

Effects of Channel Conditions on Profile of Flows in Open Channel

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It is general that the bed of natural river channel has the composite roughness — non uniform across channel transversely — and for the purpose of bank protection the toe part of the bank has the greater roughness.

In such a case two different types of flow profile must appear due to individual roughness. However practically in the plane between different roughness, the mixing of discharge and shearing friction occur and the flow profile becomes medium.

Authors published the calculation of the profile by the direct mixing discharge method in December 1966. At present authors propose the new method of calculation by means of the shearing friction and mixing discharge both occurring on the boundary between two flows with different velocities.

1. Introduction

It is important to calculate accurately the back water curve in the case of flood disaster or water profile due to dams, bridge and other hydraulic structures. In general, the river channel has the composite section which consists of different roughness. In such a case it is not able to calculate by the ordinary customary method owing to coexistence of M and S curves in one channel. Authors published the flow profile computation in the composite roughness channel by the flow mixing method in 1966. In this report introduced here, the new calculating method which involves the head loss due to vortex owing to the velocity difference between rough and smooth parts in the channel and the flow mixing in the dynamic equation of gradually varied flow.

2. The equipment for experiment

The two channels used for the experiment are rectangular and prismatic. The one is composed of the glass side wall of 40cm height and the stainless steel bottom of 8.0m reach and 50cm width. Another is 10.0m long and 60cm wide having the same sidewall height as the former.

In both channels, bottom slope can be changed from 1/150-1/200 by the slope adjuster set at the end of the channel. The vertical irregularity of the stainless steel bottom is within 1.0mm. For the discharge measurement, the two triangular weirs

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were set at the inlet of the channel. For the measurement of the depth the point gage was used.

3. Determination of roughness coefficient

The measurement was made in the following way ;

Two sections where the flow seems to be a uniform flow are chosen. At each section, the mean depth of the water area is measured. It must be calculated from the dynamic equation of gradually varied flow. Therefore n is expressed by the following equation.

$$n = \frac{By_1 R_1^{2/3}}{Q} \sqrt{S_0 + \left(1 - \frac{\alpha}{g} \frac{Q^2}{B^2 y_1^3}\right) I_1} \quad (2-1)$$

where

R_1 represents the hydraulic radius of the section 1. I_1 maybe nearly equal to

$$\frac{y_2 - y_1}{2dx}$$

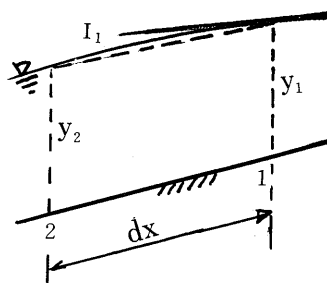


Fig. 2-1

In calculating n for the rough channel, it will be found that when the depth with regard to the height of the gravel will be used for y in Eq. (2-1), then n calculated will not have a constant value. So it is to relate the effective height of the gravel. The problem in the roughness height has been discussed by many engineers. It is not the aim of the authors experiment. So the effective height of the gravel was simply made as following.

The gravels are put on the bottom of the box with 25cm width, 15cm length and 20mm depth in the way showed in Fig. 2-2. The water is poured into this box until the almost all the gravel will be covered with the water. Next the weight of the water used for covering the gravel is measured. From this experiment, the effective water are among the gravel can be estimated. Basing this value, the roughness height of the gravel was determined to $k=8\text{mm}$ (mean diameter of the gravel $d=13\text{mm}$).

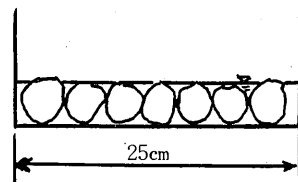


Fig. 2-2

In the rough channel y in Eq. (2-1) must be a value of the experimental depth minus k .

Since in rough channel the roughness of the bottom is much larger than the roughness of the side wall, the perimeter of the water area of the rough channel may be considered to be equal to the width of the bottom, namely B . Hence R in rough channel may be equal to the depth y . On the other hand, R in smooth channel may be equal to $By/B+2y$.

4. The technique of experimental composite channel

Putting the impermeable transparent thin vinyl plate on the center line, the rough and smooth channels are made to become independent to each other.

