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Evolution of EPM karstified model for simulation inflow into the tunnel (case study: Kermanshah-Iran)

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Abstract: Draining of groundwater from fractured or karst aquifers to the tunnel are a serious problem during of construction. Simulation of karst aquifer is a powerful tool for studying these problems. Out flow rate from the tunnel can be considered for model calibration. This article has attempted to reach to this target using MODFLOW computer code. The steady state condition has calibrated by discharge rate from the tunnel. Finally, model reached up to 90% match between observed and calculated flow rate discharged from the tunnel.

Key words: EPM model; Tunnel; Karst aquifer; Water ingress

1. Introduction

During construction tunnel, may inflow Water into tunnel, and while the media which is penetrate is a permeable rock same as carbonate formation or karstic or fractured medium, water ingresses into tunnel, and resulting in huge casualties and economic loss .It is essential to predict or at least estimating the amount of this inflow. Although it is very difficult to accurately predict the water inrush during tunnel construction a large number of researches have been devoted to the problem in recent years (caili et al., 2013).

Estimations of groundwater inflow into tunnels are often carried out with the four classical analytical methods (Kong 2011) the first is Goodman method (1965) second is Heuer and Raymer method (1995) third is Heuer Analytical method (2005) and fourth is IMS method (1985).

Besides the above – mentioned methods some others analytical solution (Zhang andFranklin, 1993; Hwang 2007; El tani, 2003; Kong, 2011) are proposed to predict the water inflow for different geological conditions (caili et al., 2013).

However analytical solution rely on given hydro-geological assumptions with simple circular or rectangular opening and they are unable to predict water inflow in complex hydro-geological conditions such as fractured rocks (Li et al., 2009).

Numerical modeling using finite element and finite difference schemes can analyze the tunnel water inflow problems in various complicated geological condition (Hwang, 2007). On water flow through fractured media, several conceptual models have been proposed so far, including: EPMM-DFMM- and hybrid models (caili et al., 2013; Berkowitz, 2002).

Some others models are also established to assess the risk of water inrush by using the software of RFPA2d and COMSOL (2012) and the finite element method (Meiri, 1985; caili et al., 2013).

In addition, there are many approaches for modeling of fractured and karst systems such as equivalent porous medium, dual porosity, discrete fractured network, channel network, and stochastic continuum models (Thangarajan, 2007).

Regarding the litho- logy of hard rocks, a simplified system has used from EPM (equivalent porous medium) approach (Barker, 1988; Moench, 1984; Witherspoon and Long 1987) and the model created using MODFLOW computer code (GMS software).There are many researches about the ability of EPM model for simulation karst mature medium for example (Cacas et al., 1990) explained as result of her research ,that the ability of equivalent porous media models to simulate regional groundwater flow in a highly karstified aquifer ,which is important for water resources and groundwater management .Or-(Anderson and Woessner, 1992) relates the equivalent porous medium flow model constructed would not be appropriate for contaminant transport modeling , however appropriate to represent hydraulic heads and recharge/discharge relationships on a regional scale.

1.1. Methodology

1.2. Identify EPM model

Fractured system is represented as an equivalent porous medium (EPM) by replacing the primary and secondary porosity and hydraulic conductivity distribution with a continuous porous medium having the so-called equivalent or effective hydraulic properties. this approach applies to the same mathematical-physical point of view as that of

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porous medium approach, but with statistical distributions of the parameters .An EPM approach assumes that the fractured material can be treated as an continuum and that a representative elementary volume (REV) of characterized by effective hydraulic parameters can be defined .Simulation of flow in fractured system using this concept requires definition of effective values for hydraulic conductivity, specific storage and porosity. These parameters are, in turn determined from aquifer testing, (Thangarajan, 2007) estimated from water balance or inverse models (Cacas et al., 1990). When EPMis considered,than standard finite difference method (FDM)or finite element method (FEM)may be applied to simulate groundwater flow in a fractured system. EPM can be applied, only if the system has high intensity of fractures; otherwise this concept is not valid.

It was reported by many research workers that EPM approach might reasonably simulate the behavior of regional flow system, while it poorly reproduces the local condition (Cacas et al., 1990).

1.3. Study area

This study focuses on anticline near the Kermanshah- Iran (Fig. 1).

