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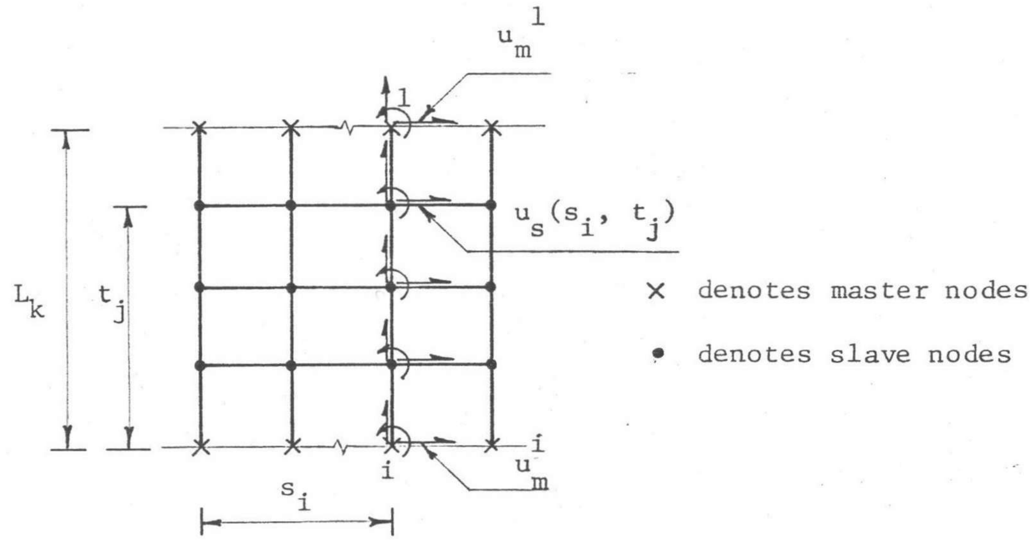


