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Division V

CHARACTERISTICS OF AN ULTRA-HIGH-PERFORMANCE-CONCRETE (UHPC) AGAINST IMPACT LOADING
PART 3: PRELIMINARY ANALYSES FOR A NUCLEAR POWER PLANT BUILDING USING UHPC AGAINST IMPACT LOADING

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ABSTRACT

Preliminary analyses against impact loading were performed to confirm a global failure behavior of a reactor building outer wall in use of a ultra-high-performance reinforced concrete containing polypropylene and steel fiber (Fc150). In the analyses, material properties such as stress-strain curve and dynamic increased factors of the Fc150 were set based upon test results. It is confirmed that a required wall thickness of Fc150 against an impact loading was reduced by approx. 30% comparing to the one of normal concrete (Fc33).

INTRODUCTION

Several types of ultra-high-performance-concretes (UHPCs) were utilized and applied to several buildings such as skyscrapers, however UHPCs have not been implemented into nuclear power plants (NPPs). In order to confirm a global behavior of UHPCs against impact loading, the preliminary analyses were performed for a reactor building outer wall in use of ultra-high-performance reinforced concrete containing polypropylene and steel fiber (Fc150). The basic characteristics of Fc150 including a dynamic increased factor (DIF) were based upon test results (See Reference 1 and 2). This study had been carried out in the project "Development of technical infrastructure for upgrading materials, structures and construction methods of nuclear power plant buildings" (See Figure 1, Reference 3).

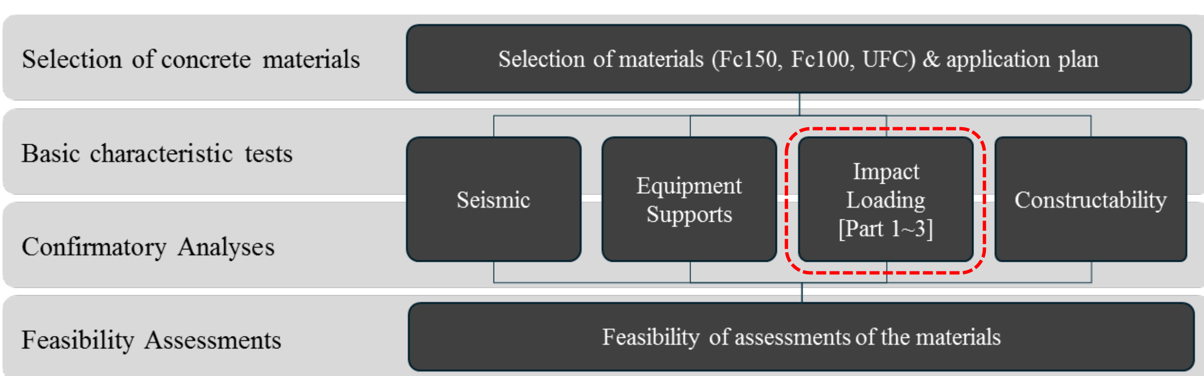


Figure 1. Outline of the project

ANALYSIS METHODS

Non-linear FEM analyses using two types of reinforced concrete wall model against impact loading were carried out for a global failure evaluation. First analysis is a global failure capacity of Fc150 and second one is a normal concrete (Fc33). The material properties of Fc150 are based upon experimental test explained in Part 1 of this study. The outline of analysis is as below.

- A target is typical area of reactor buildings' outer wall (See Figure 2)
- An element size is approx. 0.5~1.0m
- Elasto-plastic behavior is considered for both concrete and reinforced steel bar explained in Part 1 (See Figure 3, 4)
- DIF of concrete (1.25) and reinforced steel bar (1.1) is considered (DIF of Fc150 is set as 1.0 based upon test results explained in Part 2)
- Impact loading is applied to the model as a load time function (LTF) which was set in accordance with a published paper[4), 5)] (See Figure 5)
- Computer code is ABAQUS ver. R2018

