Hydraulic Models for Calculating Head Loss in Water Distribution System: a case study in Konya

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Abstract

The management of the water supply system becomes crucial day by day because of limited natural water sources and rapidly increasing population all over the world. However, the water distribution systems have various technical problems and the energy loss in the system can be counted one of these problems. In this study, the water distribution system of a designated area in the Yaka district of Konya was examined using Hardy-Cross method and, the hydraulic simulation softwares EPANET, and WaterCAD which are used in hydraulic modeling of the water distribution systems frequently. The same data of designated area were used for EPANET and WaterCAD in the study. The calculations demonstrated that the head loss calculated in EPANET is 3.5% and %16.2 lower than that calculated by WaterCAD and Hardy-Cross, respectively when PVC pipes were used in the water network. When polyethylene pipes were used in the water network, the head loss calculated in EPANET is 3.8% and %26.6 lower than that calculated by WaterCAD and Hardy-Cross, respectively. In the case of choosing WaterCAD and Hardy-Cross as the model for water distribution system, the project cost would increase slightly due to increasing the diameter of the pipes for reducing the head loss. It can be concluded that by comparing the head losses, EPANET is more efficient than WaterCAD and Hardy-Cross.

Keywords: EPANET, Hardy-Cross, Model, WaterCAD, Water distribution system.

Su Dağıtım Sisteminde Yük Kaybını Hesaplamak için Hidrolik Modeller: Konya'da bir örnek çalışma

Öz

Sınırlı doğal su kaynakları ve tüm dünyada hızla artan nüfus nedeniyle su temin sisteminin yönetimi her geçen gün önemli hale gelmektedir. Ancak su dağıtım sistemlerinin çeşitli teknik sorunları vardır ve sistemdeki enerji kaybı bu sorunlardan biri sayılabilir. Bu çalışmada, Konya ili Yaka ilçesinde belirlenmiş bir alanın su dağıtım sistemi Hardy-Cross yöntemi ve su dağıtım sistemlerinin hidrolik modellerinde sıkıla kullanım hidrolik simülasyon yazılımları EPANET ve WaterCAD kullanılarak incelenmiştir. Çalışmada EPANET ve WaterCAD için belirlenen alanın aynı verileri kullanılmıştır. Hesaplamalar, EPANET'te hesaplanan yük kaybının, su şebekesinde PVC borular kullanıldığında sırasıyla WaterCAD ve Hardy-Cross tarafından hesaplanandan %3,5 ve %16,2 daha düşük olduğunu göstermiştir. Su şebekesinde polietilen borular kullanıldığında, EPANET'te hesaplanan yük kaybı WaterCAD ve Hardy-Cross tarafından hesaplanandan sırasıyla %3,8 ve %26,6 daha düşük olarak bulunmuştur. Su dağıtım sistemi için model olarak WaterCAD ve Hardy-Cross seçilmiş durumunda, yük kaybını azaltmak için boru çapını artırılması gerektirdiğinden proje maliyeti bir miktar artacaktır. Yük kayıpları karşılaştırıldığında, EPANET'in WaterCAD ve Hardy-Cross'tan daha verimli olduğu sonucuna varılabilir.

Anahtar Kelimeler: EPANET, Hardy-Cross, Model, WaterCAD, Su dağıtım sistemi.

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1. Introduction

Providing the appropriate quality water sufficiently is one of the crucial issues in human history because of the importance of water to the life. Hence, the water distribution systems were built to achieve this aim. However, design of a water distribution system has many technical problems. Therefore, recently, an increasing number of hydraulic models to describe water distribution systems have been reported by many researchers to improve the performance of these infrastructures [1-3].

Many small-scale water supply projects in Turkey are made using the dead end method in water distribution systems by Iller Bankasi. However, there are some other methods for modeling water distribution systems to compare the energy loss. One of these methods is Hardy-Cross method that is applicable to closed-loop pipe networks. In this method, an iterative procedure is used to calculate the energy loss in the water distribution system. Topacik and San have studied the comparison of equivalent pipe and Hardy-Cross methods [4] and Lopes has developed a program for designing the water distribution system using the Hardy-Cross method [5]. Furthermore, especially, energy loss in water distribution system can be calculated using softwares by modeling and comparing the head loss for each system. One of these softwares is WaterCAD that is developed by Bentley Systems, Incorporated, Exton, PA, United States. The gradient algorithm is used in WaterCAD and particular energy equations and nodal equations are taken consideration for each pipes and nodes for both heads of nodal and pipe flow [6]. In WaterCAD, modules like Darwin Calibrator, Darwin Designer, Skelebrator and SCADAConnect helps users to make the project more specific and presents special solution ways.

