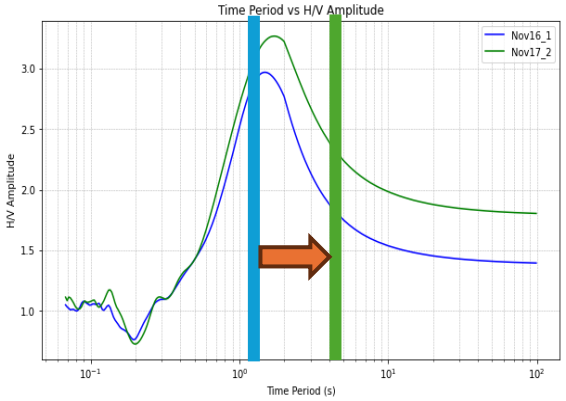
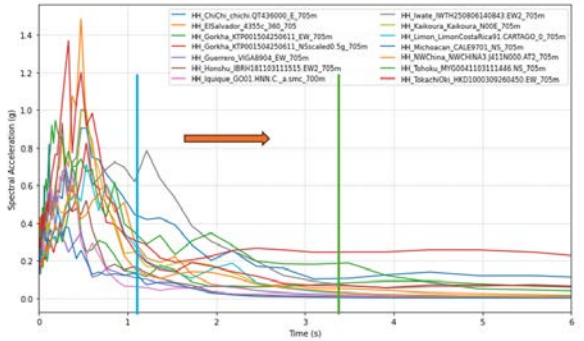
Site exploration for the design of base isolated structures based on microtremor survey





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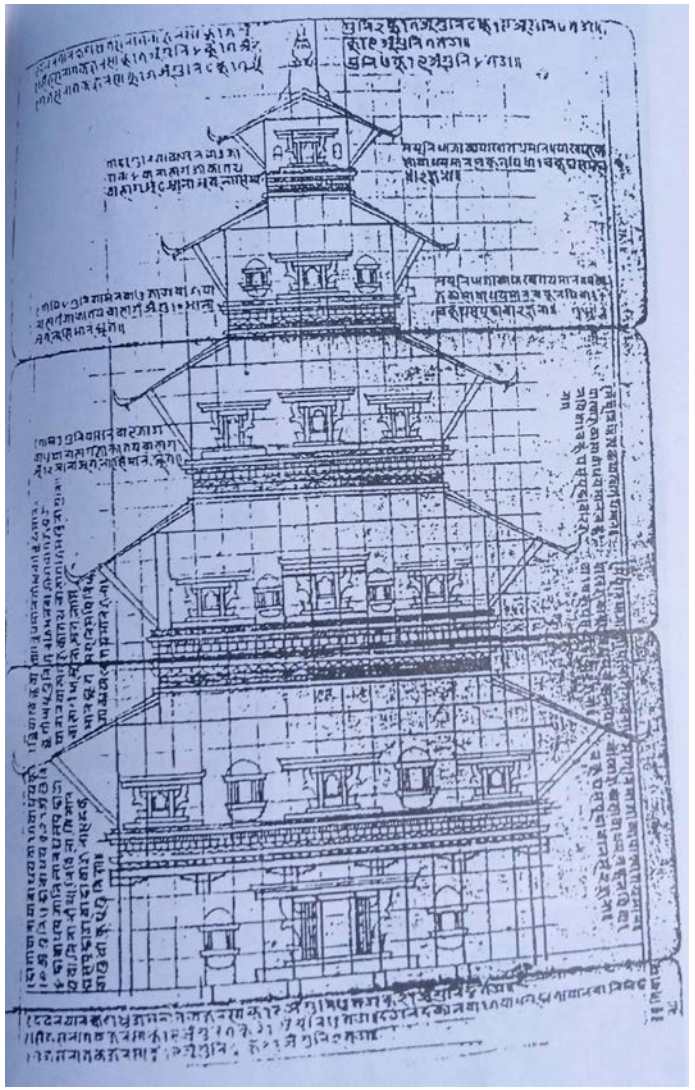
In Nepal, there exist traditional structures that exhibit base isolation effect, most notable, the Nyatpola Temple in Bhaktapur, built by King Bhupatindra Malla in 1702 CE



