SELECTION AND SCALING OF GROUND MOTION RECORDS FOR SEISMIC ANALYSIS

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Ground Motion :

- Ground motion is the movement of earths surface from the location of earthquake or explosion.
- Earthquake are usually caused when rock underground the surface of earth suddenly breaks along the fault.

Selection of Recorded Ground Accelerations for Seismic Design

- **Record selection based on earthquake magnitude (M) and distance (R):**
- Recorded earthquake can be divided as:

Magnitude consideration

Large magnitude event ($6.1 < M \leq 6.9$)

Medium magnitude event ($3.4 < M \leq 6.1$)

Minor magnitude event ($M<3.4$)

Distance consideration

Large radius event (40 km< M ≤ 90 km)

Small radius event (12 km< M ≤ 40 km)

Development of primary record sets

- Large magnitude–near fault bin

  (LMNF; $6.1 < Mw \leq 6.9$, $12\ km \leq R$);

- Large magnitude–short distance bin

  (LMSR; $6.1 < Mw \leq 6.9$, $12\ km < R \leq 40\ km$);

- Large magnitude–long distance bin

  (LMLR; $6.1 < Mw \leq 6.9$, $40\ km < R \leq 90\ km$);

- Small magnitude–short distance bin

  (SMSR; $5.4 < Mw \leq 6.0$, $12\ km < R \leq 40\ km$); and

- Small magnitude–long distance bin

  (SMLR; $5.4 < Mw \leq 6.0$, $40\ km < R \leq 90\ km$)

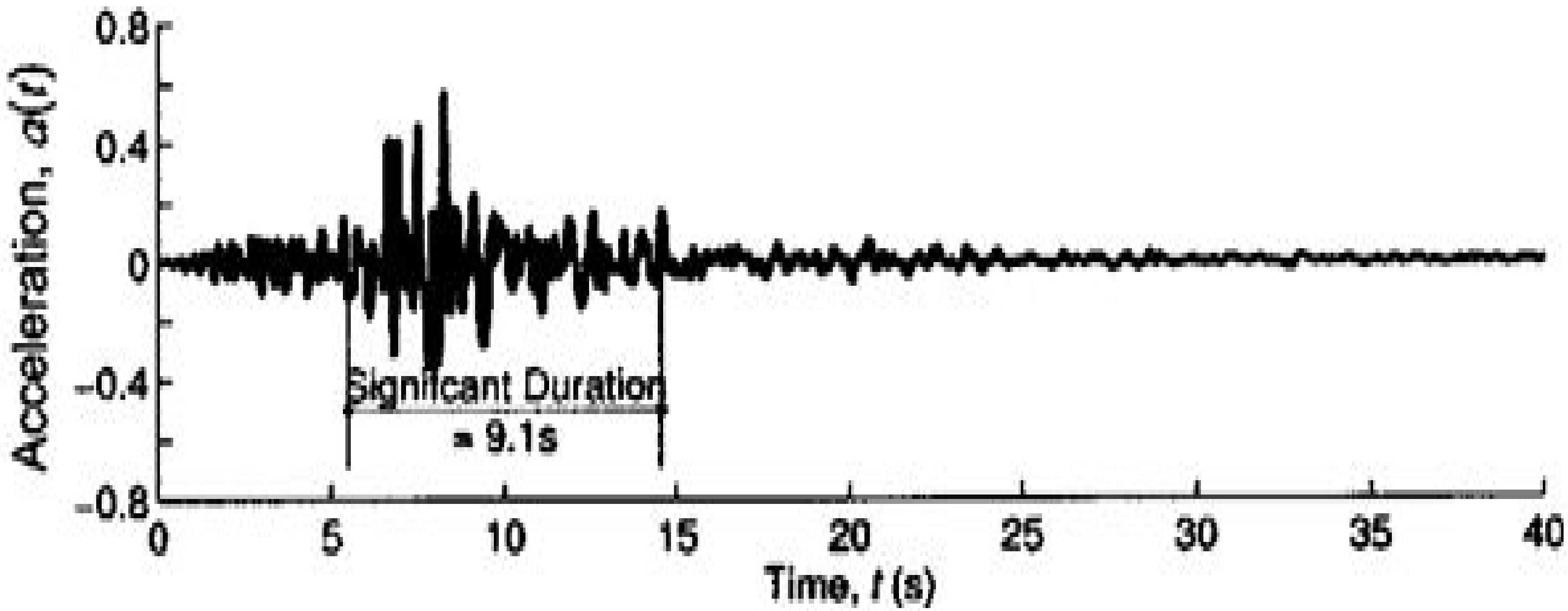
Record selection based on Soil profile

- It is complementing criteria to both earthquake magnitude and distance.
- Shear wave velocity is metric for site classification.
- Based on shear wave velocity soil can be classified as:

A - Rock	$760m/s < Vs30m \leq 1500m/s$
B - Stiff soil	$360m/s < Vs30m \leq 760m/s$
C - Soft soil	$180m/s < Vs30m \leq 360m/s$
D - Very soft soil	$Vs30m < 180m/s$

Record selection based on Strong motion duration

1.Significant duration: Time interval during which 90% of total energy recorded at the station.



Record selection based on spectral matching

- Scaling: spectral matching technique are based on scaling of selected time history in time domain. Multiplying the records with a constant factor to get close to target spectrum at a period(s) of interest.

- Spectral matching in frequency domain: modifying the frequency content to match the target spectrum.

- Spectral matching in time domain: adding the wavelets to match the target design spectrum

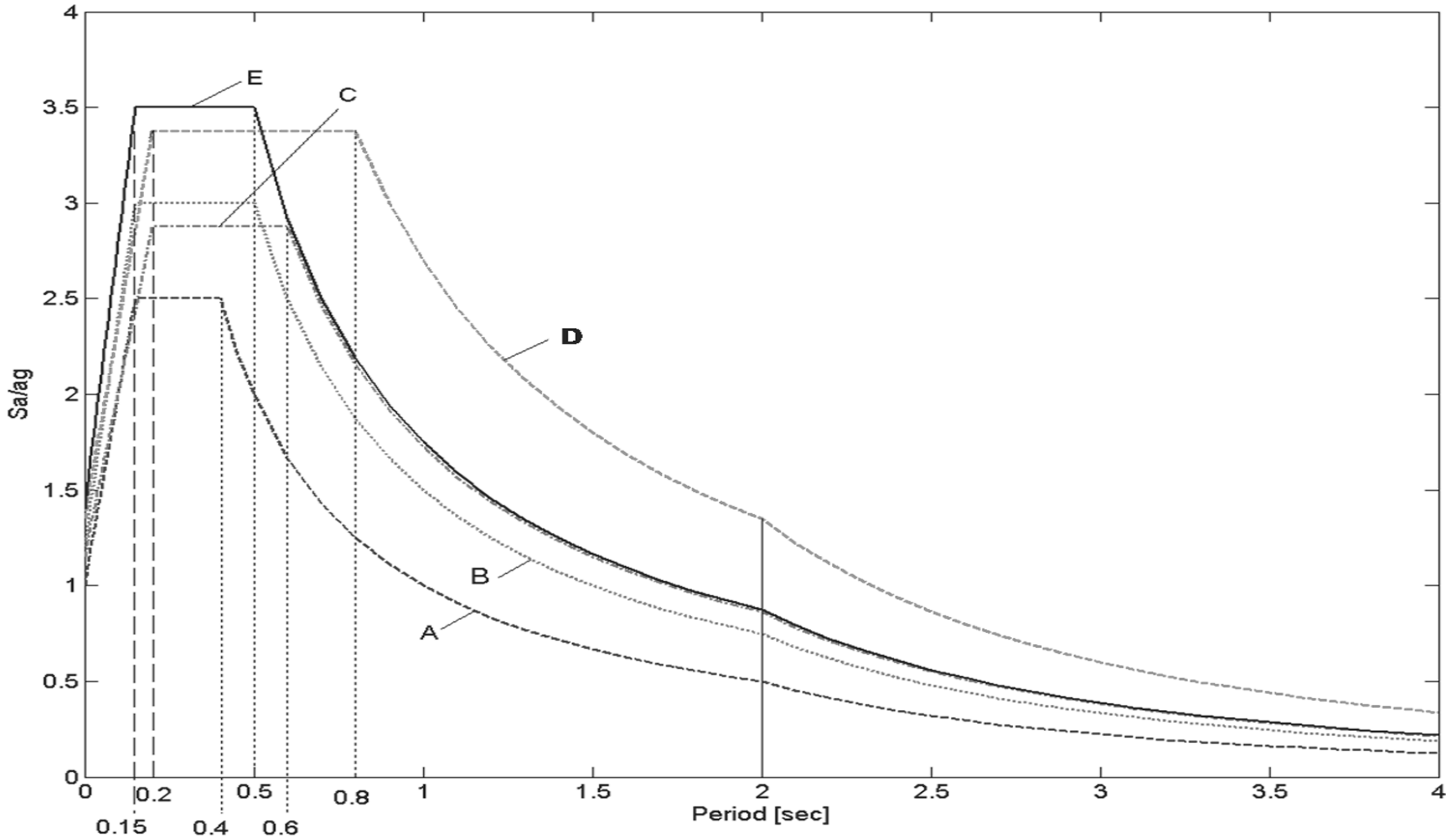
Seismic code provisions for selection of records

- Seismic codes which prescribe general guidelines to select ground motions are:
- - Euro code – 8 (Europe)
- - ASCE – 7 (USA)
- - NZS – 1170:2004 (New-Zealand)
- - GB – 50011-2001 (China and Taiwan)

Ground motion use in Europe

- EC-8 allows the use of any form of accelerograms for structural assessment, i.e. Real, artificial and simulated accelerograms.
- A minimum of 3 accelerograms.
- It allow to use 7 accelerograms average values of response quantities.
- The peak ground acceleration of individual time histories should be greater than codified peak ground acceleration

