ATC 55: Evaluation and Improvement of Inelastic Analysis Procedures
Summary - State of Practice Building Data Submitted by Practicing Engineers

Example I.D.	Office Location	Purpose of Analysis	Year of Original Construction	Stories	Floor Area (sf)	Occupancy	Seismic System	Gravity System
1	Berkeley	Upgrade	1969	12+	100,000+	Office	Concrete core walls	Steel Strap Suspension from top of cores
2	Berkeley	Upgrade	1974	12+	100,000+	Office	Concrete core walls	Steel beams/deck on core
3	Berkeley	New	1996	3+	50,000+	Housing	Plywood shear walls	Wood studs/joists
4	Berkeley	Upgrade	1930	3+	50,000+	Office/retail	Existing perimeter infill and new propped shear walls	Riveted steel
5	Berkeley	New	2000	3+	100,000+	Housing	Friction damped rocking braced frames	Steel cols/beams and wood joists
6	San Francisco	New	2000	12+	100,000+	Office	Steel SMRF and EBF	Steel cols/beams/deck
7	San Francisco	Upgrade	1920	3+	100,000+	Library /Courts	Conc frame/brick infill/new shotcrete walls	Concrete cols/beams/slabs
8	San Francisco	Evaluation	1920	12+	100,000+	City Offices	Conc Frame/brick infill	Concrete cols/beams/slabs
9	San Francisco	Evaluation	1920	3+	100,000+	Restaurant/office	Conc frame/brick infill	Concrete cols/beams/slabs
10	San Francisco	New	2000	3+	100,000+	Office	Steel EBF	Steel cols/beams/deck
11	San Francisco	Eval/Upgrade	1951	3+	10,000+	Classroom/admin	Existing R/C Frame	Concrete cols/pan joists
12	San Francisco	New	Under const	7+	100,000+	Hospital	Steel EBF, concrete shear walls at base	Steel cols/beams/deck
13	Portland	Evaluation	1982	1+	100,000+	Hi-tech fab	Steel CBF	Steel cols/beams/deck
14	Oakland	Eval/Upgrade	1972	12+	N/A	Communication	Cable braced lattice	Cable braced lattice
15	Oakland	Eval/Upgrade	1989	7+	100,000+	Office HQ	Steel SMRF	Steel cols/beams/deck
16	Oakland	Evaluation	1983	7+	100,000+	Twin OfficeTowers	Steel SMRF	Steel cols/beams/deck
17	Oakland	Evaluation	1992	7+	100,000+	Hotel/Condo	Special Conc. MF	Conc cols/slabs
18	Oakland	Evaluation	1960	7+	100,000+	Commercial/Office	Core Walls	Lift Slab
19	Oakland	Eval/Upgrade	1960	7+	50,000+	Commercial/Office	Core Walls	Lift Slab
20	Oakland	Eval/Upgrade	1927	12+	100,000+	Commercial/Office	Steel riveted frame/brick infill	Steel cols/beams/slab
21	Oakland	Eval/Upgrade	1960	7+	50,000+	Housing	Concrete shear walls	Conc core slabs/bearing walls/columns
22	San Francisco	New	2001	3+	100,000+	Office	EBF	Steel cols/beams/deck
23	San Francisco	Evaluation	1970	3+	50,000+	Office	Steel CBF/MF	Steel cols/beams/deck
24	San Francisco	Upgrade	1960	12+	100,000+	Equipment	Conc shear walls	Steel cols/beams/slab
25	San Francisco	Evaluation	1966	?	?	Office	Conc shear walls	Steel cols/beams/slab
26	San Francisco	Upgrade	1909	12+	100,000+	Office	Riveted steel frame/brick infill	Steel cols/beams/slab
