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SEDIMENT MANAGEMENT AT TEESTA III- A CASE STUDY

B. K. Ojha
Project Director, Energy Infratech Pvt. Ltd.

ABSTRACT: Himalayan Rivers are known to carry large quantity of sediment during monsoon months and therefore its handling and management is critically important for hydro project located in Himalayan region. The silt damage to under water parts of turbines is a serious challenge and therefore the strategy has been to reduce the silt concentration in the water flowing to the Power House on one hand and also to improve on the metallurgical parameters of the turbine under water parts and make them erosion resistant, reduce damage and prolong the life of turbine. The paper describes the desilting arrangement and reservoir flushing system as well as the erosion resistant coating mechanism being adopted in Teesta-III Project especially as this Project is a high head plant. The paper also highlights the need and necessity of more and more research and innovations in this field as continuous demand of electrical energy in this carbon constrained world has once again put the hydropower as the favorite flavor of the energy planners across the globe.

I. INTRODUCTION

The Teesta – III HE Project (1200MW) is a run-of the river scheme on Teesta River in the North district of state of Sikkim. The project envisages utilizing the gross head of about 816m between Chungthang and Sangkalang village to generate 5213 MU of energy in 90% dependable year. With installed capacity of 1200MW the project happens to be the third in the series of six projects planned for construction on Teesta in the state of Sikkim. Teesta – V project of 510MW has been commissioned in 2008 by NHPC (Govt. of India Enterprise) and the project is in operation satisfactorily during the last six years. The project involves the construction of 60m high concrete face rock-fill dam to divert the Teesta water upto 175 cumecs to Power House through a 7.5m diameter and 13.8 km long head race tunnel followed by two pressure shafts of 4.0m dia feeding six units of 200MW each, run by vertical pelton type turbines under a rated net head of 778 m. The water released from the turbines is carried through a tail race tunnel to join back the Teesta River upstream of the confluence with Talungchu.

II. LAYOUT OF DAM COMPLEX

The reservoir is about 1.5km in length with the gross capacity of 508.0 hectare meters and live storage of 333 hectare meters. The river carries most of the silt load in monsoon month and the river water clear with practically no suspended sediments during non-monsoon months. Two oval shaped desilting chambers have been provided 325m downstream of power intake to remove the sediment of particle size 0.2mm and above from the discharge flowing through the desilting chamber to Power House.Since it is a small reservoir the project has the provision for flushing of deposited sediments by completely draining down to maintain the live storage capacity and managing even the exceptional cases of sediment flows. Sediments trapped and deposited within the reservoir could be flushed out if sufficient transporting velocity is generated. The flushing cum spillway tunnel of diameter 11.0m (horse shoe) with invert at EL.: 1540.0m and outlet at EL.: 1481.50m and 1344m long have been provided just by the side of the power intake at about 15mU/S of dam toe. The 7.5m dia power intake has been positioned with invert at EL.: 1549.0m by the side of flushing tunnel. Two spillway tunnel of 10.0m diameter has been constructed in the left bank about 150m& 250m U/S of dam. One of the tunnel is functioning as diversion tunnel with invert at EL.; 1537.0m and shall be converted into spillway tunnel with invert at EL.: 1555.0m after construction of dam. The invert of the other spillway tunnel is at EL.: 1572.0m. The chute spillway with two bays having radial gate of size 11MX 14m is located on the left bank for passing a maximum discharge of 3500 cumecs with invert at EL.: 1565.0m.Both bays are separated by a divide wall connected to the pier upto the flip bucket. With two spillway tunnels and chutes spillway the spillway capacity is sufficient to pass the design flood of 7000 cumecs. The layout of the dam complex is shown in fig-1.

