Low-Activation Design of Reinforced Concrete for Nuclear Power Systems

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Reinforced concrete structures in a typical light water reactor or other nuclear facility become low-level radioactive wastes by thermal neutron irradiation. Since volume of the concrete waste after reactor decommissioning is very large, to reduce the radioactivity of reinforced concrete leads to cut down remarkably the amount of radioactive waste. In case of fusion reactors, it is also very important to estimate volume of radioactive waste before building a new reactor and reduce its volume and radioactivity level.

In this study, the selection of raw materials of reinforced concrete is considered to be the possible key to solve this issue.

(1) Raw materials survey and database construction
The mainly long-lived radionuclides in reactor shielding walls were found to be $^{60}$Co, $^{152}$Eu, and $^{154}$Eu generated by $^{59}$Co(n, $\gamma$) $^{60}$Co, $^{151}$Eu(n, $\gamma$) $^{152}$Eu and $^{153}$Eu(n, $\gamma$) $^{154}$Eu. In order to determine the content of these elements in raw materials of reinforced steel bar, cement, and concrete aggregate, instrumental neutron activation analysis (INAA) was applied. In addition to INAA, X-ray fluorescence (XRF) was performed to determine the content of major elements. The element contents of raw materials were incorporated into "Materials Database”, and studied the correlation between the concentrations of Co, Eu and other elements.

(2) Low-Activation Material Design Support System (LAMS)
LAMS was developed for raw materials selection using "Materials Database”. LAMS has four functions: (a) material database viewer includes chemical compositions of raw materials of reinforced bar and concrete. (b) Production process simulator includes manufacturing procedure and possible contamination or purification of certain elements enable virtual creation of chemical compositions of the products such as the reinforced concrete. (c) Optimization of raw materials mixing can be calculated by multi-objective optimization method. Simulated annealing method has good convergence and quick calculation speed. (d) Activation level of reinforced concrete structure after irradiation of various type of neutron energy spectrum can be calculated. Simultaneously, costs of raw materials to build reinforced concrete structures of new reactor can be estimated. LAMS shows design concepts of new reactor from raw materials selection to component arrangement for reduction of radioactive wastes after decommissioning.