27	San Francisco	Upgrade	1930	3+	100,000+	Office	Riveted steel frame/brick infill	Steel cols/beams/slab
28	San Francisco	Upgrade	1920	1+	100,000+	Sports stadium	Conc frame/brick infill	Conc cols/beams/slabs
29	San Francisco	Evaluation	1920	7+	100,000	Office, jail, sheriff	Conc frame/brick infill	Conc cols/beams/slabs
30	San Francisco	Evaluation	1960	3+	100,000+	Sports stadium	Concrete Frame	Conc cols/beams/slabs
31	Oakland	New	1998	12+	100,000+	Office	SMRF	Steel cols/beams/deck
32	San Francisco	New	2001	3+	50,000+	Multi purpose	Unbonded Brace	Steel cols/beams/deck
33	San Francisco	Eval/Upgrade	1960	7+	100,000+	Teaching/Research	Concrete shear walls / SCMF	Conc box cols/flat slab/brg walls
34	San Francisco	New	Under const	3+	100,000+	Research Lab	Unbonded Brace	Steel cols/beams/deck
35	San Francisco	New	1999	1+	10,000+	Communications	SCBF	Steel cols/beams/deck
36	San Francisco	New	2000	1+	10,000+	Test	OSB shear panels	Wood studs/joists
37	San Francisco	Eval/Upgrade	1958 (UBC)	1+	10,000-	Test	Stucco/gyp bd/code-prescribed bracing	Wood studs/joists
38	San Francisco	New	2000	1+	10,000-	Test	Perforated OSB shear wall	Wood studs/joists
39	LA	Evaluation	1960	12+	100,000+	Office	Conc col/flat slab	Conc col/flat slab
40	LA	Evaluation	1993	3+	100,000+	Parking	Conc ductile MF	Conc cols/Precast concrete floor framing
41	San Francisco	Upgrade	1964	3+	10,000+	Research	Conc shear walls/new flexural and coupled shear walls	Conc cols/walls
42	San Francisco	Eval	1930	3+	50,000+	Classroom/office	Conc pier/spandrel frames/ new unbonded brace	Conc cols/walls

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Example I.D.	Foundation System	Inelastic Approach	Year Analyzed	Software?	Peer Review?	Comment Reference	Issue Relation
1	SF ?	NLTH	2001	ABAQUS, DRAIN 2DX, SAP2000	Y	1,2,3,4,5	
2	PCP	NLTH	1998	DRAIN 2DX, SAP90	N	3,4,5	
3	SF	CS	1995		Y	6	
4	PCP and DP	ATC 40/ NSP	2000		NA		
5	DP and SF	NLTH	1999	DRAIN 2DX	Y	7,8,9	A(3,5,6,38,39)
6	Mat	NLTH	1999	DRAIN 2DX	N	1	
7	R/C piles	FEMA 273/ NSP	1997	FEM-I / ETABS with seq. modified stiffness	Y	10,11	C(21), F(8,9)
8	SF	CS	1993	FEM-I	Y	12	D(18,19)
9	Unknown	FEMA 273/ NSP	2001	FEM-II /SAP2000	N	13	C(21)
10	PCP	FEMA 273/ NSP	2000	SAP2000	N	14	A(1), C(23,30)
11	SF/new GB	FEMA 273/ NSP	1999		Y	15	
12	Belled piers, SF	FEMA 273/ NSP	2000	SAP2000	N	16	F(36)
13	SF	FEMA 273/ NSP	2001	SAP2000	N		
14	Mat	NSP, NLTH	2000	ANSYS	Y		
15	SF	FEMA 351NSP, NLTH	2000	DRAIN 2DX,SAP2000	Y		
16	Mat	NLTH	2000	ANSYS	N		
17	Mat	FEMA 273/NSP	1997	ANSYS	Y	17	C(21)
18	Mat	NSP Lat, NLTH vert	1999	SAP 90 Lat, DRAIN 2DX vert	N		
19	Mat	NSP Lat, NLTH vert	1999	SAP 90 Lat, DRAIN 2DX vert	N		
20	SF/Mat/Piles	NSP equal displacement	1992	SAP 90, DRAIN 2D	Y	18	F(8,9)
21	SF/Mat	NSP equal displacement	1995	DRAIN 2D	Y	19	B(7)
22	Mat	FEMA 273/ NSP	2001	SAP2000	Y	20	A(1)
23	SF	FEMA 273/ NSP	2000	SAP2000	Y	21	
