OCCURRENCE OF TURBID FLOWS FROM WELLS AT KHANPUR DAM

PRESENCE D'ECOULEMENTS TROUBLES DANS DES PUITS AU BARRAGE DE KHANPUR

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SYNOPSIS Khanpur Dam is located across Haro river which is approximately 15 Km from of Taxila. It is a dual purpose project for irrigation and municipal water supply, with gross reservoir capacity of 0.107 million acre ft. at normal reservoir elevation of 1982. The main embankment which closes the main Haro valley is 1560 ft. long at its crest and has maximum height of 167 ft. and is founded on deep alluvium (> 200 ft.) with an upstream impervious blanket.

In August 1986 when reservoir level rose to EL 1938 from 1924 elev. There were heavy turbid flows from the wells at downstream toe in the river section. Subsequently such events occurred recently another major incident occurred discharging 1.6 mcft. Several possible reasons for the turbid flows were investigated considering the source of fine material from upstream impervious blanket, shale bed rock, gouge material in the lime-stone joints, grouting material, reservoir sediments but require further study. The seepage from the alluvial foundations remains according to the reservoir levels and as such safety of dam has not been jeoperdized however vigilance during major incidents is required as downstream of wells, high pressures are indicated at several points and filters under downstream shoulder have deteriorated.

INTRODUCTION

Khanpur Dam is a 167 feet high zoned embankment Figure-1. In the river bed, a cut off to bed rock (which is 220 ft maximum) was considerably expensive and an upstream blanket 2900 ft long with thickness of 25 feet near core to 5 feet at upstream end has been provided; for location plan and structure layout refer Figure 2&3. The blanket, periphery is tied to shale where available and a single line grout cut off was provided where limestone was encountered. On right side dental concreting above elevation 1920 was done. Fig. 1,2&3.

During construction an involuntary impounding and sharp rise of reservoir from Elev.1840 to 1900.8 occurred. This caused spontaneous development of seepage, sand boiling and bogginess downstream of main dam.At that time only one well in river section had been installed and it flowed to more than 3 curces. A weighted berm and relief wells at 12.5 feet centres were installed. Because of lack of water supply distributing structures at Islamabad and heavy seepage through foundations and left abutment of main dam and elsewhere from the saddle embankments, the reservoir was impounded to maximum of 1950 Elev. in 1983, 1956 elev. in 1984, 1965 elev. in 1985 and 1962 in 1986. However due to large seepage from right saddle embankment, the reservoir was operated so as to be close to spillway crest of 1947 elev. For remedial measures to right saddle embankment, the reservoir was lowered to 1920 Elev. and on 4th August 1986 reservoir rose sharply from 1924 elev. to 1949 Elev. in couple of days and muddy water flowed through several relief wells and d/s of the drainage ditch through alluvium, with some piezometers showing as much pressure as 8 feet above the relief well top. It was decided to chock the relief wells giving muddy flows with pea gravels topped by coarse sand. This action was necessary as the turbid water was continuing from 4th August to 9th August but after choking of the relief wells and covering of other spots of turbid flows by sand, no turbidity was observed in the other close bye wells or elsewhere in ditch/downstream area:

PROBABLE CAUSES OF TURBID FLOWS

Several hypothesis were formed for explaining the phenomena and these have been discussed.

1. Blanket Malfunction/Core Failure

Blanket was inspected by side scan sonar survey and four minor sinkholes, were detected Figure-3 but compared to the quantity of material which came out, the volume of sinkholes was insignificant, the quantity of fines was estimated at 25,000 cubic feet (cft) from wells however considering flow from ditch etc the estimate would be 50,000 cft. The fines were finer than 80 u, consequently o73 about 250,000 cft of material of blanket/ core when processed would have produced the 50,000 cft of fines passed through wells/ ditches.

Main embankment dam also showed no indication of any settlement/depressions.

