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Numerical Simulation of Missile Impacts on Reinforced Concrete Plates

Chul-Hun CHUNG [a], Jungwhee LEE [a*], Han-Joo LEE [a], Raeyoung JUNG [b], Moon-Soo KIM [b]
[a]*Dept. of Civil and Environmental Engineering, Dankook Univ. Yongin, 448-701, Korea*
[b]*Structural Systems & Site Evaluation Dept., Korea Institute of Nuclear Safety, Yuseong, Daejoen, 305-600, Korea*
[*]*Corresponding author: jwhee2@dankook.ac.kr*

1. Introduction

This paper describes the procedures and results of the IRIS-2012 benchmark project which is the continued project of IRIS-2010 of OECD/NEA IAGE working group [1, 2, 3, 4, 5].

Within the scope of the project, uniaxial and tri-axial concrete tests were performed and the results were supplied by the organizing committee. With these material test data, impact simulations of IRIS-2010 experiments (VTT-IRSN-CNSC Punching P1 and VTT-IRNS Bending B1) were re-performed to improve the accuracy of the simulation results and reduce the computation time.

To reduce the computation time, one quarter of the specimen is modeled considering symmetric condition, and loading function with loading plate is adopted instead of modeling of missiles. With this approach, computation time could be drastically reduced without significant sacrifice of accuracy of the simulation results.

2. Numerical Simulations

2.1 Results of the previous simulation

As mentioned in the benchmark synthesis report authored by IRSN, maximum displacement values were similar between the calculated and measured responses. However the differences of residual displacements are relatively larger than those of the maximum displacements[3, 4]. Also, the vibration frequencies of calculated responses were much higher than that of the measured responses. Therefore, the main objective of the continued work was reducing the differences of residual displacements and vibration frequencies. Another objective was simplifying the FE model for reducing the computation time.

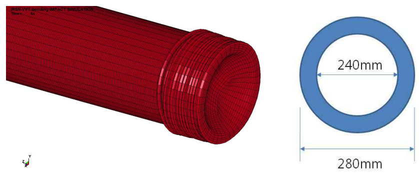
2.2 Simplification of FE Model

To reduce required computation time, the existing model previously built during IRIS-2010 project[6] was reduced to one quarter of the full model, and symmetric boundary condition is applied. After confirming that the two models, full model and 1/4 model, give reasonably consistent results, loading function with rigid loading frame replacing missile modeling is adopted.

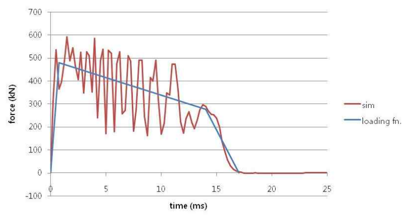
Fig. 1(a) shows the deformed shape of the soft missile after collision and the shape of the adopted rigid loading plates. Fictitious rigid loading plate is devised to make the loaded area similar with that of missile modeling approach regardless of the mesh size of the slab model. Also it is possible to load the slab continuously even if the elements under load are eroded with this loading plate approach.

In the Fig. 1(b), loading function of bending test and punching test are shown with load history acquired from missile modeling approach.

Calculated slab displacements of three cases such as 1) full modeling with missile model, 2) 1/4 modeling with missile model, and 3) 1/4 modeling with loading function, are comparatively shown in Fig. 2. CSCM concrete model[7] is utilized in these analyses. Maximum values of each case are listed in Table I, and consumed computation time of each case are listed in Table II. As shown in the Fig. 2, Table I, and Table II, computation time could be drastically reduced without significant sacrifice of accuracy of the simulation results.



(a) loading plate



(b) loading function

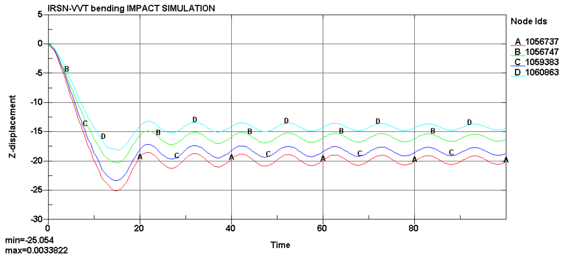
Fig.1 loading plate and function of the bending model

Table I: Comparison of the maximum displacements (mm)

