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CORRECTION OF STORY DRIFT DEMANDS OF FIRST MODE PUSHOVER ANALYSIS FOR SEISMIC PERFORMANCE ASSESSMENT

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Though the amplitude and the distribution of story drifts obtained via first mode pushover analysis may vary too much from the results of inelastic time history analyses, it is a useful tool and likely to continue to being used in the near future. Actually, there have been attempts to correct the story drifts of pushover analysis with reference to the results of inelastic dynamic analyses under a chosen set of earthquake ground motions. This study is also such an attempt. A 10-story steel special moment frame is designed per ANSI/AISC 360-10 and ANSI/AISC 341-10, and also ASCE/SEI 7-10. The spectral values used during the design are chosen as the lower bounds proposed in ASCE/SEI 7-10, for the deterministic ground motion response spectrum. The model frame is analyzed with DRAIN-2DX software. Initially, a record set consisting of 43 earthquake ground motion records is established. This set consists the whole records downloaded from the PEER Strong Motion Database, which are all near fault earthquake ground motions containing velocity pulses whereas the local site class is C per ASCE 7-10 classification. The acceleration records are not scaled in order not to ruin the characteristics of the velocity pulses, so they are used directly. Only 4 of the records resulted in interstory drift ratios higher than 0.04 rad during inelastic dynamic analyses, which indicates a probable damage with accompanying stiffness and strength degradation of connections. Thus, these 4 records are excluded from the set. The roof drift ratios as defined in ANSI/AISC 41-06 are determined for each record by inelastic dynamic analysis. Subsequently the story drift ratios of pushover analysis applied till these roof drift ratios are retained. Finally, the story drift ratios of inelastic dynamic analysis for each record and the corresponding story drift ratios of pushover analysis are gathered for each story level. Since the scaling of the near fault records is avoided, a regression analysis is performed for each story level and resultant regression equations and errors in terms of R^2 are provided. The results indicate that for the lower stories there is a strong correlation, however for the upper stories the correlation is weak. Furthermore, the location of maximum story drift ratios for each record and the differences of pushover and dynamic analyses results for these locations and relevant comments are also provided. Actually, if the maximum story drift ratio is observed on the upper stories, the difference between the static and dynamic analyses increase considerably according to the results.

INTRODUCTION

Nonlinear Static Procedure (NSP) is a widely accepted approach for seismic performance assessment of buildings next to the Nonlinear Dynamic Procedure (NDP). NSP can also be preferred solely, since the proper earthquake record set selection, fitting the relevant earthquake hazard level can be quite difficult. During the application of NSP the lateral floor displacements obtained should be approximately equal to the mean values of many number of results obtained via NDP under the effects of many earthquake ground motions. Namely, this procedure should provide reliable information for not only the roof drift (roof lateral displacement/total building height), but also the story drifts.

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Actually, the codes generally try to realize this target via the manipulation on lateral load patterns of NSP next to the main effort for determining the target displacement. According to FEMA 356, which can be assumed as the previous version of ASCE 41-06, one lateral load pattern was recommended to be selected from each of the proposed two groups. The first group involved three cases: 1- A vertical distribution proportional to the equivalent static earthquake design load. 2- A vertical distribution proportional to the shape of the fundamental mode. (The use of this two distribution cases was only permitted when more than 75% of the total mass participates in the fundamental mode.) 3-A vertical distribution proportional to the story shear distribution calculated by combining modal responses from a response spectrum analysis including sufficient modes to capture at least 90% of the total building mass. (This distribution was only permitted to be used when the period of the fundamental mode exceeds 1 s.) The second group had two cases: 1- A uniform distribution consisting of lateral forces at each level proportional to the total mass at each level. 2- An adaptive load distribution that changes as the structure is displaced. In the latest code, ASCE 41-06 there are some drastic changes about the vertical distribution of lateral loads for NSP. Accordingly, a single pattern based on the first mode shape is recommended. This was explained as: *The actual distribution of lateral forces is expected to vary continuously during earthquake response as portions of the structure yield and stiffness characteristics change. The extremes of this distribution will depend on the severity of the earthquake shaking and the degree of nonlinear response of the structure. Recent research has shown that multiple load patterns do little to improve the accuracy of nonlinear static procedures*. It is obvious that the use of multiple load patterns is not effective. However, is the current lateral load distribution adequate to construct an envelope for inelastic dynamic analyses? It is not, this is also obvious just looking at the above explanation provided by the code even if you do not have experience about the inelastic static and dynamic analyses of structures. So rather than leaning on one or multiple lateral load patterns, or in other words input parameters of the analyses, it is thought to be a good strategy to carry out too many number of dynamic analyses and statistically evaluate their results for the correction of story drift distribution.

