[illegible]

[illegible]

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Effect of Urea on the Engineering Properties of Gyseous Soil

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Summary

This study investigates the effect of urea product on the engineering properties of gypseous soil obtained from Baiji area. The investigated soil can be described as silty soil with low plasticity and high gypsum contents (32% gypsum). The maximum dry density of the compacted soil increased with the addition of urea up to 8% urea then decreased.

The direct shear test results showed that the effective angle of the internal friction (ϕ') increased with addition of urea and the increment was not more than 1^o up to 6 % urea addition . When 8, 10 and 12% urea added to the soil the increment was 2.5, 3.05 and 0.9 degree respectively, while the effect of urea on the effective cohesion (ć) was negligible. On the other hand, the unconfined compressive strength decreased with the addition of urea.

The investigated soil is non - swelling soil, however, the soil gained some swelling properties with the addition of urea and the maximum swelling properties were obtained with 8% urea.

Key Words : Gypreous Soil , Urea Product , Swelling Properties .

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[illegible]

[illegible] (Urea Fertilizers) [illegible]

[illegible] (CO_2) [illegible] (NH_3) [illegible] (130-140°C) [illegible] (200-100) [illegible] :[7]

$$2NH_3 + CO_2 \rightleftharpoons NH_2CO_2NH_4 + Heat$$

[illegible]

$$NH_2CO_2NH_4 \rightleftharpoons NH_2CONH_2 + H_2O + Heat$$

[illegible]

[illegible] :[3,8,9]

1. [illegible]:

$$NH_2CONH_2 + 2H_2O \longrightarrow (NH_4)_2CO_3$$

[illegible]

(9) [illegible] (pH) [illegible] .[4]

[illegible]:

$$(NH_4)_2CO_3 + H_2O \longrightarrow NH_4OH + NH_4HCO_3$$

[illegible]

2. [illegible] (NH_3) [illegible]:

$$NH_2CONH_2 + 2H_2O \longrightarrow CO_2 + H_2O + 2NH_3$$

[illegible]

[illegible] (NH_3) [illegible] (pH) [illegible] .[5]

[illegible]:

[illegible] (H^+) [illegible] .1
:(NH_4^+)

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

[illegible] ($SO_4^=$) [illegible]
[illegible].

$$2NH_4^+ + SO_4^= \longrightarrow (NH_4)_2 SO_4$$

[illegible]

[illegible] ($CaSO_4$) [illegible] .2
: (Calcium Tetra Amine Sulfate)

$$2NH_3 + CaSO_4 \longrightarrow Ca(NH_3)_2SO_4$$

[illegible]

[illegible] (Consolidation [illegible] (Shear Strength) [illegible] (Swelling Properties) [illegible] Characteristics) [illegible] (Compaction Characteristics) [illegible] (Index Properties) [illegible] .

[illegible]

[illegible] .1

[illegible] (Gypseous Silty Soil) [illegible] (32%) [illegible] (1) [illegible].

[illegible] .2

[illegible] (2) [illegible] .

[illegible] .3

[illegible] .(Distilled Water) [illegible]

[illegible]

[illegible] (3) [illegible] (Liquid Limit) [illegible] (Plastic Limit) [illegible] (NH_4^+) [illegible] (Double Layer) [illegible] .[6]

[illegible]

[illegible] (1-a) [illegible] (%8) [illegible] (O.M.C) [illegible] (1-b) [illegible] (M.D.D) [illegible] (1-c) [illegible].

[illegible] (dispersion) [illegible] (%8) [illegible].

[illegible]

.1 [illegible]

[illegible] (Direct Shear Test) [illegible] (%12, 10, 8, 6, 4) [illegible] (Consolidated Drained) [illegible] (4) [illegible] (Effective Cohesion (ć)) [illegible] (Effective Angle Of Internal Friction(ϕ)) [illegible] (0.9, 3.05, 2.5) [illegible] (%12, 10, 8) [illegible] (%6) [illegible].

.2 [illegible]:

[illegible] (Unconfined Compression Test) [illegible] (%12,10,8,6,4,2) [illegible] 49°C [illegible] 48 [illegible] (5) [illegible] (U.C.S.) [illegible] (Cohesionless Material) [illegible].

