論文摘要

河道冲淤問題之研究

The Mechanism of Sedimentation in Rivers

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SYNOPSIS

A dynamic framework—that of the unsteady process of Sediment movement—on which to base a study of the river transport theory of channels that have formed boundries from their own transported material or material of like nature is contributed. Rivers in general, are not susceptible to mathematical or quantitative analysis except for certain assumptions. In this paper the formula for total sediment discharge is assumed to be expressed by the general form of bed-load discharge formula, and by means of so called "Characteristic Curves Method"*(1) which combined several formulae in accepted hydraulics,makes it possible to fit into the frame work of river flow dynamics, a general formula for the unsteady process of sediment movement is given. Although these laws apply to rivers, exactly as to canals, the disturbing influences in the former required judgment in the application of the formulae.

It is concluded that the Characteristic Curves Method thus obtained is precisely applicable to controlled rivers and also is valuable in predicting resrvoir profiles during various stages of sedimentation.

中文摘要

河道沉滓之冲淤因素，錯綜複雜，目前僅能暫就影響沉滓移動之因素，進行定性之研究。至於綜合各種各種水力因素、做純理論之推論，進而進行定量之探討，則尙無暇顧之。本文旨在引用流體力學之基本定律與泥沙科學之精華，酌選影響河床冲淤之主要因素以特性曲線法*(1)研究河床冲淤現象之定量分析。

按河道中沉滓之移動現象可用下列七組水力公式合之，即(1)，水流運動方程式 (Dynamic Equation *(2)

$$\frac{\partial h}{\partial x}+\frac{1}{g}\frac{\partial v}{\partial t}+\frac{\partial}{\partial x}\left(\frac{v^2}{2g}\right)=S-\frac{v_*^2}{gR}\cdots\cdots(1)$$

(2) 水流連續定律 (Law of Contiunity)*(2)

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0\cdots\cdots(2)$$

一般河流之水流，其運動之時間變化緩慢，可近似爲定量流而省略上式中 $\frac{\partial}{\partial t}$ 各項得

$$\frac{dh}{dx}=S-\frac{d}{dx}\left(\frac{v^2}{2g}\right)-\frac{v_*^2}{gR}\cdots\cdots(1')$$

及 $Q=Av=$ 常數 $\cdots\cdots(2')$

(3) 沉滓流量公式：(Formula for Sediment transport)

影響河床冲淤之主要因素爲推移載，惟爲沉滓流量之能更近似實際河川情況計，本文引用勃崙氏推移載流量公式，將杜波、希爾德、愛因斯坦，羅斯*(3)、佐藤諸氏公式無因次化後，加以浮懸載流量之補充，得一其般公式如下：

$$\left.\begin{aligned} q_{T*}&=C_S\,(T_*-T_{*O})^m \\ \text{或}\quad q_T&=\alpha\, v_*(v_*^2-v_{*O}^2)^m \end{aligned}\right\}\cdots\cdots(3)$$

式中 $\alpha=C_s\,d/[\{(\rho_s/\rho)-1\}gd]^m$

(4) 沉滓流量連續定律 (Continuity for Sediment Discharge)

實河槽之可以二向流處理者，沉滓冲淤之連續定律可用：

$$\frac{\partial Z}{\partial t}+\frac{1}{B(1-\lambda)}\frac{\partial(q_T B)}{\partial x}=0 \quad \text{示之}\cdots\cdots(4)$$

式中λ爲空隙率。

(5) 河床坡降條件，河床坡度及冲淤厚度，基準面坡降間成立下述幾何關係，即

$$S = S_0 - \frac{\partial Z}{\partial x} \cdots\cdots\cdots\cdots (5)$$

(6) 水流阻抗法則：(Law of Resistance)

水流之阻抗法以滿寧公式 $S_f = v_*^2/gR = n^2v^2/R^{4/3}$ 示之，則得 $v_* = g^{1/2}n\ Q/h^{7/6}$ ……………(6)

(7) 磨耗法則 (Law of Abrasion)*(4)

