Behaviour of MRF Structures Designed According to IRAN Seismic Code (2800) Subjected to Near-Fault Ground Motions.

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ABSTRACT

According to the recent earthquakes (Northridge1994, Kobe1995, ChiChi1999, Bam2003) Near-fault Earthquake (N.F.E.) in the vicinity of quake field caused many damages which this matter motivated the researchers to examine more the Near-Source phenomenon of earthquakes. N.F.E come in large varieties rather than ordinary earthquakes and in comparison with ordinary motions they impose high seismic demand on the structure. Since IRAN is located at a zone which has a prone to having earthquakes and nearly in the majority of the country quake risk exists, and because in IRAN 2800 code of designing buildings against earthquake there is no mention of designing buildings at Near-Source zones, we conduct a research by selecting 5, 8 & 12 stories steel buildings designed according to IRAN 2800 code, to examine the effects of N.F.E. This article expresses the effects of N.F.E on frames responses by comparing the linear and nonlinear time history responses of structures to the earth motions at Far & Near-Source zones. According to nonlinear analysis the amounts of imposed demand of N.F.E were more than Far-fault Earthquake Due to inefficiency of 5, 8 & 12 stories structures according to several N.F.E, especial considerations for designing & strengthening of structures located at Near-Source zones of IRAN are required. Examining the structures' responses shows that in Near-Source zone, structures' seismic demand is more than Far-Source zone.

KEYWORDS:

Near-Fault & Far-Fault Earthquakes, Near-Source, Far-Source, linear & nonlinear time history analysis, Seismic demand.

1. INTRODUCTION

Near-fault ground motions are the earth's quick displacements which are produced at fault directions due to shear waves propagation. These strong motions of earth which are usually too big, are the most severe seismic loading which a structure may experience during its life. Researchers introduced remoteness & nearness to the earthquake resource as the defining indicator of Near-Source waves. ALAVI & KRAWINKLER defined the Near-Source phenomenon for the structures which are located at 10-15 Km from earthquake resource [1]. Douglas & Ambraseys chose 15Km distance from fault [2] but Chopra & Chintanapakdee considered the registered records up to 10 Km from earthquake resource as the Near-Fault ground motions [3]. These motions will be affected considerably by rupture mechanism and its direction toward the site. In this way, the registered records of Near-fault Ground motions are divided into two categories [1]:

1) Forward Directivity records

2) Backward Directivity records

If the rupture propagates toward the site, the recording at the site will show a Forward Directivity effects and if the rupture propagates away the site, the recording at the site will show a Backward Directivity record. Maximum of acceleration, velocity and displacement of Forward Directivity record is considerably greater than those of Backward Directivity record. Forward Directivity records have a great pulse at the beginning of record which this great pulse transmits most of the seismic energy of rupture to the structure. On the other hand, the Backward Directivity records have no pulse-like function.
Near-Fault Ground Motions have some distinct features which distinguish them from the Far-Fault Ground Motions. For example: Time history traces of earthquakes especially Forward Directivity motions having high period and large amplitude which often seen at the beginning of earthquake record. Existence of these distinct pulses, expose the structure to high input energy [1].
Fault normal component of Near-Fault ground motions is more severe than parallel component to the fault; while, in Far-Fault ground motions, both components have the same effects. Near-Fault ground motions components are often several times greater than Far-Fault ground motions components. Imposed seismic demand of Near-fault ground motions is greater than Far-Fault ground motions.

2. EMPLOYED N.F.E & F.F.E RECORDS OF RESEARCH

12 Near-Fault records of IRAN & the rest of the world and 3 Far-Fault records of Northridge, Landers & Chichi are employed in this research. The registered records less than 15km are chosen as the Near-Source criterion and Far-Fault ground motions of recordings are selected above 50 km. All records are provided from PEER internet site [6]. According to ground type classification of IRAN 2800 code, which is divided into four zones,3 Near-Source records are selected & since the structure is located at the third zone, Far-Fault ground motions in this ground type are chosen to compare the structure response to Near-fault ground motions. According to IRAN 2800 code, all the records scaled which their specifications & scale factor are represented in the table 2.1,2,3.