The flows are backed up by weir plate set at the end of the channel. The water profiles are measured at interval 20cm along the channel. The mean depth in cross section is considered to be the depth at the center of each channel, which measured from the bottom surface to the water surface. Then we can think theoretically that two different types of water profile (for example S.M.) co-exist in one channel.

Now the preceeding vinyl center wall is taken off. But other conditions of the channel and method of measuremet are same as before described.

Then we can find the median profile between S.M. An example of these results is shown in Fig. 2-5 as described before.

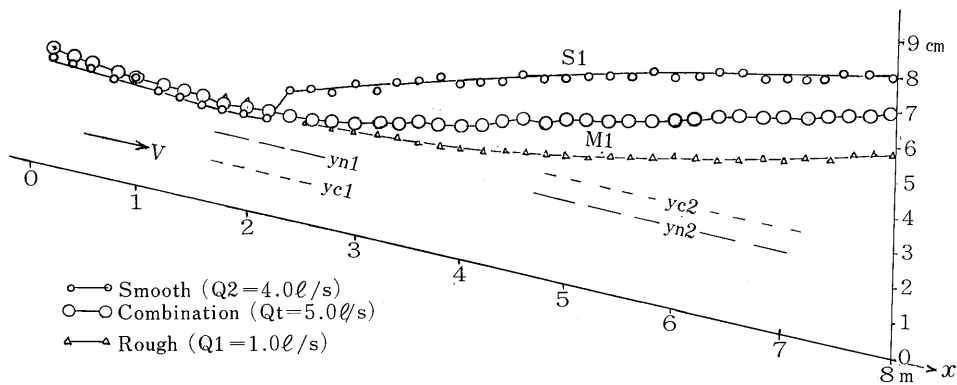


Fig. 2-5

5. The theory

Assuming two different type of channels which have rough and smooth roughness respectively coexist in one channel, we will derive the dynamic equations of flow in each channel and still more introduce into these equations the vortex loss due to shear stress acting on the boundary between two flows with different veolcities.

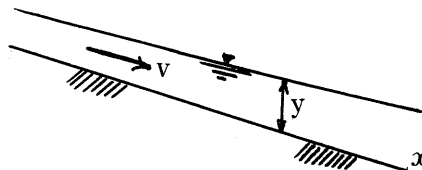
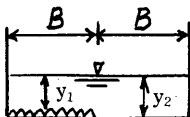
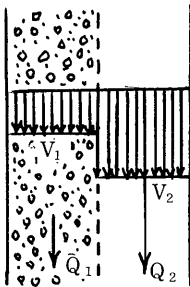


Fig. 5-1

Fig. 5-2

We first show the two following equations.

$$\left. \begin{aligned} -Sf_1 &= -So_1 + \frac{dy_1}{dx} + \alpha_1 \frac{d}{dx} \left(\frac{V_1^2}{2g} \right) + Sm \\ -Sf_2 &= -So_2 + \frac{dy_2}{dx} + \alpha_2 \frac{d}{dx} \left(\frac{v_2^2}{2g} \right) - Sm \end{aligned} \right\} \quad (5-1)$$

where

Sf_1, Sf_2 are the slopes of energy losses in channel I and II respectively,

So_1, So_2 are the slopes of bottoms of channel I and II respectively,

x shows the distance axis along channel direction,

α_1, α_2 are the correcting coefficient of energy head in channel I, II respectively,

(assume $\alpha_1 = \alpha_2 = \alpha$)

v_1, v_2 are mean velocities in channel I and II respectively,

So shows boundary friction slope due to the difference of velocities. This is a new idea, we introduce.

We assume this head loss may be proportional to the squares of velocities difference between each channel namely $(v_1|v_1 - v_2|v_2|)$. In addition, it may be proportional to the area on which the stress is acting, and inversely proportional to the squares of the channel width (it is B^2);

$$Sm = \frac{dhm}{dx} = m \frac{Q_1|Q_1| - Q_2|Q_2|}{2gB^4y} \quad (5-2)$$

where

m coefficient which has dimensionless value.