Fig. 1 The k^{th} substructure

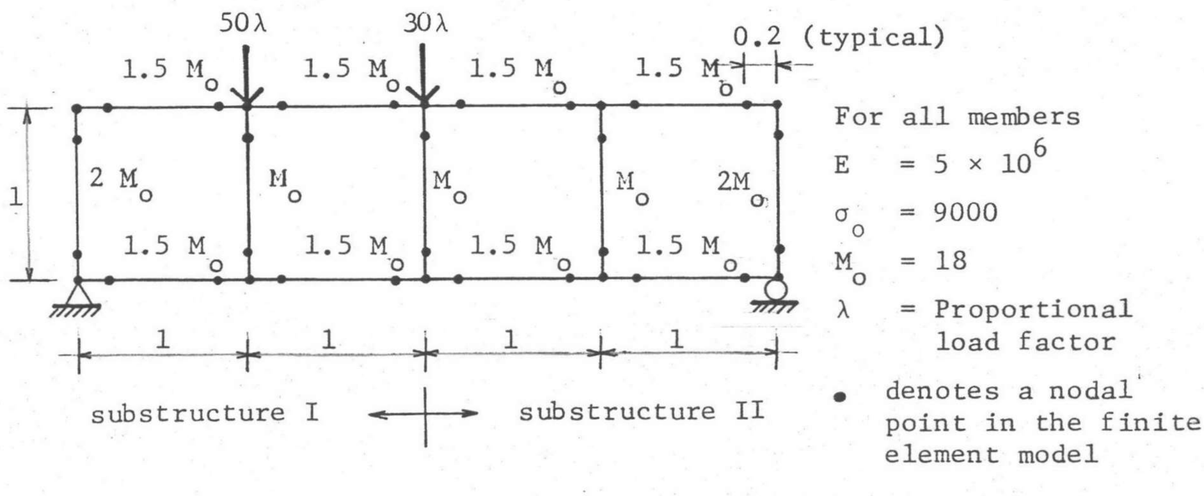


Fig. 2 (a) Vierendeel Girder - Geometry and Loading

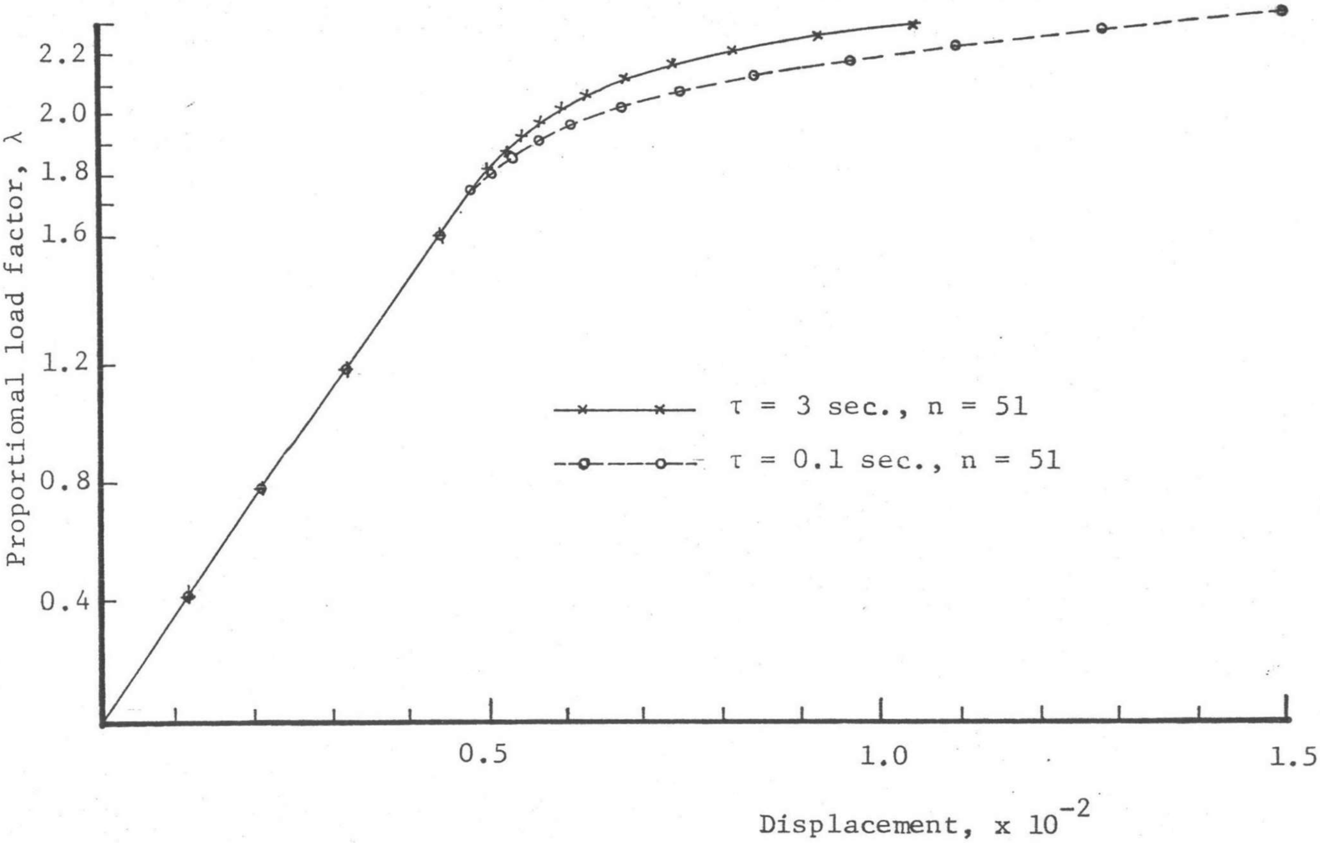


Fig. 2 (b) Vierendeel Girder - Vertical Displacement at Mid Span

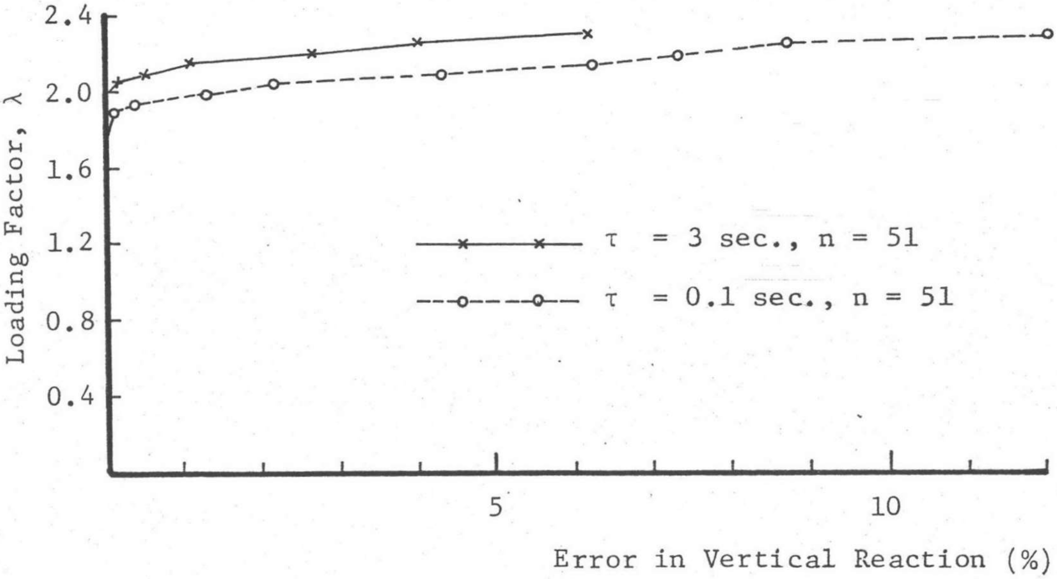
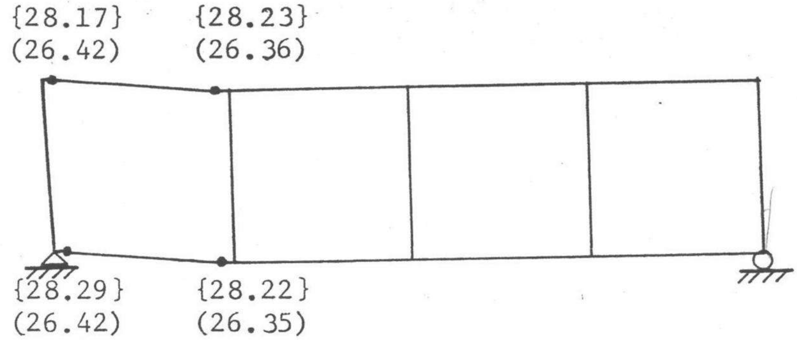


Fig. 2 (c) Vierendeel Girder - Error in Vertical Reactions



• denotes a plastic hinge

Values in parentheses are moments at collapse

{ } for τ = 3 sec., n = 51, λ = 2.25

( ) for τ = 0.1 sec., n = 51, λ = 2.10

Fig. 2 (d) Vierendeel Girder - Collapse Mechanism

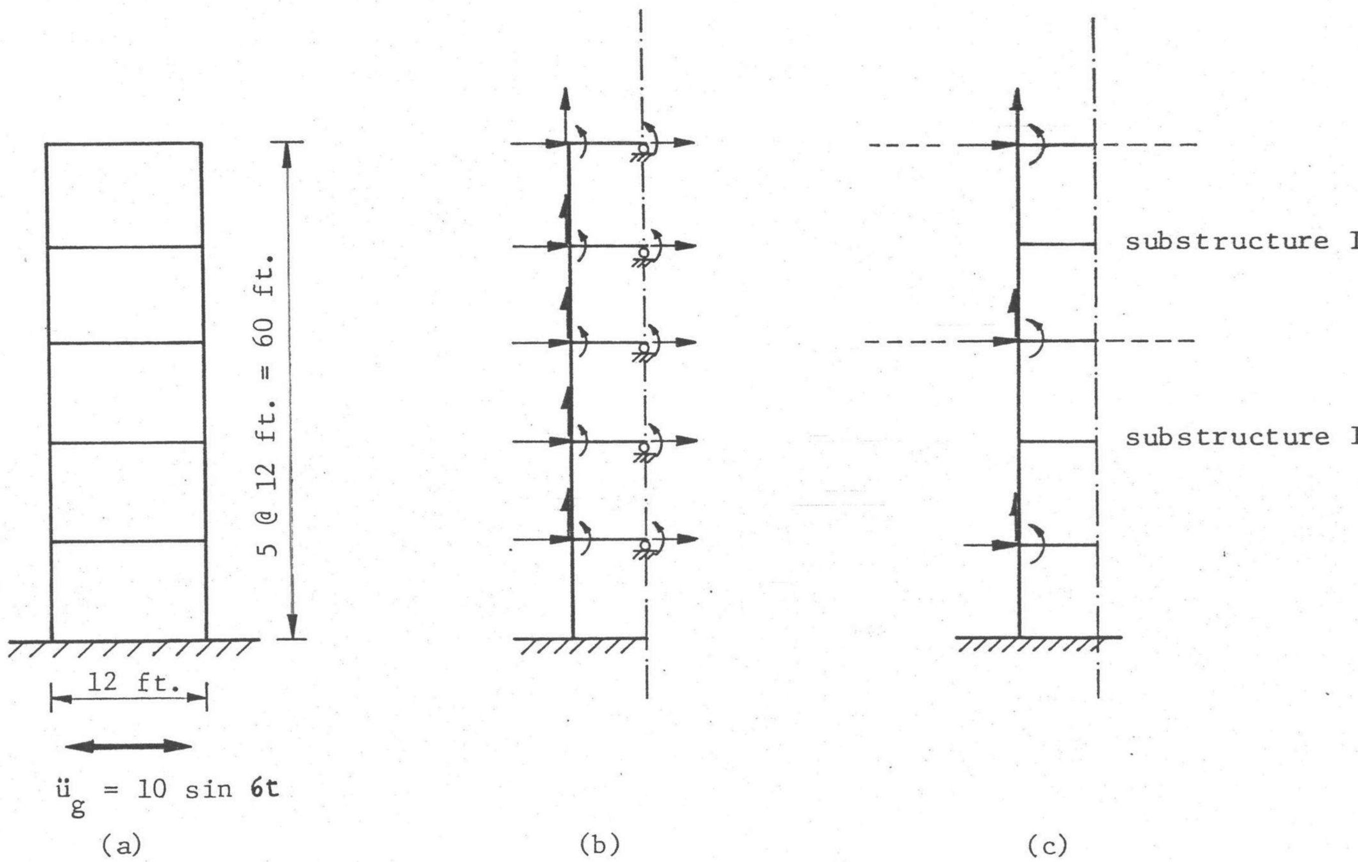


Fig. (3) Five - Story Frame (a) Geometry, (b) Full System Model (25 d.o.f.)

