EFFECT ON SEDIMENT TRAPPING & FLUSHING EFFICIENCY DUE TO SIZE VARIATION OF ORIFICES IN FLUSHING DUCT SLAB (HYDRAULIC MODEL STUDY OF RAMMAM-III HEP)

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ABSTRACT

Chocking of desilting chamber due to silt deposition results in flowing of silt laden water into the Headrace tunnel (HRT) and consequently results in erosion of turbine. Therefore, sediment trapping & flushing efficiency of the silt flushing arrangement is very important and is always established by physical model study. The paper describes results of three alternative physical model studies of desilting arrangement of Rammam-III Hydro-Electric Project (HEP) (3×40 MW), which were carried out by varying the sizes of orifices (openings) in flushing duct slab.

Rammam-III HEP, a run of river scheme, is under construction by NTPC Ltd in West Bengal, India. Hydraulic Model study of desilting chamber along with silt flushing tunnel has been carried out for assessment of sediment trapping & flushing efficiency of the silt flushing arrangement at Irrigation Research Institute Roorkee, India. Studies for desilting arrangement of Rammam-III HEP has been carried out on three alternative physical model by varying the sizes of orifices in flushing duct slab. As per the results of alternative model studies corresponding to 5000 ppm sediment concentration overall sediment trapping efficiency of desilting chamber increased from 75.5% to 84.3% from initial to final alternative. Further, for particles size greater than 0.2mm it increased from 81.6% to 90.2% due to increase in sizes of orifices of flushing duct slab with a increase in total area of all orifices from 0.298m^2 to 0.374m2 i.e. about 25.5%.

Sediment flushing efficiency also increased from 28.1% to 62.1% that too with a reduced flushing discharge i.e. from 2.345 cumec to 2.0 cumec (14.21% to 12.12% of 16.5 cumec total discharge passing through one desilting chamber). Silt deposition between orifices observed in models and worked out to proto reduced from about 1.0m to 0.6m. Choking of orifices observed in the models also reduced from 13 nos. to just one from the initial to final model. Further, no significant silt deposition was observed inside the flushing duct in the final model. However, in view of increased sizes of orifices, flushing discharge is to be controlled with partial gate opening installed on each branch silt flushing tunnel.

Keywords *: Desilting Chamber, Sediment trapping, Sediment flushing, Hydro*

1. INTRODUCTION

To decide size of desilting basin/ chamber, firstly size of the particles for removal is decided as intensity of erosion is directly proportional to the size of the particles. Particle sizes above 0.2 to 0.25 mm are extremely harmful. Further, large size sediment particles (above 0.25 mm) even with hardness lesser than 5 on Moh's scale cause wear. Similarly, fine silt even with size less than 0.05 to 0.1 mm, containing quartz wears out the underwater parts. The fine sediment can also be dangerous if the turbine is operating under high head. Sharp and angular particles cause more erosion in comparison to rounded ones. The intensity of the erosion is also directly proportional to the hardness of particles (irrespective of sizes). Those particles have a hardness value above 5 in Moh's scale are considered harmful. Incidentally, most of the Himalayan sediment contains more than 70% Quartz particles on average with hardness value 7 in Moh's scale. Hence, hardness of the particle is a highly influencing factor in the erosion rate. Therefore, design and functioning of silt flushing arrangement is important so that wear of underwater parts of machines could be avoided.

The rocks contain about 60% Quartz particles as per the petrographic studies carried out on the samples collected from the project location of Rammam-III HEP. The Rammam river water contains maximum up to 25% suspended particle of size 0.2 mm and above as per river water analysis.

The Rammam-III HEP involves construction of 122.5m long & 23m high Barrage structure with top EL 905.0m across river Rammam with four nos. spillways of 11.0m width & 7.0m height opening each with crest at EL 884.0m including a sluice bay of 11.0 m width & 7.0m height opening with its crest at EL 882.0m. The intake structure is located on right bank. A 3.5m dia horseshoe shape & 8.2 km long HRT is under construction for conveyance of water from intake to turbine. A deep seated surface power house with total capacity of 120 MW (3×40 MW) on the right bank of the river Rammam is envisaged for utilizing a gross head of 499.33m and net head of 473.00m.