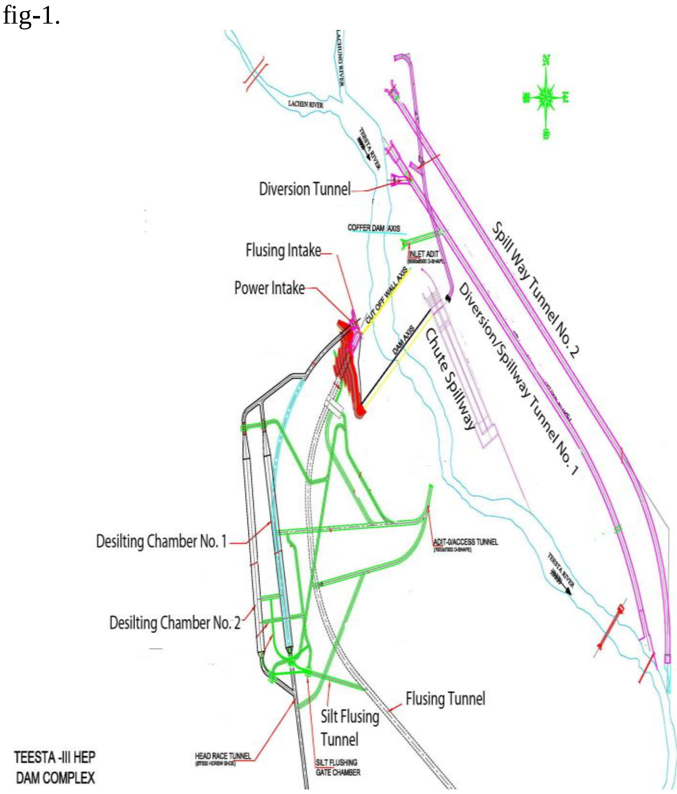


Fig-1 Dam Complex

III. SEDIMENT CHARACTERISTICS OF TEESTA RIVER

The Teesta River is one of the main Himalayan Rivers and originates from the glaciers of Sikkim in the North at an elevation of 5280m. It is a flashy mountain river and carries boulders and considerable amount of silt in monsoon month. The river flows in very steep gradient of 1 in 20 upto confluence with Lachung and Chungthang. The catchment area of Teesta above the proposed dam site is about 2787sq.km of which about 70 percent is snow bound and mostly comprising high mountains. The total area under glacier cover is estimated to about 425 sq.km. The catchment of teesta river basin is characterized by steep to very steep slopes, more than 52% of basin lies in slope category of 27° and more than 10° is either rocky cliffs or are escarpments i.e. 65° and above slope class. The rocks of this area belong to the Chungthang series (mainly calc silicate rocks, biotite schist, gneiss and quartzite) and Darjeeling series of the Kanchenjunga group comprising well jointed Augen gneiss and streaky gneiss. Rains are received mainly in the lower part of catchment below EL 4570m with annual average rainfall at dam site varying between 1600mm to 3000mm. Snowfall is quite high during December to March and then melting starts and continues up to Sept/October synchronizing with monsoon months of May to Sept. The basin is characterized by frequent occurrences of extreme meteorological events during monsoon months leading to slope transformation, accompanied with gravitation, slope wash and linear erosion under fluvo-glacial environment in North Sikkim and are mainly responsible for large quantities of silt and aggradations material which gets deposited in river channel. The high rainfall (about 2500mm) over the steeper slopes initiate runoff and subsequently the soil erosion, slope failures and slides. Large slope areas are glacial (morainic) in nature. The water sheds in the upper part of basin contributes substantial quantity of silt. The movements of glaciers over their beds reduce the rock surface to rock flour by their frictional activity. The rock flour after mixing with melt water forms the glacial milk which ultimately get transformed in to thin mud during peak melt discharge. The river discharge is high during the monsoon months and carries large quantities of sediments as runoff. Apart from weathering and erosion, other factors like deforestation, construction activities in the upstream area and the human activities also contribute to the sediment load in the river. Usually high sediment load has been observed whenever the rainfall intensity is high. The average sediment load including bed load has been estimated to be about 1.2Mcum. The combined volume of suspended coarse sediments and bed sediments has been taken on an average as 0.6 M cum. The reservoir length is only about 1.2km from dam and the river having steep gradient and therefore even large size sediments/boulders will come into the reservoir. As the power station is planned to run for 24 hours during the monsoon season, the suspended silt load will be drawn into the water conductor system and therefore if silt concentration is not reduced substantially the hard silt particles mainly quartz being transported through the silt laden water, could damage the surface of the underwater parts of the turbine. Therefore the strategy is two pronged i.e. to reduce the concentration of silt content of the water discharging into HRT and also have right kind of materials for turbine parts to have maximum erosion resistance. This project being a very high head scheme, it is essential that silt management is given due attention. The gradation analysis of suspended sediments indicate that about 40% of silt particles are more than 2mm and above (coarse) 20% is between 2mm and 0.75mm (five) and 40% are smaller than 0.075mm. The gradation curve of the suspended particles at Chungthang dam site is indicated in fig.-2.

