MODEL STUDY FOR DETERMINATION OF EFFICIENCY OF A TYPICAL SILT EJECTOR

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ABSTRACT

After construction of a barrage in the main river Teesta in West Bengal, the off taking channel from one of its bank was designed to carry water and augment the discharge of a secondary river Mahananda. The discharge of the main river was heavily laden with silt. To control the quantity of silt, a Silt Ejector was proposed to be constructed in Teesta Mahananda Link Canal for getting silt-free water for irrigation. The design discharge of the canal upstream and downstream of the Silt Ejector was 438.91 cumecs and 382.28 cumecs respectively and the discharge through the Silt-Ejector was 56.63 cumecs. A geometrically similar model of scale 1:36 was constructed in Indoor Hydraulics Laboratory on the basis of design drawings. The model incorporated about 500 m long stretch, about 400 m upstream and about 100 m downstream of the Silt Ejector. In the model, the Silt-Ejector structure was made of thin Perspex sheets. The model was run with the design discharge and with discharges 70%, 50% and 30% of the design discharge. Four nos. of gauges were installed in the model at 360 m upstream, 75 m upstream, 22 m downstream and 100 m downstream of the Silt Ejector. Another gauge was installed in the escape channel. Velocity observations were taken at 324 m upstream, near the upstream face of the Silt Ejector and 80 m downstream point of the Silt Ejector. The observed model data were validated with respect to prototype data. Mustard seeds were used as silt-charge. The entire quantity of mustard seeds passed through the Silt Ejector into the Escape Channel for all discharges, except that of the 30% design discharge. This indicated that the efficiency of the Silt Ejector was good and satisfactory except for low discharge of the order of 30% of design discharge. No undesirable flow features were noticed at the entry of the Ejector.

Keywords *: Silt Ejector, Escape Channel, Geometrically Similar Model, Sub-tunnel*

1.0 INTRODUCTION

Normally Silt Excluder is used for exclusion of silt. But it was not feasible for Teesta Barrage under prevailing field condition. As such, Silt Ejector was preferred and it was first of its kind in West Bengal. To control the quantity of silt, a silt ejector was proposed to be constructed in the Teesta Mahananda Link Canal. The design discharge of the canal upstream and downstream of the Silt Ejector was 438.91 cumecs and 382.28 cumecs respectively and the discharge through the Silt-Ejector was 56.63 cumecs. The discharge passing through the Silt Ejector was to fall on the main river downstream of the barrage. It was proposed by the authorities to carry out hydraulic model experiments to study the hydraulic performance of the Silt Ejector. The problem was referred to River Research Institute, West Bengal for model study. The model study was performed and necessary report was submitted. After detailed study, it can be said that the above report is still valid today with some modifications.

2.0 LITERATURE STUDY

Marala Ravi (MR) Link Canal, Sialkot, Pakistan is a big canal which originates from River Chenab at Marala Barrage. It faces severe problem of silt deposition on the bed of canal due to high silts and sediment discharge entering into the canal. The improvement measures were identified separately for Marala Barrage and MR Link canal. Provision of Silt Ejector was studied in a scale model by Irrigation Research Institute [1]. Chohan [2] carried out a comprehensive review of the problems in MR Link canal. Ahmad et al.[3] discussed different sediment exclusion methods and devices at the intake of canals. It was established by various experiments that an off take from a straight channel would draw greater proportion in its water than its due share depending on the discharge extraction ratio and the angle of twist. The excluders were tested for full supply discharge in power tunnel and the river discharge equal to 100,000 cusecs. It was envisaged that an excluder of ejector type or vortex excluder would be efficient for exclusion of coarse silt from power tunnel. King [4] reported that silt carrying capacity of fluid at any point depended on difference in velocity of filaments of flow just above and below the point. A small obstruction over the bed throws up the silt which fall backs and is thrown up again. This motion of silt particle is terms as siltation and depends on the bed roughness, velocity and particle size. Raju and Kothyari [5] explained the design principles of two kinds of sediment withdrawal methods namely settling basins and vortex chambers. They accomplished that the vortex chamber with high efficiency as compared to settling basin would require small flushing discharge. The negative aspect of vortex chamber is that it is suitable for small channels only.

3.0 JUSTIFICATION FOR HYDRAULIC MODEL STUDY

There are many unknown factors in the design of silt ejector such as the capacity of the silting basin in the approach channel, layout of the sub-tunnels and main tunnels, flushing velocity for the particular characteristics of the sediment to be ejected, and flow pattern of the bottom layers of the discharge, etc. As such it is essential that the layout based on the theoretical design be checked by model studies to ascertain the efficiency of the silt ejector.

