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Evaluation of LMFBR core seismic analysis - Code verification and design consideration-

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ABSTRACT

TOSHIBA has been developing a special purpose FEM code named SALCON for the seismic analysis of LMFBR core components. In this paper, the validity of design analysis by the single row configuration were evaluated. This evaluation work was performed as a part of "Intercomparison of LMFBR Seismic Analysis Codes" organized by IAEA.[1],[2],[3]

1. INTRODUCTION

TOSHIBA has been conducted series of seismic vibration tests for Japanese prototype LMFBR MONJU under the sponsorship of Power Reactor and Nuclear Fuel Development Corporation (PNC). Based on the experience of the seismic design of MONJU core components, TOSHIBA has been developing a special purpose FEM code named SALCON for the seismic analysis of core components. Details of the code and its verification by using MONJU seismic tests had been described elsewhere[4],[5]. Due the degree of freedom and the vast number of non linear calculation steps, it is preferred for the design calculation to represent the whole core seismic vibration by the central single row. So the author was very interested in evaluating the validity of this simplification.

2. CALCULATION OF PEC TESTS

In PEC Tests n.47 and n.30, eight core fuel elements and 11 reflector elements were vibrated in water as shown in Fig. 1. It was very important to evaluate the effects of the direction of the input acceleration on the core seismic behavior. In the Test n.47, the elements were accelerated in the flat-flat direction while in Test n.30 the acceleration was in the corner-corner direction.

In the calculation, eight core fuel elements and 11 reflector elements were modeled. Each of the elements was modeled by seven beams which was supported at the bottom. There were impact force elements between the adjacent elements in the top pad as well as the middle pad levels to simulate the effects of collision during the seismic vibration. The fractions of critical damping for the 1st and 2nd vibration modes were set to be 4 % and 15 % respectively.

2.1 *Test n.47*

To take into account the support condition at the inlet nozzle, a linear spring element was attached at the second node from the bottom for each of the beams.

In Test n.47, the spring constant K was adjusted to be 3000 kgf/cm to make the natural frequency of the fuel elements to be 3.2 Hz which was the dominant response frequency in the test. Then the natural frequency of the reflecting elements became 2.7 Hz by using the same spring constant.

Calculations were made with two configurations. One configuration was a single row model where the nineteen elements in the test configuration were represented by five elements in the central row. The other one was matrix model where all the nineteen elements in the test configuration were taken into account.

The diagrid acceleration data in the flat to flat direction (TH n. 61 Test n. 47, 0 db) was used for the time interval of 4.5 sec to 11.5 sec where the maximum displacement was observed in the experiment. The maximum acceleration in this time interval is 829 gal at 10.91 sec. Calculated maximum displacements by the single row model are compared with the experimental data in Table 1 at the top of the test elements in the central raw B1, A1, A0, A4, and B7. The agreements are very well.

An additional calculation was made by applying the Guyan reduction where the freedoms were condensed into the 3 nodes(Mid pad, Top pad, and Top) to decrease the computation time. The results shown in Table 1 are quite satisfactory. The computation time was only 1/5 of the original calculation which is very effective for design calculations.

The other calculation with the matrix model was also performed to justify the validity of the single row model. The Guyan reduction was also applied in this calculation. Calculated maximum displacements of 19 elements are compared with the ones by the single row model with the Gyuan reduction in Fig.2 These comparisons confirms the validity of the single row model.

2.2 *Test n.30*

In Test n. 30, the direction of input acceleration was corner to corner direction. The matrix model was used with the Gyuan reduction. A calculation was made for the time interval of 6.0

sec to 10.0 sec where the maximum displacements were observed. The maximum acceleration was 300 gal which is much smaller than that of Test n.47.

The calculated vibration was found to be very sensitive to the natural frequency of the elements, because the dominant frequency of the input acceleration is very close to the natural frequency. A calculation with the spring constant K=3000 kgf/cm resulted with smaller as well as quicker response than the measured time history. This tendency still exists in the calculation with K=200kgf/cm. The spring constant K=1500 kgf/cm was chosen which makes the natural frequencies to be 2.8 Hz and 2.4 Hz for the core fuel and reflecting elements respectively. This reduction of the natural frequency was maybe caused by the small gaps at the bottom of the elements. With this adjustment, the calculated displacement became satisfactory as shown in Fig.3.

