EVALUATION OF ADAPTIVE MODAL COMBINATION PROCEDURE FOR VERTICALLY IRREGULAR STRUCTURES

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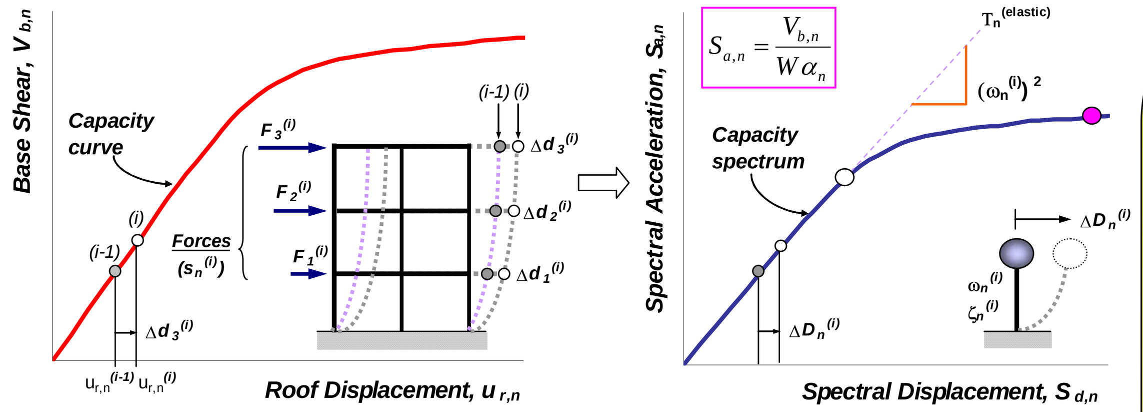
Objective

The accuracy of a new pushover methodology so called "ADAPTIVE MODAL COMBINATION (AMC)" procedure in predicting seismic response of the vertically irregular (i.e., mass irregular or setback) SMRFs using a set of forward directivity records is examined.

ADAPTIVE MODAL COMBINATION Procedure

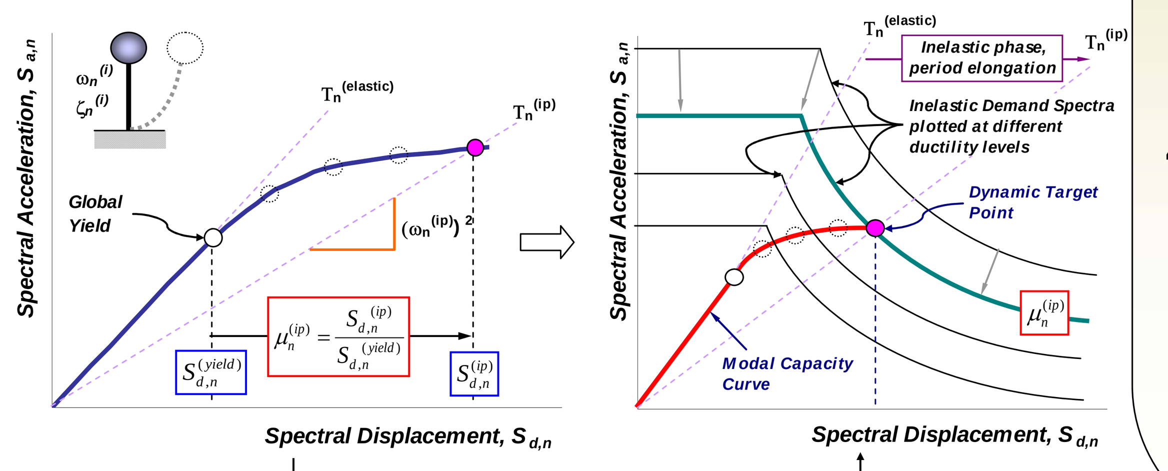


$$S_{d,n} = \sum \Delta D_n^{(i)} = \sum\left[\left(\sum_{j=1,3}(F_{n,j}^{(i)} \Delta d_{n,j}^{(i)})\right) / \left(\sum_{j=1,3}(F_{n,j}^{(i)})\right)\right]$$

AMC Procedure eliminates the need to compute the Target Displacement prior to commencing the pushover analysis.

