fig.(8): Relationship between water absorption (by weight %) after 28 days and percentage of U.F. for all sands.

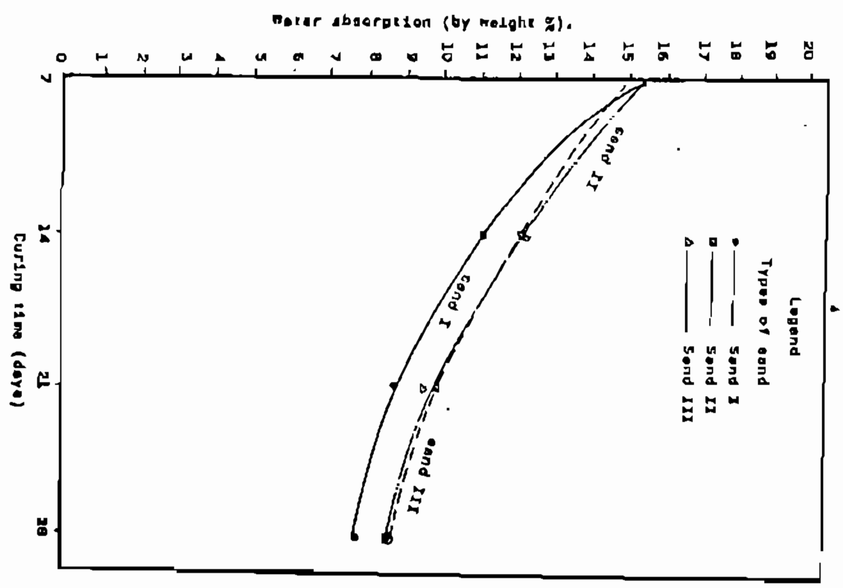

Fig.(9): Relationship between water absorption (by weight %) and curing time (days) for all sands at 6% U.F.