The spectral shapes given by EC-8



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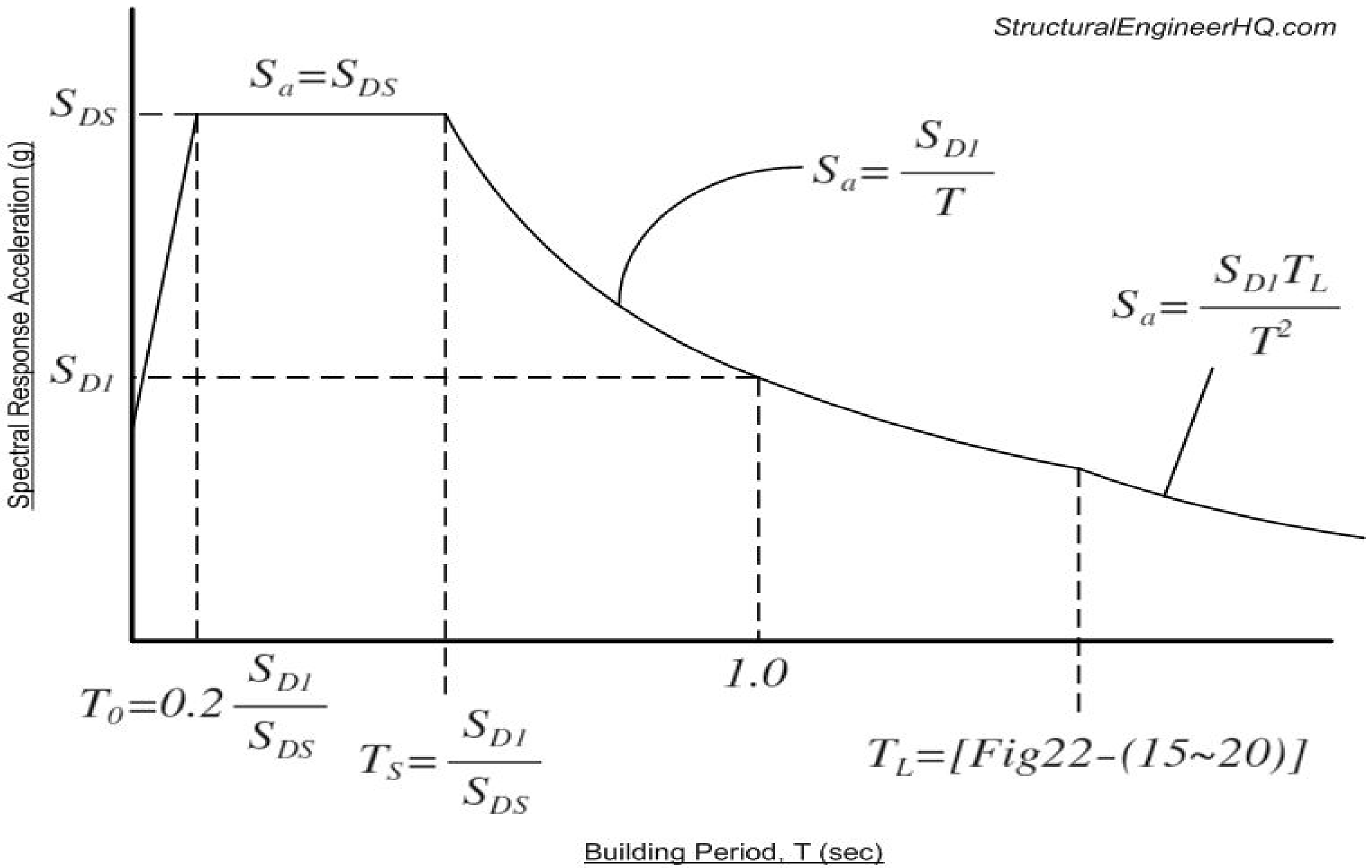
Ground motion use in United States (ASCE 7)

- ASCE-7 provides general guideline for selecting and scaling ground motions use in nonlinear response history analysis of structure.
- A minimum 3 records are required
- The matching of spectrum is performed over the period range of $0.2T_1$ to $1.5T_1$
- For three dimensional analysis spectrum representing the average of SRSS spectra of all records does not fall below 1.3 times design spectrum

Design Response Spectrum



Ground motion use in New-Zealand

(NZS 1170-2004)

- New-Zealand standard allows to use only actual records for structural assessment.
- Currently NZS 1170-2004 recommended that selection of seven records instead of three.
- Design spectrum for horizontal loading C(T) is define as:

$$C(T) = C_h(T)ZRN(T,D)$$

where, $C_h(T)$ = spectral shape factor.

Z = hazard factor

R = return period factor

N = near fault factor

Ground motion use in China (GB50011-20011) and Taiwan(Code 05)

- As per GB50011-20011 minimum 3 records are require.(at least two real and one simulated ground motion records require for analysis)

- As per Taiwan standard minimum 3 records are require.

- Spectral acceleration of each gm should be greater than 0.9 times that of design response spectrum

Comparison of seismic requirements in different world regions

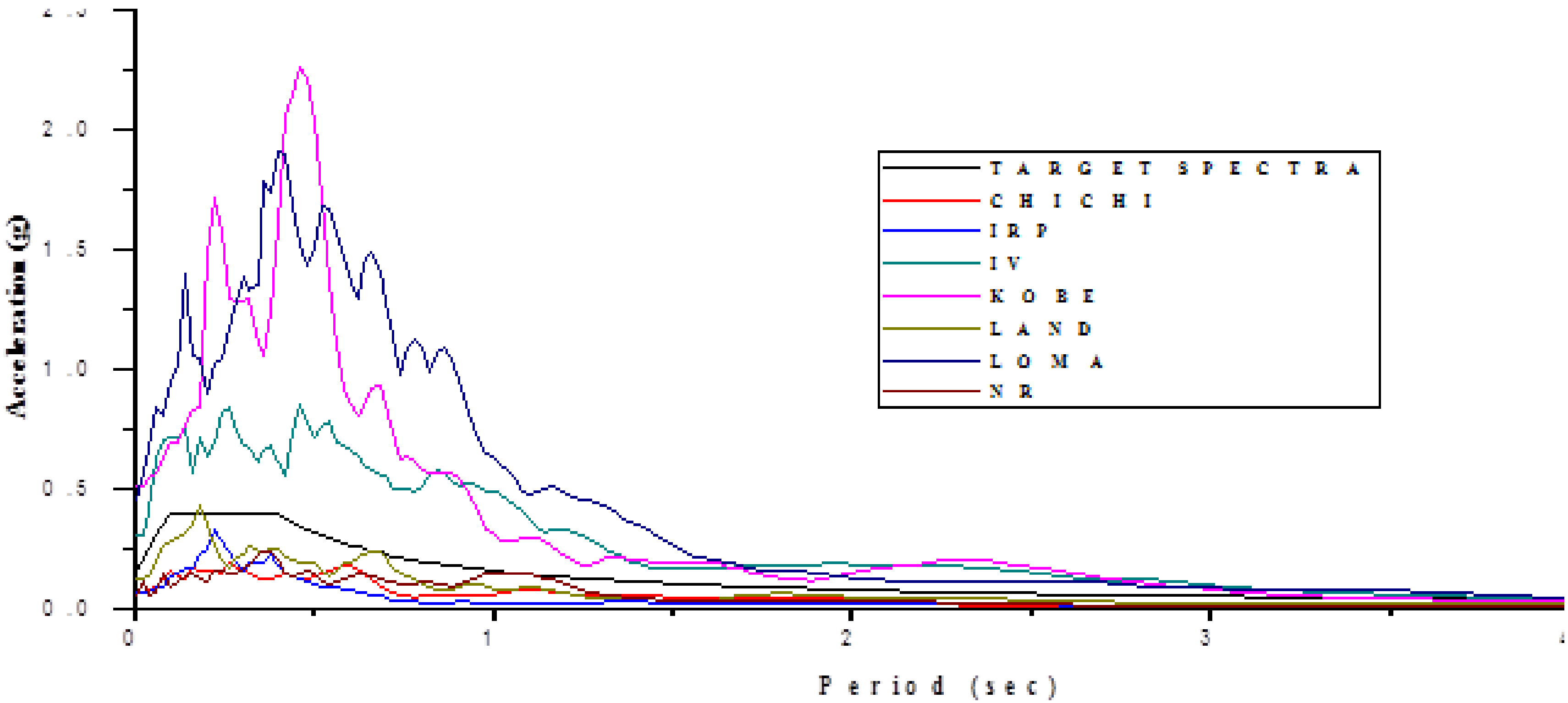
Criteria	Europe	USA	New Zealand	China	Taiwan
Minor Earthquake	95 years			50 years	30 years
Moderate Earthquake	475 years	475 years	500 years	475 years	475 years
Major Earthquake (MCE)		2475 years	2500 years	2000 years	2475 years
Seismic design basis spectrum	475 years	DBE=2/3* MCE	500 years	500 years	475 years
Minimum number of ground motions	3	3	3	3	3
Response of structure	Average response if ≥ 7 records	Average response if ≥ 7 records	Maximum response of 3 records	Average response if ≥ 7 records	Maximum response of 3 records

Criteria	Europe	USA	New Zealand	China	Taiwan
Spectral matching allowed	Yes	Yes	Yes	Yes	Yes
Matching period	$0.2T_1$-$2T_1$	$0.2T_1$-$1.5T_1$	$0.4T_1$-$1.3T_1$		$0.2T_1$-$1.5T_1$
Matching component	Sa_{avg} for all gm > 0.9*target	Sa_{avg} for all gm > target	Minimum difference between each gm and target	Sa for each gm > 0.9*target	Sa for each gm > 0.9*target
Artificial records allowed	Yes	Yes	No	Yes	Yes

