KOLDAM SPILLWAY GATE FAILURE

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ABSTRACT

Spillway gates provide a vital safety function by ensuring that flood water is discharged and thus protect the integrity of the dam. Therefore the understanding of any spillway gate failure is essential and this knowledge would be of much help in the context of an overall dam safety risk assessment. In this paper we present a case study of spillway gate failures in a recently commissioned hydrodam in Himachal Pradesh. The results from gate failure analysis suggest that the quality & reliability of the procedure has to be revisited during the fabrication of the spillway valve gate.

INTRODUCTION TO KOLDAM HEEP

Koldam HEPP is an embankment dam on the Satluj River upstream of Dehar Power House of the Beas Satluj Link Project. It is 18 km from Bilaspur off the Chandigarh-Manali Highway (NH-21) near Barmana in Himachal Pradesh, and approximately 150km from Chandigarh. The reservoir created by the dam can hold up to 560 million cubic metres of water. The dam was recently commissioned by NTPC Limited.

The project comprises of a 167m tall rock and gravel fill clay core dam with a crest length of 474m and a chute-type spillway with six 17.1m wide and 17.74m radial gates situated to the left of the dam. It further comprises of a surface-type 135m x 42m x 48m powerhouse containing four vertical Francis-type 200MW turbines to be operated with 144m hydraulic head, an open-type tailrace channel 100m in length and a surface/conventional-type switchyard.

Power generated from the Koldam HEPP will be fed into the national grid via the 400kV D/C line. The plant's power output will be supplied to a number of Indian states including Delhi, Haryana, Punjab, Rajasthan, Uttar Pradesh, Himachal Pradesh, Jammu and Kashmir, and Chandigarh. The host state Himachal Pradesh is entitled to receive 15% of the generated power free of cost and a further 12% at bus-bar rate.

KOLDAM SPILLWAY GATE VALVE FAILURE

Worldwide incidents of spillway gate failures included the total gate system - hardware, software (design) and liveware aspects (Hobbs and Azaredo 2000), as well as power supply, distribution systems, gate controls, hoists and the gate itself). Major failures were categorized based on the potential risks that have caused dam failures and those that have not caused dam failures. [ ].

The general causes of failures were categorized as

a) corrosion of the steel trunnion pins [Folsom Dam in California (USBR 1995)]
b) vibration due to eccentricity of the trunnion bearings [Wachi Dam (Yano 1968)]
c) cavitation when the control gate became stuck during the construction phase of the dam in 1974.
d) Operational failures of gates due to severe winter conditions and
e) debris accumulation

Koldam hydro project spill way flap gate valve suddenly collapsed during operation. The incident occurred on 29.08.2016 just after a month of commissioning of the dam. The purpose of the gate was to remove any floating debris when the dam gets full. As such the need for gate operation was minimum in the limited period from the date of commissioning of the dam. This paper describes the investigation to find the root cause of the failed component.

During inspection by site, it was observed that front plate of the rectangular box beam/girder was found sheared in between the lifting brackets. The plate between the spindle support flanges cracked in the middle. The beam plate got detached from the girder plates on either side due to the tearing of shop welded joint along the length of girder. (Fig-1). Secondary damages were also observed (Fig-2). Representative samples were collected from site for investigation at NETRA. The sample details are given in Table -1.

Table 1: Details of the plate samples

S.no	Description	Dimension (Width X Thickness)
1	Fractured plate with weld splatter on the fractured edge	400 m X 14 mm
2	Fractured plate-opposite part of above	400 m X 14 mm
3	Plate slightly away from failure	400 m X 14 mm

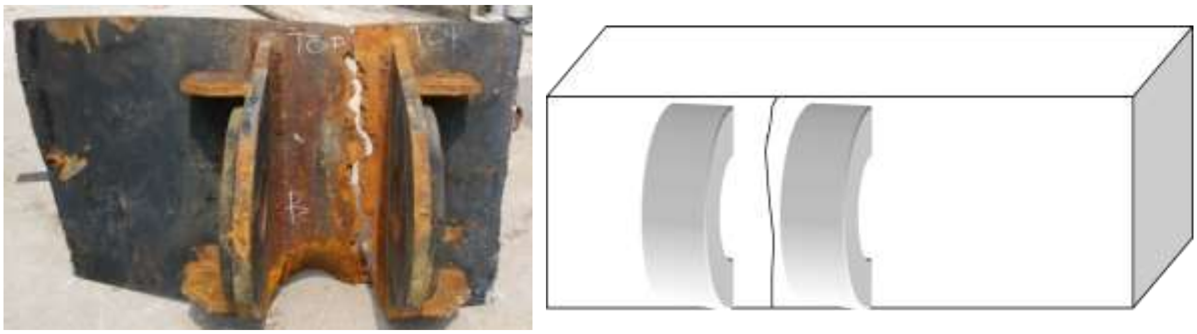

Figure – 1 (a-left) Failure in the plate between the spindle flanges, (b-right) Schematic diagram showing the failure in between the spindle support flanges. Spindle is bolted across the flanges. Bolt was missing. No damage observed to the holes in the flanges

