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THEORETICAL APPROACH OF UNIFORM FLOW VELOCITY THROUGH GROIN PILES

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Abstract
Research of uniform flow velocity through groin piles was developed on hydraulic laboratory, which differs from previous research because model of structure is groin piles. Uniform flow is influenced by two shear stress namely bottom shear stress and shear stress due to the piles of groin. Theory of uniform flow velocity is obtained by equating the shear stress due to waves and shear stress due to permeable groins. Theoretical approach verified by research in the laboratory using eight models of piles with density ranging between 18.4% - 31.4%. The verification results show that the measurement data of uniform flow velocity in the laboratory close to the results of calculations using the theory.

Keywords
uniform flow; velocity; groin piles.

INTRODUCTION

Sujatmiko (2006), uniform flow in open channel with a groin piles barrier is affected by two types of shear stress, respectively bottom shear stress and shear stress due to groin piles. Tingsanchali and Maheswaran (1990) used the hybrid finite difference and iterative model to analyzed depth average velocity equation and turbulence transport near the groin. Analyze of flow in the region near the groin tip. Rajaratnam and Nwachukwu (1983) used the model of the 3D turbulent boundary layer to analyze the deflected flow near the groin structure. The study has shown that when a groin is placed in a channel, it causes a significant disturbance to the flow for a short distance upstream and for a longer distance downstream. The disturbed flow was analyzed.

By splitting it into a deflected flow region and a shear layer. Uijttewaal (2005) made a research to finding efficient alternative designs, in the physical, economical, and ecological sense, for the standard groin as they are found in the large rivers of Europe. The experiments were performed in a physical model of a schematized river reach, geometrically scaled 1:40. Four different types of schematized groin were tested, standard reference groin, groin with a head having a gentle slope and extending into the main channel, permeable groin consisting of pile rows, and hybrid groin consisting of a lowered impermeable groin with a pile row on top. From the experiment result shown that groin standard design is possible used in the large rivers of Europe by adjusting the groin tip, shape and permeability.

Uniform Flow Velocity Through Groin Piles
Shear stress that occurs in a uniform flow through the groin piles is the bottom shear stress (τ_1) and the shear stress due to groin piles (τ_2), as shown in Figure 1.

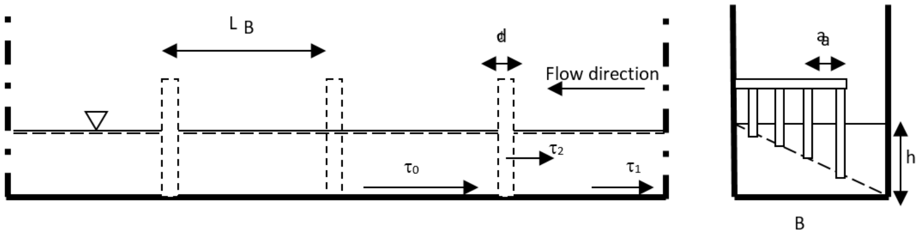

Figure 1
Scheme of shear stress in 2D model of flow.

The equation of shear stress can be formulated as follows:

$$\tau_o = \tau_1 + \tau_2 \tag{1}$$

with τ_o is total of shear stress $(\frac{N}{m^2})$; τ_1 is bottom shear stress $(\frac{N}{m^2})$; τ_2 is shear stress due to groin pile $(\frac{N}{m^2})$.

Total shear stress is the amount of bottom shear stress and shear stress due to groin piles. While the bottom as follows.

$$\tau_1 = \frac{\rho g V^2}{C_1^2} \tag{2}$$

Shear stress due to groin pile is a function of area of pile, number of pile (N) and drag coefficient (C_d). It caused function of groin piles is a barrier of flow, so the shear stress due to groin piles can be write as follows,

$$\tau_2 = F_D = C_d.\rho.A.\frac{V^2}{2} \tag{3}$$

If drag force equal to shear stress due to groin piles $F_D = \tau_2$ and area of groin piles is $A = \frac{1}{2}nhd_t$, then shear stress due to groin piles can be write as follows,

$$\tau_2 = C_d.\rho.\frac{1}{2}.n.h.d_t.\frac{V^2}{2} \tag{4}$$

Equation (2) and (4) substituted to equation (1),

$$\frac{\rho.g.V^2}{C_0^2} = \frac{\rho.g.V^2}{C_1^2} + \frac{C_d.\rho.g.\frac{1}{2}.n.h.d_t.V^2}{2.g} \tag{5}$$

$$\frac{1}{C_o^2} = \frac{1}{C_1^2} + \frac{C_d n h d_t}{4g}$$

$$C_o^2 = \frac{1}{\frac{1}{C_1^2} + \frac{C_d n h d_t}{4g}} \tag{6}$$

$$n = \frac{N}{B.\Delta L} \tag{7}$$

with C_I is Chezy coefficient without groin piles ($m^{1/2}/s$); C_o is Chezy coefficient with groin piles ($m^{1/2}/s$); C_d is drag coefficient; d_t is pile diameter (m); n is number of piles per area ($1/m^2$) ; N number of piles; B is width of channel (m); ΔL is length areas of interest (m); g is acceleration of gravity (m/s^2). If there is no effect of bottom friction ($C_1 = 0$), then Chezy coefficient after groin piles (Equation (7)) can be written as follows,

$$C_o = \sqrt{\frac{4g}{C_d.n.h.d_t}} \tag{8}$$

Chezy coefficient after groin piles influenced by the density parameter (p). Groins density (p) is the ratio between the volume of groin piles are submerged with the total volume of water.