[illegible] (Stress-Strain Curves) [illegible] (2) [illegible] (%7.5) [illegible] (%8) [illegible] (%8) [illegible] (%10) [illegible] (%12) [illegible] (Plastic-Type Of Failure).

hĜβŧǁ !ƑĐǅƬďŰƐ ƫ ƐǊǬ

ŦhƧƙ!ƒ ǇďžǕƦĜďžǉ Ƨǒ ư ơƙ Ďƙ βl5 ŦhƧƙ!ƒ ĎĜďž ư ǉƒ ƭ ƑĜƬƤ ǏǁƵ ĜǒƧĂǒ!ƒ ǉβĜďž Ƨǒƛďƙ ŦƪƒƧβ! ƘǒƧŋƒ Ă (%10,8,6,4) ĜǒƧĂǒ!ƒ ǇďžǕ ŦƽǁƙƤďž Ɣƪǉh ĜǌǉǁďžĜƶďž βƶh ŦhƧƙ!ƒ ǇďžǕƦĜďžǉ ǁ!ƦŧĂ .[7]ŦǒƶǒhƱ!ƒ Ďƙ βρĂ (6) ýĂβŋ!ƒ Ǒ5 ŦǉǒhďžǊƑĜƙǉ!ƒĂ ǕƦĜďžǉ!ƒ ǉƦǊ ǏǁƵ (Consolidation Test) ĎĜďž ư ǉŮƒ ŦhƧŋƙ ƘĜƺƒƧ5!ƒ Ŧhƪǉ Ǒ5 ǉβĜǒƨ ǁ!ĜǉǊ ǇĎ Ʊơǚǒ .[2] ƧβƬďž!ƒ ǏǁƵ βĜďžƙƵŮĜh ĎĜďž ư ǉŮƒ ƭ ƑĜƬƤ ƔĜƪơ ĜǒƧĂǒ!ƒ ǉβĜďž ǇďžĈƨŋ ǇĎ Ǐ!ǫ ǁ!Ʀ Ǒ5 Ɣhƪ!ƒ βĂƶǒĂ ŦƽĜ ư ďž!ƒ ĜǒƧĂǒ!ƒ Ŧhƪǉ ǉβĜǒƨ ýďž (Void Ratio) Ĝďžŧ .(Solid Volume) βǁƬ!ƒ Ďŋơ!ƒ ýƛǒ ǁ!ƦhĂ ŦhƧŋƙ!ƒ ĈĜǉƛĎ ĈĜďž!Ĝh ǕƦĜďžǉ!ƒ Ƨďžƺ βǉƵ ĈĜďž!ƒ Ǒ5 ƔĂƦƙ ĜǒƧĂǒ!ƒ Ŧhƪǉ ǉβĜǒƨ ýďž (c_v) ƱĜƺ ư ǉŮƒ ýďžĜƶďž ǁ!ƦŧĂ (Cc) ƱĜƺ ư ǉŮƒ ýǒ!β ŦďžǒpǑ5 ǉβĜǒƨ Ʊơǚǒ Ǉďž ƻƶ ư ƒ ǑǊ ĜǒƧĂǒ!ƒ ƘƒƧĂh ǇĎ Ĝďžŧ Ü(e_o) ƘĜƺƒƧ5!ƒ Ŧhƪǉ Ŧďžǒp ǉβĜǒƨ Ǐ!ǫ βĂƶǒ Ɣhƪ!ƒĂ ŦƽĜ ư ďž!ƒ ǁ!ƦhĂ ýơǉƙĂ ƻƶ ư ƙ ƘƒƧĂh!ƒ ǉƦǊ ǇĜ5 ĎĜďž ư ǉŮƒ ýĜďžơĎ ƧǒƛďƙhĂ ĈĜďž! Ĝǌ ư Ƨƶƙ βǉƵĂ ÜŦhƧƙ!ƒ ƘĜƑǒƨŋ .ŦhƧƙ!ƒ ŦǒƱĜƺ ư ǉƒ βƒβƨƙ