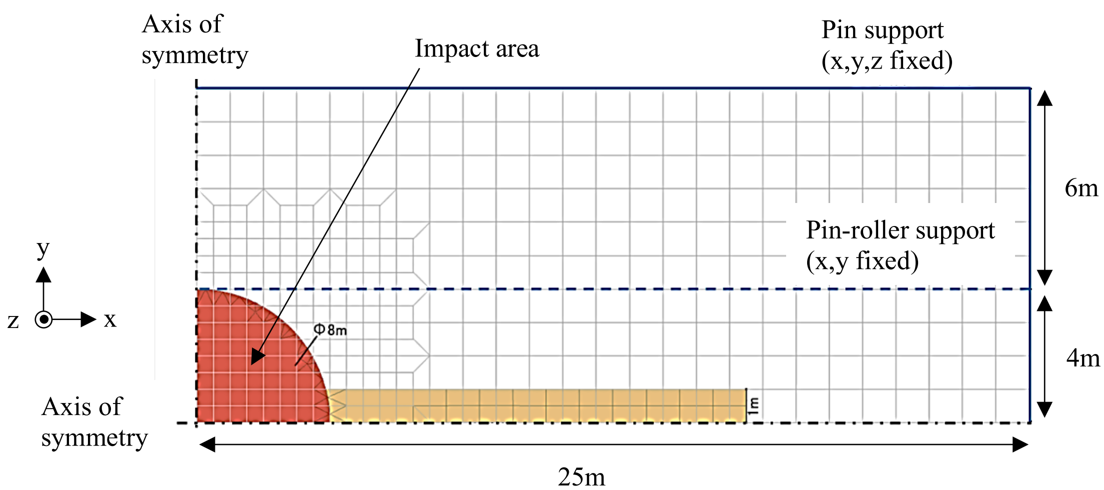


Figure 2. Analysis model of target

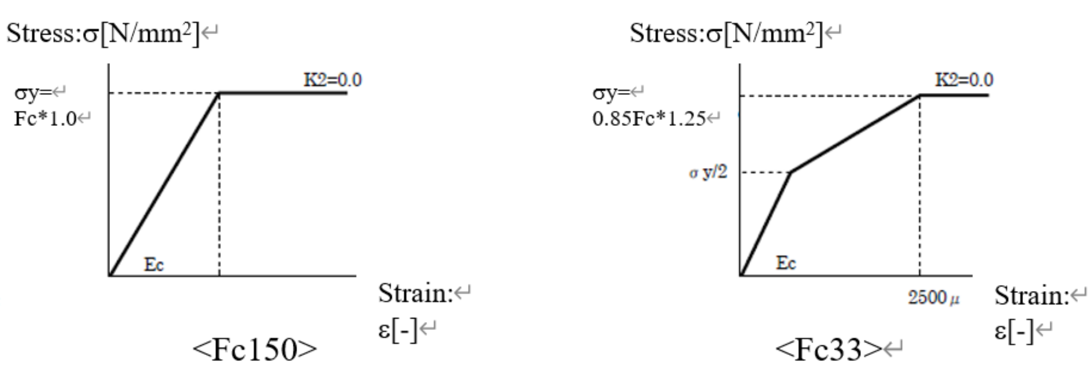


Figure 3. Stress-strain curve of concrete (compressive)

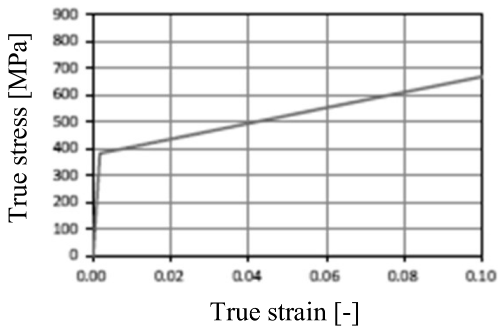


Figure 4. Stress-strain curve of reinforced steel bar (SD345, tension)