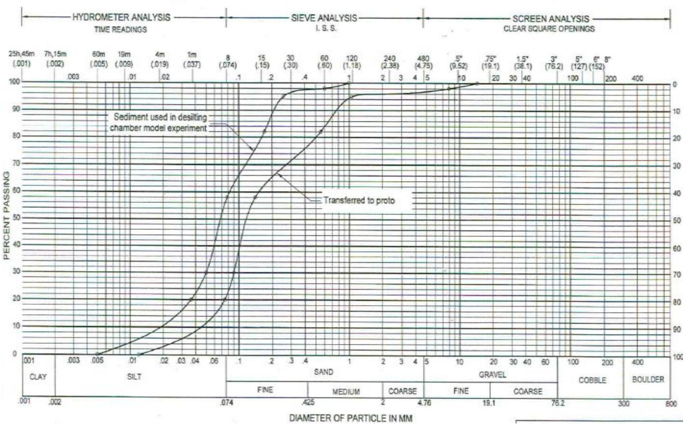


Fig-2

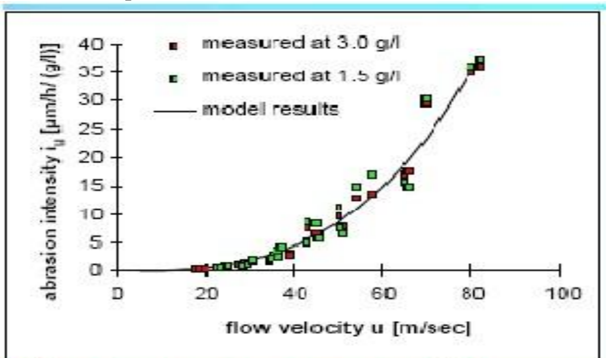
The petrography analysis of the suspended silt samples of dam site has the mineralogical composition as mentioned in table 1.

Table-1: MINERALOGICAL COMPOSITION %.

Sediment Fraction (Micron)	Quartz	Felspar	Micas		Pyroxene	Calcarem Material	Iron Oxide	Clay Minerals	Coal Vegetative Matter
			Muscovite	Biotile	Amphibole				
> 150	80.12	2.34	1.16	1.06	12.43	-	1.44	-	1.45
355-500	78.23	2.75	0.98	1.27	14.56	-	1.09	-	1.12
250-355	80.43	1.99	1.23	0.99	13.37	0.98	1	-	-
150-250	79.76	0.86	1.88	1.95	11.9	1.14	1.46	1.05	-
75-150	77.92	1.27	2.05	1.98	10.44	1.72	1.95	2.66	-
< 75	77.54	2.52	1.99	1.88	9.12	1.95	1.53	3.47	-

IV. REQUIMENT OF SILT REMOVAL FOR HYDRO TURBINE

The Electro-mechanical equipment including turbine components are being supplied by M/s Andritz Hydro. The silt erosion in under water parts of the turbine and repair and replacement of runner and nozzles etc. are the regular feature in hydro projects. The damages take place in underwater parts like runner, buckets, guide vanes, nozzles, surface liners of turbine top cover and bottom ring etc. The damages take place in the form of erosive wear. The material removal in such a process takes place due to the particles impacting as well rolling along the surface carried by water, on the turbine component surface. The process is governed by the hardness ratio of the particles and the target, microstructure of the target, the impact angle, the kinetic energy of the particles and water flow conditions on the surface of the components. As damage starts, turbulence in the assembly and the problem of erosion gets compounded. The excessive pressure of water jet may cause distortion in the profile causing turbulence and rapid damage of underwater parts. The damage becomes so severe and material loss becomes so much so that bucket profile gets disfigured..The erosion by hard silt particles occurs by formation of the deep and wide grooves, known as ploughs containing lips on the metal surface. These lips, as the erosion continues, become brittle and are detached from the grooves and flow away with the water current causing continuous loss of the material. It is therefore essential that the blade and runner bucket is made from material possessing high strength and fine grain size. The rate of erosion mainly depends on the material used for under water parts; water velocity and characteristics of silt i.e. size, shape, hardness and concentration.