3. MODELING AND STRUCTURES ANALYSIS PROCESS OF GROUND MOTIONS IN NEAR and FAR-SOURCES

In this research, three MRF steel structures with 5,8 &12 stories are employed which their design specifications are summarized in table 3.1. These buildings are geometric regular and their typical story height & bays width is 3.20m & 3m, respectively (Figure 1).
The designed sections are considered as plate girder and are showed in the table 3.2.In order to modeling the nonlinear response of structures, trilinear behavior model of SAP2000 software is employed in which FEMA273 code provides the hinges specifications. P-M-M hinges in columns & M hinges in beams are used. Damping factor of structure is proportional to the structure's period ($\xi = 5\%$).
To compare the structural response to the records, maximum roof displacements, maximum story drift & maximum story shear are selected in two directions (x, y) as the response parameters. Using the linear & nonlinear time history analysis of SAP2000 software, and also, equivalent static method of IRAN 2800 code, structural efficiency & structure response parameters under Near & Far-Fault ground motions are examined which the conclusions are expressed later. Several samples of analysis results for 5 stories building are presented in coming images.

Table 2.1- Spesification of Near Fault Ground Motions [6]

quake	year	station	component	PGA(g)	PGV(cm/s)	PGD(cm)	distance(Km)	Soil class	Ms	time of quake	PGV/PGA	PGD/PGV
Cape Mendocino	4/25/1992	89005	V	0.754	63	109.48	8.5	I	7.1	29.98	0.085	1.738
			H_1	1.497	127.4	41.01					0.087	0.322
			H_2	1.039	42	12.39					0.041	0.295
Kocaeli, Turkey	8/17/1999	Sakarya	V	0.146	13.1	6.66	4.8	I	7.8	29.995	0.091	0.508
			H_1	0.152	22.6	9.81					0.152	0.434
			H_2	0.22	29.8	17.12					0.138	0.574
Landers	6/28/1992	24 Lucerne	V	0.818	45.9	22.23	1.1	I	7.4	48.12	0.057	0.484
			H_1	0.721	97.6	70.31					0.138	0.720
			H_2	0.785	31.9	16.42					0.041	0.515
Bam	2003	Farmandari	V	0.988	39.69	18.4	<1	II	6.8	66.545	0.041	0.464
			H_1	0.636	60.603	29.822					0.097	0.492
			H_2	0.769	109.52	32.503					0.145	0.297
Kobe	1/16/1995	0 KJMA	V	0.343	38.3	10.29	0.6	II	6.9	47.98	0.031	0.269
			H_1	0.821	81.3	17.68					0.022	0.217
			H_2	0.599	74.3	19.95					0.034	0.269
Loma Prieta	10/18/1989	57007 Corralitos	V	0.455	17.7	7.11	5.1	II	7.1	39.94	0.040	0.402
			H_1	0.644	55.2	10.88					0.087	0.197
			H_2	0.479	45.2	11.37					0.096	0.252
Chi-Chi, Taiwan	9/20/1999	TCU068	V	0.486	187.3	266.55	1.09	III	7.6	89.995	0.393	1.423
			H_1	0.462	263.1	430					0.581	1.634
			H_2	0.566	176.6	324.11					0.318	1.835
Duzce, Turkey	11/12/1999	Duzce	V	0.357	22.6	19.4	8.2	III	7.3	25.88	0.065	0.858
			H_1	0.348	60	42.09					0.176	0.702
			H_2	0.535	83.5	51.59					0.159	0.618
Tabas, Iran	9/16/1978	9101 Tabas	V	0.688	45.6	17.04	3	III	7.4	32.82	0.068	0.374
			H_1	0.836	97.8	36.92					0.119	0.378
			H_2	0.852	121.4	94.58					0.145	0.779
Imperial Valley	10/15/1979	5057 El Centro	V	0.127	8.7	4.7	9.3	IV	6.9	39.54	0.070	0.540
			H_1	0.266	46.8	18.92					0.179	0.404
			H_2	0.221	39.9	23.31					0.184	0.584
Kobe	1/16/1995	0 OSAJ	V	0.064	7.5	3.73	8.5	IV	6.9	119.98	0.119	0.497
			H_1	0.079	18.3	9.26					0.236	0.506
			H_2	0.064	17	8.03					0.271	0.472
Northridge	1/17/1994	90011 Montebello	V	0.076	2.8	0.48	12.3	IV	6.7	21.82	0.038	0.171
			H_1	0.179	9.4	1.48					0.054	0.157
			H_2	0.128	5.9	2.25					0.047	0.381