NOVEL FEATURES OF NEW PUSHOVER PROCEDURE

1. **Multi-modal: The AMC procedure accounts for higher mode effects by combining the response of individual modal pushover analyses.**
2. **Adaptive: It incorporates the effects of varying dynamic characteristics during the inelastic response via its adaptive feature.**
3. **Modal Force Vectors: The applied lateral forces used in the progressive pushover analysis are based on instantaneous inertia force distributions across the height of the building for each mode.**
4. **Constant-Ductility Capacity Spectra: The target displacement is estimated and updated dynamically during the analysis by incorporating energy based modal capacity curves in conjunction with constant-ductility capacity spectra.**



With computed system ductility $\mu_n^{(ip)}$

AMC Procedure eliminates the limitations of Capacity Spectrum Method and Displacement Coefficient Method by utilizing concepts of:

ENERGY BASED INCREMENTAL MODAL DISPLACEMENT

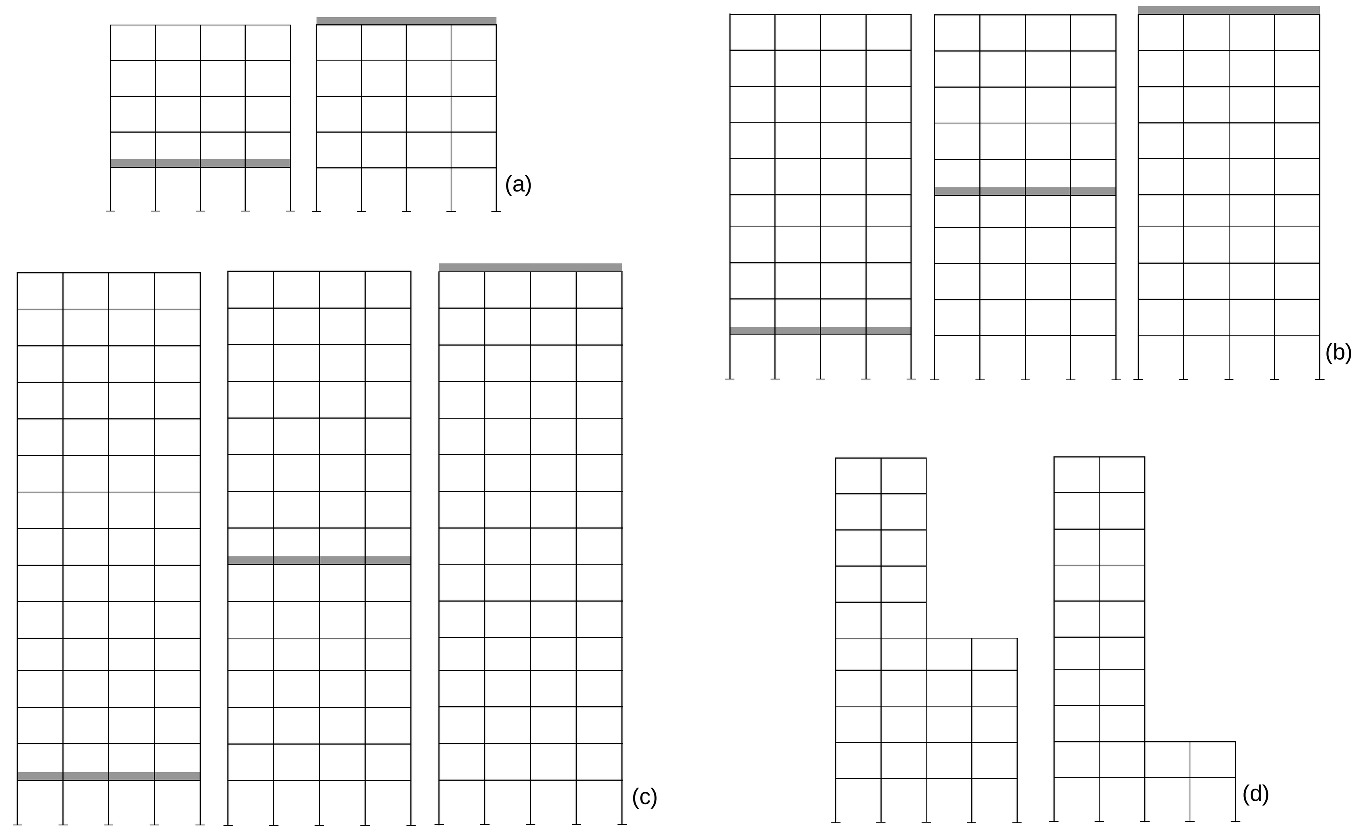
INELASTIC SPECTRA AND DYNAMIC TARGET POINT