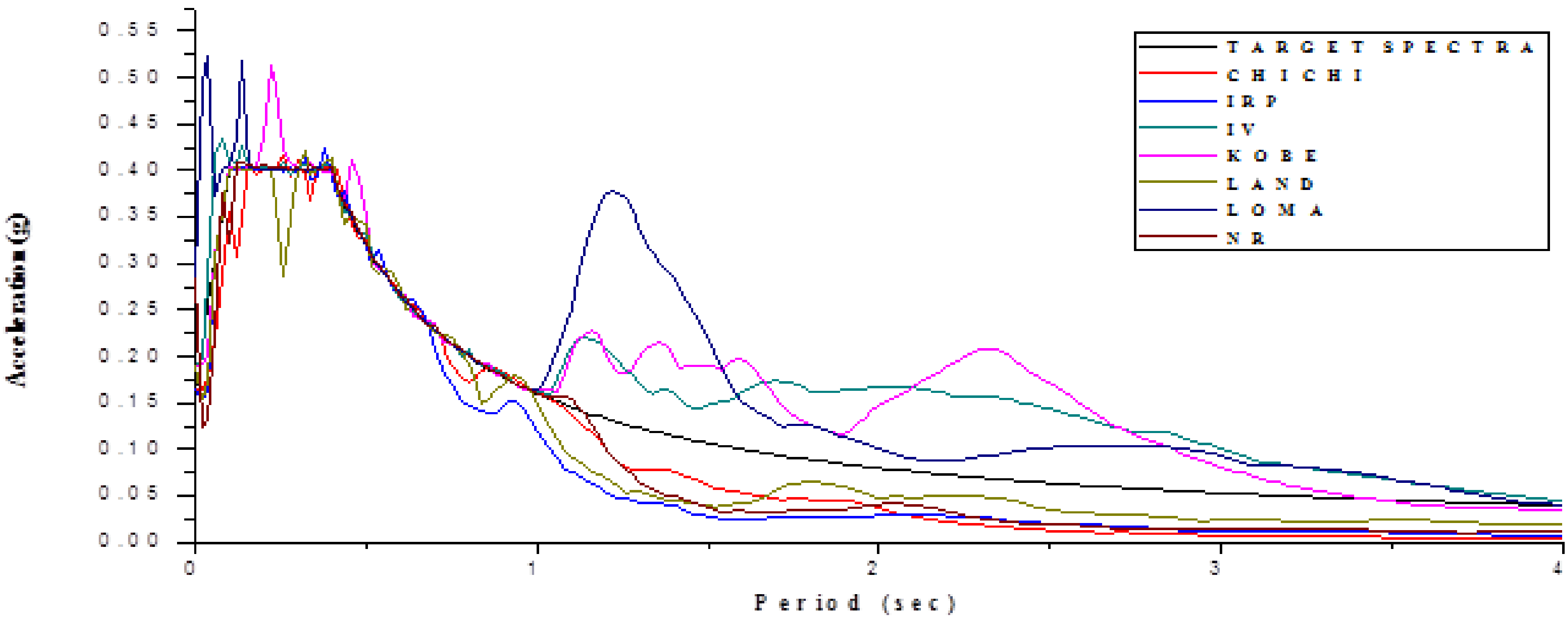
Earthquake Excitations

Earthquake Records	Year	Earthquake record description	Recording Direction / Component	Peak ground acceleration PGA (g)
Chi-Chi, Taiwan	1999	CHY101	CHICHI/CHY101-W	0.353
Irpina, Italy-01	1980	IRPINIA EQ, STURNO	ITALY/B-STU000	0.071
Imperial Valley, CA	1940	IMPERIAL VALLEY, EL CENTRO ARRAY #9, 180 (USGS STATION 117)	IMPVALL/I-ELC 180	0.313
Kobe, Japan	1995	CUE 99999, NISHI AKASHI	KOBE/NIS000	0.509
Landers, CA	1992	LANDERS, LUCERNE	LANDERS/LCN000	0.785
Loma Prieta, CA	1989	LOMA PRIETA, BRAN (UCSC STATION 13)	LOMAP/BRN000	0.453
Northridge	1994	NORTHRIDGE AFTERSHOCK, ANAVERDE VALLEY - CITY RANCH	NORTHR/ANA180	0.06

