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Dimensional Analysis of Compound Section in The Regulate Section Channel Model for Maintenance Main Channel

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Abstract. A dimensionless number is used to express the relationship between parameters and is used to describe the research results. Commonly used dimensional analysis methods are the Basic Echelon method, the Buckingham method, the Rayleight method, the Stepwise method and the Langhaar method. The compound section in the regulated section channel model aims to make the section convenient to the flow existing discharge at tidal conditions, in sediment flushing. In this study using the Buckingham's method of dimensional analysis to determine the weight equation for the flushing sediment (w) and the variables that have been scaled on the flume, W = • (B, B*, h, h*, ⊗h, t, V, Q, g, W, ⟩w, ⟩$_S$), where B is the width of the river (cm), B* is the width of the Flushing section (cm), h is the height of the water level (cm), h* is the height of the flushing section (cm), ⊗h is the difference in water level (cm), t is the tidal time period (s), V is the flow velocity (cm/s), Q is the water discharge (cm^3/s), g is the gravity (cm/s^2), ⟩S is the mass density of the sediment (gr/cm^3), ⟩w is the density of the water mass (gr/cm^3). From the analysis results obtained equations = $\frac{B^*}{B} \cdot \frac{h^*}{h} \cdot \frac{\Delta h}{h} \cdot \frac{v}{gt} \cdot \frac{Q}{gh^2t} \cdot \rho_s h^3$. Where w is the weight of the flushing sediment (gr), $\frac{B^*}{B}$ is the ratio of the design cross-sectional width to the width of the estuary, $\frac{h^*}{h}$ is the ratio of the flushing cross-sectional height to the water level, $\frac{\Delta h}{h}$ is the ratio of the height water level to water depth, $\frac{v}{gt}$ is the velocity of falling sediment, $\frac{Q}{gh^2t}$ is the discharge of sediment flushing, $\rho_s h^3$ is the hydrostatic pressure.

1. Introduction

Dimensional analysis is a mathematical technique used as a tool in solving several physical modeling problems that can be expressed in equations, which are arranged in the form of a dimensionless or dimensionless variable. Dimensional analysis helps determine systematically the relationship between dimensionless variables or dimensionless parameters. In hydraulic modeling, in particular, many dependent and independent variables are sometimes difficult to determine, and their correlation. By using dimensional analysis, it will be easier to find out between the desired variables [1]. In addition, dimensional analysis can be used:

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a) Classify equations and test the homogeneity of the dimensions of the equation and the generalities of the equation
b) Converting equations or data from one system of units to another system of units,
c) Develop equations in the form of variable correlation,
d) Derive the equation expressed in dimensionless parameters to show the relative significance of each parameter, and
e) Planning model tests and processing experimental results in the form of systematic dimensionless parameters.

Sediment flushing modeling, which is generally used in reservoirs [2], canals, [3], and irrigation [4, 6] where sediment deposits can affect structure performance. Sediment flushing is a low cost method compared to other mechanical [7]. hydraulic flushing can remove fine sediments (with cohesive material) as well as coarse sediments. In the estuary or canal, flushing sediment influences the tide [6]. In the physical model The compound section in the regulated section channel model aims to make the cross section conform to the existing discharge at tidal and low tide conditions. To determine the relationship between variables in this study, dimensional analysis used is the π Buckingham Method, to know the equation for the weight of the sediment flushing (w) to other related variables are section, discharge, sediment, fluid that can be decomposed (B, B*, h, h*, ωh, t, V, Q, g, W, ⟩w, $⟩_S$).

2. Research Method

The research method used was experimental, carried out in the River Laboratory of the Civil Engineering Department, Faculty of Engineering, Hasanuddin University.

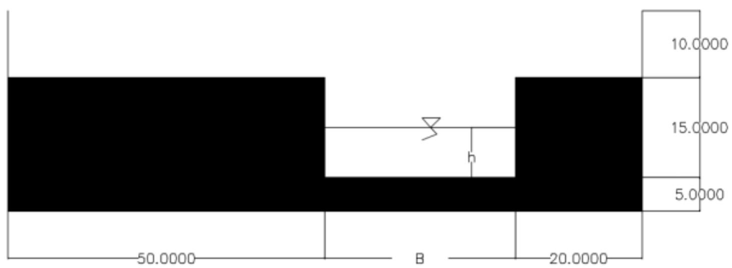
2.1. *Material*

The materials used in the study are: styrofoam to form a cross section of the estuary and sand sediments.