Table 2.2- Spesification of Far-Fault Ground Motions [6]

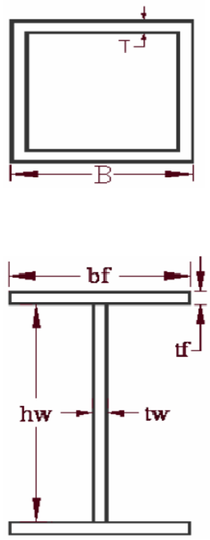
quake	year	station	component	PGA(g)	PGV(cm/s)	PGD(cm)	distance(Km)	Soil class	Ms	time of quake	PGV/PGA	PGD/PGV
Northridge	1/17/1994	90086 BUENA Park	V	0.034	1.5	0.11	64.6	III	6.7	34.99	0.045	0.073
			H_1	0.139	10.7	1.62					0.078	0.151
			H_2	0.095	8.1	1.5					0.087	0.198
Landers	6/28/1992	12026 Indio	V	0.042	6.6	3.99	55.7	III	7.4	59.98	0.160	0.605
			H_1	0.104	9.6	5.05					0.094	0.526
			H_2	0.109	15.2	9.69					0.142	0.638
Chi-Chi, Taiwan	9/20/1999	CHK	V	0.016	2.4	0.45	67.9	III	7.6	60	0.153	0.188
			H_1	0.04	5.1	1.34					0.130	0.263
			H_2	0.051	7.1	2.13					0.142	0.300

Table 2.3-Scale Factor(According to IRAN 2800 code)

Record Zone	5 Story	8 Story	12 Story
Zone 1	1.113	1.113	1.113
Zone 2	0.74	0.9	1.39
Zone 3	0.64	0.64	0.64
Zone 4	0.67	0.8	0.8
Far Fault	0.57	0.57	0.57

Table 3.1-Seismic & Structural Design Data		
Seismic Design Data according to Iran 2800 code[4]		
Lateral structural system(x,y)	Intermediate moment resistant frame	
seismic hazard	very high	A = .35
Importance factor	intermediate	I =1
Response factor (x,Y)		R=7
Ground Class		Type 3
Structural Design Data according to Iran loading code(519)[5]		
Typical Story Dead Load	550	kg/m^2
Typical Story Live Load	200	kg/m^2
Typical Story Super Dead Load	100	kg/m^2
Typical Roof Dead Load	560	kg/m^2
Typical Roof Live Load	150	kg/m^2

Table 3.2-Design Sections Specifications						
	5 Story building					
	Beam sections				Column sections	
	$b_{f(mm)}$	$t_{f(mm)}$	$h_{w(mm)}$	$t_{w(mm)}$	B(mm)	T(mm)
Story 1	250	20	400	15	400	25
Story 2	250	20	400	15	350	25
Story 3	250	20	350	15	350	25
Story 4	250	20	350	15	350	20
Story 5	150	15	30	12	350	20
	8 Story building					
	Beam sections				Column sections	
	$b_{f(mm)}$	$t_{f(mm)}$	$h_{w(mm)}$	$t_{w(mm)}$	B(mm)	T(mm)
Story 1	300	25	400	15	450	30
Story 2	300	25	400	15	450	30
Story 3	300	25	400	15	450	30
Story 4	300	25	400	15	400	25
Story 5	250	25	400	15	400	25
Story 6	250	25	400	15	400	25
Story 7	220	20	350	10	350	20
Story 8	220	20	350	10	350	20
	12 Story building					
	Beam sections				Column sections	
	$b_{f(mm)}$	$t_{f(mm)}$	$h_{w(mm)}$	$t_{w(mm)}$	B(mm)	T(mm)
Story 1	300	25	400	15	550	30
Story 2	300	25	400	15	550	30
Story 3	300	25	400	15	550	30
Story 4	300	25	400	15	500	25
Story 5	300	25	400	15	500	25
Story 6	300	25	400	15	500	25
Story 7	250	20	400	15	450	25
Story 8	250	20	400	15	450	25
Story 9	250	20	400	15	450	25
Story 10	250	20	400	15	400	25
Story 11	250	20	400	15	400	25
Story 12	250	20	400	15	400	25



