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SEISMIC STUDY OF HYBRID FRAMES

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ABSTRACT

Hybrid construction is sometimes used for seismic design in the US, but there has been very little research or design guidelines for its usage. Prior to 1950 or 1960, entire steel frames were encased in concrete for fire protection. These older structures have often behaved well during past earthquakes, and many of them are now due for rehabilitation. Today the primary use of hybrid construction is in encased steel columns used as major members in the gravity and lateral load frames. The concrete encasement increases the axial stiffness and decreases the axial deformation. The AISC design specification has been used for predicting the resistance of these composite elements.

In this study, static and non-linear dynamic analyses of the three rigid composite model frames without shear walls or bracing with three, six, and nine stories are carried out by using the dynamic analysis program DRAIN-2DX. Fiber beam-column element is used to model steel-concrete beams and columns. Six-story frame is selected as the standard number of stories. Three and nine-story frames are selected for comparison. Results are presented in the forms of displacement, shear force, and drift ratio.

KEYWORDS

Hybrid frames; composite columns

INTRODUCTION

There has been a growing need and use of composite and hybrid structures in recent years, but very little is known at present regarding their behavior under lateral static and dynamic forces. The appearance of the hybrid construction is as a result of pursuing the economy and high-efficiency of the construction, but some problems are involved in structural design. The AISC design specification has been used for predicting the resistance of these composite elements by engineers. There has been limited research to support these provisions, but experimental research would suggest that the AISC provisions were sometimes irrational and overconservative.

In this study, static and non-linear dynamic analyses of the three rigid composite model frames without shear walls or bracing with three, six, and nine stories are carried out by using the dynamic analysis program DRAIN-2DX. Fiber beam-column element is used to model steel-concrete beams and columns. Six is selected as the standard number of stories. Results from non-linear time history analysis are presented in the forms of displacement, shear force, and drift ratio envelopes (Akbas et al., 1996; Akbas et al, 1995; Shen et al, 1994; Sivakumaran, 1991).

SEISMIC DESIGN OF FRAMES

Three rigid composite model frames with three, six, and nine stories are designed for this investigation (Figs. 1 and 2). All frames are designed in accordance with the 1994 Uniform Building Code and 1994 AISC Manual. The structures have two exterior frames and 5 interior frames. All interior frames are assumed to be pinned connected and used for gravity loads only except the middle frames, that are the studied composite frames. The composite frames are made of A572Grade50 structural steel and 3500 psi of concrete. The elements used for beams and columns are summarized in Table 1. The structures are designed for a live load of 50 psf and dead load of 100 psf. The structures are assumed to be in seismic zone 4. In designing the frames, reduction factor R_w is taken as 6 for this study.

SEISMIC ANALYSIS OF THE FRAMES

The two-dimensional model of frames were built for non-linear time history analysis using a general purpose inelastic dynamic analysis program, DRAIN-2DX (Prakash et al., 1993). Fiber beam-column elements were used to model steel-concrete beams and columns. Inelastic beam elements were used in each span of girders. P-M interaction relation, suggested by LRFD, was used as yielding surface of column elements. 5% strain hardening was assumed for the post-yielding stiffness of steel beams and columns. P-Δ analysis was not considered in the analysis. The structures were subjected to three representative earthquakes, El Centro, Taft, and Northrigde (Newhall Station) and all earthquakes records were factored to 0.3g and 0.5g, respectively. The properties of the earthquakes are given in Table 2. A step-by-step time integration with constant acceleration assumption was used in the dynamic analysis. Mass was lumped at joints, and 2% viscous damping was included.

RESULTS

Results from non-linear time history analysis are presented in the form of displacement envelope, shear force envelope, and drift ratio envelope in Figs. 3, 4, and 5.

Displacement Envelope

Displacement envelopes for the frames are shown in Fig. 3. It is observed that Northridge (Newhall Station) has the most severe effect on structures. When earthquakes records were factored to 0.5g, the frames experienced nearly 25% more displacement than factored to 0.3g.