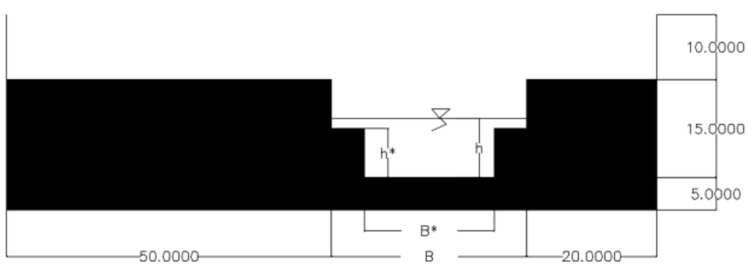
2.2. *Equipment*

The equipment used in this study are: flume size 1 m wide and 12 m long, with 2 pumps, for discharge and tide, pitot digital to measure velocity, stopwatch to measure period, camera for documentation, tables and stationery. etc. Set up research in laboratory show in figure 1 and regulate section channel model show in figure 2.

Figure 1. Set up research in laboratory



(a)



(b)

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Figure 2. Regulate section channel model; *(a). Rectangular channel;(b). Compound section channel*

2.3. Procedure

Procedure of dimensional analysis using Buckinghan method in this study includes [1,5]:

a) Identify all the variables involved in the system under study,
b) Selects 3 repeating variables. The variables must be dimensionless, none of them have the same dimension, the combination of the three variables contains the three main dimensions, and the three variables do not form a dimensionless variable. In hydraulics usually:
   1) Characteristics of linear dimensions,
   2) Characteristics of velocity and
   3) Characteristics of water mass density
c) Write general equations in variables π. This variable is the multiplication of the three repetitive variables with an unknown exponent and one residual variable.
d) Calculate the unknown exponential value by equating the exponents of the 3 principal quantities on both sides of each dimensional equation,
e) Write the final result of the general research equation in the form π
f) To get the final equation, the following steps are needed.:
   1) A dimensionless variable, directly as π,
   2) Anything π can be replaced with π is arbitrary anything. For example π1 replaced $\pi1^2$ etc,
   3) Anything π can be replaced by multiplying π p with any numeric number. For example π1 replaced 3π1 etc, and add or subtract with π others.
   4) Anything π can be replaced with π other
   5) Anything π can be replaced by multiplying these with π others. For example π1 replaced π1 x π2, etc.

3. Results and Discussion

3.1. Dimensional Analysis, Buckingham Method

a. Identify all variables involved in the study, Weight of the sediment flushing *(w) = f (channel, discharge, sediment, fluid),* $W = f(B, B^*, h^*, h, \Delta h, V, Q, q, g, W, \rho w, \rho S)$
b. Express each variable in basic dimensions, namely L: length, T: time, M: mass.

Table 1. Major Dimensional in this Research

Variable	Geometric					Kinematic				Dynamic		
	B	*B**	*h**	*h*	*Δh*	*t*	*v*	*Q*	*g*	*W*	ρ_w	ρ_s
Unit	cm	cm	cm	cm	cm	s	cm/s	cm^3/s	cm/s^2	gram	gr/cm^3	gr/cm^3
Dimensions	L	L	L	L	L	T	LT^{-1}	$L3T^{-3}$	LT^{-2}	*M*	ML^{-3}	ML^{-3}
M	0	0	0	0	0	0	*0*	0	0	*1*	1	1
L	1	1	1	1	1	0	*1*	3	1	*0*	-3	-3
T	0	0	0	0	0	1	*-1*	-1	-2	*0*	0	0

c. Define repeating, independent and dependent variables

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Table 2. Variable grouping

Group	*Parameter*	*Notation*
Independent Variable	River width (cm)	B
	Flushing cross-sectional width (cm)	B*
	Flushing cross-sectional height (cm)	h*
	Difference in water level (cm)	Δh
	Velocity (cm / s)	v
	Water discharge (cm3 / s)	Q
	Sediment mass density (gr / cm3)	ρS
	Tidal period (s)	t
Dependent Variable	Weight of displaced sediment (gram)	W
Repeating variable	water level (cm)	h
	Gravity (cm / s2)	g
	Water mass density (gr / cm3)	ρw

d. Variable equation πi, is the multiplication of three repeated variables and one residual variable, thus exhausted

