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$$R_Q = 0.299\,(\frac{H_d}{p})^{0.839}(\frac{H_d}{y_2})^{2.602}(\frac{W}{p})$$
$$^{-0.226}(\frac{d}{p})^{-0.513}(\sin\alpha_1)^{-1.622}$$

( )

R_Q

H_d

p W y_2

α_1 d

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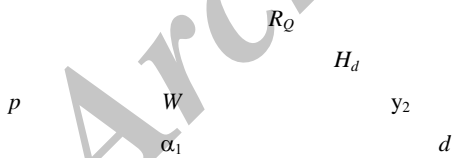
(2007) Heydari

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.(Michioku et al., 2005)

(2006) Riahi

...

(2010) Mohammed

amiri@ut.ac.ir :   *

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( )

(Tractive force) .

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$$\frac{Q}{\sqrt{g}B\,y_1^{1.5}} = -0.37 + 0.095\log Re +$$

( )

$$0.063\frac{H_d}{W} + 0.114\,\frac{d}{p}$$

.

$$\frac{Q}{\sqrt{g}B\,y_1^{1.5}} = -0.41 + 0.105\log Re +$$

$$0.031\,\frac{H_d}{W} + 0.057\,\frac{d}{p} + 0.018\,s_r$$

( )

.

$Re = Q\rho/B\mu$ $Fr = Q/(Bg^{(1/2)}y_1^{(1.5)})$ ( )   ( )

Q . $s_r = (y_1 - y_2)/H_d$

Hansen et al. .

μ g

(2005) . ρ

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(2002) Lenzi

(step-pool morphology)

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$$v_f = \sqrt{\frac{(2(\rho_s - \rho)\,g\,\beta)\,(f\ \cos s_0 - \sin s_0)\,D_x}{C_D\,\rho}}$$

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v_f

$:s_0$ $:\beta$ C_D

. $:D_x$

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(2002) Maeno et al.

(rubble

/ mound weirs)

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/ :

(2005) Hansen et al. .

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$V_v = Jm^{0.5}i^{0.54}$

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(Q/(nA)) V_v / :

J A n

m .   5.243 $(L^{0.5}/T)$

. i

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$$y_{n_{porous}} = \left[\frac{Q}{W s_0^{0.54}} \frac{3\sqrt{\lambda}}{4nm^{0.5}} \right]^{2/3}$$

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$$\theta_1 y^{sN-2s} + \theta_2 y^{sN+1} - \theta_3 = -x$$

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$\theta_{1,2,3}$ (L) x y (L)

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(Hansen et al., 2005)

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(rip rap)

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(critical stone Froude number)

$f_1 (Q_0 , B , p , W_0 , W , \alpha , \alpha_0 , d , y_1 , a , b , e ,$
$n , \rho , \rho_s , g , \mu , \sigma , n_{man} , Z_{fl} , S_0 , \sigma_t , H_{top} , y_2) = 0$

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. (Rathgeb, 2000)

Q_0

α_0 α W_0

$$Fr_{s,er} = \frac{q_s}{\sqrt{g . \frac{\rho_s - \rho_w}{\rho_w} d^3_{s,er}}}$$

( )

a,b,c

σ_t σ

H_{top} s_0 n_{man}

$:q_s$ $:Fr_{s,er}$

Z_{fl}
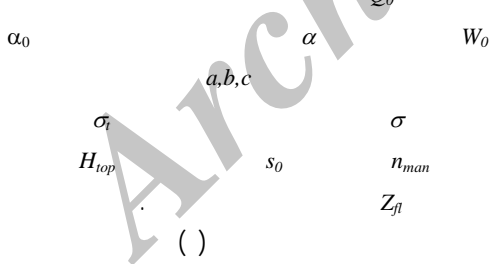
$:d_{s,er}$

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(2007) Siebel .