y_1, y_2 are the depth in channel I and II respectively, and assuming no change of water depth trans versely $y_1 = y_2 = y$

$$\frac{dy_1}{dx} = \frac{dy_2}{dx} = \frac{dy}{dx} \quad (5-3)$$

by theory of continuity

$$Q_1 + Q_2 = Q_t \quad (5-4)$$

Hence

$$\frac{dQ_1}{dx} = -\frac{dQ_2}{dx} \quad (5-5)$$

Velocity head term in Eq (5-1) may be developed as follows;

$$\begin{aligned} \alpha \frac{d}{dx} \left(\frac{v_1^2}{2g} \right) &= \alpha \frac{d}{dx} \left(\frac{Q_1^2}{2gA_1^2} \right) = \frac{\alpha}{g} \left(\frac{Q_1}{A_1^2} \frac{dQ_1}{dx} - \frac{Q_1^2}{A_1^3} \frac{dA_1}{dx} \right) \\ &= \frac{\alpha}{g} \frac{Q_1}{B^2y^2} \frac{dQ_1}{dx} - \frac{\alpha}{g} \frac{Q_1^2}{B^2y^3} \frac{dy}{dx} \end{aligned} \quad (5-6)$$

Similary in the smooth channel, velocity head change is

$$\alpha \frac{d}{dx} \left(\frac{v_2^2}{2g} \right) = \frac{\alpha}{g} \frac{Q_2}{B^2y^2} \frac{dQ_2}{dx} - \frac{\alpha}{g} \frac{Q_2^2}{B^2y^3} \frac{dy}{dx} \quad (5-7)$$

From $R_1 = y_1 = y$ and $R_2 = y_2 = y$,

$$Sf_1 = \frac{n_1^2 Q_1 Q_1}{A^2 R^{4/3}} = \frac{n_1^2 Q_1^2 Q_1}{B^2 y^{10/3}}, Sf_2 = \frac{n_2^2 Q_2 Q_2}{A^2 R^{4/3}} = \frac{n_2^2 Q_2^2 Q_2}{B^2 y^{10/3}} \quad (5-8)$$

Applying these conditions, Eq. (3-1) become

$$\begin{aligned} -\frac{n_1^2 Q_1 Q_1}{B^2 y^{10/3}} + So - Sm &= \left(1 - \frac{\alpha}{g} \frac{Q_1^2}{B^2 y^3} \right) \frac{dy}{dx} + \frac{\alpha}{g} \frac{Q_1}{B^2 y^2} \frac{dQ_1}{dx} \\ -\frac{n_2^2 Q_2 Q_2}{B^2 y^{10/3}} + So - Sm &= \left(1 - \frac{\alpha}{g} \frac{Q_2^2}{B^2 y^3} \right) \frac{dy}{dx} - \frac{\alpha}{g} \frac{Q_2}{B^2 y^2} \frac{dQ_2}{dx} \end{aligned} \quad (5-9)$$

Eliminating $\frac{dQ_1}{dx}$ from (3-9)

$$\frac{dy}{dx} = \frac{1 + \frac{Sm}{So} \frac{Q_1 - Q_2}{Qt} - \frac{Q_1 Q_2}{B^2 y^{10/3} Qt So} (|Q_1| n_1^2 + |Q_2| n_2^2)}{1 - \frac{\alpha}{g} \frac{Q_1 Q_2}{B^2 y^3}} So \quad (5-10)$$

From Eq. (3-2)

$$\frac{dy}{dx} = \frac{1 + \frac{Q_1 - Q_2}{So Qt} \frac{m(Q_1|Q_1| - Q_2|Q_2|)}{2gB^4 y} - \frac{Q_1 Q_2 (|Q_1| n_1^2 + |Q_2| n_2^2)}{B^2 y^{10/3} Qt So}}{1 - \frac{\alpha}{g} \frac{Q_1 Q_2}{B^2 y}} \quad (5-10)$$

We express $\frac{dQ_1}{dx}$ in $\frac{dy}{dx}$ from Eq. (3-9) as follows

$$\frac{dQ_1}{dx} = \frac{g}{\alpha} \frac{(Q_2|Q_2|n_2^2 - Q_1|Q_1|n_1^2)}{Qt y^{4/3}} - 2Sm \frac{g}{\alpha} \frac{B^2 y^2}{Qt} + \frac{Q_1 - Q_2}{y} \frac{dy}{dx} \quad (5-11)$$