Figure – 1 (c-left) Photograph showing operational spill gate (back side view) Note the arrangement of rectangular girder beam and the two spindles on either side for operation of the gate (d-right) Photograph showing failed spill gate (top view). Note one of the girder beam plates jettisoned out in the failed spill way gate

Figure – 2 (a-left) Spindle in free state after failure RHS plate broken, (b-right) Spindle in place after failure LHS plate got deformed

Visual Observation

Spill way flap gate plate failed in between flange area across the 400mm width of the plate. The inner surfaces of the plate showed weld splatter deposits on the fracture edge just below the top surface.

Figure – 3 Weld splatter observed on the inner surface (inside the box beam) near the fracture (top & middle). Plate edge (bottom)

Microstructural observation

Microstructural analysis of the plate near fracture edge showed presence of weld porosity & oxidized edge. Further weld structure with different layers was observed at the surface of the plate. Weld build up was observed in all the samples studied along the fracture edge. The thickness of the weld build up varied and was as high as half the thickness of the plate (14 mm) in some places.

Figure – 5 Polished surface of the failed plate in two different locations – cross section near the metal deposit due to the weld torch and cross section across the length of the plate

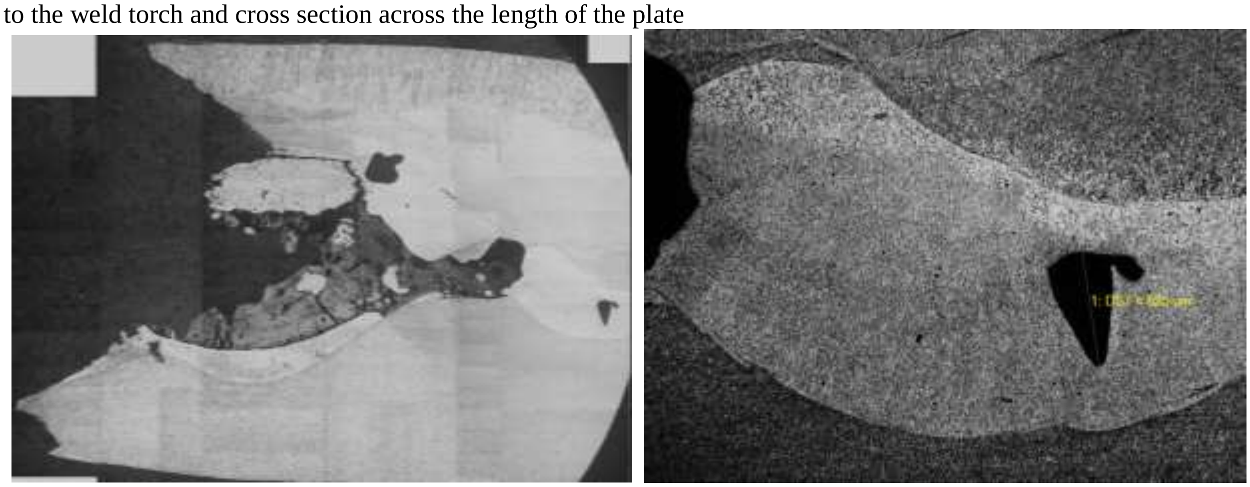

Figure – 6 Microstructural observations showed weld deposits near to external surface in the fracture edge sample. Slag and porosity were observed.

Microstructure of the plate material showed inclusions near the fracture edge. However, the IS code does not specify inclusion rating.

