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A Study on the Probability of Failure Model Based on the Safety Factor for Risk Assessment in a Water Supply Network

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Abstract

Water pipes corrode as the endurance period elapses, or become deteriorated according to the buried environment, sometimes causing functional failure and problems with stable water supply. Stable and continuous water supply for consumers requires the risk assessment of water pipes. The safety factor has been used in many fields as a direct evaluation index that can express the state of a facility and is also used as a reference to judge the necessity of pipe renewal. In this study, the safety factor was calculated in order to establish the Probability of Failure model, by using result data such as the pipe property and ratio of residual stress from the technological inspection of waterworks.

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Keywords: Probability of Failure, Priority of pipe renewal, Safety factor

1. Introduction

1.1 Background and Objectives of This Study

Most of the water pipes in Korea have been laid during a period of rapid economic growth in the 1970s and 1980s. It was felt necessary to deploy a system that prepares for the requirement of water, and supplies water reliably, without water outages. With the passage of time, water pipes can become rusted or slowly deteriorate because of the surrounding environment such as soils, roads, and ground depth, resulting in the outage of water and improper functioning. As of 2013, 1.381 pipes were more than 20 years old, and required improvement in 10 years;

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this is 27.17% of the total number of pipes. In 2024, that is 10 years later, 2,666 pipes will require improvement, which is 52.45% of the total number of pipes. Based on this data, it is expected that the risk of a water supply outage has significantly increased. In addition, deterioration is expected at the same time, since all the water pipes were laid during a short period of rapid economic growth. Thus, it is also expected that tremendous expense will be required in order to carry out these improvements, and it is inevitable that a more effective plan has to be prepared for improvement, while utilizing limited resources [1].

In order to supply water to users reliably and continuously, it is necessary to evaluate the risk of water outage, and prepare solutions for reducing the risk of water outage, by utilizing the results of a risk assessment of water supply systems. It is also necessary to accord high priority to the improvement of pipes in order to maintain water supply systems properly. For evaluation of the risk of water outage, the estimation of the pipe failure rate should be done by analyzing the various causes related to damage of the pipes. Therefore, this study intends to propose a method for estimation of the pipe failure rate, utilizing the safety coefficient calculated based on various factors that influence the failure of pipes.

1.2 Research Details

In this study, the target area was selected first. In order to understand the situation in that area, data such as the diameter of pipes in the area, the year when they were laid, type of pipe used, and event history were collected from the recovery records of water leakage, event log records, and the existing water supply situation of users. The pipe failure rate was estimated with the exponential model, using the optimized correlation coefficient by applying the actual accident log data, which was based on the safety coefficient of the pipeline. The correlation coefficient for the model was derived using the least squares technique.

2. **Research from Previous Studies and Theoretical Investigation**

2.1. Risk Analysis

A water supply system should have the capability to supply a certain amount of water continuously, even in abnormal conditions such as water leakage and the failure of pipes. If the water supply is cut off, resulting in difficulty for the users because of the non-availability of water, then it would be a negative accident. In terms of uncertainty classification, it is said to be a risk, and not an opportunity. In this case, the stochastic figure that includes uncertainty factors such as leakage and failure of pipelines, damage level caused by the cutting off of water, and the margin for mitigation of damage can be considered. The water outage risk presented in this study is an index that includes the probability that the supplier cannot provide water for users, results of damage(time for repair of broken pipes, water demand), and redundancy.

2.2. Estimated Model for Pipe failure Rate

2.2.1. Research trends

The estimation of the pipe failure rate falls into two categories: a physical model and statistical model. The physical model is based on a deterioration mechanism that directly influences the failure of pipes, and is made by understanding the extent of damage of the pipes, such as scale and rust. Thus, the physical reasons for pipe failure are clear and a wide range of variables and data can be used. However, it is very difficult to measure or examine all the pipes for the factors that cause failure, because it takes a lot of time, and is expensive. The statistical model applies two methods: one is by estimating an exponential function or linear function that has a large correlation, and the other is by using established models such as the regression analysis model, Markov model, Poisson model, or Cohort survival model. The statistical model is a macroscopic method that uses the data stored over a long period, and allows data collection with relatively low expenses. However, it has the disadvantage of not providing physical evidence of the factors that caused the deterioration of the pipes. The statistical model quantifies the structural deterioration of the pipes by historical data, and goes through a process that analyses the frequency of accidents, sequence of accidents, and status of the pipes from event logs of the water supply system.