Or we get

$$\frac{dQ_1}{dx} = \frac{F_2}{F_1} So \quad (5-11)'$$

where

$$F_2 = \frac{Q_1 Q_2}{y} - \frac{Sm}{So} \left\{ \frac{2gB^2 y^3 - \alpha(Q_1^2 + Q_2^2)}{2Qt} \right\} + \frac{g}{\alpha} \frac{Q_2|Q_2|n_2^2 - Q_1|Q_1|n_1^2}{Qt y^{1/3} So} + \frac{Q_1 Q_2 (Q_2|Q_1|n_1^2 - Q_1|Q_2|n_2^2)}{B^2 y^{10/3} Qt So}$$

$$\text{and } F_1 = 1 - \frac{\alpha}{g} \frac{Q_1 Q_2}{B^2 y^3}$$

6. Normal depth in the composite channel

The normal depth for the whole section may be defined as the depth that makes the numerator of Eq. (5-9) vanish. So the normal depth for the whole section may be expressed as follows;

- 1) In the case where Sm is appreciable,

$$yn = \left\{ (1 + fm) \frac{Q_1 Q_2 (|Q_1| n_1^2 + |Q_2| n_2^2)}{So Qt B^2} \right\}^{3/10} \quad (6-1)$$

$$\text{where } fm = \frac{Sm}{So} \frac{Q_1 - Q_2}{Qt}, \quad Sm = m \frac{Q_1|Q_1| - Q_2|Q_2|}{2gB^4 y}$$

Since yn is a multiple function of two variables Q_1 and Q_2 , the general characteristics of the normal depth curve can not easily discussed.

- 2) In the case where Sm is neglesible,

from Eq. (5-10)

$$yn = \left\{ \frac{Q_1 Q_2 (|Q_1| n_1^2 + |Q_2| n_2^2)}{So Q + B^2} \right\}^{3/10} \quad (6-2)$$

If the flow is a uniform flow,

$$\frac{Q_1}{Q_2} = \frac{n_2}{n_1}, \quad Q_1 + Q_2 = Qt$$

$$\text{So } Q_1 = \frac{n_2}{n_1 + n_2} Qt, \quad Q_2 = \frac{n_1}{n_1 + n_2} Qt \quad (6-3)$$

Substituting these relations into (6-2)

$$yn' = \left\{ \frac{2n_1 n_2}{4B^2 So} Qt^2 \right\}^{3/10} \quad (6-4)$$

Dividing Eq. (6-2) by Eq.(6-4)

$$\left(\frac{yn}{yn'}\right)^{10/3} = \frac{Q_1 Q_2 (|Q_1| n_1^2 + |Q_2| n_2^2)}{2} \left(\frac{2n_1 n_2}{n_1 + n_2}\right)^2 Qt^3 \quad (6-5)$$

Let $p = Q_1/Qt$ $s = n_2/n_1$

Eq.(6-5) is written by

$$\left(\frac{yn}{yn'}\right)^{10/3} = \frac{(1+s^2(p(1-p)\{p+(1-p)s^2\}))}{4s^2} \quad (6-6)$$

7. Critical depth in the composite channel

The critical depth that makes the denominator of Eq. (6-2) vanish, may be written as follows

$$yc = \sqrt[3]{\frac{\alpha}{g} \frac{Q_1 Q_2}{B^2}} \quad (7-1)$$

Since at the critical section of the channel the discharge of each channel may be equal, that is $Q_1 = Q_2 = \frac{Qt}{2}$.

Substituting this relation into Eq. (7-1)

$$yc' = \sqrt[3]{\frac{\alpha}{g} \left(\frac{Qt}{2B}\right)^2} \quad (7-2)$$

Dividing Eq. (7-1) by (7-2)

$$\frac{yc}{yc'} = \sqrt[3]{4 \frac{Q_1}{Q_2} \frac{Q_2}{Qt}} = \sqrt[3]{4p - (1-p)} \quad (7-3)$$

8. Method of computation

The numerical integration was used for solving the differential equation of (5-10), (5-11).

The practical computation was carried by the digital computer (FACOM 231 produced by FUJI ELECTRIC COMPANY).

To diminish the accumulaton of the error accompanying with the operation the Runge-Kutler method was used.