24	Mat	NSP - IDR	1990	SAP 90	Y		
25	Piles	FEMA 273/ NSP	2000	Custom	N		
26	Piles	ATC 40/NSP	1998	Custom	N		
27	Piles	ATC 40/NSP	1995	Custom	N		
28	SF	ATC 40/NSP	1994	Custom	Y		
29	Piles?	ATC 40/NSP	1993	Custom	N		
30	Piles	ATC 40/NSP	1993	Custom	Y		
31	Mat	NLTH	1998	DRAIN 2DX	N		
32	PCP	CS/Miranda	2000	SAP2000	Y		
33	SF	FEMA 273/ATC 40/Miranda	1999	SAP2000	Y	22	
34	PCP	NLTH/NSP/Miranda	2000	SAP2000	Y	23	F(6)
35	SF	FEMA 273/ NSP	1999	SAP2000	Y	24	
36	SF	NLTH	2000	CASHEW/Ruaumoko	NA	25	
37	SF	NLTH	2000	CASHEW/Ruaumoko	NA	25 sim	
38	NA	NLTH/FEMA 273/NSP	2000	CASHEW/Ruaumoko	NA	26,27,28	A(3)
39	SF	NLTH/NSP	1992	DRAIN 2D	N	29	A(3)
40	SF	NLTH/NSP	1994	DRAIN 2D	N	30	A(1,2)
41	DP	NSP/Miranda	1999	SAP2000	Y	31,32	
42	SF	Approximate CSM	2001	Manual	N	33	

Example I.D.	Office Location	Purpose of Analysis	Year of Original Construction	Stories	Floor Area (sf)	Occupancy	Seismic System	Gravity System
44	San Francisco	Upgrade	1959	7+	10,000+	Classroom/research	Concrete precast cladding frame/ new shear walls	Conc cols/pan joists
45	LA	New	1990	1+	50,000+	Retail	CMU walls/wood diaphragm roof	Wood framing
46	LA	Upgrade	1960	7+	100,000+	Retail	Dual concrete frame, shear wall system	Concrete cols/slab
47	LA	Eval/Upgrade	1992	7+	100,000+	Hotel	Concrete MF	Conc cols/beam/slab
48	LA	Evaluation	1960	7+	100,000+	Hospital	Nonductile and ductile conc MF	Conc cols/beam/slab
49	Portland	Upgrade	1929	3+	100,000+	Warehouse convert to office	Conc shear walls	Steel cols/girders with conc joist
50	San Francisco	Eval/Upgrade	1963	3+	10,000+	Classroom/research	Conc shear walls/new unbonded brace	Conc walls/columns/slabs
51	Irvine	Evaluation	1993	1+	50,000+	Office	Concrete walls/frames/slabs	Conc cols/joists
52	Dallas	New	2000	3+	500,000+	Hospital	Steel SMRF w/ dogbone connection	Steel cols/beams/deck
53	Dallas	New	2000	3+	200,000+	Hospital	Steel EBF	Steel cols/beams/deck
54	Seattle	New	2001	3+	100,000+	Hospital	Steel Special Truss MF	Steel cols/OWJ/deck
55	Seattle	Evaluation	1916	7+	50,000+	Office/Retail	Nonductile conc frame/HCT infill	Conc cols/beam/slab
56	Seattle	Evaluation	1985	12+	100,000+	Office	Steel MR pre-Northridge	Steel cols/beams/deck
57	Seattle	Evaluation	1992	12+	100,000+	Office	Steel MR pre-Northridge	Steel cols/beams/deck
58	Seattle	Upgrade	1960	1+	10,000+	Office	Conc MF non-ductile w/ some stone infill	Conc cols/beam/slab
59	Oakland	Evaluation	1965	7+	10,000+	Office	Concrete shear walls/non-ductile concrete frames	Conc cols/beam/slab
60	San Francisco	Upgrade	1950	7+	50,000+	Hospital	Dual - Conc shear wall/steel MF backup	Steel cols/beams/conc slab
61	Emeryville	Evaluation	1970	3+	100,000+	City Offices	Concrete shear wall / moment frame	Conc cols/beam/slab
62	Oakland	Upgrade	1907	3+	100,000+	Classroom/research	URM, retrofit with seismic isolation	URM/steel col/steel beams/conc slab
