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Research Paper

Numerical study on deformation of diaphragm cut off walls under seepage forces in permeable soils

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A R T I C L E I N F O

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A B S T R A C T

Numerical modelling using Plaxis-2D is carried out to study seepage forces on suspended type cutoff walls in highly permeable soils. On increasing differential pressure head, deformation and bending moment in cutoff walls increased. On increasing the differential pressure, the point of occurrence of maximum deformation and maximum Bending Moment in downstream cutoff wall shifts upwards but in upstream cutoff wall, shifts downward. On increasing relative density and soil modulus, the deformation and bending moments reduced. For changes in pressure head, relative density and soil modulus, the deformation and bending moment are always higher in downstream cutoff wall than upstream wall.

1. Introduction

Hydraulic structures, especially diversion structures, constructed across the river courses on pervious sandy soil foundations. As the water is stored on the upstream side of diversion dam, due to the differential pressure head between upstream and downstream, the water seep through the foundation soil. This seeping water, which is passing under the diversion structures, has destabilizing effect on these structures. Destabilizing effect of seepage flow analyzed with respect to uplift force acting on the diversion structure, exit gradient and its consequent soil movements.

Bligh [1] introduced the creep length theory and states that the creep length is the first line of seepage, which is in contact with the foundation of the structure. According to this theory, the energy loss occurs linearly along the creep length. Lane [7] improved the creep length theory of Bligh [1] and introduced different weight age for horizontal and vertical percolation lengths. He adopted 0.33 weight age for horizontal percolation length and 1.0 for vertical percolation length.

Khosla et al. [6] presented an improved method to determine the uplift pressure and exit gradient on foundation of diversion structures. According to this theory, the seepage flow passes from upstream to downstream in a streamline flow, not on the surface of the foundation as envisaged by Lane [7] and Bligh [1]. Khosla et al. [6] method is based on the concept of flow net; comprising streamlines and equipotential lines crossing each other orthogonally. Khosla et al. [6] proposed the Method of Independent Variables, in which the complex profile of structure is broken into simple profile and they are solved analytically (shown in Fig. 3). Then, corrections, for mutual interference of piles, thickness of floor and variation for slope, applied to get the pressure gradient for complex profile.

Tung et al. [19] studied the effect of seepage cutoff below earthen dam using numerical models. They reported that the increase in length of sheet piles reduces the exit gradient and shifting of sheet pile, away from downstream end increases the exit gradient and reduces the factor of safety. Moharrami et al. [11] analyzed the performance of cutoff walls under hydraulic structures against uplift pressure and piping. In their study, the authors concluded that positioning the upstream cutoff walls inclined at 70° is most beneficial in decreasing the exit gradient and consequent piping. However, the upstream cutoff wall inclined at 90° is most beneficial in decreasing the uplift pressure. Positioning the downstream cutoff wall at 130° would reduce the exit gradient and increase the factor of safety against piping. They concluded that the optimum numbers of cutoff wall in diversion dams for reduced uplift present is three.

Griffiths and Fenton [4] studied the seepage beneath the water retaining structures using stochastic methods to accommodate the soil parametric variations and analyzed the effect of parametric variation on flow rate, uplift pressure on dam and exit gradients. Mansuri and Salmasi [9] studied the effect of cutoff wall on seepage and uplift pressure in heterogeneous earthen dams using numerical simulations. In this study, they concluded that best location of cutoff wall for reduced seepage rate and piping failure is middle of dam. They also concluded

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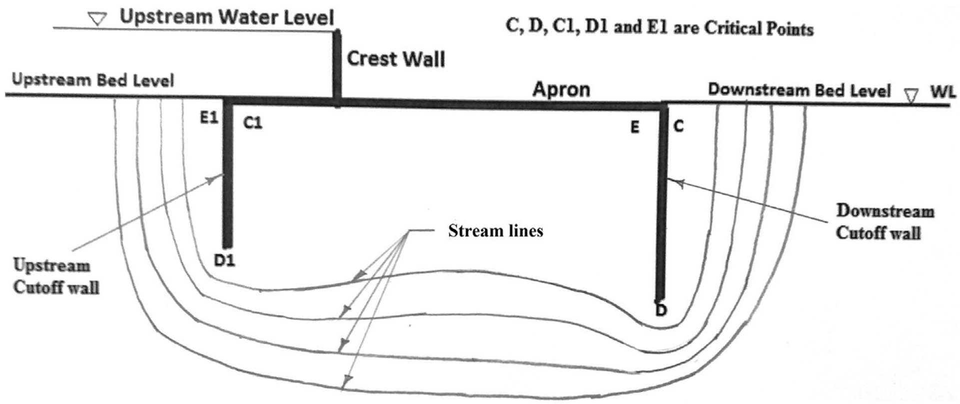

Fig. 1. Typical Diversion Structure.