The calculation is started from the upstream end.

- 1) The channel conditions (Bottom slope So , channel width B , roughness coefficient of each channel n_1, n_2) are given. The total discharge Qt is given.
- 2) The boundary values of the discharge of each channel are computed from Eq. (6-3)

That is $Q_{o1} = \frac{n_2}{n_1 + n_2} Qt$, $Q_{o2} = \frac{n_1}{n_1 + n_2} Qt$

- 3) The determination of the normal depth for entire cross section. Though this normal depth yn should be determined from Eq. (6-2) by use of the try and error method, it is very laborious. For practical purpose, it will be allowed to make an approximation as follows.

The depth in Sm is replaced by the normal depth where the head loss due to vortex is neglesible, namely yn in Eq. (6-2).

When Sm is determined, Eq. (6-1) can directly solved for yn .

- 4) For the boundary value of the depth, the preceeding normal depth multiplied by a factor mu is adopted. This factor indicates where the water surface line at the beginning lies namely above normal depth.
- 5) Let dx represent the interval of the integration, dy/dx can be computed from Eq. (5-9). At the same time, dQ_1/dx and dQ_2/dx can be computed from Eq. (5-10').

Applying the method of Runge-Kutte,

$$dx_1 = dx f(Q_{01}, Q_{02}, y_0)$$

where

y_0 represents the boundary value of the depth.

$$dQ_1 = dx g(Q_{01}, Q_{02}, y_0)$$

$$dy_2 = dx f\left(Q_{01} + \frac{dQ_1}{2}, Q_{02} - \frac{dQ_1}{2}, y_0 + \frac{dy_1}{2}\right)$$

$$dQ_2 = dx g\left(Q_{01} + \frac{dQ_1}{2}, Q_{02} - \frac{dQ_1}{2}, y_0 + \frac{dy_1}{2}\right)$$

$$dy_3 = dx f\left(Q_{01} + \frac{dQ_2}{2}, Q_{02} - \frac{dQ_2}{2}, y_0 + \frac{dy_2}{2}\right)$$

$$dQ_3 = dx g\left(Q_{01} + \frac{dQ_2}{2}, Q_{02} - \frac{dQ_2}{2}, y_0 + \frac{dy_2}{2}\right)$$

$$dy_4 = dx f\left(Q_{01} + \frac{dQ_3}{2}, Q_{02} - \frac{dQ_3}{2}, y_0 + \frac{dy_3}{2}\right)$$

$$dQ_4 = dx g\left(Q_{01} + \frac{dQ_3}{2}, Q_{02} - \frac{dQ_3}{2}, y_0 + \frac{dy_3}{2}\right)$$

The change of depth and the change of the discharge in rough channel may be expressed as follows ;

$$dy = \frac{1}{6}(dy_1 + 2dy_2 + 2dy_3 + dy_4)$$

$$dQ = \frac{1}{6}(dQ_1 + 2dQ_2 + 2dQ_3 + dQ_4)$$

- 6) The depth and the discharge in the next section become,

$$y = y_0 + dy$$

$$Q_1 = Q_{01} + dQ, Q_2 = Q_{02} - dQ$$

- 7) The preceeding steps are repeated along the channel reach.

9. Explanation of program used for computation

The type of the program is ALGOL.

The explanation will be stated with each subdivided parts of the program.

Part A) The declaration of the identifiers.

Part B) The statements of printing. The reading of the data.

Part C) The determination of the boundary values of the discharge and depth.

Part D) Computation of constant factor.

Part E) The computation of velocities, head, normal depths and critical depth for subsection and for entire cross section, respectively. The statement of the printing of the preceeding computed values.

Part F) The computation of dy/dx and dQ/dx .

Part G) The statement of the printing.

Part H) The computation by the method of Runge Kutter.

