

---

\*

( // : // : )

%

%

:

...

(BM) " "

$\tau$

kg/m<sup>3</sup> BM kPa

$\tau = 3.13 + 3.31 BM$  ( )

( )

(RAR)

% %

( )

$A_t$

$A_r$

$d_i a_i$

$\Delta\tau = 7.299 RAR$  ( )

$\Delta\tau = 4.23 RAR$  ( )

( )

$$RAR = \frac{A_r}{A_t} 100 = \frac{\sum a_i}{A_t} 100 = \frac{\pi \sum d_i^2}{4 A_t} 100$$
 ( )

( )

$\Delta\tau = 2.7 \times 10^{-6} RAR$  ( )

( )

( $\phi$ )

(c)

( $\tau$ )

( )

biomass

pinus contorta

Hengchaovanich & Nilaweera (1996)

vetiver

Burroughs & Thomas (1977)

Waldron & Dakessian (1981)

Waldron (1977)

Ziemer (1981)

( )	( )	( )	( )	( )	( )
	( )		( )	( )	( )
		( )			( )
	( )				( )
	%	$\phi$			" "
			kg/m <sup>3</sup>	kPa	BM c
( )					
( )	( )			$c=10.54+8.63 \log (BM)$	( )
				$c=11.14+9.9 \log (BM)$	( )
					( )
"	"	"	"	kPa	
( )					
	( )			( )	( )

---

Swanston (1974 a, b)  
Gray & Megahan (1981)  
Stokes et al (1996)  
Stokes et al (1995)  
pull out  
Nilaweera (1994)  
Nilaweera & Nutalaya (1999)

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Wu et al (1979)  
Luckman et al (1982)  
Coppin & Richards (1990)  
Abe & Ziemer (1991)  
Yarbrough (2000)  
Tengbeh (1989)  
loretta  
O'Loughlin et al (1982)  
Endo & Tsuruta (1969)  
O'Loughlin (1974 a,b)

...



( )

( ) ( ) ( ) ( )

( )

cm

x

x

cm

( )

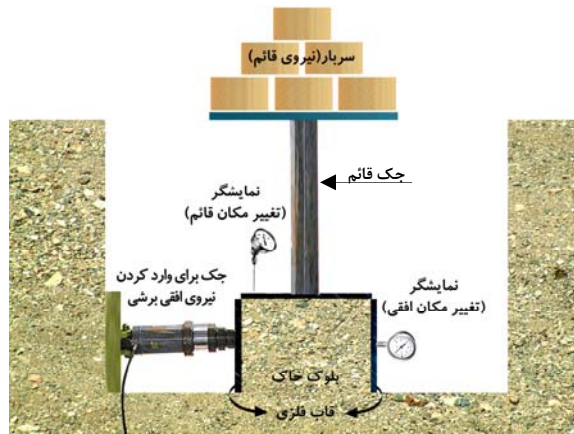
/ mm

/ mm/min

( mm)

---

Wu et al (1988)  
Wu & Watson (1998)  
Greenway (1987)  
Abe & Iwamoto (1986)  
Ekanayake & Phillips (2002)



kPa

( )

%      %

ASTM

%      %

$\tau_{max}$       ( )

