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NONLINEAR EARTHQUAKE RESPONSE OF REINFORCED CONCRETE TWO-STORY ONE-BAY BUILDING FRAMES BY COMPUTER-ACTUATOR ON-LINE SYSTEM

by

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SYNOPSIS

An earthquake response of reinforced concrete two-story one-bay building frames was simulated by the computer-actuator on-line system[1)]. A principle of the simulation by the on-line system is to solve a nonlinear differential equation for earthquake response by a digital computer taking into account the real restoring force characteristics obtained by the pseudo-dynamic loading test executed in parallel with the calculation[2)].

TEST SPECIMEN

Two plane two-story one-bay frames (Fig. 1) were analysed. One was designed to be a beam yielding type(FDR-1) under inverse triangle lateral force distribution and the other a column yielding type(FDR-2). Dimension of the test structures was about 1/3 of the prototype building. The mass of each frame was estimated so that the first natural period became about 0.4 sec. Elastic natural period and first mode is shown in Table 1. The failure mechanism and the stress distribution by non-linear static analysis are shown in Fig. 2.

LOADING SYSTEM

Test setup is shown in Fig. 3. Lateral force was applied by the actuators driven by the command from computer at the center of the beams. Axial stress of column was not applied.

SYSTEM FOR ANALYSIS

The flow diagram is shown in Fig. 4. For numerical analysis, the linear acceleration method was used until the response displacement reached at a certain limited value within linear range and then the central difference method (Lumped-impulse method[3)]) was used. The acceleration record of the Hachinohe 1968 (NS) was used for the ground motion. The acceleration amplitude was modified so that the ratio of the lateral strength of the frame in terms of the base shear coefficient (k_y) to the peak ground acceleration normalized by the acceleration of gravity (k_g) became constant (≒0.6) for all frames (Table 1). Viscous damping was not considered.

RESULTS

The measured and calculated maximum response displacements and forces are shown in Table 3. X_1 and X_2 are relative displacements from the base at the top of first and second story, respectively. δ_2 is story relative dis-

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placement at second story. P_1 and P_2 are story forces at the top of first and second story, respectively. Q_1 is story shear force at first story. Time history of the response displacement at the first story of the FDR-1 frame is shown in Fig. 5. The member-to-member response analysis based on the one-component model was used for the calculation, where the degrading tri-linear model was used for M-ϕ relationships of beams and columns. Measured shear force-story displacement relationships is shown in Fig. 6. Fig. 7 shows the ratio of the measured lateral force at the second story to that at the first story.

The results are summarized as follows;

1) In spite of the same value of k_y to k_g ratio, the response displacements of the FDR-2 frame were 10-30% larger than those of the FDR-1 frame. This tendency would be caused by the difference in failure mechanism. Because, the FDR-2 frame failed in column yielding manner, while the FDR-1 frame was beam yielding type.

2) The member-to-member response analysis could simulate well the test results. However, the maximum response displacement and force obtained from the test were 10-30% larger than those from the analysis.

3) The lateral force distribution along story fluctuated significantly during earthquake response. The lateral force at the first story became maximum where the force at the second story was not maximum.

REFERENCES

1)T.Okada, M. Teshigawara and M.Seki:"Earthquake Response Simulation on Reinforced Concrete Two-story Building Models by IIS Computer-Actuator On-line System (Part 2 and 3)", Proc. Annual Convention of AIJ,Sept.,1980

2)M.Seki and T.Okada: "Nonlinear Earthquake Response of Reinforced Concrete Building Frames by Computer-Actuator On-line System(Part 1-5), Trans. of AIJ, No.275,279,280,282,284, 1979

3)M.Teshigawara, M.Seki and T.Okada:"Nonlinear Earthquake Response of Reinforced Concrete Two-story One-bay Building Frame by Computer-Actuator On-line System(Part 1)", Proc. Annual Convention of AIJ, Sept., 1979

Table.1 Elastic Properties of Frames

T1 (sec)	T2 (sec)	1ST MODE (X2/X1)
0.42	0.12	1.96

Table.2 Parameters for On-Line Test

FRAME	MASS	Δt	GROUND MOTION	
FDR-1	0.03463	0.01	HACHINOHE NS	108.0 gal
FDR-2	($t \cdot s^2/cm$)	(sec)		124.4 gal

