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By

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The author had earlier presented two papers Nos. 138 and 142 in 1930 Session of Congress in which necessity of further research & observations on the subject was emphasized. This paper is a followup on those papers. Panjnad Headworks was built with 33 bays during 1927 to 29. During 1930-31, 16 more bays were added on the right side on the recommendation of Islam Inquiry Committee of 1929. The additional bays were designed according to the conclusions drawn and recommendations made in the earlier papers. The construction work further provided an opportunity for full scale prototype research. In all 90 pipes were installed in new bays No. 43, 44, 46 and behind the two flank walls of the new weir (extension). Panjnad weir is unique as regards the location and installation of pressure pipes. The old bays (i-33) and extension bays (34-47) are divided by a Junction Groyne.

The section of the old weir consisted of 60.5 of pervious floor on the upstream, 110' of similar pervious floor on downstream with an impervious length of 204' in between ending in 5' deep toe wall on upstream and 6' deep toe wall on downstream. There is 30' deep sheet pile line under the crest. Another sheet pile 25.5' deep was provided at the downstream end of 26' length of loose blocks converted into semi-pervious floor. The "Extension" consists of 60.5' of u/s pervious floor, 163' of impervious floor with 20' deep sheet pile on the upstream end, a similar sheet pile 45' deep downstream of it and another at the end of impervious floor. This was followed by 20'.5 long concrete blocks over 2.0' graded filter, 20' deep wells and 100 ft. long loose apron.

The pressure pipes have been located at different depths on both sides of the sheet piles and at suitable position along the horizontal floor as well as in the subsoil underneath. The pressure pipes were located with a view of study the influence of sub-soil flow on the lines of flow and variation in uplift pressures under the structure and to determine the projection of sheet piles beyond the flank walls. The level at which the pressure in pipe is recorded is the level of centre of strainer in case of horizontal strainer and its top in case of vertical strainer. The underlying strata contains medium to coarse sand from top down, and at places coarse sand is mixed with Kankar or clay. The strata has however been assumed to be a homogeneous medium.

The water level in the pipes was recorded by either lowering a tape weighted at the end or a float suspended in a metal cylinder and the float on touching the water surface lighted a lamp placed in the circuit. The first method was very crude and the second was some-what complicated. Another device was therefore resorted to; this was a bell sounder consisting of a brass rod of 7/8" in diameter, 3.5" long ending in an inverted cup. The sounder is lowered by means of a steel tape. The cup produces a sound on touching the water surface. This method gives accurate readings upto 1/16th of an inch.

The Panjnad canal was run for the first time in April 1932. The observations were started with the first ponding and continued upto October, 1932 when pond was released. The second series of observations were done when pond was again raised partly. The observations were repeated during lowering of the pond. Pressures were also recorded at 15 to 30 minutes intervals with rapid raising or lowering the pond to determine the time lag in various pipes. The change in the relative drop of pressure in certain pipes for the same head between the observation of the two series may be attributed to rapidly changing pond level, its low temperature and varying depth of silt on upstream pervious floor.

The observed pressures were plotted along the shortest distance between bottoms of end sheet piles and against the creep line. The pressure line joining the pipes located vertically below the upstream, middle and downstream sheet piles represent the normal sub-soil flow under the weir. Analysis of data from piers No. 43, 44, 45, 46 bays 46, 23 and 30, the right flank and junction groyne indicated that the ratio of pressure against total head (p/H) for any pipe is constant, pressure variation in the vertical direction at the upstream and downstream ends of floor is either logarithmic or parabolic and linear in horizontal direction under the entire floor. A vertical obstruction at the end or in the length of impervious floor not only deflects the stream lines but also changes the pressure distribution. Two pipes symmetrically placed between two upstream sheet piles (extension) always showed constant difference for liner range of observations irrespective of head and temperature changes.

For variation of pressures at the upstream end of floor, hyperbolic curves show a better fit if there is no silt deposit on U/S floor.At the downstream end both the logarithmic and the hyperbolic curves are equally good.