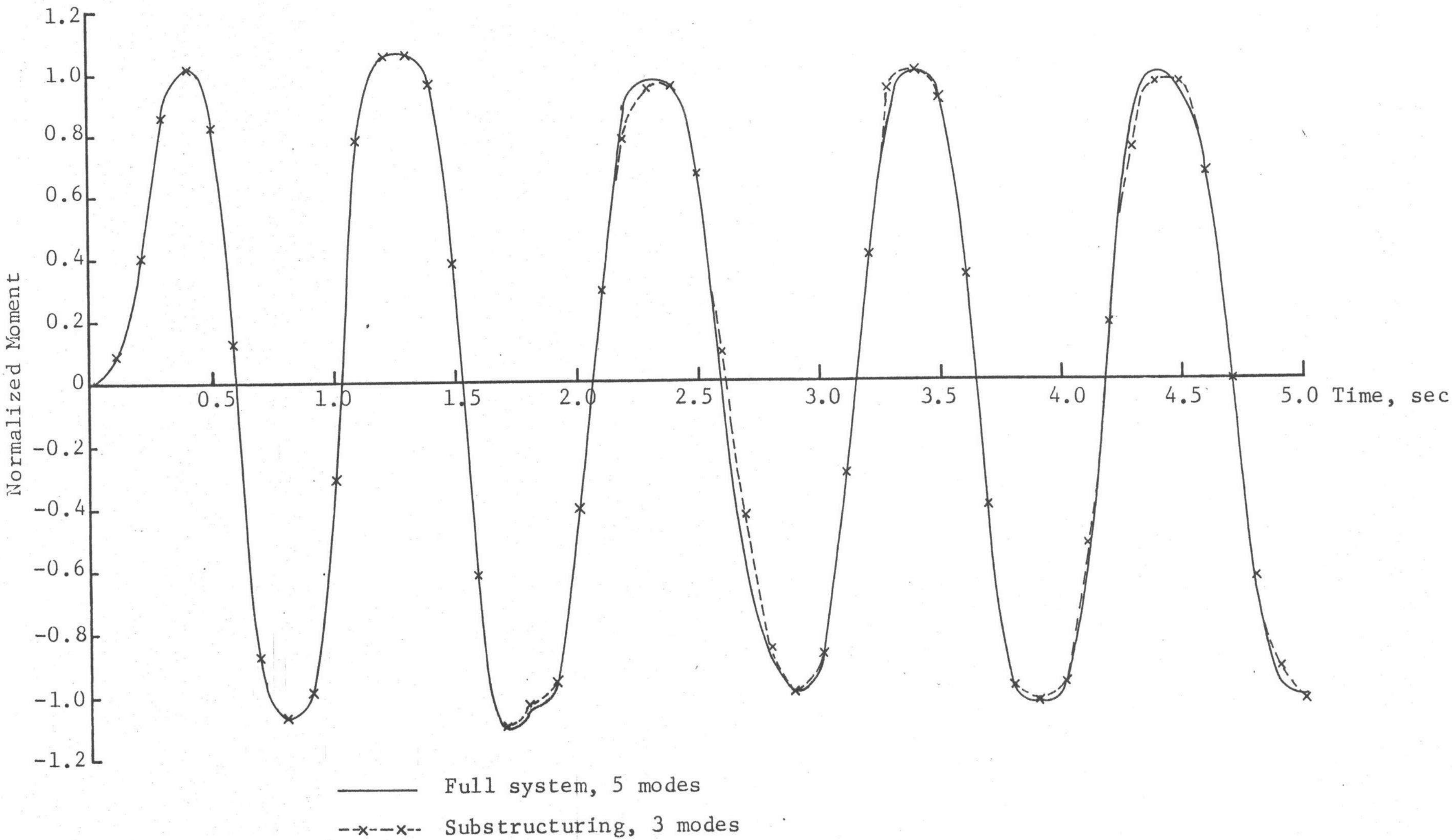


Fig. 3 (d) Five-Story Frame-Response of Moment at the End of Second Floor Beam

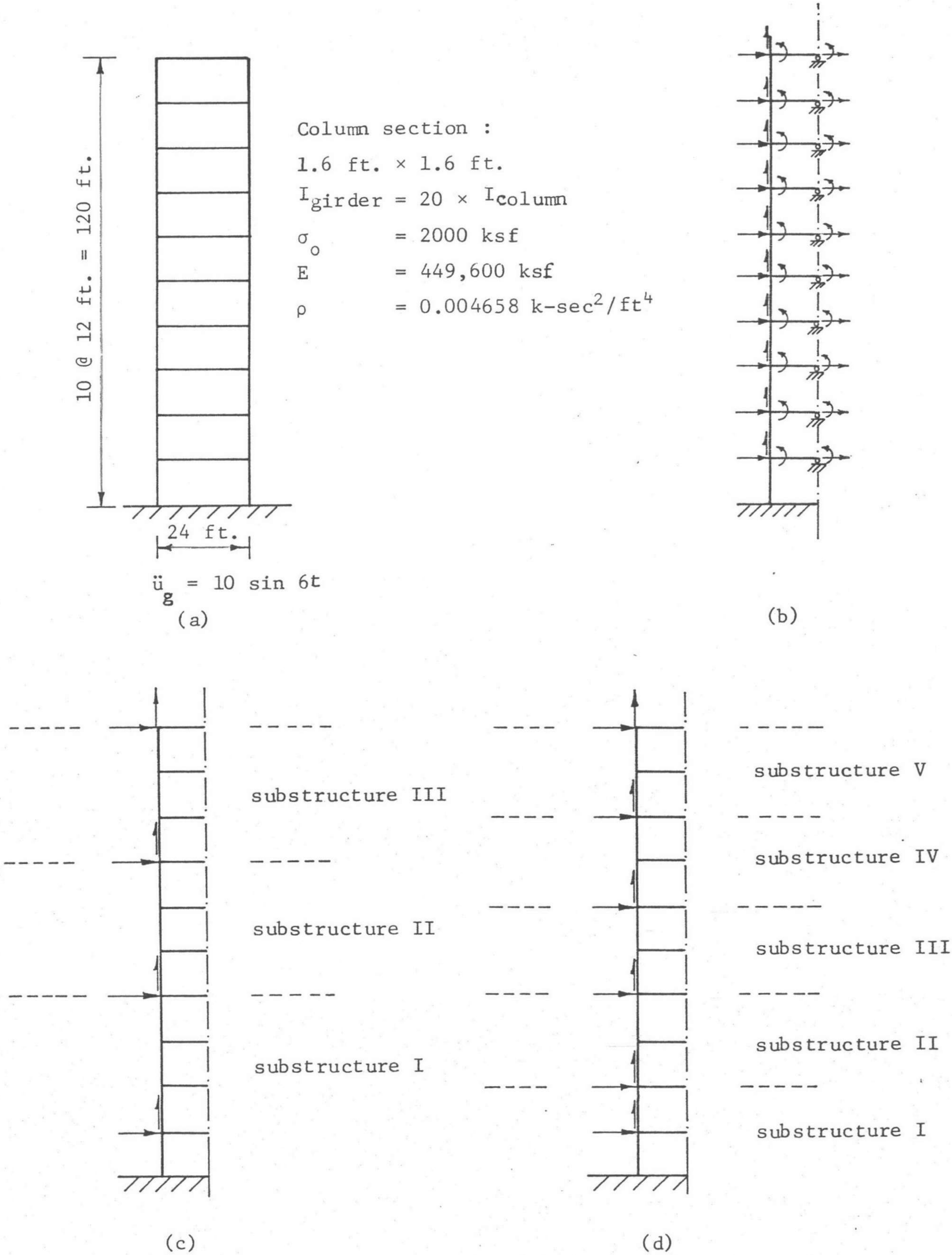


Fig. 4. Ten-Story Frame (a) Geometry, (b) Full System Model (50 d.o.f.), (c) Model 10 A (8 generalized coordinates), (d) Model 10 B (12 generalized coordinates).