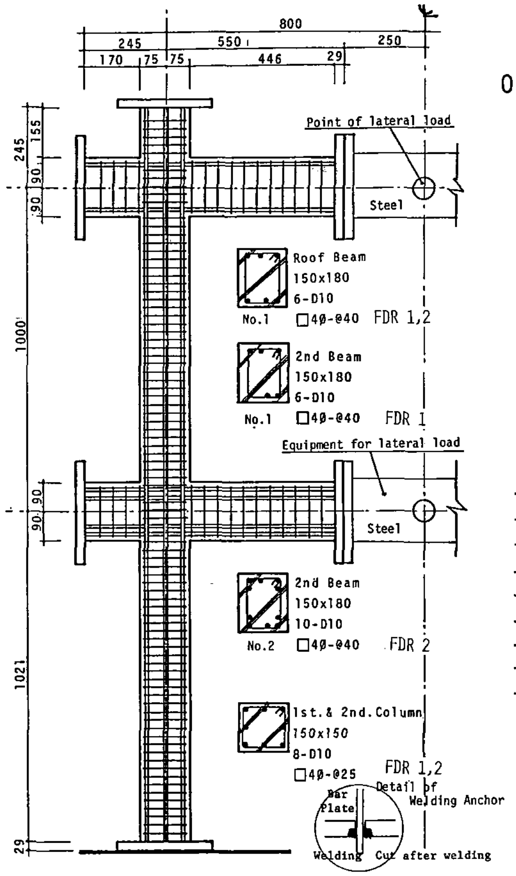

Fig.1 Test Specimen

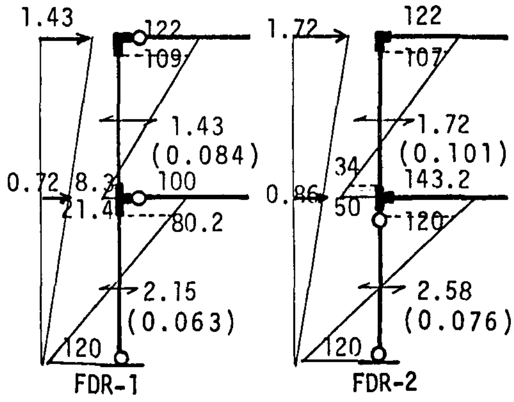

Fig.2 Stress at failure mechanism

( ) base shear coefficient

Table.3 Max Response

	FDR-1		FDR-2	
	TEST	ANALYSIS	TEST	ANALYSIS
1(cm)	2.89(3.62)	2.28(3.44)	3.79(3.62)	3.30(3.45)
2(cm)	4.77(3.64)	4.19(3.45)	5.91(3.56)	4.65(3.44)
2(cm)	2.36(3.48)	1.90(3.45)	2.60(3.49)	1.38(3.42)
1(t)	4.47(3.60)	3.64(3.20)	4.34(3.63)	3.50(3.19)
2(t)	4.33(3.44)	3.43(3.45)	4.76(2.91)	3.60(2.92)
1(t)	5.21(3.60)	4.61(3.22)	5.69(3.62)	5.16(2.84) (3.17)

X:Displacement from footing
δ:Relative displacement of story
P:Lateral force
Q:Shear force
Suffix: 1st.or 2nd
( ) : Occured time (sec)
Suffix: 1st.or 2nd story

