MULTIPLE PRECAST REINFORCED CONCRETE PANELS
FOR ASEISMIC STRENGTHENING OF R.C. FRAMES

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SUMMARY

One story, one bay model reinforced concrete frames measuring 79.5 cm by 138.0 cm were constructed and tested to investigate the effect multiple precast reinforced concrete panels of 3.0 cm thick used as infill. No axial load was applied to the columns.

The effect of : Strengthening in general; the number of panels used; monotonically increasing or reversed loading; strengthening an undamaged or damaged frame; connecting the panels both to the beams and columns or just to the beams of the frame; and using discrete or continous connection between the beams and the panels were the main parameters studied experimentally.

INTRODUCTION

In resisting the horizontal wind and earthquake forces, brick, concrete block or reinforced concrete wall infills can efficiently be used. Considerable increase in the stiffness and load carrying capacity of reinforced frames can be obtained by proper use of such infills. This method has been widely used in the past to improve the earthquake resistance before an earthquake or to repair and strengthen a building which has already been damaged, also still popular at present {1,2,3}. From the practical point of view strengthening of existing buildings, especially those which have to be used immediately after an earthquake such as hospitols, telecominication buildings etc., by means of infills is difficult. The construction may prevent the functioning of the facility for a certain period of time. Because of that research has started on the use of single or multiple reinforced concrete panels td strengthen existing buildings, especially more attention was paid to the use of multiple panels for this purpose {4,5,6,7}.

EXPERIMENTAL PROGRAM

The model frames tested in this research contained only precast reinforced concrete panels of 3.0 cm thick. Ten tests were carried out on one story one bay frames measuring 79.5 cm by 138.0 cm, with or without panels. The frames used in each model specimen had the same geometry and reinforcement detail. The dimensions and the reinforcement detail of the frames are given in Fig.I. A concrete mix was designed to have nominal compressive cylinder strength of $f'_c = 200$ kg/cm^2. Main reinforcement of the frames was consisted of 8 mm mild steel bars (average yield stress $f_y = 2952$ kg/cm^2) and the reinforcement of the panels 6 mm mild steel bars (average $f_y = 2778$ kg/cm^2). The reinforcement details of the panels are given in Fig. II. Table II contains the concrete strengths at the date of the experiments.

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The connection detail given in Fig. III was used to connect the panels among themselves and the panels to the surrounding frame.

Experimental set up is given in Fig. IV. The reaction blocks and the models to be tested were all placed in the same horizontal plane. Monotonically increasing or reversed loading was applied to the models by means of two hydraulic jacks which were placed at the foundation beam level at both ends. No axial load was applied to the columns except some confinement provided externally on the loading frame (pedestals no IV and V in Fig. IV). History of loading for each model is given in Table I.

TABLE I. HISTORY OF LOADING

(North - South direction, - South-Northdirection)

Model.	T1	T2	T3	T4	T5	T6	T7	T8	T9
D1	Monotonically increasing load upto failure								$\rightarrow P_k$
D2	Monotonically increasing load upto failure								$\rightarrow P_k$
D3	+500 -500	+1000 -1000	+1000 -1000	+1250 -1250	+1000 -1000				$\rightarrow P_k$
D4	+500 -500	+1000 -1000	+1000 -1000	+1250 -1250	+2000 -2000	+3000 -3000	+4000 -4000		$\rightarrow P_k$
D5	Monotonically increasing load upto failure								$\rightarrow P_k$
D6	+500 -500	+1000 -1000	+1250 -1250	+2000 -2000	+3000 -3000	+4000 -4000	+7000 -7000		$\rightarrow P_k$
D7	+500 -500	+1000 -1250	+ 750 -1250	+ 750 -1750	+1500 -2500	+2000 -4000	+2500 -5500		$\rightarrow P_k$
D8	+500 -500	+1000 -1000	+1000 -1000	+1250 -1250	+2000 -2000	+3000 -3000	+4000 -4000		$\rightarrow P_k$
D9	+500 -1250	+ 750 -1250	+ 750 -1250	+ 750 -1750	+1500 -2500	+2000 -4000	+2500 -5500		$\rightarrow P_k$
D10	+500 -500	+1000 -1000	+1000 -1000	+1250 -1250	+2000 -2000	+3000 -3000	+4000 -4000	+5000 -4500	$\rightarrow P_k$

P_k : Failure load (Given in Table II)
Δ_k : Failure displacement (Given in Table II)
T_i : i'th Load Cycle

EXPERIMENTAL RESULTS

Fig. V is an example of the load-displacement curves. By the aid of the load-displacement curves stiffness changes and dissipated energies were evaluated {8}. Figs. VII, VIII are examples after failure. The failure modes, failure loads P_k, failure displacements Δ_k and the total dissipated energies upto the failure loads are given in Table II.

