様式３

学 位 論 文 要 旨

論文題名　Study on Replacement Plan with Statistical Analysis for Water Distribution Pipelines

（統計解析を用いた水道配水管路の更新計画に関する研究）

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（ 学位論文要旨 ）

Water-supply consumers today are seeking high standard water services that correspond to their improved living environment. As a result, waterworks services around the world have been making efforts to provide stable supply of high quality water. However, in Korea the average revenue water ratio of the entire country in relation to the amount of fees collected for the production of water supply facilities was 83.5% in year 2011, lower than other developed countries with advanced water supply systems. This low revenue water ratio is caused by leakage in and deterioration of pipelines. There are many factors that contribute to leakage and deterioration, and these factors have some kind of correlation between them. Firstly, the cause of leakage and deterioration is found in the pipe material. Traditional materials such as PVC, PE and CIP (Cast Iron Pipe) are weaker to leakage and deterioration than comparatively new materials such as DIP (Ductile Iron Pipe). Moreover, the pipe aging is another factor, and there are more than 20% water distribution pipelines that are over 21 years old. This means such water distribution pipelines are already deteriorating. Other cause of leakage is pipe corrosion, particularly with physical and chemical soil properties. However, as it is too difficult to directly measure the degree of corrosion, it is necessary to indirectly measure and assess corrosion in pipes. When water leakages and pipeline accidents occur, water can be cut off and cause direct damage to consumers, while affecting others as a result of roads being blocked off and hindered use of surrounding facilities during pipeline restoration. Consequently, it is necessary to replace water distribution pipelines for preventing leakages. The aim of this research was to suggest how to effectively plan water distribution pipeline management by considering three methods: to indirectly check the present conditions of pipes through a statistical approach, to effectively calculate the replacement rate of pipes through economic evaluation within the limited budget, and to calculate the replacement priority of pipes by predicting pipeline accidents and the extent of damages that may happen in the future. This paper comprises five chapters and includes a discussion on these three methods.

Chapter 1 provides a general description of the research background, purpose and composition; while Chapter 2 evaluates the present pipe conditions in an effective way. The study particularly regards pipe corrosion as a representative factor of pipe condition, because corrosion of pipes cause cracks and bursts that lead to water leakage, pipe repair, and even water quality problems. It should be noted here that it is difficult to evaluate pipe corrosion. Pipes laid underground are hardly

excavated for examination. Pipe corrosion is also related to many factors such as pipe materials, pipe age, surrounding soil conditions, water quality, pipe maintenance and management, and so forth. Hence, in order to evaluate pipe corrosion without excavation, a method of indirect evaluation is necessary. For this study we focused on external corrosion by firstly searching references on pipe corrosion and then analyzing samples with pipe characteristics and using soil test. During this process, statistical approach was applied to this study due to insufficient data. In particular, discriminant function analysis and regression analysis were applied to the analyses of soil properties and pipe characteristics, respectively. We then developed models applied to the study area for evaluating pipe corrosion. In addition, this study also evaluated future risks by utilizing developed models.

Chapter 3 deals with the rate of annual replacement of main distribution pipelines. Water pipelines age with time and aged pipelines cause leakages and other water supply problems. Thus, a replacement plan is needed to effectively maintain these pipelines. This study proposes a long-period simulation using an accidental damage occurrence model that handles water pipeline damage contingencies. It involves the calculation for the post-damage maintenance scenario and the preventive maintenance scenario, as well as comparative analyses of the costs and the affected population, ultimately achieving a highly cost-effective replacement plan. Here, as occurrence of failure may be influenced by various contingent factors like random phenomena, the failure probability was calculated using Monte Carlo simulation. Next, the results of the simulation were applied to economic evaluation using benefit–cost analysis. Economic evaluation is necessary because budgets for pipeline replacement are limited. In this study, the benefit is shown as the affected population, while the cost is the sum of total repair cost and total replacement cost. From this we were able to set the annual replacement rate for main distribution pipelines through the simulation model and economic evaluation. In addition to this, the replacement of key pipelines was also introduced.