2. DESILTING ARRANGEMENT

2.1 Desilting Chambers

Two desilting chambers 140.0 m long are to be constructed for removal of sediments particles of size coarser than 0.20mm. An 11.925m long inlet transition has been provided for increase in area of desilting chamber and size of desilting chamber worked out analytically to achieve a flow through velocity of about 0.22 m/sec corresponding to average discharge of 30.7 cumec in desilting chamber and fall velocity of the undesirable particles for removal of more than 90% of particles coarser than 0.2mm. As per the camp curve, sediment removal efficiency of about 95% is obtained. A 7.5m long transition on outlet of desilting chamber has also been provided. At the bottom of each desilting chamber settling trench and flushing duct are provided. A total discharge of 33.0 cumec is proposed to divert through power intakes. Out of which 28.31 cumec will be utilized for power generation and the balance 4.69 cumec for sediment flushing.

Design of inlet transition is carried out in such way to achieve the followings as mentioned in CWPRS Guidelines for Design of Desilting Basin (Pressure Flow)

- Adequate drop in forward velocity
- No separation of flow
- Uniform velocity distribution along horizontal plane
- Sufficiently high velocity prevailing in the transition to prevent settlement of coarse sediment on the slope of transition
- No settlement of sediment immediately downstream of transition to prevent blocking of openings connecting desilting chamber to flushing tunnel below

Generally, a flare angle of 6° to 9° and bed slope of 1V: 2H to 1V: 2.3H is considered for initial design.

Figure 1, Figure 2 and Figure 3 shows plan and sections of desilting chamber.

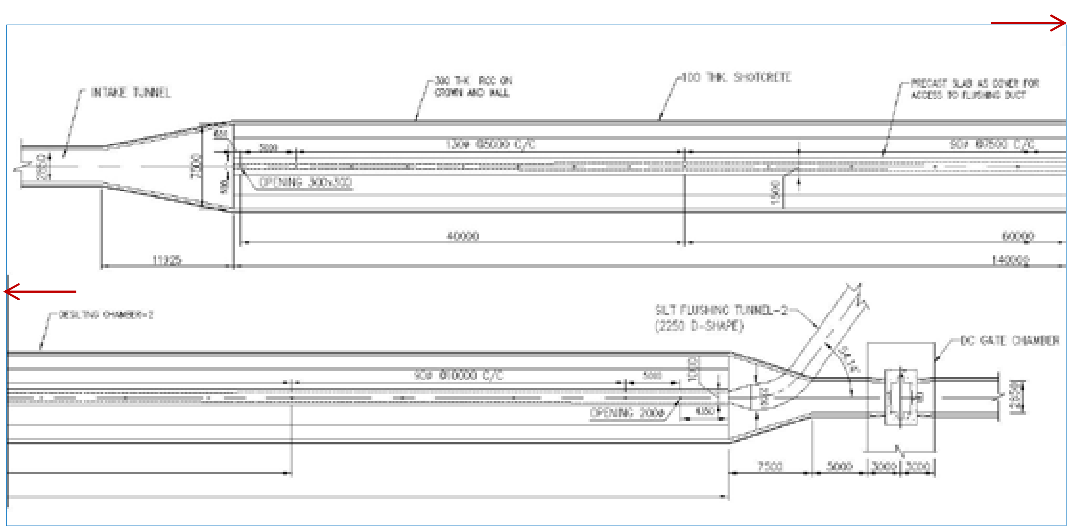


Fig. 1 : Desilting Chamber Plan with initial size & spacing of orifice in flushing duct slab

