

Geological aspects of seepage problem and its management at Khanpur dam project, Pakistan

Mohammad Saleem Khan¹, Mian Ali Gul² and Mubashir Aziz³

¹Department of Geological Engineering UET Lahore

²WAPDA, High Head Power Projects, Besham

³Department of Civil Engineering, UET Lahore

Abstract

Seepage problem is one of the important tasks to be resolved associated with embankment dams. Often preconstruction arrangements are made to reduce the seepage through dam's abutments and valley fill deposits. The usual treatments include grouting; cut-off wall, clay blanketing and dental treatments which are adopted to cut down the possible seepage paths. The amount of seepage and type of treatments are directly related to the nature of geological formations and associated structural features.

For the past twenty five years of dam operation seepage is still one of the major problem at Khanpur Dam Project. At maximum conservation level of 1980 feet seepage quantity is about 50% of the base inflows of the river and its increasing trend is a threat to the dam safety and water storage. The study of the geological aspects indicates that the major seepage paths are associated with limestone formations and through a number of normal faults in Chohae area. Instead of costly treatment over a large scattered area, management measures are suggested for conservation of reservoir and utilization of 35% of seepage water at gravity flow.

Keywords: Khanpur Dam; Limestone; Seepage; Uplift pressures; Management measures

1. Introduction

Khanpur Dam is located in Haripur district of Khyber Pukhtunkhwa province at River Haro. The dam was constructed in 1985 to irrigate lands in Haripur and Rawalpindi districts. It also provides municipal water supply to Rawalpindi, Islamabad and industrial area of Taxila. The dam has a gross storage capacity of 1,06,000 acre feet, hence on the basis of storage capacity it is considered as a large dam (Fig. 1).

Since the first impounding in 1983 which took place due to heavy rains in the catchment area of the dam, very high level of seepage was recorded from all the structures of the dam (Khan et al., 2011). After the necessary remedial measures the dam started its operation in 1985. Even after the operation for 25 years, seepage is still one of the major problems of the dam. At maximum conservation level of 1980 feet, about 50 % of the base inflows of the river are lost through seepage (Khan et al., 2011).

Seepage control measures at dams are usually carried out through drilling and grouting to seal

the discontinuities and have been reported frequently (Turkmen, 2003; Romanov et al., 2003; Khan and Qureshi, 2004; Uromeihy and Barzegari, 2007; Khan et al., 2011). On application of grouting for seepage reduction with reference to Khanpur dam, Khan and Qureshi (2004) reported, over-all seepage reduction of 59%, 29% and 20% at corresponding reservoir level of 1920, 1930 and 1940 feet have been achieved. However the records of the Khanpur Dam indicate that no significant reductions have been achieved so far at higher reservoir level of 1950 feet and above of the dam where no grouting was carried out.

A number of other treatments have been worked out by various researchers to control the seepage problem and bring the losses to acceptable limits. Khan et al. (2011) while discussing the post impounding problems of dams constructed in carbonate geology have described, "A number of seepage control measures such as grout curtain, dental treatment and impervious blanket were provided at the time of construction which did not prove sufficient".

