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*By*

**A. N. KHOSLA**

The Author has noticed serious effects of the sub-soil flow on the upstream and downstream floor of some of the drainage siphons on main line of Upper Chenab Canal for the first time in 1915 which caused boiling below the drop wall of Dugri syphon at RD 35800. Despite repairs and other necessary measures, piping showed marked increase in 1921 resulting in settlement of the right wing wall cracks in the face wall and barriers. Provision of 20 feet deep sheet pile below the bed level also proved to be ineffective and damage extended to the upstream floor. Further measures included rebuilding of the upstream floor in cement concrete and constructing new side walls in 1923-25. The downstream wing walls were remodelled and placed on wooden piles and the downstream floor was strengthened. Springs continued to blow sand at the end of upstream and downstream floors and resulted in settlement cracks in 1928. The repair and extension work was based on a hydraulic gradient of 1 : 10 without considering the high spring level around the work. The object of the paper is to show the shortcomings of Bligh's Hydraulic Gradient Theory adopted for repairs.

Similar damages were noticed at Jauryan Syphon. Wing walls and face wall showed cracks with settlement of barrel lips in 1926. After a thorough examination of the alternatives 2 feet thick puddle did not reduce uplift pressures under the floor. The pressures were rather governed by sub-soil water level around the work. The floor of syphon was remodeled in 1929 but it was ineffective in controlling further damages. A close study of the sub-soil flow conditions revealed that shallow end curtain wall was the real source of high uplift pressures. A sheet pile, 8' feet deep along-with strainers was provided at Dugri Syphon floor in 1929 and a similar sheet pile was proposed for Jauryan Syphon.

A flaw in the existing concept of flow through sub-soil emerged as the main conclusion of the investigations. An improvement in the principles for design of structures resting on saturated soil called for experimental work on scientific basis. Pressure pipes were installed at suitable depths at both the syphons to determine the uplift pressures with varying canal sypply level and the spring level. Another objective was to find exact location of relief strainers, their contribution in reducing the uplift, and to ascertain the true free water level in the open bed against the apparent water level. It was observed that water level in the pipes recorded rise as the well points were sunk deeper indicating the existence of a relationship between the depth of a well point and the pressure recorded in the pipe. A number of observations were made covering depth below floor upto 23 feet. The normal spring line (NSL) was obtained by joining the pressure levels in the pipes embeded in upstream floor. To derive a general law, difference between NSL and indicated pressure in each pipe (strainers closed) was recorded for each depth of filter point. These results were found to be independent of canal water level.

The true free water surface is the level to which water rises in subsoil. due to static head if there is no flow in vertical direction. Vertical flow commences when difference of static head exists, for example in presence of drain in which water level is lower than NSL. A pipe inserted in the path of flow would record wter level belowm indicating a loss of head. Data was plotted for all the head losses to generate a "Loss of Head Curve".

According to Darcy, velocity of flow in sub-soil varies directly with head and inversely with length of flow. Darcy's. relation, in form of a Mathematical ralation can be written as V=Ki=Kh/y:v is velocity of flow, K is the transmision constant, i is the fall gradient or head h divided by distance y. v=Kdh/dy. A curve plotted between h and dh/dy gave a straight line confirming the relation h=k dh/dy. It can readily be concluded that V=k"h where K"=constant, which means that velocity of flow at any point in sub-soil is directly proportional to loss of head from normal spring level at that point. the "loss of head curve" show that rate of loss of head increases as the depth below the surface decreases. The velocity, therefore, increases as the depth decreases which implies an increase in the tendency for dislocation of sub-soil as the depth decreases. There is a critical velocity for each type of soil particle and a velocity above it will dislocate the particles. Phenomenon of dislocation is vigorous at the bed level and decreases with increasing depth till critical velocity is reached where dislocation altogether stops. This depth is termed the "critical depth" and corresponding loss of head from NSL is called the "critical head".

Rate of inflow per foot length of strainer will increase as depth below ground decreases. The loss of head due to friction is greater in the presence of strainer as compared with sand column. The formation of springs leads to degradation of bed and consequent lowering of point of critical flow. If velocity and loss of head attain critical values at a certain point underneath the floor, the particles will get deslocated for some distance and cracks will appear in the floor due to settlement. As the process continues the degradation and consequent settlement accelerates and will extend to the face wall and endanger the main structure.

"Blowing up" or the upligt is caused by static head and "Blowing out" pressure responsible for undermining the floor is due to the kinetic head at a point. The sum of these two heads equals the drop from the normal gradient line to apparent water level in the drain. Reasonable floor thickness and thicker inverted filter provide a good combination to counteract both the heads for safety of structure. A comparison between performance of wells and sheet piles shows that wells do not provide an absolute cutoff like the sheet piles which are however, not self supporting. Pressure is not normally built up upstream of wells due to presence of slits between them. Floor may be adequately reinforced to withstand stresses resulting from a possible building up of pressure on the upstream face of the end sheet pile. The strainers installed immediately below the sheet pile at upstream end are helpful in reducing the depth of the sheet pile. The strainers provide an additional safety to floor by disallowing the particle movement towards the open bed. It is desirable to provide sheet piles reaching critical depth and provide strainers for additioanl relief. The slit size must be very fine to block the carrying away of fine particles fo the sub-soil. The strainers may, however, be blanked off in the clay strata because fine clay particles pass through the slits to initiate cavitaiton.

The design of structure on a given soil depends on the critical head for its particle. the critical head for Punjab sand is 6 inches to one feet. For Dugri Syphon the critical gradient is assumed as 1:9 against critical depth of 11.4 ft. Further experiments are needed for determining the critical head and critical gradient for different types of soil. Sufficient observations are not available at present for establishing a general law for relating rise in the pressure pipes with increase of depth in vertical direction or distances in horizontal direction. Practical application of the phenomenon outlined in this paper has been discussed in a separate paper by the author.