$\pi_1 = h^x . g^y . \rho w^z . B$

$M = 0+0+z+0 = 0, \quad z=0$

$T = 0-2Y+0+0 = 0, \quad Y=0$

$L = X+Y-3z+1 = 0, \quad X=-1$

$$\pi 1 = \frac{B}{h} \quad (1)$$

$\pi_2 = h^x . g^y . \rho w^z . B^*$

$M = 0+0+z+0 = 0, \quad z=0$

$T = 0-2Y+0+0 = 0, \quad Y=0$

$L = X+Y-3z+1 = 0, \quad X=-1$

$$\pi 2 = \frac{B^*}{h} \quad (2)$$

$\pi_3 = h^x . g^y . \rho w^z . h^*$

$M = 0+0+z+0 = 0, \quad z=0$

$T = 0-2Y+0+0 = 0, \quad Y=0$

$L = X+Y-3z+1 = 0, \quad X=-1$

$$\pi 3 = \frac{h^*}{h} \quad (3)$$

$\pi_4 = h^x . g^y . \rho w^z . Dh$

M = 0+0+z+0 = 0, z=0
T = 0-2Y+0+0 = 0, Y=0
L = X+Y-3z+1 = 0, X=-1

$$\pi 4 = \frac{\Delta h}{h} \quad (4)$$

π_5 = $h^x . g^y . \rho w^z . t$
M = 0+0+z+0 = 0, z=0
T = 0-2Y+0+1 = 0, Y=1/2
L = X+Y-3z+0 = 0, X=-1/2

$$\pi 5 = \frac{t.g^{1/2}}{\sqrt{h}} \quad (5)$$

π_6 = $h^x . g^y . \rho w^z . v$
M = 0+0+z+0 = 0, z=0
T = 0-2Y+0-1 = 0, Y=-1/2
L = X+Y-3z+1 = 0, X=-1/2

$$\pi 6 = \frac{v}{\sqrt{g.h}} \quad (6)$$

π_7 = $h^x . g^y . \rho w^z . Q$
M = 0+0+z+0 = 0, z=0
T = 0-2Y+0-1 = 0, Y=-1/2
L = X+Y-3z-3 = 0, X=-2.5

$$\pi 7 = \frac{Q}{\sqrt{g}.h^{2.5}} \quad (7)$$

π_8 = $h^x . g^y . \rho w^z . W$
M = 0+0+z+1 = 0, z=-1
T = 0-2Y+0+0 = 0, Y=0
L = X+Y-3Z+0 = 0, X=-3

$$\pi 8 = \frac{w}{\rho_w \, h^3} \quad (8)$$

π_9 = $h^x . g^y . \rho w^z . \rho s$
M = 0+0+z+1 = 0, z=-1
T = 0-2Y+0+0 = 0, Y=0
L = X+Y-3z-3 = 0, X=0

$$\pi 9 = \frac{\rho_s}{\rho_w} \quad (9)$$

e. Write the final result of the general research equation in the form π

$\pi 1 = \frac{B}{h}$, $\pi 2 = \frac{B^*}{h}$, $\pi 3 = \frac{h^*}{h}$, $\pi 4 = \frac{\Delta h}{h}$, $\pi 5 = \frac{t.g^{1/2}}{\sqrt{h}}$ $\pi 6 = \frac{v}{\sqrt{g.h}}$, $\pi 7 = \frac{Q}{\sqrt{g}.h^{2.5}}$,
$\pi 8 = \frac{w}{\rho_w \, h^3}$, $\pi 8 = \frac{\rho_s}{\rho_w}$

$$f\left(\frac{B}{h}, \frac{B^*}{h}, \frac{h^*}{h}, \frac{\Delta h}{h}, \frac{t.g^{1/2}}{\sqrt{h}}, \frac{v}{\sqrt{g.h}}, \frac{Q}{\sqrt{g}.h^{2.5}}, \frac{w}{\rho_w \, h^3}, \frac{\rho_s}{\rho_w}\right) \quad (10)$$

