Floor Response Evaluation for Auxiliary Building Subjected to Aircraft Impact Loading

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1. Introduction

Research on aircraft impact has grown gradually in a theoretical and experimental way since Riera [1] method was first introduced. Most of these studies have been mainly focused on global and local (penetration, perforation, scabbing of concrete etc.) damage of the structures subjected to an aircraft impact [1-4]. These studies have been aimed to verify and ensure the safety of the targeted walls and structures especially in the viewpoint of the deterministic approach. However, a probabilistic safety assessment as well as deterministic approach for the damage of the internal component in the nuclear power plants (NPPs) subjected to aircraft crash is also needed. A probabilistic safety assessment for aircraft crash includes many uncertainties such as impact velocity, mass, impact location, shape, size, material etc. of aircraft. In this paper, an impact location was selected among the various parameters. This paper found the acceleration floor response spectra at specified locations (safety related components) on the target structure that assumed to be impact velocity 150m/s and maximum fuel for the specified aircraft model.

2. Auxiliary Building Model

A model shown in Fig. 1 of a building with characteristics similar to auxiliary building was prepared for the purposes of this paper. The plan dimensions are 67.7m×74.6m and height is 37.9m, divided to six elevations. The impact is to the 67.7m wide wall at the fifth slab in Fig. 1. The finer hexahedral solid element mesh was employed in the impacted side of the building as shown in Fig. 1.

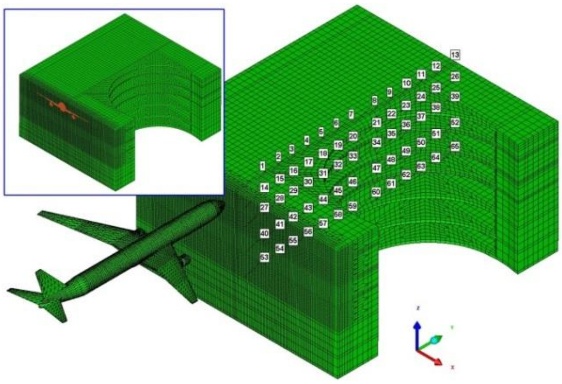


Fig. 1. Model of auxiliary building and of the aircraft and Load area for Riera force history

The floor and backside of the building had a course hexahedral solid element mesh. The fixed boundary condition was applied by restraining translations and rotations at the bottom of building as shown in Fig. 1. Also, the node point number 51(located third floor) at which acceleration response spectra were computed is indicated.
The material model and parameters of this study are described in Table 1. The dynamic increase factor (DIF) was applied at concrete compressive strength [5]. Also, the building natural frequency has 6.79Hz.

Table 1. Concrete Materials Properties

Young's Modulus (kg/m^2)	Poisson's Ratio	Density (kg/m^3)
2.70E9	0.17	2.403
f_{cu} (kg/m^2)	f_{ct} (kg/m^2)	DIF
356.9E4	35.69E4	1.25

3. Aircraft Model and Force-Time History Curve

As shown in Fig. 2, the reaction force at the rigid target is obtained from impact simulation with the 767 model crashed into the target at the assumed initial velocity 150m/s and fuel 70t.

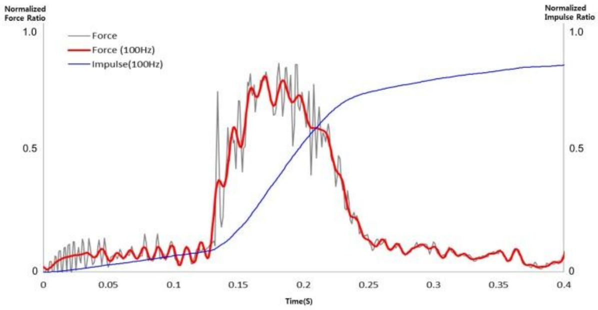


Fig. 2. Force-Time history and impulse curve

The computed reaction force curve (gray line) contains a considerable amount of high-frequency and potentially spurious structural response ("noise"). In order to compare the reaction force curve with the revised force curve (thicker red line); the reaction force curve is passed through a low pass numerical filter (100Hz).
Fig. 1 shows the area where the force history is applied. In this example, the loading up to 0.141 Sec was only applied to the fuselage circle. After the loading until 0.229 Sec is applied to the wing also

added to the fuselage. Finally, the fuselage load is continued until reaching the end of the analysis. The load is applied as time varying uniform pressures over the area indicated in Fig. 1.

