IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 4, Special Issue 6, March 2017

Impact of Underground Structures on Flow of Groundwater – A Review

Anjana CR[1], **Arathi Ashok**[2], **Prabhitha PS**[3], **Mini M**[4]

Final Year, Dept of Civil Engg, LBS Institute of Technology for Women, Thiruvananthapuram, Kerala, India [1,2,3]

Assistant Professor, Dept of Civil Engg, LBS Institute of Technology for Women, Thiruvananthapuram, Kerala, India[4]

Abstract: Property economics favours the vertical development of cities but flow of groundwater can be affected by the use of underground space in them. In this paper we will study the impact of disturbances caused by underground structures (tunnels, basements of buildings, deep foundations, etc.) on the groundwater flow in aquifers. Impervious structures modify the groundwater flow pattern because the structure reduces totally or partially the aquifer section

Keywords: Barrier effect, foundation, groundwater, tunnels, piles.

I. INTRODUCTION

Half of the world's population now live in cities. The phenomenon of urbanisation is such that this proportion will reach 70% by 2050. Despite this anticipated anthropic pressure, the protection of natural spaces remains a major challenge in the effort to limit horizontal urban sprawl. The influence of the two main constraints, anthropic pressure and property economics, leads (mechanically) to the vertical development of urban areas, particularly due to the potential provided by some subsoils to support urban growth. In parallel, urban subsoil is now recognised as a space rich in resources: available water, available space, geomaterials and geothermal heat, which play a vital role in ensuring sustainable land development but for which regulations remain wanting. This results in a lack of coordination and planning in the exploitation of this space, illustrated by conflicts over use, and which can be detrimental to the different systems of the underground environment.

When a linear underground structure is constructed in the ground where the groundwater level is extremely close to the surface, it blocks the flow of groundwater. Barrier effect is defined as the increase in head loss along flow lines caused by the reduction in conductance associated with an underground construction.

II. IMPACT OF UNDERGROUND STRUCTURES

(Guillaume Attard, YvanRossier, Thierry Winiarski, LoannCuvillier, Laurent Eisenlohr)

The aim of the study was to quantify the cumulative impact of underground structures on the flow of urban groundwater. A methodology to assess the actual and the potential state of the groundwater flow in an urban area is proposed. The modeling process consists of solving the diffusivity in the porous media equation for the entire area studied. The FEFLOW® code was used to solve the diffusivity equation using the finite element method. All the structures were integrated in the 3D numerical model with their geometry. This process requires delimiting the area studied with an assignment of material properties and boundary conditions. They integrated drainage systems considering a seepage face with a Dirichlet BC, and pumping and reinjection wells were integrated by defining a Neumann BC. A Dirichlet boundary condition (BC) was applied to the upstream and downstream contour. A Neumann BC was applied to the upper surface of the model to reproduce recharge from precipitation and network losses. A Cauchy BC was applied to represent interactions between rivers and groundwater.

The results show that underground structures fragment groundwater flow systems leading to a modification of the aquifer regime. Structures with drainage systems are shown to have a major impact on flow systems. The comparison between the actual state and the potential state of urban groundwater flow shows that the underground structures have fragmented the flow systems.

The following conclusions were drawn from the study:

(1) Underground structures involving pumping/reinjection rates caused a fragmentation of urban flow systems. Consequently, the urban groundwater regime had been modified and an inversion of the interaction between the groundwater and the river was observed. This regime modification can lead to an influx of polluted water from the river to the groundwater

(2) Regarding water table elevation, the cumulative effect of underground structures was a global drawdown. This drawdown was caused by pumping devices (i.e. pumping wells and structures with drainage systems). Due to the strong dependence of the actual water table elevation on pumping devices, the potential state of water table elevation

DOI 10.17148/IARJSET

(i.e. water table elevation in case of no pumping device operation) should be taken into account when building new structures. The stoppage of several pumping devices could lead to the flooding of underground floors.

(3) Because of the small hydraulic gradient of the area studied, the impact of impervious structures was negligible. On the other hand, the influence of structures with drainage systems was emphasized. These underground structures have a major influence on urban flow systems.