Actually we have some certain knowledge about the characteristics of earthquake records, for example we know that near fault pulse like records increase the higher mode effects considerably which will certainly affect the story drift distribution along the elevation and also the success of NSP adversely. As an initial attempt, a 10-story steel special moment frame is analyzed for a record set consisting of 43 earthquake ground motion records. This set consists the whole records downloaded from the PEER Strong Motion Database, which are all near fault earthquake ground motions containing velocity pulses whereas the local site class is C per ASCE 7-10 classification. The acceleration records are not scaled in order not to ruin the characteristics of the velocity pulses, so they are used directly. Only 4 of the records resulted in interstory drift ratios higher than 0.04 rad during inelastic dynamic analyses, which indicates a probable damage with accompanying stiffness and strength degradation of connections. Thus, these 4 records are excluded from the set. The model frame is designed per ANSI/AISC 360-10 and ANSI/AISC 341-10, and also ASCE/SEI 7-10. The spectral values used during the design are chosen as the lower bounds proposed in ASCE/SEI 7-10, for the deterministic ground motion response spectrum. The model frame is analyzed with DRAIN-2DX software. P-Delta effects are taken into consideration via the leaning columns constructed based on the stiffness properties of gravity and orthogonal columns.

Initially the roof drift ratios are determined for each record by inelastic dynamic analyses. Subsequently the story drift ratios obtained by pushover analysis applied till these roof drift ratios, are retained. Finally, the story drift ratios of inelastic dynamic analysis for each record and the corresponding story drift ratios of pushover analysis are gathered for each story level. Since the scaling of the near fault records is avoided, a regression analysis is performed for each story level and resultant regression equations and errors in terms of R^2 are provided.

MODEL FRAME

Basic geometric properties of the model frame can be found in Fig.1. The span length is chosen as 6.5 m (21.33 ft) based on the findings of a previous work (Özhendekci and Özhendekci 2012) in which similar span length/story height ratios are found to provide optimum solution in both design (economy) and seismic performance aspects for 10 story SMFs. All of the columns and beam sections are chosen as W sections. The structural steel used for the elements with W sections is A992 (Fy = 34.5 kN/cm^2, 50 ksi). The profiles assigned to the cross sections of the model SMF is provided in Table.1. Each column has two splices, so columns consist of three components with different profiles assigned.

Dead load value assigned to the normal stories is 3.83 kN/m^2 (80 psf) including the weight of structural steel elements. Live load applied to the normal stories is 3.11 kN/m^2 (65 psf) including the weight of partition walls. Dead and live load values assigned to the roof used for promenade purposes are 3.11 kN/m^2 (65 psf) and 2.87 kN/m^2 (60 psf), respectively. The site class which the sample building is assumed to be constructed on is C. The mapped maximum considered earthquake spectral response acceleration values at short and 1 second periods are 1.5g and 0.6g, respectively. Seismic design category of the sample building is D. Seismic response modification factor (R) is 8 and deflection amplification factor (C_d) is 5.5.

The detailed information concerning the design procedure and gravity columns can be found in working paper (Ozhendekci 2014).

Table 1. Assigned profiles to the cross sections of structural elements of the sample SMF

Element Type	**COLUMNS**		
Element Title*	**C1**	**C2**	**C3**
Assigned Profile	W14×311	W14×257	W14×233

Element Type	**GIRDERS**									
Element Title*	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**
Assigned Profile	W21×73	W24×84	W24×84	W24×76	W24×76	W21×73	W24×62	W21×50	W18×40	W16×31

*Element titles are addressed in Fig. 1.