Mass Irregularity & Geometric Irregularity (Setback)

According to IBC:

Mass Irregularity: is considered to exist if the effective mass of any story is more than 150 percent of an adjacent story. A roof that is lighter than the floor below is excluded from this consideration.

Vertical Geometric Irregularity (Setback): is considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130 percent of



SMRFs used in this study: (a) 5-story, (b) 10-story, (c) 15-story (shaded floor indicates the location of mass irregularity) and (d-e) 10-story setback frames.

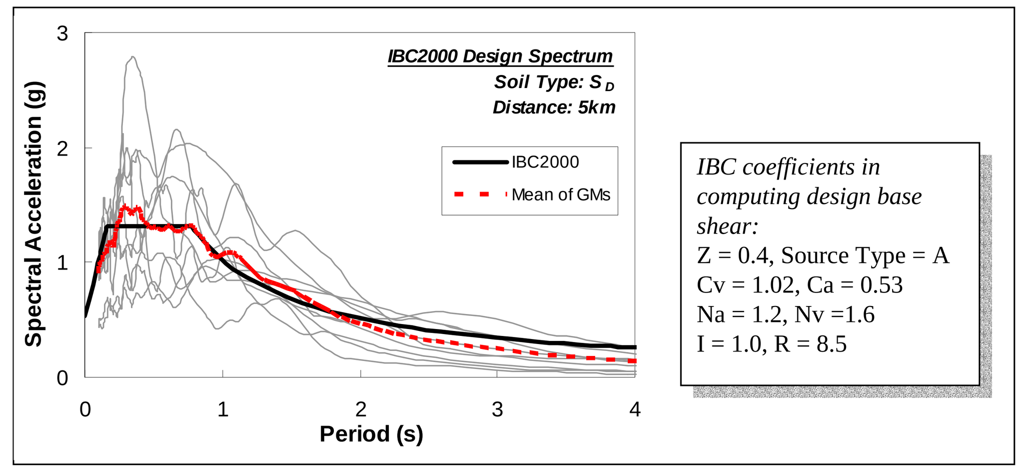
All frames were designed in a region of high seismicity with soil-type "D" and located about 5 km from causative fault. The designs satisfy the strong column-weak beam requirement of the code and the size and shape of beams and columns were chosen to satisfy code drift limitations.

Ground Motion Data (Near-fault Forward Dir.)