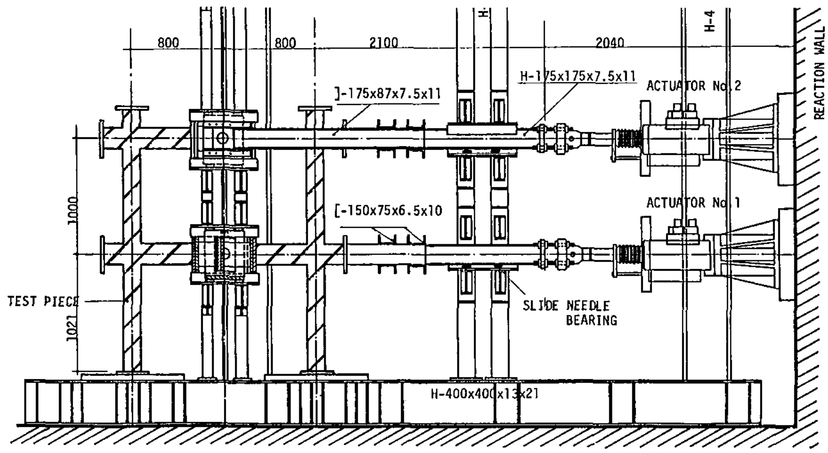

Fig.3

Test Setup

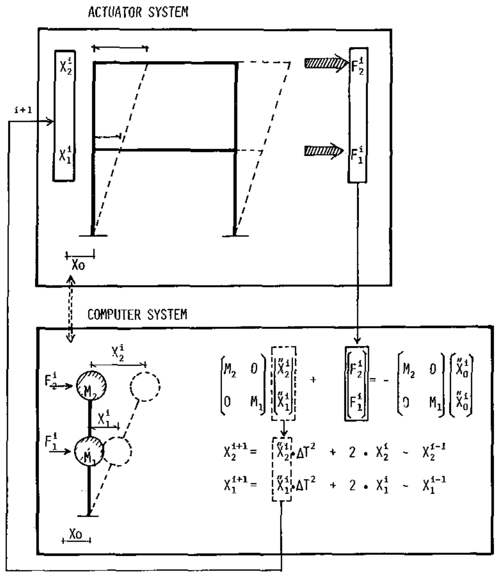

Fig.4. Flow chart of On-Line Test

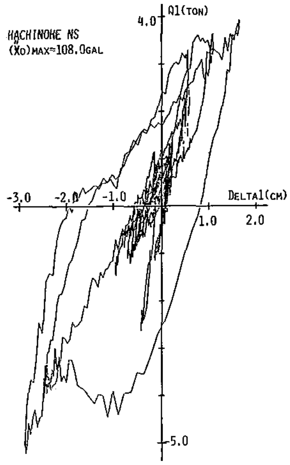

Fig.6-1 FDR1 Q1-δ_1

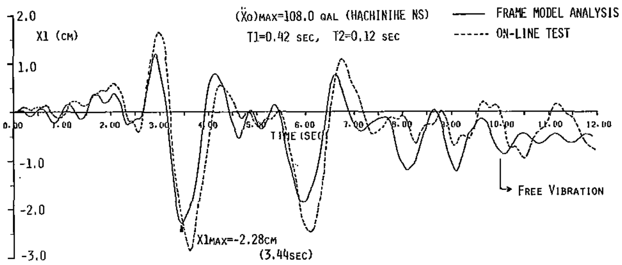

Fig.5 FDR1 X1 Time History

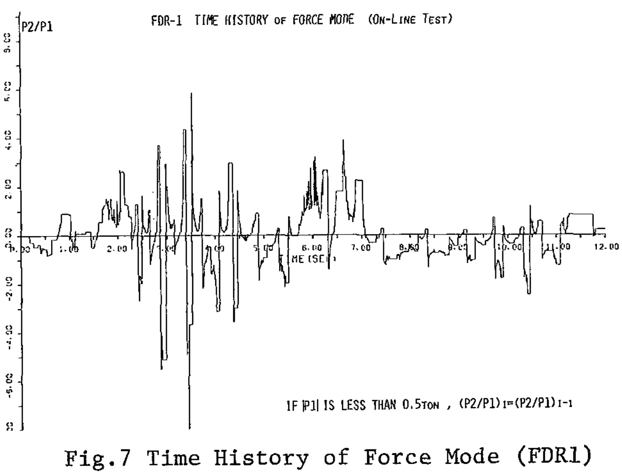

Fig.7 Time History of Force Mode (FDR1)

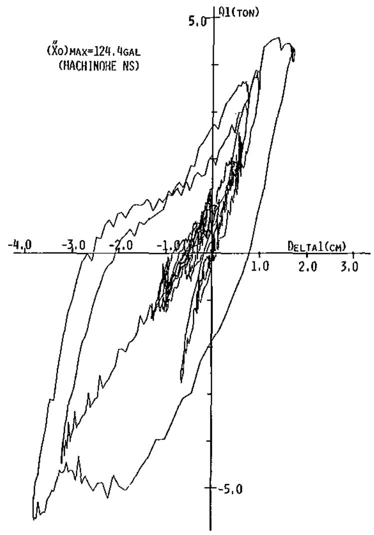

Fig.6-2 FDR2 Q1-δ_1