Shear Force Envelope

Shear force envelopes are shown in Fig. 4. The frames attract the most shear force when subjected to Northridge (Newhall station) earthquake. The shear forces that the frames attract when subjected to El

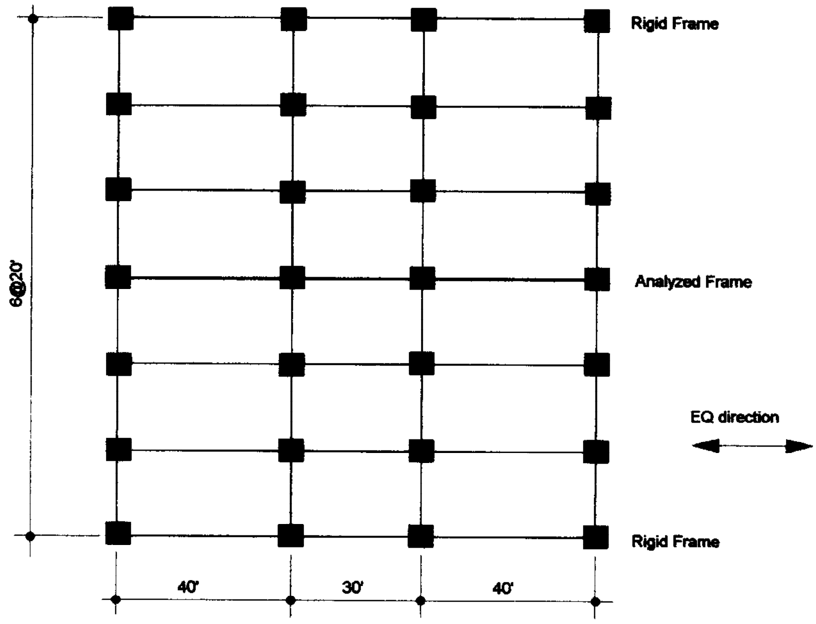

Figure 1. Plan of the structures

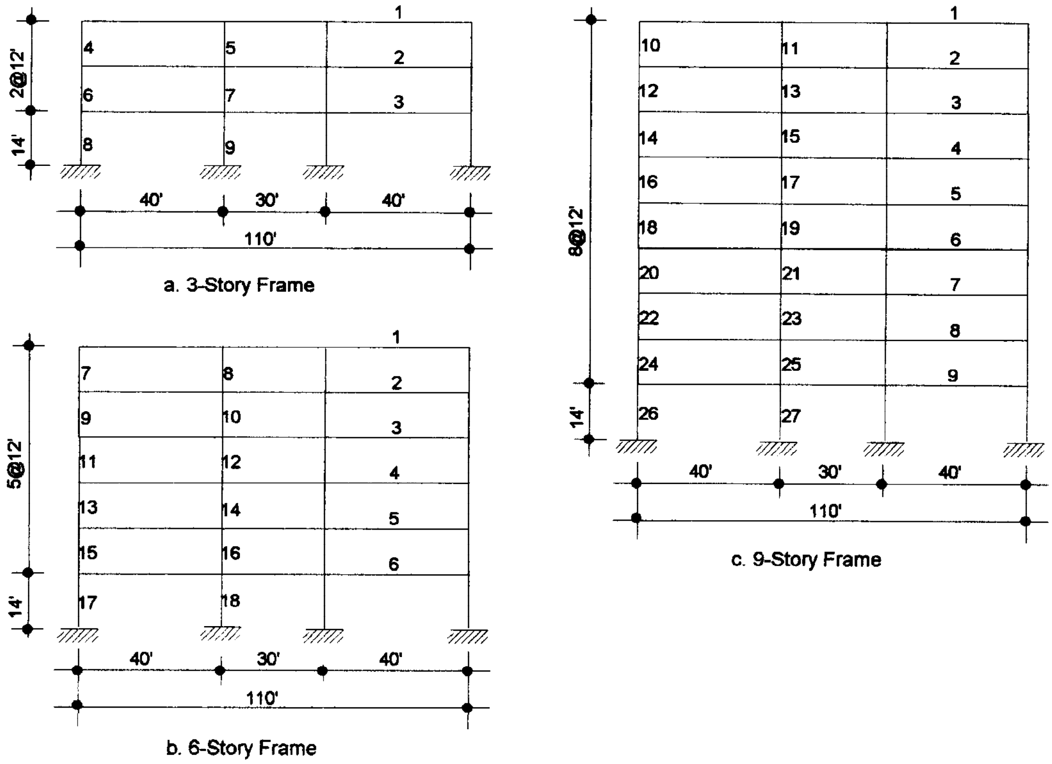

Figure 2. Elevation of the frames

Table I. Elements and member sizes of the frames

Type	Cross Section (in/in)	W-Shape	No. of Reinf. bars
1	---	W24x84	---
2	---	W30x124	---
3	---	W30x124	---
4	18/18	W10x112	4-#8
5	18/18	W10x112	4-#8
6	20/20	W14x109	4-#10
7	20/20	W14x109	4-#10
8	20/20	W14x109	4-#10
9	20/20	W14x109	4-#10

a. Details of the 3-Story Frame

Type	Cross Section (in/in)	W-Shape	No. of Reinf. bars
1	---	W24x76	---
2	---	W33x152	---
3	---	W33x152	---
4	---	W33x152	---
5	---	W33x152	---
6	---	W33x152	---
7	18/18	W10x77	4-#8
8	20/20	W12x106	4-#9
9	18/18	W10x77	4-#8
10	20/20	W12x106	4-#9
11	20/20	W12x106	4-#9
12	24/24	W14x145	4-#10
13	20/20	W12x106	4-#9
14	24/24	W14x145	4-#10
15	20/20	W12x120	4-#9
16	24/24	W14x233	4-#11
