

Performance Assessment of Taunsa Barrage Subsidiary Weir for Long Term Rehabilitation Planning

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Abstract

Taunsa barrage has been rehabilitated by constructing a subsidiary weir at 800 ft distance from the barrage crest. The stilling basin floor was strengthened by replacing 2 ft top layer with 3 ft thick, high strength structural concrete, whereas the impact and friction blocks were replaced by chute blocks and end sill, respectively. While designing rehabilitation project at Jinnah barrage the Detail Design Consultants proposed a similar structure, the subsidiary weir to be constructed at 600 ft from the barrage crest. The replenishment of loose stone in gabion is recommended whereas the stilling basin floor was considered adequate.

Arguments have emerged regarding hydraulic justification of subsidiary weir being proposed at the Jinnah barrage. It looks imperative that the energy dissipation systems of both the barrages are to be reviewed. Furthermore, suitability of the constructed subsidiary weir at Taunsa barrage is to be studied to establish its role in the barrage operation.

This research indicated that both the barrages have distinct energy dissipation mechanism; therefore the provision of subsidiary weirs may independently be justified. The study revealed that the energy dissipation system at Taunsa Barrage is jump type, whereas it is impact/jump type at Jinnah barrage. Tail water levels at Taunsa barrage are adequate indicating that the subsidiary weir was not required. The proposed subsidiary weir at Jinnah barrage would change energy dissipation concept and will have serious hydraulic consequences. Furthermore, the subsidiary weir adversely affects hydraulic functioning of these barrages and reduces their discharging capacity.

Key Words: *Taunsa barrage, Jinnah Barrage, Subsidiary Weir, Rehabilitation of Barrages, Retrogression*

1. Introduction

Rehabilitation of an existing hydraulic structure is a challenging task. A hydraulic structure can only be rehabilitated if hydraulic/structural deficiencies are precisely identified [1, 2]. Feasibility Report [3] noted that the stilling basin floor and impact blocks were repeatedly damaged at Taunsa barrage. Excessive retrogression and consequently sweeping of hydraulic jump were considered as the main reasons for these damages [3]. Special Committee Report [4], First Report [5], Second Report [6], Report of 1973 Committee [7], Evaluation Report [8], Expert Group Report [9] observed that the sweeping of hydraulic jump occurred at higher discharges ($> 400,000$ cusec). Chaudhry [1] noted that the ripping of concrete floor in stilling basin could be a concrete quality problem instead of a hydraulic issue. The ripping of concrete floor was never reported at Jinnah Barrage, in spite of having higher velocities in stilling basin as compared with that of Taunsa Barrage.

In Year 2008 a subsidiary weir has been constructed at 800 ft downstream of the Taunsa barrage. The Design Report [10] proposed a similar structure (subsidiary weir) to be constructed downstream of the Jinnah barrage.

2. Taunsa Barrage Details

Taunsa barrage consists of 53 weir bays; whereas left and right undersluices are having 7 and 4 bays, respectively. The barrage width between abutments is 4346 ft and clear water waterway is 3862 ft. Two divide walls bifurcates weir and undersluices sections of the barrage. In left and right undersluices, along the divide walls two fish ladders are provided. Taunsa barrage has 22 ft wide navigation bay and silt exclusion system in its right and left undersluices, respectively. The barrage is designed for a flood of 1,000,000 cusec; however a super flood of 1,200,000 cusec may pass without endangering the barrage. It is mentioned earlier that a subsidiary weir has been constructed downstream of the barrage to raise tail water level (Figure 1(a)).

3. Jinnah Barrage Details

Jinnah barrage consists of 42 weir bays; two undersluices each consisting of 7 bays with clear span of 60 ft. The barrage width between the abutments is 3781ft, whereas clear waterway for the weir and undersluices sections is 2520 ft and 420 ft, respectively. Two divide walls bifurcates weir and undersluices sections of the barrage. In