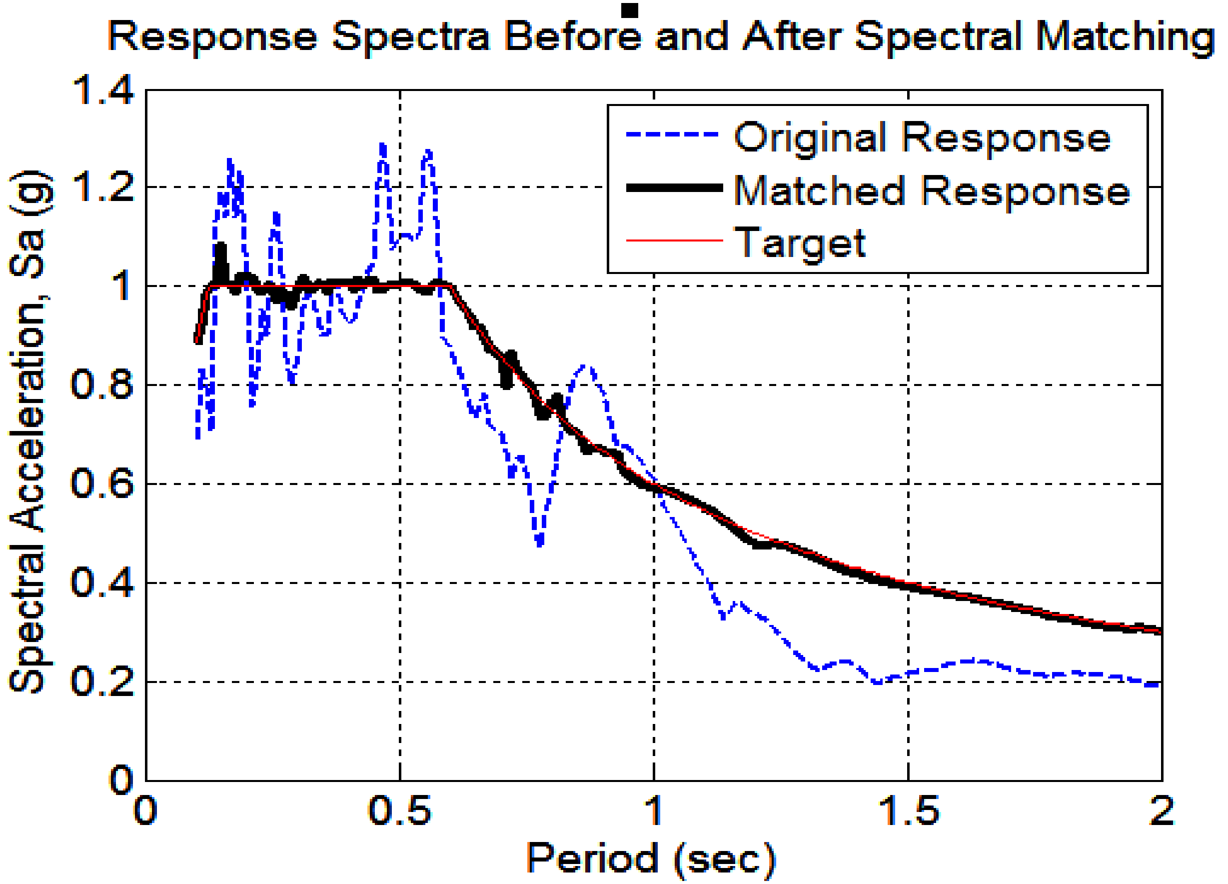
Spectral Mapping



Spectral Matching



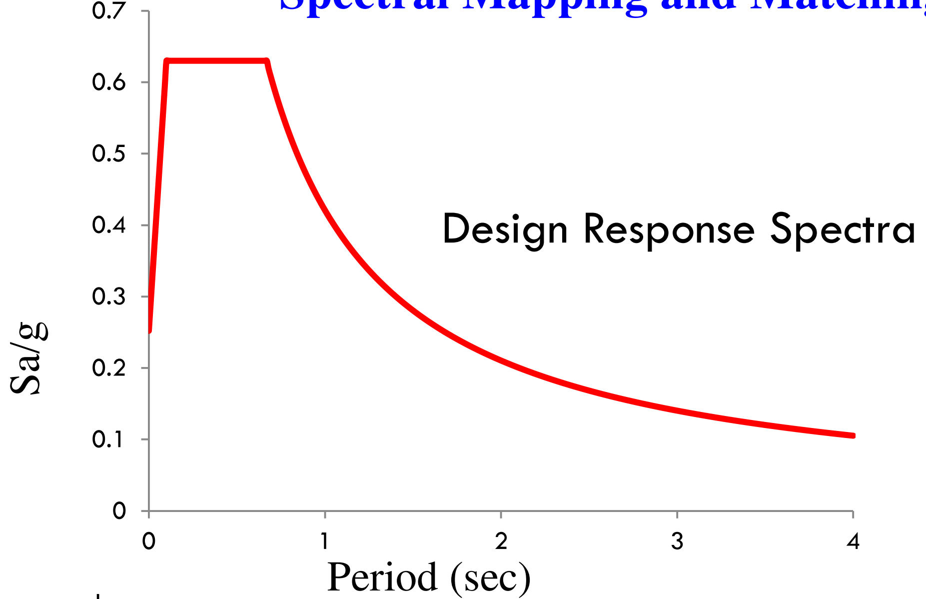
Ground motion scaling

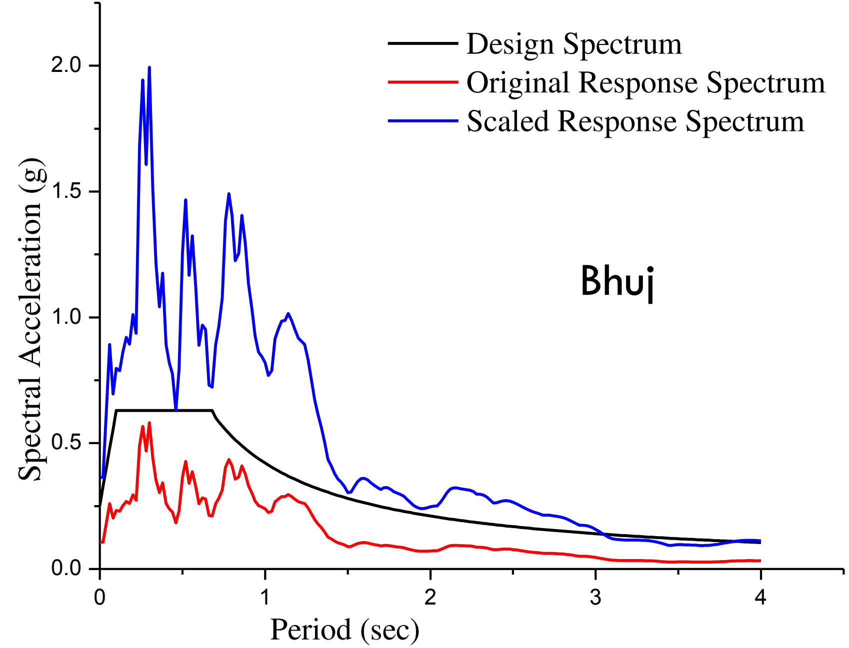


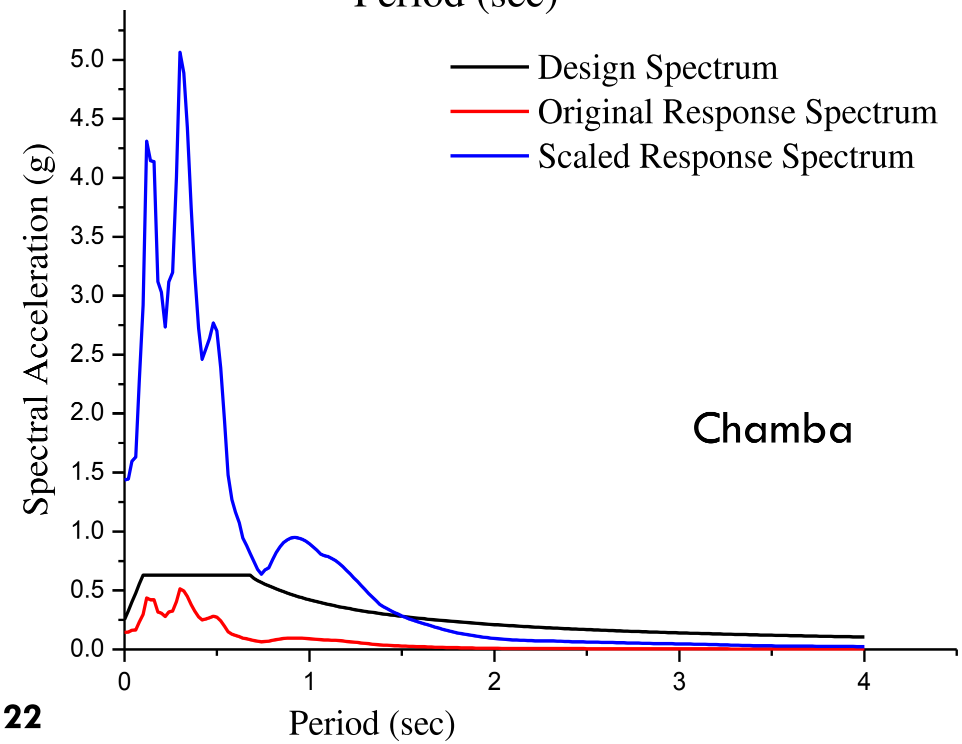
Earthquake Records

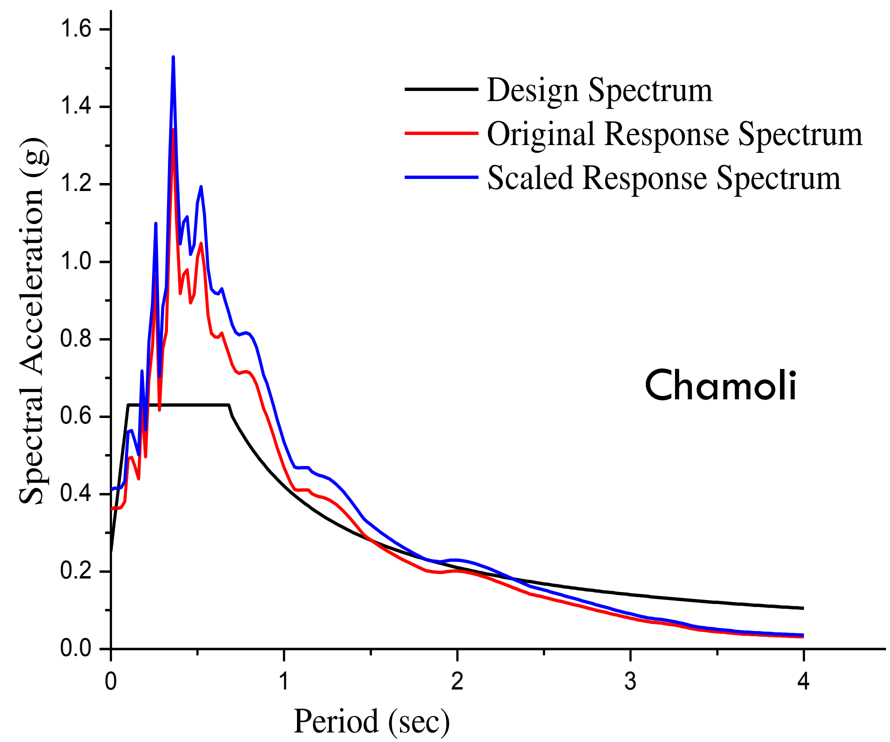
Earthquake Records	Year	Earthquake record description	Recording Direction / Component	Peak Ground Acceleration (g)	Scale
Bhuj, India	2001	Ahmedabad, India	N 78 E	0.31	3.43
Chamba, India	1995	Chamba, India	N 00 E	0.47	9.85
Chamoli, India	1999	Gopeshwar, India	N 20 E	0.42	1.14
Ind- Burma Border	1988	Bokajan, India	S 56 E	0.22	4.48
Imperial Valley, CA	1979	USGS 952, El Centro Array 5	S 40 E	0.41	0.79
Northridge	1994	USC, 90091 LA, Saturn St.	N 20 E	0.24	3.65
Uttarkashi, India	1991	Bhatwari, India	N 85 E	0.34	3.47

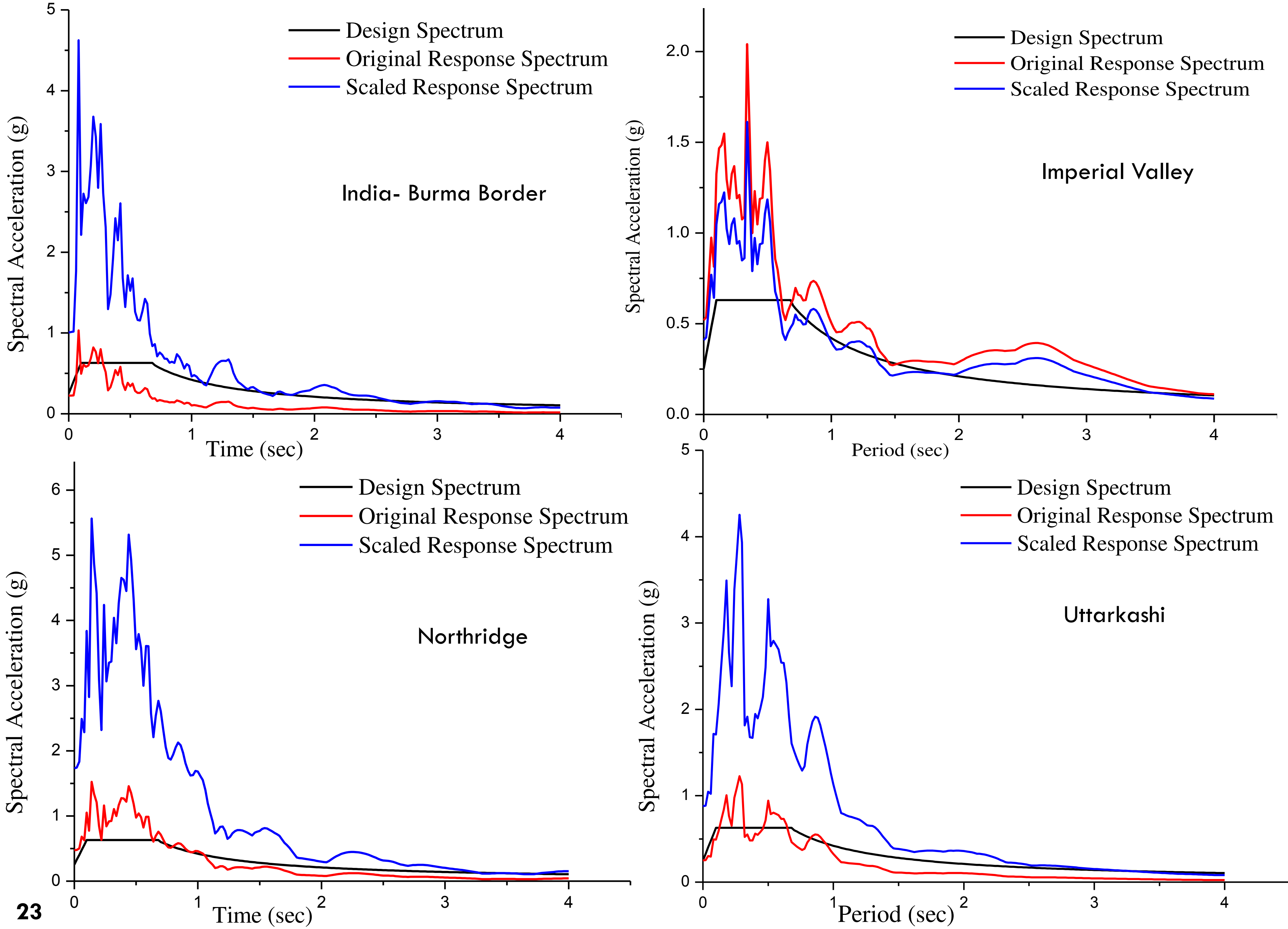
Spectral Mapping and Matching

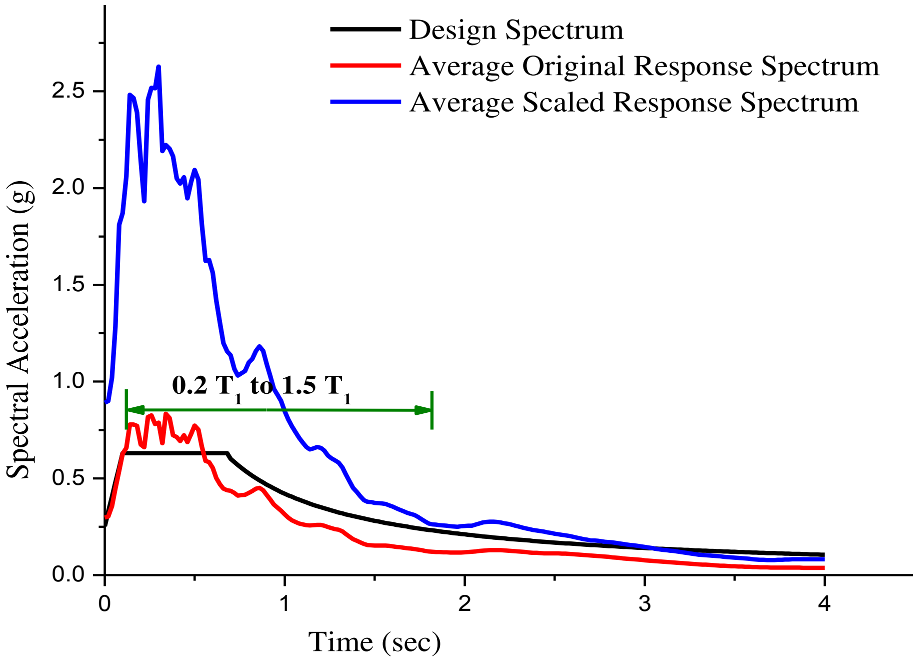









Design Spectrum
Original Response Spectrum
Scaled Response Spectrum
India- Burma Border
Spectral Acceleration (g)
Time (sec)
Imperial Valley
Period (sec)
Northridge
Uttarkashi