3. DESIGN CONSIDERATION

The selection of the direction of the input acceleration is a very important issue for the core aseismic design. As shown in section 2.1, the LMFBR core can be represented by the single row model when the input acceleration was in the flat to flat direction (x-direction). Therefore, if the direction of the input acceleration can be represented by the x-direction, the design calculation becomes very simple. The validity of SALCON code under the corner to corner excitation (z-direction) was demonstrated in section 2.2. So, several calculations were performed under the same condition except the input acceleration direction; x- vs. z-direction.

The first comparison was performed with the core configuration shown in Fig.4, the test elements for the PEC tests are modeled but in different arrangement to simulate the actural core responce. The input acceleration was that of Test n.30. The calculated maximum displacements in the direction of excitation are compared in Fig.5. The maximum displacements scattered in the same region.

The second comparison was performed with the Monju test configuration of 37 elements as shown in Fig.6. The Monju input acceleration normalized to 600 gal was used for 1 sec. The calculated maximum displacement and impact forces were plotted in Fig.7 and 8.

Although, the calculation need more varification work, the seismic load maybe calculated by the single row model with the input acceleration in the direction of flat to flat.

REFERENCE

1) IAEA-TECDOC-798, May 1995, IAEA.

2) IAEA-TECDOC-829, Oct. 1995, IAEA.

3) IAEA-TECDOC-882, May 1996, IAEA.
4) Y. Sasaki, etal., SMiRT 7,F7/3,1983
5) Y. Sasaki, etal., SMiRT 11,E16/3, 1991

Table 1 Maximum Displacements at the Top of the Components (PEC Test n.47)

Location Item	Core Fuel B1(cm)	Core Fuel A1(cm)	Reflector A0(cm)	Reflector A4(cm)	Reflector B7(cm)
SALCON	4.51	4.68	5.13	5.12	5.11
Experiment	4.82	4.74	5.07	5.09	5.04
Ratio(C/E)	0.94	0.99	1.01	1.01	1.01
Guyan Reduction	4.35	4.50	4.95	4.91	4.97

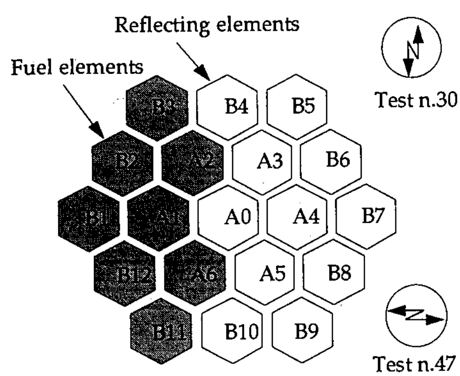

Fig.1 Configuration of PEC Tests

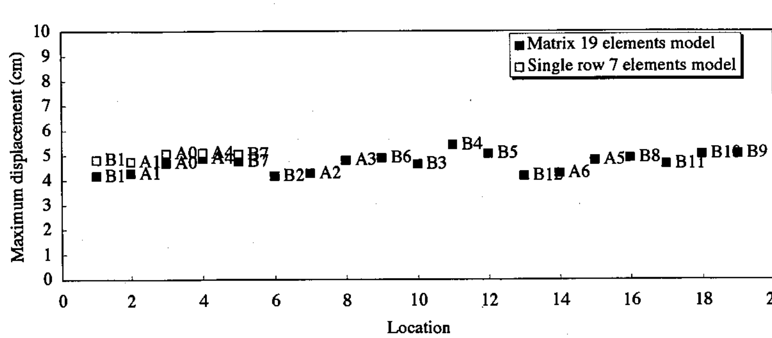

Fig. 2 Calculated maximum displacement (Matrix vs. single row model)