No	Year	Earthquake	M_W	Mech.[1]	Recording Station	Dist.[2] (km)	Data Source[3]	Comp.	PGA (g)	PGV (cm/sec)
1	1989	Loma Prieta	7.0	OB	Capitola	8.6	1	000	0.53	35.0
2	1994	Northridge	6.7	TH	Rinaldi Rec. Stn.	8.6	2	S49W	0.84	174.8
3	1994	Northridge	6.7	TH	Jensen Filt. Plant	6.2	1	022	0.42	106.3
4	1994	Northridge	6.7	TH	Slymar Converter Sta East	6.1	1	018	0.83	117.5
5	1994	Northridge	6.7	TH	Slymar Converter Sta.	6.2	1	142	0.90	102.2
6	1994	Northridge	6.7	TH	Sepulveda Va. Hospital	9.5	1	270	0.75	85.3
7	1994	Northridge	6.7	TH	Sylmar Olive View Hospital	6.4	1	360	0.84	130.4
8	1994	Northridge	6.7	TH	Newhall LA Fire Stn.	7.1	1	360	0.59	96.4
9	1994	Northridge	6.7	TH	Newhall Pico Canyon	7.1	1	046	0.45	92.8
10	2004	Parkfield	6.0	SS	Fault Zone 1	5.0	2	360	0.82	81.2

[1] *Faulting Mechanism = TH: Thrust; SS: Strike-slip; OB: Oblique;*
[2] *Closest distance to fault*
[3] *Data Source = 1: PEER (http://peer.berkeley.edu/smcat); 2: Cosmos (http://db.cosmos-eq.org)*

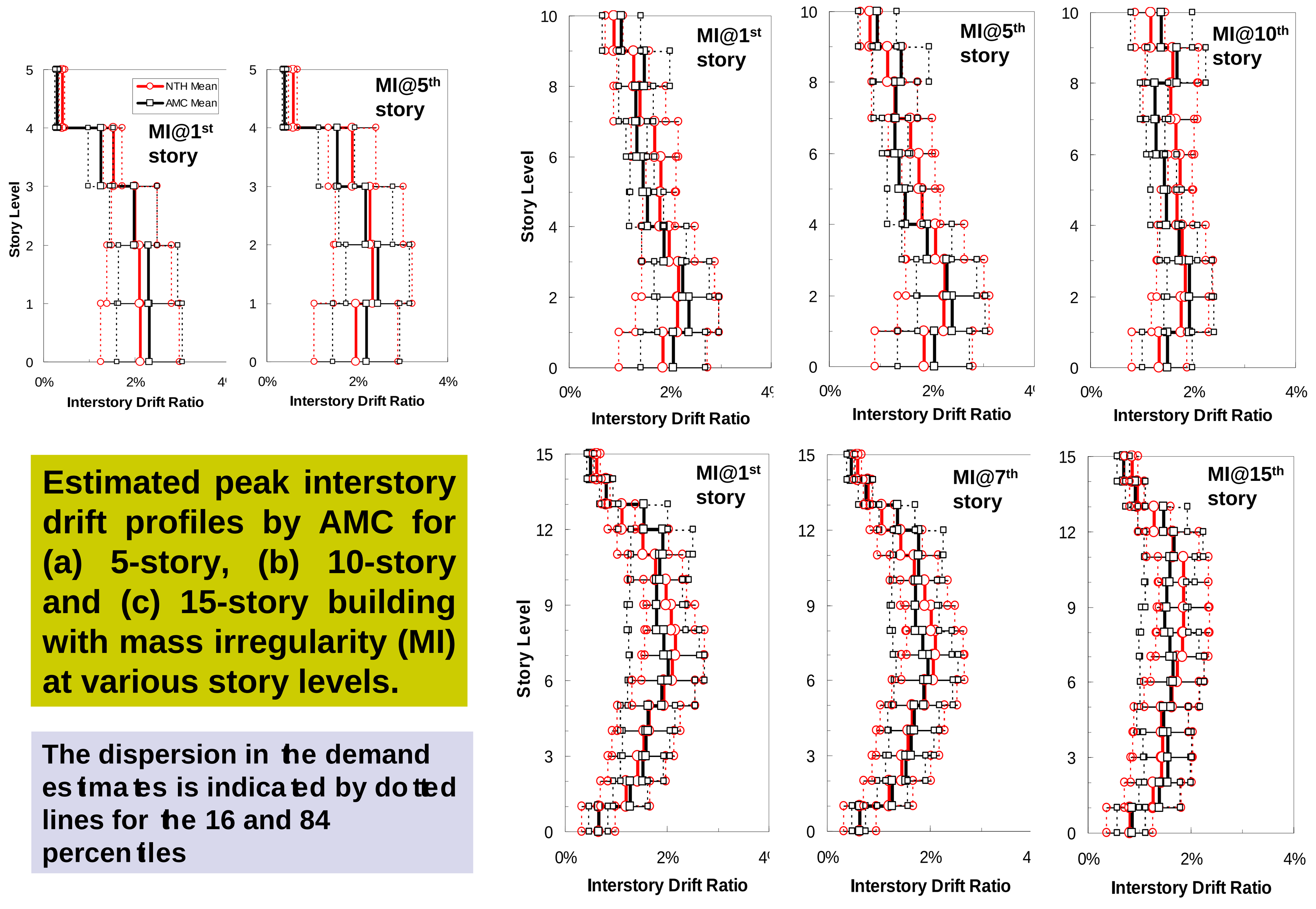
Ground motions from recent major Californian earthquakes were carefully compiled so that the mean acceleration spectrum of the selected records matches the IBC design spectrum across a wide range of spectral periods.



