工事報告

Desin and Construction of Sand Trap On the Kerasaan Sub-Project in the Simalungun Area

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I. Introduction

1. Simalungun Irrigation Project

The Simalungun Irrigation Project is located in the Simalungun district of North Sumatera Province, Indonesia.

Total irrigable area under the project is 49,500 ha with 117 sub-projects, and Kerasaan sub-project which is the the biggest covers about 5,000 ha

The topographic conditions of the project area is steep with an average slope of 1 : 100 from the south-western part to the Northeastern part.

The dry searson in the project area comes from January through March having about 150 mm of monthly rainfall, while wet season is from September through November with about 300 mm of monthly rainfall.

The mean annual rainfall is about 2.500mm and mean daily temperature is approximately 24.4℃. And the average evaporation is 3.9mm /day.

There are four major rivers in the project area. They are Bah Bolon, Bah Tongguran, Bah Hapal and Bah Pamujian. The water source of Kerasaan sub-project is Bah Bolon.

Total number of weirs are 201 ea and total length of irrigation canal is 881km. Related structures in the irrigation canal are 9,151ea.

After finish of all construction in the project, rice production will be increased to 227,000 T /year, and cropping intensity of the project area will be increased from 115% to 190%, New rice paddy area of 7,435ha will be extended and new farm road development is 299km.

2. Kerasaan sub-project

A. Profile

The Kerasaan sub-project area is located at the Northeastern part of Simalungun area with distance of about 20~40km from the main city of project area, Pematang Siantar.

The Kerasaan sub-project area is bounded by Bah Bolon river at South and East while by palm oil and rubber plantantions in West and North.

The topography of the Kerasaan area is generally flat with varing elevation of 60m above mean sea level in the northern part and 130m in the southern part.

Several small creeks are located at the center and downstream part of the project area, and they flow into the Bah Bolon river.

Most rivers in the project area are generally deep with V-shape outcropped with weathered tuff rock in the bed.

The gross area of the Kerasaan sub-project is 6,560ha including the existing rice paddy of 3,405ha, village/road of 549ha, canal site of 162 ha, upland area of 531ha and other miscellaneous area of 1,913ha.

Out of the existing rice paddy, about 120ha is seasonally utilized for fish culture. After the construction, the irrigable area has been increased to 5,000ha.

B. Engineering works

The major engineering works have been constructed as follows :

- Rebuilding of one main headwork and one supplementary weir
- Construction of canal : 72,940m
- Construction of canal structures : 116ea
- Rehabilitation of existing canal structures : 10 ea
- Construction of 4m-wide inspection road along the main and secondary canals : 25,500m

The Kerasaan headwork has been built at the same site of old weir in Bah Bolon river. New modern weir is equipped with intake facilities, scouring sluices, waterway and parshall flume.

The major figures of the weir are as follows :

Name of headworks	Kerasaan
Water resources	Bah Bolon river
Irrigable area	5,000ha
Catchment area	635.6km^2
Design flood(1/100)	1,030m^3/s
Type of weir body	Parabola curved masonry
Type of stilling basin	U.S.B.R. Type I
Length of weir crest	125m
Max. over flow depth	2.83m
Weir height	5.20m
Foundation condition	Soft rock(tuff)
Size of intake gate (B×H)	2.0×1.5m~3ea
Size of scouring sluice	2.5×3.16m~4ea
Weir body	Masonry
Surface of weir body	Hegh strengthen stone
Water measuring device	Parshall flume

C. Operation of the system

At the time of the design, it was planned that most of sand would be collected and flushed out by scouring sluices at the weir. So, after completion of construction, operation of the scouring sluices were made every Saturday to flush out sand from the weir. But sediment deposit was increased in the irrigation canal.

This means that sand sluices can not prevent sand intrusion into the canal. Because of sand deposit in the upstream part of the main canal, canal capacity was greatly reduced and there was danger of overflow of water on the bank.

The reduction of canal capacity should be recoverd and canal safety against overtopping of water should be kept. Therefore, new sand trap was proposed additionally and constructed.

II. Design of sand trap

1. Definition

Sand trap is a kind of structure installed at upper portion of canal in order to prevent sediments flowing into irrigation canal.

The sand trap consist of settling basin and flushing gate. The settling basin is generally made by deepening the bottom of the canal or widening of the canal. Here deepening of the canal was adopted.

The deepening is made so that an adequate flow area can be obtained for forcing sedimentation, and the bed of settling basin is sloped longitudinally so that the sediment deposit can be flushed down by the flowing water. At the end of downstream of the settling basin, flushing gate is installed to flush out the sediments into the nearby river.

2. Major contents of design

A. The length of the settling basin, 200m, was decided on the assumption that the sediment would be flushed once a week.

B. The basin was made by deepening of canal bed instead of widening of canal width, considering the present condition of construction status, shape of sand trap, flushing effect and economical point of view.