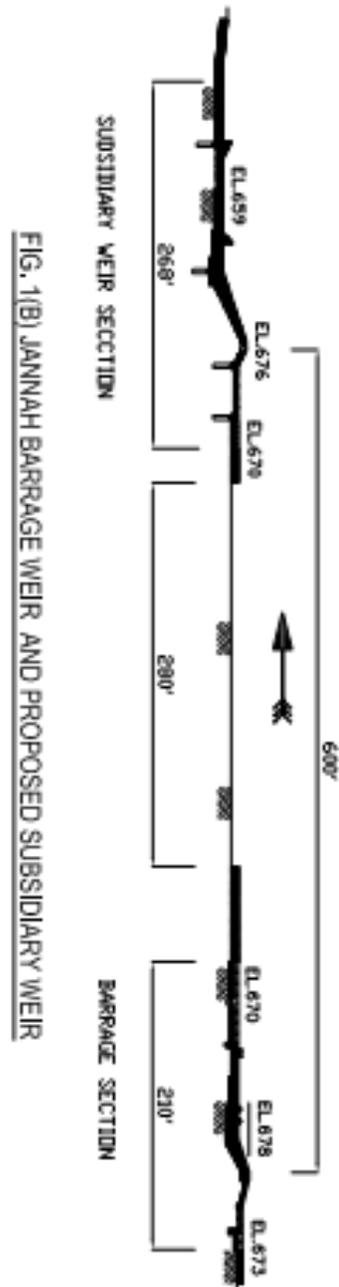
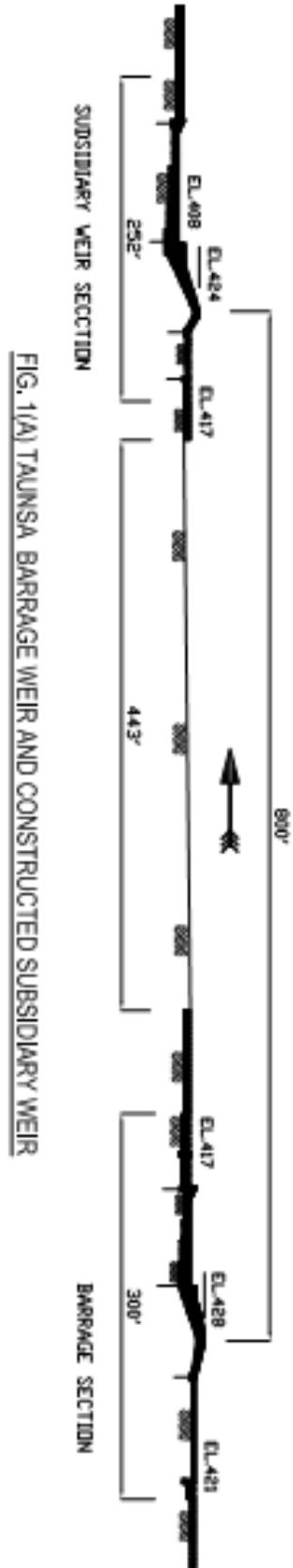


Fig. 1 Long section of Taunsa and Jinnah Barrages and subsidiary weirs

left and right undersluices, two fish ladders are provided along the divide walls. The design discharge of this barrage is 950,000 cusec; however a super flood of 1,100,000 cusec may be passed through the barrage. It is earlier mentioned that to raise tail water level, a subsidiary weir has been proposed at 600 ft distance from the barrage crest (Figure 1(b)).

4. Performance Evaluation of Taunsa Barrage

4.1. Reasons for Damages at Taunsa Barrage

Extensive studies were carried out in the past to establish reasons of uprooting of impact blocks and ripping of concrete floor. IRI Report [11] noted that Taunsa barrage had withstood maximum retrogression and accretion trend had already been set in. It was further observed that the barrage is hydraulically safe up to a discharge of 1,000,000 cusec.

Feasibility Report [3] noted that “the excessive retrogression at Taunsa barrage has been one of the most serious problems. The tail level has been lowered by about 7 ft with very little dissipation of kinetic energy. Model Study Report [12] has noted that due to the presence of excessive retrogression, safe capacity of the barrage has been reduced. However, the analysis of tail water levels data (Table 1) revealed that the existing water levels were adequate to form hydraulic jump on glaxis.

It is pertinent to mention here that the retrogression at Jinnah and Taunsa barrages are almost the same. Furthermore, the distance between crest and downstream

floor is 8 ft at Jinnah barrage whereas this value is 12 ft at Taunsa barrage. The downstream velocities remain higher (due to less water depth by 4 ft) at Jinnah barrage as compared with that at Taunsa barrage. Possibility of floor ripping and impact blocks uprooting could be more at Jinnah barrage, however no such damages have ever been reported.

Chaudhry [13] noted that the damages at Taunsa barrage stilling basin floor could be due to poor quality structural and mass concrete. Structural concrete of 1 ft thick was insufficient; consequently the mass and structural concrete were separated. Uprooting of impact blocks occur because they were not properly anchored. In case of Taunsa barrage the skin concrete thickness (1ft) was insufficient to hold impact blocks.

