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Seismic Assessment of RCS Moment Frames under Near Fault Earthquakes

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1- Introduction

The RCS composite moment frame systems began to gain popularity in both the United States and Japan in the late 1970's and early 1980's. In the United States, this system came about as an attractive modification of traditional steel moment frames for mid-to high-rise buildings in relatively low seismic zone. In Japan, RCS composite systems were developed as alternative to low-rise for supplies of reinforced concrete frames of low rise reinforced concrete moment frames in high seismic zones. The aim of this was to take advantage of the long-span capabilities of steel beams to provide column-free spaces for low-rise office buildings and retail stores. Due to the complex problems such as time and money for reinforcement beams for concrete buildings and buckling and weight of the column and difficulty of work at high elevation, and also the need for strength in the construction and installation of steel buildings, in the early 80's, the idea of hybrid structures (CFT, RCS, SRC, etc.) was developed in order to optimize the use of materials. Due to the use of reinforced concrete columns and steel beams in these frames, the properties of steel and concrete intervene in these structures, in the case of compressive strength of concrete in the columns and the tensile strength of steel beam to be used in order to reduce the cross-section of members and thus lower the weight of the building and reduce construction costs. By reducing structural weight, the force on foundations reduces and as a result low thickness and less weight for foundations will be achieved. The use of concrete in the columns due to high compressive strength of concrete along with steel beams give the best behavior because of high tensile strength steel.

2- Research Method

In this research, the seismic demand of composite RCS structures under near fault earthquakes is investigated with respect to far fault earthquakes. For this purpose, 5 composite RCS intermediate moment resisting frames with 4, 7, 10, 15 and 20 stories and 5 spans were designed and then nonlinear dynamic analysis was performed on the structures using the OpenSees software. Then 10 far fault and 10 near fault accelerographs were used respectively according to Tables 1 and 2. All used accelerograms that have been received from the site of Peer, had a view to soil type of III on the basis of regulations seismic design of Iran (2800) or dirt Class of D based on the classification guidelines of FEMA. To draw the whole reactionary response, the software of SeismoSignal was used and all accelerograms before scaling had their equal maximum with acceleration (PGA). In order to perform nonlinear dynamic analysis on intended frames, the OpenSees software was used and the results of story displacement, drift angle and story shear have been provided in the full paper (Figures 1 and 2). Selected records were applied to the models and finally the decision has been made among the obtained responses. For scaling, the accelerograms method was used for scaling of the Fourth Edition 2800 guideline. In order to investigate RCS frames capacity, nonlinear static analysis with the triangle pattern was used and the results for the structures of 10 and 15 stories have been presented. The target displacement was calculated using the publication of 360 for determined frames. Range of Immediate Occupancy Level (IO), Life Safety Level (LS) and the Collapse Prevention Level (CP) have been shown according to FEMA356. According to Figures 3 and 4, it can be understood that by increasing the span, the capacity of composite frame has increased which demonstrates the advantage of long steel beams in the bays opening. By increasing span, ductility of composite frame has decreased.

3- Conclusion

- Displacement and drift angle of structures with a span of 5 meters under near-fault records was more than that of far fault records. In fact, due to higher energy input to the structure as a result of near fault earthquakes in all discussed structures, displacement caused by near fault earthquakes was more than the displacement caused by far fault earthquakes.
- By increasing in the number of stories, displacement differences and the drift angle due to near and far records reduced.
- Base shear of 5 meters span structures under near-fault records was more than the base shear under far fault records and by increasing the number of stories, the difference was reduced.
- By increasing span length in low-rise structures near-fault earthquake governed and in high-rise structures far fault earthquake dominated. In fact, by increasing span length, the far fault earthquake effect was more in high rise structures.
- By increasing span length, base shears differences caused by near and far earthquakes decreases.
- In all structures with a 5-meter span, drift angle results from near fault were more than drift angle results caused by the far fault. However, the high-rise structures with 7-meter spans, drift angle in the upper and lower stories caused by the far fault were greater than the drift angle results from near fault.
- In the span of 7 meters, displacement of tall structures due to far fault earthquakes was more than near fault earthquakes.
- Story shear of lower and upper stories in high-rise structures with 7-meters span caused by far fault records was more than near fault.

By increasing span length, the total capacity of the composite frame has increased, which indicated the advantage of steel beams in long-span.

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Table. 1 Characteristics of near fault accelerograms used in this study

Near Fault Records								
NO.	Earthquake name	Date [yy-mm-dd]	Station	R [Km]	PGA [g]	PGV [cm/sec]	PGD [cm]	Magnitude
1	Chi-Chi,Taiwan,	1999.9.30	TCU051	7.66	0.20	41.2	59.19	7.62
2	Chi-Chi,Taiwan,	1999.9.30	TCU055	6.36	0.21	36.87	22.02	7.62
3	Imperial Valley-06	1979.10.15	El Centro Array #7	0.56	0.42	79.15	40.83	6.53
4	Erzican, turkey	1992.3.13	95 Erzincan	4.38	0.48	72.95	24.79	6.69
5	LomaPrieta,	1989.10.18	Gilroy - Historic Bldg.	10.97	0.26	31.37	6.42	6.93
6	LomaPrieta,	1989.10.18	Gilroy Array #2	11.07	0.35	35.10	8.54	6.93
7	Northridge	1994.1.17	DWP 75 Sylmar-Converter	5.19	0.64	95.07	33.43	6.69
8	Northridge	1994.1.17	DWP 74 Sylmar-Converter	5.35	0.71	109.38	52.35	6.69
9	Kobe, Japan	1995.1.16	Takatori	1.47	0.65	117.14	33.06	6.9
10	Kobe,Japan,	1995.1.16	KJMA	0.96	0.71	77.83	18.87	6.9