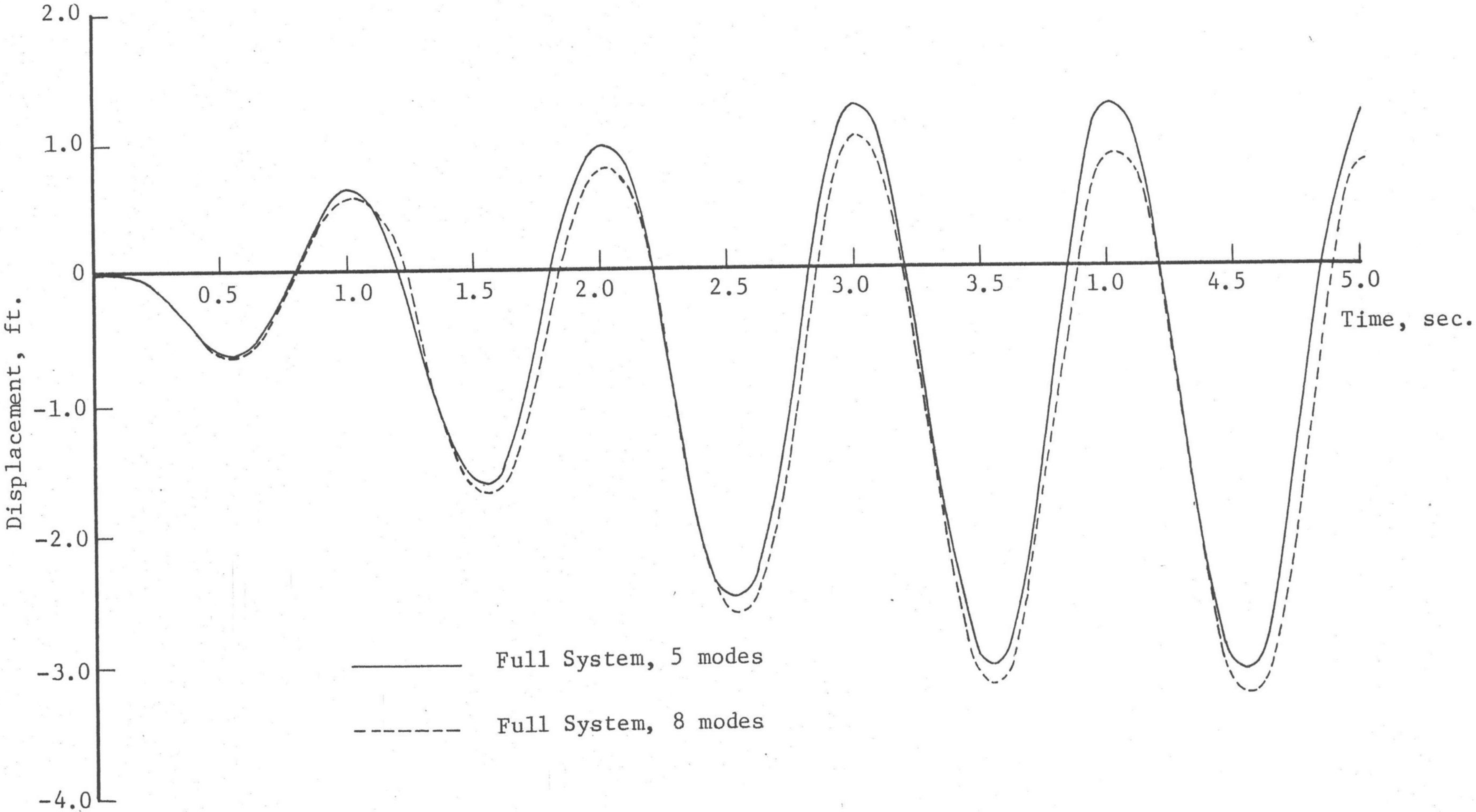


Fig. 4 (e) Ten-Story Frame-Horizontal Displacement Response at Top Story of the Full System Analyses.