Fy=2400 kg/Cm2

Fu=3700 kg/Cm2

plate specification:st-37

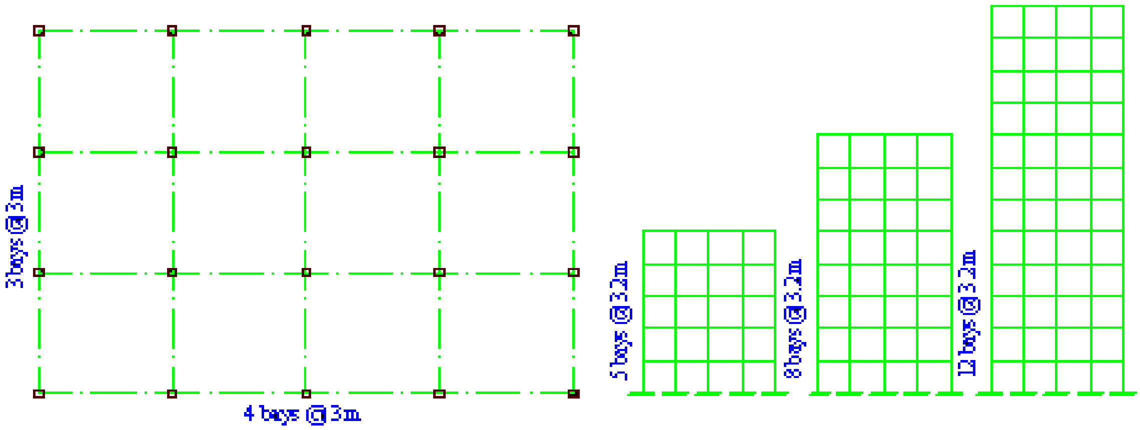


Figure 1 Plan & Elevation of employed buildings.

