Rare Foundation Media for Masonry Spillway at Lhasi dam, Baran District, Rajasthan - A Case Study

*Sharma, V.P. **
Senior Geologist
Pareek, Suresh
Engineering Geology Division, Geological Survey of India, WR,
15-16 Jhalana Doongri, Jaipur, Rajasthan.
**Corressponding author: e-mail- vps2448@gmail.com*

Abstract

The geotechnical investigation of Lhasi medium irrigation project has brought to light peculiar foundation strata in the area mainly occupied by Vindhyan sediments and Deccan Trap. The peculiarity of strata led to number of modifications in the design of the spillway. The atypical geotechnical characteristics of the strata exposed at the foundation level was an enigma for the geologist as well as design engineers.

The project area is mostly covered with alluvium having exposures of basaltic flows of Deccan traps on the right side of the dam underlain by sedimentary rocks of Vindhyan Super group and an intervening thick section of decomposed white sandstone. This intervening unit was identified *prima facie* as forming part of the Vindhyan sequence. After detailed studies, it was found to be an altogether different unit of argillaceous immature sandstone / lithic-wacke of volcanoclastic origin with stray pebble size clasts, which may represent a paleosol / infratrappeans. This unit having a thickness of more than 25 m and underlain by typical Vindhyan shale/sandstone sequence, is in fact a unit probably deposited prior to the onset of Deccan volcanism. The peculiar characteristic of this unit is its two components with altogether different geotechnical properties. The upper 15 m thick portion of the unit is soft and semi-consolidated followed by quite hard, compact and massive lower portion with sub-angular clasts of chert, jasper and other rocks fragments, a feature common to both portions of the unit. The upper portion of the unit has very poor cohesiveness, when water charged. As such the rock though has low permeability, is highly vulnerable to scouring due to high water absorption and non-cohesive matrix.

The geotechnical attributes of this peculiar unit are such that any contact of this upper unit with the structure is undesirable. Slightest scouring along the contact with the structure may prove to be fatal in due course. I view of the unsuitability of this foundation media further deep drilling was opted and a good foundation media (the lower portion of the same unit) was intersected at 15 m depth from earlier proposed foundation level throughout the extent of the structure. The rock is quite massive with very good RQD % and high compressive strength. Subsequently, the structure was redesigned to conventional ogee type spillway leaving aside all other options with low confidence level.

1. Introduction:

The Lhasi Medium Irrigation project with a gross storage capacity of 30.80 Mcum envisages construction of 17.56 m high and 2545 m long earthen dam originally designed with 114 m long chute spillway. The spillway is situated on the extreme right side of the dam, where a hill composed of basaltic rock forms the abutment. The construction stage geotechnical investigation of the dam was initiated in 2007. The investigation revealed that the rock exposed at the proposed designed foundation is not suitable for the structure. The peculiar characteristics of this stratum were an enigma for the geologist as well as

design engineers. The atypical characteristics of the strata led to modifications in the design of the structure but the confidence level of the engineers was not very high. In view of the unsuitability of this stratum, it was decided to find out at what depth, in fact, the suitable bed rock i.e. Vindhyan sediments are available.

Further investigation was taken up to find out the depth of the bed rock and three boreholes were drilled in the spillway section. The suitable bed rock was intersected at a depth of 15 m from the proposed foundation level. This rock to everybody's surprise was not the typical Vindhyans as expected but lower portion of the same argillaceous sandstone with entirely different geotechnical attributes, which continues for a depth of 10 m in one of the boreholes with fairly good to excellent RQD ranging from 32% to 100 % with an average of 72 %.

2. Project Geology:

The project area is characterized by a rolling topography mostly covered with alluvium with exposures of Deccan basalt flows occupying the higher grounds. Both 'Aa' and 'Pahoehoe' flows are exposed in the area (figure 3). The basaltic flows are underlain by rocks belonging to Vindhayan Super group comprising Lower Bhander Sandstone, Sirbhu Shale and thick section of highly decomposed and friable calcareous clay and sandy clay (Gaikwad et al, 1984). The later (friable sandy clay) was of concern as the foundation media for the spillway and detailed studies of this strata was carried out during the investigation of the project (V.P. Sharma 2009 & 2013, V.P. Sharma & S. Pareek, 2011)

3. Geotechnical Investigation of Chute Spillway:

The cut sections of the hill slope as well as the strata exposed at the designed foundation level of the spillway was examined. The rocks exposed in this section are highly weathered basalt underlain by semi-consolidated mildly calcareous immature sandstone (figure 1). The whole unit has certain variations in the upper part with two main varieties; the purplish pink and grayish white. The later variety continues further down up to considerable depth. The contact of the basalt with this argillaceous unit is marked by about one m thick indurated cherty clay. The peculiar characteristic of this unit is its two components with altogether different geotechnical properties. The upper 15 m thick portion of the unit is soft and semi-consolidated followed by a well compacted and silicified, quite hard and massive lower portion with sub-angular clasts of quartz, chert and other rock fragments of Vindhyan sediments, a ubiquitous feature common for whole unit., though with varying proportions from place to place. The rich concentration of these clasts gives an appearance of conglomerate in some of the horizons (figure 2) especially at the contact zone of both the portions of the unit.