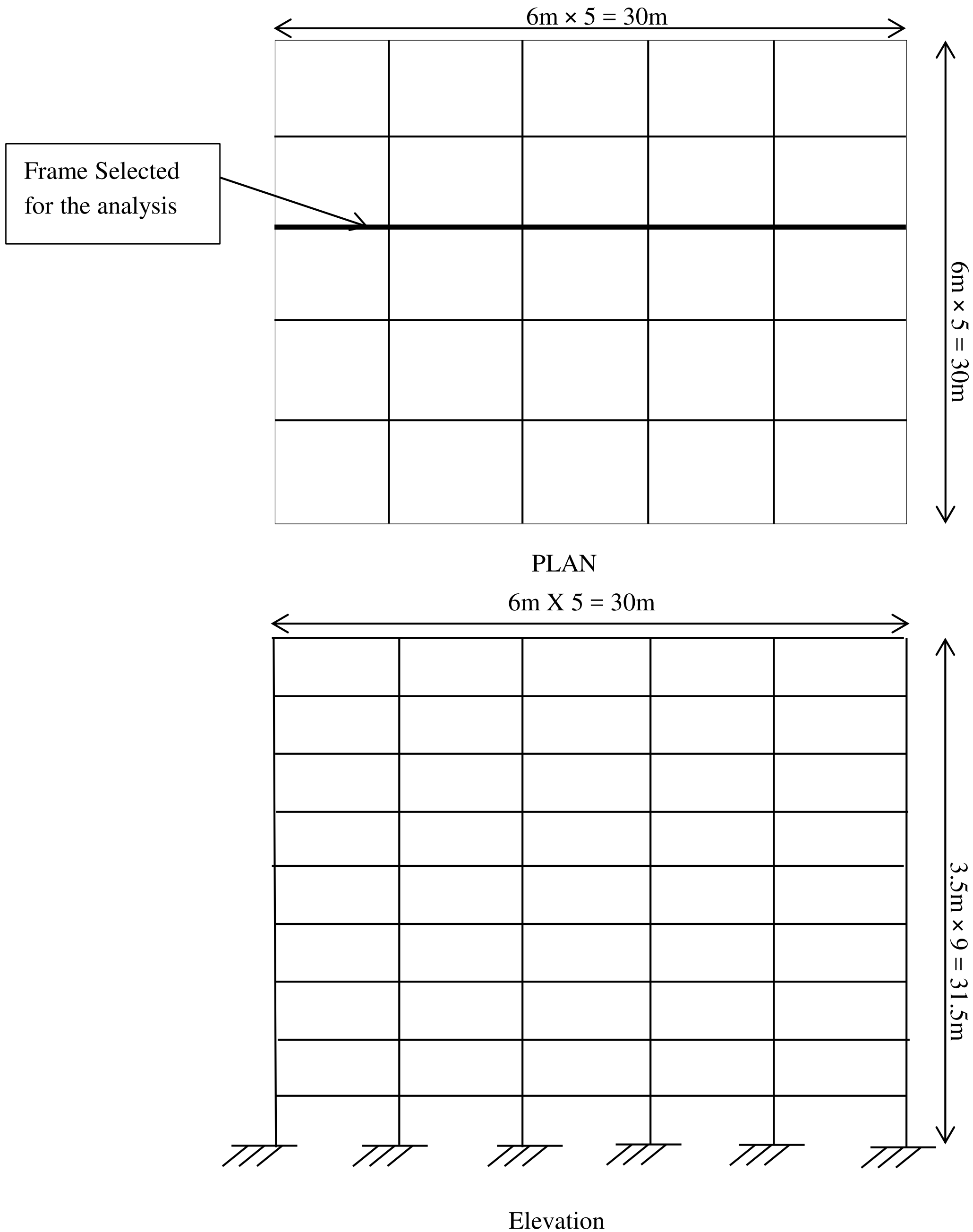


Comparison of average scaled response spectra of all ground motions with design spectrum

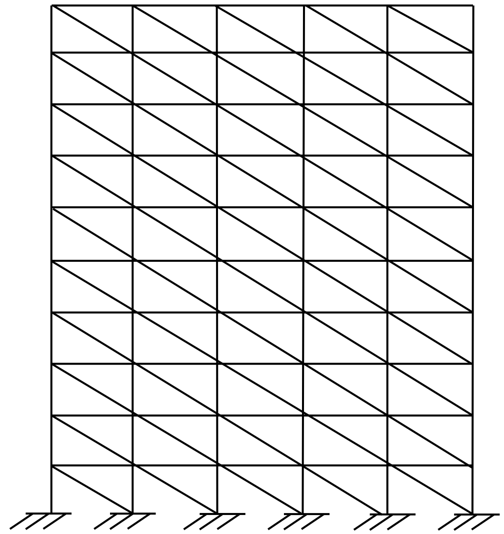
THANK YOU

Case Study of
Incremental Dynamic Analysis

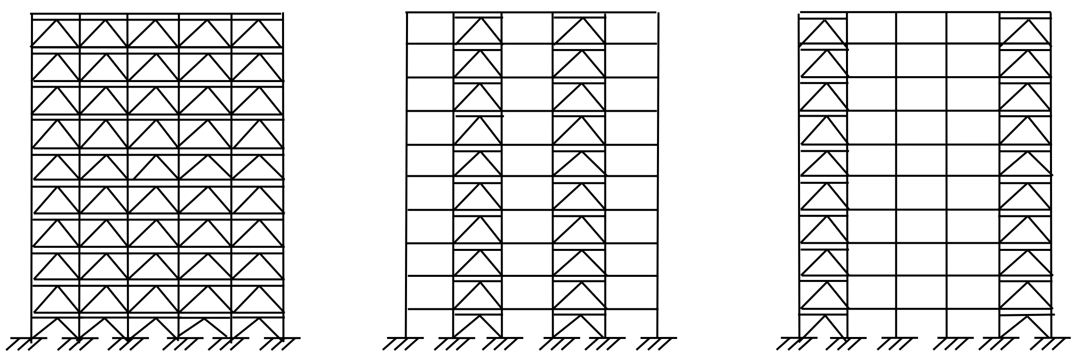
Modeling



Plan and Elevation of SMRF

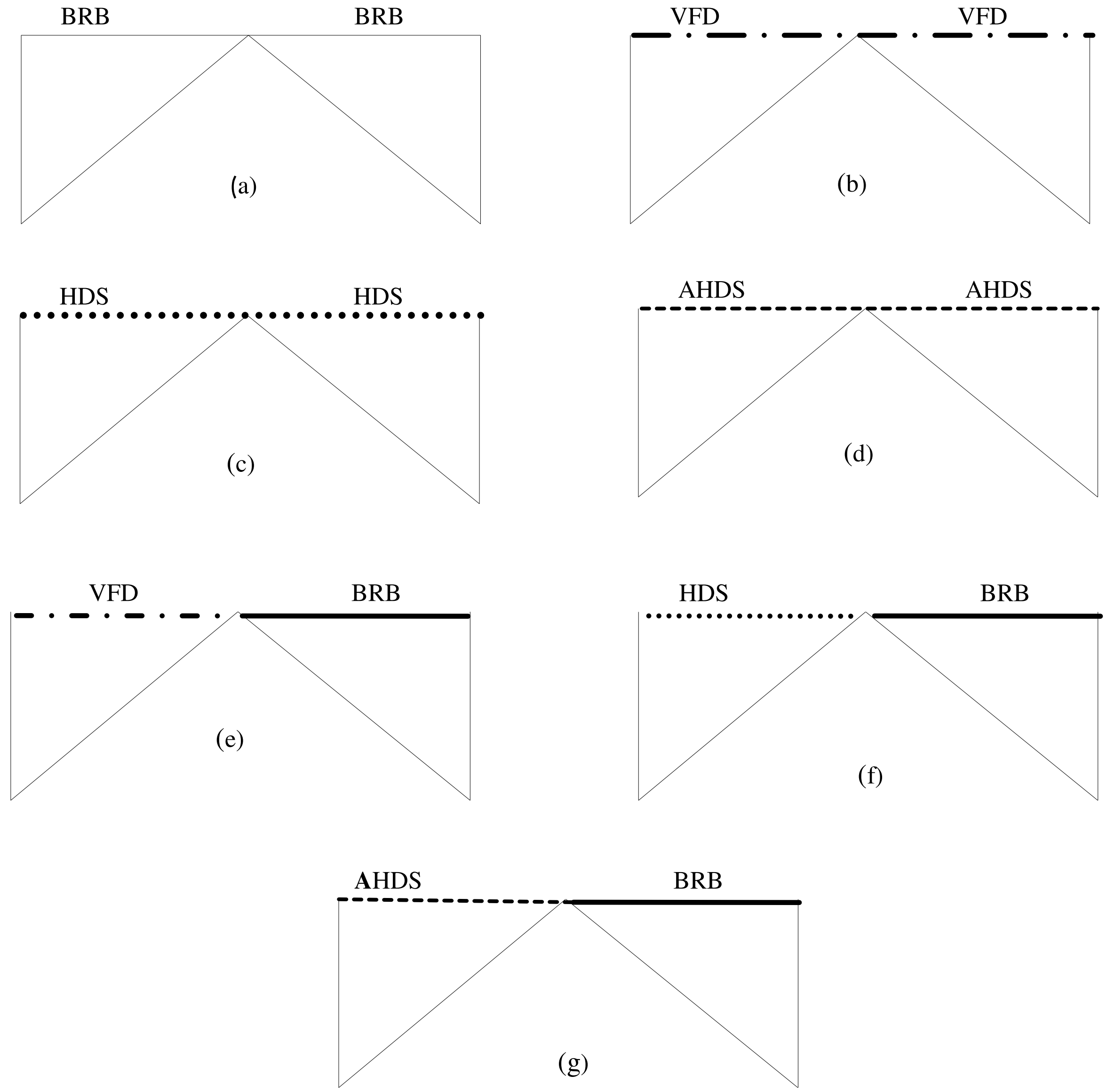


Structural frame(with masonry wall)



(a) (b) (c)