河床沉滓磨耗法則可用 $d = d_0\ e^{-\frac{k}{3}x}$ 示之……(7) 式中 d_0 為基準斷面沉滓粒徑。

河床之或冲或淤可聯立解上述七方程式，分析 v_*，h，q，S，q_B，v_{*c} 及 Z 等七個未知數，由Z值之正負可判斷冲淤量之多寡。

上述未知數中臨界剪力速度 v_{*c} 可由沉滓粒徑關係，以距離之函數表示之，即

$$v_{*c}^2 = \frac{T_c}{\rho} = \frac{C}{\rho}d = C_1 d = C_1 d_0 e^{-\frac{k}{3}x} \cdots\cdots (8)$$

亦即臨界始動水深 h_K 為：

$$h_K = gn^2Q^2/v_{*c}^2 B^2 = gn^2Q^2/C_1\ d_0\ Be^{-\frac{k}{3}x} \cdots\cdots\cdots\cdots (8')$$

今將(6)式及(8′)式代入(3)式中，微分 $\partial(q_T B)/\partial x$ 得

$$\partial(q_T B)/\partial x = A''\left(B'\frac{\partial h}{\partial x} + C'\frac{dB}{dx} + D'\right) \cdots\cdots\cdots\cdots (9)$$

式中

$$\begin{cases} A'' = -\left\{\dfrac{\alpha n^{2m+1} g^{m+1/2} Q^{2m+1}}{B^{2m}\ h^{13/6}} \left(\dfrac{1}{h^{7/3}} - \dfrac{1}{h_K^{7/3}}\right)^{m-1}\right\} \\ B' = \left\{\dfrac{7}{6}\left(\dfrac{1}{h^{7/3}} - \dfrac{1}{h_K^{7/3}}\right) + \dfrac{2m}{h^{7/3}}\right\} \\ C' = 2m/Bh^{4/3} \\ D' = -hkm/3\ h_K^{7/3} \end{cases} \cdots\cdots (10)$$

將 (9) 式代入 (4) 式中得沉滓冲淤連續方程式為

$$\frac{\partial Z}{\partial t} = A'\left(B'\frac{\partial h}{\partial x} + C'\frac{dB}{dx} + D'\right) \cdots\cdots\cdots\cdots (11)$$

式中 $A' = \dfrac{\alpha n^{2m+1}}{(1-\lambda)} \dfrac{g^{m+1/2}\ Q^{2m+1}}{B^{2m+1}\ h^{13/6}} \left(\dfrac{1}{h^{7/3}} - \dfrac{1}{h_K^{7/3}}\right)^{m-1}$

將水流運動方程式 (1) 代入 (11) 式中得

$$\frac{\partial Z}{\partial t} + A'B'\frac{\partial Z}{\partial x} = A'\left\{B'\left(S_0 - \frac{d}{dx}\left(\frac{v^2}{2g}\right) - \frac{n^2v^2}{R^{4/3}}\right) + C'\frac{dB}{dx} + D'\right\} \cdots\cdots\cdots (12)$$

(12) 式可用一組特性曲線表示之，即

$$\begin{cases} dx/dt = A'B' \\ dz/dt = A'\left\{B'\left(S_0 - \dfrac{d}{dx}\left(\dfrac{v^2}{2g}\right) - \dfrac{n^2v^2}{R^{4/3}}\right) + C'\dfrac{dB}{dx} + D'\right\} \end{cases} \cdots\cdots\cdots (13)$$

(13) 式即為上述七個方程式之聯立解，可藉之以解冲淤進展速度，各期間冲淤厚度及各河段冲淤深度。假定基準面與河床一致時 (13) 式復可簡化為

$$\begin{cases} \dfrac{dz}{dt} = A'\left(B'\dfrac{dh}{dx} + C'\dfrac{dB}{dx} + D'\right) \\ \dfrac{dx}{dt} = A'B' \end{cases}$$

本解可供穩定河道之設計，冲淤河道之治理，及水庫淤積後各期坡降之判斷，使河床冲淤問題得一定量之分析。*(5)

參考資料

(1) Iwagaki Y: "On the River-bed Variation and its Stability" Proc. 6th National Congress for Appl Mechanice. p. 361-366 (1959).

(2) Ven-Te Chow "Open Channel Hydraulics" (1959)

(3) H. Rouse "Engineering Hydraulics" (1949)

(4) A. Schokolitsch: "Handbuch der Wasserbaues Wien, Bd, I. S. 163-164 (1950)

(5) 符號及詳細內容參閱臺大土木研究所民國五十學年度畢業論文。