The upper portion of argillaceous unit is moderately hard and highly brittle when dry but once saturated becomes very soft and crumbles under fingers. The rock is highly porous with high water absorption. The permeability of the loosely cemented purplish pink sandstone at RL-336.40 m and that of white calcareous sandstone at RL-332.50 m are

3.93 x 10^{-4} cm/sec and 6.43 x 10^{-4} cm/sec respectively, indicating low permeability. The grain size analysis of the two varieties reveal that the weight percent of the matrix smaller than 0.075 mm size are 27.47 % for white sandstone and 42.57 % and the rest consists of assorted sub angular grains of mostly quartz with stray grains of other minerals / rock fragments. The white sandstone is coarse grained whereas the purple one is dominantly fine grained sandstone. The grain size distribution of these two samples is given below.

Table 1
Grain Size Distribution

Grain size	Cumulative weight percentage (%)	
	White sandstone	Purple sandstone
Coarse sand	44.06	9.38
Medium sand	14.26	11.95
Fine sand	14.21	36.10
Silt	17.54	29.99
Clay	9.93	12.58

The X-ray diffraction analysis of the fine fractions (>0.075 mm) of these two samples indicated that the matrix of white sandstone is composed of 95 % quartz, 4 % calcite and 1 % Illite and that of purplish pink sandstone 98 % quartz and 2 % Illite.

The clayey/silty matrix of the sandstone forming about 25% to 40 % of the rock is not lithified and non plastic and thus has very poor cohesiveness owing to miniscule amount of clay minerals and as such has very low shearing strength, when water charged. The calcareous clayey matrix is dispersible and washed out when water charged and the rock gets disintegrated into granular aggregates. As such the rock is highly vulnerable to scouring by high energy water flows. However, in confining and calm water conditions the same may remain intact until and unless disturbed by flowing water and exposed to air. The rock is quite massive with literally no joints and fracture zones.

Since, the dam has to be founded on this rock itself as there is no alternative site available, following three suggestions were given for consideration while redesigning the spillway.

1. Either the foundation rocks should be excavated up to the level below scouring depth and refilled with suitable well compacted impermeable, cohesive non-swelling soil up to the designed foundation level and the structure be constructed on raft foundation.
2. The dam should be protected from water entering into the foundation rocks by providing an impermeable cut off wall of concrete all around the chute spillway up to at least 2 m below scouring depth.
3. Some other alternative structure other than the chute spillway may be designed for discharging the water as per the foundation media available.

Based on these recommendations a few alternative designs viz. piano key spillway, provision of cut off wall all around the structure and friction piles etc were contemplated

but none of the design suited and proved safe for the construction of spillway in the upper semi-consolidated portion of the unit. And thus the structure was finally redesigned to conventional ogee spillway with sound wing and training walls with 15 m deep foundation. The depth of the foundation was almost double the height of the structure above *nsl*.

References:

1. Gaikwad, L.D., Parihar, C.P.S and Shukla Rajendra (1984): Geology of parts of Chhipabarod and Chhabra tehsils, Kota and Jhalawar districts, Rajasthan (Unpublished GSI report FS 1980-81).
2. Geology and Mineral Resources of Rajasthan, Geological Survey of India, Miscellaneous Publication No. 30, part 12, 3rd Revised Edition, 2011.
3. Rawat, J.S., (2007): Report on Pre-Construction Stage Geotechnical Investigation for Lhasi Medium Irrigation Project, Baran District, Rajasthan (Unpublished GSI Report, FS: 2006-07).
4. Sharma, V.P., (2009): Report on Construction Stage Geotechnical Investigation of Lhasi Dam, Baran district, Rajasthan (Unpublished GSI Report, FS: 2007-08).
5. Sharma, V.P. and Pareek, S., (2011): A Report on Geotechnical Investigation of Proposed Chute Spillway of Lhasi Dam, Baran district, Rajasthan (Unpublished GSI Report, FS:2010-12)