4.0 HYDRAULIC MODEL

The model was constructed inside the Indoor Hydraulics Laboratory and the model was constructed on the basis of design drawings. A geometrically similar model of scale 1: 36 was constructed. The model incorporated about 500 metres long stretch of the Link Canal, the reach covered a length of about 400 metres upstream and about 100 metres downstream of the Silt Ejector. Due to shortage of space, the Escape Channel was reproduced for a length of about 30 metres only. The water was supplied to the model through a re-circulating water supply system. The required discharge was measured over a rectangular sharp crested weir and fed into the canal through a stilling basin. Silt traps were provided on the downstream of the canal and also at the downstream ends of the Escape Channel. Four nos. of gauges (shown in Fig. 1 and 2) were provided at 360 m upstream (G1), 75 m upstream (G2), 22 m downstream (G3) and 100 m downstream (G4) of the proposed Silt Ejector. One gauge G5 was provided at a place about 12 m from the start of the Escape Channel, about 22 m from the exit of the Silt ejector tunnel. In the model, the Silt Ejector structure was made of thin Perspex sheets.

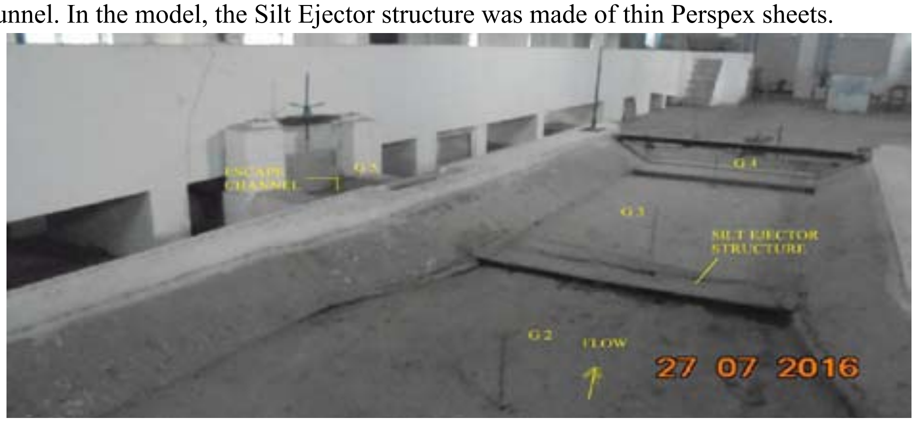

Fig 1 : Photograph of Silt Ejector Model

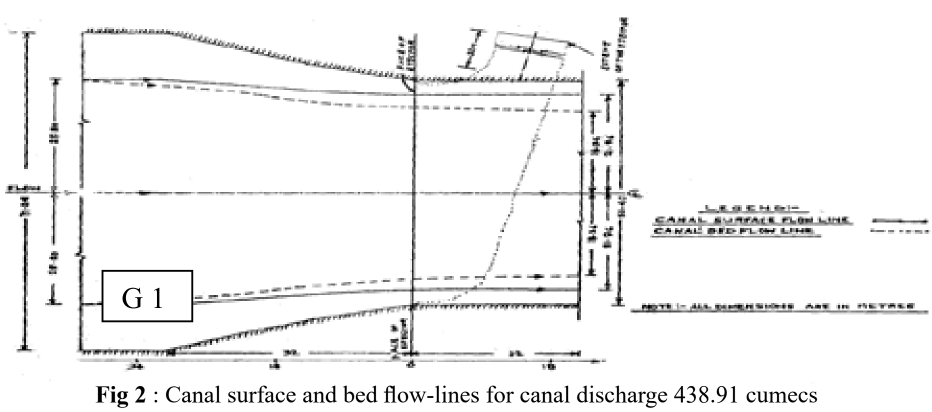

Fig 2 : Canal surface and bed flow-lines for canal discharge 438.91 cumecs

4.1 Observations

A discharge equivalent to 438.91 cumecs was passed through the model. The downstream canal gauge G4 was maintained at the design value of 115.588 m with the help of the downstream control gate. The gauge G5 of the Escape Channel was maintained at the design value of 112.174 m by controlling the downstream gate of the Escape Channel. Gauge readings of G1, G2 and G3 were observed. Model gauge readings were 113.808, 113.698 and 113.643 metres whereas the computed gauge readings from the design data supplied were 113.731, 113.631 and 113.610 metres respectively. Both