Simulation of small-scale impact model tests into reinforced concrete panel

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1. INTRODUCTION

In this report, one impact test of small-scale engine model struck on reinforced concrete panel, symbolized as S4, reported by Sugano et al. (1993), are simulated using explicit dynamic finite element procedure ANSYS/LS-DYNA. The effects of the concrete model, erosion criteria, and missile angle on the damage of the reinforced concrete panel are discussed. The results show that: (1) The simulated damage models of this impact tests show overall comparable characteristics of the reinforced concrete panel after the impact; (2) For Impact tests reported by Sugano et al. (1993), the Winfrith concrete model (material type 84) can predict better results than the K&C Concrete Model - Release III (material type 72R3) and the Johnson-Holmquist concrete model (material type 111).; (3) The erosion criterion of the maximum principle strain at failure is more appropriate than other two criteria, i.e., the shear strain at failure γ_{max} and the principal stress at failur σ_{max} for the cases studied in this report; (4) In general, the local damage of the reinforced concrete panel under oblique impact decreased, compared with that under the perpendicular impact.

2. Review of Experimental impact tests (Impact tests S4 reported by Sugano et al. (1993))

Sugano et al. (1993) conducted a series of small-, intermediate-, and full-scale impact model tests on reinforced concrete panels. In this report, one small-scale impact model tests, Cases S4, are selected for simulation.

Detailed test conditions for missiles and reinforced concrete panels used in Cases S4 are shown in Table 1. The missiles used in Cases S4 are shown in Fig. 1. A deformable missile (SED) was used in Impact test S22 to model the actual GE-J97 engine, while a rigid missile having the same diameter and weight as the deformable missile was used in Cases S4. In Impact test S4, the head of the rigid missile was made of solid steel and its rear part was made of aluminum. As shown in Table 1, the difference between Impact test S4 and Impact test S5 is only the velocity of the rigid missiles.

The test panel used in these three cases is shown in Fig.2. The design compressive strength of concrete was 23.5 MPa. The diameter, yield strength, and ultimate strength of the rebar were 6 mm, 447.2 MPa, and 585.1 MPa, respectively.

The test results for Cases S4 are listed in Table 2.

Table1 Detailed test conditions for Cases S4

	Missile					Test panel				
Cases	Types	Rigidity	Dia. (mm)	Weight* (kgf)	Velocity (m/s)	Thick. (mm)	F_c (MPa)	P_0 (%)	P_w (%)	Steel linear
S4	SER	Rigid	101	3.6	150	210	23.5	0.4	0.0	

F_c: design compressive strength of concrete P_0: reinforcement ratio for main rebar P_w: reinforcement ratio for shear rebar

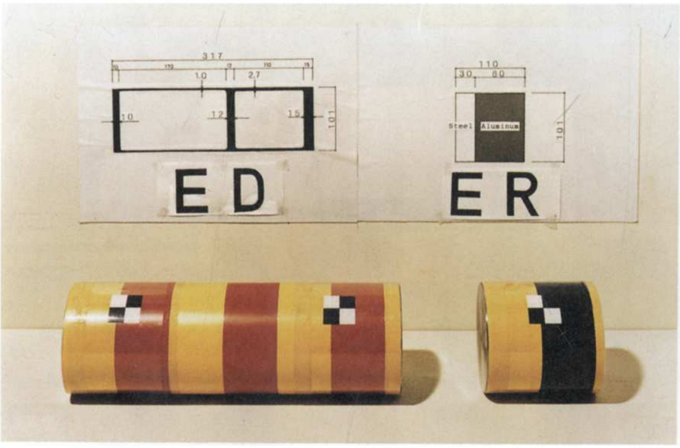

Fig.1 Exterior views of the missiles (S4:ER)

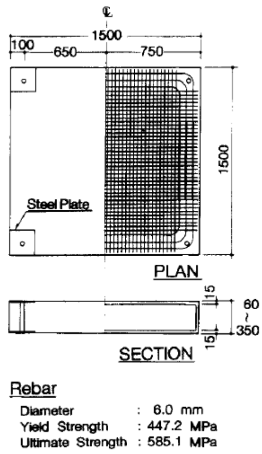

Fig.2 Test panel for Cases S4.

Table2 Test results for Cases S4

Cases	Missile		Damage to test panel			Damage to Missile mode and length after test (m)
				Dimensions of crater (mm)		
	Types	velocity (m/s)	Mode	Front depth	Rear face width*height	
S4	SER	128	S	24	550*525	No damage

3. Simulation

3.1 Finite element model

Fig. 3 shows the FE modelling of rigid missile and reinforced concrete panel for Impact test S4. The 8-node solid

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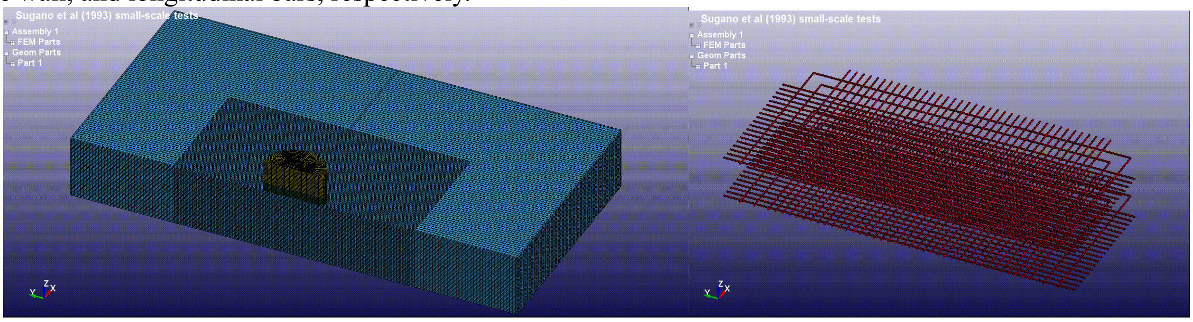
element with one integration point was used to model the rigid missile the concrete wall in Fig. 3(a). The Hughes-Liu beam element with 2*2 Gauss quadrature was used to model longitudinal bars in Fig. 3(b).