10. Program for the water profile

```

begin comment real length: =5;
real S0, Qt, dQ1, dQ2, dQ3, dQ4, Q1, Q2, y, y0, dy, dy1, dy2, dy3, dy4, x,
dx, yn, yc, D, V1, V2, he1, he2, EL, mu, Q01, Q02, L, Sdx, SO31, SO32,
n1, n2, n2, W1, W2, W3, W4, m, Sm, DEN, y5, y6,
integer i select;
LFEED; CRLF; Print string (COMPUTATION OF WATER PROFILE);
CRLF; CRLF;
Prints tring (SLOPE, WIDTH 1(M) WIDTH 2(M) ROUGHNESS 1
ROUGHNESS 2
TOTAL DISCHARGE (L/S.),); GRLF;
READ REAL (SO); Print string ('1/'); Print integer (fix(10./SO)):
Print string ('0.25 0.25,); Read real (n1): Read real (n2): Print fix (n1,
5, 3); Print fix (n2, 6, 3); Space (6);
Read real (Qt); Print fix (Qt*1000.0, 3, 3); CRLF; CRLF:
Print string ('X(M) Y(CM) Q1(L/S) Q22(L/S) P1 P2 V1 V2 he1(CM)
he2(CM) YN(CM) YC(CM),); CRLF; CRLF:
Read real (dx); Read real (L); Read integer (SELECT); Read real (mn);
Read real (m);
if SELECT 1 then begin Q01:=2/(n1+n2) * Qt
    Q02:=n1/(n1+n2) * Qt;
    y0:=Q01 * Q02 * (n1↑2 * Q01+n2↑2 * Q02)/0.0625 * Qt * S0) )↑0.3;
    y5:=y0;
    Sm:=0.0766/y0 * (Q01 * abs(Q01-Q02 * ads(Q02)));
    y0:=mu * 1.0+Sm/S0 * (Q01-Q02)/Qt)↑0.3 * y5
end else
begin Q01:=0.5/ * Ot; Q02:=0.49 * Qt;
    y0:=mu * (1.795 * Q01 * Q02)↑0.3333;
end;
SO31:=(n1/0.25)↑0.6/SO↑0.3; SO32:=(n2/0.25)↑0.6/SO↑0.3;
D:=0.0625 * SO * Qt; Sdx:=SO * dx;
W1:=8.90 * n1↑2/Qt/SO; W2:=8.90 * n2↑2/Qt/SO;
W3:=n1↑2/D; W4:=n2↑2/D; Part D
for x:=0.0 step dx until L do
begin
    E1:=20.0-SO * x * 100.0:
    y:=y0; Q1:=Q01; Q2:=Q02;
    V1:=Q1/0.25y; V2=Q2/0.25|y;
    he1:=y+V1 * abs(V1)/19.6; he2:=y+V2 * abs(V2)/19.6;