surface flow lines and bed flow lines of the canal were taken from about 45 m upstream of Silt Ejector to 22 m downstream of the sub-tunnel entrance. These are presented in Fig 2. No undesirable flow features were noticed at the entry of the Silt Ejector. No eddies or vortices were observed. The flow was tranquil and smooth in all cases. Velocity observations were taken at 324 m upstream point near G1, near the upstream face of the Silt Ejector, 80 m downstream point of the Silt Ejector near G4. The velocities are presented in Tables 1, 2 and 3. The average velocity of the whole section near G1 comes to about 2.088 m / sec whereas the design value is 2.013 m / sec. The verticals of velocity observations are presented in Fig. 3 and Fig. 4. Plan of a typical Silt Ejector is shown in Fig. 5.

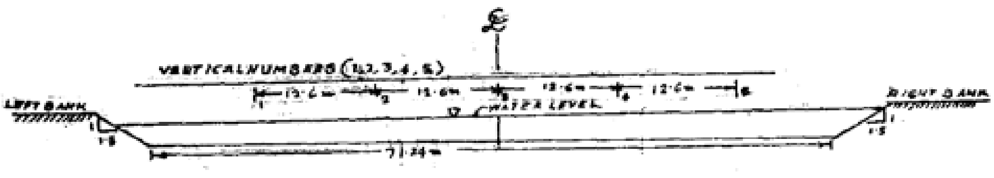

Fig 3 : Canal cross-section at 324 metre upstream of Silt Ejector

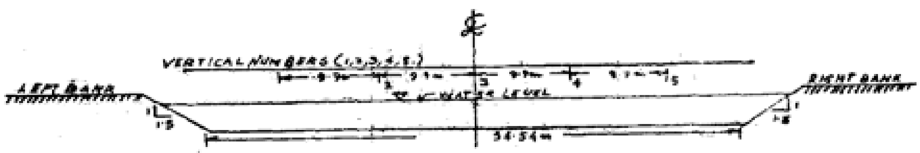

Fig 4 : Canal cross-section at 80 metre downstream of the Silt Ejector

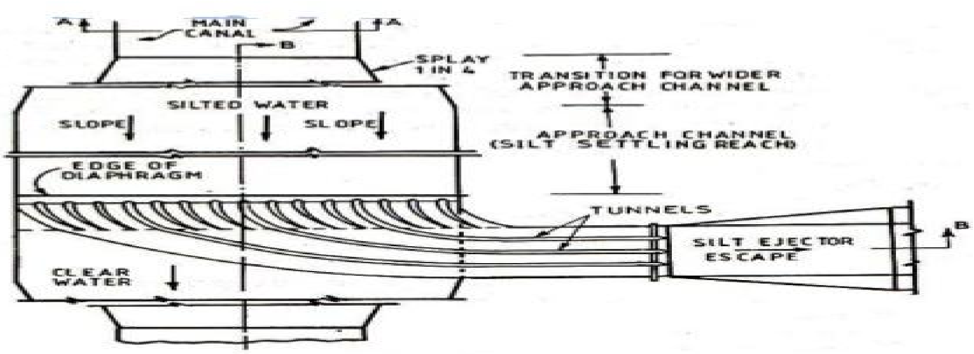

Fig 5 : Plan of a Silt Ejector (Source : Google Search)

Table 1 : Velocity distribution in the canal at 324 m upstream of the Silt Ejector with design discharge 438.91 cumecs

Velocity in m / sec	Vertical numbers from Left to Right (vide Fig. 3)					Average velocity in m / sec
	1	2	3	4	5	
Bed velocity	1.681	1.879	1.879	1.879	1.879	1.839
Velocity at 0.6 depth	2.059	2.224	2.143	1.783	2.143	2.07
Surface velocity	2.377	2.521	2.45	1.971	2.45	2.354
Mean velocity						2.088

Table 2 : Velocity distribution in the canal at 80 m downstream of the Silt Ejector with design discharge 438.91 cumecs

Velocity in m / sec	**Vertical numbers from Left to Right (vide Fig. 4)**					**Average velocity in m / sec**
	1	**2**	**3**	**4**	**5**	
Bed velocity	1.681	1.681	1.681	1.681	1.681	1.681
Velocity at 0.6 depth	1.879	1.971	1.879	1.879	1.879	1.897
Surface velocity	2.224	2.224	2.224	2.143	2.143	2.192
Mean velocity						1.923