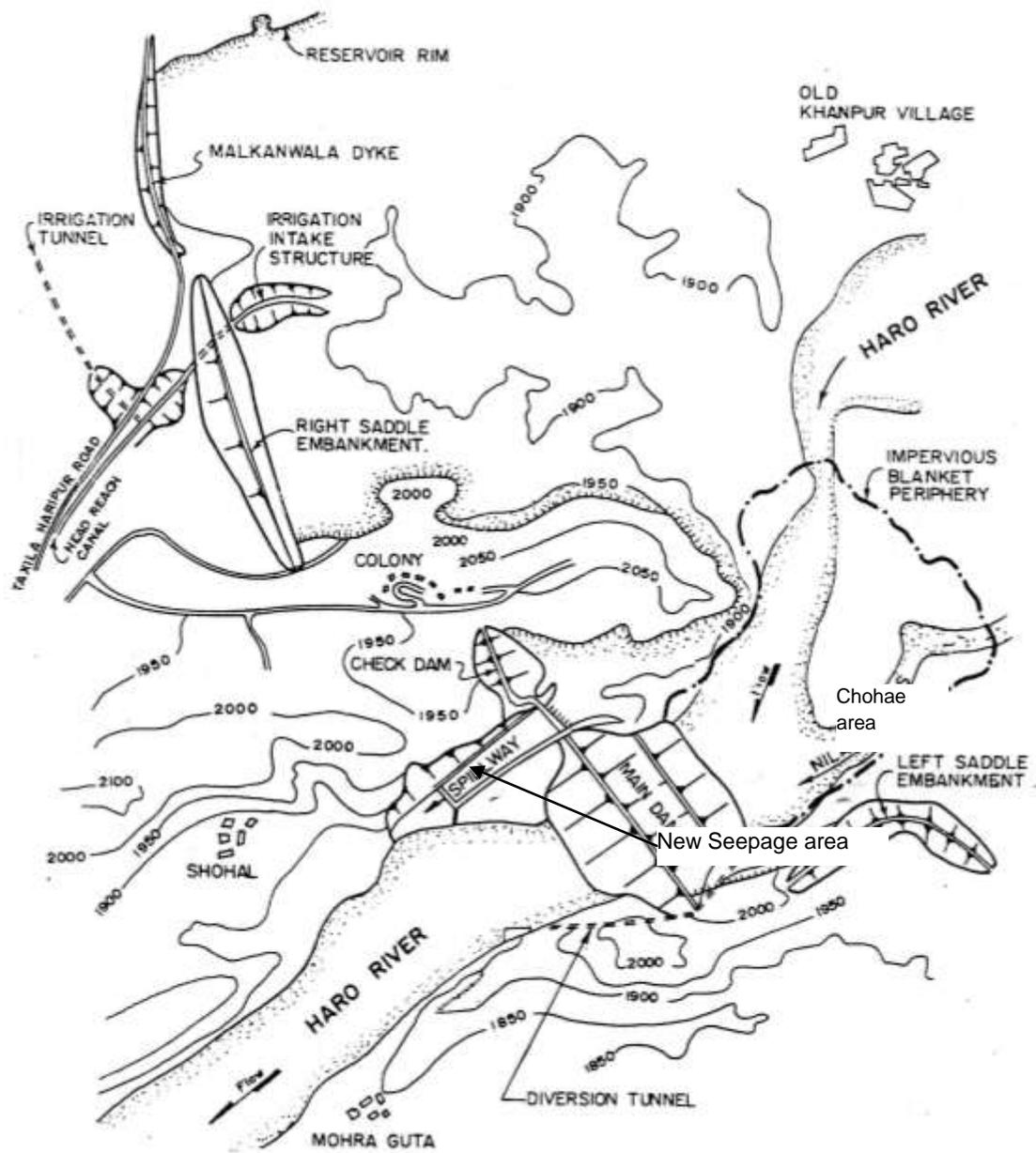


Fig. 1. Location map of Khanpur Dam indicating the major dam structures (ACE, 1984)

In the recent years various researcher have investigated the seepage problem with respect to geological features. For example Uromeihy and Barzegari (2007) studied the joint system of the rock units and highlighted the role of geological features as, “when seepage is a common problem in most of the dam sites where the impounding water seeks paths of least resistance through the dam, its foundation and abutments, the ground condition and the geological features of the dam site greatly influence the amount of seepage and its relevant effects”.

Sometimes normally adopted treatments to control seepage such as grout curtain, dental treatment and impervious blanket do not work; then again geological investigations are scrutinized. Hence in this paper focus of the study is towards the geological aspects which are responsible for high rates of seepage through large dams such as Khanpur dam. In addition to routine solutions, management measures are also proposed to overcome the problem.