63	Oakland	Eval/Upgrade	1960	3+	50,000+	Medical Lab	Concrete shear wall / moment frame	Conc cols/beam/slab
64	Oakland	Eval/Upgrade	1968	7+	100,000+	Apartments	Concrete coupled shear wall	Conc walls/slab
65	Oakland	Eval/Upgrade	1960	3+	100,000+	Classroom/research	Concrete walls / PT girders	Conc waffle/cols
66	Oakland	Eval/Upgrade	1907	3+	50,000+	Classroom	URM/steel CBF	Wood frame/URM walls/steel frame
67	Oakland	Eval/Upgrade	1960	7+	100,000+	Classroom	Conc shear wall	Conc waffle/col
68	Oakland	Eval/Upgrade	1931	3+	10,000+	Classroom/office	URM/Conc shear wall/steel braced frame	Steel cols/beams
69	Oakland	Eval	1971	12+	100,000	Office	Pre-Northridge SMRF	Steel cols/beams
70	Oakland	Eval	1969	12+	100,000	Office	Non-ductile conc MF	Steel cols/beams
71	Oakland	?	1972	7+	100,000	Apartments	RC/CMU wall	Conc slab/RC and CMU walls
72	Oakland	?	1948	?	50,000+	Church	RC/MF/Shear Walls	Conc cols/beam/slab

Example I.D.	Foundation System	Inelastic Approach	Year Analyzed	Software?	Peer Review?	Comment Reference	Issue Relation
44	SF, new "belt"	NLTH/NSP/Miranda	1999	DRAIN 2D/SAP2000	Y	34,35	
45	SF	NSP	1990	DRAIN 2D	N	36	
46	SF	NSP	1997	DRAIN 2D	N	37	A(5)
47	SF	FEMA 273/ NSP	1998	DRAIN 2D	N	38	
48	SF	FEMA 273/ NSP	2000	SAP2000	Y	39	
49	SF	FEMA 273/ NSP	2000	SAP2000	N	40,41	F(8,9)
50	SF	NSP	2000	SAP2000 (linear)	Y	42	
51	SF	FEMA 273/ NSP	2000	SAP2000	N	43,44,45	F(7)
52	SF	ATC 40/NSP	1999	SAP2000/ETABS v6.21	Y	46,47,48,49,50	
53	SF	ATC 40/NSP,Army TM-5-809-10-1	2000	SAP2000/ETABS v6.21	Y	47,48,49,50,51	A(3), F(7)
54	R/C Piles	FEMA 273/NSP	2000	SAP2000	N	52,53,54,55	A(5), D(17)
55	SF	FEMA 273/ NSP	1998	SAP2000	Y	56	
56	SF	NSP/SAC method	1999	SAP2000	N	57,58	A(3)
57	SF	FEMA 351	2001	SAP2000	N	59	
58	Conc piles	NSP	1996	SAP 90 plus spreadsheets for bookkeeping	Y	60,61,62	A(3)
59	SF	FEMA 273/NSP	2001	SAP7.4	N	63,64	A(5)
60	SF	FEMA 273/NSP	1998	DRAIN 2D	N	65	
61	SF	ATC 40/NSP	1998	SAP2000	N	66	D(18)
62	SF	NSP	1996	SAP2000	Y	67	F(7,9)
63	SF	FEMA 273/NSP/ATC 40	1996	Manual	Y	68	A(3,6)
64	SF/Drilled piers	FEMA 273	?	Manual	Y	69	C
65	Piles	FEMA 273	?	Manual	N	70	C(21)
66	SF	NSP	1995	Manual	Y	71	
67	DP	FEMA 273/NSP/ATC 40	1998	SAP 2000/Manual	Y	72	C
68	SF	FEMA 273	2001	ETABS	N	73	
69	SF	FEMA 273/NSP	2000	SAP2000	Y	74	
70	Piles	FEMA 273/NSP	1999	SAP2000	Y	75,76,77	
71	SF	FEMA 273/NSP	1999	SAP2000	Y	78	
72	SF/caissons	FEMA 273/NSP	2000	SAP 2000	N	79	F(7)

Example I.D.	Comment I.D.	Meaning Clarity	Comment Description
1	1	?	Vertical time-history work with SAP2000
	2	?	Lateral time history work with ABAQUS
	3	?	Soil-Structure Interaction
	4	?	Carbon fiber shear retrofit to force flexural mechanism
	5	?	Foundation Retrofit
2	6		Mechanism studies revealed the need to upgrade tiedowns to avoid splitting of sill plate splitting. Plywood shear mechanism forced by preventing tiedown failure.