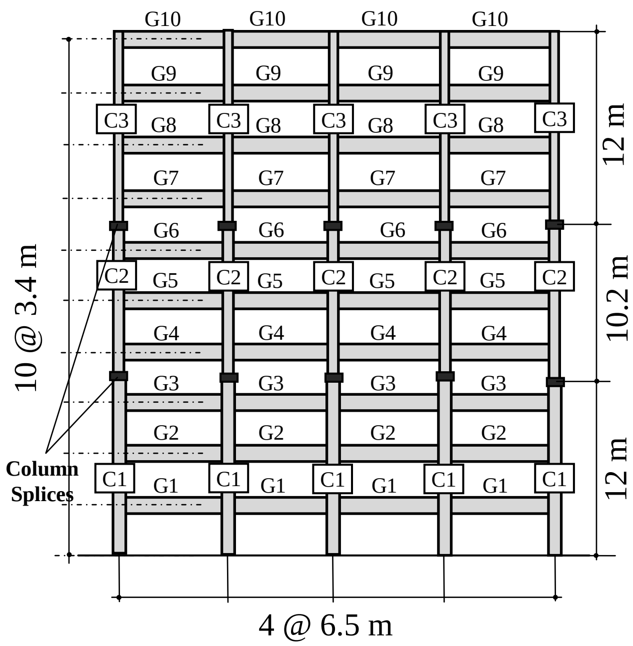

Figure 1. Basic geometric properties and cross section labels of the model frame

EARTHQUAKE RECORDS

Initially, a record set consisting of 43 earthquake ground motion records is established. This set consists the whole records downloaded from the PEER Strong Motion Database, which are all near fault earthquake ground motions containing velocity pulses whereas the local site class is C per ASCE 7-10 classification (Table.2). Among each horizontal record pair the one with the higher PGA value is selected. The acceleration records are not scaled in order not to ruin the characteristics of the velocity pulses, so they are used directly. Only 4 of the records resulted in interstory drift ratios higher than 0.04 rad during inelastic dynamic analyses, which indicates a probable damage with accompanying stiffness and strength degradation of connections. Thus, these 4 records (with NGA # of 779, 1492, 1505 and 1510) are excluded from the set.

Table 2. Properties of the earthquake records

NGA #	Direction	Event	Year	Mechanism	Mw	R_{jb} (km)
451	FP	Morgan Hill	1984	Strike-Slip	6.19	0.2
459	FN	Morgan Hill	1984	Strike-Slip	6.19	9.8
496	FP	Nahanni, Canada	1985	Reverse	6.76	0
763	FN	Loma Prieta	1989	Reverse-Oblique	6.93	9.2
779	FN	Loma Prieta	1989	Reverse-Oblique	6.93	0
802	FN	Loma Prieta	1989	Reverse-Oblique	6.93	7.6
803	FN	Loma Prieta	1989	Reverse-Oblique	6.93	8.5
825	FP	Cape Mendocino	1992	Reverse	7.01	0
828	FP	Cape Mendocino	1992	Reverse	7.01	0
879	FN	Landers	1992	Strike-Slip	7.28	2.2
983	FN	Northridge-01	1994	Reverse	6.69	0
1009	FN	Northridge-01	1994	Reverse	6.69	14.6
1013	FN	Northridge-01	1994	Reverse	6.69	0
1085	FN	Northridge-01	1994	Reverse	6.69	0
1086	FN	Northridge-01	1994	Reverse	6.69	1.7
1148	FP	Kocaeli, Turkey	1999	Strike-Slip	7.51	10.6
1182	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	9.8
1193	FP	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	9.6
1202	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	12.6
1480	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	19.8
1482	FP	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	19.9
1486	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	16.7
1489	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	3.8
1492	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	0
1493	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	6
1494	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	5.3
1496	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	10.5
1499	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	8.5
1501	FP	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	9.8
1505	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	0
1510	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	0.9
1511	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	2.8
1515	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	5.2
1519	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	7
1528	FP	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	2.1
1529	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	1.5
1530	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	6.1
1531	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	12.9
1548	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	13.2
1550	FN	Chi-Chi, Taiwan	1999	Reverse-Oblique	7.62	8.3
2457	FN	Chi-Chi, Taiwan-03	1999	Reverse	6.2	18.5
2627	FN	Chi-Chi, Taiwan-03	1999	Reverse	6.2	13
3475	FP	Chi-Chi, Taiwan-06	1999	Reverse	6.3	0

Moment magnitude of the earthquake ground motions are between 6.19 and 7.62. Generally, fault normal components have the velocity pulses, however the component which has velocity pulse has chosen. However, if the both components consist velocity pulses, than the one with higher PGA value is chosen. Joyner-Boore distance of the whole records are smaller than 20 km.