TABLE II. EFFECT OF STRENGTHENING IN GENERAL
(B : Bending Failure; P : Punching Faulire; S : Shear Failure)

Model	f'_c (kg/cm^2) Frame	f'_c (kg/cm^2) Panel	Initial Stiffness k_m (kg/cm)	Failure Mode	P_k (kg)	Δ_k (mm)	E (kg-cm)
D1	250	-	5000	B-Frame	1800	38.8	4800
D2	263	77	12500	P-Panel	6000	22.8	6350
D3	244	-	5076	B-Frame	1250	26.4	6232
D4	233	140	12500	P-Panel	7000	26.2	14743
D5	159	159	11111	S-Frame	12750	37.0	19550
D6	200	200	12500	S-Frame	12000	29.0	29363
D7	250	125	7895	P-Panel	7500	21.7	13404
D8	270	270	14286	S-Panel	11000	23.7	18058
D9	244	122	7142	S-Panel	8000	27.0	22560
D10	263	254	6667	Weld Failure	5000	13.4	8390

EVALUATION AND DISCUSSION

The envelope curves corresponding to the loading in the N-S direction are given in Fig. VI and compared.

For the effect of strengthening in general all the models, for the effect of number of panels used model pairs (D4-D8) and (D7-D9); for the effect of monotonically increasing or reversed loading (D1-D3), (D2-D4) and (D5-D6); for the effect of strengthening a damaged or undamaged frame (D4-D7) and (D8-D9), for the effect of panel-to-column connection (D2-D4) and (D5-D6); and for the effect of using discrete or continous connection (D7-D10) were compared {8}. The damaged frame of model D1 after the test was used in model D7. Similarly damaged frame of D3 in D9, and D2 in D10 were used. The failure loads were normalized to give a nominal strength of f'_c = 200 kg/cm in order to reduce the effect of different concrete strengths. Either the concrete compressive strength itself or its square root was used for this normalization, depending upon the failure mode.

CONCLUSIONS

Experimental results pointed out the positive effect of strengthening a frame with precast R.C. panels on stiffness, load carrying capacity and energy dissipation. Thus if damaged or undamaged R.C. frames are strengthened as proposed in this exparimental program :

i) Initial stiffness of the frame increases by 1.3 ~ 2.9 times,
ii) The load carrying capacity increases by 7~9 times,
iii) 1.3~4.9 times more energy is dissipated,
iv) Failure modes are not influenced by the reversed loading,
v) When the number of panels increase from 2 to 4 or when panel-to-column connections are provided, the failure mode changes from compression failure to shear failure,
vi) When the number of panels increase from 2 to 4, more energy is dissipated,

vii) When a damaged frame is strengthened instead of an undamaged frame, initial stiffness decreases by %50-60,

viii) Initially stiffness is slightly influenced by the number of panels and by the panel-to-column connections,

ix) More energy is dissipated by the continous connection.

ACKNOWLEDGEMENTS

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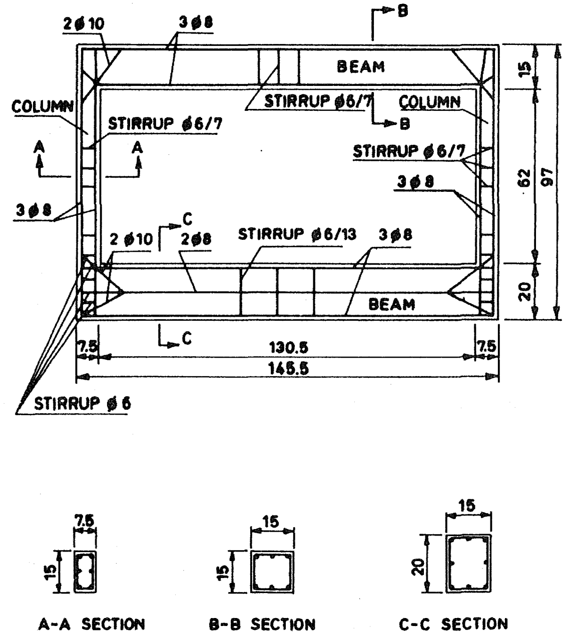

NOTE : ALL THE DIMENSIONS ARE GIVEN IN cm.

