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THE KALABAGH BARRAGE

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Kalabagh Barrage was constructed for feeding the channels to irrigate the Doab between the rivers Indus and Jhelum called the Thal Project. Gross Command area by this barrage is estimated as 19.3 lac acres. According to 1940 estimates, the total cost would be Rs. 7.72 crores of which the headworks will cost Rs. 1.88 crores.

Pakki Shah village on left bank was selected as the site of headworks in 1936 because of certainty of correct cost estimation, facility of construction, shingle bed foundation, low afflux and easy access by road as well as railway etc. Maximum design discharge for the barrage has been taken as 9,50,000 cusecs after analysis of past data. There is enough freeboard to pass a superflood of 11,00,000 cusecs with increased afflux. The maximum discharge actually encountered has been 818,510 cusecs on 29.8.29. The canal has been designed to take upto 10,000 cusecs with a pond level of 694. An afflux of 15% or 3 on the normal flood level of 693 is considered suitable, giving H.F.L. upstream of 696. Excessive retrogression downstream of the weir is ruled out because of underlying shingle bed and the smallness of pond. It is taken as 2 as against 4 to 5 for other barrages. This gives a minimum downstream level of 672.00 and a maximum cross head of 22 for which the barrage is designed.

Width between abutments is 3797 based on Lacey's relationship with an average intensity of 290 for 11 lac cusecs discharge. The waterway consists of 56 spans, each of 60' clear, with 7 piers and 2 divide walls of 25 each. Undersluices, 14 spans of 60, each are provided to facilitate the diversion of river over the completed barrage, allow the unwatering of weir for subsequent maintenance and inspection, and help silt control into the canal by the formation of a deep channel near its off-take, in which low velocities of approach could be secured. The crest level of undersluices is RL 675 while the weir crest level is RL 678. Cistern levels have been fixed at RL 667 and RL 670 for undersluices and weir portions respectively. The length of cistern was calculated and provided as 70' for weir portion and 75' for undersluices. Low cistern levels and length are provided to ensure that any hypercritical flow from the weir does not pass beyond it.

The position of standing wave is stable on a sloping glacis. More intense wave is produced on flatter glacies and the range of the trough requiring heavy thickness of floor will also be greater. A series of experiments were conducted in Research Institute and a slope of 1 : 4 was adopted on the upstream side and 1 : 3 on the downstream side. The crest width of 6' is fixed. The total length of the weir floor is 140' and that of undersluices 150'.

The river has a shingle bed for several miles above the weir site. Therefore 18" quartzite sets instead of concrete are proposed for facing/pitching in those portions of the section which will be subject to movement of shingle at higher velocities. Staggered friction blocks are suggested to be provided in trapezoidal rows. Staggered friction blocks are suggested to be provided in trapezoidal rows. Originally, three lines of sheet piles viz; at upstream side, at downstream side and at the toe of the glacis were proposed but because of shortage of piles due to War, it is decided to provide one line of 7.5 piles on the downstream end. Cut-offs walls are provided on other locations. An exit gradient of 0.289, giving a factor of safety of 3.46, is calculated and it is considered to be quite safe for a shingle bed. The pressures under the floor are determined by reading off from the curves based on the mathematical solutions for elementary forms and are subsequently checked by the Research Institute.

The gravity section is preferred to raft design as shingle is locally available, making the gravity section much more economical. Inverted filters, flexible protection, deep pier foundations and flank walls are provided by using standard practices and designs. In the beginning, it was considered to provide all the 14 undersluices bays on the right side as the river after leaving the railway bridge upstream hugs the right bank. Later on however half of them are provided on right side and half on the left side for ease of unwatering, repairing and river control.

Divide wall is provided in a headworks to form a deep channel and it controls silt entry into the canals. From the examination of data, a 300' long divide wall has been found to be the best for least silt entry into the canal. Silt excluders and silt extractors are the devices for the control of silt in canals and these are provided in the headworks and canals respectively. Khanki type silt excluder was found to be more efficient and hence is adopted. Silt excluders prevent the entry of coarse rolling silt and a proportion of the suspended silt into the canal, while the silt extractors draw out or eject the suspended heavy silt from the canal. A regulator is proposed to be provided at RD 3300 of the canal in order to maintain optimum water level in the reach above it and a series of five extractors are provided in this reach. The head regulator is designed to take 8160 cusecs with pond level RL 692. With the pond level at RL 694 however, it can pass 4000 cusecs extra.