```

```

yn1:=SO31 * Q1/abs (Q1) * abs(Q1) ↑ 0.6;
yn2:=SO32 * Q2/abs(Q2) * ab *abs(Q2) ↑ 0.6;
yc1 =1.215 * Q1/abs(Q1) * abs(Q1) ↑ 0.6667;
yc2:=1.215 * Q2/abs(Q2) * abs(Q2) ↑ 0.6667;
print fix(x, 2, 2): print fix(y * 100.0+EL2.3);
print fix(Q1 * 1000.00,2,3): print fix (Q2 * 1000.0,2,3);
print fix(Q1/Qt, 1, 2); print fix (Q2/Qt, 1, 2);
print fix(V1, 1, 2); print fix(V2, 1, 2) '
print fix(he1 * 100.0+EL 2, 3); print fix(he2 * 100.0+EL, 3, 3);
print fix(yn1 * 100.0+EL, 2, 3); print fix(yn2 * 100.0+EL, 2 ,3);
print fix(yc1 * 100.0+EL, 2, 3); print fix(yc2 * 100.0+EL, 2, 3);
i:=0 RET i:=i+1;
Yn:=Q1 * Q2 * (n1 ↑ 2 * abs(Q1)n2 ↑ 2 *abs(Q2)/D
Yc:=1.795 Q1 * Q2
DEN:=Sdx/(1.0-Yc/y ↑ 3);
Sm:=m/0.0766y * Q1 * abs(Q1(-Q2*abs(2);
dy:=(1.0Sm/SO * (Q1-Q2)/Qt-YN ↑ 3.333)* DEN;
dQ:=((Q1-Q2)/y-Sm/SO*(1.25 * y ↑ 3-Q1-Q2*Q2)/Qt/y
      +(W2 * Q2abs(Q2)-W1 * Q1 * abs(Q1)y ↑ 1.3333
      +Q1 * Q2 *(Q2*abs(Q1( * W3-Q1 * abs(Q2) * W4)/Y ↑ 4.3333)
      * DEN
if i:=1 then begin
y6:=abs(1.0+Sm/SO * (Q1-Q2)/Qt) ↑ 0.3;
print fix(Y6 * 100.0+EL 2, 3);
print fix(YC/abs(YC) * abs(YC) ↑ 0.3333 * 100.0+EL2,3): CRLF;
space (7); print fix (y*100.0, 2, 3); space (26);
print string(' (,); print fix(Sm * dx * 100. 02, 5);
print string(' (,); print fix(he1 * 100.0, 2, 3)
print fix(he2 * 100. 0,3, 3): print fix(yn1 * 10 0. 2, 3)
print fix(yn2 * 100.0, 2, 3): print fix(yc1 * 100. 0,2, 3)
print fix(yc2 * 100. 0,2, 3);
print fix(y6 * 100. 0,2, 3) print fix(yc/abs(YC) * abs(YC) 0.3333
* 100. 0, 2, 3): CRLF: CRLF;
end:
if i:=1 then begin dy1:=dy; dQ1:=dQ; y:=y0+dy1 * 0.5
Q1:=Q01+0.5 * dQ1; -Q2=Q02-0.5 * dQ1; go to RET; end;
if i:=2 then begin dy2:=dy; dQ2:=dQ; y:=y0+dy2 * 0.5
Q1:=Q01+0.5 * dQ2; Q2:=Q02-0.5 * dQ2 go to RET; end;
if i:=3 then begin dy3:=dy; dQ3:=dQ y:=y0+d1/3
Q1:=Q01+dQ3; Q2:=Q02-dQ3 go to RET; end
dy4:=dy dQ4:=dQ
dy:=(dy1+dy2 * 2.0-dy3 * 2.0-dy4) * 0.16667

```

Part E

Part F

Part G

Part H

```

y0:=y0+dy;
dQ=(dQ1+dQ2 * 2.0+dQ3 * 2.0+dQ4) * 0.16667;
Q01:=Q01+dQ; Q02:=Q02-dQ;
end
end; LFEEE
end end of Program

```

11. Result of experiment and analysis

Calculating the normal depth and critical depth for each channel.

$yn1=2.1\text{cm}$, $yc1=1.2\text{cm}$

$yn2=3.0\text{cm}$, $yc2=2.4\text{cm}$

Thus the type of the profile in rough channel is $M1$, while in the smooth channel $S1$. In this case the profile in the combination channel may be considered to be formed by the co-existence of the $M1$ flow and $S1$ flow.

The result of experiment on the water profiles in the separated channel are shown in Fig.(2-5) shows the profiles in the case where the discharges of each channel are regulated in such a way that the depth of each channel are equal in the part of uniform flow in the upstream. The profile in the combination channel is shown in the same figure for comparison. Roughness coefficient is determined as 0.03 for the rough channel and 0.01 for smooth channel (See Fig. 2-3, Fig. 2-4)

12. The result of computation

The computations were carried out by the digital computer, changing the values of m from 0.0 to 2.5. The sample of the result of computation as shown in Table 1.

Table 1.
FLOW PROFILE IN COMPOSITE ROUGHNESS CHANNEL
 $N1=0.03$ $N2=0.01$ $B=0.250(\text{M})$ $DX=0.20(\text{M})$ $SO=1/156$ FACTOR $M=0.10$

X (M)	Y (CM)	Q1(L/S)	Q2(L/S)	P1	P2
0.00	2.465	1.250	3.750	0.25	0.75
0.80	2.904	0.960	4.039	0.19	0.80
1.60	3.459	0.673	4.326	0.13	0.86
2.40	4.028	0.462	4.536	0.09	0.90
3.20	4.593	0.330	4.669	0.06	0.93
4.00	5.153	0.269	4.730	0.05	0.94
4.80	5.708	0.273	4.726	0.05	0.94
5.60	6.258	0.335	4.664	0.06	0.93
6.40	6.802	0.444	4.555	0.08	0.91
7.20	7.341	0.587	4.412	0.11	0.88
8.00	7.874	0.752	4.248	0.15	0.84
8.80	8.403	0.926	4.073	0.18	0.81
9.60	8.927	1.100	3.899	0.22	0.77
10.00	9.188	1.185	0.23	0.76	

*P1 is percentage of Ql in rough part.