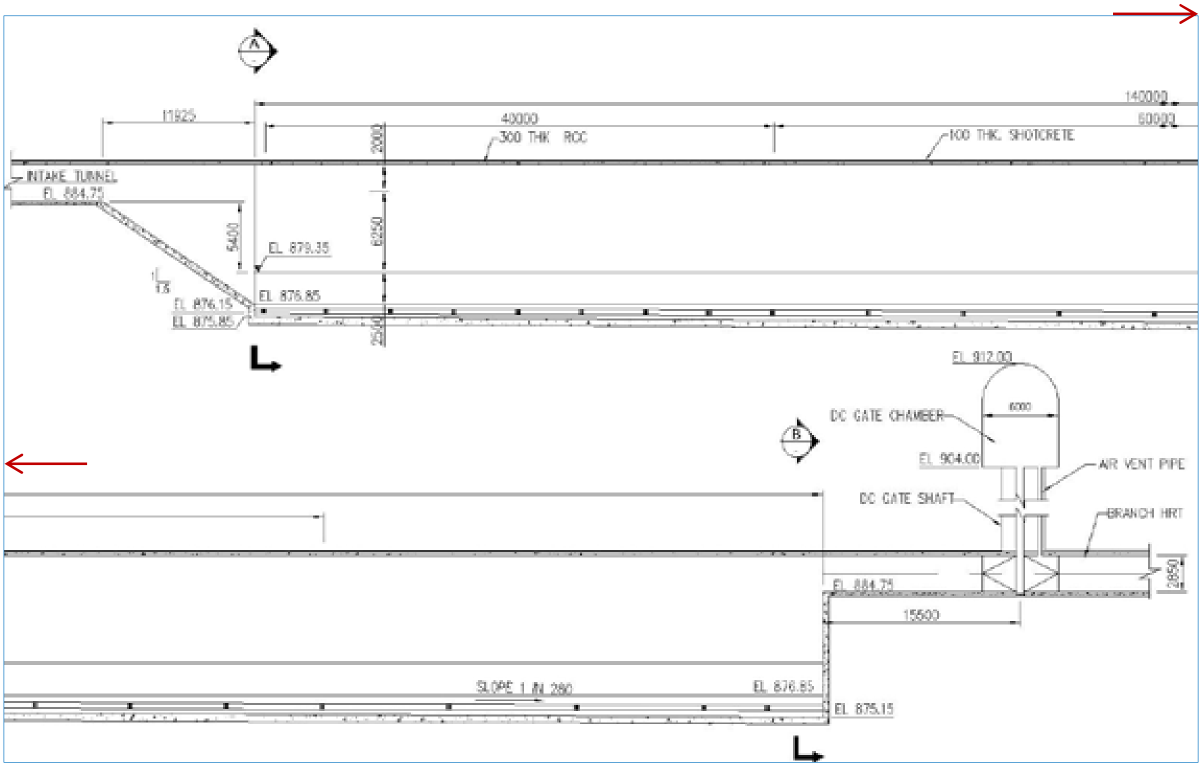


Fig. 2 : Longitudinal Section through Desilting Chamber with Settling Trench & Flushing Duct