IBC2000 design spectrum together with pseudo-spectral acceleration spectra of near-fault forward directivity records (Left), and IBC coefficients in computing design base shear (Right).

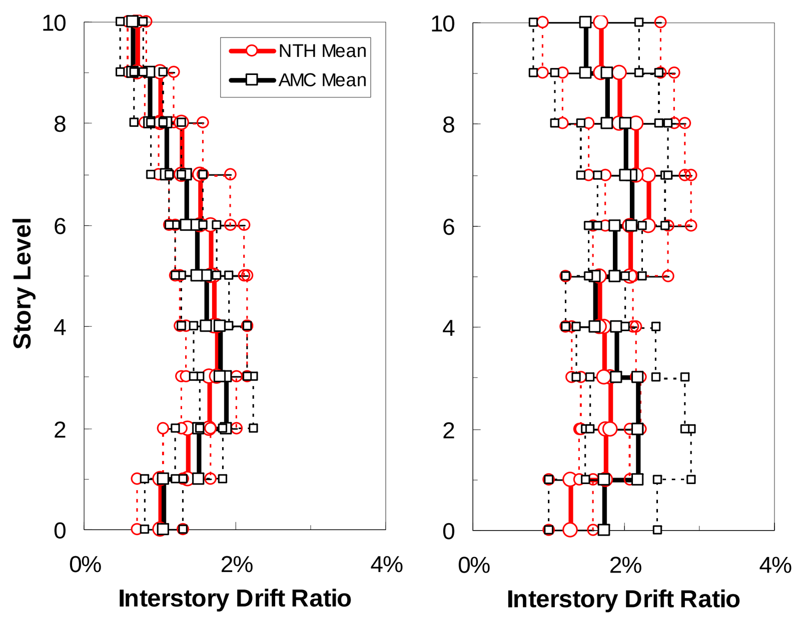
Each individual record satisfies the soil and distance constraints of the design spectrum. Records were therefore used in their original form without scaling.

Comparison of AMC Estimates with NTH Results



Estimated peak interstory drift profiles by AMC for (a) 5-story, (b) 10-story, and (c) 15-story building with mass irregularity (MI) at various story levels.

The dispersion in the demand estimates is indicated by dotted lines for the 16 and 84 percentiles



Estimated peak interstory drift profiles by AMC compared to NTH analyses results for 10-story building having setback at second story level (Left) and fifth story level (Right).

Conclusions

This study evaluates the accuracy of the recently developed AMC procedure in predicting the seismic response of vertically irregular (mass irregularity or vertical setbacks) steel moment frames subjected to near-fault forward directivity records. By including the contributions of a sufficient number of modes of vibration (generally two to three), it is demonstrated that the proposed AMC procedure is able to estimate interstory drift profiles with acceptable accuracy when compared to results from NTH analyses.