For any malfunction of blanket/core of main dam seepage should have increased which was not the case however the relief wells discharging turbid flows showed continuous rise at the expense of total seepage which was according to seepage recorded previously at corresponding reservoir levels.

There was a waste dump near upstream toe of dam on right which was large enough to produce the quantity of fines passed but no depression /sinkhole was observed.

Similarly no depressions were noted in the blanket which could be caused by removal of silt lenses within alluvium

2. Density Current Theory

The reservoir rise before the incident was as a result of occurrence of floods. Density current or gravity flows could somehow gain entry to the alluvial and then on to the relief wells/ditches.

Incoming flood flows could scour the valley in the gorge portion of Haro river/Nilan Kas upstream of the upper periphery of the reservoir and then find entry to the open work gravels of a possible burried valley with permeability of 10^{-1} cm/sec and continue under the blanket to downstream wells and ditch. This would presuppose a continuous open work gravel formation. Also the sampling of suspended sediment load of Haro river does

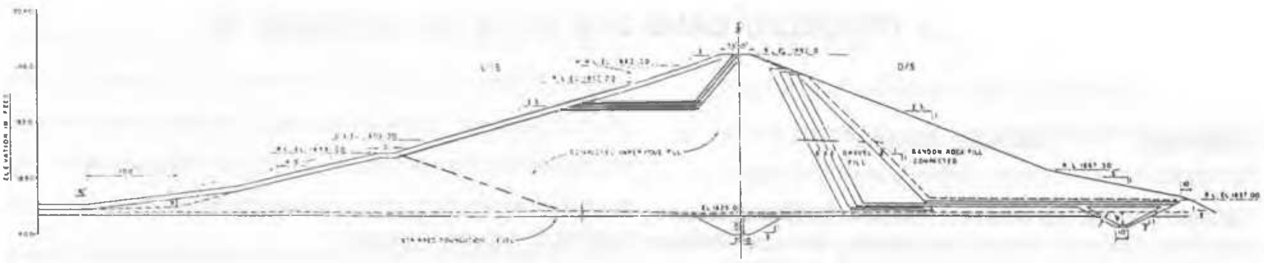

FIG. 1 Typical Cross-section of Khanpur Dam

FIG. 2 Location of Khanpur Dam

not show as high concentration as recorded by the wells having turbid flows. Also density current does not form unless sediment concentration of inflow is larger than 11000 ppm (30 kg/cum) and also should contain fines of less than 0.025 mm grading.

3. **Liquefaction of Shales of Left Abutment**

   This was too remote an idea and no evidence was found inspite of an earthquake prior to the incident.

4. **Hydraulic Fracturing of Core.**

   The main argument against this to happen is that no change in seepage at downstream toe has been recorded. Such a phenomena would be progressive leading to failure of embankment.

5. **Effect of Left Abutment Grouting**

   The event of turbidity was simultaneous with the grouting of left abutment and resulting partial blockage of drainage system which indicated rise of 10 to 20 feet. High grouting pressure involves sufficiently high pressures to initiate turbidity however the quantity of grout which was pumped into the abutment was fraction of the volume of fines of turbid flows.

   Gouge material from rock formation of left abutment also is very little, although it is closest to the colour of fines of turbid flows.

INVESTIGATION OF THE CAUSES

Several more incidents of mud flows occurred subsequently with details as below.

No.	Date of incident	Reservoir Level	Duration Hrs.	Quantity Cu.ft	Well showing turbidity
1	04.08.86	1938	105	25000	02.10.19
2	25.08.87	1915	20	10	
3	11.10.87	1928	45	150	
4	12.03.88	1911	27	10,29	
5	04.07.88	1919	110	30000	10,11,27 28,29
6	11.07.88	1926	18	3900	11,21,26 27,28,29
7	16.07.88	1940	76	16000	3,11,21, 22,25,26 29,30
8	31.07.88	1953	140	14600	25,29
9	30.07.89	1915	10	1277	3,4,11, 12,21,22, 25,29,30
10	31.07.89	1920	11	2842	
11	13.10.89	1936	14		
12	30.01.92	1939	20		
13	03.08.92	1952	40		
14	17.08.92	1969	-		
15	09.09.92	1982	57 days 1.6 m.cuft		

Colour of Fines from Turbidity

Colour of fines from wells where turbidity was experienced was matched with material used for blanket, for core, gouge material of limestone strata of left abutment, suspended sediment sample from Haro river upstream, grout mix, shales. This exercise was inconclusive.