FIGURE I. REINFORCEMENT DETAIL OF THE FRAMES STRENGTHENED

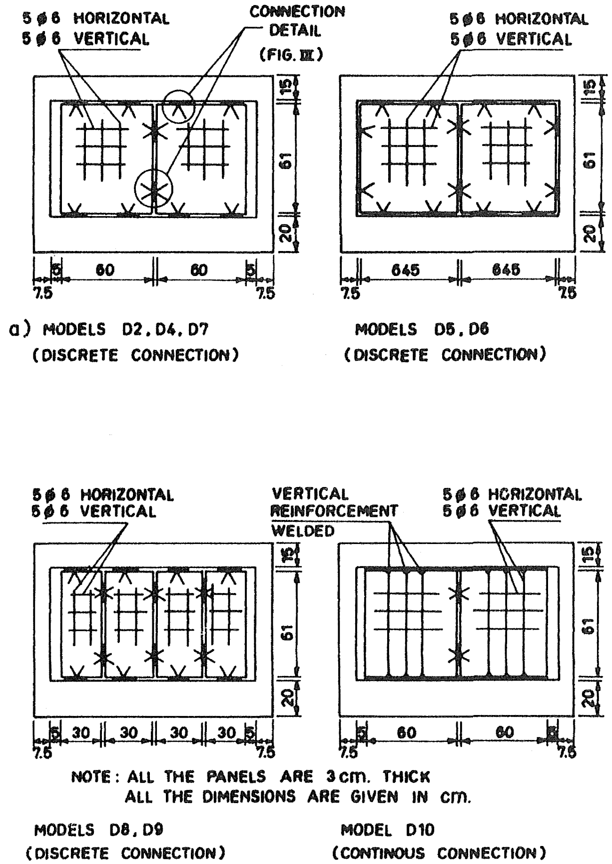

FIGURE II. REINFORCEMENT DETAILS OF THE PANELS

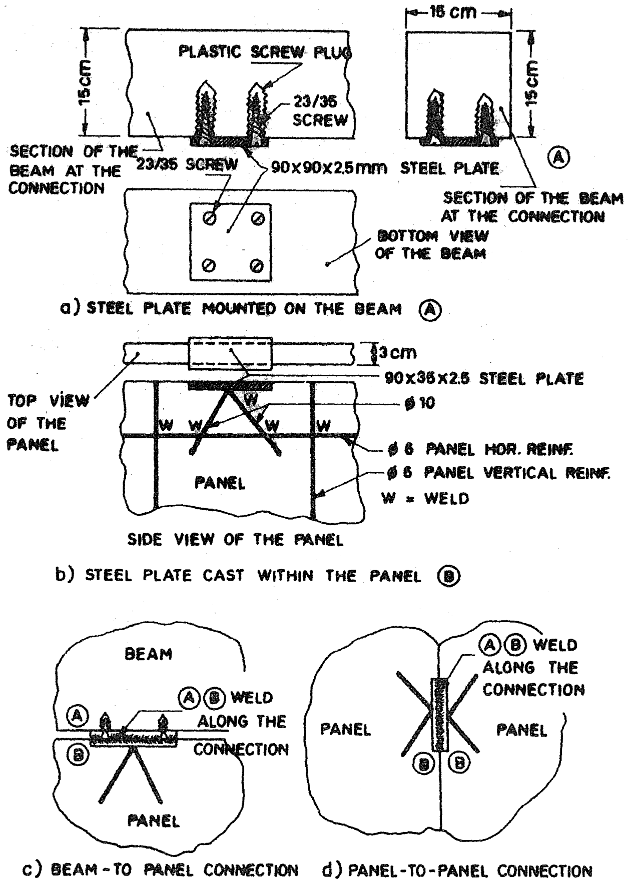