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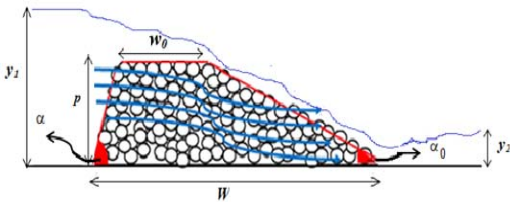
$$d_{s,er} = 1.71 s_0^{0.68} \ q_s^{\frac{2}{3}} \ (\frac{\rho_w}{\rho_s - \rho_w})^{\frac{1}{3}}$$

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(Streeter, 1981)

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(2002) Maeno et al   .

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(Herrera and

$$\tan(\alpha_0) = a(\frac{d}{p})^b \, (\frac{d-\sigma}{d})^c \, (\frac{y_1 - y_2}{p})^d \, (\frac{q}{\sqrt{g \cdot \frac{\rho_s - \rho_w}{\rho_w} d^3}})^f$$

. Felton, 1991)

. ( ) ( )

$$d = \frac{\sum d_i \times w_i}{\sum w_i}$$

( )

. ( )

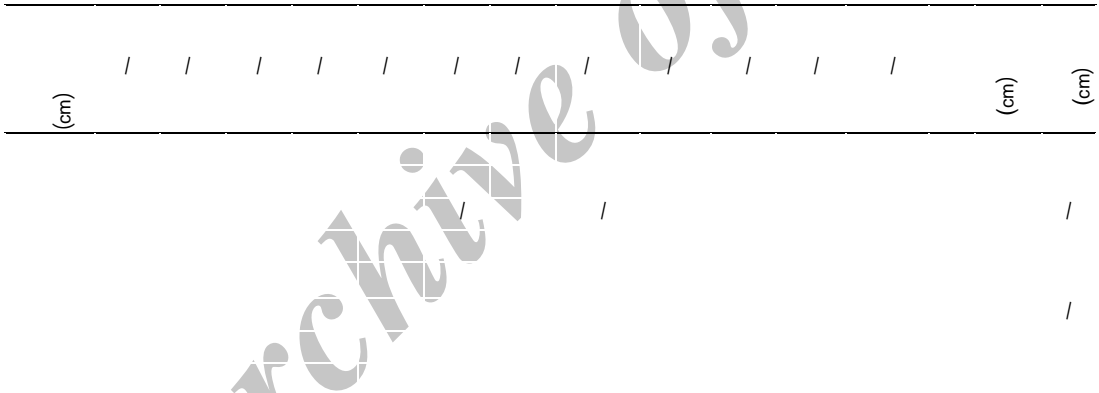$$\sigma = \left[\frac{\sum (d - d_i)^2 \times w_i}{\sum w_i}\right]^{1/2}$$
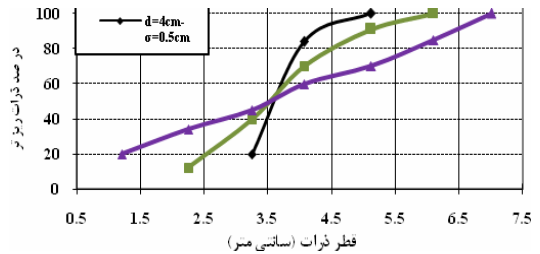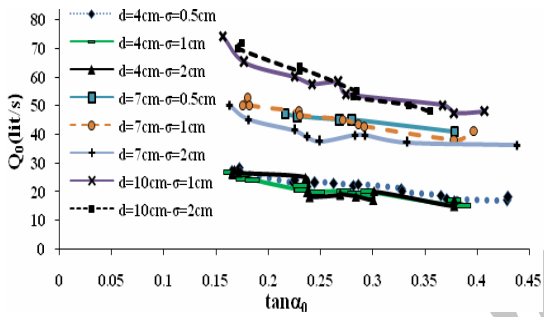
( )

i 　　 d_i

/ . / /

w_i

lit/s

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(cm)

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(Profile indicator)

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Q$_0$(lit/s)

- d=4cm-σ=0.5cm
- d=4cm-σ=1cm
- d=4cm-σ=2cm
- d=7cm-σ=0.5cm
- d=7cm-σ=1cm
- d=7cm-σ=2cm
- d=10cm-σ=1cm
- d=10cm-σ=2cm