(4) Transient simulation demonstrated the temporal stability of flow system structure for this case. Thus the relevance of the steady state approach for the quantitative depiction of flow systems was demonstrated. The stability of flow systems was considered an asset regarding underground planning.

III. EVALUATION OF THE HYDRAULIC CONDUCTIVITY OF AQUIFERS WITH PILES

(Lei Ma & Ye-ShuangXu&Shui-Long Shen)

In this experiment, a sandy soil is considered as an aquifer and polyvinylchloride pipes are adopted as piles. Piles are distributed in rectangular and triangular layouts.

Research shows that the effective medium theory (EMT) could be used to calculate the equivalent hydraulic conductivity (keq) of a heterogeneous medium with other material inclusions. In order to verify the applicability of EMT in an aquifer with piles, an experimental investigation is conducted and the values are compared. The EMT theory doesn't take into account the layout of piles while finding keq. The keq is found using the EMT formula for a homogeneous medium embedded with another type of low-permeability medium,

$$k_{\mathrm{eq}} = \frac{1}{D}\left[\frac{f_0}{k_0 + (D-1)k_{\mathrm{ef}}} + \frac{f_1}{k_1 + (D-1)k_{\mathrm{ef}}}\right]^{-1}$$

$f_0<0.6$

Where,

f_0 and $f_1$represent two represent two different probability replacement ratios for each medium. For the test case in this study $f_1 = 1 - f_0$

k_0 and k_1 represent two different hydraulic conductivities, one for each medium

The laboratory investigation was conducted using a rectangular box. The layout pattern and total number of piles were changed to investigate the blocking effect of the piles on groundwater seepage. Throughout the seepage test, the simulated groundwater level was set as a constant value at both upstream and downstream boundaries. Groundwater levels were measured before and after the installation of the piles, and the flow rate was also measured throughout the tests. There were six monitoring tubes in total, with two located at the upstream side, two at the downstream side,and two in the pile area.

The keq value of the experimental setup by using the formula,

$$k_{\mathrm{eq}} = \frac{2Q(x_2 - x_1)}{a(h_2^2 - h_1^2)}$$

Where,

Q-Flow rate through the system

h_1, h_2- the groundwater levels in two observation wells

x_1, x_2- the distances between the downstream end and the two observation wells a- width of seepage area

From the experiment it was found that existence of piles in aquifer had an influence on both the flow rate and the groundwater level. The groundwater at the downstream end receives less recharge from upstream end when the number of piles increases. This causes flooding in the upstream portion. The blocking effect of piles on seepage is related to both the volume replacement ratio of piles to sand and to the layout pattern of piles. With the same replacement ratio, the flow rate through an aquifer with a rectangular layout of piles is greater than with a triangular layout of piles when the flow is parallel to the pile distribution lines. The head difference is also greater in rectangular layout. The blocking effect also depends upon the flow direction. The blocking effect is strongest when the rotational angle is between 30^0 to75^0. After comparing the keq it was found that the EMT predicts keqof a rectangular layout very wells, but it doesn't work well for triangular layout. This is due to different seepage path for each layout. A correction factor is proposed to find the keq for triangular layout using EMT.

IV. THE IMPACT OF THE BUILDING FOUNDATIONS ON THE GROUNDWATER

(Guoping Ding, Jiu J. Jiao and Dongxiao Zhang)

In paper, the impact of the building foundations on the groundwater regime was studied using hypothetical flow and transport models. The paper uses a three-dimensional hypothetical model to investigate the change of groundwater flow system as a result of distributed foundation blocks in urban areas. The urban area is considered as a bimodal system: the original porous media with high hydraulic conductivity and the deep foundation blocks with low hydraulic conductivity. Stochastic realizations with different percentages of low-permeability blocks are used to represent the distribution pattern and the percentage of the deep foundations. The models are first run without foundation blocks and then with foundations. The changes of hydraulic head, groundwater discharge to the sea and seepage to the ground surface after foundations are added are investigated.