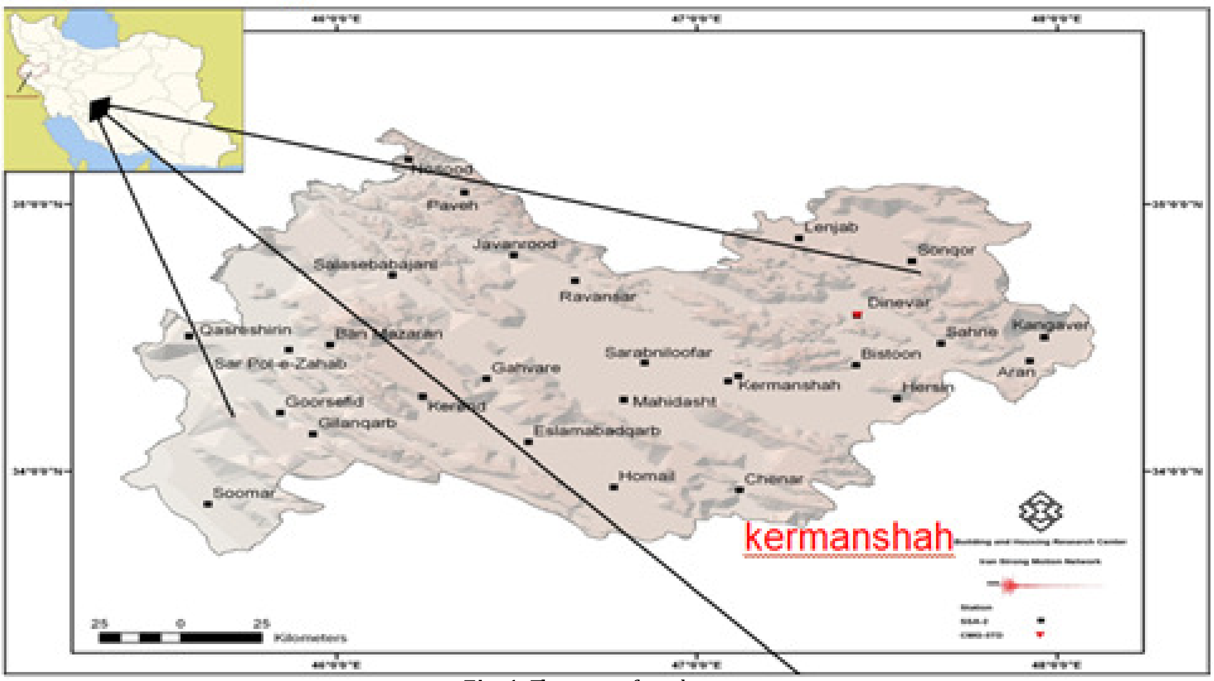

Fig 1: The map of study area

2. Properties of the media

2.1. Geological setting

The study area actually is the core of a great crushed anticline that has outcropped in the central point of the area. The llithology of this formation is limy shale and micrite limestone, named ILAM FO (ILAM formation) which has been trapped by Lopha member of GURPI Formation. Its hydraulic behavior is liked as impervious around the aquifer. The trend of strata is north-west to south-east. Dip direction is perpendicular to it from two sides. There is a lineament in North West of area that separates ILAM Formation from GURPI Formation. The simplified geological map of site is shown in Fig.2.

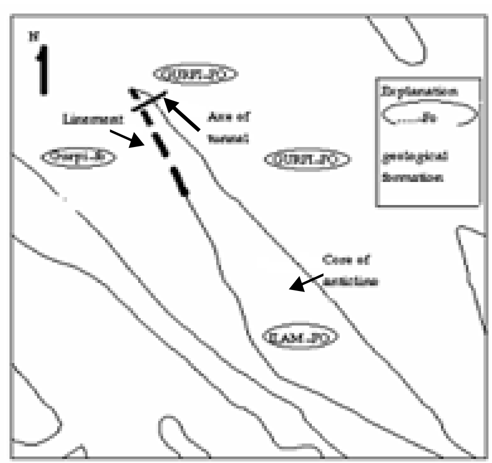

Fig. 2: Basic geological map of the study area

2.2. Site underground investigation:

There are two suitable boreholes in the area, BH27 and BH E.

BH27 is a geotechnical borehole in165 meters depth consist of alternating micrite limestone and limy shale. Its location is about 3 meters far from the alignment of the tunnel in the end part of North West of the of study area. Hydraulic conductivity of layers in this borehole can divided into two layers. The upper layer from top surface to about 145 meters has low permeability about 1-2 lugeon (A Lugeon is a unit devised to quantify the water permeability of bedrock and the hydraulic conductivity resulting from fractures, 1 Lugeon unit = 0.0000001 meter per second) and lower layer from 145 meters until the end of thickness of ILAM Formation has high permeability about 30 lugeon based on geotechnical test boreholes.

The BHE, which is an extraction well for drinking purpose, drilled in upper layer. The upper layer in BH27 has observed in this borehole too. Location of this borehole is about 2 kilometers far from BH27 in south east direction. Schematic block diagram of model has shown in Fig.3.

2.3. Recharge and discharge of aquifer

Discharge simulated based on four wells in 5 and 2 kilometers and in vicinity of tunnel. These wells discharge groundwater about 2333-1555-130-95 cubic meter per day, respectively.

The recharge rate parameter caused from precipitation is 0.0014 meter per day.