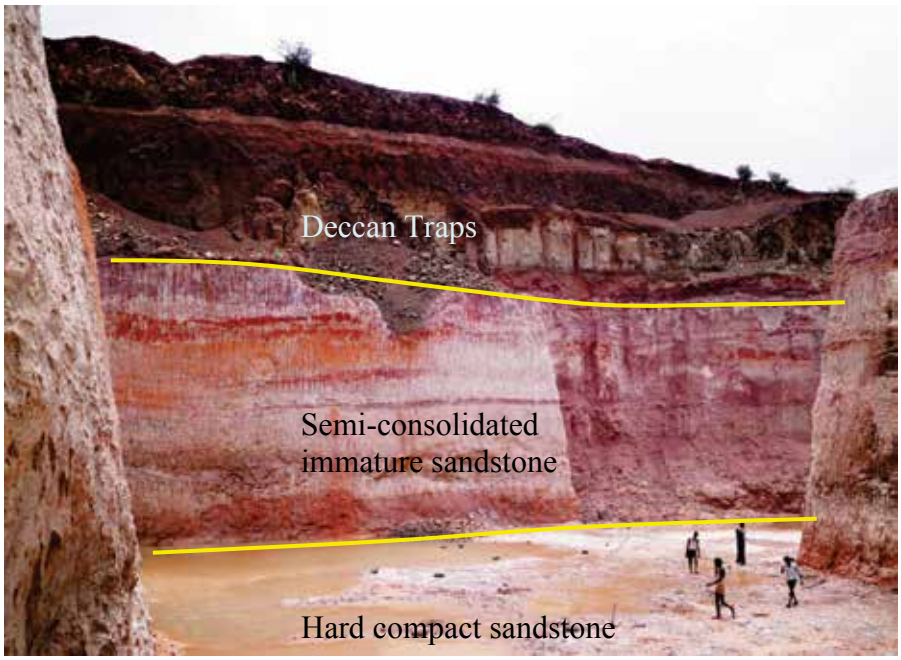

Figure 1 A view of foundation excavation for right wing wall and spillway

Figure 2 A piece of silicified conglomeratic sandstone excavated at Foundation level

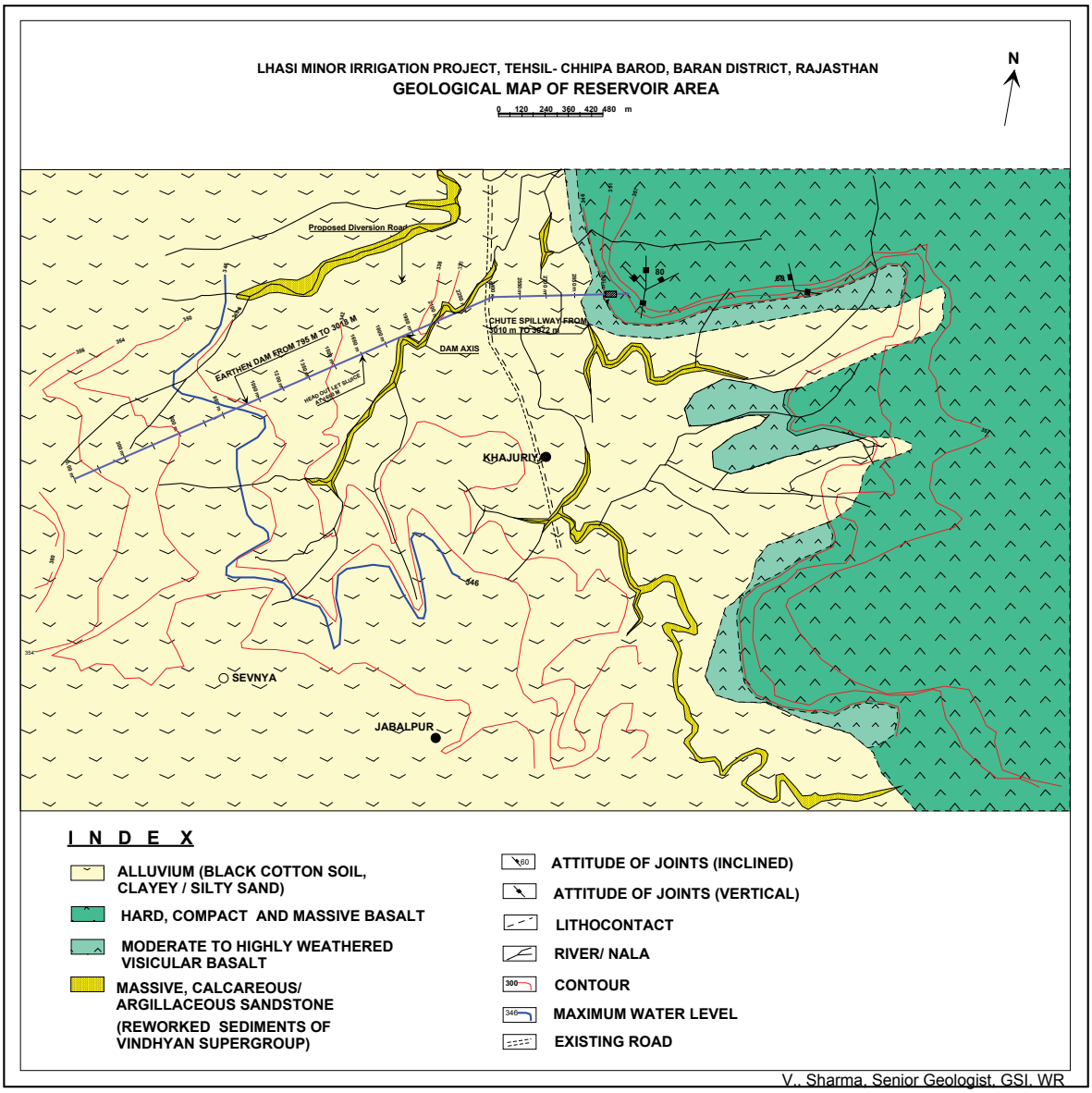

Figure 3 Geological map of the reservoir area, Lashi dam, Baran district, Rajasthan