Table 2. (cont.) Properties of the earthquake records

NGA #	R_{rup} (km)	V_s30 (m/s)	PGA	Arias Dur. (s)	Bracketed Dur. (s)	a/v	T_p (s)
451	0.5	597.1	1.0798	5.4	11.375	1.5393	1.1
459	9.9	663.3	0.2435	6.9	10.44	0.6885	1.2
496	4.9	659.6	0.3397	9.1	14.335	0.9807	0.81
763	10	729.6	0.2941	5.2	6.54	0.9553	1.8
779	3.9	477.7	0.9439	10	17.595	0.9736	3
802	8.5	370.8	0.3627	8.4	11.37	0.6529	4.5
803	9.3	370.8	0.403	11	14.09	0.565	1.9
825	7	513.7	1.4314	6.5	19.2	1.2099	4.9
828	8.2	712.8	0.6296	17.3	20.18	1.0423	0.95
879	2.2	684.9	0.7165	0	33.255	0.5015	5.1
983	5.4	525.8	0.5179	8	15.515	0.7689	3.5
1009	23.6	392.2	0.2737	15.3	15.555	0.8456	2.4
1013	5.9	629	0.5764	6.5	9.99	0.7476	1.7
1085	5.2	370.5	0.8387	7.2	17.035	0.7201	3.5
1086	5.3	440.5	0.7326	5.8	11.34	0.5967	3.1
1148	13.5	523	0.1523	10.3	6.675	0.395	6.7
1182	9.8	438.2	0.312	25.8	31.612	0.4828	2.6
1193	9.6	427.7	0.1754	26.9	31.58	0.3581	6.2
1202	12.7	555.2	0.261	28.1	34.215	0.6191	1.4
1480	19.8	495	0.1345	22.9	22.445	0.2154	5.4
1482	19.9	540.7	0.1527	26.7	26.885	0.2764	8.1
1486	16.7	465.6	0.1403	18.5	18.8	0.3193	8.6
1489	3.8	487.3	0.281	21.5	27	0.6274	12
1492	0.7	579.1	0.389	16.1	27.995	0.2307	8.5
1493	6	454.6	0.2247	22.1	28.185	0.5376	13
1494	5.3	460.7	0.1682	22.9	28.335	0.2762	10
1496	10.5	440.2	0.1267	26.9	28.19	0.291	13
1499	8.5	495.8	0.21	21.2	20.84	0.6219	12
1501	9.8	476.1	0.1334	31.7	37.58	0.1827	5.1
1505	0.3	487.3	0.562	12.5	26.905	0.2947	12
1510	0.9	573	0.333	27	37.62	0.3766	5.1
1511	2.8	615	0.3041	29.5	39.985	0.4795	4
1515	5.2	472.8	0.2489	22.6	24.575	0.4436	9.2
1519	7	561.8	0.099	21.8	16.595	0.1844	9
1528	2.1	504.4	0.238	19.7	24.62	0.4495	6.6
1529	1.5	714.3	0.2932	16.5	25.68	0.2747	9.7
1530	6.1	494.1	0.1323	20.9	20.17	0.2128	8.3
1531	12.9	543.8	0.1104	28.7	24.53	0.3497	12
1548	13.2	599.6	0.1875	20.7	21.945	0.2385	9
1550	8.3	538	0.1695	19.8	23.568	0.3264	10
2457	19.6	427.7	0.1868	8.6	5.85	0.5645	3.2
2627	14.7	615	0.5242	3	12.09	0.8838	0.91
3475	10.2	509	0.5316	6.8	8.905	1.4225	1

EVALUATION OF RESULTS OF THE ANALYSES

The roof drift ratios, maximum story drift ratios and the location of the maximum story drift ratios are obtained via inelastic time history analyses for all of the records. Subsequent to each analysis, the story drift ratio of the *floor level* –which undergoes the maximum story drift under dynamic load- is obtained with pushover analysis. This pushover is performed till the roof drift ratio value which was obtained for the relevant record. These results are provided in Table.3.

