Industrial Science
Vol.1,Issue.5/June. 2014 **ISSN** : 2347-5420

Research Papers

EFFECT OF SCOURING IN BASALTIC ROCK ON HYDRAULIC STRUCTURES IN THE VICINITY OF PUNE REGION

T. D. Bhosale , G. A. Hinge and N. J. Sathe

Department of Civil Engineering, Sinhgad College of Engineering, Pune.
Department of Civil Engineering, Bhivrabai Sawant College of Engg & Research, Narhe, Pune.
Department of Civil Engineering, Sinhgad College of Engineering, Pune.

Abstract

Scouring of the rock is the erosion of the rock due to the velocity exhibited by the stream channels and different localities. The present paper describes, the scouring effect of Basaltic Rock on hydraulic structures in the vicinity. In this paper we have made an attempt, which shows the scour of rock due to high velocity of water jet in the tail channel.Also the difference in RL'S between the spillway guide wall and bridge pier is helpful to show the adverse effect of scouring in tail channel for both the dam sites.
In order to study scouring effect of rock (Bollaert 2001) prepared a CSM model (comprehensive scour model), which is very useful to find physics of rock scour or also to predict future scour formation.

KEY WORDS:

Rock Scour, plunge pool rock scour, CSM, tail channel scour, future scour prediction.

I.INTRODUCTION

Rock scour take place when erosive capacity of water exceeds the ability of rock to resist it. (E.F.R.Bollaert 2001), generally it takes place at the downstream of overtopping dams, downstream of spillways in plunge pools, around bridge pier and at tail channel. For assessment of rock scour it needs characteristics of turbulent flows leading to scour. Also it needs brief study of failure mechanism of rock so as to study its erosive capacity.

As the erosion of the rock mainly take place by following three physical processes (Bollaert, 2002):

1.Rock block removal (due to pressure fluctuations in the joints or to shear flow)
2.Rock mass and rock block fracturing (suddenly or progressively with time),
3.Rock mass and rock block abrasion (long term agents).

As all the above process has its own time scale of occurance ranging from instantaneous to long term action. The physics of this action are quite complex & thus difficult to incorporate into scour prediction practical engineering model (Bollaert, 2002)
As the main objective of this study involves different civil engineering aspects such as surveying, hydraulics and rock mechanics.

II.PREVIOUS WORK:

Case Study 1:

1)Kariba dam plunge pool scour-Quasi 3D numerical predictions:

Kariba dam is a 128 m high double curvature arch dam located on a Zambezi river at the border between Zambia &Zimbabwe .As the dam is known worldwide for its impressive plunge pool scour hole of almost 90 m below the tail water level, which is an unpredicted value in dam history. For this dam based on gate opening & bathymetric surveys since 1960, quasi 3D time- dependent numerical scour computations have been made to assess the scour potential of the Gneiss rock for the next 50 yrs.

For computations they have used the comprehensive scour model (CSM model, Bollaert 2004) of 1/65 scale .The model has been calibrated based on past flooding &the corresponding scour observed. Input data for numerical modelling of Kariba dam:

1)Hydrology at the dam site:

For this they have collected the flood data since 1962,for each of the six gates the following information has been used, opening ratio, opening duration, lake level ,tail water level, adjacent or (neighbouring) gates functioning or not or no of gates.

From this study he interpreted that the general shape of the scour hole in accordance with the number of days of adjacent functioning gate 1 shows limited scour, gate 2 is in between gate 6 nevertheless shows deep scour formation also.

2)Geomechanical characteristics:

As the dam site is having Gneiss rock which have been defined separately for the North bank and South bank. Hammer test from the North bank site shows that the Gneiss rock is of very good quality.ie. (150-250 MPA). Along the south bank, the rock mass shows frequent near vertical joint but no sub horizontal joint set. Hammer test indicates an UCS of 50-100 MPA. i.e. Median strength rock. The rock looks very massive, with almost no fissure. Typical rock block shape is rather cubic.