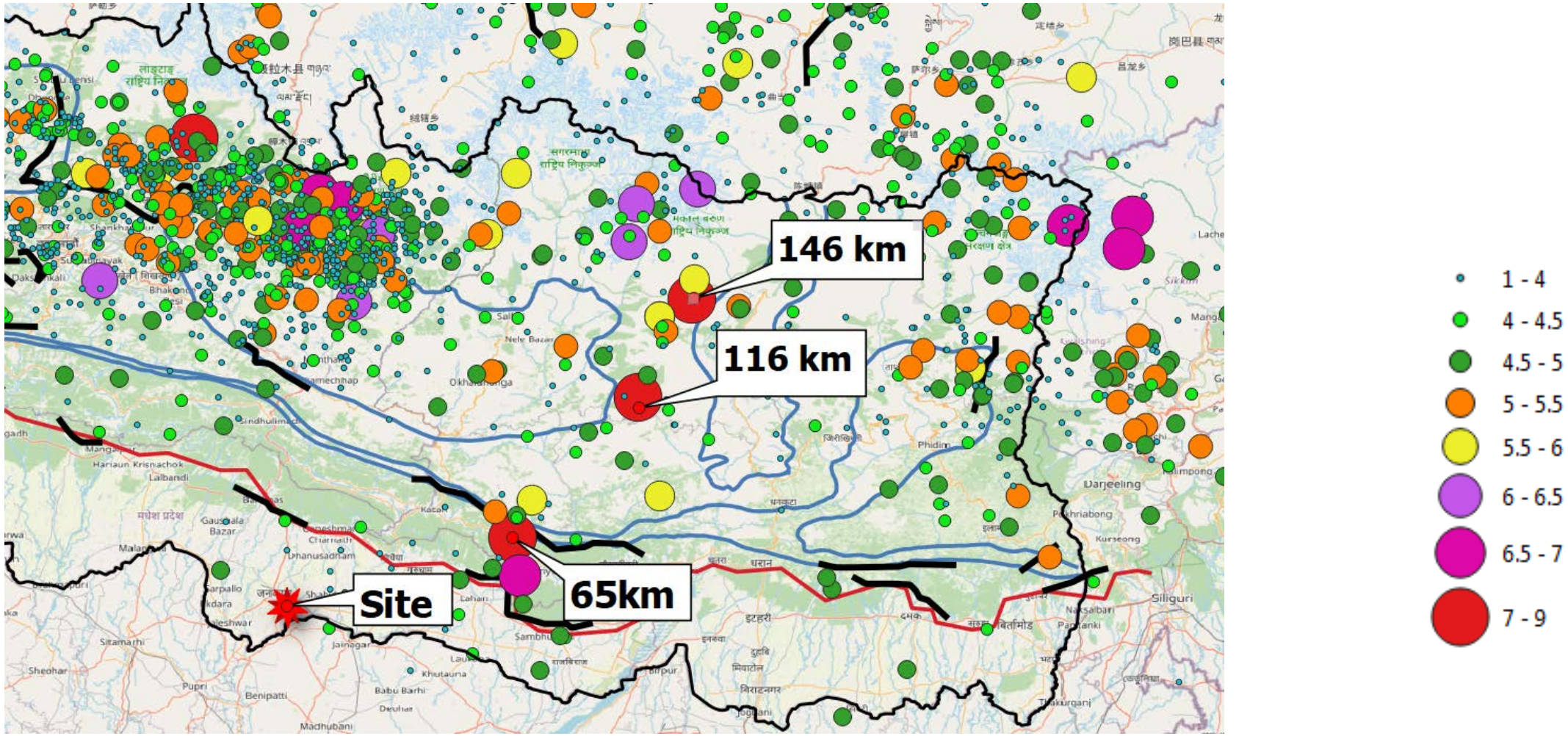
Survived 4 major earthquakes:

1767, Mw7.9
1833, Mw8.0
1934, Mw 8.4
2015 , Mw 7.8

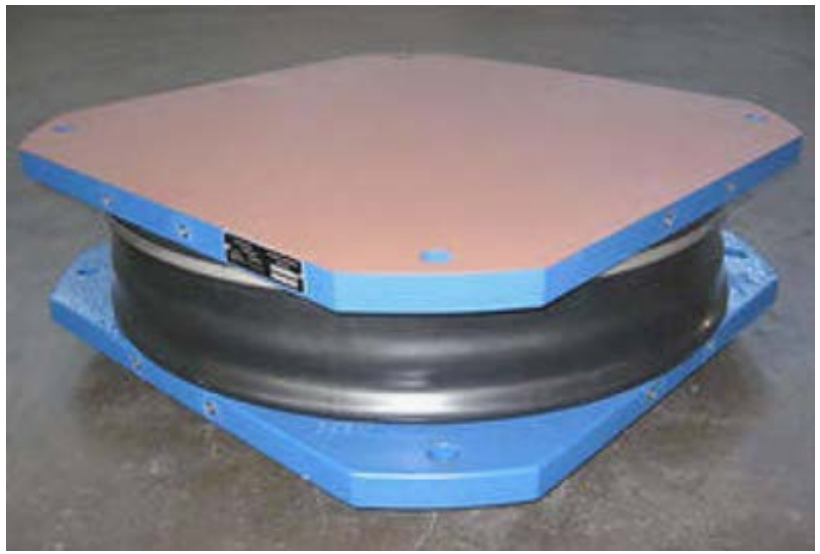
Construction drawing of Nyatpola from around 1700. Built between December 1701 to July 1702 CE

Motivation | Method | Results

BTCC site and the location of the great Mw 8.2 Nepal-Bihar earthquake in 1934, along with known faults. Researchers have different estimates for the epicenter, which range from 65km to 146 km from the BTCC site.



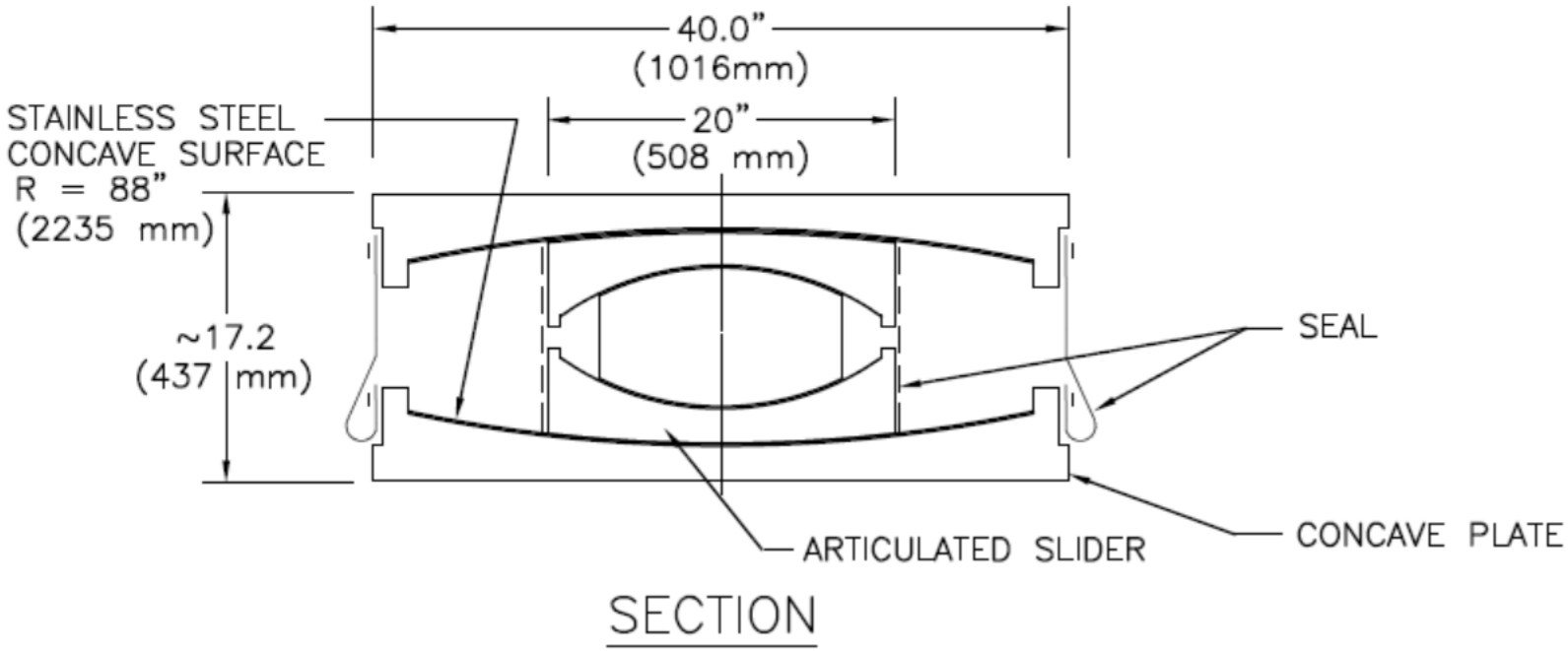
Picture C: Example Triple Pendulum bearings with 4 bottom shear-lugs connected.