4. Riera Force History versus Missile-Target Interaction Method

4.1 Numerical Results

The numerical simulation for varying aircraft impact areas on the auxiliary building carried out using Hydrocode. As shown in Fig. 3, the displacement of node point No. 1(located fifth floor) along the impact direction has been plotted. Unlike the general results on the aircraft impact analysis, displacements of missile-target (M-T) interaction method was occurred less than Riera history method because the external wall between fifth and forth floor was impacted by residual fragment of airframe as shown in Fig. 3.

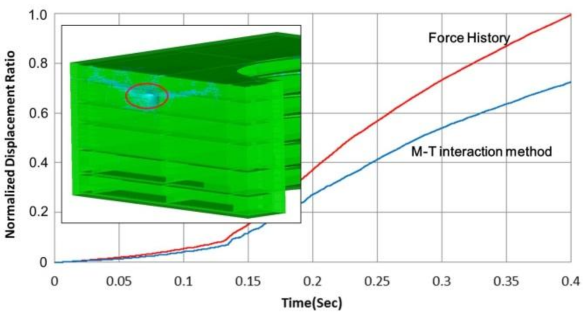
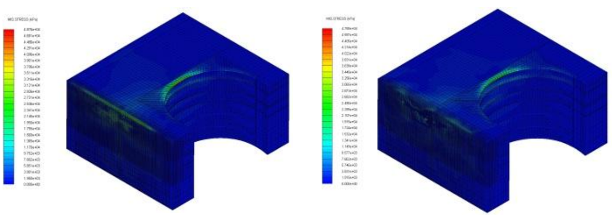


Fig. 3. Displacement ratio of node point No. 1along the impact direction

The stress contours in auxiliary building at 0.4 Sec has been presented in Fig. 4. The auxiliary building on the impact region and the top floor has been partially founded to be under tension.



(a) Riera Force History (b) M-T Interaction Method

Fig. 4. Mis. Stress contour in concrete in the direction of loading at 0.2 sec

As shown in Fig. 4, a maximum stress 48.76MPa was occurred at Riera force history and a maximum stress 47.89MPa was shown in M-T interaction method. The maximum stress around impact location, roof and fifth floor was found at 0.2 sec.

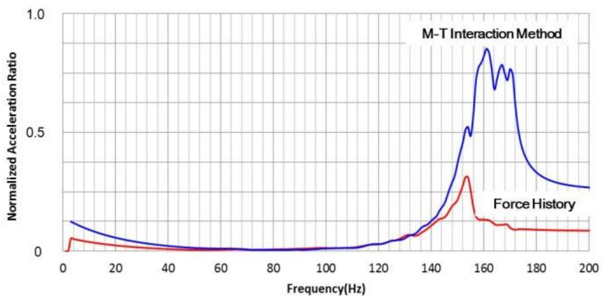


Fig. 5. Normalized acceleration response spectra(ζ=5%) of node point No. 1along the Impact Direction

Fig. 5 show the normalized acceleration response spectra computed at node point No. 1 indicated in Fig. 1 from the two analysis methods. The spectra from the impact analysis show more high frequency energy between 140 and 180 Hz than the spectra from the Riera force history analysis.