Table 3. Roof Drift Ratios and Roof Displacements, Maximum Story Drift Ratios and Location of Maximum Story Drift Ratios for time history analyses (TH) The story drift ratio of the relevant floor level for pushover analysis for the same roof displacement

Record	Floor Level of max story drift	Max Story Drift (TH)	Max Story Drift (PO)	Roof Drift	Roof Disp(cm)	Ratio of max story drifts (TH/PO)
451	10	0.028	0.007	0.008	25.8	4.05
459	10	0.014	0.004	0.004	14.4	3.80
496	10	0.012	0.006	0.006	20.5	2.00
763	10	0.008	0.004	0.004	14.1	2.18
802	6	0.020	0.018	0.014	48.9	1.12
803	9	0.022	0.010	0.014	45.9	2.14
825	10	0.022	0.009	0.014	46.3	2.52
828	10	0.021	0.007	0.010	33.5	2.86
879	5	0.034	0.032	0.025	83.9	1.08
983	5	0.026	0.023	0.018	60.0	1.10
1009	6	0.017	0.014	0.012	39.6	1.20
1013	8	0.020	0.011	0.013	42.7	1.74
1085	4	0.030	0.023	0.017	59.3	1.32
1086	5	0.028	0.025	0.019	64.6	1.12
1148	9	0.006	0.004	0.004	13.8	1.39
1182	3	0.018	0.016	0.013	45.1	1.13
1193	4	0.018	0.018	0.013	45.7	1.02
1202	9	0.021	0.009	0.011	36.5	2.44
1480	9	0.013	0.008	0.009	31.1	1.66
1482	4	0.013	0.013	0.010	35.2	0.94
1486	9	0.008	0.005	0.005	15.6	1.75
1489	9	0.012	0.008	0.008	28.4	1.53
1493	9	0.010	0.007	0.007	23.3	1.47
1494	9	0.012	0.007	0.007	23.1	1.74
1496	3	0.013	0.011	0.009	30.3	1.24
1499	9	0.008	0.006	0.006	19.2	1.41
1501	4	0.032	0.025	0.020	66.4	1.27
1511	3	0.016	0.013	0.010	35.1	1.29
1515	6	0.015	0.012	0.010	35.3	1.30
1519	4	0.013	0.012	0.010	33.3	1.01
1528	3	0.016	0.013	0.010	34.5	1.22
1529	7	0.030	0.023	0.020	67.5	1.31
1530	4	0.014	0.015	0.011	38.4	0.98
1531	9	0.009	0.006	0.006	19.8	1.56
1548	4	0.016	0.014	0.010	35.5	1.14
1550	9	0.013	0.007	0.006	21.9	1.93
2547	4	0.014	0.013	0.010	33.7	1.12
2627	10	0.032	0.007	0.010	34.2	4.34
3475	9	0.013	0.006	0.006	20.7	2.15

For the records with pulse period value smaller than 2 s, the ratio of the maximum story drift ratio of the time history analysis to the story drift obtained by pushover analysis for the relevant floor level is higher than 2 (except for the record with NGA# of 1013) . Moreover, for such records maximum story drift ratios are observed at higher stories, namely 7 records max story drift ratios are observed at 10th floor level and for 3 records at 9th floor level. Such records with much more difference among static and dynamic analyses results are highlighted in Table.3. For the whole set the displacements obtained with time history analyses are higher than pushover analyses except for the records with NGA numbers of 1482 and 1530. The distribution of the maximum story drift ratio to the floor levels are: seven 10th floor, twelve 9th floor, one 8th and one 7th floors, three 6th and three 5th floors, eight 4th floor and four 3th floor levels. Majority of the maximum story drift locations are at the upper half of the frame elevation, especially at 9th and 10th stories as expected for the near fault records with velocity pulses.

Next to the evaluation of the maximum story drifts, the relation between the story drift ratios obtained via time history and pushover analyses are statistically evaluated for each floor level. Since the records are not scaled to a certain hazard level for the sake of preserving the characteristics of velocity pulses, regression analysis is performed. The results are povided in Figs.2-8.