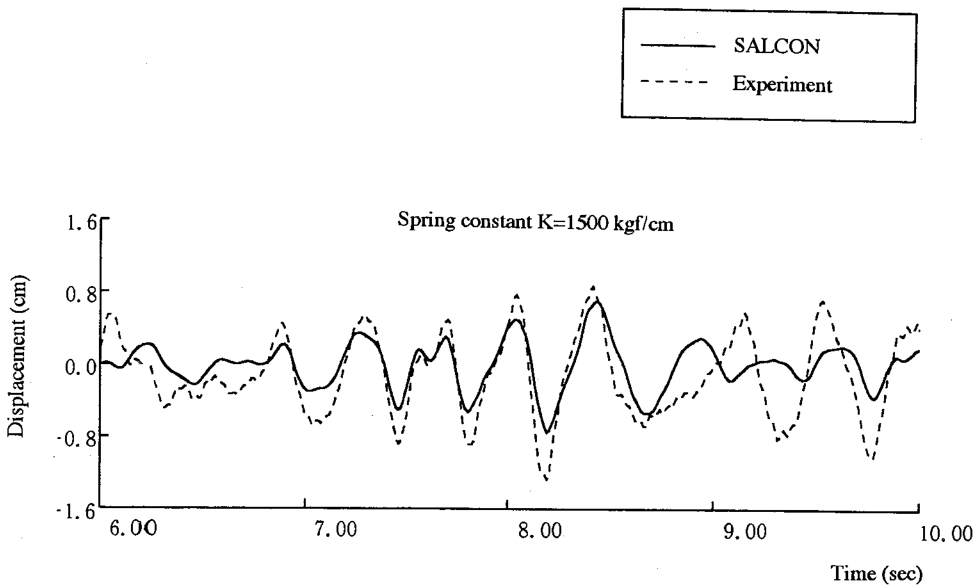

Fig.3 Comparison of displacement time history (PEC Test n.30)