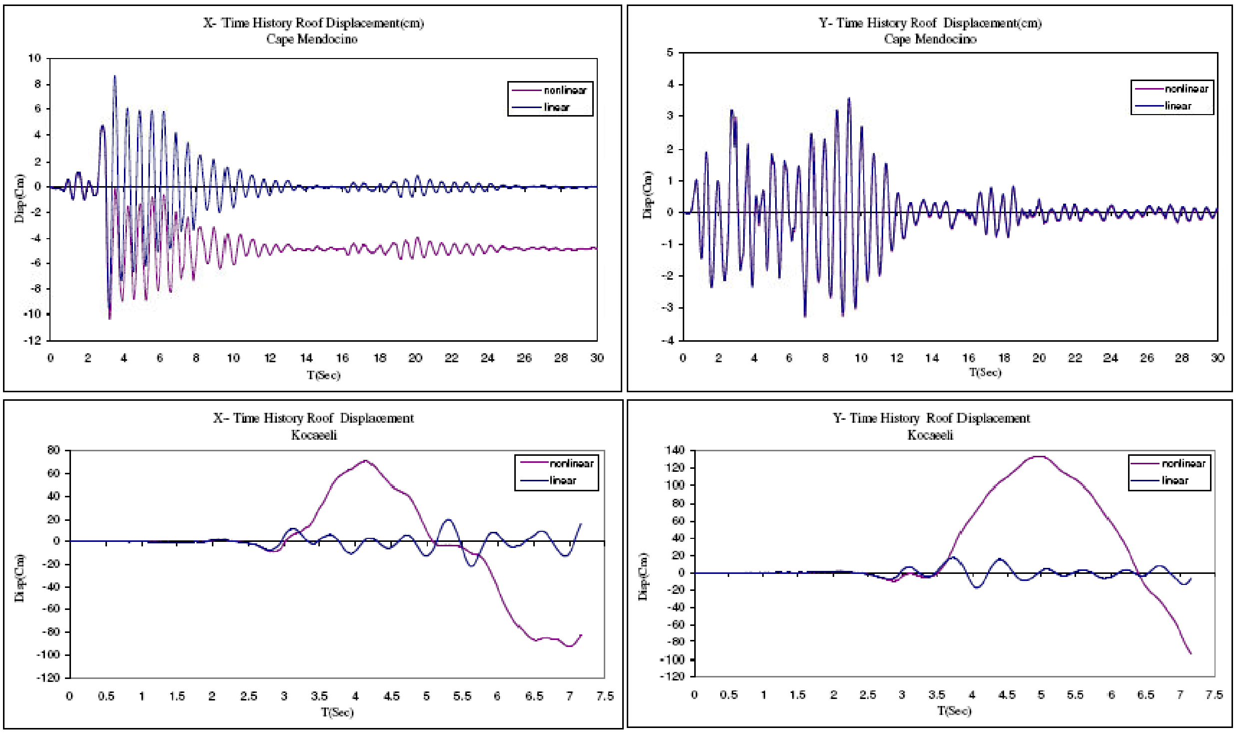
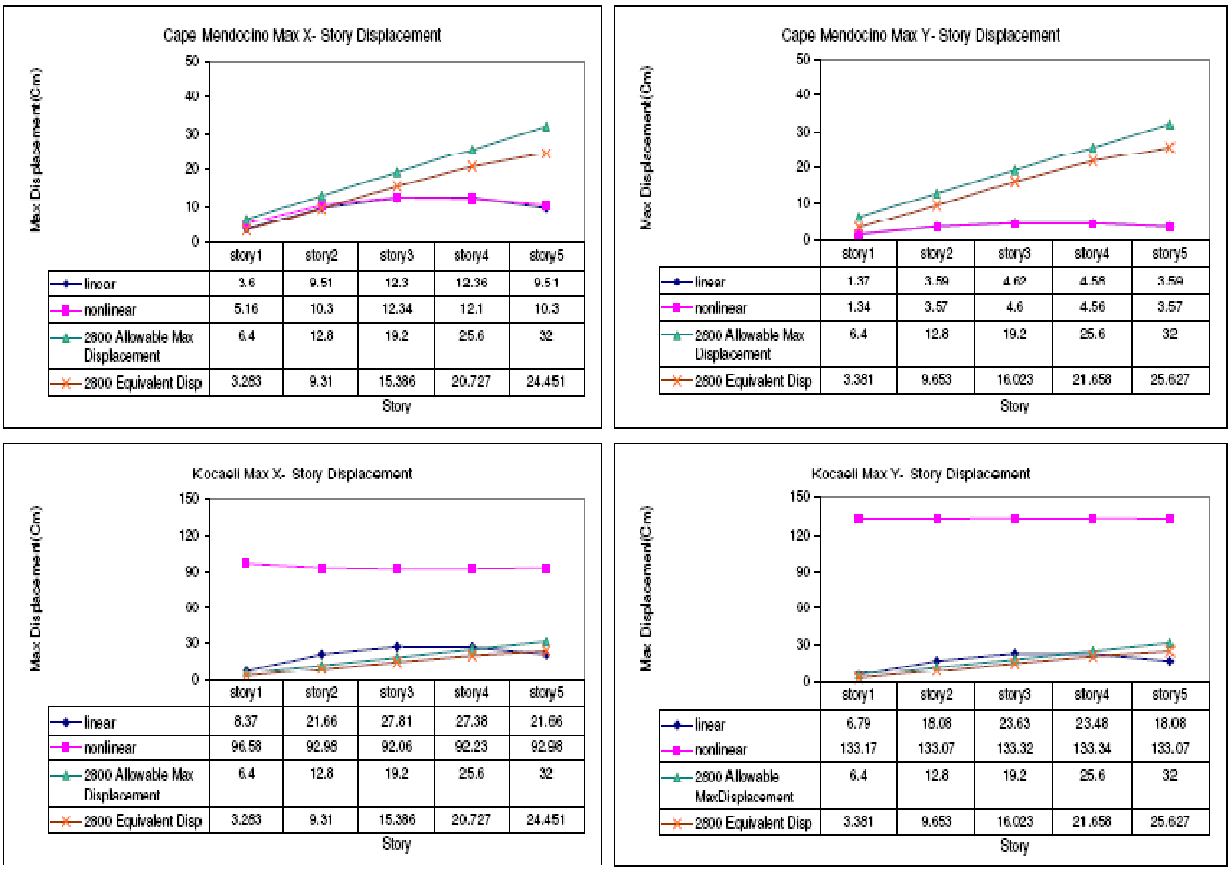


Figure 2 Five story roof displacement of two near-fault quakes (Cape Mendocino & Kocaeli).