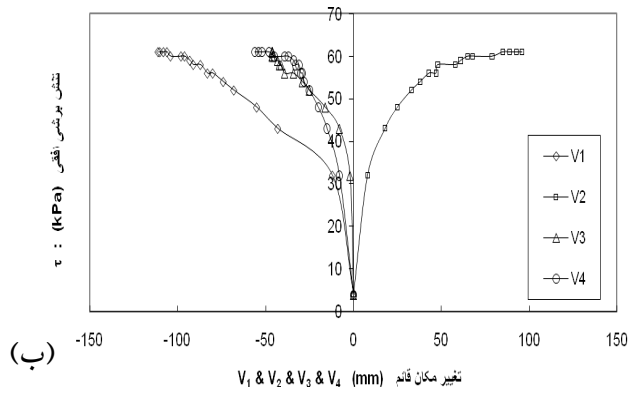
$\sigma_v$

$d_{max}$      $d_{50}$       %      %

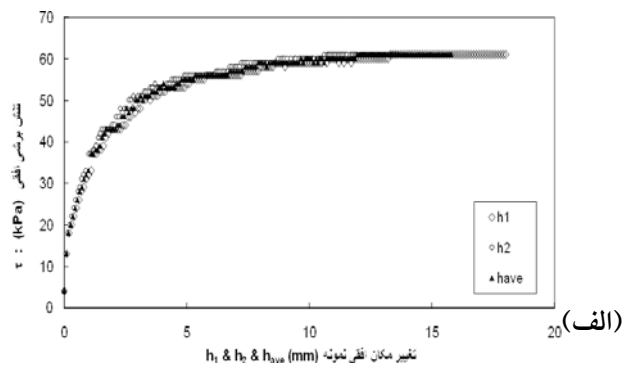
%      %

%

IP (%)	LL (%)	w (%)	$\rho$ (kg/m <sup>3</sup> )			
				Gravelly lean clay	CL	
		/		Sandy lean clay	CL	



(ب)



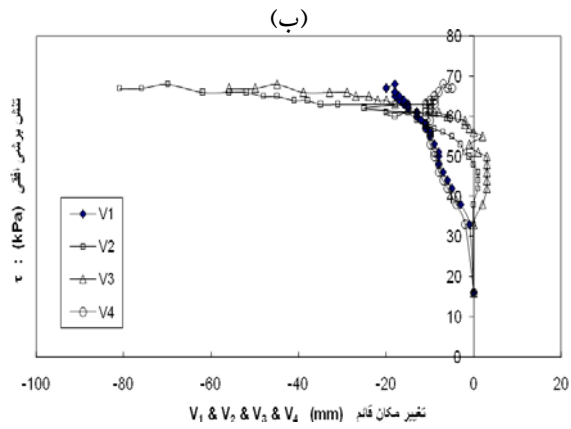
(الف)

kPa

( $h_{ave}$ )

( $h_2$   $h_1$ )

(



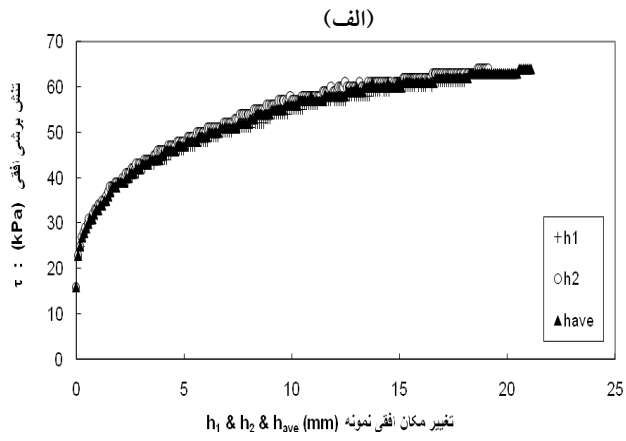
(ب)

kPa

( $h_{ave}$ )

( $h_2$   $h_1$ )

(



(الف)

% /

/ / / ( )

( )

(RAR)

φ

( )

C

(φ)

(C)

( )



...

		(kg)	$\sigma_v$ (kpa)	$\tau_{max}$ (kpa)	RAR(%)	$d_{50}$ (mm)	$d_{max}$ (mm)	
				/	/	/		
				/	/	/		
				/	/	/		
				/	/			
				/	/	/		
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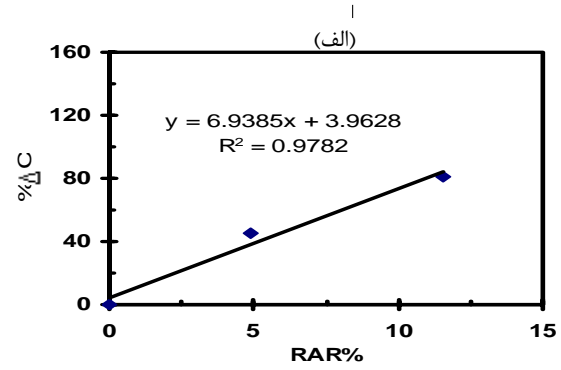
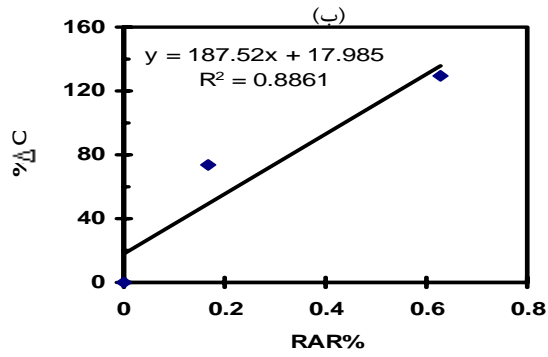
	RAR (%)	$d_{max}$ (mm)	$d_{50}$ (mm)	C (kPa)	( ) $\phi$	$\Delta C$ (kPa)	$\Delta C$ (%)	$\Delta\phi$ ( )	$\Delta\phi$ (%)
				/	/				
			/	/	/	/		/	
			/	/	/			/	
				/	/				
	/		/	/	/	/		/	
	/		/	/	/	/		/	