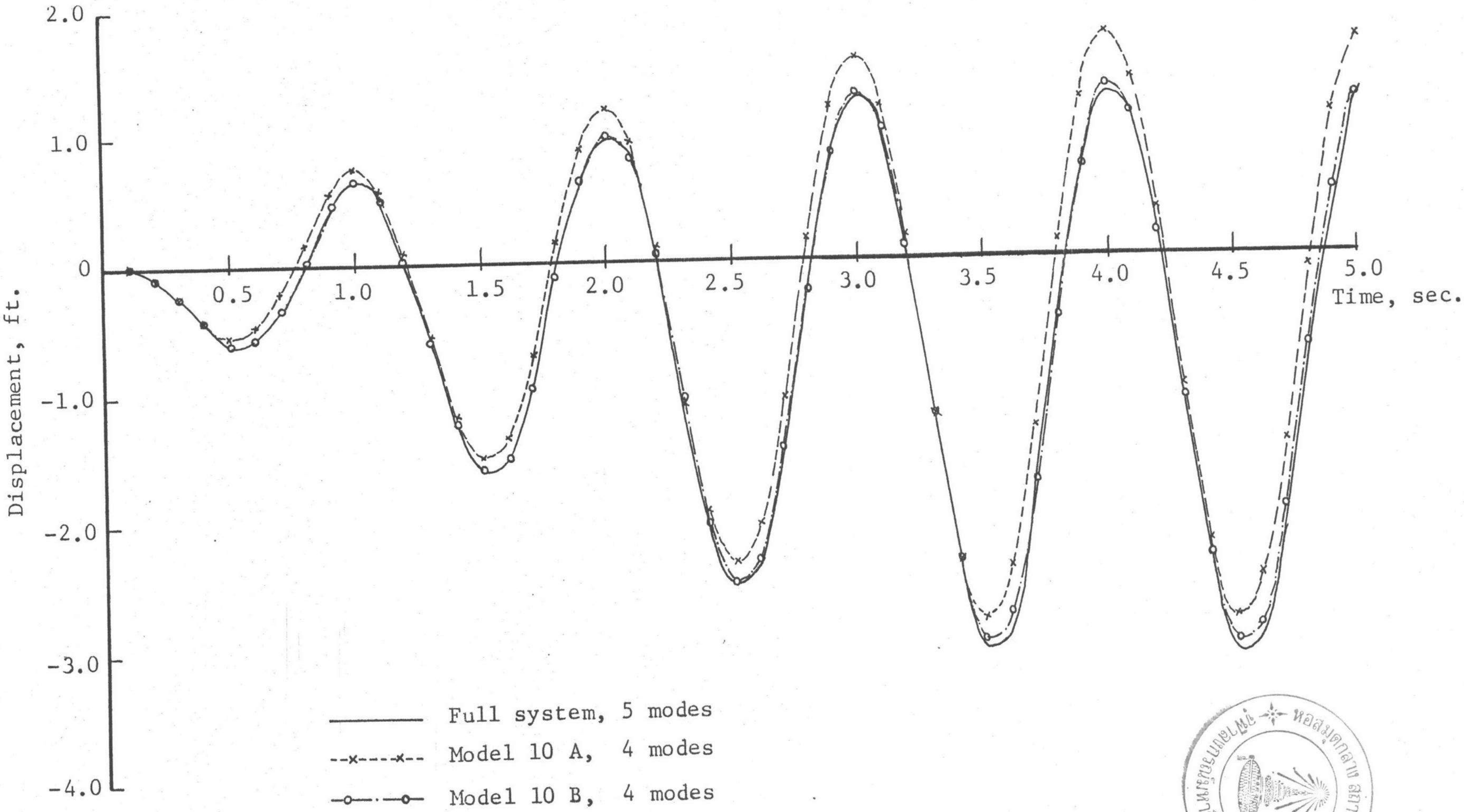


Fig. 4 (f) Ten-Story Frame-Horizontal Displacement Response at Top Story

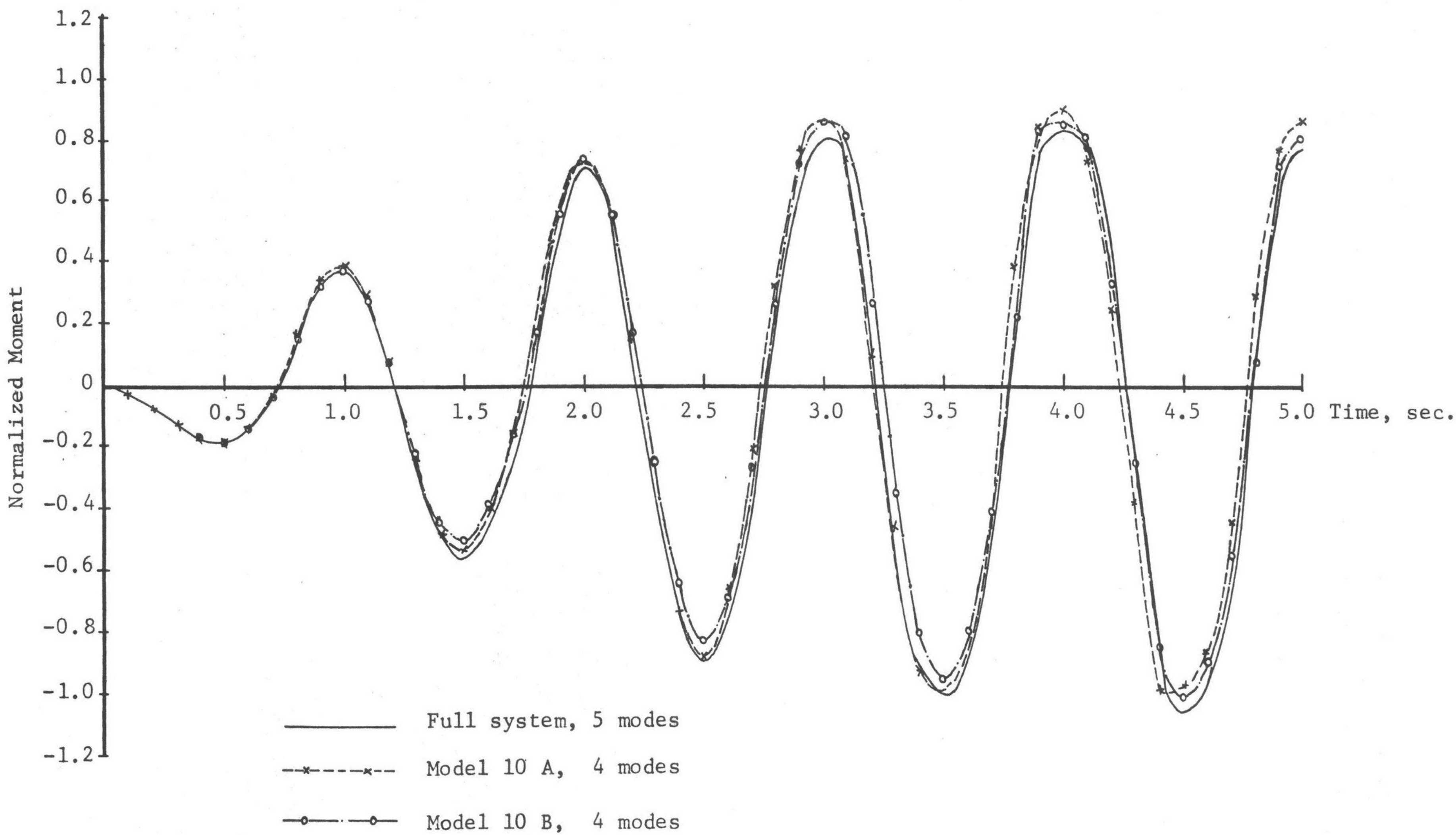


Fig. 4 (g) Ten-Story Frame-Response of Moment at Column Base

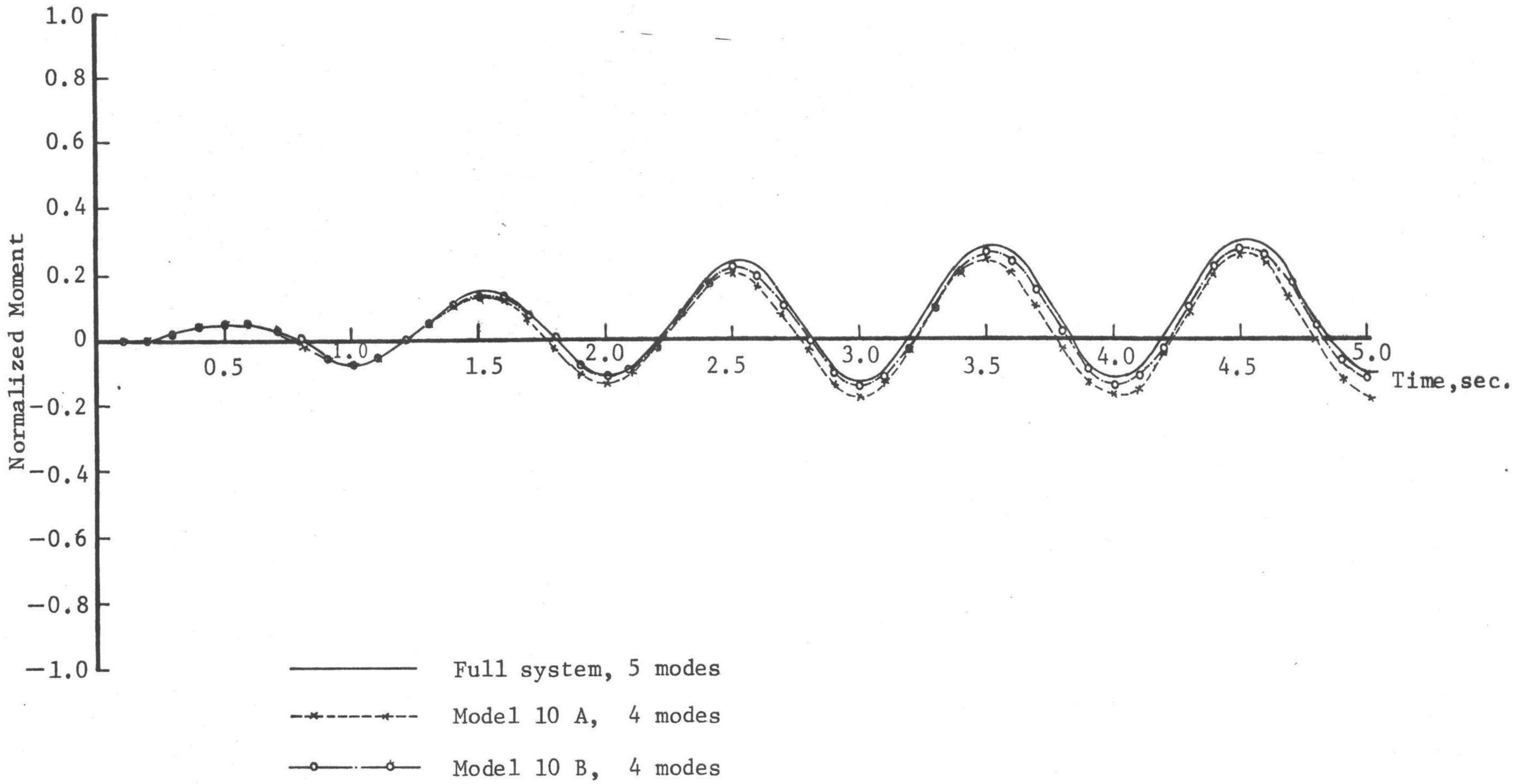