Abrasion increases exponentially with the speed of sand particles.

TURBINE RUNNER

The Teesta-V power station(3X170MW) is under operation for the last six years and it has been observed that damage of underwater parts is quite noticeable, especially the runner, guide vane, facing plates of upper & cover rings necessitating repair/ replacement in two years. Teesta – III Project has vertical pelton turbines operating under a rated head of 780m and as the jet velocity is very high (about 100m/sec) all possible efforts are being made to reduce the rate of damage by selecting suitable material for under water parts and minimizing the erosion on account of sediment size and its concentration in the water passing through its turbine. The past experience with many operating project indicate that erosion rate is reduced substantially if the silt concentration is kept below 2000 ppm and particle size is reduced below 0.2mmwith sediment removal of 90%.

V. DESILITING ARRANGEMENT

Initially it was planned to have three desilting chambers but alternative proposals of two nosdesilting chambers in parallel and of different widths depths and lengths were studied and finally the two oval shaped underground desilting chambers have been provided of size 320m (L) x 17m (W)x 23(high) for a design discharge a 101cumecs each. The length of upstream transition is 40m and downstream transition being 10m.The intake tunnel of 7.5m diameter shall be bifurcating in to two tunnels connecting the two desilting chambers. The layout of the desilting system is shown in fig3

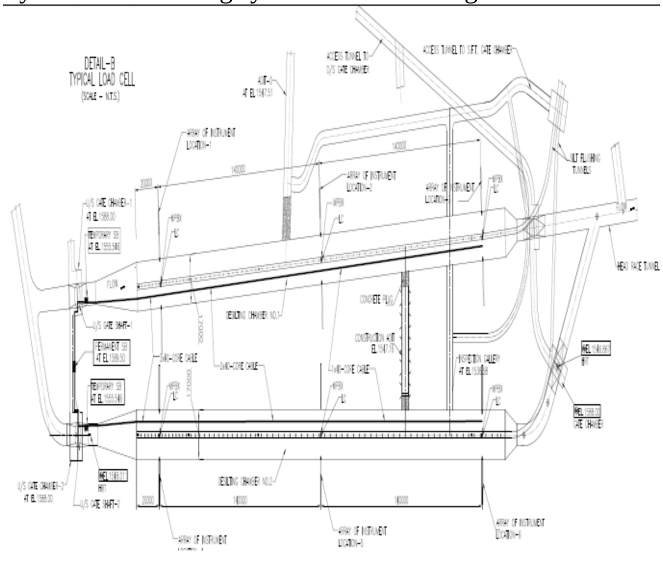


Fig-3

The bottom portion is provided with slope of 40* so that the settled silt particle flow down easily into the trough below and carried further through the silt flushing tunnel and disposed into the river .The sediment in each chamber will settle into the central cunnette 2m wide and depth varying between 0.5m to 2.0m.The efficiency of the arrangement as per model studies is more than 90%.The x-section of the desilting chamber is shown in fig-4:

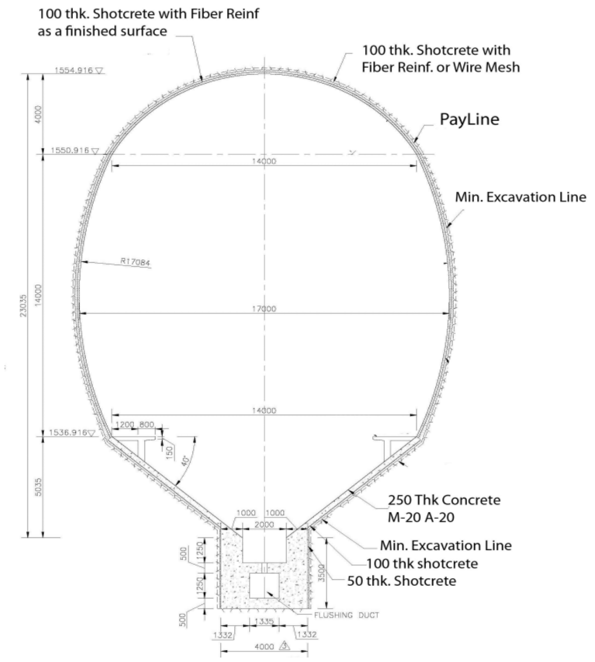


Fig-4 Cross-section of desilting chamber

Considering 13.5 cumecs of discharge for flushing, a total of 101cumecs of discharge shall be entering the chamber with flow through velocity of 25cm/sec. The flow area i.e. width and depth of the chamber has been so fixed that flow through velocity of about 25cum/sec as required for removal of sediment coarser than 0.20mm is maintained. The length of the chamber of 320m has been worked out at by the horizontal distance travelled by the silt particle within the time required for the particles to settle down from the top layer of the flow to the bed of the desilting basin. Hydraulic model studies for desilting chamber was carried out at Hydraulic Research Institute Bahadrabad , Uttarakhand to test the hydraulic efficiency of the desilting chamber and adequacy of flushing system. Studies were conducted on a scale of 1:15, geometrically similar model representing the desilting chamber from 50m of intake tunnel, complete desilting chamber and part of HRT with full flushing tunnel at bottom. Different size openings were adopted at variable spacing in the covering slab separating flushing duct from desilting basin hopper bottom. Dimension of the desilting basins are decided by the principle of fall velocity of the sediment particle which is to be removed from the flow. The fall velocity dependent on size and specific gravity of settling particle is approximated using empirically derived relationships based on laboratory observations. Based on model studies it was found that this 320m long 23m high desilting chamber was adequate for settlement of sediments coarser than 0.2mm diameter with an overall silt trapping efficiency for 2000 ppm silt concentration discharge as more than 93%. The test result indicated that 590ppm and 7800ppm silt concentration were passing through HRT and flushing duct during the model testing as furnished in table-2. It was also observed that for flushing discharge of 17.5cumecs (20%), the hydraulic efficiency of the flushing of sediments may increase substantially.

Table-2
OBSERVED SILT TRAPPING EFFICIENCY OF DESILTING CHAMBER

Sl. No.	Intake Discharge (Cumec)	Flushing Discharge (Cumecs)	Silt Concentration entering Intake (PPM)	Observed Silt concentration in PPM		Overall efficiency in %	Observed Silt concentration of > 0.2MM size particle in PPM			Efficiency for >0.2MM Size particles in %
				HRT	FD		Intake	HRT	FD	
1	101	13.5	1000	264	4100	77.13	340	24	1300	93.88
2	101	13.5	1500	400	5714	76.9	510	38	1990	93.54
3	101	13.5	2000	590	7800	74.44	680	52	2920	93.38

VI. 0RESERVOIR FLUSHING

It has been understood through model testing as well as actual experience that reservoir emptying operation is quite effective in flushing sediment. With lowering of the reservoir level, the scouring can move progressively up the valley as more velocities can be generated through the entire fetch of the reservoir. The flushing have been planned during floods when sediment flow is high which may initiate currents favourable for initiating scouring of the deposited sediments apart from giving passage to the flowing silt water. The 11m dia flushing tunnel with invert at EL 1540.0m almost 4-5m above river bed level was tested on the model to ascertain its functional efficacy. The efficiency of hydraulic flushing of sediment deposits is mainly influenced by the inflow and outflow discharges, sediment concentration, outlet characteristics and length and other configuration of the reservoir. During the model testing it was observed that 70 to 80% flushing was occurring during the 3 hours of model run(19 hrs- proto type) and by another one hour almost 100% of the sediment upto confluence point was flushed out. The sediment upstream of flushing intake was deposited to maximum EL 1550.00m and a tendency of deep channel at EL 1540.00m along upstream face of Coffer dam was observed in all experiments. The model at 200 cumecs and 300cumecs discharge was studied and hydraulic performance in regard to sediment flushing was found satisfactory. Therefore it has been recommended to do periodic flushing during monsoon or flood period in a regular manner to avoid consolidation of sediment deposits especially cohesive clay deposits and to avoid back water effect upstream of dam.