hĜβŧǁ ƢƑƻŦďŰƐ ƫ ƐǊǬ

Ǒù5 ƘƛβùơǑƙ!ƒ ǬĜ5ƙǉŮƒ ǇƧǊĜƲ Ƨǒƪ5ƙ ýŋŮĂ ŦǒƤĜ5ƙǉƒ Ƨǒƺ Ƨhƙƶƙ ŦǁƱǉďž! ŦǒƶǒhƱ!ƒ ŦhƧƙ!ƒ Ǉǫ ŦƽǁƙƤďž ĜǒƧĂǒ Ɣƪǉh ĜǌǉǁďžĜƶďž βƶh ŦhƧƙ!ƒ ǇďžǕƦĜďž Ƨǒ ư ơƙ Ďƙ βl5 ÜĜǒƧĂǒ!ƒ ǉβĜďž! Ŧ ư Ƨƶďž!ƒ ŦhƧƙ!ƒ ƠƱƪ ǁ ù!ƦĂ Ü ǬĜ5ƙǉŮƒ ƭ ƒĂƤ ƔĜƪơ ĎƙĂ [7] ýƛďžŮƒ ǑhĂƱƧ!ƒ ăĂƙơďž!ƒĂ ǏďžƲƶ!ƒ ŦƽĜƛŧ!ĜhĂ(%10, 8, 6, 4) Ƨǚơ!ƒ ǬĜǚ5ƙǉŮƒ ŦǚhƧŋƙĂ (Constant Swelling Test) ƘǚhĜƛ!ƒ Ďǚŋơ!ƒ ŦǚhƧŋƙ ĈƒƧŋǚh ýŧƬ!ƒ Ǒ5 Ŧơ ư Ăďž ǬĜ5ƙǉŮƒ ŦhƪǉĂ Ʊƺ ư Ŧďžǒp ǏǁƵ ĜǒƧĂǒ!ƒ Ƨǒƛďƙ Ǉǫ . [1] (Free Swelling Test) . (7) ýĂβŋ!ƒ ǁ!ƦŧĂ (3)

(%8) βơ Ǐ!ƒĂ ÜŦƽĜ ư ďž!ƒ ĜǒƧĂǒ!ƒ Ŧhƪǉ ǉβĜǒƨ ýďž βƒβƨƙ ǬĜ5ƙǉŮƒ ƭ ƒĂƤ ǇĎ ǊƑĜƙǉ!ƒ Ǉďž Ơ ư ƙǒ ǇĜ5 ŦďžĜƵ ǉƧĂƬhĂ (34.5 Mpa) ǬĜ5ƙǉƒ Ʊƺ ư ǏǁƵĎĂ (%0.58) ǬĜ5ƙǉƒ Ŧhƪǉ ǏǁƵĎ ƘǉĜŧĂ ýǉƙ ĜǊβƶh .ŦƑƱƒĂ ǬĜ5ƙǉƒ ƭ ƒĂƤ ƘƒƦ Ĝǌǉďžh ŦhƧƙ!ƒ ƻǉƬƙĂ ŦǁǒǉpĎǒl!ƒ ǉƦǊ βƒβƨƙ ǑǉĂǒŮƒ ýβĜhƙ!ƒ Ŧƶƪ ǇĎ Ŧǒơ ÜŦhƧƙǁ! ǑǉĂǒŮƒ ýβĜhƙ!ƒ ǇƧǊĜƲ Ǐ!ǫ βĂƶǒ ǬĜ5ƙǉŮƒ Ɣhƪ ǇĎ ýǒ!β! Ŧďžǒp ǏǁƵĎ ǇĜ5 ǁ!Ʀŧ Ü(8) ýĂβŋ!ƒ Ǒ5 Ơ ư Ăďž Ĝďžŧ Ă ýǉƙ ĎƙĂ (%8) βơ Ǐ!ƒĂ ĜǒƧĂǒ!ƒ Ŧhƪǉ ǉβĜǒƨ ýďž .Ĝ ư ǒĎ ĜǒƧĂǒ (%8) Ŧhƪǉh ŦhƧƙ!ƒ ŦǁďžĜƶďž βǉƵ ǇĜŧ (P.I) ŦǉĂβǁ!ƒ