2. Geological setup

The geology of Khanpur dam site is predominantly composed of limestone formation of Margalla Hill limestone Formation of Eocene age (Shah, 1977). Associated Consulting Engineers have classified the formation into twelve rock units given in Table 1 (ACE, 1984). The river valley at dam site is filled with thick alluvial deposits. Series of anticline and syncline structures are present in the area. The river at dam site flows through eroded anticline where as right and left abutments are synclines as shown in the typical cross section along the axis of the main dam (Fig. 2). The strike of all these rock units is day lighting in the reservoir from where huge amount of water enters through contact planes and

discontinuities which seeps out downstream of the dam. An uninvestigated source of seepage is from Chohae area where a number of normal faults are responsible for huge amount of water loss through seepage.

3. Methodology

Reconnaissance Survey was carried out and data of seepage after grouting treatment for 11-years was collected from the records of Khanpur dam Project (WAPDA, 1999). The seepage measurements at Khanpur Dam are made according to the standard methods of international repute such as v-notch, partial flume and flow meter measurements.

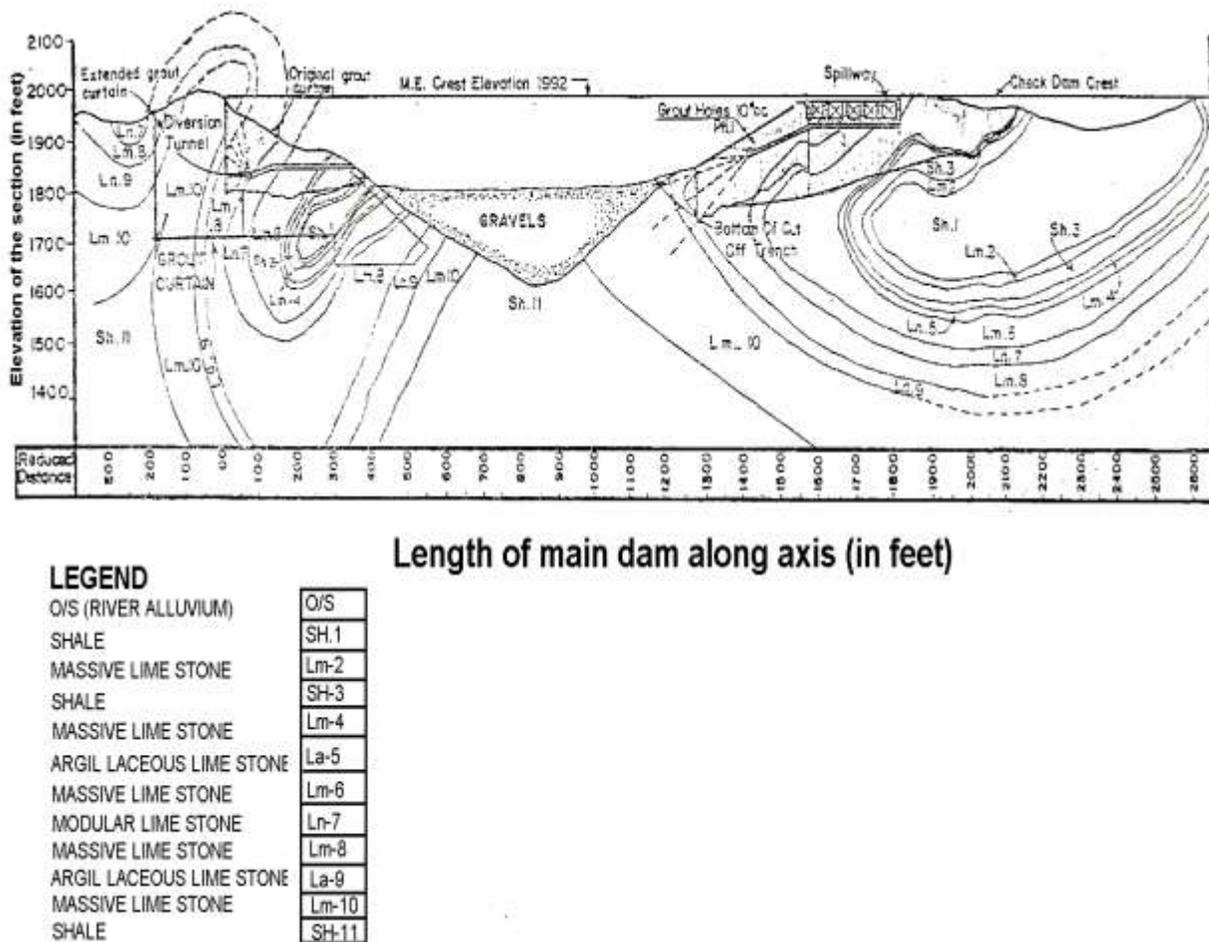


Fig. 2. Typical cross-section along the axes of the main dam indicating the sub-surface geological and structural setup responsible for high seepage (ACE, 1984)