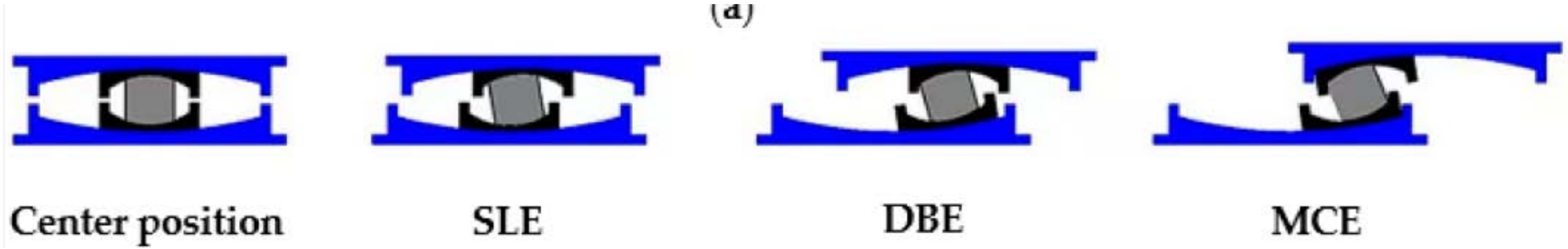


Description of Triple friction pendulum base isolator

it reduces earthquake forces by increasing the natural period of the building and dissipating energy through friction.