ƭ Ƨ!ƒ ŦǒǁďžƵ Ǒ5 ĜǌǒǁĎ ǊƙƱĜ ư ǫ ĈĜǉƛĎ ĈĜďž!ƒ Ǉďž ƵĈƨŋ ƭ ƙďžƙ βp ĜǒƧĂǒ!ƒ ǉβĜďžh ŦǁďžĜƶďž!ƒ ŦhƧƙ!ƒ ǇĎ ŦhƧƙ!ƒ ǇďžǕƦĜďžǉ Ƨǒ ư ơƙ Ďƙ βl5 ǁ!Ʀ! ÜĜǌǒǁƵ ýĂƬơ!ƒ Ďƙ Ǒƙ!ƒ ǊƑĜƙǉ!ƒ ǏǁƵ ƧƛƱǒ ƒƦǊĂ ƑǒƑƨŋ ǬƼƙǉƙĂ ĜǒƧĂǒ!ƒ ýĂǁơďž ǕƦĜďžǉ!ƒ ǉƦǊ Ǐ!ǫ ƻǒ ư Ď ÜĜǒƧĂǒ!Ĝh ŦǁďžĜƶďž Ƨǒƺ Ă (ǬĜ5ƙǉŮƒ ŦďžǒβƵ ŦhƧƙ ǑǊĂ) ŦǒƶǒhƱ!ƒ ýĂǁơďž ǇƧĂďžƺďž!ƒ ŦhƧƙǁ! ǬĜ5ƙǉŮƒ ŦhƪĂ Ʊƺ ư (9) ýĂβŋ!ƒ ǇǒhĂ .(%150,100,50) ŦƽǁƙƤďž ƨǒŧƒƧƙhĂ βǉƵ ƘǉĜŧ ŦhƧƙǁ! ǬĜ5ƙǉƒ ƱƺưĂ Ŧhƪǉ ǏǁƵĎ ǇĎ Ʊơǚǒ ǊƑĜƙǉ!ƒ Ǉďž .ǉǚƵĎ ǇƧĂŧƦď!ƒ ƨǒŧƒƧƙ!ĜhĂ ĜǒƧĂǒ!ƒ Ʊƺ ư ŦďžǒpĂ (%0.95) Ǐ!ǫ ǬĜ5ƙǉŮƒ Ŧhƪǉ ƘǁƬĂ Ŧǒơ Ü (%100) ƨǒŧƒƧƙh ĜǒƧĂǒ!ƒ ýĂǁơďž ĎƒβƤƙƪ ŦhƧƙ!ƒ ƭ ĜƬƙďžƒ Ŧhƪǉ ǇĎ βŋĂ ýĂǁơďž!ƒ ƒƦǉh ŦǁďžĜƶďž!ƒ ŦhƧƙ!ƒ ǊƑĜƙǉ ýǒǁơƙ βǉƵĂ (41.4 Kpa) Ǐ!ǫ ǬĜ5ƙǉŮƒ ǑǊ ýĂǁơďž!ƒ ƒƦǉh ŦǁďžĜƶďž!ƒ ŦhƧƙǁ! ǑǉĂǒŮƒ ýβĜhƙ!ƒ Ŧƶƪ Ŧďžǒp ǇĎ Ĝďžŧ ÜĜhƧlƙ (%8) ƘǉĜŧ ĜǒƧĂǒ!ƒ ǉβĜďž! ƻǚƙƤƒ Ɣhƪ βĂƶǒĂ .(8 ýĂβŋ) (%8) ŦhƪǉhĂ ĜǒƧĂǒ!ƒ ǉβĜďžh ŦǁďžĜƶďž!ƒ ŦhƧƙǁ!Ă ǑǉĂǒŮƒ ýβĜhƙǁ! Ďǒl! ŦhƧĜlďž ÜĜǌƬƧ ŦǒǁďžƵ ĈĜǉƛĎ ĜǒƧĂǒ!Ĝh ŦǁďžĜƶďž!ƒ ŦhƧƙ!ƒ ǕƦĜďžǉ! ǬĜ5ƙǉƒ ŦĂβơ Ǐ!ǫ ǉǚƵĎ ǇǒƙlǒƧƱ!Ĝh ƘĜƬĂơƪǁ! ǊƑĜƙǉ!ƒ Ǒ5 ŦǁďžĜŧ ǉƧĂƬh ǕƦĂďžǉ!ƒ Ǒ5 ýƬĜơ!ƒ ǬĜ5ƙǉŮƒ ƩĜǒp Ďƙ βl5 (ĜǒƧĂǒ!ƒ ýĂǁơďž ŦƽĜ ư ǫ) ŦǒǉĜƛ!ƒ ŦǒƧƱ!ƒ ĜďžĎ .ĎĜďž ư ǉŮƒ ƨĜǌŋ

ǑhĂƱƧ!ƒ ăĂƙơďž!ƒ Ǉďž ýƥƒ ǑhĂƱƧ ăĂƙơďžh ƘƧ ư ơ ǕƦĜďžǉ! ǬĜ5ƙǉƒ ƭ ƒĂƤ ƩĜǒp Ďƙ ǁ!Ʀŧ Ʊƺ ư Ŧďžǒp Ǒ5 Ƨǒhŧ ƳĜ5ƙƧƒ ƱơĂ!Ă Ü(%100) ƨǒŧƒƧƙh ĜǒƧĂǒ!ƒ ýĂǁơďžh ĜǊƧďžƺ ĎƙĂ (%2) ƧƒβǁĎh ýƛďžŮƒ Ŧďžǒp ǉƦǊĂ Ü(127.65 Kpa) ǬĜ5ƙǉŮƒ ƱƺưĂ (%4) Ǐ!ǫ ǬĜ5ƙǉŮƒ Ŧhƪǉ ƘǁƬĂ Ŧǒơ Ü ǬĜ5ƙǉŮƒ ŦhƪǉĂ Ǉďž βǒƨǒ ĜǒƧĂǒ!ƒ ǉβĜďž! ŦhƧƙ!ƒ ƭ ĜƬƙďžƒ Ŧhƪǉ ǉβĜǒƨ ǇĎ ǏǁƵ ýβǒ ƒƦǉĂ ŦlhĜƪ!ƒ ǊƑĜƙǉ!Ĝh ŦǉĜƲǁĎ Ŧǒ!ĜƵ .ŦǒƤĜ5ƙǉŮƒ ĜǌƬƒĂƤ