$$p = \frac{\frac{1}{2}NAz}{\frac{1}{2}B\Delta Lh} \times 100\% = \frac{NAz}{B\Delta Lh} \times 100\% \tag{9}$$

with N is number of piles; A is area of pile (m^2); z is heigth of submerged piles (m); B is width of channel (m); ΔL is length areas of interest (m); h is heigth of flow (m). Equation (7) substituted into the equation (9),

$$p = nA\frac{z}{h} \times 100\% \tag{10}$$

Groin piles were rounded vertical piles, so the area of sectional pile (A) is $1/4\pi d_t^2$ and then substituted into equation (10),

$$p = \frac{n\pi {d_t}^2}{4}\frac{z}{h} \times 100\% \tag{11}$$

with d_t is pile diameter (m); n is number of piles per area. If $h \leq z$ then $z = h$ density of piles on equation (11) can be written as follows,

$$p = \frac{n\pi {d_t}^2}{4} \times 100\% \tag{12}$$

From equation (12) could be find the number of piles per area (n),

$$n = \frac{4P}{\pi d_t^2} \tag{13}$$

If number of piles per area (n) substituted into equation (8) then chezy coefficient due to groin piles can be written as follows,

$$C_o = \sqrt{\frac{g\pi d_t}{C_D 2ph}} \tag{14}$$

If we know that velocity flow in the open channel can be written as follows,

$$v_{tanpa\ groin} = C\sqrt{R.I} \tag{15}$$

then Chezy coefficient due to groinpiles and density of groin substituted into equation (15), velocity of flow through groun piles can be written as follows,

$$v_{groin} = \sqrt{\frac{g\pi d_t}{C_d 2ph}}\sqrt{RI} \tag{16}$$

with v is velocity of flow (m/s); g is acceleration of gravity (m/s^2); d_t is pile diameter (m); C_d is drag coefficient; p is density of groin piles (%); h is height of flow (m); I is energy slope.

Effect of Groin Piles to Uniform Flow Velocity

Theoretical approach of velocity flow due to groin piles as written on equation (16) and velocity flow without groin piles as written on equation (15), can be written the equation of reduction coefficient as follows,

$$C_r = \frac{\langle v\rangle_{groin}}{\langle v\rangle_{tanpa\ groin}} = \frac{1}{C}\sqrt{\frac{g\pi d_t}{C_d 2ph}} \tag{17}$$

From equation 17 could be shown the relation of reduction coefficient (C_r) and drag coefficient (C_d) as showed on Figure 3. From the graph showed that drag coefficient (C_d) of research ranges between 0.88 until 3.4, while drag coefficient (C_d) on.Sujatmiko (2006) was 0.95.

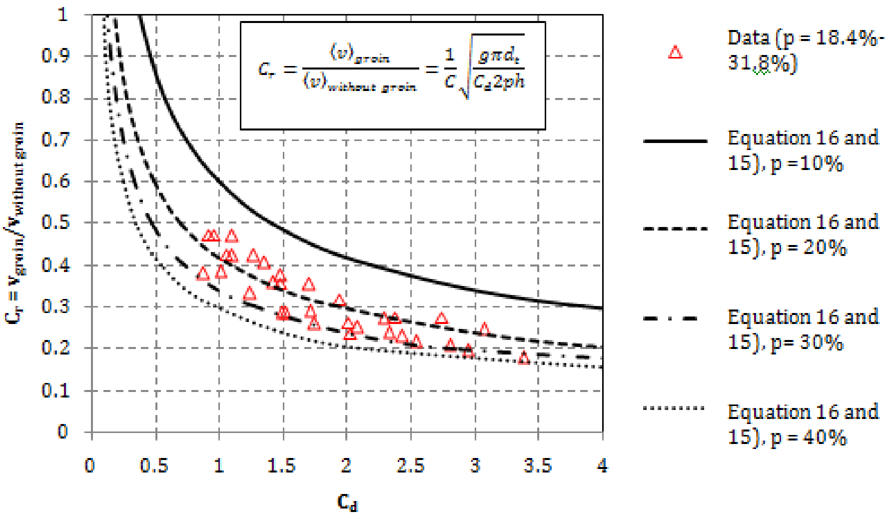

Figure 2
Relation of reduction coefficient ($C_r = \frac{\langle v \rangle_{groin}}{\langle v \rangle_{without\ groin}}$) and drag coefficient ($C_d$) with variation of density (p).

Figure 2 shown that reduction coefficient (C_r) was influenced by drag coefficient (C_d) and density of groin piles (p). The greater density of groin piles (p) effect the smaller drag coefficient (C_d) and reduction coefficient (C_r) because velocity of flow after groin piles getting slower. The parameter to determined reduction of velocity was density of groin piles. The greater density of groin piles will be effect the smaller Chezy coefficient.

CONCLUSIONS

Based on the development of theory and experimental results, conclusions can then be described as follows.

1. Velocity of flow through groin piles can be calculated by
   $v_{groin} = \sqrt{\frac{g\pi d_t}{C_d 2ph}}\sqrt{RI}$
   with $\frac{g\pi d_t}{C_d 2ph}$ is resistance parameter of groin piles.
2. Verification of velocity of uniform flow through groin piles $(v)_{groin}$ with the experiment data shown that result in accordance with drag coefficient (C_d) = 0.88 – 3.4.

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