4.2 Retrogression

Feasibility Report [3] noted that the tail water level had gone down by about 7ft and 4ft, in case of gated and ungated flow, respectively. Feasibility report further mentioned that the tail water level at the design discharge of (1,000,000 cusec) is EL444; consequently prevailing water level, considering retrogression of 4 ft shall be EL440, whereas the tail water level maintained in physical model study was EL433.40 (Table 1). The hydraulic conditions developed at physical model were totally dissimilar to that of prototype (Figure 2). It is to be noted that in Year 2009 the observed tail water level for various discharges were quite adequate. Figure 3 shows that the jump remains above middle third of glaxis. It seems that the provision of subsidiary weir on Taunsa barrage was conceived mistakenly [14].

Table 1 Water Level at Taunsa Barrage

Discharge cusec	Tail Water Levels (EL)				
	Design Repot 2005	Model Study Report IRR-1172			Recorded Year (2009)
	U/S S-Weir	U/S S-Weir			
		Min Required for Jump Formation	Attained	Maintained D/S Sub-Weir	
100000	428.00	423.50	428.50	425.50	428.00
200000	430.00	427.00	430.50	428.00	428.80
300000	432.00	429.00	432.25	429.50	429.60
400000	433.50	430.70	433.50	430.30	-----
500000	435.00	432.50	434.75	431.10	-----
600000	436.20	434.20	436.00	431.70	-----
700000	437.50	435.50	437.00	432.20	-----
800000	438.50	437.00	438.00	432.70	-----
900000	439.50	438.00	439.00	433.10	-----
1000000	440.50	439.00	439.75	433.40	-----

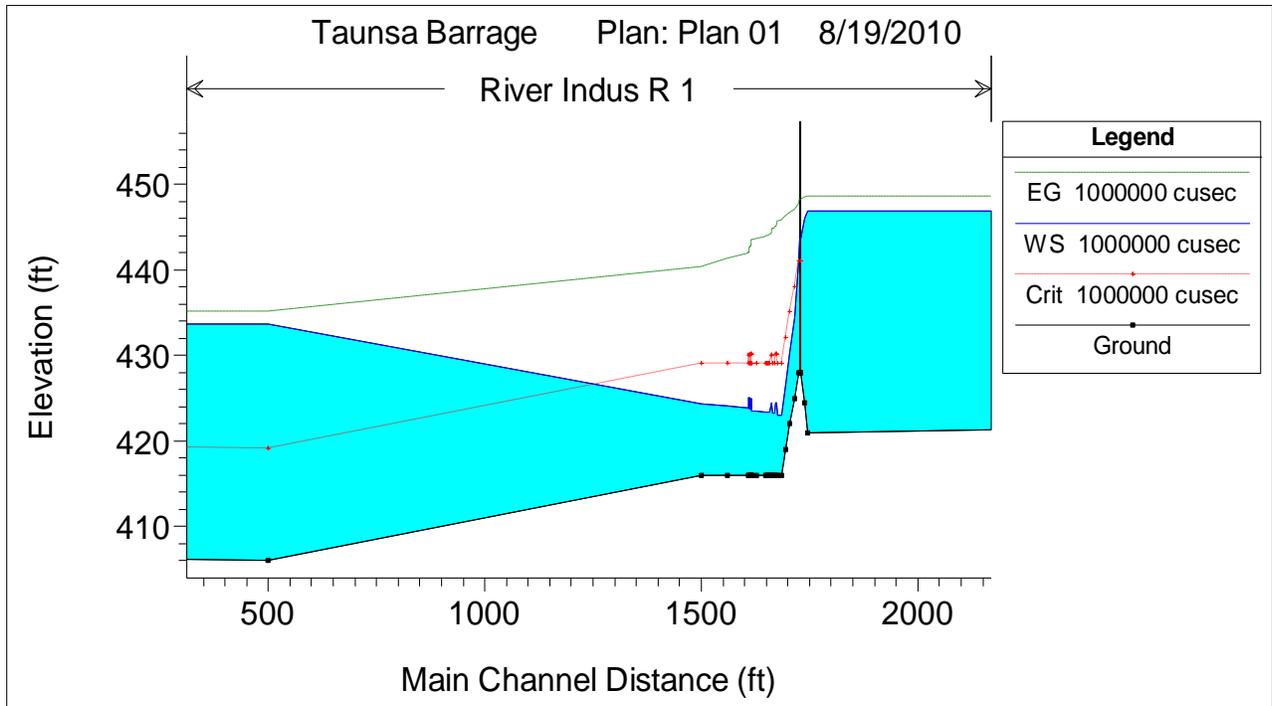


Fig. 2 Profiles at the discharge of 1000000 cusec, (Tail water level EL 433.40)