Various possible realizations of foundation distributions were generated using stochastic parameters derived from a topographical map of an actual coastal area in Hong Kong. The effective hydraulic conductivity was first calculated for different realizations and the results show that the effective hydraulic conductivity can be reduced significantly. Then a hypothetical numerical model based on FEFLOW is set up to study the change of hydraulic head, groundwater discharge, and seepage to the ground surface after foundations are added. The study focuses on the modification of the groundwater system by deep foundations in the long term. It is assumed that groundwater flow is in a steady state before urbanization and achieves another steady state after urbanization when deep foundations of high-rise buildings are added. The water levels and groundwater discharge from the two steady-state models with and without foundation blocks are compared. The groundwater level and flow are modified to various degrees, depending on the foundations percentage and the distribution pattern of the buildings. When the foundations percentage is high and the building foundations are aggregated, the hydraulic head is raised significantly and the originally one-dimensional groundwater flow field becomes complicated.

V. EVALUATION OF FLOW REDUCTION DUE TO HYDRAULIC BARRIER ENGINEERING STRUCTURE

(YohannesYihdego)

In this study a vertical barrier forming the exclusion system in relation to partials extending into an impermeable stratum was analysed using a 3-D numerical modelling. It is used to quantify the effect of hydraulic barrier on flow. Engineered barriers may be used to divert the direction of contaminated groundwater flow to keep it from reaching drinking water wells, wetlands, or streams. They also may be used to contain and isolate contaminated soil and groundwater to keep them from mixing with clean groundwater. Cut-off walls are used to exclude groundwater from an excavation, to minimize the requirement for dewatering pumping.

A sheet piling causes a discontinuity in the groundwater head. The theoretical assumption is that the extent to which the groundwater is influenced by a barrier (sheet piles), largely depends on the proportion to which the barrier cuts off the water bearing layers/aquifers. This paper assesses the optimum amount of sheet pile cut off, based on the depth of the sheet piles in proportion to the depth of the water bearing layer for the hypothetical Levee work to control groundwater flow and contaminant migration timing. To estimate the optimum sheet pile length, modelling was undertaken using MODFLOW-SURFACT code, an advanced MODFLOW based code developed by HydroGeoLogic Inc. The model allows computing discharges per unit length of levee/sheet pile in a hypothetical case. The simulated inflow past sheet pile per meter width, with a hydraulic resistance varying from 5, 10 and 15 days and zone budget are determined. The % reduction in flow after 5 and 10 days (of the 15 day flood duration) is also plotted. It can be seen that for 0 % cut off the % reduction in flow is 0 and for 100 % cut off the % reduction in flow is 96, 94 and 92 % at 5, 10 and 15 days respectively. From this study it can be derived that less water lows to a levee structure surrounded by sheet piles, depending on the depth of the sheet piles in proportion to the depth of the water bearing layer. The reduction appears to be significant not earlier than with a percentage of cut-off exceeding a value of 60–70 %.

VI. RISE OF GROUNDWATER TABLE WHEN FLOW IS OBSTRUCTED BY SHALLOW TUNNELS

(Paul G. Marinos&Michael Kavvadas)

The paper investigates the steady state rise of groundwater table on the upstream of a shallow tunnel due to the obstruction of groundwater flow in the direction normal to the tunnel axis.

When a tunnel is constructed below water table or intersecting the water table, the existence of tunnel forces the groundwater to circumvent it by locally increasing the length of flow path and corresponding flow velocity. The required energy loss is provided by the locally increased hydraulic gradient in the length of influence. The increased hydraulic gradient in turn causes a moderate rise of water table in the upstream side. The magnitude of rise of groundwater table was investigated by 2D finite element steady state flow model around a cylindrical tunnel located at a depth (d) below groundwater table. The hydraulic gradient of water table was assumed to have a uniform initial gradient in the direction perpendicular to the tunnel axis. A graphical plot of depth of tunnel crest below initial water table in the x-axis and steady-state water table rise in the upstream in y-axis is used to analyse the results. The magnitude of rise of water table depends on the size of tunnel, depth of tunnel below water table and the hydraulic gradient. It is a time dependent process. Water table rises after construction of tunnel and reaches its maximum value corresponding to steady state condition. This paper proposes a simple analytical method to predict the water table rise due to the construction of tunnel and the magnitude depends on the size of tunnel very much. For typical values of hydraulic gradient (0.5%-5%) the predicted water table rise is of the order of 1-10% of the size of tunnel. It shows the effect of presence of tunnel in water table rise is very much.