Fig. 4(h) Ten-Story Frame-Respose of Moment at the End of Second Floor Beam

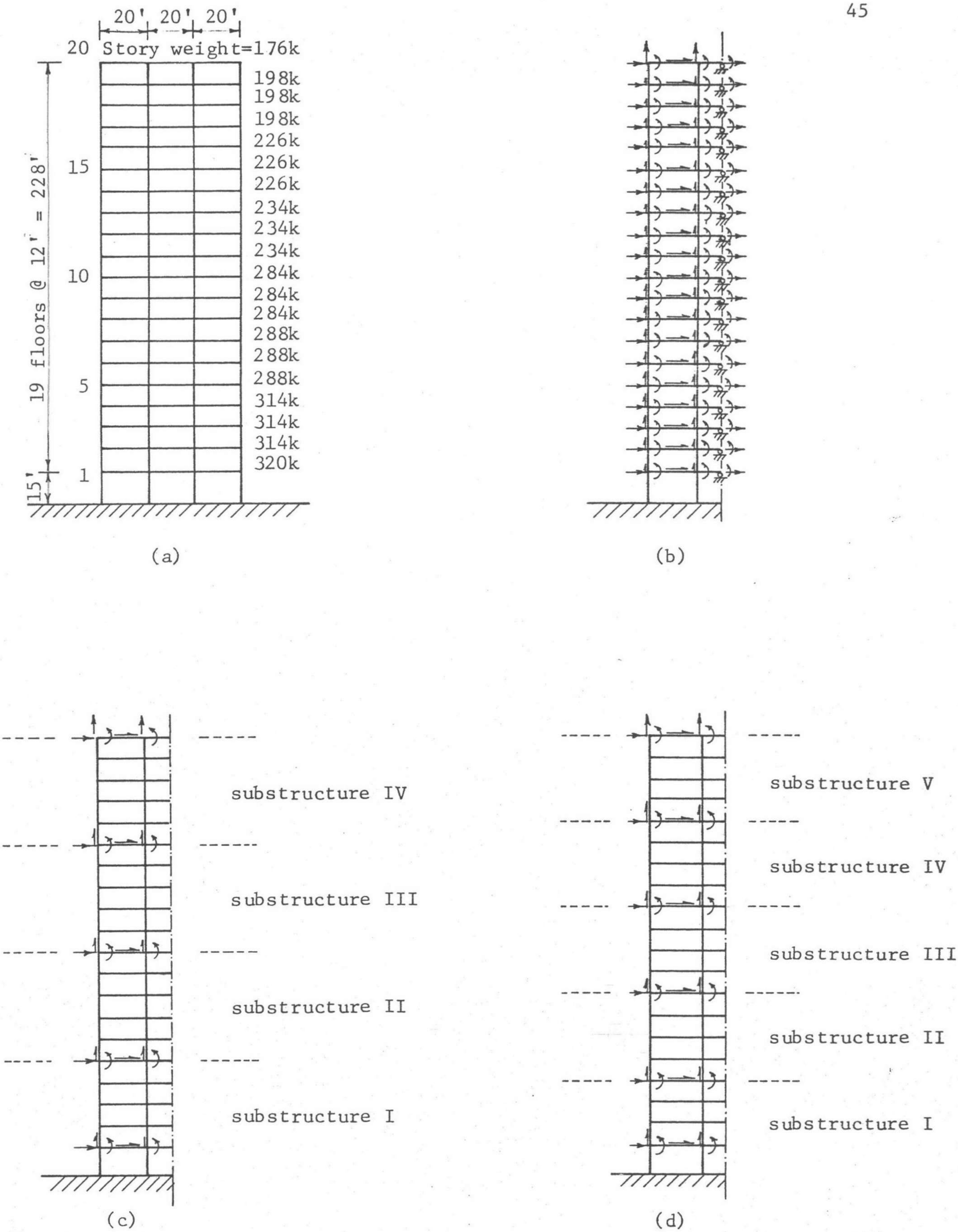


Fig. (5) Twenty-Story Frame (a) Geometry, (b) Full System Model (160 d.o.f.) (c) Model 20 A (30 generalized coordinates), (d) Model 20 B (36 generalized coordinates.)