Cape Mendocino Max X- Story Displacement

	story1	story2	story3	story4	story5
linear	3.6	9.51	12.3	12.36	9.51
nonlinear	5.16	10.3	12.34	12.1	10.3
2800 Allowable Max Displacement	6.4	12.8	19.2	25.6	32
2800 Equivalent Disp	3.263	9.31	15.386	20.727	24.451

Cape Mendocino Max Y- Story Displacement

	story1	story2	story3	story4	story5
linear	1.37	3.59	4.62	4.58	3.59
nonlinear	1.34	3.57	4.6	4.56	3.57
2800 Allowable Max Displacement	6.4	12.8	19.2	25.6	32
2800 Equivalent Disp	3.381	9.653	16.023	21.658	25.627

Kocaeli Max X- Story Displacement

	story1	story2	story3	story4	story5
linear	8.37	21.66	27.81	27.38	21.66
nonlinear	96.58	92.98	92.06	92.23	92.98
2800 Allowable Max Displacement	6.4	12.8	19.2	25.6	32
2800 Equivalent Disp	3.263	9.31	15.386	20.727	24.451

Kocaeli Max Y- Story Displacement

	story1	story2	story3	story4	story5
linear	6.79	18.08	23.63	23.48	18.08
nonlinear	133.17	133.07	133.32	133.34	133.07
2800 Allowable MaxDisplacement	6.4	12.8	19.2	25.6	32
2800 Equivalent Disp	3.381	9.653	16.023	21.658	25.627

Figure 3 Five story Max story displacement of two near-fault quakes
(Cape Mendocino & Kocaeli).

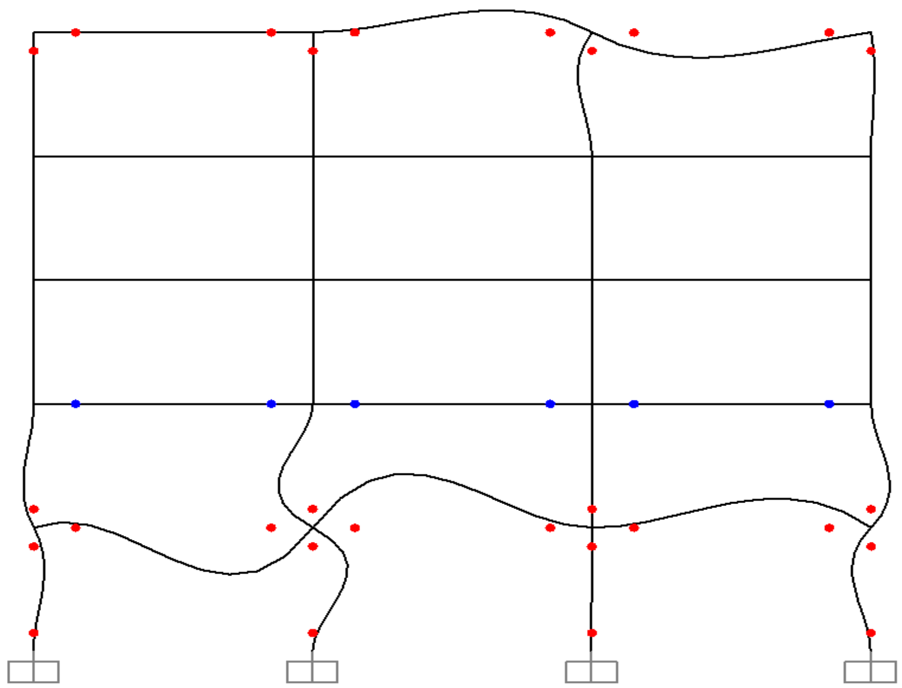


Figure 4 Non-distributed nonlinear hinges in the height of the building in BAM NFE.