17	20/20	W12/120	4-#9
18	24/24	W14x233	4-#11

b. Details of the 6-story frame

Type	Cross Section (in/in)	W-Shape	No. of Reinf. bars
1	---	W24x76	---
2	---	W33x118	---
3	---	W33x118	---
4	---	W36x160	---
5	---	W36x160	---
6	---	W36x160	---
7	---	W36x160	---
8	---	W36x160	---
9	---	W36x160	---
10	18/18	W10x77	4-#8
11	18/18	W10x77	4-#8
12	18/18	W10x112	4-#8
13	20/20	W12x120	4-#9
14	18/18	W10x112	4-#8
15	20/20	W12x120	4-#9
16	20/20	W10x106	4-#9
17	24/24	W14/145	4-#10
18	20/20	W12x106	4-#9
19	24/24	W14x145	4-#10
20	20/20	W1x120	4-#9
21	24/24	W14x193	4-#11
22	20/20	W12x120	4-#9
23	24/24	W14x193	4-#11
24	24/24	W14x233	4-#11
25	24/24	W14x283	4-#11
26	24/24	W14x233	4-#11
27	24/24	W14x283	4-#11

c. Details of the 9-Story Frame

Table II. Ground motion components and their properties

Site	Date	Location	Compon.	Max. Acc. ($m/sec.^2$)	Magnitude
Imperial Valley	1940	El Centro	S00E	0.3483g	7.0
Kern County	1952	Taft	S69E	0.1793g	5.9
Northridge	1994	Newhall	---	0.63g	6.4

Centro and Taft earthquakes of 0.3g are slightly bigger than the design shear force, differ significantly for 0.5g.