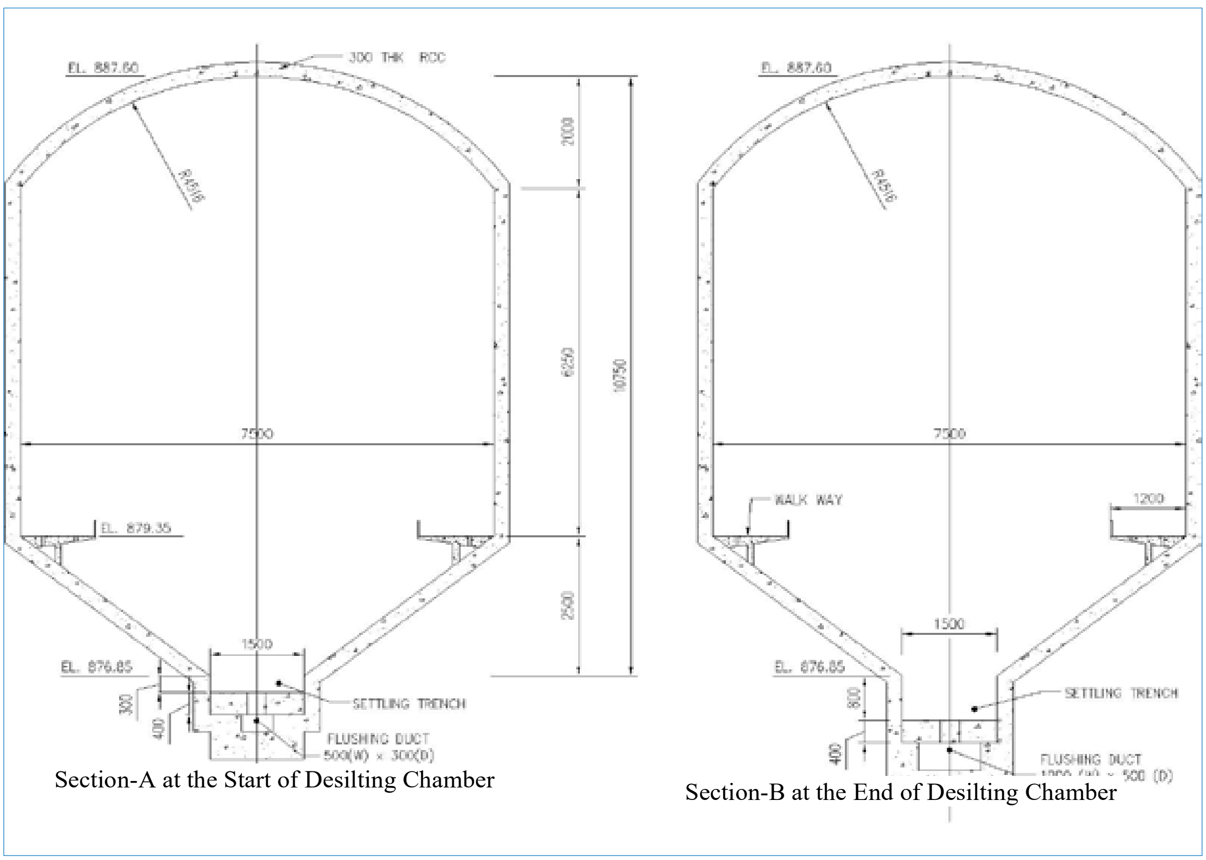


Fig. 3 : Cross Section of Desilting Chamber with Settling Trench & Flushing Duct

2.2 Silt Flushing Tunnel and Channel

Silt laden water from each flushing duct (with size 1.0m x 0.5m at the end of desilting chamber) will pass further through 2.25 D-shape branch silt flushing tunnel (SFT). Gate of size 1.0m (H) and 2.25m (W) has been envisaged for installation on each branch SFT for regulated flushing discharge of 2.345 cumec from each desilting chamber with partial gate opening. In view of this, there will be pressure flow up to gate location. Therefore, analytically flow velocity, corresponding to flushing discharge envisaged for each chamber, in the flushing duct at the end of desilting chamber will be about 4.69 m/sec and in portion of branch SFT (between flushing duct and upstream of gate) velocity will be of the order of 0.51 m/sec due to larger cross-sectional area of branch SFT adopted in view of construction difficulties. Further, gate opening, required for releasing envisaged flushing discharge, works out about 0.28m corresponding to head i.e. difference between overt level of branch SFT and gate sill level using empirical formula given by Swamee (1992) for free flow orifice. Accordingly, exit velocity downstream of gate works out to be of the order of 3.70 m/sec. Thereafter, flow in branch SFT will be open channel flow with a velocity of about velocity 4.60 m/sec with slope of 1 in 8.27. Two branch SFT i.e. one form each desilting chamber are merged in to single main SFT of 2.25 D-shape and about 110m long. The velocity in main SFT works out to be of the order of 6.5m/sec. Thereafter, after a drop of about 4.5m/sec, water through an open channel (2.25m wide & 1.75m depth with invert EL. at 841.0m) will be discharged into the river. Figure 4 & Figure 5 shows the layout plan & section of silt flushing tunnels and channel respectively.