The mesh size for the concrete along the z axis shown in Fig. 3 was set to 0.5 cm. The mesh size for the concrete along both the x and y axis shown in Fig. 3 was generally set to 1.0 cm; however, the mesh size for the middle part of the concrete ($0 \le x \le 40\ cm$, $-40\ cm \le y \le 40\ cm$) was set to 0.5 cm along both the x and y axis. The size for the rigid missile and the bars was set to 0.5 cm. As a results, there are 33792, 895104, and 17072 elements for the rigid missile, concrete wall, and longitudinal bars, respectively.

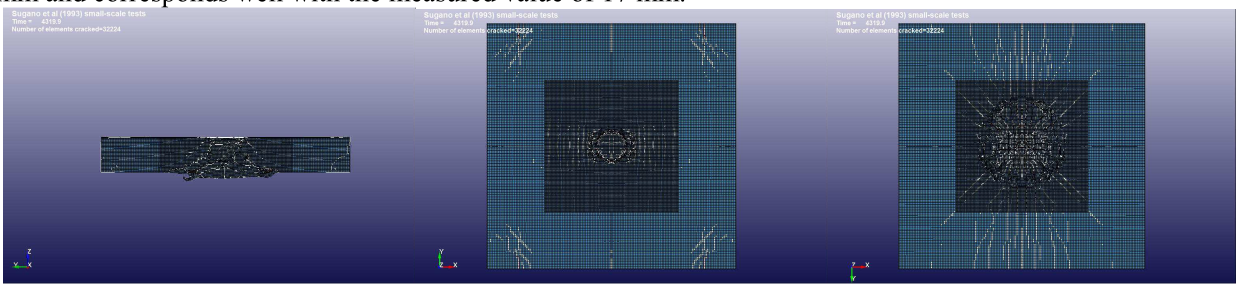


(a) the rigid missile and concrete panel in Impact test S4 (b) longitudinal bars in Impact test S4.

Fig.3 Finite element type and mesh

3.2 Results

Fig. 4 shows the simulated damage of the test panel in Simulation at 4320 μs. The simulated damage of the reinforced concrete panel can be characterized as the just scabbing mode and agrees well with the experimental result. Fig. 5(left) shows the simulated time history of the velocity of the rigid missile in z-axis direction. Fig. 5(right) shows the simulated time history of the displacement of the rigid missile in z-axis direction. The predicted penetration depth is approximately 17.5 mm and corresponds well with the measured value of 17 mm.



(a) Front view (b)Top view (c)Bottom View

Fig.4 The simulated damage of the test panel in Simulation at 4320 μs.

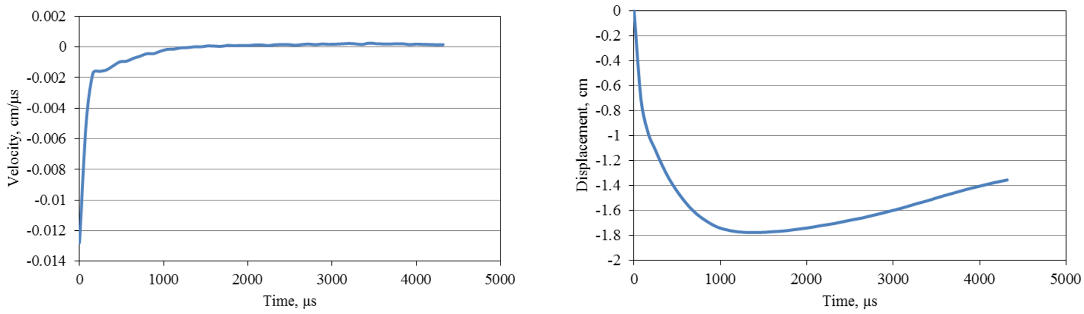


Fig.5 The simulated time history of the velocity(left) and deformation(right) of the rigid missile in z-axis direction

4. CONCLUSIONS

In this report, one impact test of small-scale engine model struck on reinforced concrete panel, symbolized as S4, reported by Sugano et al. (1993), are simulated using explicit dynamic finite element procedure ANSYS/LS-DYNA. The effects of the concrete model, erosion criteria, and missile angle on the damage of the reinforced concrete panel are discussed. From the numerical results, the following conclusions can be made:(1) The simulated damage models of these four impact tests show overall comparable characteristics of the reinforced concrete panel after the impact,(2) For Impact tests reported by Sugano et al. (1993), the Winfrith concrete model (material type 84) can predict better results than the K&C Concrete Model - Release III (material type 72R3) and the Johnson-Holmquist concrete model (material type 111).

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