Table 1. Geological classification of the rock units for Khanpur Dam Project (ACE, 1984)

S.No	Lithology	Legend
1.	Shale	Sh-1
2.	Massive Limestone	Lm-2
3.	Shale	Sh-3
4.	Massive Limestone	Lm-4
5.	Argillaceous Limestone	La-5
6.	Massive Limestone	Lm-6
7.	Nodular Limestone	Ln-7
8.	Massive Limestone	Lm-8
9.	Argillaceous Limestone	La-9
10.	Massive Limestone	Lm-10
11.	Shale	Sh-11
12.	River Alluvium	RA

4. Results and discussions

The results of seepage measurement from various structures of the dam for the years 2000-2010 (after completion of grouting), at three reservoir levels of 1940, 1960 and 1980 feet are given in the tables 2, 3 and 4 respectively. The data indicate that the dry spell spread over 4-years ended during 2002 and wet spell filled the reservoir to the maximum reservoir level of 1980 feet. The seepage analysis shows that at reservoir levels of 1940 and 1960 feet, the seepage amount is almost constant and no significant reduction is recorded. However, seepage measured at maximum conservation level of 1980 feet is highlighting increasing trend which is probably due to increase in hydraulic head and dissolution of highly fractured limestone.

Table 2. Seepage measured in cusecs from various structures at reservoir level of 1940 feet

Year	Main Dam	Plunge Pool	Right Saddle	Left Saddle & Valley Seepage*
2000	4.70	31	0.40	8.80
2001	4.70	29	0.40	6.74
2002	5.02	27	0.40	6.05
2003	5.38	13	0.20	8.40
2004	5.16	34	0.33	7.60
2005	4.55	22	0.03	4.90
2006	-	-	-	-
2007	-	-	-	-
2008	-	-	-	-
2009	6.00	32.68	0.18	10.00
2010	-	-	-	-

*Seepage amounts from Chohae area and New Seepage area are also included.

Table 3. Seepage measured in cusecs from various structures at reservoir level of 1960 feet

Year	Main Dam	Plunge Pool	Right Saddle	Left Saddle & Valley Seepage*
2000	-	-	-	-
2001	8.36	45	1.34	8.10
2002	-	-	-	-
2003	6.55	43.80	0.50	11.15
2004	-	-	-	-
2005	6.45	41.90	1.05	11.65
2006	6.38	43.00	0.67	11.30
2007	6.48	43.00	0.61	11.70
2008	6.48	41.81	0.40	11.60
2009	6.50	45.00	0.36	11.10
2010	-	-	-	-

*Seepage amounts from Chohae area and New Seepage area are also included.

Table 4. Seepage measured in cusecs from various structures at reservoir level of 1980 feet

Year	Main Dam	Plunge Pool	Right Saddle	Left Saddle & Valley Seepage*	Diversion Tunnel (Estimated)
2000	-	-	-	-	-
2001	-	-	-	-	-
2002	-	-	-	-	-
2003	8.10	47.50	5.00	14.10	-
2004	-	-	-	-	-
2005	7.90	47.70	3.70	14.00	-
2006	-	-	-	-	-
2007	8.00	51.19	4.18	14.00	-
2008	7.84	53.00	4.50	14.12	-
2009	7.50	52.50	3.00	13.78	-
2010	7.40	51.00	4.00	14.62	8.00

*Seepage amounts from Chohac area and New Seepage area are also included.