A 25 roadway is provided over the regulator while a 10 Arterial Road Bridge with one 2.5 foot walk-over the barrage is finally chosen. This bridge will serve as a road link between Punjab and NWFP. Diverging type of guide banks are proposed, as these ensure a smoother enterance and reduce the chances of lateral flow. Top levels of the marginal bunds are kept 2' higher than the guide banks so as to allow for rise in the level at the guide bank noses. A T-head spur is also provided to protect the left marginal bund. Gates and gearings were manufactured in the Central Workshops at Amritser.

Two divisions, with five sub-divisions were responsible for the construction of Kalabagh Barrage. Power Division looked after the power house and workshops whereas construction of headworks, supply of material, railway and quarry was the responsibilities of Kalabagh Division. 300 tenders were received on the basis of revised form of Haveli Schedule of rates and the average of the rates tendered approximated very closely to the schedule. Land acquisition was done by special Land Acquisition Officer.

Pitching stone was obtained from Paikhel quarry but because of certain limitations, supplement supply from Sikhanwala quarry was necessary.

Stone sets were acquired from Nowshehra and Abbotabad. The supply of shingle was arranged from a shingle quarry about 2 to 3 miles from the weir. About 120 lac bricks were obtained from the government kilns and about 80 lac purchased locally. To cope with power needs and the heavy repair work of the plant in use, power capacity of 900 K.W capacity was provided. A programme of work was drawn and 1941-42 was fixed for the completion of the barrage.

Theodolites were fixed on two high pillars on both sides of weir line for checking levels. The cill girders and grooves were also aligned from these. A 10' width on the upstream, downstream and flanks for possible drains etc, was added to the designed sections for excavation. General methods of well sinking, which are good for a sandy soil, failed for the shingle bed as the usual sand grab proved to be an utter failure in this case. The method finally adopted was to unwater the well approximately to curve level as far as possible and excavate the shingle inside and outside the well manually.

Two big concrete mixers were used. Batching was done on volume basis. Slump tests were carried out every morning in order to get rough guide for the water quantity but final adjustment was generally done by trial after seeing the workability of the concrete at site. Kalabagh barrage is the first major work where almost all of the concrete was mechanically vibrated. Curing of weir floor was done by pipe line fitted with pumps at suitable intervals wheres large mattresses made of gunny bags were used for the curing of divide walls and friction blocks. Extensive form-work was avoided because of the use of precast shells in the weir. Ordinary wooden or brick shuttering etc., were the general types used for various other works.

To check the safety of the work, a large number of pressure pipes were installed for measuring actual pressures under the barrage floor. These observations indicated that the actual pressures were 10 to 20% higher than those theoretically assumed in the design. However, these results were doubtful as observations were taken at low head and value was not assumed correctly. Other wrong assumptions were also considered in the pressures measurement and it was decided that the weighting of the floor or its extension was not necessary at present. However, it was stressed that no hollows should remain under the work and grouting must be done with great care and the pressures should be kept under observations.

A number of precautions, in addition to more extensive grouting, were taken. The shingle in bays 1 to 7 of left undersluices and 8 to 13 of the weir was excavated to the level upto which there was any possibility of runnel formation and replaced by pure sand. All cross walls were taken down to rest on undisturbed soil and all drainage water was passed through bajri filters to avoid piping. The order of pouring the concrete blocks was such as to do the lowest level work first. This was rigidly observed. Lowering of the sheet pile line in left under-sluices was also done.

Note :

Paper No. 251 appeared at pages 1 to 66 of the Proceedings of Engineering Congress 1942, Vol : XXX. It has 10 plates. the discussions on the paper are recorded at pages 251 a to 251 w, and mainly concern formulae and assumptions used in the paper. For details the interested reader may refer to the full paper.