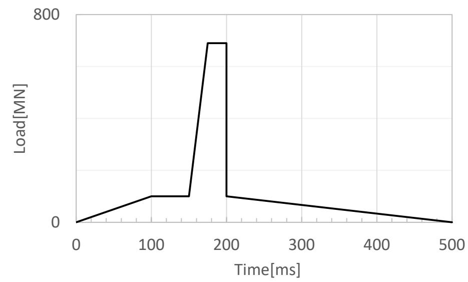


Figure 5. Load time function

ANALYSIS CASES

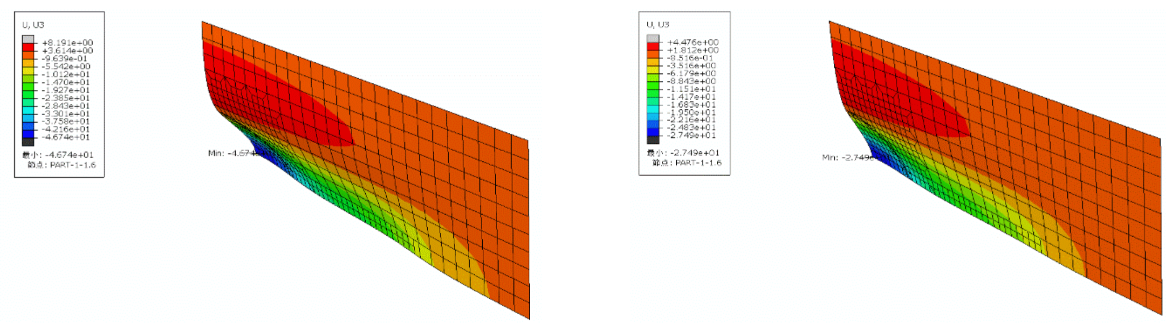
Parametric analyses (total eight (8) cases) are carried out to study the effect of Fc150 as shown in Table 1. The wall thickness is presented as a ratio comparing to the base case (Case 3). A ratio of reinforced steel bar is constant as approx. 1.0% for each wall thickness.

Table 1: Analysis cases

Case	Ratio of wall thickness	
	Fc150	Fc33
1	N/A	1.3*T
2	N/A	1.05*T
3	N/A	T (Base case)
4	N/A	0.95*T
5	0.9*T	N/A
6	0.75*T	N/A
7	0.7*T	N/A
8	0.65*T	N/A

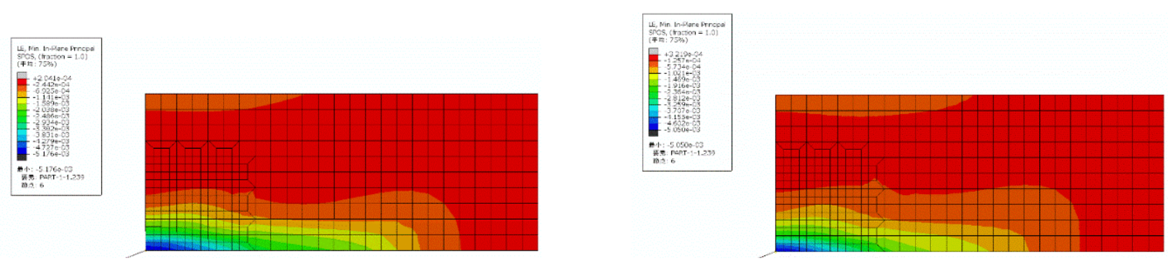
RESULTS

Analysis results of global failure evaluation are shown in Figure 6 through 8. Since a tendency of analysis results is similar, Case 7 (Fc150, 0.7*T) and Case 3 (Fc33, T) are selected as representative cases. Figure 6 shows deformation diagrams at a timing of maximum deformation. Figure 7 shows maximum concrete compression strain diagrams. Figure 8 shows maximum reinforced steel bar tensile strain diagrams. According to the figures, maximum values of deformation, concrete compressive strain and reinforced steel bar tensile strain are shown at a center of impact area. Figure 9 through 11 show displacement, concrete strain and reinforced steel bar time histories at the center of the impact area. It is confirmed that the maximum values were obtained around approx. 0.18 sec (shortly after the LTF reached maximum load).