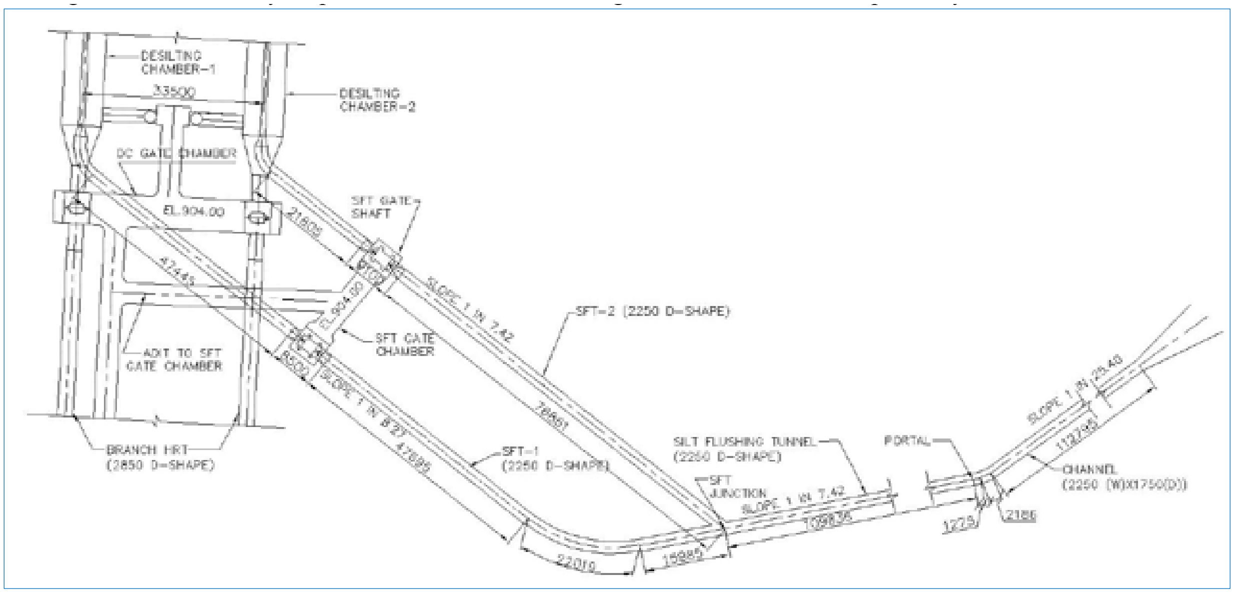


Fig. 4 : Silt Flushing Tunnel and Channel Layout Plan

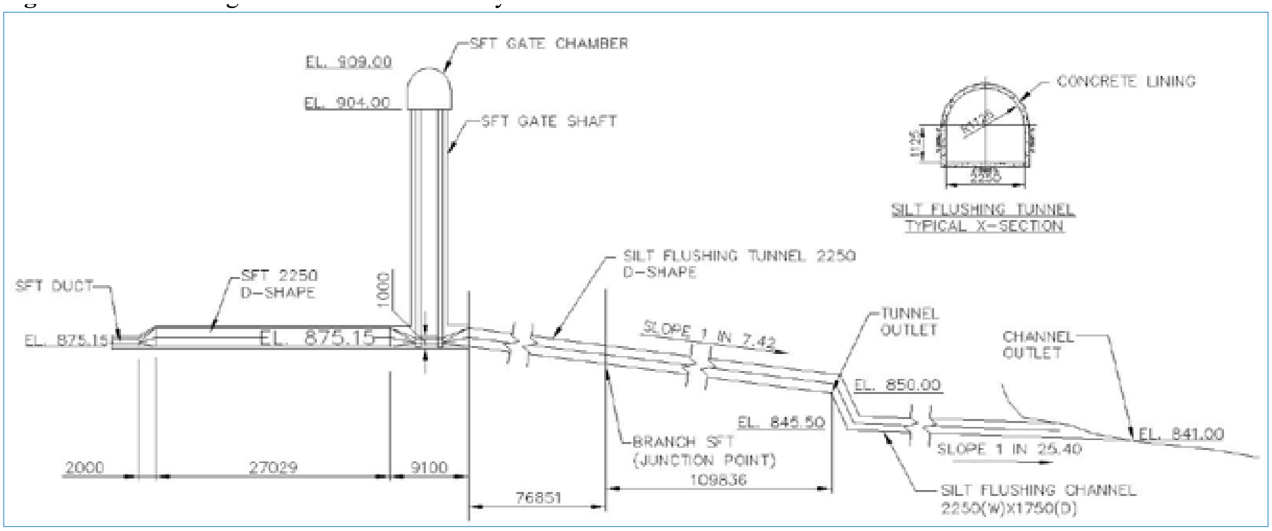


Fig. 5 : Section along Silt Flushing Tunnel and Channel

3. MODEL STUDY

Hydraulic model studies for Rammam-III HEP were carried out on a 1:7.5 scale geometrically similar model constructed for one of the desilting chambers as per the sizes shown in Figure-1, Figure-2 & Figure-3. The construction of model also includes part of intake tunnel and a suitable reach of HRT for observing concentration of silt in the HRT after removal of sediments in desilting chamber. After flushing duct, branch SFT has also been included in the model up to gate including transitions and some portion downstream of gate. Further, sediment size is simulated in the model on fall velocity criteria and percentage gradation of the material has been nearly matched with percentage gradation of the silt data of actual site. Sediment concentration was reduced in terms of ppm depending upon the amount of water quantity flowing in model. For carrying out initial physical hydraulic model study, preliminary size and spacing of orifices (orifice) in flushing duct slab were kept keeping in view the criteria that the first opening is required to be larger for allowing removal for higher rate of deposition and larger size of particles. However, in view of various parameters affecting the flow through these orifice (like head loss in orifice & flow characteristics in flushing duct and sediment deposition in between the orifice), therefore, there is no definite criterion for working out the size and spacing of these orifices. It has been mentioned in CWPRS Guidelines for Design of Desilting Basin (Pressure Flow) that as per experience gained from model studies for desilting basins for various projects, size of the first opening should be adequate to pass 20 to 30 % of the flushing discharge with a velocity of 3.0 m/s. The total area of the orifice can be broadly estimated for passing the remaining