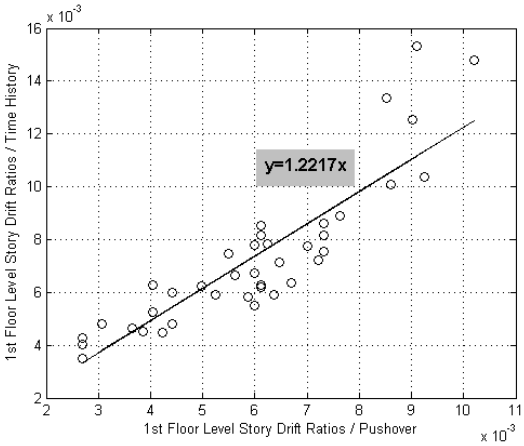

Figure 2. 1st Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

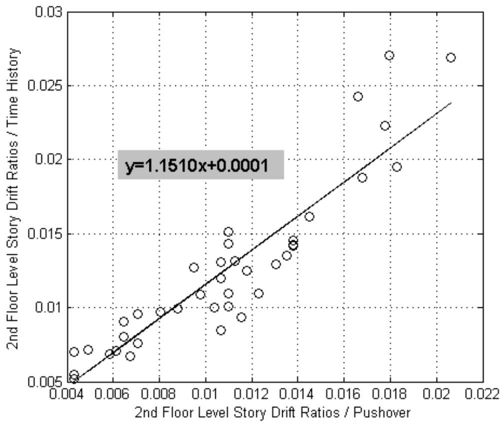

Figure 3. 2nd Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

According to the statistical evaluation of this 10 story model frame with the chosen records, there is a strong correlation between the story drift ratios obtained via pushover and time history analyses for especially middle third of the frame. R^2 values are given in Table.4. Regression model fit is very well with R^2 values higher than 0.9 for 4th, 5th and 6th floor levels. Regression model fit is satisfactory with high R^2 values higher than 0.7 for 1st, 2nd, 3rd and 7th floor levels.-However for the upper third of the building the regression formula seems to be not applicable with a very low R^2 value for 8th story and it is zero for the top 2 stories. The question that should be asked at that point is : Is R^2 enough to decide whether the regression analysis works or not, solely?

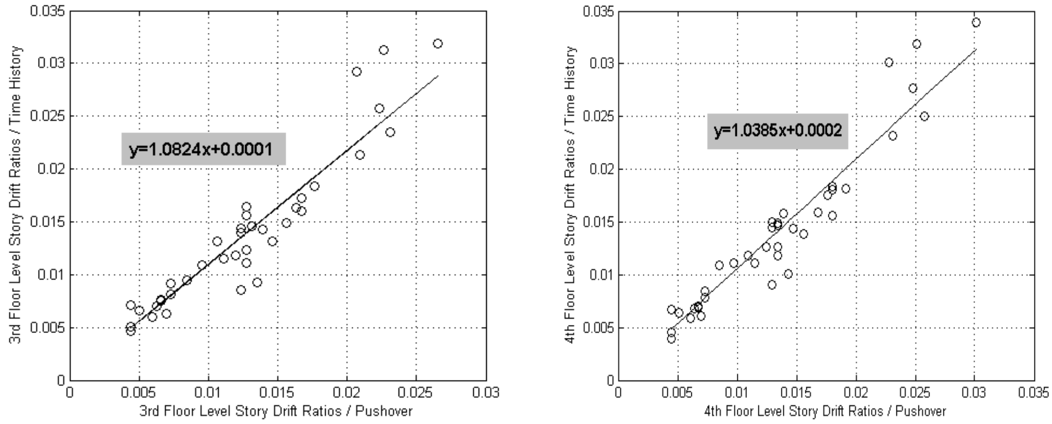

Figure 4. 3rd and 4th Floor Levels - Story Drift Ratios obtained via Pushover vs. Time History Analyses