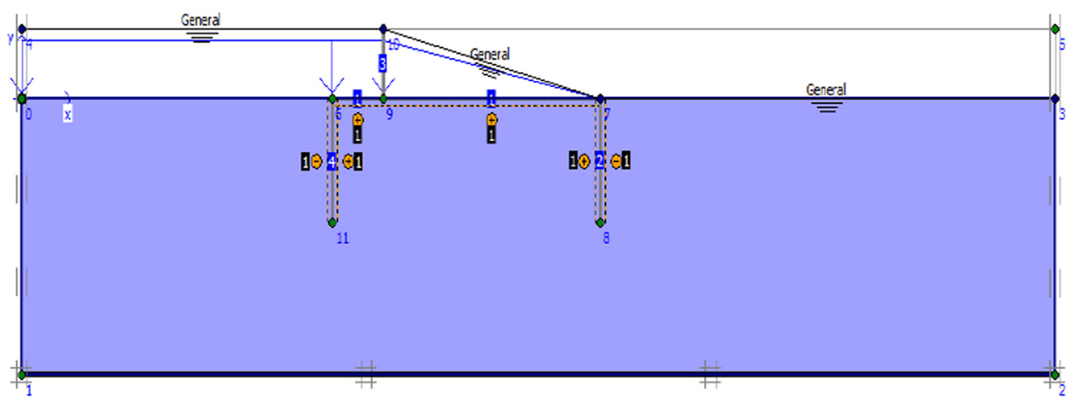

Fig. 2. Model of Diversion Dam.

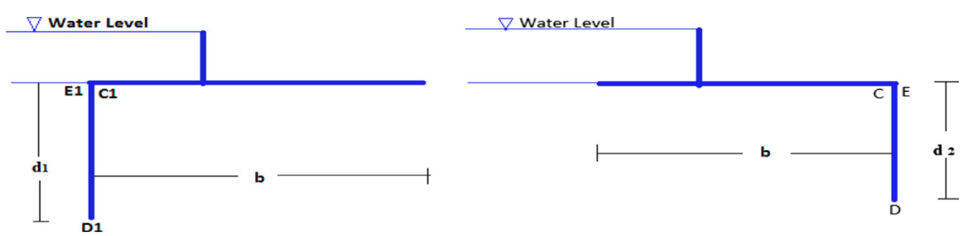

Fig. 3. Method of Independent Variables.

Table 1
Properties of structural elements.

Structure	EA in KN	EI in KN m^2	Thickness d in m	ν	Depth D in m
Upstream cutoff wall	1.50E + 07	4.50E + 05	0.6	0	9.0
Downstream cutoff wall	1.50E + 07	4.50E + 05	0.6	0	9.0
Apron	2.90E + 10	5.45E + 06	1.5	0.15	–
Body wall	4.84E + 07	2.52E + 07	2.5	0.15	5.0

that on increasing the depth of cutoff wall, the rate of seepage and total uplift pressure reduced. Kalkani and Michali [5] carried out experiments on rate of seepage flow under steady flow conditions, with depth variations of cutoff walls.

Luo et al. [8] studied the suffusion in sandy gravel foundation with partially penetrating cutoff wall. It was concluded that the seepage drag forces cause erosion, migrate particles and results in increasing the permeability, while filtration induces clogging, and decrease the permeability. Mansuri et al. [10] have studied the effect of angle and location of cutoff walls on uplift pressure in diversion structures. They concluded that minimum uplift pressure and maximum exit gradient occurs when the cutoff wall is placed at upstream end. When the cutoff wall is placed at downstream end, uplift pressure increases to maximum and exit gradient reduces to minimum. When the cut off wall is located at middle of the dam, the rate of seepage is at maximum.

Shayan and Tokaldany [17] studied the effects due to blankets, drains and cutoff walls on uplift pressure and exit gradient by using both laboratory and numerical models. The authors concluded that the best position of cutoff wall to reduce the seepage flow is downstream end and to reduce the uplift force is upstream end.

Experimental study on internal erosion in sandy gravel foundation of a suspended cutoff wall was conducted by Wang et al. [20], and they concluded that the seepage discharge and permeability decrease with increasing confining stress; however, the critical hydraulic gradient increases. The study on internal erosion mechanism around cracks in seepage barriers conducted by Rice and Duncan [15,16] concluded that due to high differential hydraulic pressure and pore pressure regime changes, seepage barriers are susceptible to develop cracks. Federico and Iannucci [3] have stated that due to upward seepage flow in the downstream side of the structure, particle migration is likely occur; with reduction in effective vertical stresses, changes the permeability, porosity and unit weight of soil and may make the geotechnical system unstable.