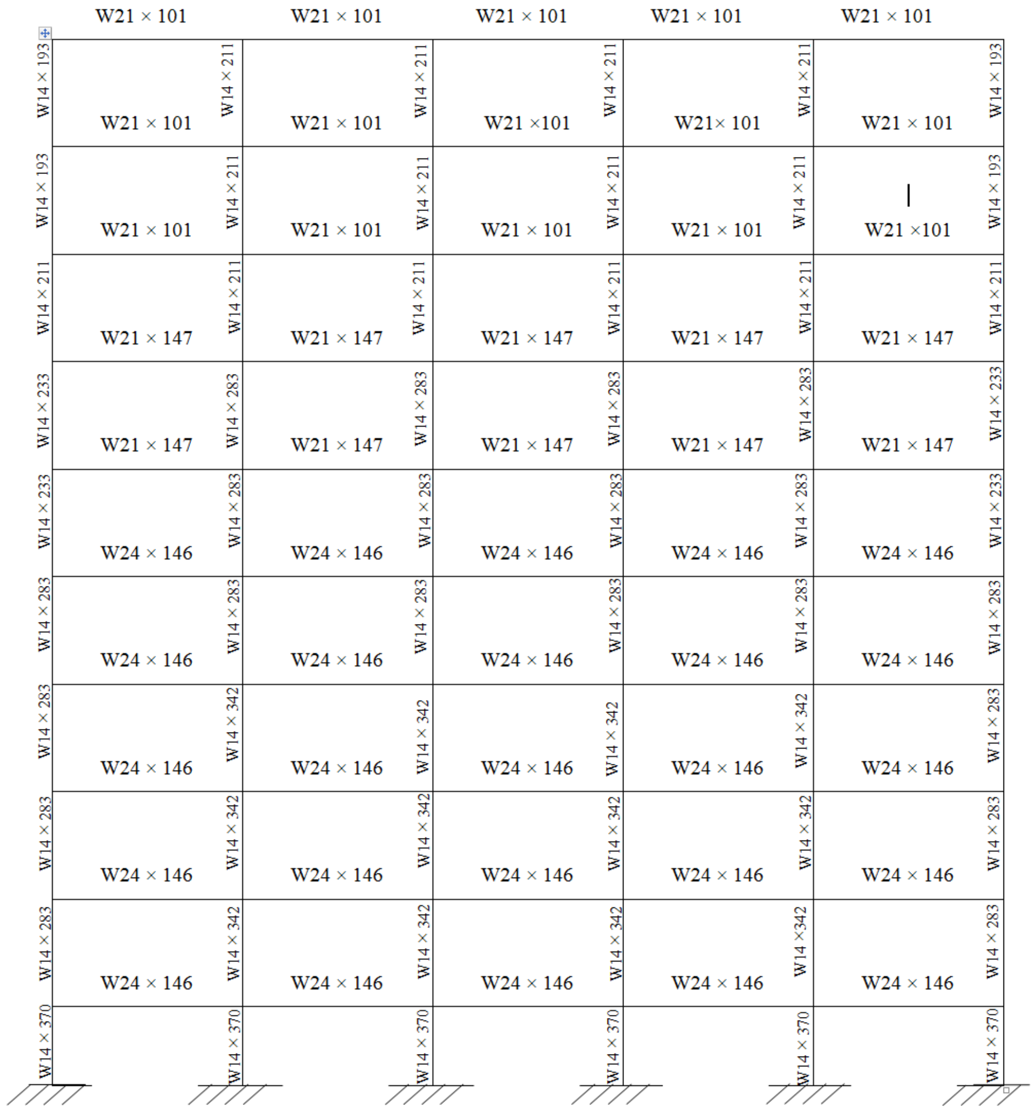
Structural frame with energy dissipating devices a) Energy Dissipating System in all bays (AO Case) b) Energy Dissipating System in inner - outer bays (IO Case) c) Energy Dissipating System in outer - outer bays (OO Case)



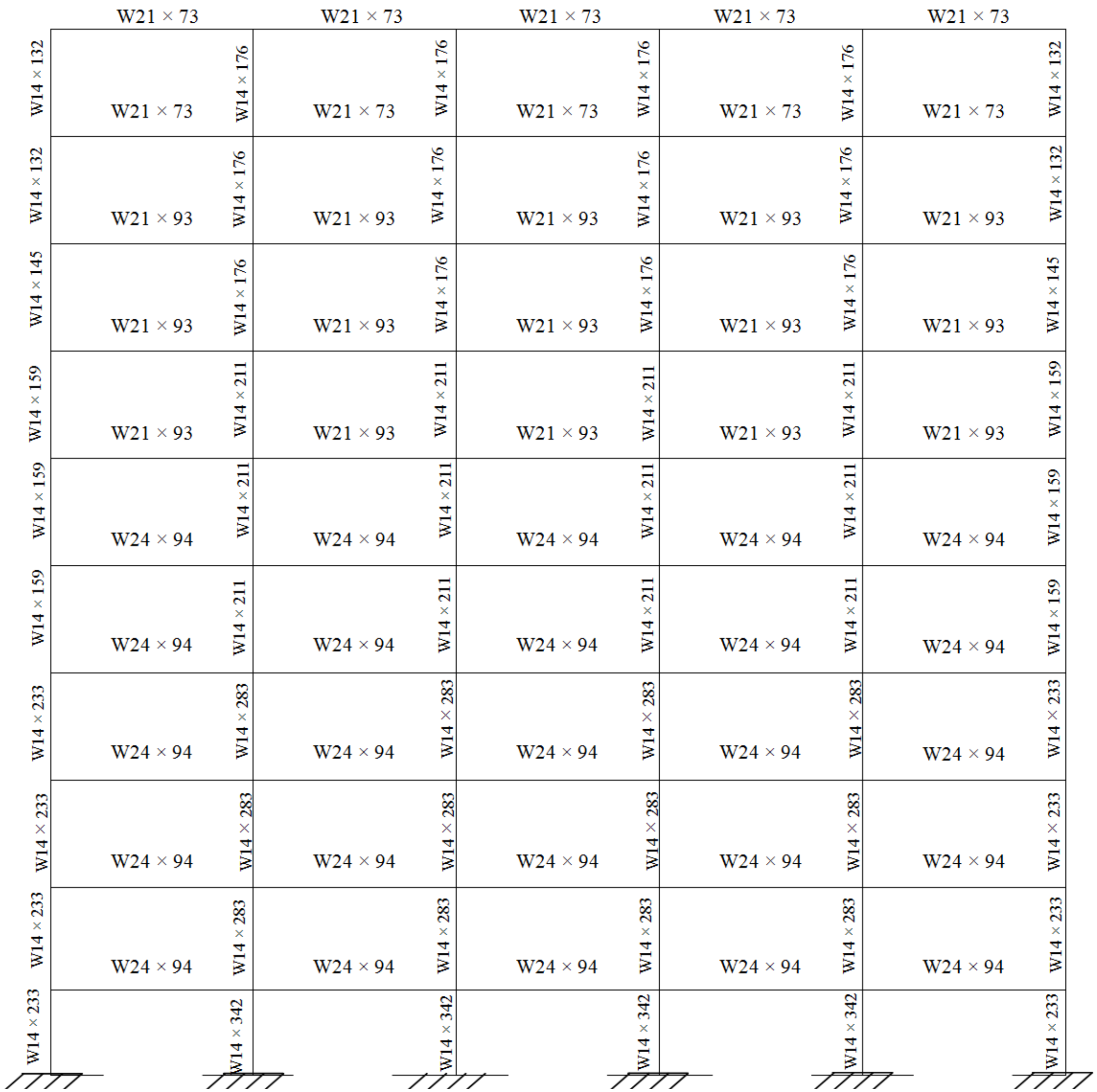
Schematic diagram of MSMRF with (a) BRB on both sides of CB (b) VFD on both sides of CB (c) HDS on both sides of CB (d) AHDS on both sides of CB (e) BRB + VFD on both sides of CB (f) BRB + HDS on both sides of CB (g) BRB + AHDS on both sides of CB

Structural Systems

Sr. No.	Structural Configuration	Abbreviations
1	Steel Moment Resisting Frame (BARE)	SMRF (Bare)
2	Steel Moment Resisting Frame with masonry infill wall	SMRF (Soft)
3	Modified SMRF with BRB in all bays (BRB AO)	MSMRF + BRB AO
4	Modified SMRF with BRB in Inner – Outer Bays (BRB IO)	MSMRF + BRB IO
5	Modified SMRF with BRB in Outer – Outer Bays (BRB OO)	MSMRF + BRB OO
6	Modified SMRF with VFD in all bays and all stories (VFD AO)	MSMRF + VFD AO
7	Modified SMRF with VFD in inner-outer bays (VFD IO)	MSMRF + VFD IO
8	Modified SMRF with VFD in outer-outer bays (VFD OO)	MSMRF + VFD OO
9	Modified SMRF with HDS in all bays (HDS AO)	MSMRF + HDS AO
10	Modified SMRF with HDS in Inner – Outer Bays (HDS IO)	MSMRF + HDS IO
11	Modified SMRF with HDS in Outer – Outer Bays (HDS OO)	MSMRF + HDS OO
12	Modified SMRF with AHDS in all bays (AHDS AO)	MSMRF + AHDS AO
13	Modified SMRF with AHDS in Inner – Outer Bays (AHDS IO)	MSMRF + AHDS IO
14	Modified SMRF with AHDS in Outer – Outer Bays (AHDS OO)	MSMRF + AHDS OO
15	Modified SMRF with BRB + VFD in all bays (BRB+ VFD) AO	MSMRF + (BRB+VFD) AO
16	Modified SMRF with BRB + VFD in Inner - Outer bays (BRB+VFD) IO	MSMRF + (BRB+VFD) IO
17	Modified SMRF with BRB + VFD in Outer - Outer bays (BRB+VFD) OO	MSMRF + (BRB+VFD) OO
18	Modified SMRF with BRB + HDS in all bays (BRB+HDS) AO	MSMRF + (BRB+HDS) AO
19	Modified SMRF with BRB + HDS in Inner - Outer bays (BRB+HDS) IO	MSMRF + (BRB+HDS) IO
20	Modified SMRF with BRB + HDS in Outer - Outer bays (BRB+HDS) OO	MSMRF + (BRB+HDS) OO
21	Modified SMRF with BRB + AHDS in all bays (BRB+AHDS) AO	MSMRF + (BRB+AHDS) AO
22	Modified SMRF with BRB + AHDS in Inner - Outer bays (BRB+AHDS) IO	MSMRF + (BRB+AHDS) IO
23	Modified SMRF with BRB + AHDS in Outer - Outer bays (BRB+AHDS) OO	MSMRF + (BRB+AHDS) OO

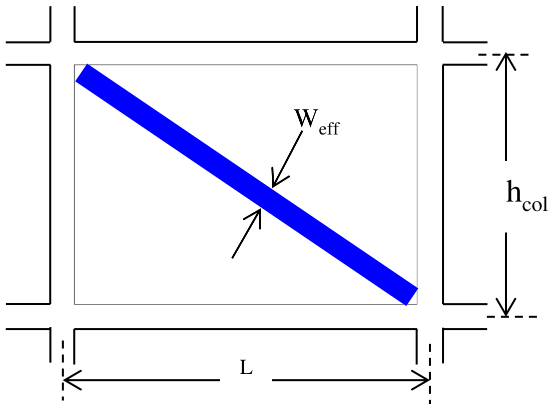


Structural Frame without EDD



Modified Structural Frame

Modeling of Wall Strut



$$A_e = W_{eff}\ t$$

$$W_{eff} = 0.175\left(\lambda_h h_{col}\right)^{-0.4} r_m$$

where,

$$\lambda_h = \sqrt[4]{\frac{E_m t \sin 2\theta}{4 E_c I_c h_m}}$$

$$\theta = \tan^{-1}\frac{h_m}{L}$$

λ_h	= Coefficient used to determine equivalent width of infill strut
h_{col}	= Column height between center line of beams
h_m	= Height of infill panel
E_c	= Modulus of elasticity of frame material
E_m	= Modulus of elasticity of infill material
I_c	= Moment of Inertia of Column
r_m	= Diagonal Length of Infill Panel
t	= Thickness of infill panel and equivalent strut
L	= Length of infill panel