C. In the curved reach of the basin, a guide wall was proposed at the center of the settling basin to accelerate sand flushing.

D. Deepening of canal botton from the existing canal bed at the end of sand trap was decided as 1.57m based on hydraulic calculation and flood water level of the Bah Bolon river.

E. Two flushing gates were proposed for effective maintenance and 70m of masonary lined downstream drain canal was proposed to evacuate sand and water to the river.

3. Details of densign calculations

A. Given conditions

1) Main canal

Canal discharge(Qn)	$=7.396m^3/s$
Water depth(d)	=1.21m
Side slope(V : H=1 : m)	=1 : 1.5
Flow Velocity(V)	=0.57m/s
Energy Gradient(I)	=0.00016
Botton width(B)	=9.0m

2) Sediment

Assumed sediment concentration=300mgf/*l* (From measured date at Batu Gajah station of Bah Bolon) unit weight of sediment=$1.3tf/m^3$

B. Hydraulic design

1) Fall Velocity ; stoke's formular

$$V_f=\frac{1}{18}D^2\ \frac{G_s-G_w}{\mu}g=\frac{1}{18}(0.007)^2$$

$$(\frac{2.65-0.998}{0.00977})9.80=0.0045$$

$$\fallingdotseq 0.004m/sec.$$

Where, D=Minimum diameter of deposited material (0.007cm is assumed)

G_s =Specific gravity of deposited material

G_w=Specific gravity of water in 20℃

V_f =Fall velocity of design particle (m/s)

μ =Absolute viscocity of water in 20℃ (Poise)

g =Acceleration of gravity(m/sec^2)

2) Volume of sediment deposit

$$V_s=(300mgf/l)\times Qn\times T/W=300\times 7.396$$

$$\times 24\times 3{,}600\times 10^{-6}\times\frac{1}{1.3}=147m^3/day$$

Where, V_s=Volume of sediment deposit (m^3/day)

Assumed sediment concentration=300 mgf/*l*

Unit weight of sediment(W)=$1.3tf/m^3$

T=1 day

3) Average area of sand pocket

$$LB=\frac{Q_n}{V_f}=\frac{7.396}{0.004}=1.849m^2$$

Where, L=Length of settling basing(m)

B=Width of settling basin(m)

Relation between L and B should be L/B>8, so L>8 B($8B^2$>1,849)

B<15.2 m, L>121.65m

4) Calculation of sand trap canal slope(I_n)

a) Wetted area

$$A_n=\frac{Q_n}{V_f}=\frac{7.396}{0.40}=1.849m^2$$

Where, A_n = Wetted area at normal discharge (m^2)

V_n = Average normal velocity in the sand trap

= 0.40(m/sec) (given by Indonesian Standards)

$$A_n = \frac{B_1 + B}{2} \times d + B \cdot d_o = 18.49m^2$$

$d_o = 0.60m$

b) Hydraulic Radius(R_n)

$$R_n = \frac{A_n}{P_n} = \frac{A_n}{B + 2d\sqrt{1+m^2} + 2d_o}$$

$$= \frac{18.49}{9 + 2\times1.21\sqrt{1+1.5^2} + 0.6\times2} = \frac{18.49}{14.563} \fallingdotseq 1.27$$

c) Strickler roughness coefficient(kg)

$$n_s = \left[\sum_{i=1}^{n} \frac{(P_i n_i)^{1.5}}{P_i}\right]^{2/3}$$

$$= \frac{(2\times1.2\sqrt{1+1.5^2}\times0.017^{1.5} + 9\times0.022^{1.5} + 2\times0.6\times0.017^{1.5})^{2/3}}{(2\times1.21\sqrt{1+1.5^2} + 9 + 0.6\times2)^{2/3}}$$

$= 0.02$

$$K_s = \frac{1}{n_s} = 50$$

Wher, n_s : Roughness coefficient

d) Sand Trap cannel slope(I_n)

$$I_s = \left[\frac{V_n}{R_n^{2/3} \cdot K_s}\right]^2 = \left[\frac{0.4}{1.27^{2/3} \times 50}\right]^2$$

$= 0.46 \times 10^{-4}$

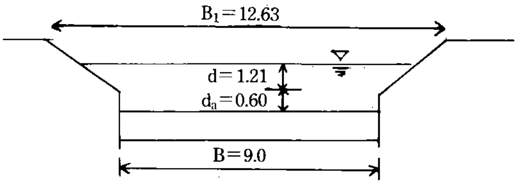

Fig. 1. Cross profile of sand trap

5) Calculation of energy gradient during flushing (I_s)

– Velocity for scouring(V_s) : 1.5m/sec (given by Indonesian standards)

– Discharge for scouring(Q_s) :

$Q_s = 1.2Q_n = 1.2 \times 7.396 = 8.875m^3/s$

$$A_s = \frac{Q_s}{V_s} = \frac{8.875}{1.5} = 5.916m^2$$

Where, As : wet profile during flushing(m^2)

– Water depth of sand trap(hr)

Botton width(B) assumed 9m

$$h_s = \frac{A_s}{B} = \frac{5.916}{9} = 0.658m$$

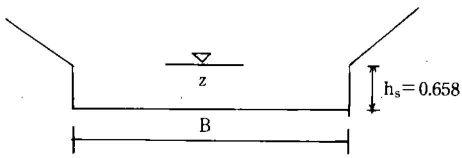

Fig. 2. Cross profile of sand trap.