Path of Turbid Flow Entry into Wells

a) Possible route through the bedrock joints of left abutment through the lower limb of syncline into the limestone strata LM8 day lighting below relief wells RW10 and RW37 which were the drainage wells through which the first event turbid flows occurred Fig.4.

   It may be mentioned that during construction stage, when a freshet raised the pond level from 1840 elev. to 1900 elev. only one well was installed in the valley and its discharge rose to over 3 cusecs. Subsequently each well which was put in to relieve close bye well carried discharge greater than 3 cusecs whereas the well which was relieved of flows recorded less than 1 cusec. This phenomena resulted in connecting the deep permeable strata to the wells and provided path to the fines freely to the wells.

b) The other path is possibly a continuous open work under the blanket to upstream periphery of blanket or at other location on the periphery. The flood inflows at inlet to the reservoir would have sufficient velocity to curry even sand particles and as such a filter would develop to exclude reheated mudflow incidents which has not developed so far the last incident of Sept.1992 carrying 1.6 million cuft puts doubt on the source of fines.

c) Large dumping of materials was done close to Left abutment as portion of the side slope could not be treated with dental concrete. Again the problem is that a filter should develope to exclude subsequent events as the material dumped had only 20% of fines of grading passing dowstream.

FINDINGS AND RECOMMENDATION

It is apparent, the key to the situation is that seepage has not increased execpt that wells carrying mudflows increase their discharge in relation to the other well closebye. The mechanicsm of seepage control for the dam is therefore not affected.

All the filters in wells around the screen and the downstream drainage mattress have deteriorated due to the mudflows more so when the mud flow ceases. This is evident o73 from high pressures downstream of the drainage wells. No. adverse boilling or piping has happend as downstream of dam large amount of waste fill was dumped to some distance.

However the filters need rehabilitation as it would affect the seepage control features of the dam and may eventually lead to piping failure.

It is surprising that mudflows through wels have continued and no filter effct has hapened in the processing of fines during the mudflows.

It is requried to be vigilant during a major incident and find out the path for the mudflows at inlet of reservoir or along the left abutment.

Bed material sampling along lelft periphery of reservoir may reveal the source of fines. Echo sounding using low frequency echosounder may determine the sediment thickness deposited by the inflows.

It is required to design a filter suitable for wells by experimenting in a large permeater as done for the problem of sinkhole development in Auxiliary Dam of Tarbela.