80
70
60
50
40
30
20
10
0

0   0.05   0.1   0.15   0.2   0.25   0.3   0.35   0.4   0.45

tanα$_0$

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N×sinα$_2$

N)

.(α$_2$

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/   (MRE)   ( )

.   SPSS

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                                                                                                          ( )

$$\tan(\alpha_2) = 0.023 \, (\frac{d}{p})^{-0.832} \, (\frac{\sigma}{d})^{-0.117} \, (\frac{y_1 - y_2}{p})^{-1.978} \, (\frac{q}{\sqrt{g.\frac{\rho_s - \rho_w}{\rho_w}d^3}})^{-1.455}$$

                                                              ( )   ( )

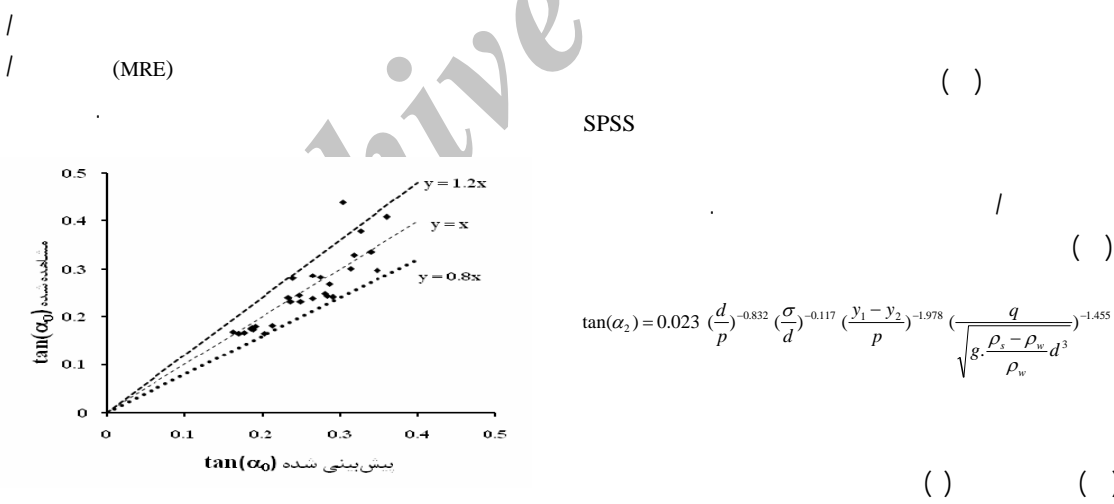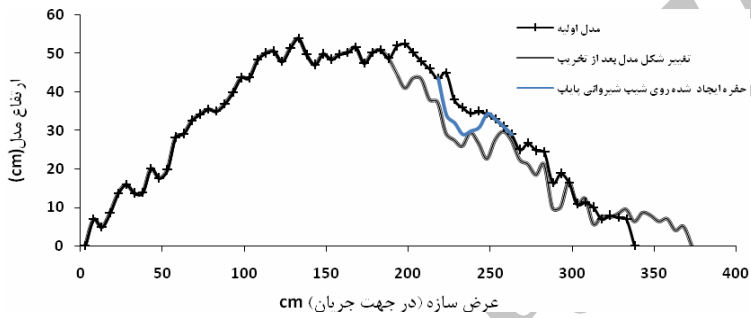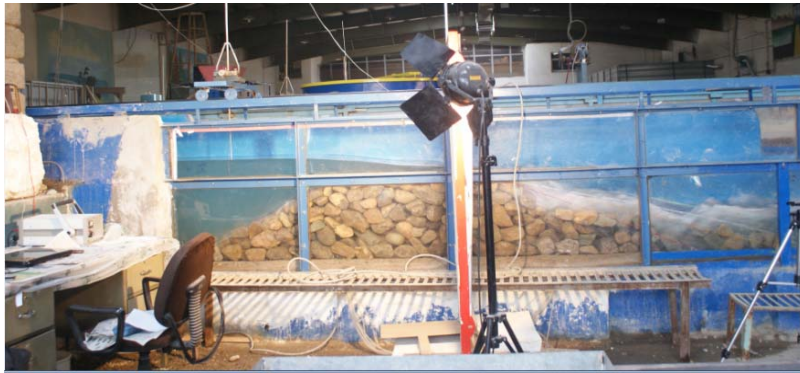   .