4.2 Floor Response Spectra at Various Impact Positions

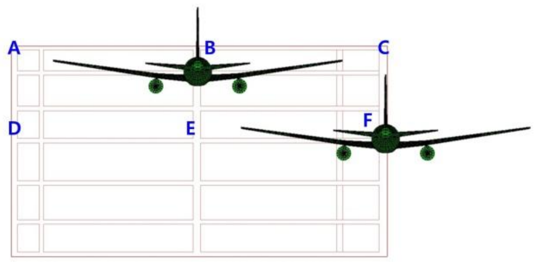


Fig. 6. Various aircraft impact positions

For the aircraft impact with many uncertainties, the impact location on target structure is very important parameter. Thus, the aircraft impact analyses for selected six points in Fig. 6 were performed using missile-target interaction method.

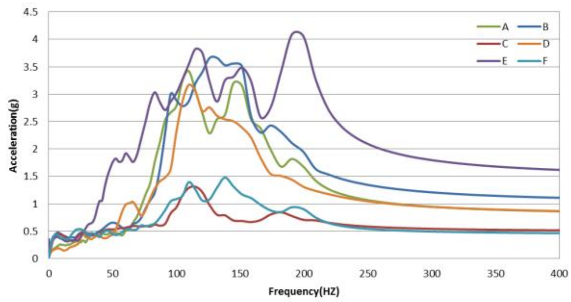
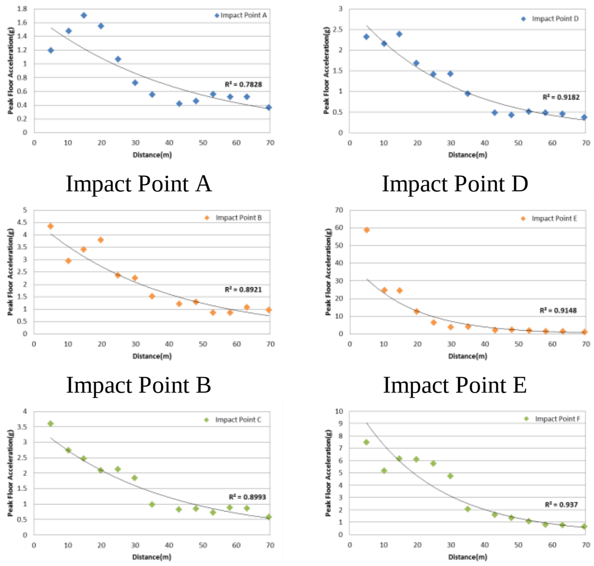


Fig. 7. Acceleration response spectra(at node point No. 51 of Fig. 1) with various impact locations

The floor response spectra (at node point No. 51 of Fig. 1) with various impact locations were shown in Fig. 7. The highest acceleration response was indicated at case E (in Fig. 7), because the distance of impact energy transfer was shortest. The acceleration response at the A, D cases (aircraft impact for the only half section) show more high response between 100 and 150 Hz than the C, F cases (the impact area at impact equal to A, D.), because the long distance for energy transfer.

4.3 Correlation between Peak Floor Acceleration and Distance



Impact Point A Impact Point D
Impact Point B Impact Point E
Impact Point C Impact Point F

Fig. 8. Peak floor acceleration response at each node point location (A distance zero is located on the vertical external wall subjected to impact loading.)

The Correlation between peak floor acceleration and distance from the impact location was shown in Fig. 8. In order to show that PFA and distance from the impact location, R-squared value was used as shown in Fig. 8. The response at impact point F shows the most correlation. However, the response at impact point A shows the correlation less than the other points, because a distance of impact point A and response node points is far.

5. Conclusions

In order to obtain the floor response in case of the crash with a various locations, the analyses for the auxiliary building subjected to aircraft impact were performed using Riera force history method and missile-target interaction method. The difference between responses in case of the building floor subjected to impact was occurred. Thus, in order to obtain the more accurate results, missile-target interaction method was used. This paper found the response at the selected point (node point No. 51). Also, the correlation of response between distance and impact locations was obtained. In these results, the safety related components should be affected by the various impact locations. In order to probabilistic assessment for the safety related components, the assessment for a various parameters (velocity, mass, materials etc.) as well as impact locations should be needed.

Acknowledgement

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