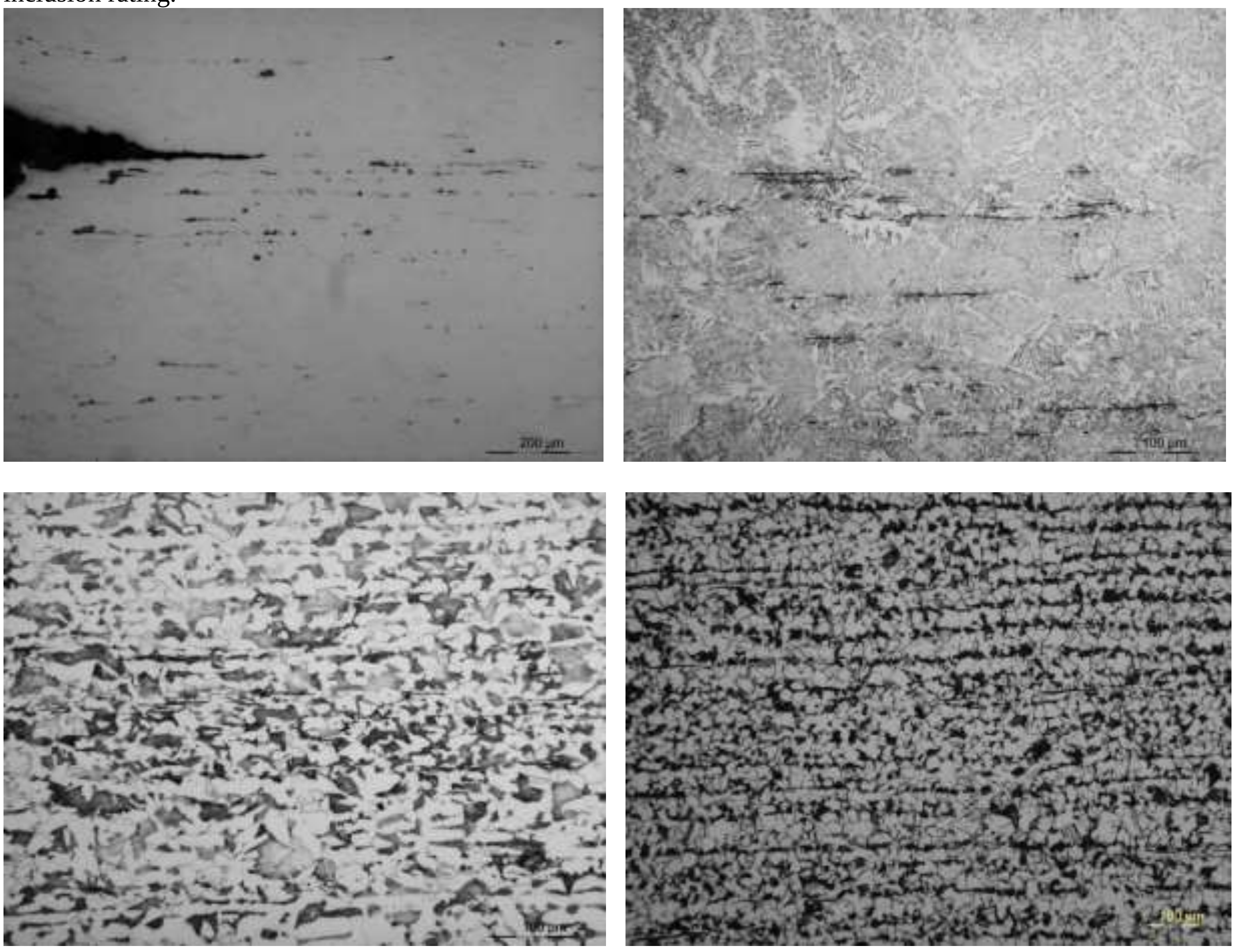

Figure – 7 Microstructural observations showed inclusions near the fracture edge as well as in the plate material away from failure. Ferrite & pearlite structure was observed.

Chemical composition

Chemical composition of the steel plate and the weld build up was analyzed using Optical Emission Spectrometry (OES). The material conformed to E410 (Fe 540) grade composition as per IS 2062:2006. Chemical analysis of weld build up showed low carbon as compared to the base metal.

Steel grade	C %	Si %	Mn %	S%	P%	CE
E410 (Fe 540) grade As per IS 2062:2006	0.20 max	0.45 max	1.50 max	0.045 max	0.045 max	0.44
Analyzed (base metal)	0.17	0.31	1.45	0.043	0.027	0.43
Analyzed (weld build up)	0.14	0.37	1.21	0.023	0.024	-

Mechanical Properties

Hardness of the plate was measured through the thickness of the plate in three different locations.

Table 2: Hardness of steel plate

Fracture edge - WS	195	171	139	172	182
Fracture edge – WB	286	274	269	257	248
Away from Fracture edge – BM	233	221	265	218	227

[WS – Weld splatter, WB – Weld build up, BM – Base metal]

Charpy impact strength of plate near the failure showed much higher energy values.

Sl No	Description	Y.S, Mpa	Tensile Strength Mpa	Elongation %	Charpy V Notch Impact Energy, J	
					RT	-20ºC
1	E410 (Fe 540) grade As per IS 2062:2006	410 min	540 min	20 min	50	25
2	Analyzed (plate build up sample)	468.2	572.3	17.3	240,240,260	166,200,180

In the present case the failure of individual gate valve has not resulted in any serious consequence but the possibility exists if breakdown occurs at a critical time of flood release. It appears that the spindle support flange was inadvertently welded short of distance so as to support the spindle head. To rectify the mistake the welded flange was removed using gas cutting as was evident by the presence of molten metal near the fracture edge. The flange was then properly welded at the required distance so as to correctly hold the spindle. To fill up the gap welding was done with similar material composition. Microstructural change & hardness values through the thickness have established this fact. At spillways, the gates, hoists and controls are all made up of similar plate material and failure of a single gate can be followed by failures at other gates. Therefore the practice of weld repair in seemingly insignificant location should not be allowed.

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