3) Comprehensive scour model:

CSM (Bollaert 2004) estimates the ultimate depth of scour & the time evolution of scour in fractured rock. The main physical processes that are responsible for rock mass destruction by turbulent flow impingement are

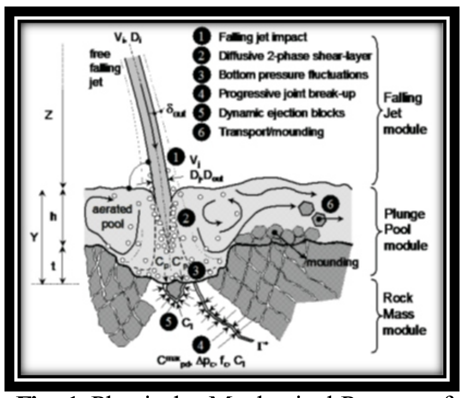


Fig. 1. Physical – Mechanical Process of Scour of Fractured media, such as rock in a plunge pool (E.Bollaert, 2005)

1)CFM module: Hydrodynamic fracturing of closed end joints (Joints not completely formed yet).
2)DI module: Dynamic uplift of blocks (joint network is completely formed).
3)QSI module: peeling off of rock block due to high velocity of turbulent flow fluctuation.

PRESENT WORK:

In Maharashtra region, Basaltic rock is present everywhere. About 85% of Maharashtra is covered by Igneous volcanic rock Deccan trap basalt. While designing any type of dam Geology of the tail channel plays an important role, which carries the flood water.

In Maharashtra region, there are various dams, in which there is a continuous spill channel erosion though they are having different geology.

Considering the availability of data with the irrigation department, government of Maharashtra, we have selected case of Panshet and Chaskaman dam as our case history for the present study.

Geology of Panshet:

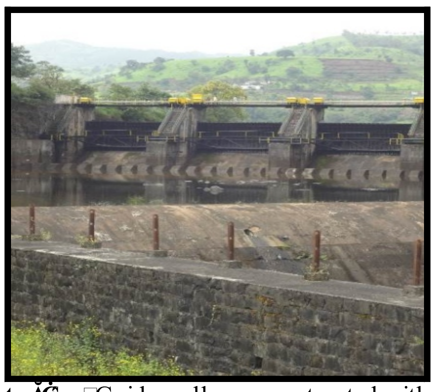
Panshet Dam is constructed about 40 kms from Pune city. It is an earthern dam with spillway to the right. Hydrothermally altered block jointed (Plate 3) and deeply weathered compact basalt and volcanic breccia with red lava matrix (Plate 2) occur along the spill channel. It is an ideal condition for serious scouring. Therefore very elaborate protection were carried out. Three fall structures and guide walls are constructed and all around the bed concrete apron protection wall adopted. Even after these energy dissipation arrangements, deep gullies are formed at the site.

The volcanic breccias are well introduced during the formation of the strata. The physical property of the breccias is to get eroded when they come to atmospheric conditions. But they are good building material when underlained condition (M. S. Mundhe, et.al. 2007).

t ■ǛƐ ϯ Side wall of downstream of the spillway scoured rigorously.

t ■ǛƐ ϯ Spillway channel scoured across due to occurrence of brecciated rock

t ĂĞ ى The bed concrete apron protection wall adopted just near the Spillway location



t ĂĞ ى Guide walls are constructed with energy dissipating structures.

t ĂĞ ي: Deep Gullies formation process occurring in the spillway channel.

t ĂĞ ي: Three Falls and Guide walls are constructed at Panshet Tail Channel

GEOLOGY OF CHASKAMAN:

Chaskaman Dam is constructed about 65 kms from Pune city. It is a gravity dam with spillway to the right. The local geology varies from Panshet. The rocks exposed in the spillway channel is a compact basalt which comprises of the sheet jointing occurring in it. It is an ideal condition for serious scouring. Therefore very elaborate protection is carried out to avoid the further erosion of the spillway channel. Guide walls are constructed and all around the bed concrete apron protection wall adopted, even after these energy dissipation arrangements, deep gullies of about 15 feet in height are formed at the site. The sheet jointed basalt appears as if the rocks are lained one above the other.