In Chapter 4 we proposed the replacement order for distribution pipelines. Current existing water pipeline replacement plans almost follow the order of aged pipelines, but such plans can be vulnerable to risks. The cause of a pipe's deterioration is not only due to aging but also various other factors. Accidents along important pipelines cause more impact both directly and indirectly on consumers. Thus, this study aims to propose an efficient water pipeline replacement plan by considering risk prevention and factors that cause the deterioration of pipelines.

For this study we attempted to analyze risks through three analyses. The first analysis was for predicting the number of pipeline damages to find out how many times the pipes would be damaged in the future. The second analysis was for estimating the restoration time which represented indirect disadvantages of pipeline damage accidents by pipe repair time. The third analysis was for investigating the direct impact on consumers when a pipeline is intercepted at the damaged point. From these analyses we were able to obtain the quantitative rank of risks in each analysis. As the risk ranking of each analysis is different, it was necessary to find the overall risk ranking. Consequently, in this study we introduced the predicted risk index (PRI) to estimate the overall risk ranking. In conclusion, the highest PRI eminently deserves the utmost priority for pipeline replacement. This study also proves that replacement in order of PRI has an advantage over replacement in order of aged pipes using the simulation model given in Chapter 3.

Chapter 5 presents the conclusions of this research and recommendations based on the conclusions. In the conclusions a summary of this research is provided and the achievement of the present study is discussed. Recommendations were made for further considerations on proposed methods to evaluate and replace the water distribution system in Korea.

注意　２０００字程度、１２ポイントで記載

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研　究　業　績　一覧

*印は，本論文に直接関係するものを示す

1．論文（査読あり）

No.	論文名	掲載誌	巻，号，頁	発行年	著者名
1*	Study on the Characteristics of Night Flow Components for Leakage Management in District Metered Areas	5th IWA Specialist Conference on Efficient Use and Management of Urban Water	P-14 (6 Pages)	2009	M. C. Kim K. H. Jang J. Y. Koo
2*	A Study on Characteristics of Night Flow Components for Leakage Management in District Metered Areas （in Korean）	Journal of Korean Society of Water and Wastewater	Vol. 23 No. 6 pp. 871-879	2009	J. Y. Koo K. H. Jang M. C. Kim
3*	Analysis of the Effects of Water Leakage Prevention Management using Mesh Data of Water Distribution Networks	Water loss 2012 Manila, Philippines	No.110 (8 Pages)	2012	Y. Arai T. Inakazu A. Koizumi H. Ariyoshi M. C. Kim J. Y. Koo
4*	A Long Term Planning of Water Pipeline Rehabilitation Considering Preventive Maintenance	The 9th International Symposium on Water Supply Technology in YOKOHAMA 2012	OP2-1 (8 Pages)	2012	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
5*	Statistical Approach for Corrosion Prediction under Fuzzy Soil Environment	Journal of Environmental Engineering Research	Vol. 18 No. 1 pp. 37-43	2013	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
6*	Study on Water Distribution Control Simulation Method to Reduce the Amount of Water Consumption during Pipeline Cleaning	The 5th IWA-Aspire Conference & Exhibition	Accepted (8 Pages)	2013	T. Kunizane T. Inakazu A. Koizumi M. C. Kim Y. Arai
7*	Estimation of Priority Rank of Water Pipeline Replacement through Risk Analysis	Japan Society of Civil Engineers Ser.G (Environmental System Research)		2013	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
8*	Study on Simulation Analysis Using the GIS for Reduction of Residual Chlorine in Water Distribution System	Japan Society of Civil Engineers Ser.G (Environmental System Research)		2013	T. Kunizane T. Inakazu A. Koizumi K. Shimizu M. C. Kim H. Kitazawa C. Sato