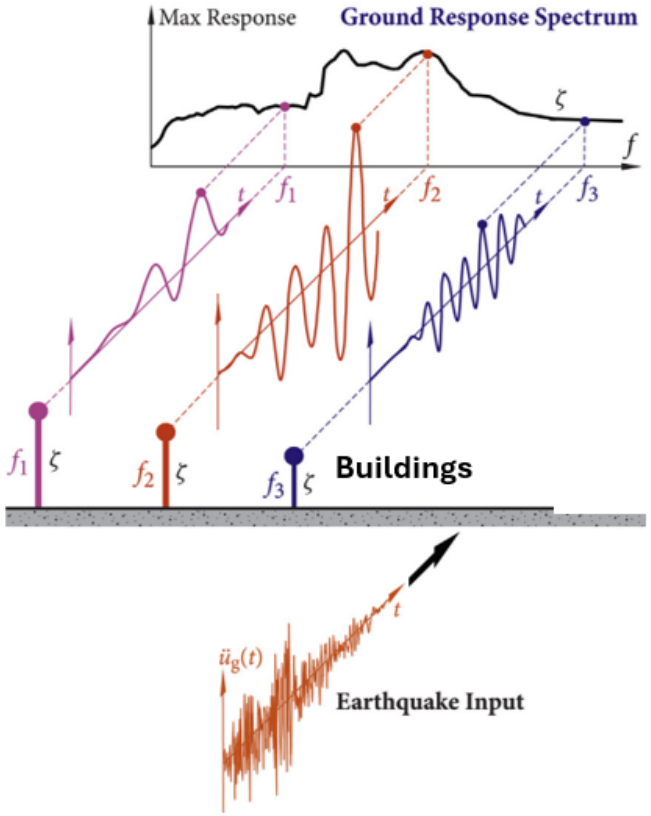
Motivation → Method → Results

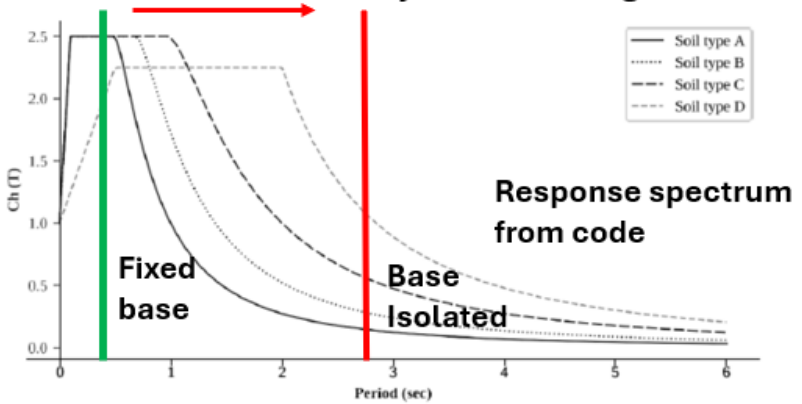

40.0"
(1016mm)
20"
(508 mm)
STAINLESS STEEL
CONCAVE SURFACE
R = 88"
(2235 mm)
~17.2
(437 mm)
SEAL
ARTICULATED SLIDER
CONCAVE PLATE
SECTION

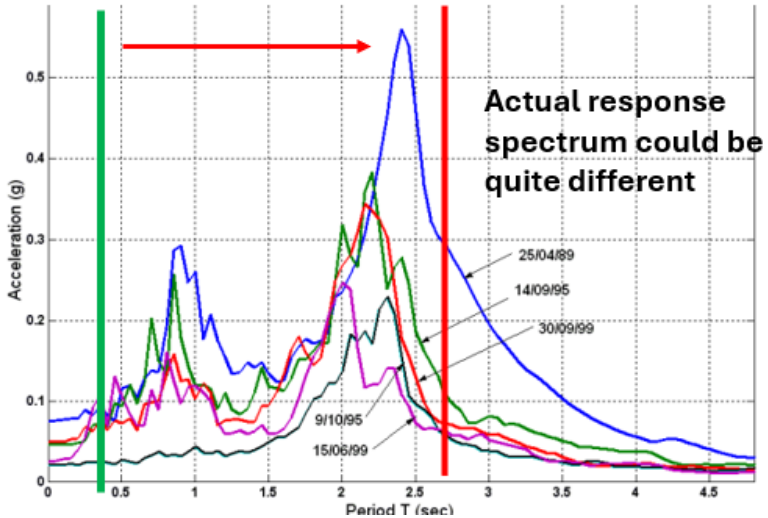

(a)
Center position
SLE
DBE
MCE

Necessity of site-specific response spectrum

Site specific response spectrum is needed to justify the use of base isolators by demonstrating that long period amplification does not occur.