5	7		Parametric study on foundation k, diaphragm k, and friction force
	8		Damper modeled using simple spring hook and gap assembly
	9		Time-History results compared to pushover
7	10	?	Stiffness degradation not possible to model directly
	11		[ETABS] method was cumbersome but it was all we had for 3D
8	12		Global model not done, stories above podium assumed to take equal displacements
9	13		Stiffness degradation not possible to model in SAP2000
10	14		NSP may overestimate link rotations due to assumed monotonic increase in deformation
11	15		After calculating target displacement, the capacity of each limit state for each element was calculated as a function of the weight of the building("%g"), and the "sequence" of limit states/collapse was determined based on the relative capacities in addition to engineering judgment. It was estimated that many limit states would be prevented by rocking of the foundation of this stiff, heavy, 3 story building without a basement on sandy soil.
12	16		For in-house project team information and understanding. Not for OSHPD or review. Check of nonlinear hinge progression and mechanism location and max displacement at roof. Met target displacement.
17	17		Columns were removed to simulate column shear failures
20	18		Pushover was done largely as a series of elastic analyses with lots of Excel bookkeeping
21	19		Analysis was straightforward. Determination of target displacement was problematic.
22	20		Immediate Occupancy provisions [of FEMA 273] are too conservative
23	21		FEMA 273 was not complete with respect to steel moment frames - had to use info. From SAC
33	22		FEMA 273 shear strain ratios exceeded in local areas - deemed not to be hazardous

Example I.D.	Comment I.D.	Meaning Clarity	Comment Description
34	23		Results are highly sensitive to chosen pushover profile and to initial period
35	24		Client requires pushover by policy. FEMA 273 acceptance for Immediate Occupancy has max DCR of 0.8, so pushover is not valuable
36	25		Analysis involved teams at UCSD and Caltech
38	26		Analysis includes orig 1994 UBC design calcs by GFDS
	27		Prediction calcs by UCSD, blind prediction analyses by 5 international teams
	28		Studied with and without finish material
39	29		Analysis coupled with cyclic lab test to evaluate performance of the flat slab seismic system
40	30		Identified cause of collapse due to 1994 Northridge Earthquake
41	31		Required program intended to design project for life-safe performance to DBE event with collapse prevention check at MCE.