Cross section of sediment pocket in empty condition at Q_s

$$R_s = \frac{A_s}{P_s} = \frac{5.916}{9 + 2\times0.658} = 0.573m$$

$$I_n = \left[\frac{V_s}{R_s^{2/3} \cdot K_s}\right]^2 = \left[\frac{1.5}{0.5736^{2/3} \times 45}\right]^2$$

$= 23.3 \times 10^{-4}$

K_s for masonry canal is 45.

For proper flushing, the velocity should remain subcritical or <1.

$$F_r = \frac{V}{\sqrt{gh}} = \frac{1.5}{\sqrt{9.8\times0.658}} = 0.591 < 1$$

From shields diagram (Refer Table 3),

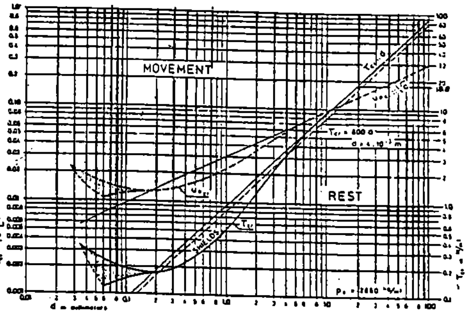

Fig. 3. Critical shear stress and critical shear velocity as a function of grain size for ρs = 2650kg/m(sand)

$\tau_{cr}=\rho_g$ hs $I_s=1{,}000\times9.8\times0.658\times23.3\times10^{-4}$
$=15N/m^2$

Where τ_{cr} : Critical tractiveforce(N/m^2)

ρ : Density of water

Particle with diameter smaller than 15mm can be scoured

6) Length of sand trap(L)

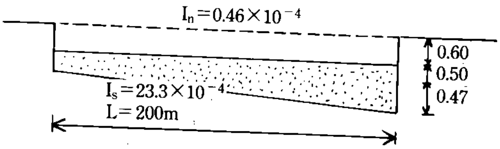

Fig. 4. Longitudinal section of sand trap

a) Based on sand volume

Volume of sediment per week(V_d) : 147(m^3/day)×7day=1,029m^3

$V_d=0.50\times B\times L+1/2(I_s-I_n)L^2$ B

$1{,}029=0.50\times9\times L+0.50(23.3-0.46)\times10^{-4}\times L^2\times9$

$1{,}029=4.50L+0.0103\ L^2$

$0.0103\ L^2+4.50L-1{,}029=0$

$$L=\frac{-4.50+\sqrt{(4.50)^2+4\times0.0103\times1{,}029}}{2\times0.0103}=166$$

Adopt L=200m

$V_d=0.50\times9\times200+0.0103\times200\times200=918+412=1{,}330>1{,}029.\ \therefore$ O.K

b) Based on settling time of particles

Settling time : $\frac{h_n}{V_f}=\frac{5.81}{0.004}=452.5sec$

Where, h_n=water depth(m),

V_f=fall velocity(m/sec)

Since the average velocity in the sand trap is 0.40 m/sec.

Length of sand trap, $L=452.5\times0.40=181m<L=200\ \therefore$ OK,

c) Efficiency

$$\frac{h_n}{W_o}=\frac{L}{V_n},$$

$$W_o=\frac{h_n\cdot V_n}{L}=\frac{1.81\times0.40}{200}=0.0036m/s$$

From Fig. 5 diameter of particle size is obtained

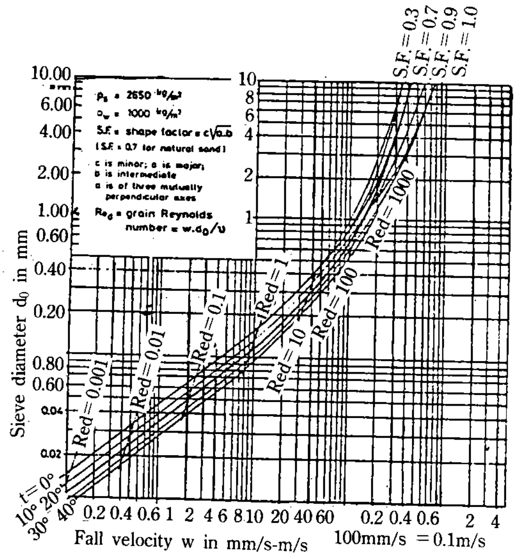

Fig. 5. Relationship between sieve diameter and fall velocity for stall water

d=0.065mm<0.07mm(given size of particle)