Effective width of wall

Floor	L (mm)	E_c (N/mm^2)	t (mm)	θ (Deg)	sin2θ	E_m (N/mm^2)	I_c (mm^4)	h_m (mm)	λ_h	h_{col} (mm)	r_m (mm)	W_{eff} (mm)
Floor 0 to 3	6000	200000	230	26.56	0.80	5500	1.42E+09	3000	0.00073	3500	6800	830
Floor 4 to 6	6000	200000	230	27.32	0.82	5500	791000000	3100	0.00085	3500	6800	780
Floor 7 to 9	6000	200000	230	28.07	0.83	5500	266000000	3200	0.00111	3500	6800	700

Earthquake Records

Earthquake Records	Year	Earthquake record description	Recording Direction / Component	Peak Ground Acceleration (g)	Scale
Bhuj, India	2001	Ahmedabad, India	N 78 E	0.31	3.43
Chamba, India	1995	Chamba, India	N 00 E	0.47	9.85
Chamoli, India	1999	Gopeshwar, India	N 20 E	0.42	1.14
Ind- Burma Border	1988	Bokajan, India	S 56 E	0.22	4.48
Imperial Valley, CA	1979	USGS 952, El Centro Array 5	S 40 E	0.41	0.79
Northridge	1994	USC, 90091 LA, Saturn St.	N 20 E	0.24	3.65
Uttarkashi, India	1991	Bhatwari, India	N 85 E	0.34	3.47

Buckling Restrained Braced Frame

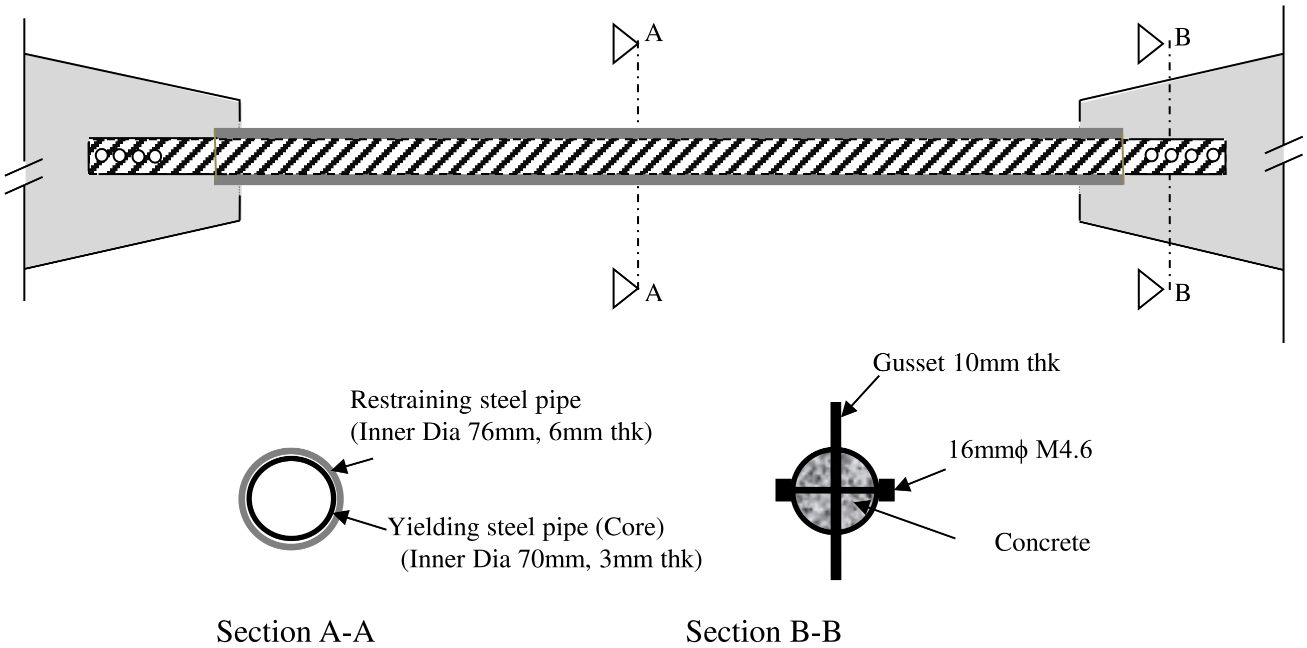
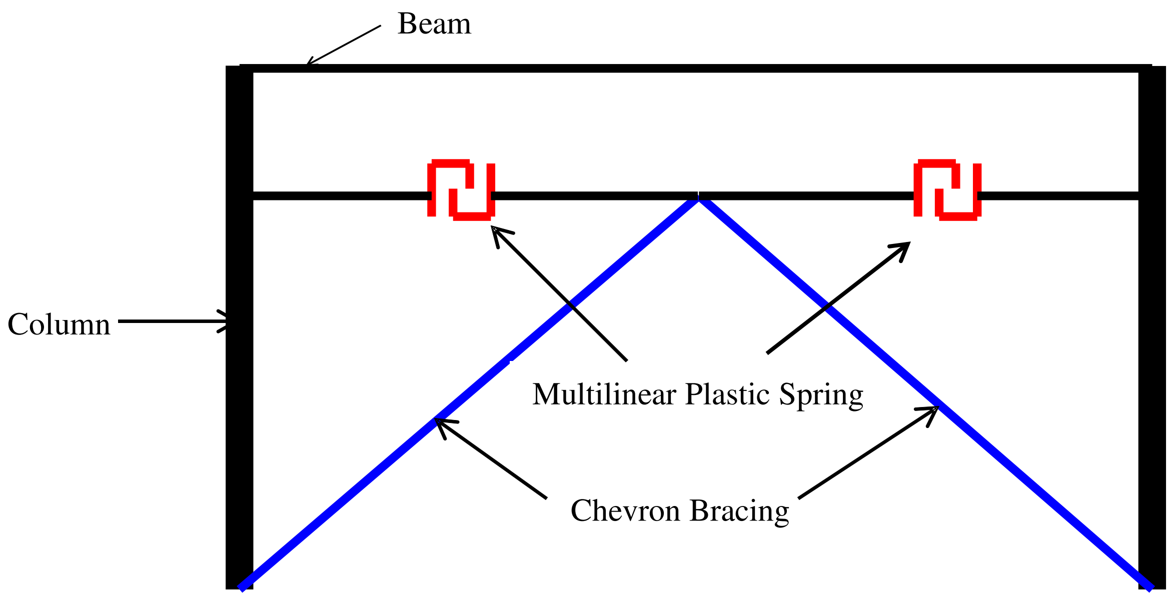


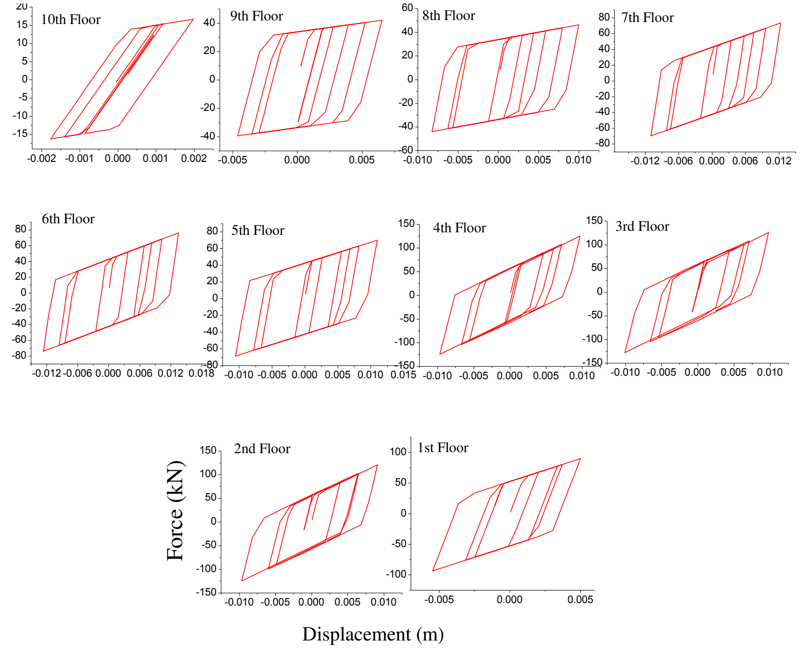
Figure 3.18 Buckling restrained brace

*** In this research work, BRBs of three variations (Strength wise) are used. Dimensions shown here are of the strongest BRB which is used in bottom four floors.

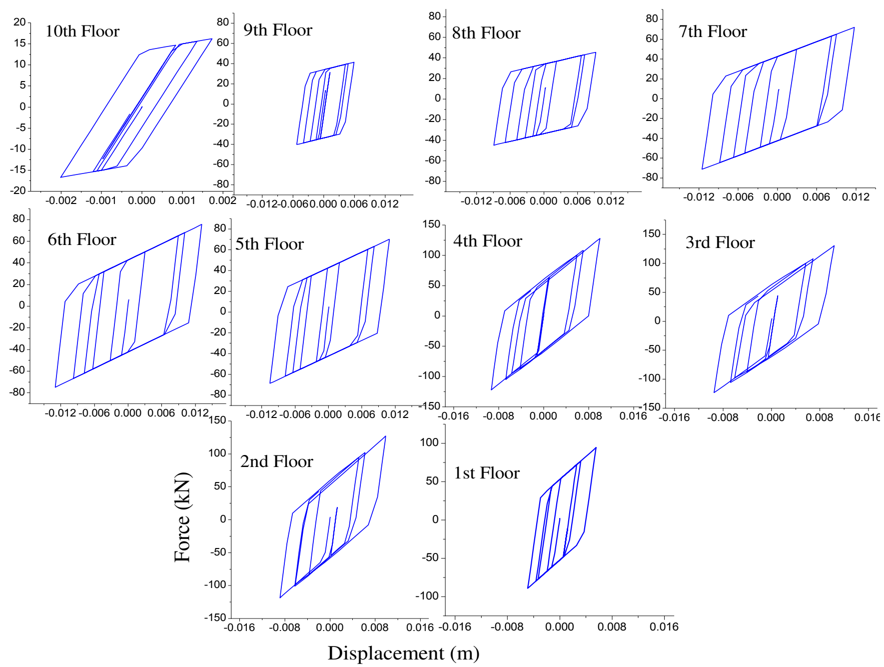
Buckling Restrained Braced Frame



Modeling of BRB placed on both sides of CB



Device Hysteresis loop for BRB installed in MSMRF (Tension side)