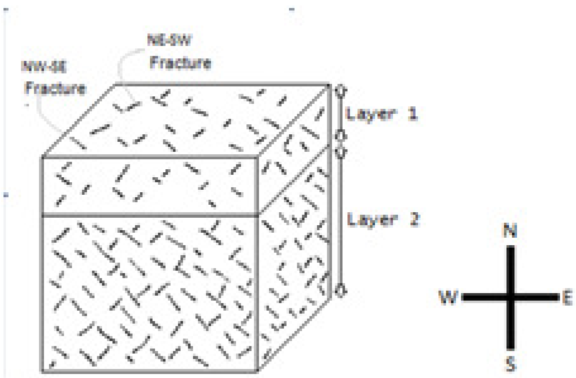

Fig. 3: Schematic block diagram of the model

2.4. Boundary condition

Based on previous explanation (2-1) the boundary condition of model is NO FLOW boundary according to impervious layer are there in all around the aquifer.

3. Simulation

Simulation based on MODFLOW computer code (GMS software) with two layers and 99 rows and 83 columns and 1 stress period (Steady state condition) and has used from drain and well and recharge packages accordance to MODFLOW computer code.

4. Calibration

In this step of create and run model the results of model compare with equivalent observed data relative flow rate discharge from tunnel (after crossed (passed) the ILAM FO as karstic aquifer). After some correction such as hydraulic conductivity of tunnel, the model reached about and upper than 90% consistence, with this explanation that observed measurement of flow rate of tunnel was 258 litre per second and this flow rate calculate by model amount of 268 litre per second. Green symbol plotted in Fig.4 (on the axe of tunnel) emphasis this perfect accordance.

5. Results

Results shown below:

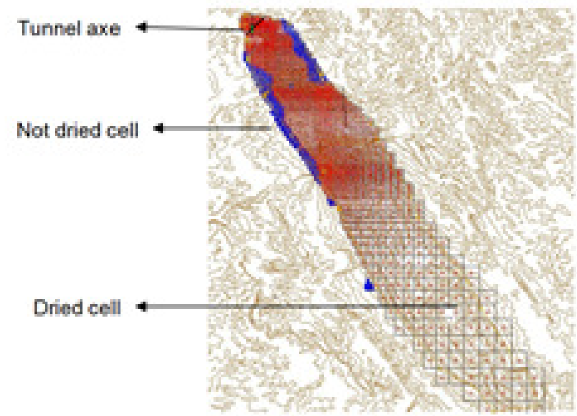

Fig 4: Calculated contours of heads after running model in simulated time in layer1.

As one see in Fig.4 almost grids in layer1 has been dried that accordance with field data.

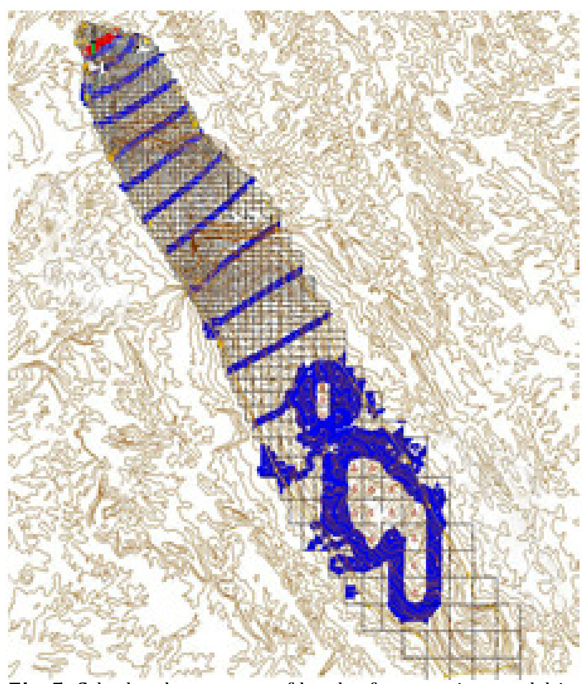

Fig 5: Calculated contours of heads after running model in simulated time in layer 2

In Fig.5 one can see almost there is not dried grid in aquifer and flow direction is south east to North West towards to tunnel. Green symbol plotted in the top of the model area represented out flow rate of tunnel has perfect match in calibration.

6. Limitations

6-1-The thickness of layer 2 is approximation..
6-2- lack of monitoring wells for determining fluctuation and static water table.
6-3-lack of joint study and structure maps and geophysical approaches and more boreholes with suitable distribution for provide block diagram and correlate strata and layers.

7. Conclusion

Present study even though has worked with insufficient data but has gotten relatively a good consistence with real system, it seems due to deep understand of geological concept and over all have good conceptual model and additional suitable and simple boundary condition. Another conclusion is at least under this hydrogeological condition we can use MODFLOW for simulating fractured or karstic aquifer and then predication the amount of flow rate and the mechanism of water that drains into tunnel and choose the best option for control it during construction of tunnel. Certainly if it was possible to get more temporal data and run model in transient condition and used from more resources such as monitoring wells for calibration and verification, the results was better, and hope it will be do in future.

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