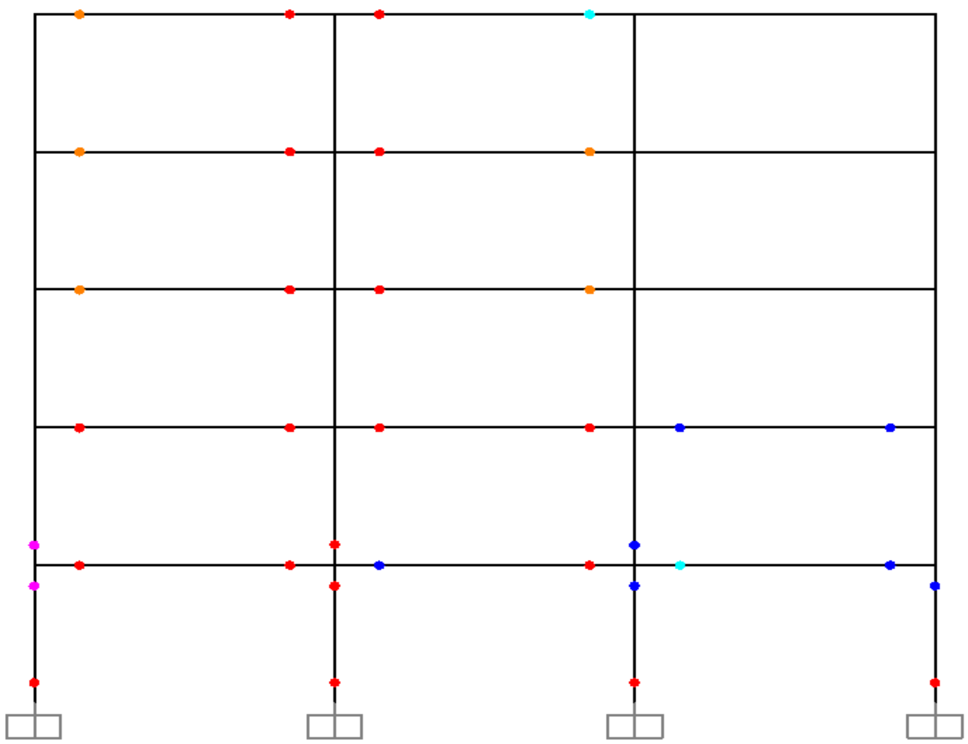


Figure 5 Distributed nonlinear hinges in the height of the building in NORTHRIDGE FFE.

4. CONCLUSION

1) A 12stories building under 7 N.F.E records, a 8 stories building under 3 N.F.E records & a 5 stories building under 8 N.F.E records missed their structural efficiencies, which two below comments are conducted:

a) N.F.E Motions have more sever effects on short period & high period structures and its effects are less on medium period ones.

b) Inefficiency of designed structures under N.F.E motions according to IRAN 2800 code, especially the short & tall buildings, verifies an essential revision in IRAN code & considering the Near-source effects.

2) As expected, all the structures had a qualified and acceptable function under Far-Fault Ground Motions, since IRAN code spectra is acquired through Far-Fault Ground Motions.

3) Examined story shear charts verified a difference between story shear distribution of high buildings and the expected one according to IRAN 2800 code. For example, according to code, the maximum story shear occurs in the first story and it diminishes in upper stories & meets its least at the roof story; while here, for a 12story building the least amount of story shear occurs in the 7th story (instead of roof story) and the story shear in the 11th story is greater than the previous ones.

4) Since too much energy with distinct pulses at the beginning of the record are imposed to the structure by NFE records, nonlinear hinges propagation is not seen at structure's height; While ,it exists at Far-Fault ground motions (Figure 4 & 5).

5) Structures which have not missed their bearing capacity under Near-Fault ground motions, while the structure's maximum displacement does not exceed the code's allowed one, in some cases, the structure's maximum drift exceed the code's allowed amounts.

Acquired conclusions affirm that it is essential to strengthen the lower stories of short & tall buildings and intermediate stories to limit maximum stories drifts to allowed code amounts.

6) The imposed seismic demand on the structures under N.F.E records is too much greater than that of F.F.E records.

7) In N.F.E ground motions, there are remarkable differences among the fault parallel & normal components at imposed seismic demand, while they never seen in F.F.E ground motions.

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