Table 3 : Observation of velocities at the upstream face of the Silt Ejector Sub-tunnels with design discharge of 438.91 cumecs in the canal upstream of the Silt Ejector (Velocities were observed at 3.6 m upstream of the face of the Silt Ejector)

Velocity in m / sec	**Sub-tunnel numbers (from Left to Right)**												**Average velocity in m/ sec**
	1	2	3	4	5	6	7	8	9	10	11	12	
Bed velocity	1.57	1.46	1.57	1.46	1.33	1.33	1.46	1.33	1.33	1.33	1.46	1.46	1.424
Velocity at 0.6 depth	1.78	1.78	1.78	1.68	1.68	1.78	1.88	1.78	1.68	1.78	1.68	1.78	1.755
Surface velocity	1.97	1.97	1.97	1.97	1.88	1.97	1.97	1.97	1.88	1.88	1.88	1.97	1.94
Mean velocity													1.706

4.2 Escape Discharge

The discharge passing through the Silt Ejector into the Escape channel was measured volumetrically and they reasonably agreed with the design discharge. The measured model discharge corresponds to about 61.71 cumecs as against the design discharge of 56.63 cumecs. In order to measure the discharges passing through the individual tunnels separately, water was allowed to flow through each tunnel closing the other three tunnels at the end. Due to this closure, there was a rise of water level in the main canal model. However it indicates that with a particular canal water level, the discharge through each of the tunnels was reasonably the same.

4.3 Silt Movement

The bed load transport was simulated in the model by injection of mustard seeds. Mustard seeds were injected at a section 380 metres upstream of the Silt Ejector. The entire quantity of the mustard seeds passed through the Silt Ejector into the Escape Channel. The same experiments were repeated with plastic balls which rolled along the bed and the same result was observed. The mechanism of suspended sediment transport and deposition was not included in the present study.

4.4 Model run with discharges lower than design discharge

Considering the fact that for a part of the year, the canal may have to run with discharges lower than the design discharge, it would be of interest to know the discharge passing through the Silt Ejector and the indication of bed load movement. The model was run with discharges 70%, 50% and 30% of the design discharge (438.91 cumecs) which were discharges of 307.24 cumecs, 219.46 cumecs and 131.67 cumecs respectively. The velocities observed at 324 m upstream and 80 m downstream of the Silt Ejector at 0.6 depths are presented in Table 4 and 5. The velocities observed at the face of the sub-tunnels are presented in Table 6, 7 and 8. The discharges passing through the Silt Ejector tunnels for discharges 70%, 50% and 30% of the design discharge were about 46.24 cumecs, 33.94 cumecs and 18.54 cumecs respectively. Mustard seeds were injected as bed materials and in all cases except very low discharge of the order of 30% of the design discharge, entire quantity of the injected materials passed out of the Silt Ejector Sub-tunnels. In case of 30% design discharge, the injected materials were observed to get accumulated in front of the Silt Ejector sub-tunnels. Even if they were pushed inside the sub-tunnels, they were not easily moving out. This phenomenon may be attributed to low average bed velocity in front of the sub-tunnels. The flow was smooth in all cases.

Table 4 : Velocity at 0.6 depth in the canal at 324 m upstream of the Silt Ejector with different canal discharges

Discharge in cumecs	Vertical numbers from Left to Right (vide Fig. 3)					Average velocity in m / sec
	1	2	3	4	5	
307.24 (70% of design discharge)	1.97	2.057	2.057	2.057	1.97	2.022
219.46 (50% of design discharge)	1.878	1.878	1.97	1.97	1.878	1.915
131.67 (30% of design discharge)	1.97	1.878	1.782	1.782	1.571	1.797

Table 5 : Velocity at 0.6 depth in the canal at 80 m downstream of the Silt Ejector with different canal discharges

Discharge in cumecs	Vertical numbers from Left to Right (vide Fig. 4)					Average velocity in m / sec
	1	2	3	4	5	
307.24 (70% of design discharge)	1.878	2.057	2.057	1.97	1.878	1.968
219.46 (50% of design discharge)	1.878	1.878	1.782	1.782	1.571	1.778
131.67 (30% of design discharge)	1.571	1.571	1.571	1.571	1.571	1.571

Table 6 : Velocities at the upstream face of the Silt Ejector Sub-tunnels with discharge 307.24 cumecs (70% of design discharge) in the canal upstream of the Silt Ejector (Velocities were observed at 3.6 m upstream of the face of the Silt Ejector)