FIGURE III CONNECTION DETAIL

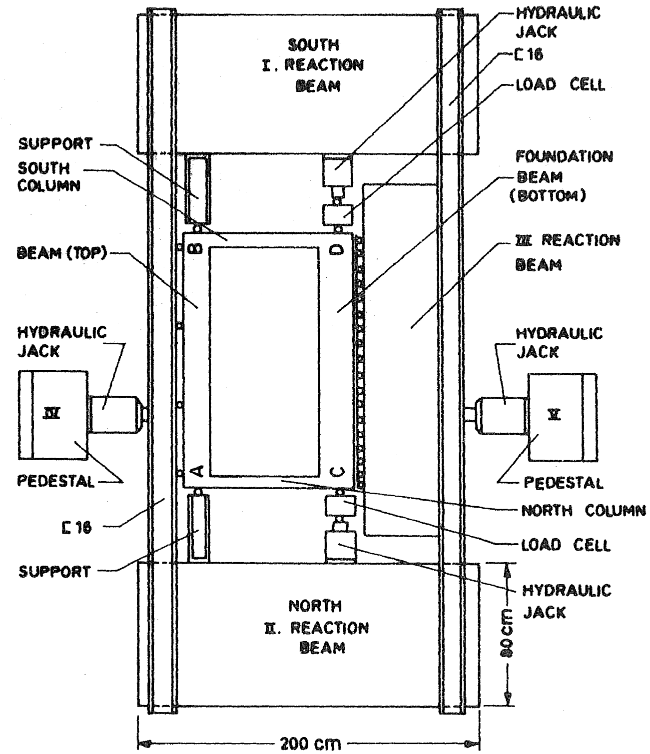

FIGURE IV EXPERIMENTAL SETUP

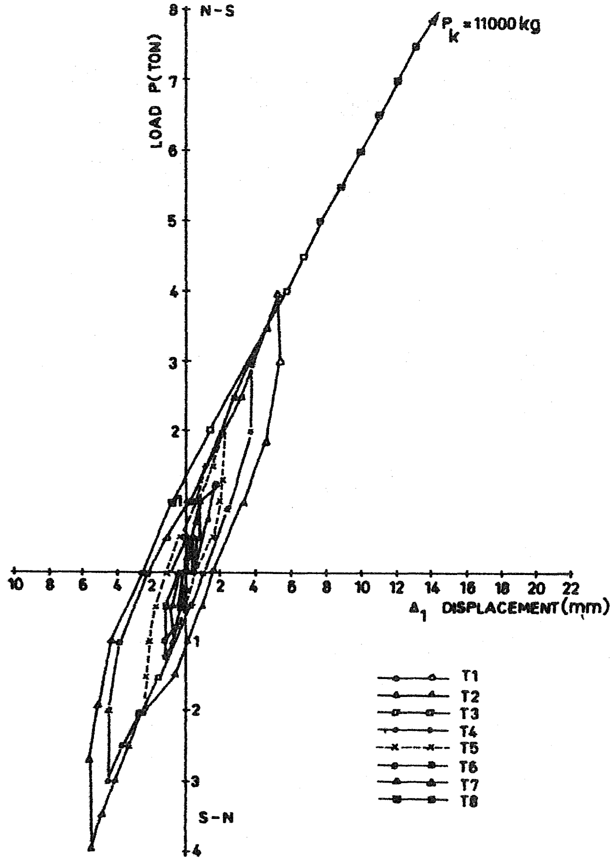

FIGURE V. LOAD - DISPLACEMENT CURVE (D8)