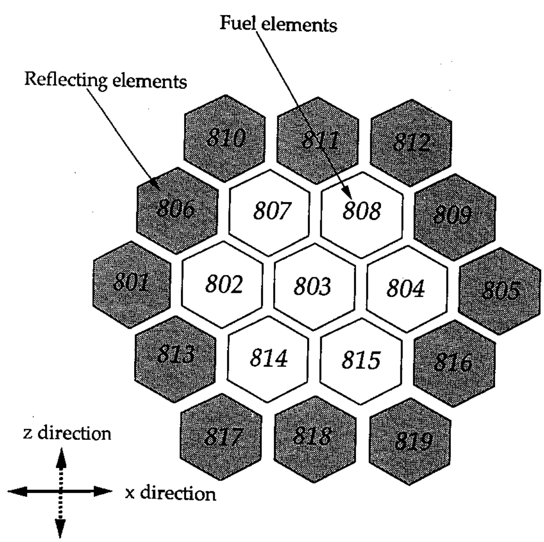

Fig.4 Configuration of XZ Analysis

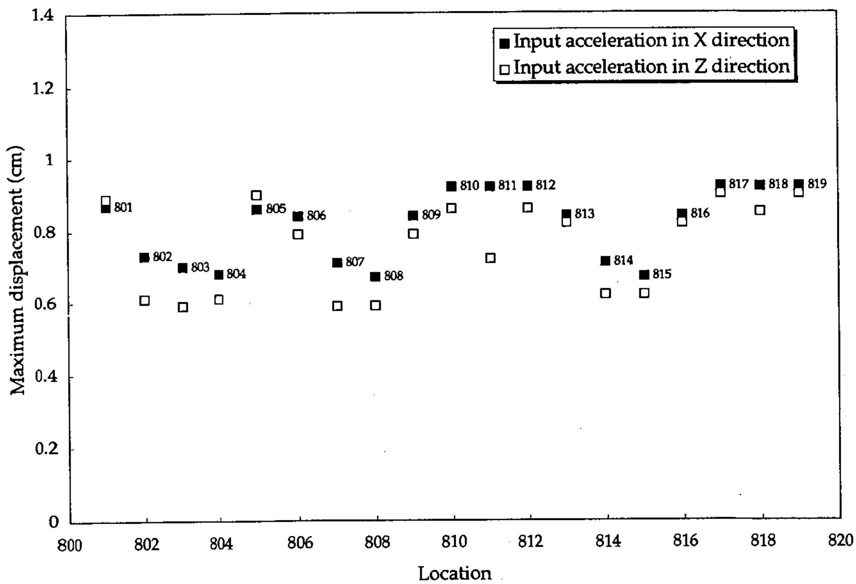

Fig. 5 Comparisonof max displacement X vs Z direction exicitation

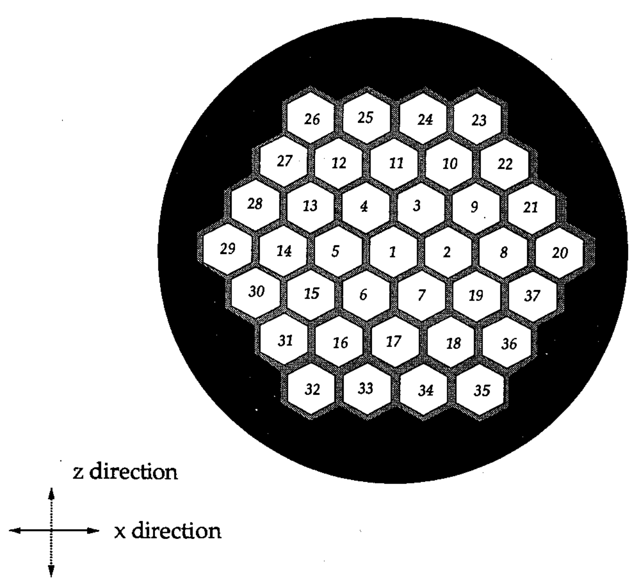

Fig. 6 Configuration of Analysis
(Monju assemblies were used)

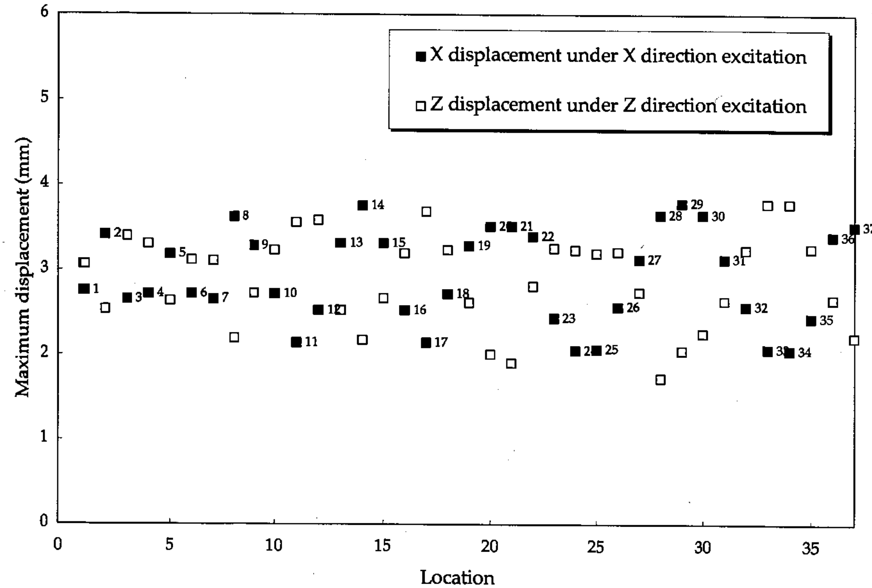

Fig. 7 Comparison of max displacements between X and Z direction excitation (Monju)

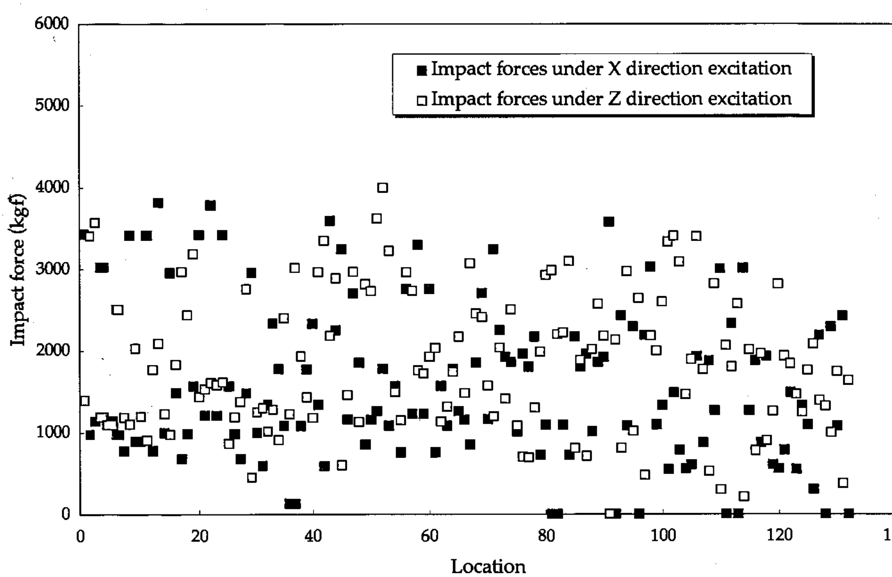

Fig. 8 Comparison of impact forces between X and Z direction excitation (Monju)