P2 is percentage of Ql in smooth part.

13. Comparison between experiment and computation analysis

An example of Comparison between experiment and computation analysis by Eq. (5-10) is shown in Fig. 13-1 when $m = 0.1$ we can find the good agreement between experiment and computation analysis.

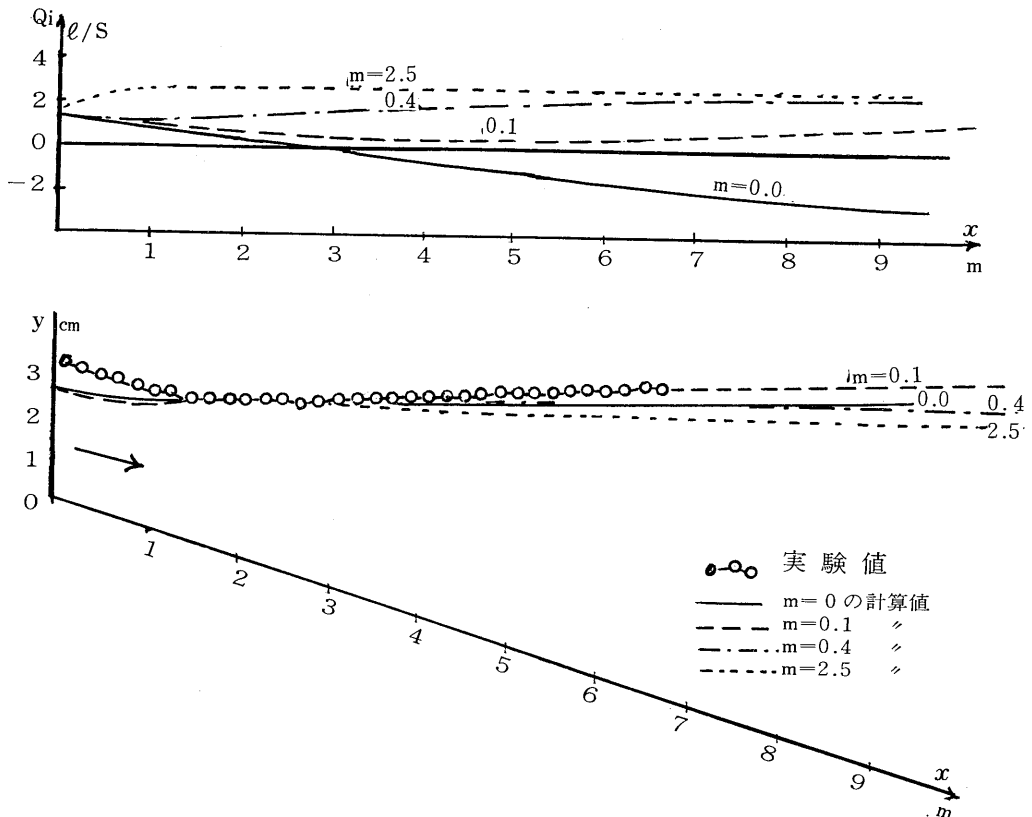


Fig. 13-1

14. Conclusion

Under existing circumstances, the water profiles in the combination channel are computed by use of an equivalent roughness that is considered to be the representative of the subdivided sections. Though some discussion on equivalent roughness for a uniform flow in the combination channel have been done, it is doubtful that this is equivalent roughness coefficient will be able to be directly applied to a nonuniform flow.

Authors observe the flow streaming in the combination channel and establish the dynamic equation which is deduced from the basic assumption that the cross sectional water surface is horizontal transversely. By use of the author's equation the local discharge in each subsection can be solved, while the method of the equivalent roughness does not give any information of the local discharge. Thus author's equation will be effective in such a case where the local discharge will be needed for designing the

hydraulic structures, for instance in the case of the sediment transportation of the river.

The authors equation looks like complicated a little. But it takes not so much time in the computation of the water profile by use of computer.

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