Table. 2 Characteristics of far fault accelerograms used in this study

Far Fault Records								
NO.	Earthquake name	Date [yy-mm-dd]	Station	R [Km]	PGA [g]	PGV [cm/sec]	PGD [cm]	Magnitude
1	Manjil, Iran	1990.6.20	Tonekabun	93.62	0.11	14.43	4.83	7.37
2	Manjil,Iran,	1990.6.20	Qazvin	49.97	0.13	10.89	3.36	7.37
3	Chi-Chi,Taiwan,	1999.9.20	CHY065	83.43	0.10	13.66	8.10	7.62
4	Chi-Chi,Taiwan,	1999.9.20	TAP095	109.01	0.13	19.93	9.04	7.62
5	Kobe,Japan,	1995.1.16	HIK	95.72	0.14	14.81	2.31	6.9
6	Tabas,Iran,	1978.9.16	Ferdows	91.14	0.10	7.08	7.18	7.35
7	Northridge,	1994.1.17	Featherly Park - Maint	82.32	0.10	6.58	0.66	6.69
8	Loma Prieta	1989.10.18	SF Intern. Airport	58.65	0.28	24.52	4.8	6.93
9	Loma Prieta	1989.10.18	Oakland - Title & Trust	72.20	0.20	27.61	5.94	6.93
10	Loma Prieta	1989.10.18	Oakland - Outer Harbor Wharf	74.26	0.28	41.86	9.6	6.93

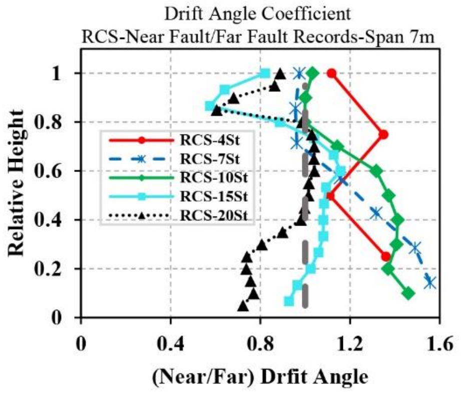

Fig. 1 The ratio of story drift angle caused by near fault records to far fault records for 7-meter span structures.

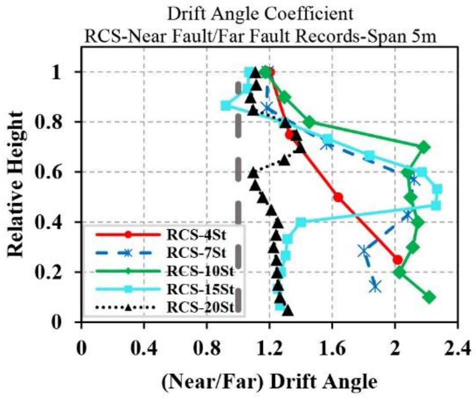

Fig. 2 The ratio of story drift angle caused by near fault records to far fault records for 5-m eter span structures.

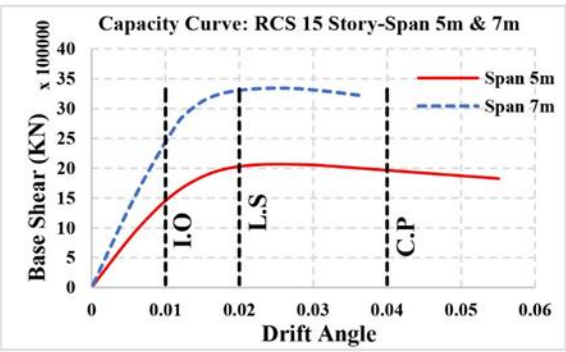

Fig. 3: Capacity curve of RCS 15 story

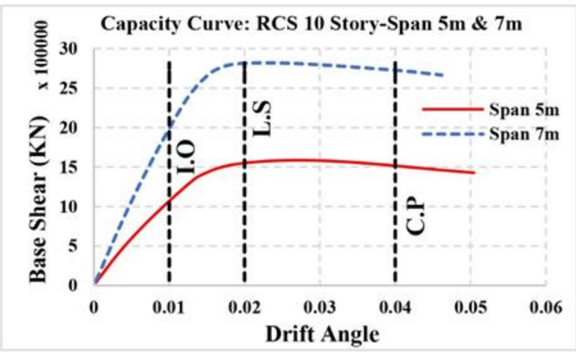

Fig. 4 Capacity curve of RCS 10 story