Where, W_o=permissible fall velocity

$$W = 0.004\text{m/sec} \quad \frac{W}{W_o} = \frac{0.004}{0.0036} = 1.10$$

W_o=0.0036m/sec

$$V_o = 0.40\text{m/sec} \quad \frac{W}{V_o} = \frac{0.004}{0.40} = 0.01$$

Where, W : Design fall velocity of sediment (m/sec)

V_o : Average velocity(m/sec)

From grapic efficiency(Fig. 6) of 0.78 is obtained.

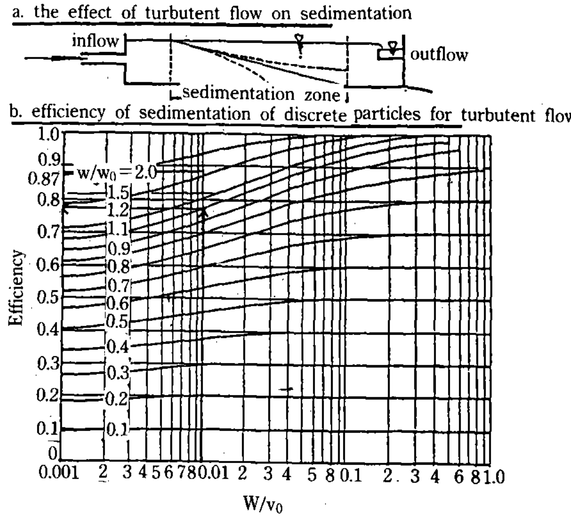

Fig. 6. Camp's sediment removed graph for turbulent flow(Camp, 1945)

4. Design drawings

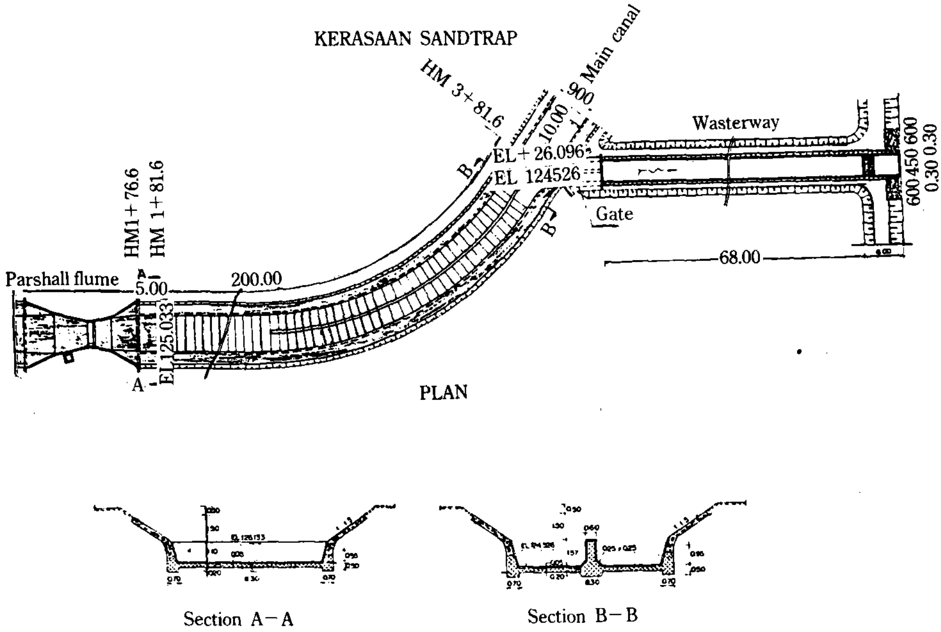

Fig. 7. Desigin drawing of karasaan sand trap

Ⅲ. Construction

The construction of sand trap was made in early 1991. The sand trap was constructed by stone masonry works, stone and mortar(1 : 3).

And on the surface of masonry works, plastering mortar was placed. Mixing ratio of cement and sand for plastering for prevention of leakage and smoothness of surface is 1 : 2.

Some parts of the foundation were reinforced by sand bedding for improvement of bearing capacity.

Fig. 8. Down stream of karasaan weir left side is sand trap construction/Right site is by pass water way

Ⅳ. Effect and future study

After construction of sand trap, sand sluices in the weir and flushing gates in the sand trap are operated every weekend.

The sediment states on the downstream of main and secondary canals were improved. More study is needed for efficient operation. Operation during dry and rainy seasons may be different and interrelation between sand sluices and sand trap could be found after intensive study.

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