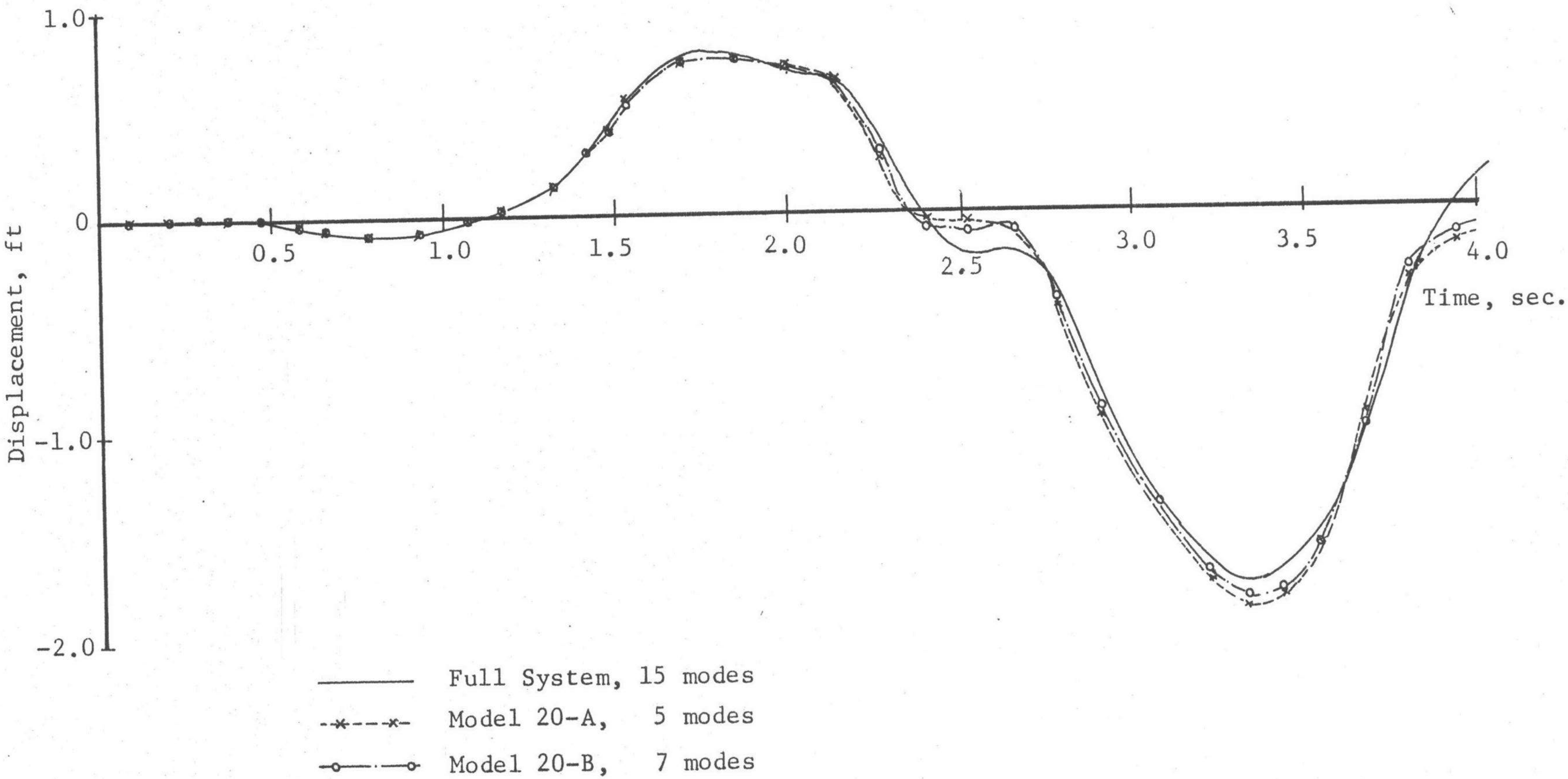


Fig. 5 (e) Twenty-Story Frame-Horizontal Displacement Response at Top Story

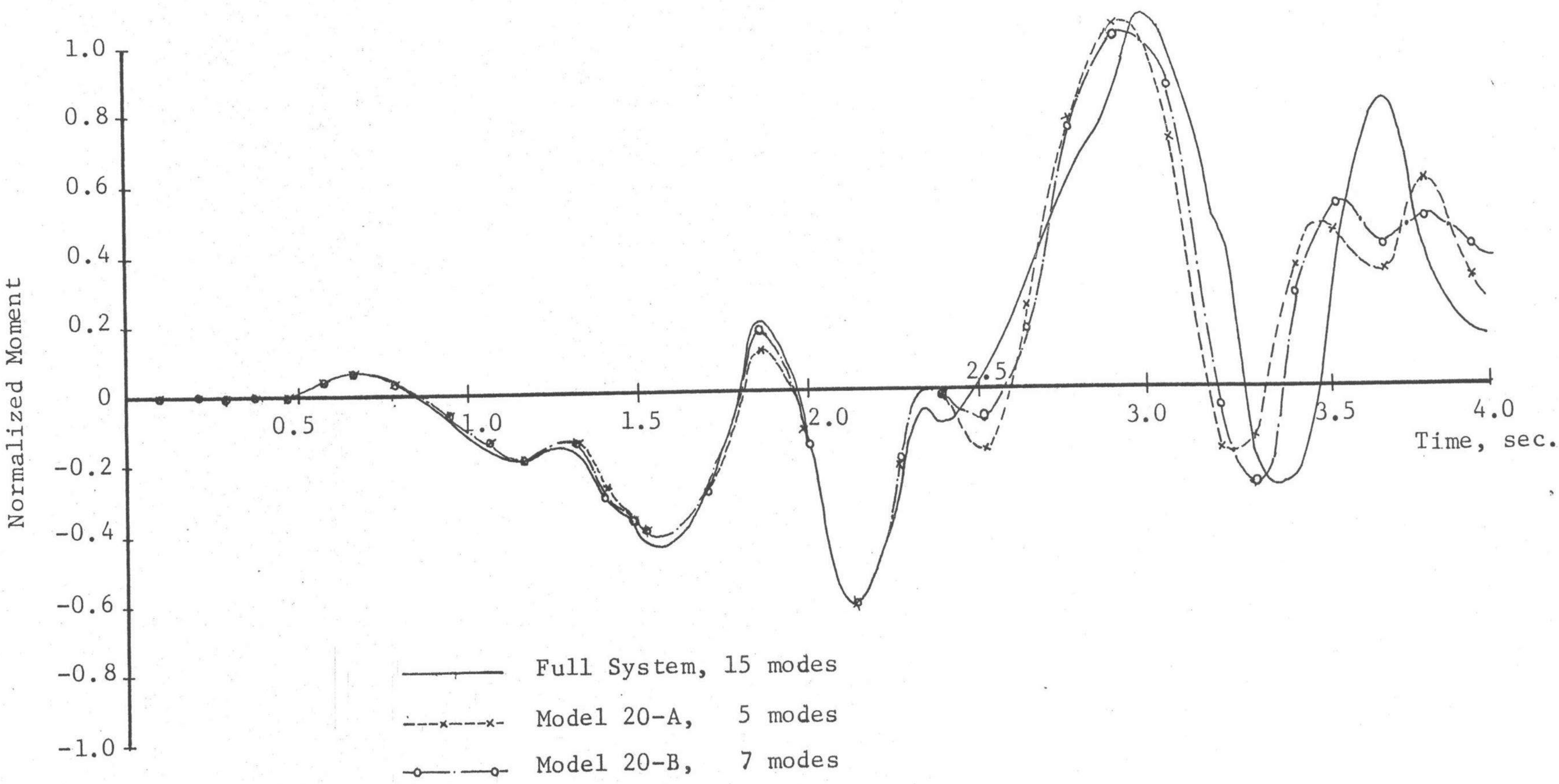


Fig. 5 (f) Twenty-Story Frame-Response of Moment at the End of Exterior Second Floor Beam