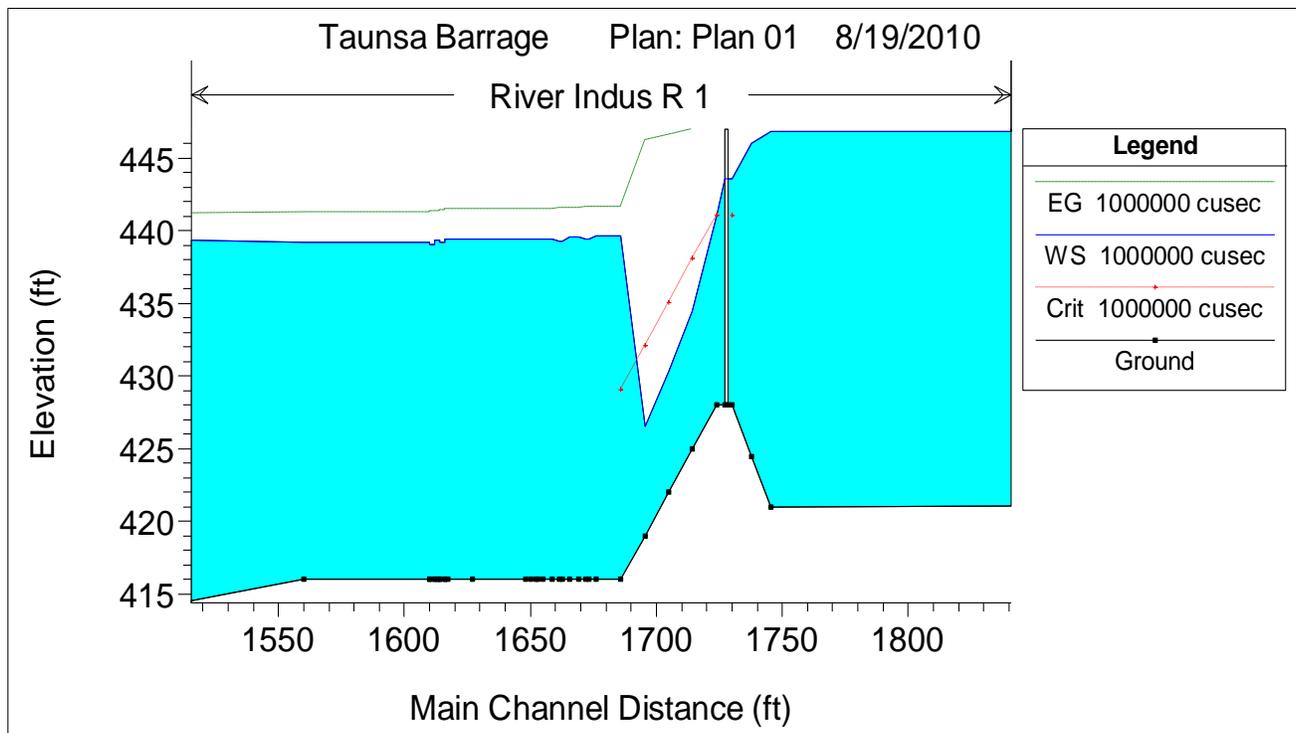


Fig. 3 Profiles at the discharge of 1000000 cusec, (Tail water level EL 439.50)

4.3 Energy Dissipation

Feasibility Report [3] noted that due to the drop in tail water level the efficiency of stilling basin has been reduced by 70%. It is already stated that the tail water levels are adequate and further rise of tail water level with the construction of subsidiary weir is inconsequential. The efficiency of stilling basin may remain unchanged after the construction of subsidiary weir.

The replacement of impact blocks with chute blocks during rehabilitation may not be a logical decision. Impact blocks enhance mixing and reduce water velocity near the channel bed. Furthermore, the loose stone apron is being placed at EL417 as compared with its original level (EL416). Relatively higher velocities/turbulence may further increase launching of loose stone apron [15].

4.4 Head Across and Seepage

Model Study Report [11] noted that the excessive retrogression in water level has increased exit gradient. It is pertinent to mention here that the existing water levels upstream and downstream of the subsidiary weir are almost the same (Table 1). The model study report did not mention how exit gradient will be abridged after the construction of subsidiary weir. Head across and exit gradient before and after the construction of subsidiary weir remained almost unchanged.