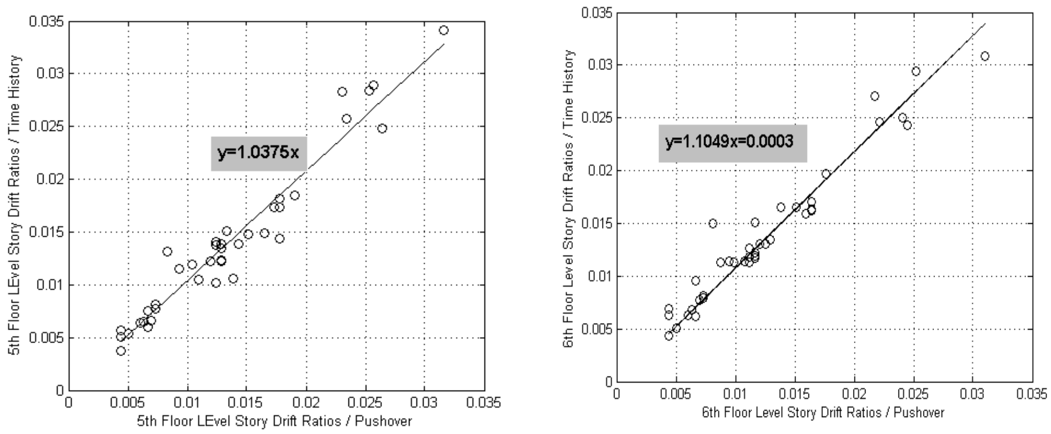

Figure 5. 5th and 6th Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

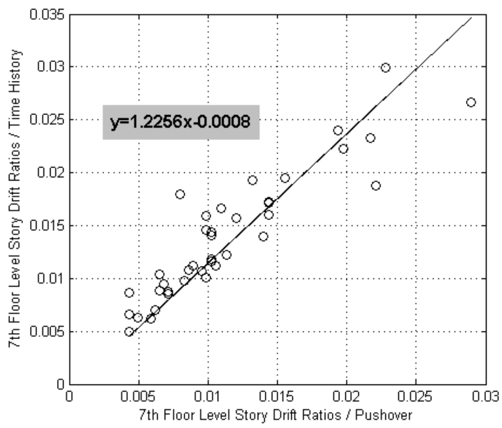

Figure 6. 7th Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

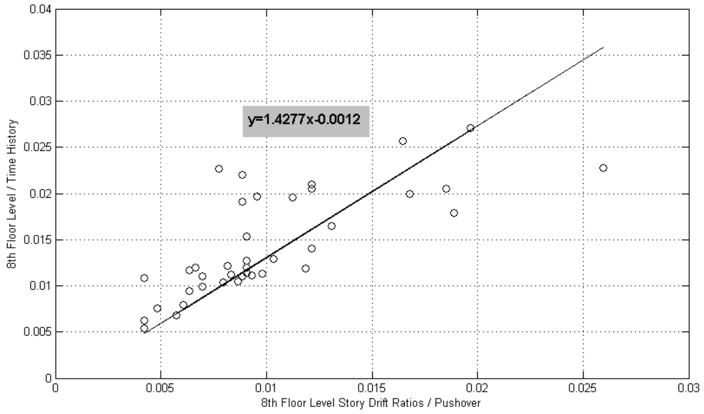

Figure 7. 8th Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

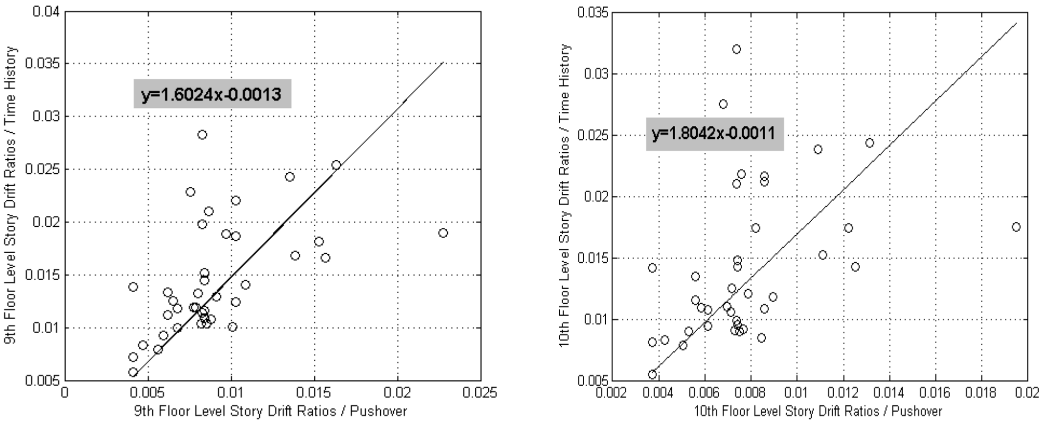

Figure 8. 9th and 10th Floor Level - Story Drift Ratios obtained via Pushover vs. Time History Analyses