VII. INFLUENCE OF UNDERGROUND STRUCTURES AND INFRASTRUCTURES ON THE GROUNDWATER LEVEL INTHE URBAN AREA OF MILAN, ITALY

(L. Colombo, P. Gattinoni& L. Scesi)

In this paper, the case of Milan (Italy) is discussed. First, the hydrogeological setting of the area is described and the monitoring data are analysed to reconstruct the regional increasing trend of the water table .Afterwards, a 3D numerical model of the groundwater flow system is described. More in detail, the study starts from a numerical model of the whole aquifer system of Milan, based on the data arising from previous studies. This model considered the two main aquifers of Milan and it was calibrated in steady state with reference to the maximum water table observed. Finally, the interference of underground structures and infrastructures with the aquifer system is simulated and the results are discussed. Modelling results show local deformations of the water table nearby the underground structures and infrastructures. These deformations consist in a rise of the groundwater located upstream the impermeable elements (with respect to the water flow direction), whereas a groundwater drawdown is located downstream. Rise and drawdown reach maximum values of about ±15 cm where the underground structures have a major development in a direction orthogonal to the groundwater flow, where the metro lines are deeper. Structures and infrastructures, acting as impermeable elements, also involve a change in the water flow path and flow velocity. At the same altitude of the impermeable elements the flow slows down (both upstream and d increase ownstream), whereas in depth (below the impermeable elements) the flow velocity. Actually.such an increase may bring about erosive phenomena, especially for the finest soil particles, which in the long term can lead to settlements and instabilities of the structures.

VIII. EXPERIMENTAL INVESTIGATION

Based on the above journals referred, it was concluded that underground structures reduces the area of aquifer section, thereby causing a reduction in effective transmissivity, leading to a rise in the water table up gradient and a lowering down gradient. Rising water levels may flood basements, promote soil salinization, affect flora by rotting the roots of plants , reduction of the bearing capacity of shallow foundations, expansion of heavily compacted fills under the foundation structures, settlements of poorly compacted fills upon wetting, increase in loads on retraining systems or basement walls of buildings. The lowering of heads on the downgradient side can cause seawater intrusion in coastal aquifers, ground subsidence, death of phreatophytes and, the drying of wells and spring.

An experimental study was proposed to analyse the severity of the problem. The main objective is to find the equivalent hydraulic conductivity with respect to volumetric replacement ratio when these structures were incorporated into the modeled underground system. For conducting experimental investigation an underground system is simulated using a rectangular tank of dimensions 1.2m*0.75m*0.75m, which will be filled with sandy soil to represent aquifer. Polyvinylchloride pipes are adopted as piles and tunnels. Polyvinyl materials are used to represent the impervious basements.Hydraulic conductivity of the simulated area will be obtained with and without inclusions. As a remedy a bypass filter media and infiltration trenches can be proposed.

ACKNOWLEDGEMENT

We would like to express our deep sense of gratitude to the Dr.Jayamohan J, Principal and HOD (Department of Civil Engineering) and also to all staff members for their constant support and guidance.

REFERENCES

[1] Deterministic modelling of the cumulative impacts of underground structures on urban groundwater flow and the definition of a potential state of urban groundwater flow: example of Lyon, France Guillaume Attard, YvanRossier, Thierry Winiarski, LoannCuvillier, Laurent Eisenlohr

[2] Evaluation of the hydraulic conductivity of aquifers with piles Lei Ma & Ye-ShuangXu&Shui-Long Shen Modelling study on the impact of deep building foundations on the groundwater system Guoping Ding, Jiu J. Jiao and Dongxiao Zhang

[3] Evaluation of Flow Reduction due to Hydraulic Barrier Engineering Structure YohannesYihdego

[4] Rise of Groundwater table when flow is obstructed by shallow tunnels Paul G. Marinos& Michael Kavvadas

[5] Assessment of the effects of underground structures on groundwater flow, and corrective measures TakeichiSekiguchi, YasuoHozaki

[6] Influence of underground structures and infrastructures on the groundwater level inthe urban area of milan, italy L. Colombo, P. Gattinoni& L. Scesi Barrier effect of underground structures on aquifers

[7] EstanislaoPujades, Ander López, Jesus Carrera, EnricVázquez-Suñé, Anna 2 Jurado