VII. COATING OF TURBINE PARTS

The Teesta River carries lot of silt during monsoon months and peaks abnormally during high discharges. Silts contain high quartz content of more than 80% with hardness ranging 5-7 on mho scale. The underwater part is expected to operate under silt concentration up to 1000ppm. Therefore the turbine parts like runner buckets (inside and inlet area outside), injector housing, injector nozzle and nozzle ring (inside area), nozzle tip (outside area) are designed and provided with erosion resistant coating to minimize damage due to silt erosion. Critical examination of the silt data and chemical analysis of water has been given due consideration while designing the turbines, spherical valves and other auxiliary equipment's, susceptible to abrasive effect of silt including the selection of materials, coatings and paintings which will resist abrasion and enable easy and quick maintenance/replacement of worn-out component. Various studies have shown that hardness is perhaps the most important characteristics as it has better resistance to indentation and scratching by hard particles. However poor ductility may lead to localization of strains and development of cracks and therefore a material of high hardness with some definite amount of ductility as well as high tensile toughness and strain hardening characteristics are the best choice. Considering various metallurgical factors affecting silt erosion like cast structure, microstructure and mechanical properties, the 13/4 type steel belonging to this category was selected for turbine parts. The parent material for runner is G-X5 cr Ni 13:4(1.4313) for Teesta machines and coating with tungsten carbide. The coating material is SXH 70 powder and the coating is deposited on the desired metal surface by high velocity oxygen fuel thermal spray process (HVOF) with thickness 0.3mm +/- 0.1mm except for fringe areas of coating. The HVOF coatings are very dense, strong and show low residual tensile stress or in some cases compressive stress which enables thicker coatings to be applied than previously possible with other processes. The properties of the coating material are

Type : Tungsten Carbide
Density : 13500 kg/m3 (as sprayed)
Micro hardness : 900-1200HVO.3
Adhesive bond strength : 70-100MPa (tensile test)
Silt erosion resistance : 80-90 times better than steel 13/4 with silt containing 38%
minerals with hardness equal to and greater than 5.5.

Normally the repair and maintenance of turbine is done during the non-monsoon months annually and in two years as per requirement. The partial repair in the form of grinding etc. could be done at site annually however in every two year full repair by way of welding, grinding and heat treatment and new coating with SXH70 could be undertaken to extend the life of turbine parts. The coating not only extends the lifetime but also reduces therepair and maintenance and thus enhances availability of machine and thereby higher power output and higher productivity and thus making coating a cost effective exercise.

VIII. CONCLUSION

The desilting arrangement in hydroelectric projects is essential to manage the silt in the discharging water so as to prolong the life of runner and other turbine parts. The high cost of desilting arrangement raises a question as to whether we could have a improved metallurgy and protective coatings which could allow higher sediment particle size through the turbines and thus reduce the size and cost of the desilting system.The underwater part is primarily controlled by its metallurgical properties. The cast and heat treated microstructure as well as the mechanical properties have significant effect on its erosion resistant behavior. The metallurgist and scientist community should take this challenge of developing appropriate technology for some new materials having better erosion resistance.

IX. ACKNOWLEDGEMENTS

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REFERENCE

[1] Detailed project Report and unpublished reports of Teesta-III project
[2] Model test report of Desilting basin and flushing tunnel by IRI Bahadrabad, Uttarakhand
[3] Mr. D.B. GoelIIT Roorkee- Metallurgy of erosion of underwater parts in hydroelectric projects(proceedings of 3rd International conference on Silting problems in hydropower projects Feb 2008.
[4] Carrying capacity study of Teesta Basin- Centre for Interdisciplinary studies for mountain hill Environment (CISMHE) Delhi University.

Biographical details of the Author:-

Brajesh Kumar Ojha "FIE", Project Director (Energy Infratech Pvt. Limited) "Presently working in Teesta III HE Project (1200 MW) in Sikkim". Graduated in Civil Engineering from Bhagalpur University Bihar in 1984 and joined National Hydro Electric Power Corporation (NHPC) a Govt. of India Enterprise in Feb 1985. The author has worked in NHPC Limited, the largest Hydropower Utility in India for more than 23 years. During this period he was involved in Design and Construction of various Hydropower Projects in the country. He worked as Chief Engineer for the construction and commissioning of Teesta Stage V (510 MW) HE Project and also as Project Director in the construction of Teesta Stage VI (500MW) HE Project being presently developed by M/S LancoInfratech Limited.