Table 4. R^2 values obtained via the regression analyses of the story drift ratios of the floor levels

Floor Level	*1st*	*2nd*	*3rd*	*4th*	*5th*	*6th*	*7th*	*8th*	*9th*	*10th*
R^2	**0.7818**	**0.8437**	**0.8799**	**0.9156**	**0.9410**	**0.9357**	**0.7387**	**0.2953**	**0**	**0**

Actually, it is crucial to keep in mind the way how we use the drift ratios of pushover analysis during performance assessment procedures. We generally try to estimate the mean story drift ratio for a chosen earthquake set with a particular earthquake hazard level by the use of pushover analysis results. Thus it is rational to examine the relation between the mean story drift ratios of the chosen record set and the results of the pushover analysis which is performed till the mean roof drift ratio of the dynamic analysis. Besides the regression equations of all the stories can be tested in this sense constructing a rational tool to decide whether the regression works or not next to the R^2 values. It should be underlined that the roof drift mentioned above is the ratio of the top lateral displacement to the total building height as defined in ANSI/AISC 41-06. In Table.4, all of these relations are provided. Though unsatisfactory regression fits observed at the top third of the frame in terms of R^2, story drift ratios are not that unsatisfactory; the ratio of the regression estimates to the mean story drifts obtained with the mean values of time history analyses are nearly 0.9 for top four stories with a minimum of 0.863 for the eight floor levels. Whereas these ratios are unacceptable for the pushover estimates with a minimum ratio of 0.54140 for the top story. It seems the use of regression equations is safer and more accurate than pushover analysis. It is obvious that a modification factor is necessary for the top 4 stories; such as 1.15. However, the value of this modification factor can be best determined by a wide parametric study with different record sets.

Table 5. Story Drifts and "Estimated/Mean" Story Drift Ratios for Pushover Analysis and Regression Equations

Floor Level	Story Drift Ratios and the Ratios between the Estimates and the Mean Values obtained by time history analyses of the record set				
	Mean /Time Hist.	**Pushover Est.**	**Ratio-Push.**	**Regression Est.**	**Ratio-Reg.**
1	0.00732	0.00636	0.86853	0.00777	1.06108
2	0.01249	0.01154	0.92333	0.01338	1.07075
3	0.01378	0.01355	0.98330	0.01477	1.07158
4	0.01411	0.01432	1.01490	0.01507	1.06815
5	0.01394	0.01383	0.99225	0.01435	1.02946
6	0.01389	0.01252	0.90144	0.01353	0.97440
7	0.01391	0.01095	0.78694	0.01261	0.90695
8	0.01440	0.00955	0.66283	0.01243	0.86300
9	0.01447	0.00864	0.59694	0.01255	0.86672
10	0.01401	0.00758	0.54140	0.01258	0.89826

CONCLUSIONS

According to the results of this study, for the records with pulse period value smaller than 2 s, the ratio of the maximum story drift ratio of the time history analysis to the story drift obtained by pushover analysis (with a first mode lateral load distribution) for the relevant floor level are higher than 2. This yields the results of pushover analyses to be unsafe in terms of the amplitude and distribution of the story drift ratios. Thus, as an attempt to correct the story drift ratios obtained via pushover analysis, regression analyses are performed for each story level. The relation between the story drift ratios obtained via time history and pushover analyses are statistically evaluated by regression analyses carried out.

It can be expressed that regression equations derived herein are applicable for the correction of the story drift ratios obtained for especially the middle and the lower stories of the model frame, but for the top four stories it is obvious that a modification factor is needed. For the model frame and earthquake set used in this study this factor can be taken as 1.15. However it should be underlined that the parametric study will be extended in an ongoing research since the methodology proposed herein has been found out to be promising.

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