Simplified by operating (multiply and / or divide) between the non-dimensional variables, remove the constant values, so that the sum is simpler.

$$\pi 10 = \frac{\pi_2}{\pi^1} = \frac{\frac{B*}{h}}{\frac{B}{h}} = \frac{B*}{B} \quad (11)$$

$$\pi 11 = \frac{\pi 4}{\pi 5^2} = \frac{\frac{\Delta h}{h}}{\left(\frac{t.g^{1/2}}{\sqrt{h}}\right)^2} = \frac{\Delta h}{t^2 g} \quad (12)$$

$$\pi 12 = \pi_6 . \pi_7 = \frac{v}{\sqrt{g.h}} . \frac{Q}{\sqrt{g}.h^{2.5}} = \frac{v.Q}{g.h^3} \quad (13)$$

From the equation 12 and 13, can be written into the following equation

$$\frac{\Delta h}{t^2 g} . \frac{v.Q}{g.h^3} = \frac{\Delta h}{h} . \frac{v}{gt} . \frac{Q}{gh^2 t} \quad (14)$$

So that the equation can be written as

$$\frac{B*}{B} . \frac{h*}{h} . \frac{\Delta h}{h} . \frac{v}{gt} . \frac{Q}{gh^2 t} . \frac{w}{\rho_w h^3} . \frac{\rho_s}{\rho_w} \quad (15)$$

In this study, are looking for the weight of the sediment flushing (w) :

$$w = \frac{B*}{B} . \frac{h*}{h} . \frac{\Delta h}{h} . \frac{v}{gt} . \frac{Q}{gh^2 t} . \rho_w h^3 . \frac{\rho_s}{\rho_w} \quad (16)$$

From equation 16, the 6th and 7th terms are multiplied so that the equation for weight of sediment flushing becomes:

$$w = \frac{B*}{B} . \frac{h*}{h} . \frac{\Delta h}{h} . \frac{v}{gt} . \frac{Q}{gh^2 t} . \rho_s h^3 \quad (17)$$

3.2. *Dimensional Analysis Of Compound Section In The Regulate Section Channel Model For Maintenance Main Channel*

From previous calculations, the equation in this study is the weight of the sediment flushing is:

$$w = \frac{B*}{B} . \frac{h*}{h} . \frac{\Delta h}{h} . \frac{v}{gt} . \frac{Q}{gh^2 t} . \rho_s h^3$$

Where w is the weight of the sediment flushing (gr), $\frac{B}{B*}$ is the ratio of the width of the estuary to the cross-sectional width of the design , $\frac{h*}{h}$ is the ratio of the cross-sectional height of the flushing to the water level, $\frac{\Delta h}{h}$ is the ratio of the difference in water level to water depth, $\frac{v}{gt}$ is the rate settling velocity, $\frac{Q}{gh^2 t}$ is the discharge of sediment flushing $\rho_s h^3$ is the hydrostatic pressure of water.

4. Conclusions

Based on the results of the discussion, some conclusions can be drawn, The variable that affects the research studied is the weight of the sediment flushing *(w) = f (channel, discharge, sediment, fluid),* *W = f (B, B*, h*, h, Δh, V, Q, q, g, W, ρw, ρS)*. From the calculation of the dimensional analysis of the Buckingham method, this research equation is obtained

$$w = \frac{B^*}{B} \cdot \frac{h^*}{h} \cdot \frac{\Delta h}{h} \cdot \frac{v}{gt} \cdot \frac{Q}{gh^2 t} \cdot \rho_s h^3$$

Where w is the weight of the sediment flushing (gr), $\frac{B}{B^*}$ is the ratio of the width of the estuary to the cross-sectional width of the design , $\frac{h^*}{h}$ is the ratio of the cross-sectional height of the flushing to the water level, $\frac{\Delta h}{h}$ is the ratio of the difference in water level to water depth, $\frac{v}{gt}$ is the rate settling velocity, $\frac{Q}{gh^2 t}$ is the discharge of sediment flushing $\rho_s h^3$ is the hydrostatic pressure of water.

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