%

(ΔC)

%



( : (

( )

mm

φ

( )

mm

$d_{50} = l$

φ

$d_{50} = l$

( )

%

( ) ( )

kPa

CL

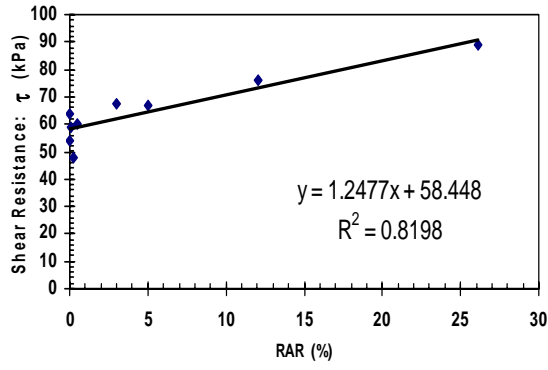
: ( )

$\tau = 1.25RAR + 58.45$

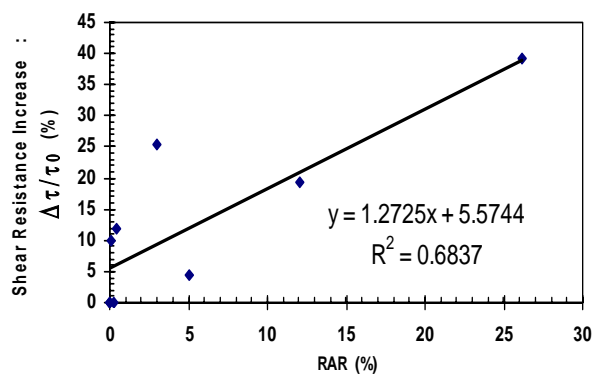
( )

...  
 $R^2 = /$  ( ) (  $\tau_0$  )  $RAR$  kPa  $\tau$

$\frac{\Delta\tau}{\tau_0} = (1.27RAR + 5.57) \div 100$  ( ) (  $\Delta\tau$  )



kPa



kPa

" "

% " "

:" ( )

" "

$\tau = 3.18Ln(RAR) + 44.34$  ( )

$$\tau = 1.6RAR + 85$$

( )

CL

$$R^2 = /$$

RAR kPa       $\tau$       ( )

:

$$\frac{\Delta\tau}{\tau_0} = (14.34Ln(RAR) + 99.88) \div 100 \quad ( )$$

" "

%

( )

CL

%    %

$\delta$

:      ( )