Velocity in m / sec	Sub-tunnel numbers (from Left to Right)												Average velocity in m/sec
	1	2	3	4	5	6	7	8	9	10	11	12	
Bed velocity	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.11	1.11	1.33	1.33	1.33	1.12
Velocity at 0.6 depth	1.78	1.78	1.78	1.68	1.68	1.78	1.88	1.78	1.68	1.78	1.68	1.78	1.76
Surface velocity	1.97	1.97	1.97	1.97	1.88	1.97	1.97	1.97	1.88	1.88	1.88	1.97	1.94
Mean velocity													1.61

Table 7 : Velocities at the upstream face of the Silt Ejector Sub-tunnels with discharge 219.48 cumecs (50% of design discharge) in the canal upstream of the Silt Ejector (Velocities were observed at 3.6 m upstream of the face of the Silt Ejector)

Velocity in m / sec	Sub-tunnel numbers (from Left to Right)												Average velocity in m/sec
	1	2	3	4	5	6	7	8	9	10	11	12	
Bed velocity	1.19	1.03	1.11	1.03	1.03	1.03	1.03	0.94	0.94	0.94	0.94	1.03	1.02
Velocity at 0.6 depth	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.11	1.11	1.11	1.11	1.11	1.16
Surface velocity	1.33	1.33	1.33	1.26	1.33	1.33	1.26	1.26	1.26	1.26	1.26	1.26	1.29
Mean velocity													1.16

Table 8 : Velocities at the upstream face of the Silt Ejector Sub-tunnels with discharge 131.67 cumecs (30% of design discharge) in the canal upstream of the Silt Ejector (Velocities were observed at 3.6 m upstream of the face of the Silt Ejector)

Velocity in m / sec	Sub-tunnel numbers (from Left to Right)												Average velocity in m/sec
	1	2	3	4	5	6	7	8	9	10	11	12	
Bed velocity	1.11	1.03	1.03	1.03	1.03	1.03	1.03	0.94	0.94	0.94	0.94	0.94	1.00
Velocity at 0.6 depth	1.19	1.19	1.19	1.19	1.19	1.19	1.11	1.03	1.11	1.11	1.19	1.11	1.15
Surface velocity	1.19	1.26	1.26	1.33	1.33	1.26	1.19	1.19	1.19	1.26	1.26	1.19	1.24
Mean velocity													1.13

5.0 DISCUSSION

It was seen that the water surface slope in the canal was fairly reproduced in the model. The discharge passing through the tunnels reasonably agreed with the design discharge of 56.63 cumecs. Experiments with mustard seeds and plastic balls as bed load showed that ejection by the Silt Ejector is satisfactory in all cases except for very low discharge of the order of 30% of the design discharge. No undesirable flow features were observed at the entry of the Ejector.

6. CONCLUSIONS

The following conclusions are drawn from the present study.

(i) Efficiency of the Silt Ejector is satisfactory in all the cases except for very low discharge of the order of 30% of design discharge. The efficiency of the Silt Ejector is calculated for bed load primarily. It will also be indicative for suspended load.

(ii) The difference in water level in the canal upstream of the Silt Ejector and the outfall channel at the exit of the ejector tunnel should be sufficient to extract the desired sediment. A working head of about 1 m is generally considered satisfactory for the purpose.

(iii) The quantum of discharge to be run through sediment ejector and frequency of its operation would vary in different periods of the year depending on the sediment load carried in the canal and this may be achieved by operating regulating gates as and when required. It would be desirable to operate the gates fully open or fully closed.

(iv) A velocity of 8 ft/sec to 10 ft/sec through the tunnel is adequate to move sand size sediments.

(v) An escape discharge equal to 10 to 20 percent of the full supply discharge of the canal downstream of the ejector will be sufficient for removal of silt load. The escape channel is given a steeper slope so that the silt is discharged back to the river through the shortest route.

(vi) The height of tunnel should be 20 to 25% of the design depth of water in canal.

(vii) Normally a minimum head of at least 2.5 ft is required to operate the Silt Ejector.

(viii) During the period when sediment ejector is not required to function, it is desirable to operate the regulation gates occasionally for short periods to flush the tunnels consistent with the economy in water requirements for irrigation. Otherwise, the tunnels are likely to get choked and may require manual clearance which may be possible only during closure of the canal.

(ix) At times during the normal operation of the sediment ejector, the approach channel and / or tunnels or both may require flushing. This may be done by running the tunnels in rotation to achieve higher velocities.

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