[illegible]

[illegible]

.1 [illegible]

.2 [illegible]

.3 [illegible]

.4 [illegible] (Cc) [illegible] (C_V) .

.5 [illegible] (%8) [illegible]

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(*)ƕƓƥȽǂǁ ƕǏǂǏǁƣǁƐ ƫ ƐǋƋƣǁƐ (1) üǋƣǁǁ

31	(%) L.L.	ǁ ƧƕƧƙƒ ƥĂƥơ Atterberg limits
24	(%) P.L.	
7	(%) P.I..	
2.62	(Gs) ŎƵĂǰ!ƒ ǇƨĂ!ƒ	
3.75	(%) ȽŏĂ ư ƶ!ƒ ƥƒĂƋ!ƒ Ƚƕʅǰ	
34.74	(%) T.S.S Ƚƕƒƙ!ƒ ƟűƋŬƒ Ƚƕʅǰ	
32	(%) Gypsum Ʃƕŋ!ƒ Ƚƕʅǰ	
14	ýƋƧ!ƒ(%)	ȽƕƧƙǁ! Őƕŏƕơ!ƒ ýŏǁơƙ!ƒ
68	ǇŏƧƷ!ƒ(%)	
18	ǇŏƱ!ƒ(%)	
ML	Unified Classification system	
1.81	(3Ƌʅ/Ƌƺ) ǏƋƱƶ!ƒ Ƚ5Ɠŋ!ƒ Ƚ5ƓƛǂƋ!ƒ	
13	(%) ýƛƋŬƒ ŐƕĂƱƧ!ƒ ăĂƙơƋ!ƒ	

(*) .ƘŬĂƓơƋ ǂ űƛ ǇƋ ƧƛǂŬ ýƥƶƋ ýƛƋƙ Ƚŋŏƙǰ ýǂ

(5)(ƑǏƥǋǏǁƐ) ƒ ǀƥƋǁƐ ƣǏƊƑƓƥƑǀǁƐ ƔƣƑƊ ƫ ƐǋƋƣ !ǉƈ (2) üǋƣǁǁ

NH₂CONH₂	Formula ƕǏǋƑǏƊǏǀǁƐ ƕƺǏƬǁƐ
ýĂƋ/Ƌƺ 60.06	Molecular weight ŎƑŏƨŋ!ƒ ǇƨĂ!ƒ
(C) ƧĂǁƕƙƋ	Physical state at 25C ȽŏƑƓŏƨŏƨ!ƒ Ƚ!Ɠơ!ƒ
3Ƌ/Ƌƺǂ 1335	Unit weight Ƚ5ƓƛǂƋ!ƒ
Ƌ 135	ȽŏƶŏƕƱ!ƒ ƧƓǋƮǰŬƒ ȽŋƧƥ Normal melting point
1.323	ýƑƓʅǁ! ŎƵĂǰ!ƒ ǇƨĂ!ƒ Specific gravity of liquid at 25C
119	Solubility ǇƓƕĂƦ!ƒ (gm/100 ml H_2O at 25C)
-108	Heat of solution ȽƕƒƦŬƒ ǀƧƒƧơ (*)(Btu/Ib)

(*) Btu/Ib = ǀƥơĂ ȽŏƧƒƧơ ȽŏǰƓƱŏƧƕ .