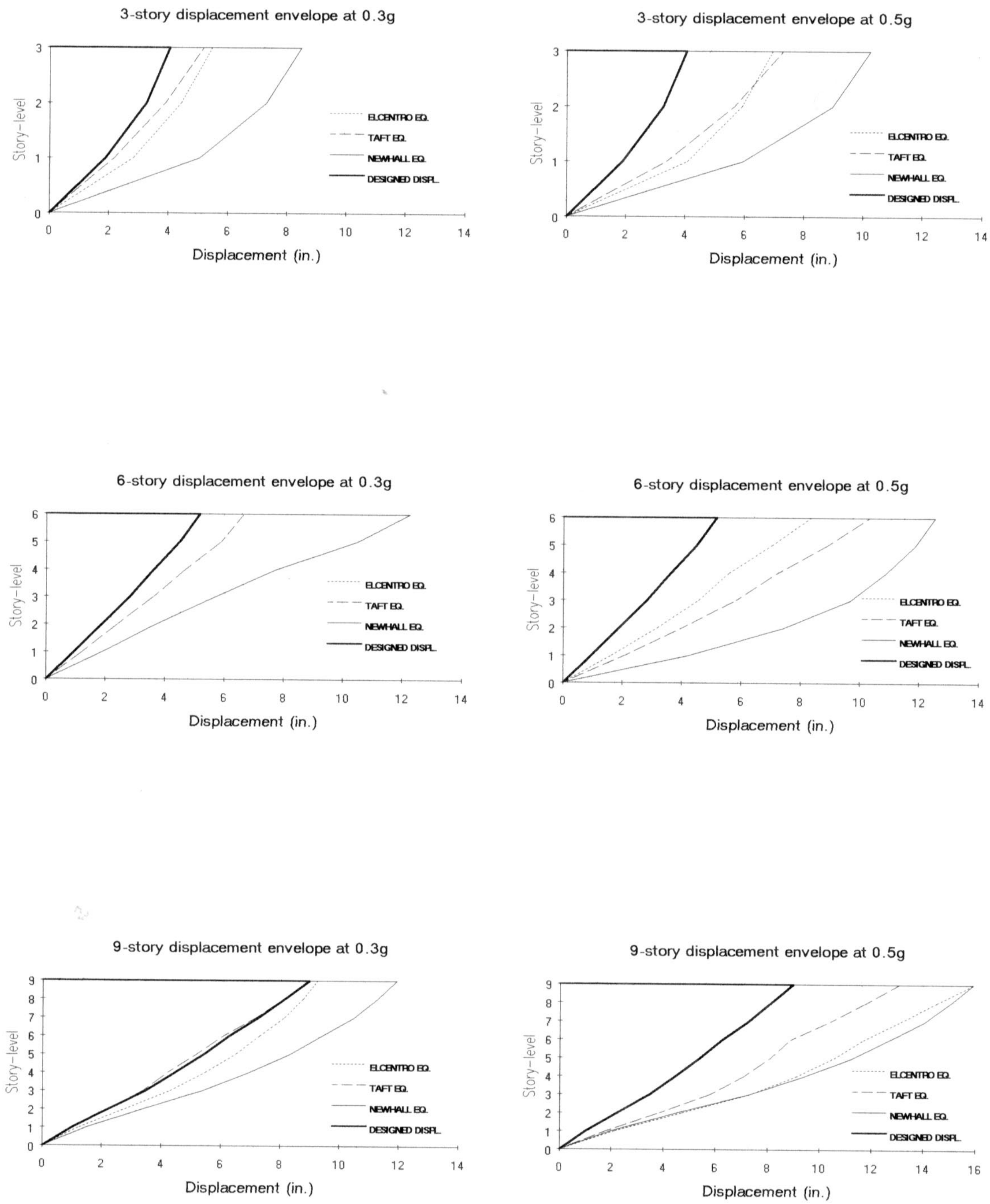

Figure 3. Displacement envelopes

Drift Ratio Envelope

Drift ratio envelopes are shown in Fig. 5. As can be seen from Fig. 5, Northridge (Newhall station) earthquake causes the biggest drift ratio on the frames among the three earthquakes.