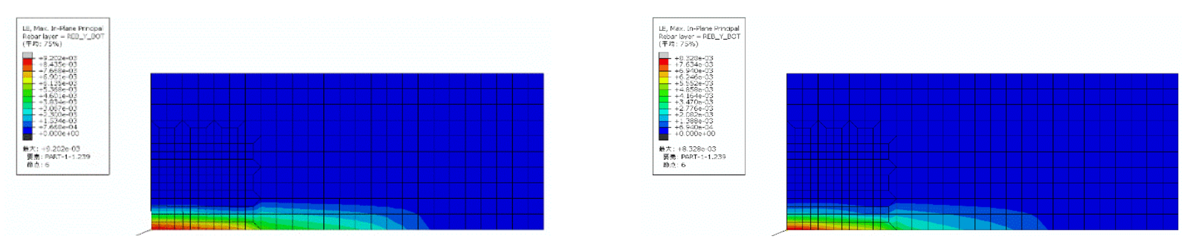
Fc150 (Case7) Fc33 (Case3)

Figure 6. Deformation diagram



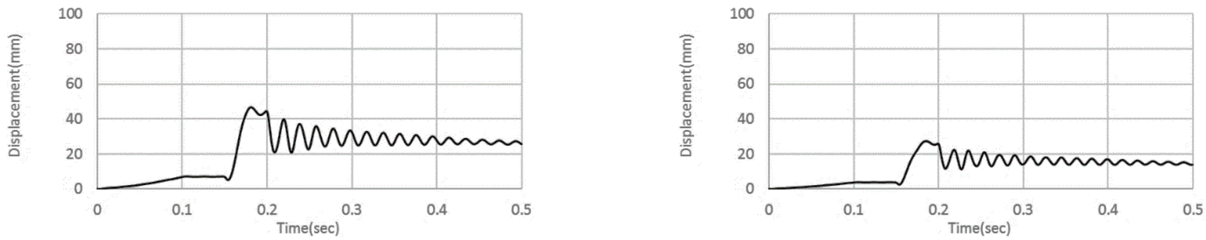
Fc150 (Case7) Fc33 (Case3)

Figure 7. Maximum concrete compressive strain diagram



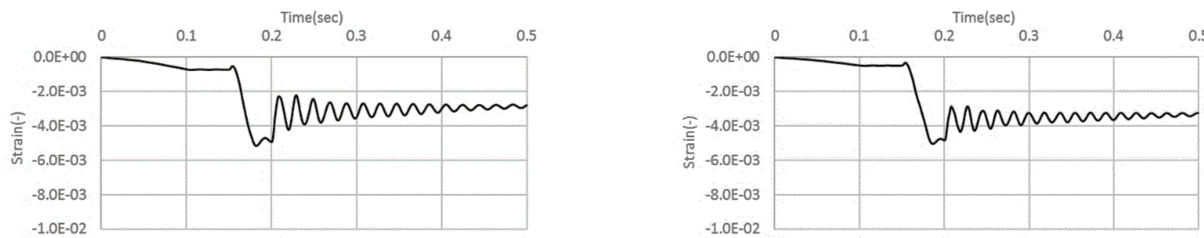
Fc150 (Case7) Fc33 (Case3)

Figure 8. Maximum reinforced steel bar tensile strain diagram



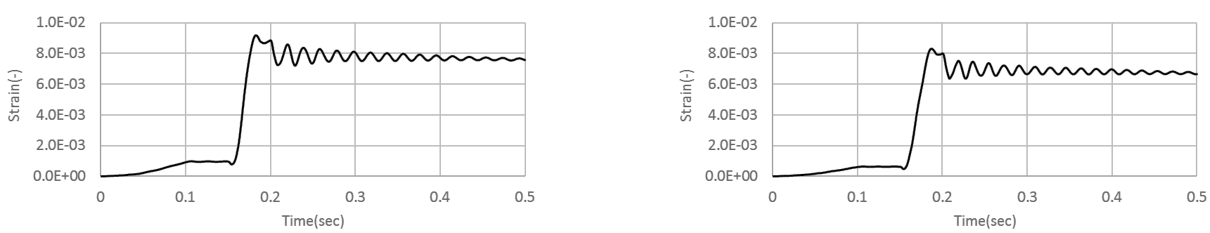
Fc150 (Case7, 0.7*T) Fc33 (Case3, T)

Figure 9. Displacement time histories at the center of impact area



Fc150 (Case7, 0.7*T) Fc33 (Case3, T)

Figure 10. Concrete strain time histories at the center of impact area



Fc150 (Case7, 0.7*T) Fc33 (Case3, T)