(3)

15	12	10	8	6	4	2	0	(%) Urea
18	20	24	25	25.5	28.0	28.5	31	(%) L.L
12	13	15	15.5	16.5	19	20.5	24	(%) P.L
6	7	9	9.5	9	9	8	7	(%) P.I

(4)

12	10	8	6	4	0	(%) Urea
0	0.055 (5.4)	0.1 (9.8)	0.085 (8.3)	0.05 (4.9)	0.05 (4.9)	Cohesion (ć) (kg/cm^2),(kN/m^2)
36.65	38.8	38.25	36.35	35.95	35.75	Angle of internal friction (ϕ')

(*) (5)

Cured for 48 hr at 49 ć	**Without curing**	**Curing condition**
U.C.S (kg/cm^2) ,(kN/m^2)	U.C.S (kg/cm^2),(kN/m^2)	Urea Addition (%)
6.15 (603.1)	5.35 (524.6)	0
---	5.11 (501.1)	2
5.105 (500.6)	5.066 (496.8)	4
---	4.64 (455.0)	6
3.565 (349.6)	4.385 (430.0)	8
---	3.677 (360.6)	10
2.036 (199.6)	3.125 (306.4)	12

(*)

(6)

10^{-7}×Cv cm^2/sec	Cc	Void ratio (e_0)	(%) Urea
5.02	0.032	0.3965	0
6.72	0.035	0.445	4
10.85	0.051	0.46	6
37	0.081	0.51	8
80.5	0.106	0.54	10

[illegible] (7)

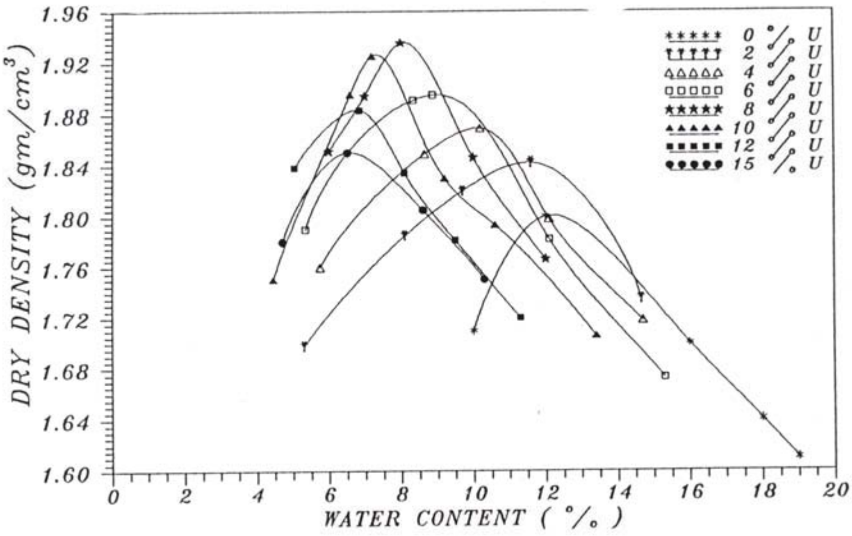
(%) [illegible]	[illegible] psi (kPa)	[illegible] (%) Urea
0	0	0
0.23	2.5 (17.25)	4
0.47	4 (27.6)	6
0.58	5 (34.5)	8
0.05	1.5 (10.35)	10

[illegible] (C.E.C) [illegible] (8)

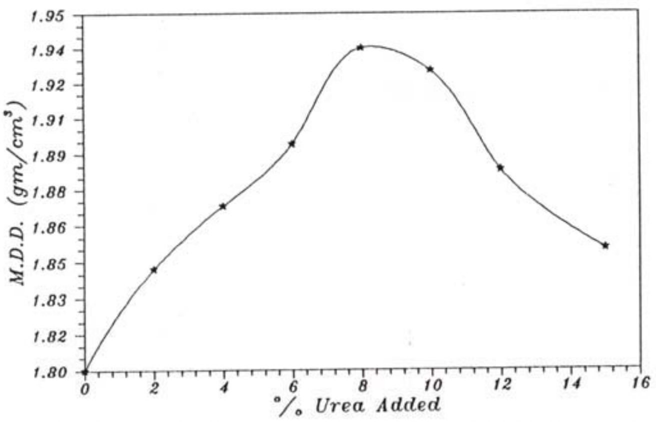
[illegible] (% 100)	15	10	8	4	0	[illegible] (%) Urea
19	9	13	20	14	12	[illegible] C.E.C

[illegible] (9)

