Paper No. 294
Year 1952

OBSERVATION RECORD AND ANALYSIS OF PRESSURE PIPE DATA OF WEIRS ON PERMEABLE FOUNDATIONS

DR. MUSHTAQ AHMAD

Paper No. 294
Year 1952

OBSERVATION RECORD AND ANALYSIS OF PRESSURE PIPE DATA OF WEIRS ON PERMEABLE FOUNDATIONS

By

DR. MUSHTAQ AHMAD

Pressure pipes are installed on a number of weirs and irrigation works like level crossings and siphon etc. to monitor uplift pressures due to seepage flow through permeable foundation. The method of observations and their record keeping has an appreciable effect on analysis and interpretation of data. The basic data of a hydraulic structure like construction drawings, proposed upstream and downstream water levels, subsoil data and presence or otherwise of springs and cavities provide a useful basis for the analysis of the problem. The observations during operation of the structure include the recording of water levels in pressure pipes, temperature of water and subsoil, flow water levels along the structure, scour and spring levels if any. Upstream and downstream water levels are measured by guages whereas the water levels in pressure pipes are recorded by means of bell sounder or by Mecabe water level indicator. The temperatures are recorded by the use of maximum and minimum thermometers.

The record of a set of observations is likely to contain errors and accuracy of observations lies in the degree of skill of an observer and the technique to avoid sources of error. The errors usually result from installation of pressure pipes in a way different from their specified design, human element in observations, and mal-functioning of the pipes due to choking of strainer, leakage of pipe or inability of the pipe to respond accurately to change in water levels. Observations during unsteady flow conditions also introduce errors in measurement. The abnormal functioning of the pipes can be tested by observing the rate of fall and rise in water levels. The observations should be made fortnightly or atleast monthly, and under conditions when the water levels have remained steady for at least 24 to 36 hours. The records of data should be kept on standard forms.

The purpose of pressure pipe observations and analysis is to take care of safety of the hydraulic structure, to avoid damage to the floor of structure by excessive uplift pressures and to safeguard against undermining and piping. The hydraulic gradient along the seepage path at any point depends upon the percentage ratio of head above the downstream water level to the head across along the structure. the stability of weir floor at any point depends upon the balance of forces due to uplift pressure, the weight of masonary and that of water over the floor, if any. The condition of safety against uplift pressure is that the weight of floor under dry as well as submerged conditions in the worst case, must exceed the upward force due to seepage head. At the tail end of the structure the soil particles can easily be displaced if residual seepage uplift force is more than their submerged weight. The hydraulic gradient at exit is called critical or flotation gradient if the vertical component of the uplift is sufficient to lift the soil particles. In an ordinary structure critical gradient is generally not possible to occur on sand foundation. However, some factors like a scour hole extending towards the cutoff toe, presence of local surge, non homogeneity of substrata, sudden change of head and high spring levels can lead to critical exit gradient, and Mr. Khosla proposed factors of safety for various types of sub soils ranging from 1/3 to 1/7 as against 1:1 under theoretical critical conditions.

The presence of a cavity or loose contact of floor with subgrade can initiate undermining or piping. One of the purposes of analysis of pressure pipe data is to detect the presence of such cavities or loose contact points. The effect of cavity as shown by hydraulic model studies, is to steepen the exit hydraulic gradient immediately above and below the cavity, whereas it becomes almost horizontal along the cavity. Presence of a cavity close to the end of floor provides on easy path to emerging subsoil flow lines. This in turn steepens the exit gradient beyond permissible safe limits and may result in progressive start of undermining leading to sand boiling and complete failure of the hydraulic structure.

Safety of the weir structure on permeable foundation can be monitored by comparison of hydraulic gradient from pressure pipe data with the theoretical values obtained by employing Khosla, Bose and Taylor methods. The complex weir section with a number of sheet piles is divided into elementary forms to apply the above method for determining uplift pressure at key points. These values are then corrected for the mutual interference of piles, the thickness of the floor and the slope of the floor. This method is based on the assumptions of two dimensional seepage flow in a homogeneous deep stratum, absence of any silt blanket upstream or downstream of the floor, and that of any temperature gradient in the direction or against the direction of flow. Any variation of these factors can cause a departure of the observed data from theoretical values. A complete understanding of actual seepage flow conditions and the ways to eliminate discrepancies in observed data is needed for the purpose of comparison. Three dimensional seepage flow is predominant in case of cross flow through weir bays due to different water levels across weir bays or due to change in design along weir length. The effect of this condition on observed data can be determined from hydraulic model studies in case of serious doubts about the safety of the structure.

The available evidence regarding horizontal stratification indicates that in case permeability increases along the depth, the difference in hydraulic gradient from the structure on homogeneous subgrade is not as great as in case of vertical stratification. The structures lying on sand underlaid by an impermeable clay layer of finite depth in which the sheet pile pierces the clay layer will result in downstream uplift pressures independent of the upstream water levels. For a pileless floor resting on sand of finite depth underlain by an impermeable clay stratum of infinite depth, the uplift pressures have been found to be less under downstream half than in case of the infinitely deep sand provided the floor length is atleast four times the depth of sand strata; otherwise it is not appreciable. Sufficient experimental data is not available for the effect of mixture of sand and clay on uplift pressure. A model of Kalabagh weir on a foundation of sand and shingle mixed in different ratios shows that uplift pressures are generally higher than those of homogeneous sand foundation.

Model tests to study the effect of silt blanket indicate that the uplift pressure immediately below the silt blanket decreases with an increase in thickness of silt blanket. The effect of a silt blanket is similar to the presence of cavity in that it flattens the hydraulic gradient between measured points. In such a case complication crops up in the analysis of pressure pipe data and it becomes essential to eliminate the effect of silt blanket. Elimination of effect of silt blanket can be achieved by the application of graphical method or by formula method. The graphical method does not clearly indicate regions of flatter gradient as compared to normal gradient. The formula method follows from the graphical method by plotting a graph between uplift pressure and proportional relative position of pipes. It should however be noted that accuracy of this method depends upon the reading of the first pipe.

The study of the effect of temperature on uplift pressure shows that in the absence of silt blanket the temperature difference between the upstream and subsoil water of about 15°C can cause a change in uplift pressure by 5%. The effect of temperature gradient is minor as compared to the silt blanket effect and may be masked by observational errors.

Statistical analysis should be performed before comparative study of accumulated observed pressure pipe data with the theoretical values to rectify the observational error. All those values should be rejected which are negative, or more than twice the general run of values, or less than half of the general run of values. The values of uplift pressure which differ from mean value by more than three times the corresponding standard deviation should also be rejected. The average percentage of mean to theoretical value is applied to all the actual values and the results are compared with the theoretical values. The plot should indicate that region of the structure which is unsafe against the uplift as well as the period of the year during which the structure is likely to be unsafe.