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Preliminary Study on Impact Resistances of Fiber Reinforced Concrete Applied Nuclear Power Plants

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1. Introduction

The safety improvements of nuclear power plants against large civil aircraft crashes are able to be obtained by increasing the toughness of concrete using the fiber reinforced concretes which are able to be acquired by relatively simple processes of adding fibers to a concrete mix without significant changes of design and construction. Studies to improve the impact resistance depending upon design parameters for fiber reinforced concrete, such as type of fibers and application ratio, are in progress. Authors assessed first the impact resistance of concrete walls depending upon fiber types and missile impact velocities [1]. The safety assessment of nuclear power plants against large civil aircraft crashes have been accomplished for normal concrete and fiber reinforced concretes in this study.

2. Impact Resistance of Fiber Reinforced Concrete Applied Reactor Containment Building

2.1 Finite Element Model of Reactor Containment Building

Typical type of reactor containment building was chosen to evaluate the impact resistance of fiber reinforced concretes. Fig. 1 shows the pre-stressing tendons, reinforcement bars and concrete structure models of finite element analyses. Three dimensional embedded truss elements for reinforcement bars and pre-stressing tendons are used and three dimensional solid elements for concrete structure are used in finite element modeling

2.2 Aircraft Impact Loading: Impact Load-Time History and Aircraft Finite Element Model

An impact load-time history of large civil aircraft with impact velocity of 150m/sec proposed by Takeuchi [2] was selected as an external pressure load. The variations of impact load-time histories with impact velocities of 155, 160, 165, 170, 175 and 200 m/sec are plotted in Fig. 2. Also, finite element model of large civil aircraft (left image in Fig.1) are used for the missile-structure interaction analyses of nuclear power plant against large civil aircraft crashes.

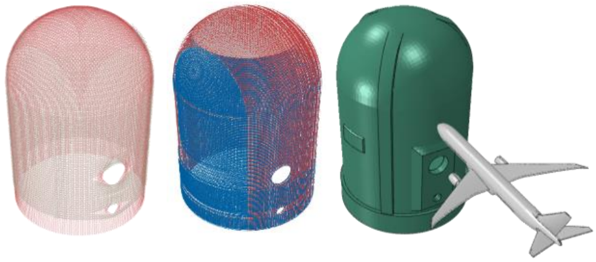

Fig. 1. Finite element model of reactor containment building and large civil aircraft.

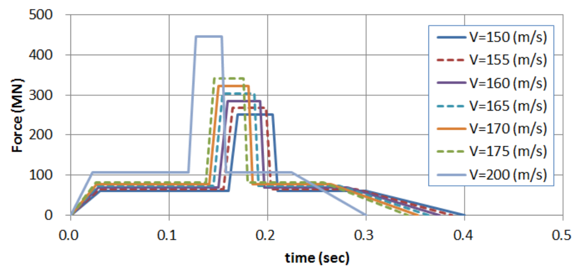

Fig. 2. Impact load-time histories according to impact velocity.

2.3 Fiber Effects on Impact Resistance

The maximum displacements at impact point shown in Fig. 3 were computed for each impact velocity with different concrete type and the maximum displacement ratios to normal concrete at impact velocity 150 m/sec are shown in table I. From the table I, the impact resistance enhancements represented by the maximum displacement ratios to the normal concrete at impact velocity 150 m/sec are only 0.04 for 1 % steel fiber reinforced concrete and even zero for 2 % polyamide reinforced concrete. It seems that there is no performance enhancement of impact resistance of fiber reinforced concrete applied to reactor containment building in the cases of impact velocity 150 m/sec considered in this study. Even some impact velocities form 155 to 170 m/sec show that normal concrete is a little tougher than 2 % polyamide fiber reinforced concrete. The impact resistance of fiber reinforced concrete walls at least 25 % ~ 70 % enhanced compared to the normal concrete wall for impact velocities higher than 100 m/sec [1], these results are not an anticipated impact resistance enhancements of fiber reinforced concrete applied to nuclear power plants.