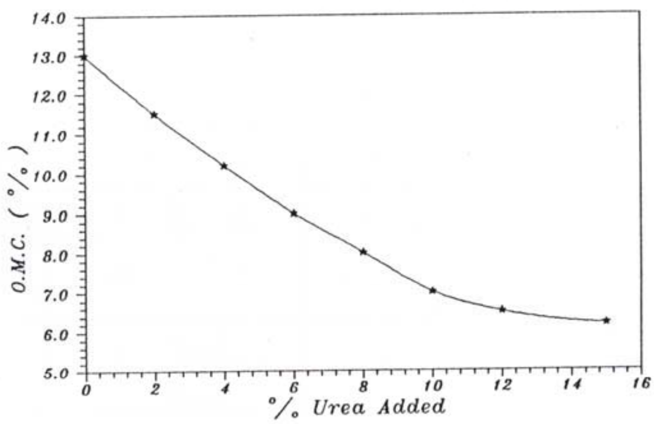
(%) [illegible]	[illegible] psi (kPa)	[illegible]	
0.47	5.5 (38)	% 50	
0.95	6 (41.4)	O.M.C	% 100
4.0	18.5 (127.65)	O.M.C - 2 %	
0.46	5.5 (38)	% 150	



(**1-a**) ül ʅ



(**1-b**) ül ʅ



(**1-c**) ül ʅ

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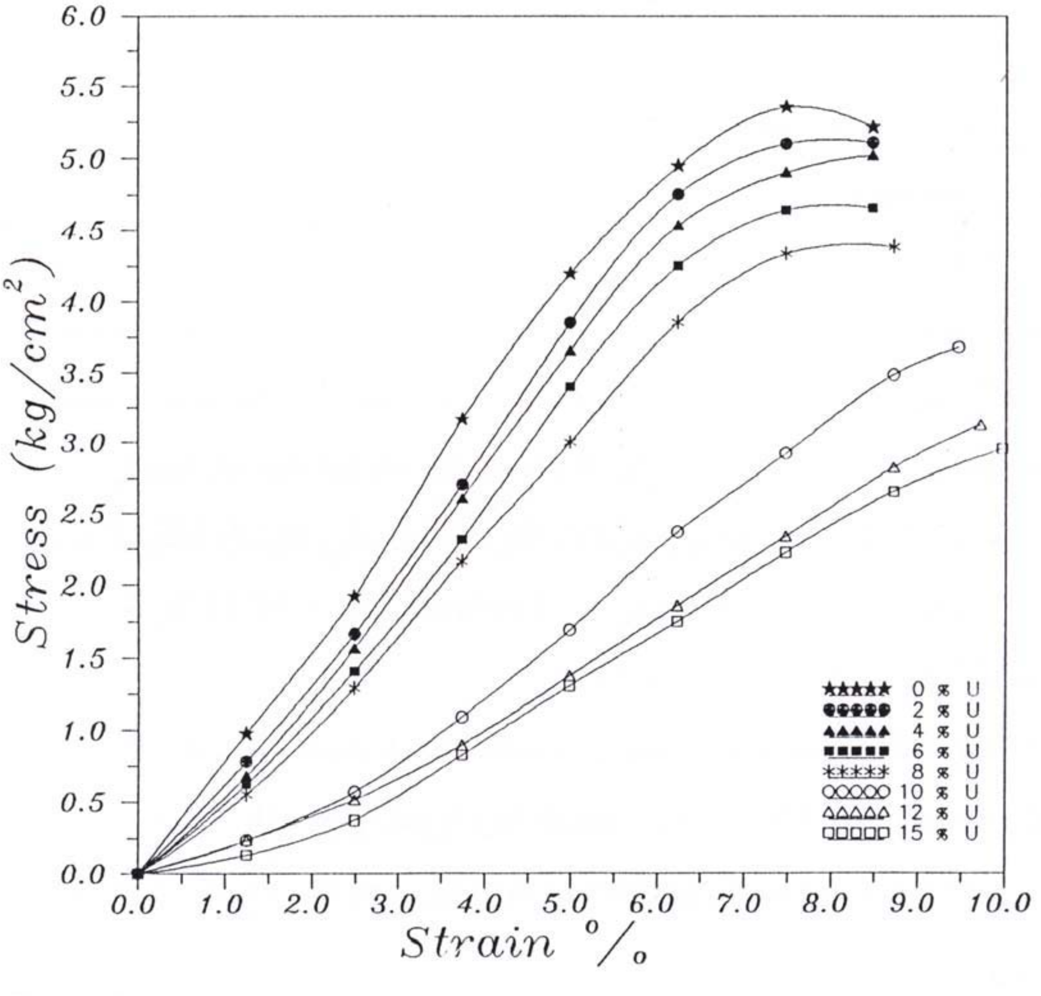