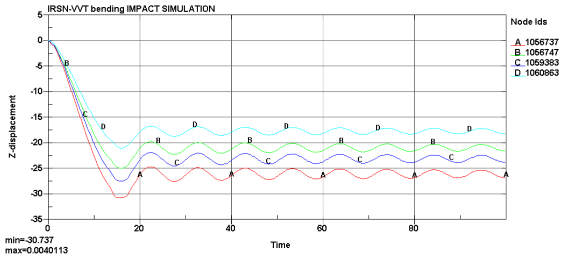
Case	Full, missile	1/4, missile	1/4, loading fn.	Test
Bending	25.0	30.7	29.3	27.0
Punching	3.7	3.6	4.9	5.2

Table II: Comparison of the computation time (hrs)

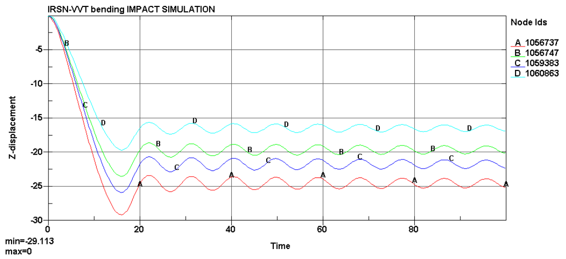
Case	Full, missile	1/4, missile	1/4, loading fn.
Bending	33	14	1
Punching	441	42	3



(a) Full model, missile modeling



(b) 1/4 model, missile modeling



(c) 1/4 model, loading fn.

Fig. 2. Comparison of the displacement response of bending test simulation

2.3 Consideration of the supporting structure

Although the computation time is largely reduced by 1/4 modeling and loading function approach, the vibration frequency is still considerably higher than the experimental results. To match the vibration frequency of the simulation result with that of experimental result, supporting frame and column is additionally considered in the FE model as shown in the Fig. 3. With this consideration, global vibration of supporting structure mainly caused by the axial deformation of the columns could be included in the impact response of the slab.

The displacement results of the two models, the model with and without supporting structure, are compared in the Fig. 4. Also CSCM concrete model was utilized in these analyses. As expected, major vibration frequency is lowered and became closer to the experimental results.

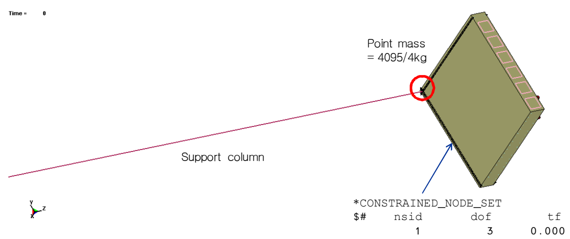
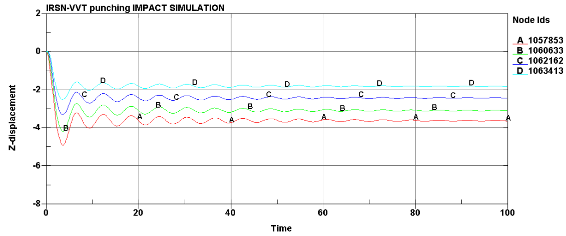
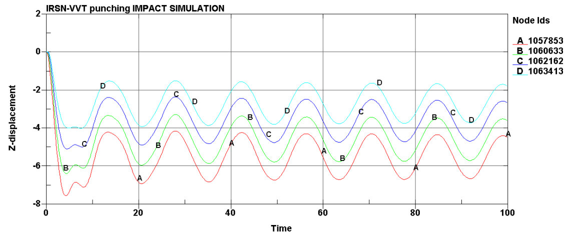


Fig. 3. Modeling of the supporting structure



(a) FE Model without support frame



(b) FE Model with supporting frame

Fig. 4. Effect of supporting structure modeling (punching test case)

3. Conclusions

Conclusions and lessons learned through the previously mentioned procedure are as follows.

1) Computation time could be reduced considerably without significant sacrifice of accuracy of the simulation results by adopting 1/4 model and loading function with loading plate approach.

2) More realistic vibration frequency of the slab displacement response could be simulated by considering support columns and frame mass. Therefore, it is reasonable to conclude that the major vibration frequency of the slab response is governed by the vibration of the supporting structure rather than vibration of the slab itself.

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