２．国際学会

No.	論文名	掲載誌	巻，号，頁	発行年	著者名
1*	A Study on pipeline Rehabilitation Planning Using Pipeline Accidental Damage Occurrence Model	The 1st International Conference on Green Environmental Technology 2011	PB-11 pp. 379-380	2011	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
2*	A Case Study of Pipeline Rehabilitation Planning Considering Key Pipeline Priority	The 10th Seoul-Tokyo International Symposium of Water and Environmental Engineering	pp. 139-151	2011	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
3*	A Study on the Diagnosis Model for Water Distribution Pipe Corrosion	The 11th Seoul-Tokyo International Symposium of Water and Environmental Engineering	pp. 96-108	2012	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
4*	A Statistical Study on the Influence of Soil Properties on External Corrosion for Water Distribution Pipe Maintenance	IWA world water congress & exhibition	Theme 7 (4 Pages)	2012	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
5*	A Study on Risk Ranking of Water Distribution Network for Water Pipeline Replacement Plan	The 5th IWA-Aspire Conference & Exhibition	Accepted	2013	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo

３．口頭発表

No.	論文名	掲載誌	巻，号，頁	発行年	著者名
1*	A Study on the Development of Sewage Treatment Plant Optimal Management Model by Inflow Increase during Rainfall (in Korean)	Korean Society of Water and Waste water 2008 Fall conference	pp. 890-891	2008	M. C. Kim K. L. Kim J. Y. Koo
2*	A Development of Optimal Construction model for Small Distribution Block's Boundary (in Korean)	Korean Society of Environmental Engineering 2009 Fall conference	pp. 180-181	2009	M. C. Kim K. P. Kim J. Y. Koo
3*	Study on Comparison between HDSM and DDSM for Water Distribution System Analysis	第 61 回全国水道研究発表会講演集	pp. 624-625	2010	M. C. Kim K. P. Kim J. Y. Koo
4*	A Comparative Study of HDSM Model and DDSM Model for Water Distribution Network (in Korean)	Korean Society of Environmental Engineering 2010 Spring conference	pp. 232-233	2010	M. C. Kim K. P. Kim J. Y. Koo

5*	Development of Prediction Model for External Corrosion Utilizing Pipe Body Excavation Sampling Data	第 63 回全国水道研究発表会講演集	pp. 686-687	2012	M. C. Kim T. Inakazu A. Koizumi J. Y. Koo
6*	管路施設健全度の向上効果に関する一考察	土木学会第 67 回年次学術講演会講演概要集	pp. 167-168	2012	森永 拓 稲員とよの 小泉 明 荒井康裕 國實 誉治 金 敏哲
7	残塩濃度低減化シミュレーションによる追塩シナリオの検討	土木学会第 68 回年次学術講演概要集		2013	清水 和輝 稲員とよの 國實 誉治 金 敏哲 小泉 明 北澤 弘美 佐藤 親房

上記のとおり相違ありません。

平成 25年 6月 5日

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※講演も記載すること。著者名は全員記載し、ご本人に下線を引いてください。
ご本人のローマ字入力のお名前も下線をお願いいたします。
主要論文に＊など印をつけてください。

【英文の表記について】
英語タイトルの大文字と小文字を研究業績一覧の中で統一すること。
1つの単語が 2 行にわたる場合は、必ず音節（シラブル）で区切りハイフン（-）を入れて、次の行に送ること。

様式５

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３　平成２０年　８月２０日　ソウル市立大学環境工学部卒業（韓国）

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６　平成２２年１０月　１日　首都大学東京大学院都市環境科学研究科博士後期課程
都市基盤環境学域入学

７　平成２５年　９月　　日　首都大学東京大学院都市環境科学研究科博士後期課程
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受 賞 歴

Best 5 poster presentation (2012 IWA world water congress & exhibition)

上記のとおり相違ありません。

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