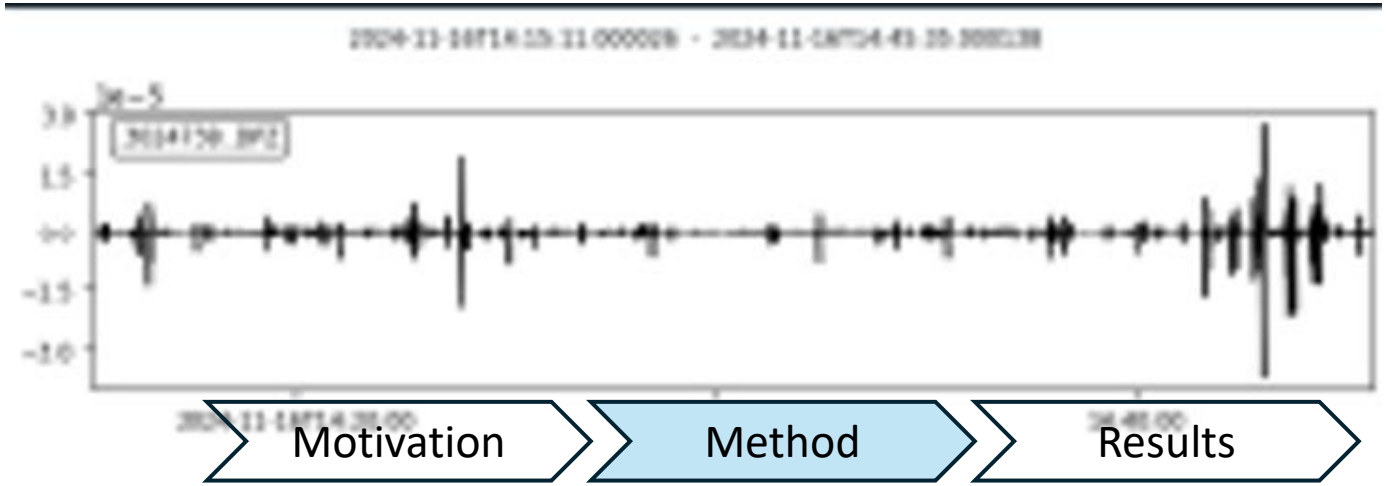
Schematic sketch only, NOT ACTUAL data

- ❑ Standard code spectra may not represent local soil conditions.
- ❑ Site-specific response spectra capture the actual amplification caused by local geology.
- ❑ The figure is schematic and illustrates why local site effects matter.
- ❑ Site-specific spectra lead to safer and more reliable structural design

Drilled up to 60m depth for site specific response spectrum development

Motivation | Method | Results

Microtremor survey with circular array with radii 5m, 25m, 50m, 100m, 150m



Motivation → Method → Results

- Ambient vibrations were recorded using circular arrays with radii of 5, 25, 50, 100, and 150 m.
- Different array sizes allow investigation of different depths.
- The survey is non-invasive, economical, and suitable for urban environments.
- Microtremor surveys efficiently estimate deep subsurface shear-wave velocity.

These 14 ground motions where used to perform the 1-D non-linear dynamic ground motion analysis based on Hybrid Hyperbolic (HH) method using PySeismoSoil. This determines how the input ground motion is modified by the soil mass above the bedrock.

SN	Event	Year	Country	Magnitude (Mw)	Hypocentral Distance (km)	Identifier	Original PGA in g		
							EW	NS	Vert.
1	Gorkha	2015	Nepal	7.8	85	KTP	0.262	0.152	0.127
2	Honshu	2011	Japan	7.9		IBRH18	0.617	0.312	0.178
3	Iwate-Miyagi	2008	Japan	6.9	8.3	WITH	1.458	1.162	3.945
4	Kaikoura	2016	New Zealand	7.8	27.7	WTMC	1.009	1.014	3.028
5	Tohoku	2011	Japan	9	131	MYG	1.295	2.752	1.916
6	Tokachi Oki	2003	Japan	8	69.5	HKD	0.989	0.827	0.471
7	ChiChi	1999	Taiwan	7.6	15.8	TCU129	1.001	0.623	0.341
8	Limon	1991	Costa Rica	7.7	22	CDMG QL91A059	0.257	0.216	0.125
9	Guerrero	1989	Mexico	7.1	21.8	VIGA8904	0.354	0.129	0.317
10	Michoacan	1997	Mexico	7.1	36.9	CALE9701	0.357	0.422	0.405
11	El Salvador	2001	El Salvador	7.6	79.7	Santiago de Maria	0.702	0.864	0.431
12	Iquique	2014	Chile	8.2	171	Chusmiza	0.236	0.363	0.164
13	Jiashi	1997	China	6.1	27.7	NWChina3 Jiashi	0.274	0.300	0.384
14	Gorkha0.5g	2015	Nepal	>7.8	NA	Scaled	0.500	NA	NA

Key Message: Multiple earthquake records capture a range of possible seismic demands.

Vs profile was obtained to a depth of 767m, with Vs30 = 238m/s

Vs(m/s)	Depth (m)
167.4	0.0
167.4	11.7
316.4	11.7
316.4	26.5
371.0	26.5
371.0	89.3
393.8	89.3
393.8	90.7
418.0	90.7
418.0	151.6
426.4	151.6
426.4	153.9
448.2	153.9
448.2	155.3
510.1	155.3
510.1	216.8
604.1	216.8
604.1	704.2
767.4	704.2