	32		MCE event controlled design
42	33		Pushover to existing and schematic upgrade for UCB budgeting purposes
44	34		Difficulties modeling existing surface-mounted precast pre-tensioned cladding panels, weakly doweled to frame
	35		Eccentric footings for new shear walls required special modeling of foundation-structure assembly
45	36		Diaphragm flexibility and nonlinearity including effect of interior walls and drag strut were analyzed
46	37		Very effective in showing performance with different assumptions
47	38		Analysis was coupled with laboratory cyclic testing of components with deficient ductile ties to to evaluate performance under seismic and hurricane loading
48	39		Very effective to show life safety when concrete frame-beam joints are the problem/weak links
49	40		SAP2000 has some severe limiting problems
	41		New software desperately needs to be developed…In time it will be
50	42		Difficulties included modeling the existing box column shafts, outdated reinfocement detailing, and basement wall interaction with superstructure above
51	43		Many load cases to cover for FEMA 273 guidelines
	44		Convergence was difficult to achieve even for a relatively simple model and depended greatly on the method of solution used
	45		The shear capacity of the concrete columns was difficult to evaluate by the FEMA 273 methods (Eq 6-4) due to constantly changing parameters

Example I.D.	Comment I.D.	Meaning Clarity	Comment Description
52	46		Design basis was 1997 UBC
	47		At Owner's request, bldg was checked for final draft IBC2000 - 50% higher base shear, 50% lower drift allowance
	48		Performance point was calculated using ATC 40 and SAP2000
	49		For dynamic analysis, site specific response spectrum was used, due to closeness of Wasatch Fault
	50		Tests were conducted at U Utah to prove that continuity plates were not required for the large column and beam sections
53	47		Army TM CSM was basis of design
	48		FEMA 273 reqs used for performance requirements and member ductility
	49		Performance point was calculated by ATC 40, and by TM and SAP2000 (results were different)
	50		ETABS used for dynamic analysis and member design.
	51		Drift limits difficult to establish, as codes have different performance categories (Operational, Immediate Occupancy, etc.)
54	52		Performed fully 3d pushover including torsional effects
	53		Considered range of possible gravity loads (per 1997 UBC) explicitly
	54		Established hinge modeling and acceptance criteria for STMF's based on the literature
	55		A paper summarizing the issues identified was published by SEAOC
55	56		FEMA-BSSC Case Study
56	57		Used guidelines of SAC MF Project
	58		Pushover complemented linear dynamic methods
57	59		Primary evaluation was based on linear dynamic analysis
58	60		Used an adaptive load pattern based on modal response at each significant step in the analysis process
	61		Results are described in a paper presented at the EERI 6th National Conference
	62		Compared displacement demands using FEMA 273, and ATC 40
59	63		In running SAP pushover, we had to vary the tolerance paramenters
	64		The most troublesome problem in implementing the FEMA procedures was developing nonlinear hinge properties (strength and ductility)
60	65		Retrofit was a partial upgrade utilizing an external steel braced frame founded on caissons
61	66		Linear elastic analyais used. Due to complexity of building, loads were applied in a distributed manner, rather than lumped at floor levels.
62	67		First use of SAP2000 required additional time to learn modeling and managing enormous post-processing task
63	68		ATC-40 predicts displacement demand 2 of 3 times higher than displacement coeff. And equal energy for the short period (0.3 second) structure with lateral strength of about 0.4g.
64	69		Considered effects of foundation overturning displacement

Example I.D.	Comment I.D.	Meaning Clarity	Comment Description
65	70		Walls governed by foundation rotation at base with dowels to tension piles yielding. Degrading shear behavior in some girders.
66	71		Used 25% draft of FEMA 273 as guidance
67	72		Challenge: soil-structure interaction. 1) Uncertain behavior of foundation system under vertical and lateral loads. 2) Determine target disp. With effect of foundation.
68	73		Building was obviously inadequate. Retrofit concentrated on reducing drift to acceptable limits for URM infill and granite cladding. Required signif. Strength and stiff. Above conventional retrofit.
69	74		For ductile joints, the C.P. acceptance is limited to Point 2, (Theta p at M max). Seems overconservative for C.P. Theta p is 1.4% to 1.7%, however beams retains sig. Capacity @ 2% to 3% Theta p.
70	75		Joint shear capacity in FEMA is less than that in ACI. Aslso FEMA defintion is unclear. What is exterior joint w/o transverse beams?
	76		ACI would allow15 root fc, and FEMA allows 12. Per table 6-9.
	77		Conforming vs. non-conforming ties. FEMA 273 says conforming are closed stirrups, there is no reqmt for supplemental cross ties.
71	78		Shear wall drift limits
			Including rocking effects for the exsiting conditions.
			Diaphragms - not elastically responding.
72	79		Time to evaluate structure to a reasonable level challenged the budget. Difficult to determine load path for complex structures due to time limit.