Recently, WaterCAD was used by researchers to plan and evaluate the performance of water distribution system and to model the formation of the chemicals in the system [7-10]. Another method for modeling the water distribution systems is EPANET software which is open-structured and developed by the United States Environmental Protection Agency (USEPA). In EPANET software, the head loss equations are based on Newton-Raphson iteration method to solve the simultaneous equations which are derived from the flow and head loss in the water distribution system. Some researchers were used EPANET to model the water distribution system, to reduce the energy cost, to optimize the leakage and calibrate the water distribution system, and to model the residuals of chemicals in water networks [11-15].

In this study, it has been studied to compare the head losses in the water distribution system using Hardy-Cross method and different hydraulic models to operate the water distribution system more efficiently and at lower cost by achieving minimum head loss.

2. Material and Method

A region, which covers an area of 45000 m² is located in Yaka Neighborhood of Meram district of Konya, Turkey, was selected for hydraulic modeling (Fig. 1). The elevations in the chosen region vary between 1167 m and 1106 m. The water demand of the region, which was calculated as daily and hourly by taking into consideration of population of the chosen region, is met from a 5000 m³ reservoir.
Two types of pipes, which were PVC and polyethylene, were used in the study. The number and the length of the pipes were 14 and 1397.5 m, respectively. In EPANET, initially, the tank and nodes were located in the working area depending on their coordinates and ground elevations. Then, the pipes were placed in accordance with the network in the region and their properties were entered (diameter, roughness coefficient). Hourly water consumption data calculated according to population were given to the nodes and hydraulic simulation was run (Fig. 2). The energy loss in polyethylene pipe was also calculated for both methods.

In WaterCAD, first, the tank and the nodes were placed according to their coordinates and ground elevations in chosen area as designated previously. Then, the pipes were located in the network. The diameters of the pipes were introduced to the software and the roughness coefficient was determined by software depending on material type of the pipes. The water consumption data was introduced to the nodes and hydraulic simulation was run (Fig. 3). The simulation was run over a period of 24 hours. Adjustments were made to update hydraulic data every fifteen minutes by software.

All calculations were carried out using Darcy Weisbach equation. Friction factor (f) is used to calculate the friction head loss ($h_f$) in Darcy Weisbach equation [16]. The friction head loss was identified as below [16];

$$h_f = f \frac{L V^2}{D^2 g}$$

where $D = 4A/P$ denotes the hydraulic diameter of the pipe (A and P denote cross-sectional area and wetted perimeter, respectively), $L$ denotes the length of the pipe, $V$ denotes average flow velocity, and $g$ denotes the acceleration due to gravity.

The head loss in PVC pipe and polyethylene pipe were calculated for all methods.

3. Results and Discussion

Comparison of the head losses in the water distribution system of a designated area was performed using Hardy-Cross method and different hydraulic models in this study.

The results indicated that the head loss in each PVC pipe differed depending on the model used (Figure 4).

The total head loss for chosen region using PVC pipes was calculated as 0.498 m, 0.516 m, and 0.594 m for EPANET, WaterCAD, and Hardy-Cross respectively (Figure 5). In other words, the total head loss was obtained 3.5% and %16.2 less in EPANET than in WaterCAD, Hardy-Cross, respectively. It could be said that the lowest head loss was achieved using EPANET.

When polyethylene pipes were used in the water distribution system, the head loss for each pipe in EPANET and WaterCAD was calculated similar (Figure 6).
The total head loss was 0.429 m, 0.445 m, and 0.584 m for EPANET, WaterCAD, and Hardy-Cross respectively (Figure 7). The total head loss was obtained 3.8% and 26.6 less in EPANET than in WaterCAD, Hardy-Cross, respectively.

If the same water distribution system is modeled with WaterCAD and the head loss is desired to be at the same level, the diameter of pipes would be increased in order to reduce the energy loss and the cost of the water distribution system would increase.

Using Hardy-Cross method to calculate head loss in the water distribution system will result in the highest head loss and in turn the cost of the system would be the highest one. It can also be said that choosing polyethylene pipes instead of PVC pipes will reduce the cost because polyethylene pipes cause lower head loss comparing to PVC pipes.

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