Plate 7: Downstream part of the Chaskaman Dam side spillway (2001)

Plate 8: Bridge Pier foundation exposed due to scouring of rocks at Chaskaman Dam side spillway (2001)

Plate 9: Downstream part of the Chaskaman Dam side spillway (2001)

Plate 10: Present scene of Bridge Pier foundation exposed due to scouring of rocks at Chaskaman Dam side spillway (Nov.2013)

Plate 11: Present scene of EDA portion of rocks at Chaskaman Dam side spillway (Nov.2013)

METHODOLOGY:

As the above study includes the following civil Engg aspects,Surveying: To find out the level difference between spillway and bridge pier, so as to know the scouring effect of rock, throughout the length of the channel.which is also useful to determine the eroded section of stream channel due to higher velocity of water jets.

Hydraulics: As Stream gauge data was obtained from both the sites (Panshet and Chaskaman) generally the data obtained is based on the daily stream flow from the spillway gate opening during the rainy season. This Gauge data will be helpful to calculate the erosive capacity of water flowing through the stream channel, which is responsible for scouring of tail channel for both the sites. Also the hydraulic variables includes slope of stream Power, discharge, shear stress, and velocity of water flowing through the spill channel

Rock Mechanics: To understand the weathering of the rocks or scouring of the rocks the properties of the rocks are studied here. The properties based on the UCS, Physical Properties like, weathering due to water contact, Composition of the rock.

It also includes the various treatments to be given to control the velocity of water flowing through the channel.

DISCUSSION:

1) SLOPE ON STREAM POWER:

The stream power is computed directly from the daily flow data. The stream power is computed as:

$P = \gamma\, q\, s_f\, L$

Where P is the unit stream power, γ is the unit weight of water, q is the unit discharge, s_f is the energy gradient and L is unit length of the channel in the direction of flow (Annandale 1995). Since it is assumed that sf is equal to the slope of the bed (s_o), a substitution of variables in above equation gives,

$P = \gamma\, q\, s_o\, L$

It is evident from the above equation that the channel slope is an important variable in determining the stream power. At sites where survey data obtained was compaired to the slopes estimated from the field visit, significant differences in the channel slope were observed.

I)Calculation of erosive power of water flowing through chaskaman dam tail channel for max.and min. flow:

As stream power is given by the formula,

$$P = \gamma\, q\, s_o\, L$$

For max.flow:

For the Chaskaman dam, hydraulic variables are as follows,
As the Stream power is given by the following formula,
$P = \gamma$ q so L (Annadale1995)
Where, γ=9810KN/m^3, Unit discharge
q=2.15m^3/sec.m, $s_0 =_{1in60,L=787m(Uptobridgepieronly)}$
P=9810×2.15×13.11×787
=217.61×106 kW/m^2
For minimum discharge,
q=0.43m^3/sec.m
P=9810×0.43×13.11×787
P = 43.52×106 kW/m^2

These are the max. And min.values of the stream power obtained from the daily flow data of Chaskaman dam site during rainy season in 2013. Due to this stream power, rock samples from the tail channel are exposed above the surface and they travels with the same velocity of flow and tapers on each other and on the bridge pier, Due to this tapering of rock samples on the surface of the bridge pier, the foundation as well as the front face of the bridge pier is damaged and the reinforcement material is come out from the footing surface. (Plate 8,10),so in order to protect bridge pier they did some concreting work near the bridge pier footing(2009) and also at that time in order to minimize velocity of water flowing through the chaskaman dam tail channel, they have already constructed guide bunds at the downstream part of bridge so as to avoid further rock erosion from the channel as well as to control velocity of water flowing through the channel. Due to this provision rock erosion from the chaskaman dam tail channel site is minimized now, which can be easily predicted by compairing some photo snaps also.