discharge with velocity of 3.0 m/s. Further, size of the orifice may be decreased progressively towards the downstream as sediment concentration and size of the sediment settling goes on decreasing towards downstream. The size of last opening is kept a little larger than the opening just on its upstream as smaller size of the material settling near the outlet end forms a reverse ramp at the upstream edge of the skimming weir as observed in model studies of other projects.

The sediment size is simulated in the model on fall velocity criteria and percentage gradation of the material is tried to match as per percentage gradation of the material available at the site.

3.1 Size of Orifices in Flushing Duct Slab in Model-1, Model-2 & Model-3

Table 1 : Details of orifices

Orifice No.	Size of Orifices in mm			Distance
	Model-1	Model-2	Model-3	
1	300 x 300	300 x 300	300 x 300	650 mm from the start
2 to 9	130 ϕ	130 ϕ	130 ϕ	@ 5000 mm c/c
10 to 17	90 ϕ	120 ϕ	130 ϕ	@ 7500 mm c/c
18 to 20	90 ϕ	105 ϕ	130 ϕ	@ 10000 mm c/c
21	200 ϕ	200 ϕ	200 ϕ	@ 5000 mm c/c

As mentioned in the above table, in all the various alternatives of the models total 21 nos. of orifices were provided. Size of first orifice i.e. 300 x 300mm & last orifice 200mm dia was kept same in all models and they were located 650mm from upstream end of desilting chamber and 4350mm from downstream end of chamber. Further, sizes of openings from 2 to 9 were also kept same in all models located at @ 5000mm c/c form the first opening. Sizes of orifice from 10 to 17, located @ 7500mm c/c interval from the 9th opening onward were increased from 90mm to 120mm dia and 120mm to 130mm dia in alternative Model from 1 to 2 and 2 to 3 respectively. Orifices sizes of 18 to 20 located at @ 10000mm c/c from the 17th opening onward were also increased from 90mm to 105mm dia and 105mm to 130mm dia in alternative Model from 1 to 2 and 2 to 3 respectively. Thus, total flow area in various alternatives Models from 1 to 3 was kept 0.30m2, 0.35 m^2 and 0.37 m^2 respectively.