Table I: Maximum displacement ratio to normal concrete, impact velocity 150 m/sec

Impact velocity (m/sec)	Concrete Type			Ratio to NORM		Impact resistance	
	NORM	PA2	S1	PA2	S1	PA2	S1
150	1.00	1.00	0.96	1.00	0.96	1.00	1.04
155	1.12	1.14	1.05	1.02	0.94	0.98	1.07
160	1.28	1.41	1.16	1.10	0.91	0.91	1.10
165	1.59	1.72	1.30	1.08	0.82	0.92	1.22
170	2.06	2.06	1.56	1.00	0.76	1.00	1.32
175	2.50	2.43	1.87	0.97	0.75	1.03	1.34
200	10.19	7.27	4.51	0.71	0.44	1.40	2.26

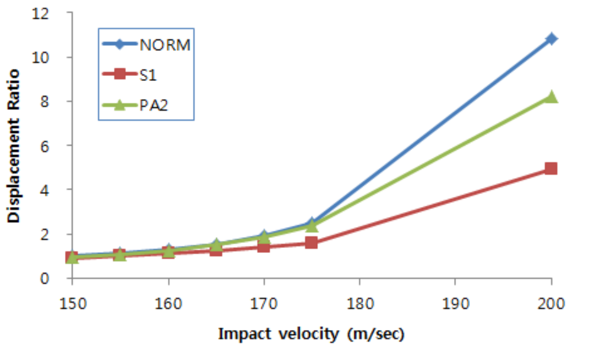

Fig. 3. Maximum displacement ratios to normal concrete with impact velocity 150m/sec.

Table II: Maximum displacement ratio to normal concrete, 100 % pre-stressing force

PS Force	Concrete Type			Ratio to NORM		Impact resistance	
	NORM	PA2	S1	PA2	S1	PA2	S1
no rebar	2.59	2.11	1.76	0.81	0.68	1.23	1.47
0 %	2.10	1.84	1.42	0.88	0.68	1.14	1.48
50 %	1.19	1.22	1.08	1.03	0.91	0.98	1.10
90 %	1.01	1.01	0.97	1.00	0.96	1.00	1.04
100 %	1.00	1.00	0.96	1.00	0.96	1.00	1.04
175	2.50	2.43	1.87	0.97	0.75	1.03	1.34
200	10.19	7.27	4.51	0.71	0.44	1.40	2.26

The reasons why the impact resistances of fiber reinforced concrete reactor containment building of cylindrical pre-stressed structure type are not enhanced as much as those of flat fiber reinforced concrete walls may come from the factors such as the cylindrical shaped geometry, pre-stressing effects which are not included in flat fiber reinforced concrete walls. Table II summarized the maximum displacement ratios as the impact resistance of normal concrete, 1 % steel fiber reinforced concrete and 2 % polyamide fiber reinforced concrete for pre-stressing force efficiencies. The first row labeled as “no rebar” summarized the maximum displacement ratio of reactor containment building simply assumed as bare concrete structures with no reinforcement bars and no tendons. The pre-stressing forces of tendons are assumed as 0 %, 50 %, 90 % and 100 % of effective pre-stressing forces, and the maximum displacements of each pre-stressed containment system are computed and compared to the maximum displacement of normal concrete with 100 % of effective pre-stressing force. From these results, it seems that the most affective factor on impact resistance is thought as the pre-stressing forces of tendons.

3. Conclusions

Studies on the safety assessments on the nuclear power plants against large civil aircraft crashes are ongoing actively. As a step of evaluating the applicability of fiber reinforced concrete in means of ensuring more structural safety of the nuclear power plants against impact, the impact resistance for the 1% steel and 2% polyamide fiber reinforced concretes have been evaluated.

For reactor containment building structures, it seem there is no impact resistance enhancement of fiber reinforced concrete applied to reactor containment building in the cases of impact velocity 150 m/sec considered in this study. However this results from the pre-stressing forces which introduce compressive stresses in concrete wall and dome section of reactor containment building.

Nonetheless there may be benefits to apply fiber reinforced concrete to nuclear power plants. For double containment type reactor containment building, the outer structure is a reinforced concrete structure. As shown in table II, the impact resistances for non pre-stressed cylindrical reactor containment buildings are enhanced by 23 to 47 % for 2 % polyamide fiber reinforced concretes and 1 % steel fiber reinforced concretes respectively. For other buildings such as auxiliary building, compound building and fuel storage building surrounding the reactor containment building, there are so many reinforced concrete walls which are anticipated some enhancements of impact resistance by using fiber reinforced concretes. And heavier or faster large civil aircraft impacts produce higher impact loading to NPP structures, so it can be said that the benefits of fiber reinforce concrete usages to the pre-stressed reactor containment buildings are obvious from a point of view of the impact resistance enhancement.

ACKNOWLEDGEMENT

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REFERENCES

[1] B.M. Jin, S.J. Jeon, Y.J. Kim, Y. Lee and Y.H. Kim, Preliminary Study on Evaluation of Impact Resistance Performance of Fiber Reinforced Concrete Walls, Transaction of Korean Nuclear Society Spring Meeting, Jeju, May 2012.
[2] Y. Takeuchi, Aircraft Collision Study to the SB Air-inlet Portion, APP-1000-S2C-84, Westinghouse, 2007.