Plate 12. Guide bund provided at the downstream of bridge to control velocity of flow as well as future rock scouring in river portion (2009)

2) COMPARISION OF TWO SITES:

The recent cross section were plotted and the average change in elevation across the width of the channel was used to determine the amount of erosion throughout the length of the channel for both the sites.

For this surveying work we have used modern surveying instrument named as GPS (Global positioning system instrument) which gives the correct value of RL'S at that location with the help of GPS satellite and these values of RL'S are Georeference with the Google earth to get the actual eroded profile along the width of the channel.

These sections shows the amount of erosion throughout the length of tail channel for both the sites.

1)Chaskaman dam current river bed profile:

Plate.12 Eroded section of Chaskaman dam tail channel.

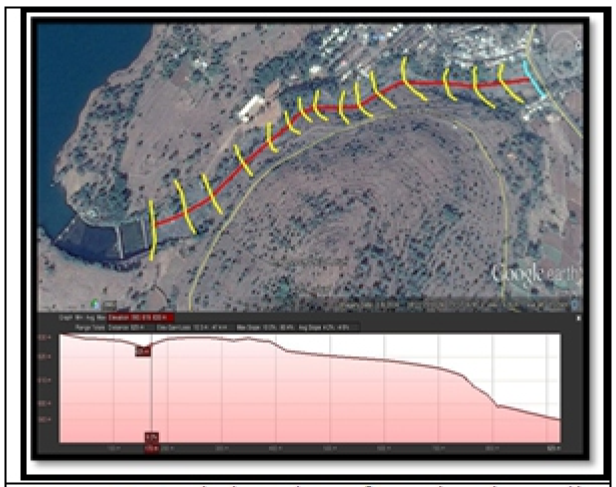


Plate.13 Eroded section of Panshet dam tail channel.

3) ROCK MECHANICS:

As the rock samples present at both the sites are as follows:

The rocks occurring at the dam site are Compact Basalt, compact porphyritic Basalt, Amygdaloidal basalt, Volcanic breccia with fragments held together by zeolization, volcanic breccia with grey lava matrix, Streaky compact porphyritic basalt with green infillings, Black tachylitic basalts, Red tachylytic basalt, sheet jointed basalts.

Geotechnical characteristics of site rock:

As these Geotechnical properties plays a vital role in rock erosion generally there is a co relation between stream power and crushing strength of rock, if the crushing strength of rock is minimum then it can be scoured easily and if it is more it takes a long time for scouring of that particular rock samples, as the rock scouring is a totally time dependent phenomenon. Following are the Geotechnical characteristics of site rocks. (R.B.Gupte-1980)

1)Compact Porphyritic basalt:
*Avg.Crushing strength is 1295kg/cm^2
*Avg .water absorption is 0.67

2) Amygadoidal basalt:
*Avg.crushing strength is 681 kg/cm^2
*In wet condition it is 659 kg/cm^2

3) Volcanic Breccia:
*Max.crushing strength is 390 kg/cm^2
*Min.Crushing strength is 150 kg/cm^2
*Avg.crushing strength is 291.66 kg/cm^2

3) VARIOUS TREATMENTS TO BE GIVEN TO CONTROL FUTURE ROCK SCOUR:

At both the dam sites, rock scouring takes place due to the insufficient energy dissipation by the stilling basin of the dam, also the hydraulic jump is swiped out from the stilling basin, due to the higher velocity of flow the the guide wall constructed at the end of Panshet dam stilling basin is washed out, so it needs re design of stilling basin or it also needs provision of friction blocks for Chaskaman dam stilling basin.

To prevent downstream scouring, the tail water depth should be about the same as the depth in the stilling basin, if this is true the hydraulic jump is submerged inside the stilling basin, due to which maximum energy will be dissipated by the stilling basin.