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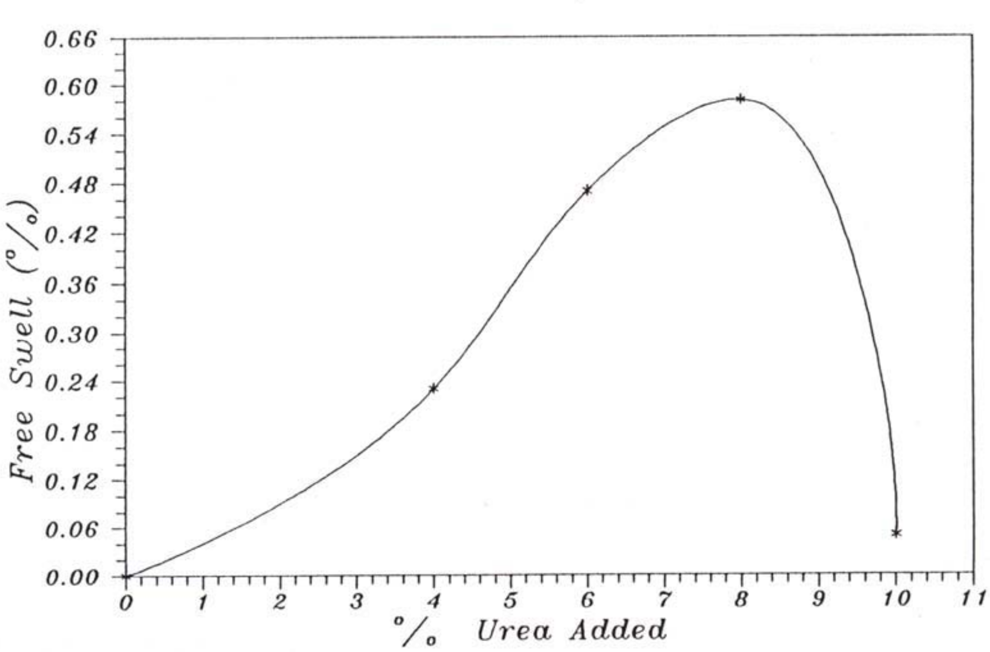

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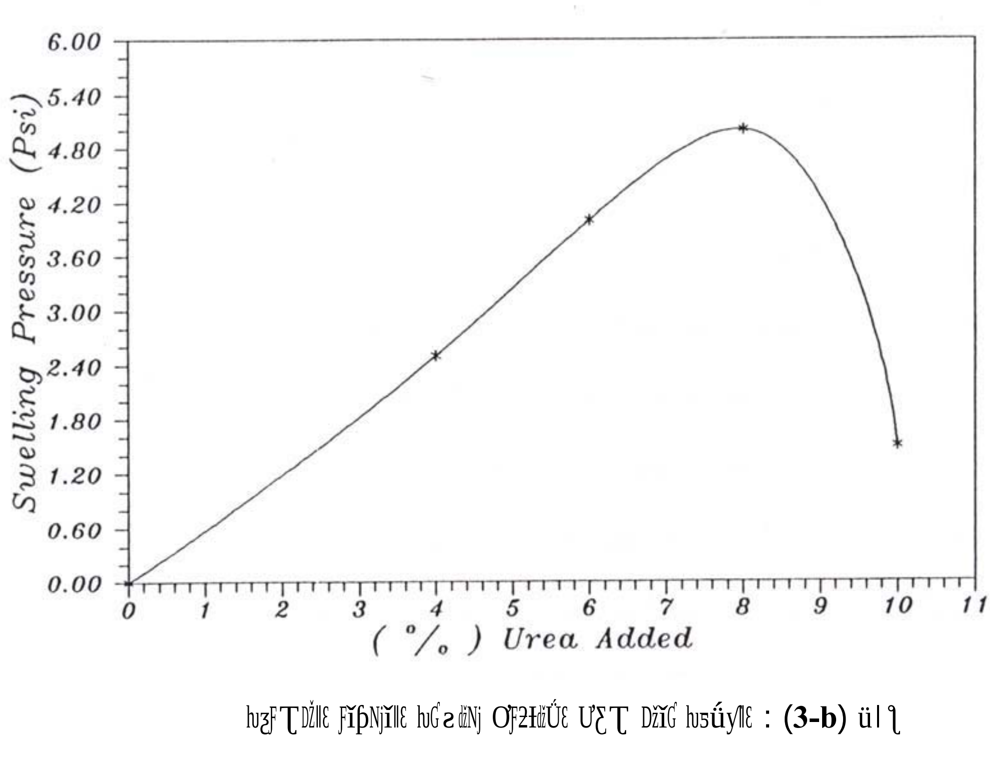

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