Bose had mathematically calculated that (Discussion on Author's paper 138, 1930) pressure drop on either side of an intermediate sheet pile is equal this is approximately correct. In extension bays, there is a total head loss of 6.8% at the 20' intermediate sheet pile out of which 3.8% is on U/S. The sheet pile at U/S end of floor is responsible for 50% head loss whereas similar sheet pile at D/S end gives a loss of 20% of total head. The intermediate sheet piles merely serve as a second line of defence in the eventuality of disaster and is otherwise not very effective. The plot of downstream pressures shows that residual head at exit end of floor is 1.12 i.e. 7% of total head of 16.4 and increases to 1.37 for a head of 19.5 for which the weir is designed. It therefore seems necessary to conduct experiments to determine the safe residual head with and without inverted filters. It is noted that in case of Panjnad weir at downstream end the pressure and velocity decrease in the direction of flow i.e. upward, which is unlike the phenomenon at Dugri Syphon (Paper No. 138).

The scanty data available from the three pipes inserted in each of the bays 23 and 30 afford an apportunity to compare the behaviour of two sections of the weir. The uplift pressures below the gate line of old weir is lesser by 1.3 to 4.1% but the residual head is higher, 2.46 for total head of 19.5' as compared with extension. this could cause piping through relief pipes and should be plugged to avoid considerable damage expected from their operation. The stream lines are deflected from vertical to horizontal by 31' in the old weir and by 26' in "extension". It shows that the removal of entire U/S floor of original weir will cause a small change in uplift pressures. The pressures can improve if the 30' sheet pile under the crest is moved to under the U/S end of U/S glacis. The data further indicates that if 40' long upstream floor end one sheet pile could be omitted in extension, resulting increase in pressure below the gate line will be 1. to 5%. A single 30' sheet pile is better than two sheet piles of 20'. The intermediate sheet piles of 20' and 30' give a drop of 6.6% and 10.6% respectively. The length of upstream floor can be considerably cut down without causing significant increase in uplift pressures on rest of the impervious floor.

Analysis of pressure pipe data leads to the following conclusions:-

1. The flow of water under the weir is streamlined and obeys laws of hydrodynamics for flow of very viscous fluids.

2. For any point, the ratio (P/H) is constant but silt deposit on pervious floor and temperature changes may influence it.

3. The pressure variation in vertical flow outside U/S and D/S ends is either hyperbolic or logarithmic. The velocity is maximum where water enters the subsoil and minimum at the exit end.

4. The rate of pressure drop along the horizontal floor between U/S and D/S pile lines is constant and bears a linear relation with distance. The Bligh Creep Theory is applicable only for this distance.

5. Head loss (51%) is maximum at U/S sheet pile (20') in extension.

6. A head loss of 20% is obtained with 163' long floor in extension.

7. A head loss of 21% is obtained due to downstream sheet pile.

8. Out of 28% head loss contributed by the horizontal floor, only 6.6% is due to intermediate sheet pile. The 30'

intermediate sheet pile in original weir gives a local drop of 10.6%.

9. In extension the residual head at the exit is 1.36' for maximum head of 19.5'. It needs provision of inverted filter.

10. Correct knowledge of subsoil flow can help in achieving considerable economy in large hydraulic structures by cutting down the length of U/S floor and omitting superfluous sheet piles.

11. A 30' pile line is 50 to 75% better than two 15' pile lines because it is only the upper pile line that makes the major contribution.

In a large hydraulic structure, as a rough rule the depth of end pile lines should be equal to total head for the structure but in river works not less than 20' in any case. The depth of D/S pile line should be adequate to result in safe residual head at the exit end. On an average, the percentage loss of head at U/S sheet pile may be taken as twice the depth of pile line and that at the D/S sheet pile the same as the depth of sheet pile. The floor length should be enough to dissipate the balance of head assuming the gradient between 1/20 & 1/30 (for sand) and with due consideration for standing wave and retrogression of river bed.

This investigation aims at presenting comprehensive but simple formulae for design of weir, which conforms to laws of hydro dynamics. It should be a policy to install pressure ipes in future in all the hydraulic structures in consultation with the research authorities.

Note :

Paper No. 162 appeared at pages 50 to 88 of the Proceedings of Engineering Congress, 1933 Vol: XXI. There are 5 appendices and 13 plates giving details of pressure pipes.