The year wise seepage losses at various reservoir levels (above the grouting zone) indicate no reduction which is due to untreated open joints present in vertical cliffs. It is also notable that the process of Self-healing due to sedimentation only worked in Northern pocket of the reservoir where substantial reduction in seepage is recorded at right saddle. The following two new management measures for controlling seepage are suggested;

- A large amount of seepage can be utilized with very little effort. The minimum seepage amount from Chohae area, New Seepage area, Left Saddle and Diversion Tunnel is

approximately 20 cusecs which increases to 30 cusecs at maximum conservation level of the reservoir (Table 4). These seepage outflows are suggested to be connected through a controlled outlet near Mora Gutta with the existing Old Punjkatha Irrigation Canal which was abandoned due to supplies through Left Bank Canal from Khanpur Dam. Almost at all reservoir levels this seepage water would be supplied to irrigate the Punjkatha area and Punjkatha Outlet Left Bank Canal will remain closed, hence 35% of total seepage will be utilized for irrigation purpose.

About 65% of the total seepage losses at all levels is related to the Plunge Pool seepage. The ingress of Plunge Pool seepage is from the open joints exposed in the vertical cliffs (Khan et al., 2011) of limestone surrounding the rest house area and large number of sinkholes spread in the spillway approach area of the reservoir (WAPDA, 1999). The minimum seepage at 1920 feet level from Plunge Pool is 30 cusecs which is 50 cusecs at maximum reservoir level of 1980 feet. Initially, it was expected that during the reservoir operation of few years the sedimentation will provide natural blanket which would seal the entries below the level of 1920 feet and decrease substantial amount of Plunge Pool seepage. But in contrast to the expected results the maximum sediments deposits took place in the northern pocket of the lake due to continuous releases from irrigation sluice where it sealed almost 100 % ingress.

- b. To control the seepage through Plunge Pool instead of costly treatment of drilling and grouting to whole of the rest hill, as alternate solution it is suggested that the flood releases should always be made through spillway instead of escape off at Haro River at Left Bank Canal of Khanpur Dam. The release of flood from spillway will help to divert the sediments towards southern pocket of reservoir which may provide natural blanketing in the spillway approach channel. Further more the left over grouting works recommended in the light of third Periodic Inspection Report (Ali, 1993) should be completed to seal the windows under abutments and spillway approach channel.

5. Conclusion

The study indicates that the geological set up of the Khanpur dam site is major cause of high seepage. By adopting management measure, approximately 30 cusecs of seepage water can be utilized through old Punjkatha irrigation canal.

Acknowledgement

Mr. Asim Rauf Khan, Project Director, Water and Power Development Authority, Khanpur Dam Project and Muhammad Bashir are greatly acknowledged for providing necessary data for this study.

References

- ACE, 1984. Geological Maps and related file record, Khanpur Dam Project by Associated Consulting Engineers (ACE).
- Ali, S.M., 1993. Third Periodic Inspection Report on Khanpur Dam Project. Published by Associated Consulting Engineers, Lahore Pakistan.
- Khan, M.S., Gillani, T.A., Gul, A., 2011. Post impounding problems and management measures in carbonate geology at Khanpur Dam Project. *Journal of Science International*, 23, 1232-1236.
- Khan, M.S., Qureshi, M.S., 2004. Application of grouting for seepage reduction and dam safety in carbonate geology, its management and evaluation. *Journal of Science International*, 16, 265-270.
- Romanov, D., Gabrovsek, F., Dreybrodt, W., 2003. Dam sites in soluble rocks, a model of increasing leakage by dissolutional widening of fractures beneath a dam. *Engineering Geology*, 70, 17-35.
- Shah, S.M.I., 1977. *Stratigraphy of Pakistan*. Geological Survey of Pakistan, Quetta, Memoirs.
- Turkmen, S., 2003. Treatment of seepage problem at the Kalecik Dam Turkey. *Engineering Geology*, 68, 159-169.
- Uromeihy, A., Barzegari, G., 2007. Evaluation and treatment of seepage problems at Chapar Abad Dam, Iran. *Engineering Geology*, 91, 219-228.
- WAPDA, 1999. Khanpur Dam Project, sinkhole treatment diagram and Note by Project Monitoring Organization, Tarbela Dam.