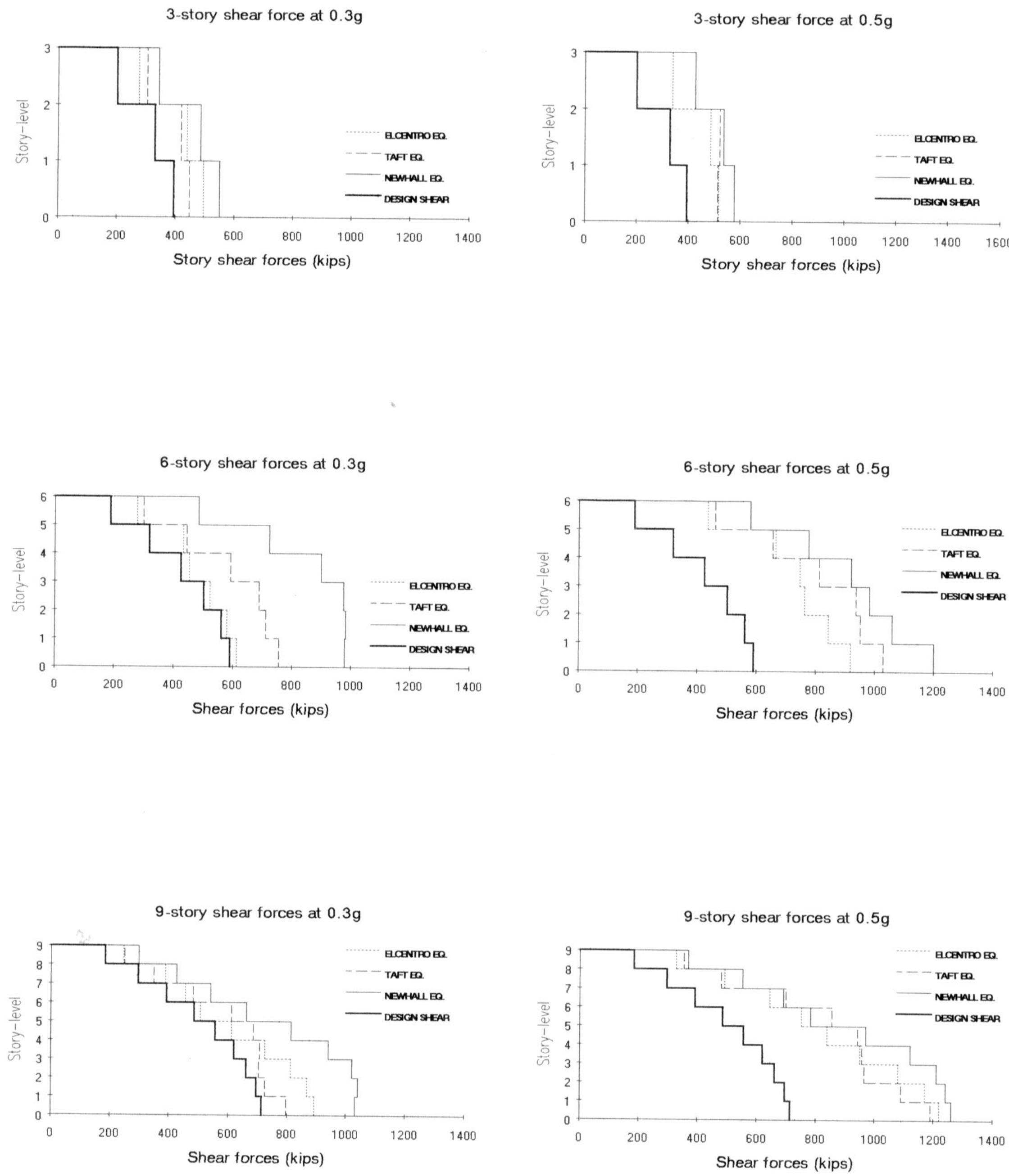

Figure 4. Shear force envelopes

CONCLUSIONS

Several conclusions can be drawn from the above study:

1) Global seismic response of hybrid frames has similar patterns as observed in steel moment-resisting frames in terms of modes of vibration, distribution of shear force. However, the local behavior such as ductility of critical elements, connection behavior, and beam-column strength ratio is significantly different from those in steel frames.

2) The assumed reduction value of Rw = 6.0 does not assure conservatism even for 0.3g El Centro earthquake ground motion. The ductility ratio of hybrid structures need to be further studied.