$$\tau = 0.41RAR + 26.37 \quad ( )$$

$$R^2 = /$$

$\delta$

% /

$$\frac{\Delta\tau}{\tau_0} = (1.53RAR - 2.07) \div 100 \quad ( )$$

/

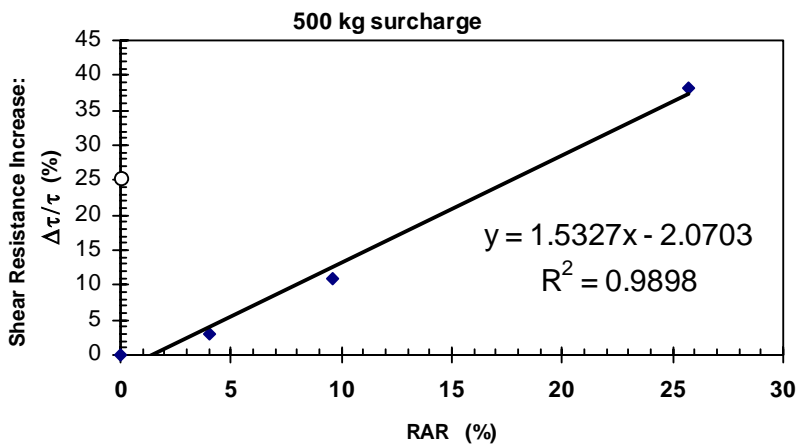
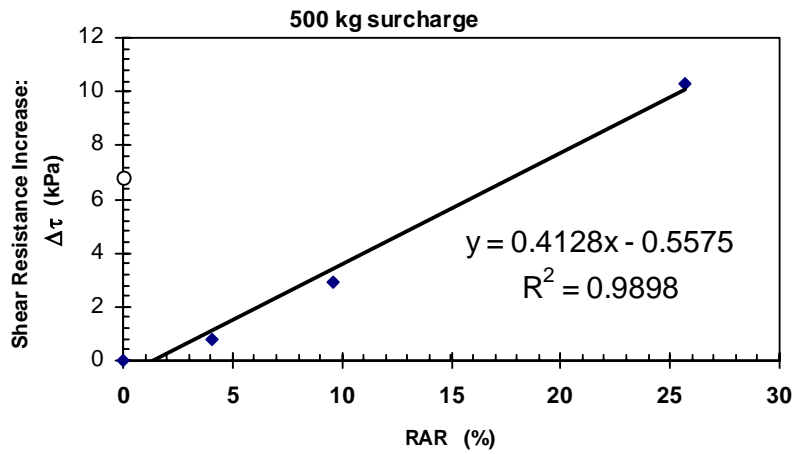
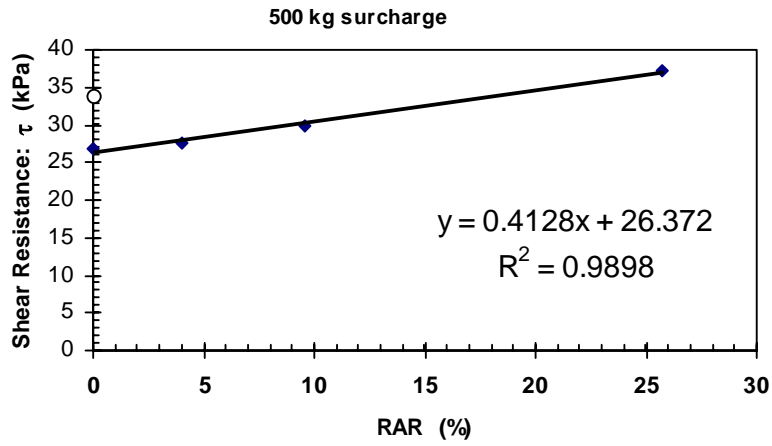
kPa

$\tau$       ( )

( )

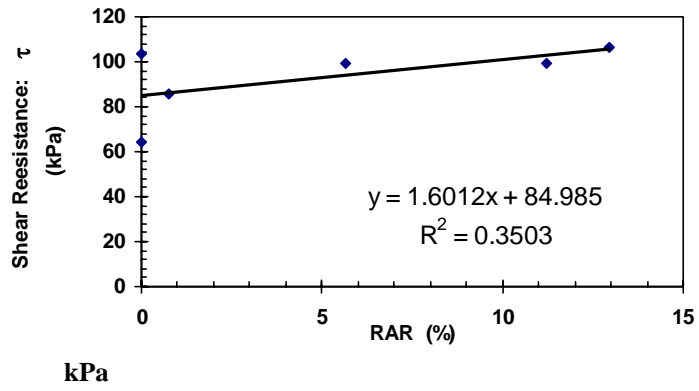
kPa

RAR



kPa

%



( )

( )

%

( )

( )

( )

( )

( )

/ /

kPa

%

"

"

:( )

:( )

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## Variation of shear resistance parameters in fine grain soils due to willow roots density

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### Abstract

Stabilization of river terraces and natural soil slopes in rangelands by means of tree roots as a reinforcement agent is an environmental adopted method which needs to be developed. In this research a series of tests was carried out on soil blocks containing willow roots and without roots using a large scale in situ direct shear test apparatus. The results were analyzed based on direct shear theory to calculate the cohesion and internal friction angle of rooted and non-rooted soil. The results reveal that in spite of a slight decrease of 8% in the internal friction angle, the appearance cohesion of lean clay soils increase significantly up to 130%. The results of this research are presented in forms of linear and logarithmic relations between increased shear strength and root density at different depths of soil.

**Keywords:** Willow, Shear strength, Cohesion, Internal friction angle, Lean clay, Root density, Natural soil slope, Stabilization, Environment

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