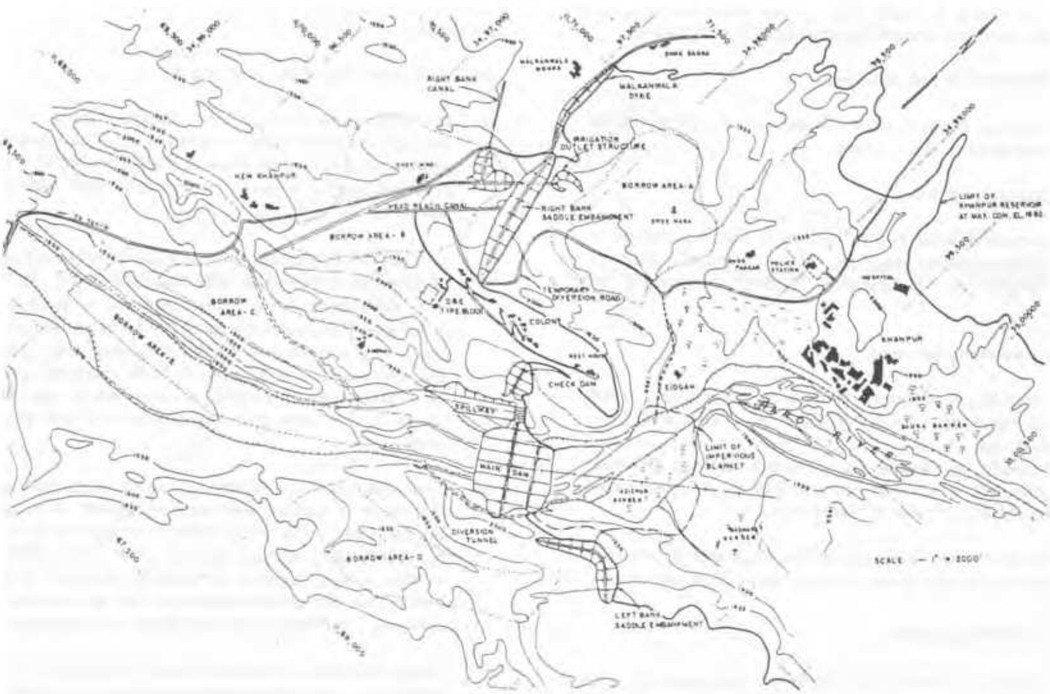

FIG. 3 Lay-out of Various Structures of Khanpur Dam

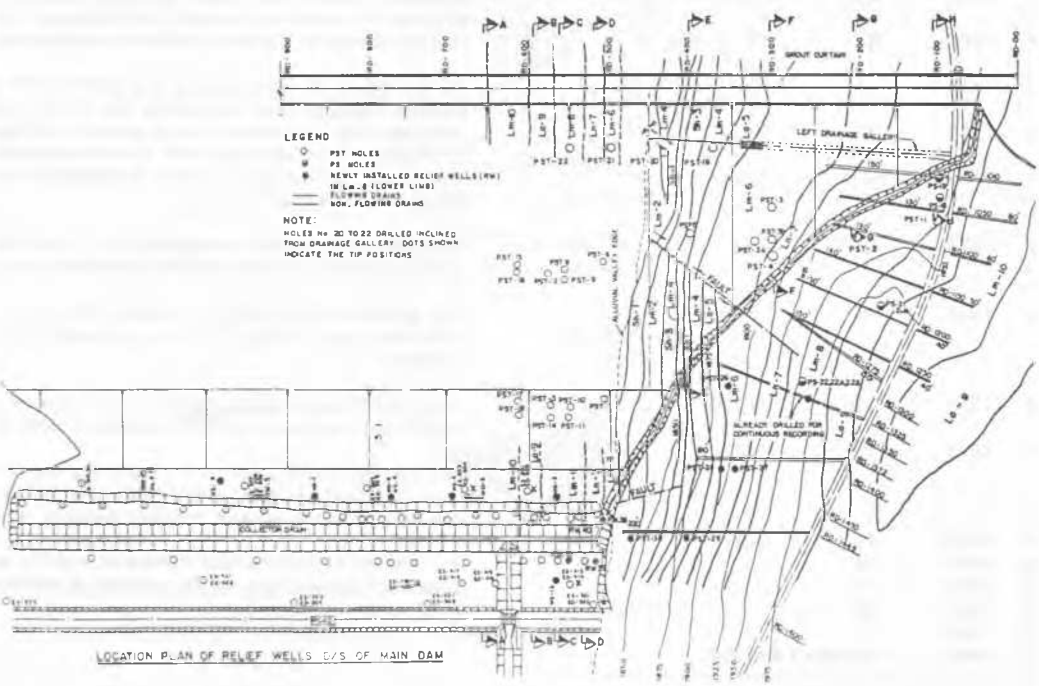

FIG. 4 Location of Drainage Wells at Khanpur Dam