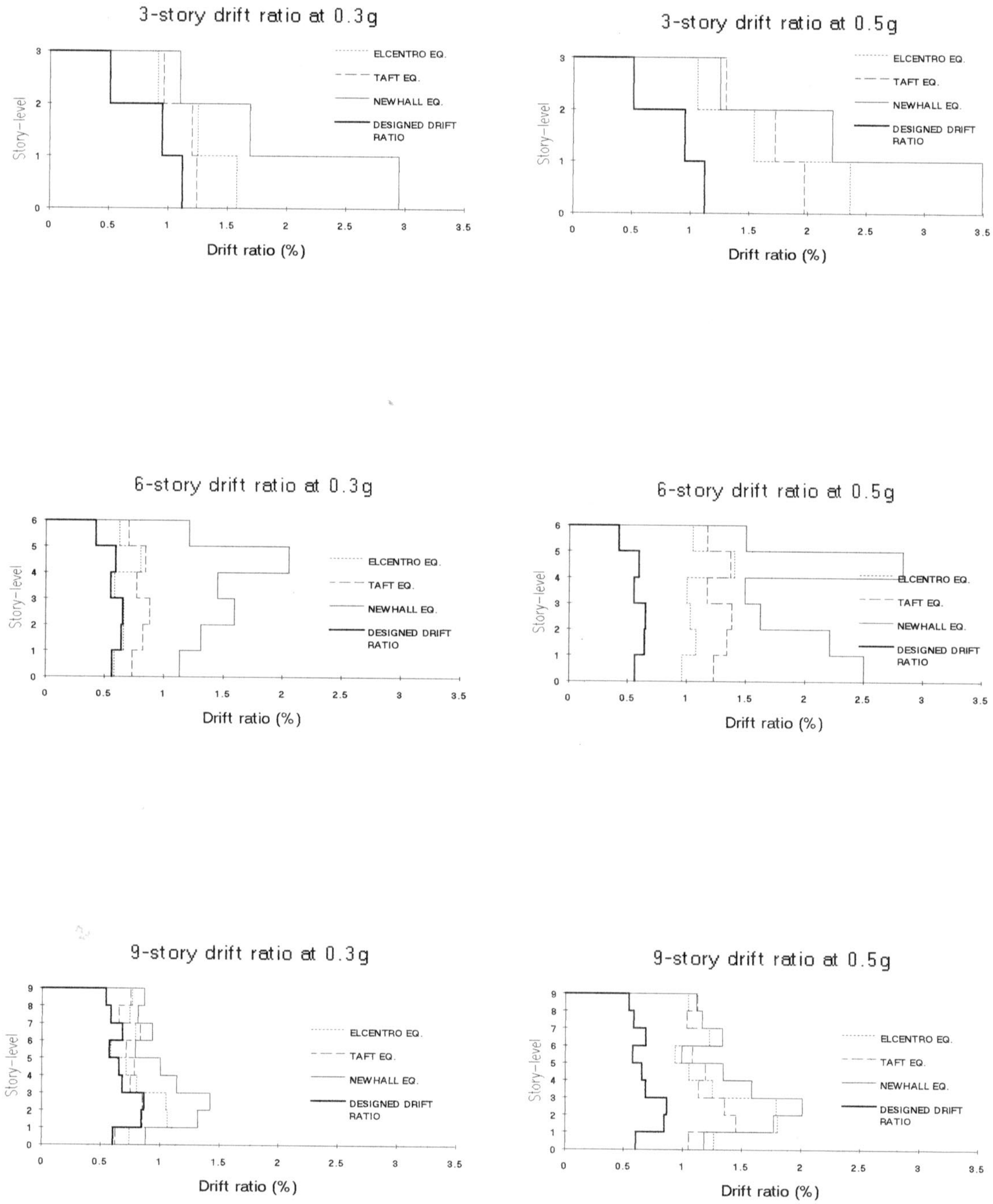

Figure 5. Drift ratio envelopes

3) It is important to model the critical columns by refined models such as the fiber model used in this study in order to capture the effect of local plastic deformation and concrete crack on the global ductility.

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