Figure 11. Reinforced steel bar strain time histories at the center of impact area

Figure 12 shows a summary of analysis results. According to the figure, a strain level of concrete and reinforced steel bar is almost same between Case7 (Fc150, 0.7*T) and Case3 (Fc33, T). The tendency of strain level in the other cases (such as Case8 and Case4) is similar. It is confirmed that a required wall thickness of Fc150 for global failure evaluation could be reduced approx. 30% comparing to Fc33. It is noted that a relationship between required thickness of global failure evaluation would be different depending on evaluation condition such as a span of target (wall and/or roof), LTF etc.

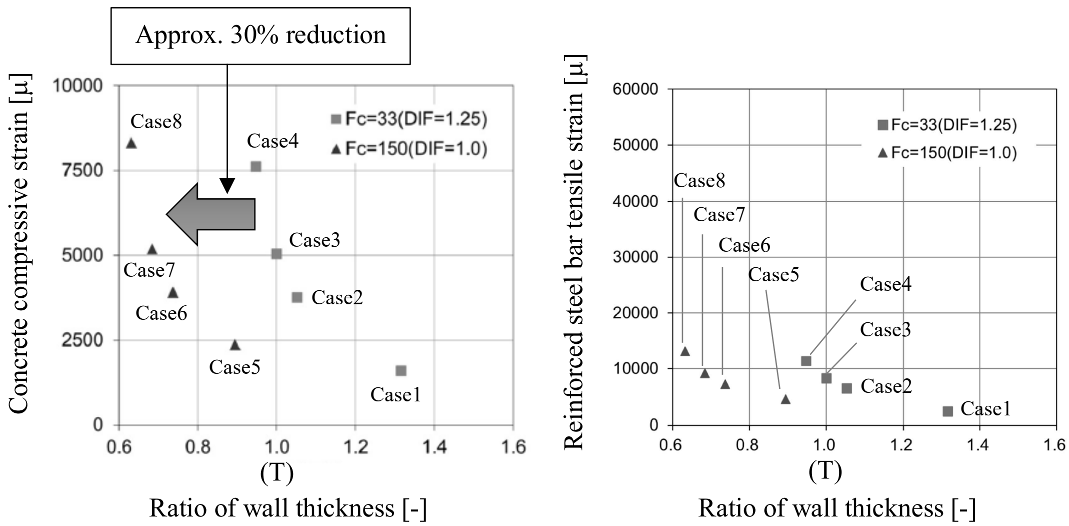


Figure 12. Summary of analysis results

CONCLUSIONS

In order to confirm a global failure behavior of a reactor building outer wall in use of ultra-high-performance reinforced concrete containing polypropylene and steel fiber (Fc150), preliminary analyses were conducted against impact loading. Analysis results showed that a required wall thickness of Fc150 is reduced by approx. 30% comparing to a normal concrete (Fc33).

ACKNOWLADGEMENT

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REFERENCES

K. Kodera, et al (2022): CHARACTERISTICS OF AN ULTRA-HIGH-PERFORMANCE-CONCRETE (UHPC) AGAINST IMPACT LOADING PART 1: BASIC CHARACTERISTICS TEST AND EVALUATION OF BEARING FORCE OF UHPCS, SMiRT26, Germany

K. Yabuuchi et al (2022): CHARACTERISTICS OF AN ULTRA-HIGH-PERFORMANCE-CONCRETE AGAINST IMPACT LOADING PART 2: IMPACT TESTS USING REINFORCED CONCRETE PANELS AND HIGH STRAIN RATE COMPRESSION TESTS, SMiRT26, Germany

G. Nagashima et al. (2022): FEASIBILITY ASSESSMENT OF ULTRA-HIGH-PERFORMANCE-CONCRETE APPLICATION TO NPPs, SMiRT26, Germany

Manish Kumar et al (2017): AIRCRAFT IMPACT ON BASE-ISOLATED NUCLEAR POWER PLANT BUILDINGS, SMiRT-24, Korea, August,

Iliev V et al: ASSESSMENT OF IMPACT LOAD CURVE OF BOEING 747-400, International Scientific Journal