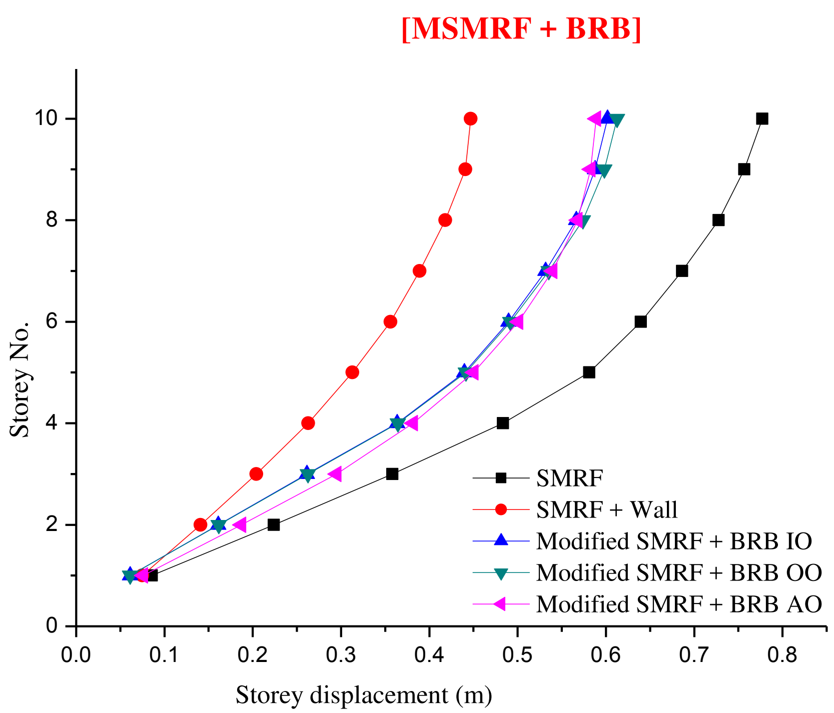


Device Hysteresis loop for BRB installed in MSMRF (Compression side)

Dynamic properties of structural configurations with BRB

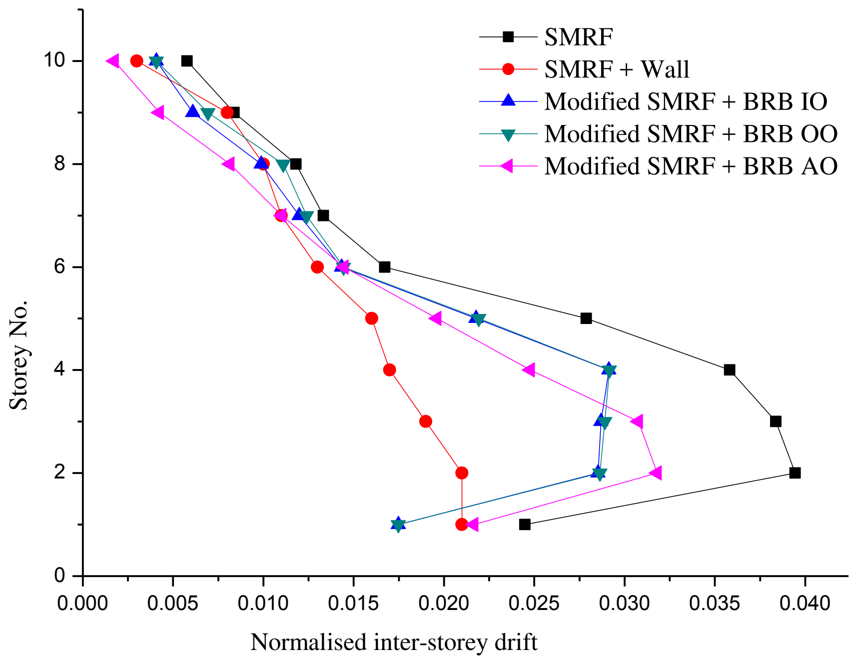
Sr. No.	Structural configuration	1st mode period (sec)	1st mode frequency (cyc/sec)	1st mode damping ratio	Damping coefficient (kN-s/mm)
1	Steel Moment Resisting Frame (BARE)	1.44	0.69	5.13	N/A
2	Steel Moment Resisting Frame with masonry infill wall	0.81	1.24	6.23	N/A
3	Modified Steel Moment Resisting Frame	1.95	0.51	3.11	N/A
4	Modified SMRF with BRB in All bays (BRB AO)	1.74	0.58	4.31	N/A
5	Modified SMRF with BRB in Inner – Outer Bays (BRB IO)	1.73	0.57	9.12	N/A
6	Modified SMRF with BRB in Outer – Outer Bays (BRB OO)	1.73	0.57	9.03	N/A

Storey displacement along the height of the structure



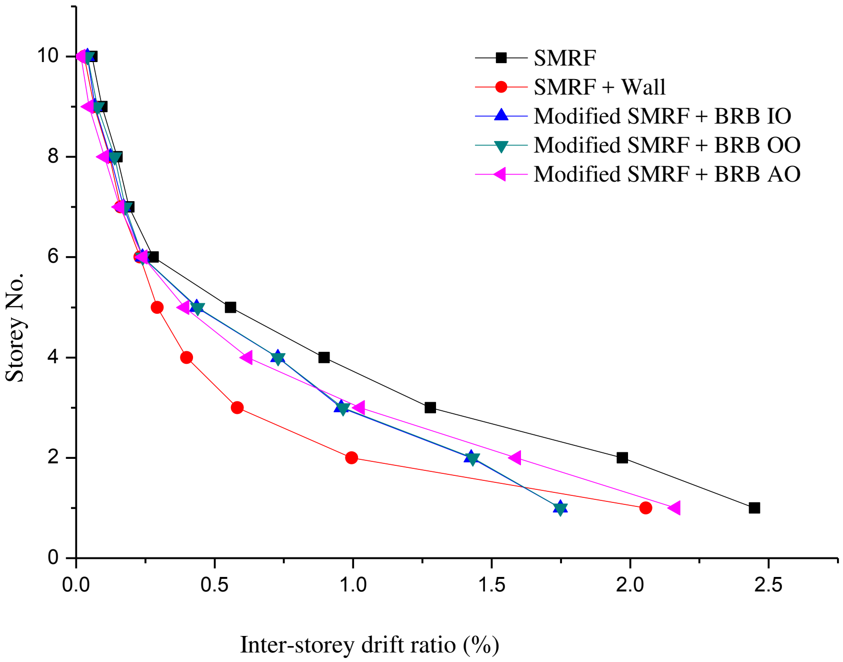
Inter-storey drift along the height of the structure

[MSMRF + BRB]



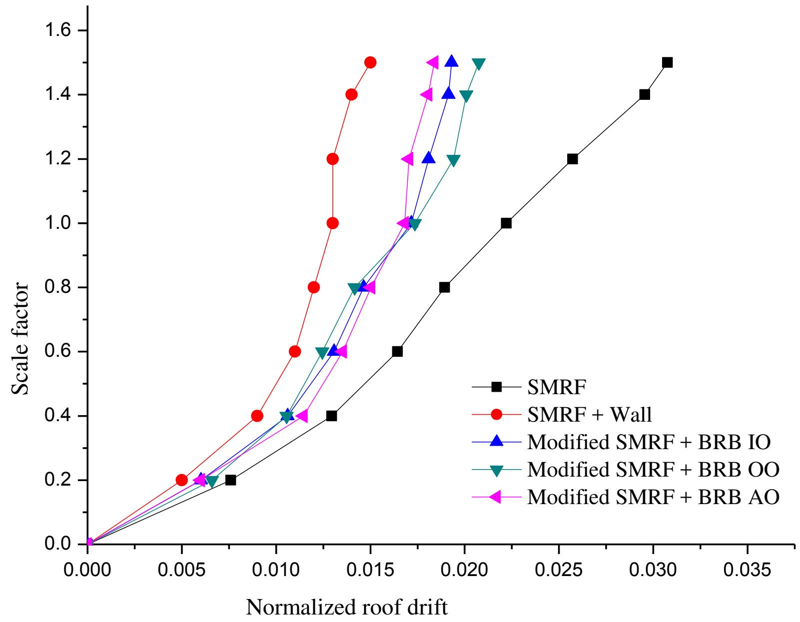
% Inter-storey drift ratio with respect to scale

[MSMRF + BRB]



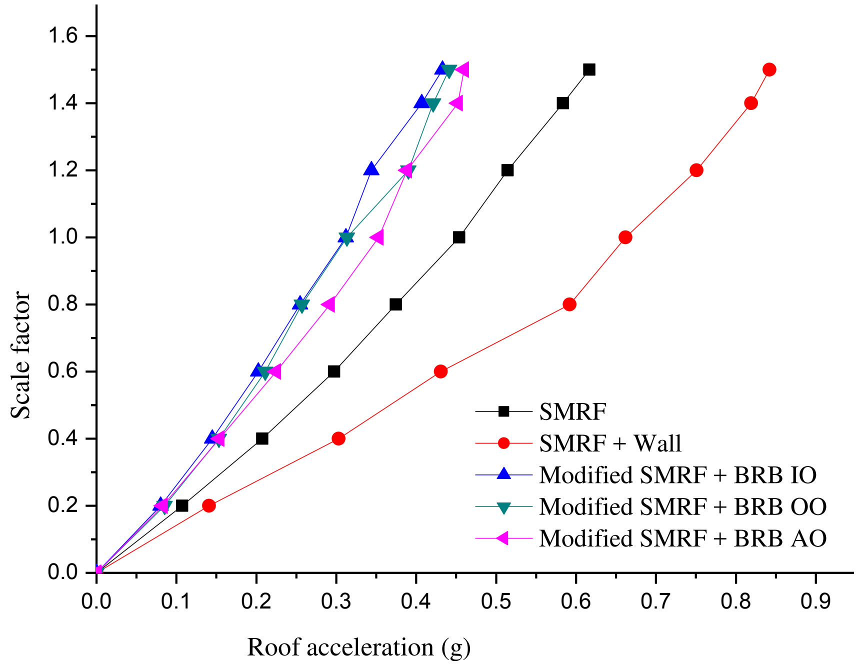
Roof drift with respect to scale factor

[MSMRF + BRB]



Roof acceleration with respect to scale factor

[MSMRF + BRB]



Base shear with respect to scale factor

[MSMRF + BRB]