At Chaskaman dam site, during the construction of dam due to the maximum flow from the spillway maximum rock scouring has been already occur, but in 2009 they have constructed Guide bunds exactly downstream face of the bridge pier due to which rock scour is minimized from the river portion.

Gabions are rectangular baskets or mattresses made of galvanized (and sometimes polyvinyl chloride-coated) steel wire in a hexagonal mesh. The gabion is provided with steel wire in a hexagonal wire mesh. The individual baskets are then wired together and filled with stone. The lids are finally

Closed and laced to the baskets, forming a large, heavy mass. If the Gabions are provided as a covering to the bridge pier then foundation of bridge pier as well as face of bridge pier opposite to the direction of flow may get protected, Because there will be no any tapering of rock samples on the face of bridge pier due to the provision of Gabion structure.

At Chaskaman dam site in order to prevent further rock scouring from the river portion they have constructed guide bunds in 2009, due to which velocity of flow through the tail channel as well as scouring is min imised so there is a need of construction of such a type of structure at downstream part of Panshet dam tail channel also.

Drop structures are commonly used for flow control and energy dissipation. Changing the channel slope from steep to mild, by placing drop structures at intervals along the channel reach, changes a continuous steep slope into a series of gentle slopes and vertical drops. Instead of slowing down and transferring high erosion producing velocities into low non-erosive velocities, drop structures control the slope of the channel in such a way that the high, erosive velocities never develop. The kinetic energy or velocity gained by the water as it drops over the crest of each structure is dissipated by a specially designed apron or stilling basin. The drop structures discussed here require aerated napes and are, in general, for subcritical flow in the upstream as well as downstream channel. Provision of such a structure at both the dam sites will also minimized the velocity of flow and protect the downstream part from further scouring.

ACKNOWLEDGEMENT:

The first and last authors of the paper are thankful to the Management and Administrative Officers of Sinhgad College of Engineering, Pune for their co-operation during the visits to the site. The first author is also thankful to the officers (Mr. Kuthwad and Mr. P. D. Kand) of Irrigation Department, Government of Maharashtra, for providing permission to collect the data and photo snaps during the field studies.

REFERENCES:

1.Briaud, J. L. (2008): Case histories in soil and rock erosion: Woodrow Wilson Bridge, Brazos River Meander, Normandy Cliffs, and New Orleans Levees., Jour. Of Geotechnical and Geo-Environmental Engg. ASCE, Oct. 2008.

2.Mundhe, M. S., Kulkarni, S. R., and Hangekar, C. (2007): Engineering geology in dam safety. ICOLD 75th annual meeting, Saint Petersbarg, Russia, June 24-29, 2007.

3.E. F. R. Bollaert (2005): A Prototype scaled rock scour prediction model, Report to President Aqua Vision Engg. Ltd., Chemin des Champs - Courbes, Switzerland. pp 1269 – 1283.

4.Cheng, M. H., Liao, Pan, W. I, Li, G.W. I, Huang, M.-W.I, Lo, W. H. I, Hsu, S. T. (2008): The Mechanics of Scour in the Marine Environment, Proceedings 5 ICSE-08 Rock Scour and Erosion, pp. 724 - 733.

5.Kariba dam plunge pool scour: Quasi -3 D numerical prediction (E. F. R. Bollaert, M. C. Munodawafa, D. Z. Mazvidza, ICSE 6 Paris-August 27- 31, 2012.

6.Numerical scour prediction at Choranche dam (Erik F. R. Bollaert, Benoit Blancher Olivier chulliat, Frederic Laugier, ICSE 6 Paris-August 27- 31, 2012. pp, 1151-1158)

7."Shoreline and channel erosion protection ''Overview of alternatives, WRP technical note HS _RS-4.1 January 1998.

8.Marathe S.S, Kulkarni S.R, KarmakarB.M and Gupte R.B. (1980) Variation in the nature of Deccan

Trap Volcanity of Western Maharashtra in Time and space.
9. Hydraulic Design of Energy Dissipaters for Culverts and Channels HEC 14 September 1983 Metric Version