3.2 Observations of various Alternatives Hydraulic Models

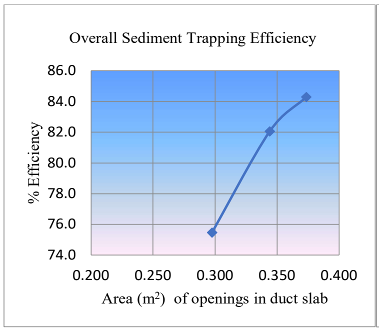
Physical hydraulic model studies were carried out on three alternatives models only by changing sizes of orifices in the slab of flushing duct at the bottom of desilting chamber without any change in other parameters including operating conditions except reduction in flushing discharge from 2.345 cumec to 2.0 cumec in second and third alternatives. Each model was run for about one hour of model running (corresponding to 2.45 hours in proto). However, water samples were collected from the outflows of the HRT and flushing tunnel after about 30 minutes from the start of sediment feeding. The observations were made in the various alternative models corresponding to 5000 ppm sediment concentration after model run by opening the panels. Conditions of orifices in flushing duct slab after model run were found as under:

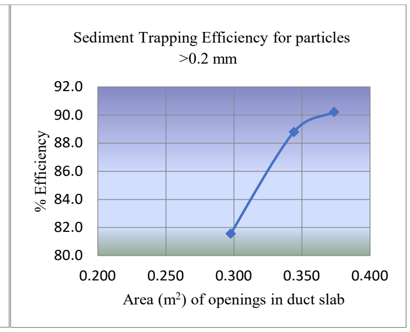
Model 1 : Orifices Nos. from 8 to 20 chocked (13 Nos.), whereas orifices Nos. from 1 to 7 & 21 opened

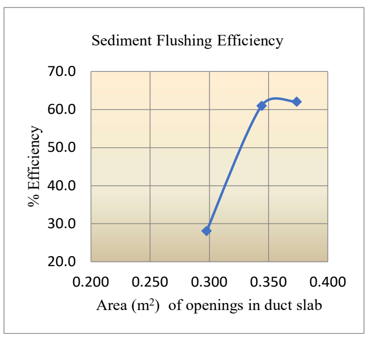
Model 2 : Orifices Nos. 11 & 18 chocked (2 Nos.), whereas all other 19 orifices opened

Model 3 : Orifices No. 20 chocked (1 No.), whereas all other 20 orifices opened

After running of all alternative's models, silt concentration in water flowing to HRT was of the order of 1430, 1021 & 894 ppm whereas in SFT it was found to be 7453, 20645 & 21590 ppm respectively in Models 1 to 3. Overall silt trapping efficiency improved progressively with increase in size of orifices 75.5% to 82.1% and 82.1% to 84.3% whereas for particles size coarser than 0.2mm from 81.6% to 88.8 & 90.2% from alternative Model 1 to 2 and 2 to 3. Sediment concentration of particles coarser than 0.2mm 800 ppm in intake reduced progressively from 172 to 102 & 102 to 89 ppm in final model. Silt flushing efficiency in the three alternatives model improved from 28.1% to 61% and 61% to 62.1% from alternative Model 1 to 2 and 2 to 3 as shown below in the graphs.







Silt deposition also reduced in the model on upstream transition slope, u/s portion of chamber and near orifices as shown in the following photographs. Also, in final model no silt deposition was found in flushing duct.

Model-1 Model-2 Model-3

Photographs : Showing Silt Deposition in Chamber in various alternative models

4. CONCLUSIONS

It can be seen from results of various alternatives Models (with varying sizes of orifices) that better sediment trapping efficiency as well as flushing efficiency may be obtained by providing larger size of orifices, in comparison to the sizes of orifices arrived conventionally i.e., for controlling flushing discharge through these, in flushing duct slabs and that too with reduced envisaged flushing discharge. However, flushing discharge is to be controlled with control gates installed at the flushing outlet tunnels/ channels rather than controlling through orifices in flushing duct slab. Further, due to better sediment flushing efficiency, silt deposition in desilting chamber, a serious problem in hydropower projects in Himalayan region, is also reduced. However, hydraulic model study, with reduced spacing of orifices and equal sizes except first & last as per Model-3, may also be carried out to see the effect of spacing of orifices also.

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