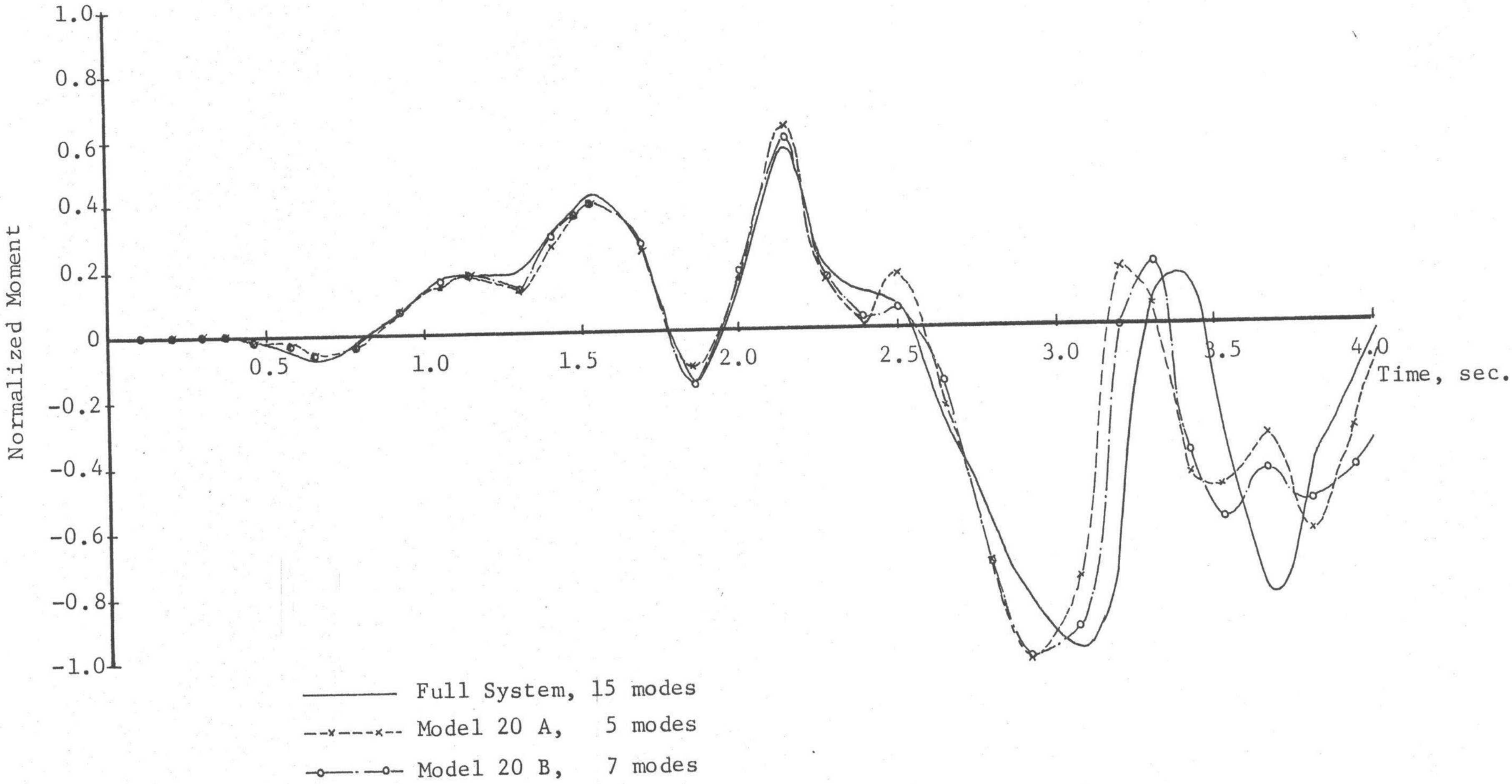


Fig. 5 (g) Twenty-Story Frame-Response of Base Moment of Interior Column

Table 1 - Member Properties for the Five-Story Frame

Story	Column Size (in × in)	Beam Size (in × in)	Floor Mass ($k\text{-}sec^2/ft4$)
1-3	22 × 22	10 × 22	0.625
4,5 (top)	14 × 14	8 × 16	0.625

For all members : σ_o = 367.2 ksf

E = 449,600 ksf

ρ = 0.004658 $k\text{-}sec^2/ft4$

Note : 1 kip = 4.45 kN, 1 ksf = 47.904 kN/m^2

1 $k\text{-}sec^2/ft4$ = 515.68 $kN\text{-}sec^2/m4$

Table 2 - Natural Periods (in seconds) and Errors for the Five-Story Frame

Mode No.	Full System	Substructured System	Error %
1	0.6494	0.6476	- 0.28
2	0.2610	0.2497	- 4.33
3	0.1344	0.0879	-34.60
4	0.0887	0.0419	-52.76
5	0.0519	0.0185	-64.35

Table 3 - Maximum Horizontal Displacement at Top Story and Maximum Normalized Moment at the End of the Second Floor Beam of the Five Story Frame

	No. of Modes Used	Max. Displ. (ft.)	Max. Normalized Moment
Full System	5	0.4238	1.114
With Substructuring	3	0.4295	1.098
Error, %		1.34	-1.44

Table 4 - Natural Periods (in Seconds) and Percentage Errors (in Parentheses) for the Ten-Story Frame

Mode no.	Full System	Model 10 A	Model 10 B
1	0.9087	0.9074 (-0.14%)	0.9101 (+0.15%)
2	0.2957	0.2792 (-5.58)	0.2901 (-1.89)
3	0.1656	0.1459 (-11.89)	0.1582 (-4.47)
4	0.1190	0.1050 (-11.74)	0.1131 (-4.96)
5	0.0937	0.0759 (-18.97)	0.0904 (-3.52)

Table 5 - Maximum Horizontal Displacement at Top story and Maximum Normalized Moment at Column Base of the Ten-Story Frame. (Figures in parentheses are the percentage errors)

	No. of Modes Used	Max. Displ. (ft.)	Max. Normalized Moment
Full System	5	3.042	1.0488
Model 10 A	4	2.772	0.9609
		(-8.87%)	(-8.38%)
Model 10 A	5	(large error)	(large error)
Model 10 B	4	2.970	1.0054
		(-2.37)	(-4.14)
Model 10 B	5	3.141	1.0298
		(+3.25)	(-1.81)

Table 6 - Member Properties for the Twenty-Story Frame

Relative Stiffness of Columns and Girders, Ratio (EI) : $(EI)_o$			
Story	Exterior Column	Interior Column	Girders
18-20	1.0	2.0	4.0
15-17	1.5	3.0	6.0
12-14	3.0	6.0	
9-11	4.5	9.0	8.0
6-8	6.0	12.0	
3-5	10.0	20.0	10.0
1-2	12.0	24.0	

Reference Stiffness $(EI)_\sigma$ = 133,500 $k\text{-}ft^2$

E = 4,176,000 ksf

σ_o = 5,184 ksf

Note : 1 ksf = 47.904 kN/m^2, 1 $k\text{-}ft^2$ = 0.413 $kN - m^2$

Table 7 - Natural Periods (in seconds) and Percentage Errors (in Parentheses) for the Twenty-Story Frame

Mode no.	Full System	Model 20 A	Model 20 B
1	2.8080	2.8264	2.8239
		(+0.65%)	(+0.57%)
2	1.0074	0.9616	0.9756
		(-4.55)	(-3.16)
3	0.5648	0.5116	0.5216
		(-9.42)	(-7.65)
4	0.4144	0.3922	0.3951
		(-5.36)	(-4.66)
5	0.3750	0.3415	0.3484
		(-8.93)	(-7.09)
6	0.3033	0.1931	0.2575
		(-36.33)	(-15.10)
7	0.2405	0.1447	0.1951
		(-39.83)	(-18.88)

Table 8 - Maximum Horizontal Displacement at Top Story and Maximum Normalized Moment at the Left End of Exterior Second Floor Beam of the Twenty-Story Frame (Figures in Parentheses are Percentage Errors)

	No. of Mode Used	Max. displ. (ft.)	Max. normalized moment
Full System	15	1.780	1.075
Model 20 A	5	1.879	1.026
		(+5.56%)	(-4.56)
Model 20 A	7	1.878	1.118
		(+5.50)	(+4.00)
Model 20 B	7	1.835	1.032
		(+3.09)	(-4.00)

Table 9 C.P.U. Time for the Twenty-Story Frame Analyses

	No. of Modes Used	Execution Time	Percentage Difference Compared with that of the Full System
Full System	15	30 min. 19 sec.	——
Model 20 A	5	37 min. 51 sec.	+ 24.85%
Model 20 A*	5	29 min. 02 sec.	- 4.23%
Model 20 B	7	40 min. 35 sec.	+ 33.86%
Model 20 B*	7	30 min. 52 sec.	+ 1.81%

* denotes analyses without substructuring but the full system coordinates are reduced to retain only the master coordinates

VITA

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