                                                                                                .

$$MRE = \frac{\sum_{i=1}^{N} \left| \frac{Q_i - \overline{Q_i}}{Q_i} \right|}{N}$$

                                        ( )

                                                                                          (MRE)

$$RMSE = \left[\frac{\sum_{i=1}^{N} (Q_i - \overline{Q_i})^2}{N} \right]^{\frac{1}{2}}$$
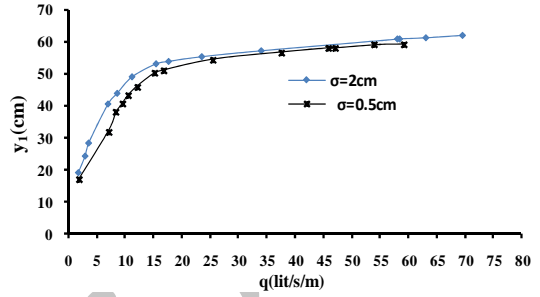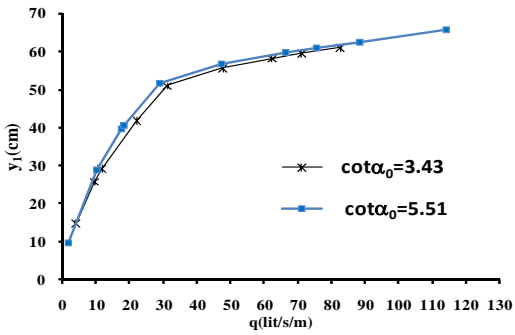
                                        ( )

                                                        ( )   (RMSE)

$\overline{Q_i}$ Q_i ( )   ( )

. N .   ( )

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) (2006) Riahi ( ) (:

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Riahi

(2006)

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$y_1(cm)$

cotα₀=3.43

cotα₀=5.51

q(lit/s/m)

σ=1cm   d=7cm

$y_1(cm)$

σ=2cm
σ=0.5cm

q(lit/s/m)

: d=4cm

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Maeno et al.

Riahi (2006) (2002)

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$y_1(cm)$

d=4cm
d=7cm
d=10cm

q(lit/s/m)

/ :

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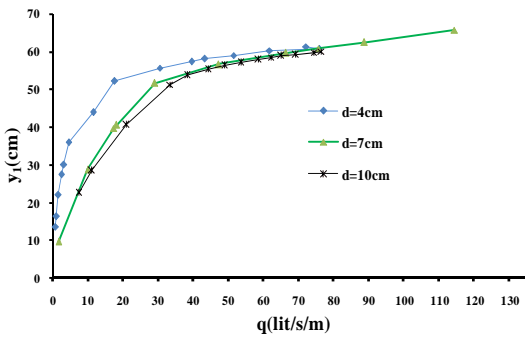
Q_0　　　　　　　　　　　　　　　　.

(　　　　　　　　　)　　　　　.

.　　　　　　　　　　　.(Kamann et al, 2007)

.

Q_0

(Armor Layer)　　　　　Q_0　　　.

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(　　　)

Q_0

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(Heydari, 2007)

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J

a,b,c

B

C$_D$

d

Z_{fl}	:	$d_{s,er}$	
α		D_X	
α_0		g:	
α_I		H_d	
β		H_{top}	
μ		n_{man}	
ρ		n	
σ		P	
$\theta_{1,2,3}$	:	Q_0	
		Q	
		q_s	
σ_t		R_Q	
M		s_0	( )
I		v_f	
λ		W	
		W_0	:
		y_2	

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