4.5 Discharging Capacity

Reduction in discharge capacity of a barrage may develop high level floods on its upstream and endangers protections bunds. The Model Study Report [11] mentioned that "Taunsa barrage was designed for a discharge of 1,000,000 cusec but due to excessive retrogression, safe discharging capacity has been reduced".

The specific discharge through a barrage/weir depends upon head and drowning ratio. The constructed subsidiary weir has raised water level on its upstream; consequently the drowning ratio has been increased. The increase in drowning ration has reduced discharge coefficient and consequently the discharge capacity of Taunsa barrage has been reduced. Moreover the crest level for barrage (EL425) and subsidiary weir (EL424) is almost the same; the channel flow may develop at undersluices for un-gated flows.

4.6 Annual Inspection and Maintenance

Inspection of floor and river survey is usually carried out in winter when downstream water depth becomes very low. After the construction of subsidiary weir the water level between barrage and subsidiary weir remain above 8 ft, consequently the river survey and floor inspection becomes too difficult. Replenishment of loose stone apron

and repair of floor in deep water is expensive and difficult. Furthermore, additional resources would be required to maintain two independent structures (Barrage and Subsidiary weir).

5. Jinnah Barrage and Proposed Rehabilitation Project

Jinnah barrage has passed more than 64 years of its life quite comfortably. No structural damages were reported in the past except the impact blocks have been replaced in Year 2003; first time since the barrage was constructed. At present the blocks were in good health. Design Report [10] also noted that the concrete strength of stilling basin floor, glacis, divide walls, is greater than 4000 Psi.

The Design Report [10] proposed a subsidiary weir to be constructed at 600 ft downstream of the barrage. Divide walls are to be extended up to the subsidiary weir and further down to bifurcate weir and undersluices sections of the barrage. After the construction of subsidiary weir and divide walls three channels will be developed between barrage and the subsidiary weir. The navigation bay shall also be extended up to subsidiary weir.

5.1 Energy Dissipation Concept and Discharge Capacity

The weir section of barrage has crest and floor levels at EL678 and EL670, respectively, whereas corresponding levels at undersluices are EL675 and EL667. Alternative Report [1] noted that to develop hydraulic jump on glacis the stilling basin floor should be at EL664, indicating that existing level is up by at least 6 ft. If retrogression of 7 ft is assumed than the floor will be at EL662. Feasibility Report [10] noted that the subsidiary weir stilling basin should be at EL659, indicating that barrage stilling basin is up by 11ft.

It is pertinent to mention here that length of downstream glacis is 25.3 ft (1:3 slope), which is inadequate to keep hydraulic jump on it. Even if stilling basin floor is assumed at EL664, length of glacis will be 44.3 ft. The deficient glacis length cannot be addressed without lowering stilling basin floor level [15]. Energy dissipation concept at the Jinnah barrage is therefore different as compared with that of Taunsa barrage.

Energy dissipation system at Jinnah barrage is consisted of stilling basin and two rows of impact blocks, whereas two rows of friction blocks are placed as end sill. Chaudhry [2] noted that the arrangement is efficient and is not very sensitive to downstream water depth. If water depth becomes less than the conjugate depth, the impact blocks will take impact of water and divert it. Energy dissipation takes place partly in air and partly in water, whereas the

friction blocks help in controlling water depth and allowing shingle to pass.

As stated earlier, a subsidiary weir is being proposed downstream of the Jinnah barrage [10]. The elevation difference between barrage and subsidiary weir crest is just 2ft. The barrage crest in undersluices section is the same as that of the subsidiary weir. The proposed subsidiary weir will raise water level and consequently increases drowning ratio at the barrage. The increase in drowning ratio will reduce discharge capacity of Jinnah barrage and endangers flood protection works on upstream. The channel flow may develop at undersluices and hydraulic control may shift at the subsidiary.

6. Conclusions

Hydraulic performance of Taunsa barrage with constructed subsidiary weir is reviewed for assessment of need of such weirs to rehabilitate other barrages. It is noted that the tail water levels at Taunsa barrage were adequate to develop hydraulic jump on glaxis and the constructed subsidiary is not having any hydraulic significance. Furthermore, constructed subsidiary has reduced the discharge capacity of Taunsa barrage. Plugging of a breach in upstream protection bunds would be difficult in the presence of the subsidiary weir, as the pond level even at low discharges becomes high.

The energy dissipation concepts at Jinnah and Taunsa barrages are dissimilar. No hydraulic/structural problem persists at the Jinnah barrage. The proposed subsidiary weir will reduce discharge capacity of Jinnah barrage and endanger upstream protection bunds.

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