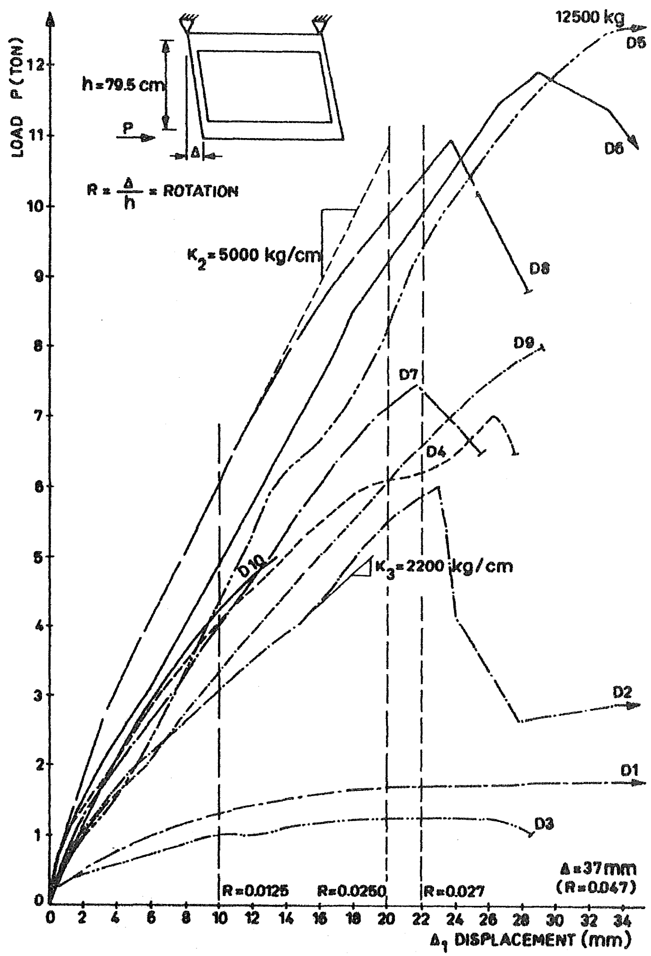

FIGURE VI. ENVELOPE CURVES

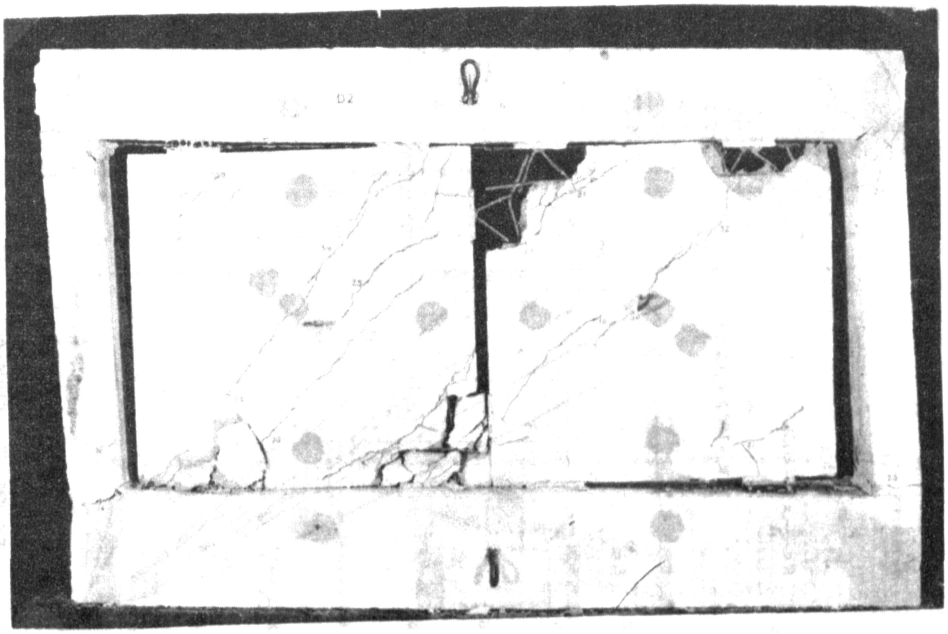

FIGURE VII. MODEL D2 AFTER FAILURE

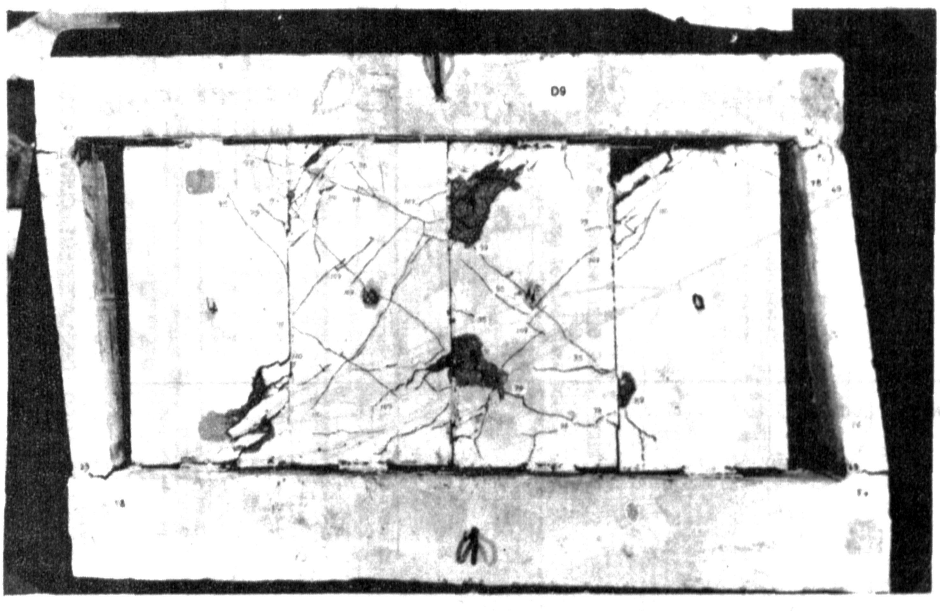

FIGURE VIII. MODEL D9 AFTER FAILURE