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A Study on Deriving the Importance and Feasibility of Demolition Sequences and Evaluation Factors of Major Components for Deriving Standard Decommissioning Scenarios for Pressurized Heavy Water Reactor Nuclear Power Plants

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1. Introduction

Recently, South Korea has decided to permanently shut down the Wolsong-1 nuclear power plant and is currently preparing for the decommissioning of commercial pressurized heavy water reactors (PHWR) for which there is no prior experience in the world.

In this study, the demolition order of the main large component and the main factor for deriving the standard decommissioning scenario are derived by utilizing the integrated module currently under development. The validity and reliability of the evaluation were ensured by deriving the basic plan for establishing demolition scenarios and utilizing the Analytic Hierarchy Process (AHP) technique.

2. Methods and Results

2.1 Overview of Evaluation Modules

2.1.1 Work Difficulty Evaluation Module

This module evaluates the difficulty of each demolition process, which affects the unit cost factor (UCF) of the decommissioning cost evaluation, by considering factors such as accessibility, respiratory protective equipment, ALARA (as low as reasonably achievable) principle, and protective clothing in the working environment.

2.1.2 Cost Evaluation Module

Using the difficulty factors and unit cost factors such as labor costs, equipment costs, and facility costs, evaluates the cost of demolition of large components.

2.1.3 Demolition and Operator Exposure Dose Evaluation Module

This module determines the demolition sequence of the major large component and derives the worker's exposure dose for each structural element depending on the method used (e.g., decontamination, volume reduction, cutting).

2.1.4 Quantity Evaluation Module

Considering the cutting conditions of the major large component derives the quantity of decommissioning waste based on the number, size, volume, and thickness of the cut materials.

2.2 Basic Approach for Establishing Standard Decommissioning Scenarios

To derive standard Decommissioning scenarios for a pressurized heavy water reactor (PHWR), fundamental strategies and major work procedures must be determined. The integrated module considers the major demolition procedures, such as cutting and removal, decontamination, and packaging scenarios.

For the cutting and demolition procedures, the selection of the target material, cutting operation, and demolition must be considered, and the results of cost evaluation, equipment, time, and the number of workers must be linked to the cost evaluation module.

For the decontamination procedures, the selection of the decontamination method must be considered, and the cost evaluation must account for the equipment, time, number of workers, and secondary waste generation.

For the packaging procedures, UCFs are selected for each stage of the process, and an evaluation is made of the number of cutting pieces and packaging containers required based on the volume. The equipment cost factors (e.g. purchase and Consumables fee etc.) must also be considered.

2.3 Derivation of Major Evaluation Factors (Practitioner Evaluation)

2.3.1 Ranking of 24 Factors Considering the Order of Demolition Sequence

Dismantling Order (I)	Dismantling Order (II)	Dismantling Order (III)	Dismantling Order (IV)	Dismantling Order (V)	Dismantling Order (VI)
Structure Highest	Structure Highest	Structure Dose Level	Dismantling Structure	Labor Cost	Labor Cost
Labor Cost	Structure Dose Level	Area Dose Level	Structure Dose Level	Working time	Dismantling Structure
Structure Dose Level	Area Dose Level	Equipment Cost	Area Dose Level	Dismantling Area Location	Working Type
Area Dose Level	Labor Cost	Labor Cost	Labor Cost	해체대상물	Working time
Equipment Cost	Equipment Cost	Dismantling Structure	Consumables Cost	Working Type	Working Consideration
Consumables Cost	Dismantling Area Location	Consumables Cost	Equipment Cost	Working Consideration	Structure Dose Level
Dismantling Structure	Working time	Dismantling Area	Dismantling Area Location	Structure Dose Level	Area Dose Level
Worker Number	Controlled Area (O, X)	Dismantling Area Location	Working Consideration	Area Dose Level	Dismantling Area Location
Working time	Dismantling Structure	Working Type	Dismantling Area	Equipment Cost	Equipment Cost

Fig. 1. Derivation of ranking of major factors (Practitioner)

To develop a standardized decommissioning scenario using the integrated module, 10 internal practitioner evaluation was conducted for 24 input factors, and the importance scoring of the input factors considering the demolition sequence was derivered. The ranking of the input factors considering the order of demolition was derived as shown in Figure 1.

2.3.2 Selection of Optimal Input Factors Considering the Demolition Sequence

Based on the results, three input factors were selected for each module, as shown in Table I. but, the quantity evaluation module was excluded from the main evaluation module because it was judged that it would not act as a variable for deriving the standard decommissioning scenario.

Table I: Deriving optimal input factors

Evaluation module	Optimal factor
Work difficulty evaluation module	Accessibility, Structure dose level, Area dose level
Cost Evaluation Module	Labor cost, Equipment cost, Consumables cost
Demolition sequence and operator exposure dose evaluation module	Structure, Working type, Working time

2.4 Derivation of Weights for the demolition Sequence and Optimal Input Factors (Expert Evaluation)

2.4.1 Derivation of AHP Evaluation Methodology

To perform an expert evaluation using the AHP evaluation technique, the nine factors derived based on the results of the Practitioner evaluation and the linkage between the demolition sequence and the evaluation criteria are shown in Figure 2.

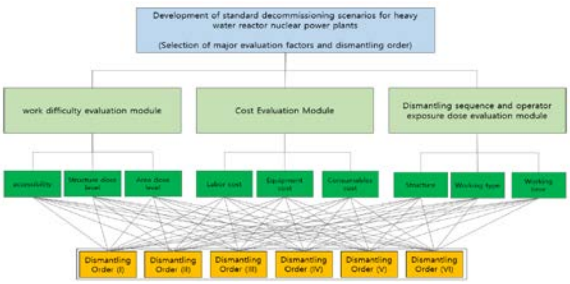

Fig. 2. Linkage between sub-criteria and alternative evaluation between input factors

2.4.2 Results of Evaluation

The order of demolition of major large equipment was derived as shown in Figure 3. Also, the order of the nine sub-criteria was derived as shown in Figure 4. In the difficulty evaluation module, the weight of the working area radiation level was evaluated as the most important factor. In the cost evaluation module, labor cost and in the demolition sequence and worker radiation evaluation module, working time was evaluated as the most important factor.

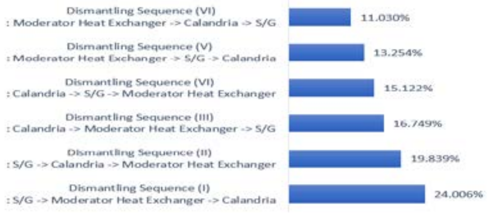

Fig. 3. Dismantling sequence of major structure (Expert)

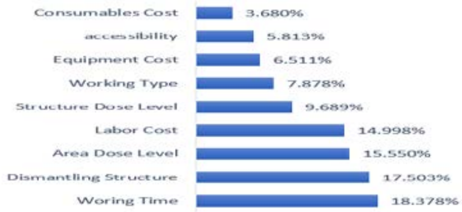

Fig. 4. Derivation of ranking of major factors (Expert)

3. Conclusions

In this study, as a preliminary step to derive a standard decommissioning scenario for domestic heavy water reactor nuclear power plants, a study was conducted to secure the validity and reliability of the decommissioning sequence and input factors. By using a decision-making model, the relative importance was converted into a ratio scale, and quantitative data along with qualitative elements were confirmed for the main input data that can be used in the integrated module. In future studies, a database of input factors (variables) and other input factors (default) derived from this study will be established to derive a standard decommissioning scenario considering the demolition order.

4. Acknowledgments

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