Vs30 = 238m/s

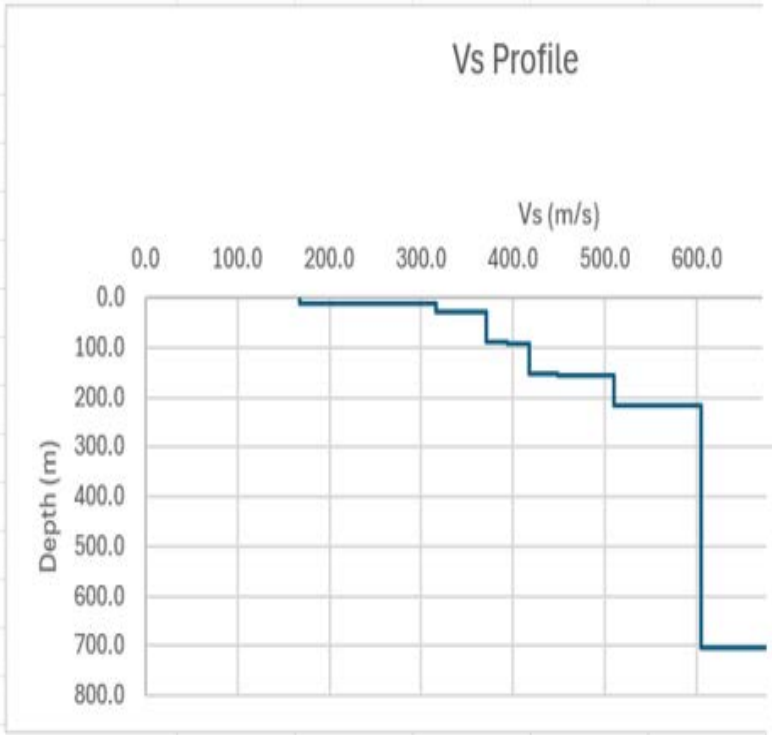


Table 2. NEHRP Soil Types based on shear wave velocity of upper 30 m.

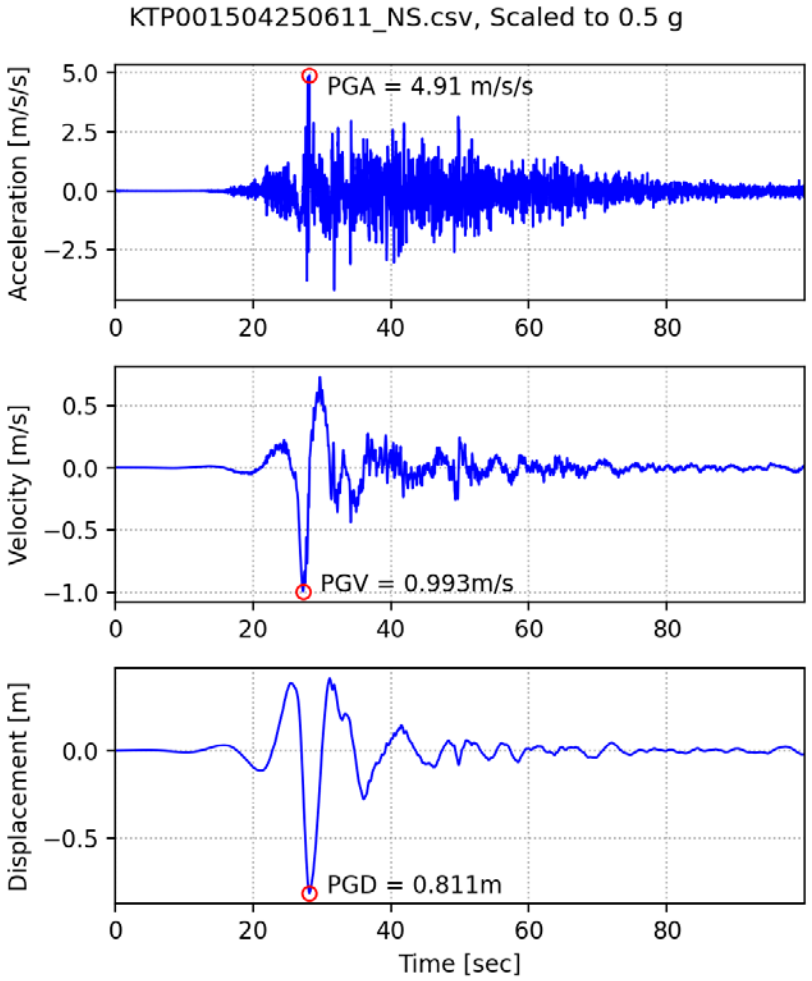
Soil Types	Rock/ Soil Description	Average shear wave velocity (V_{s30}) m/s
A	Hard rock	> 1500
B	Rock	760-1500
C	Dense soil/soft rock	360-760
D	Stiff soil	180-360
E	Soft soil	<180
F	Special soils requiring special evaluation	

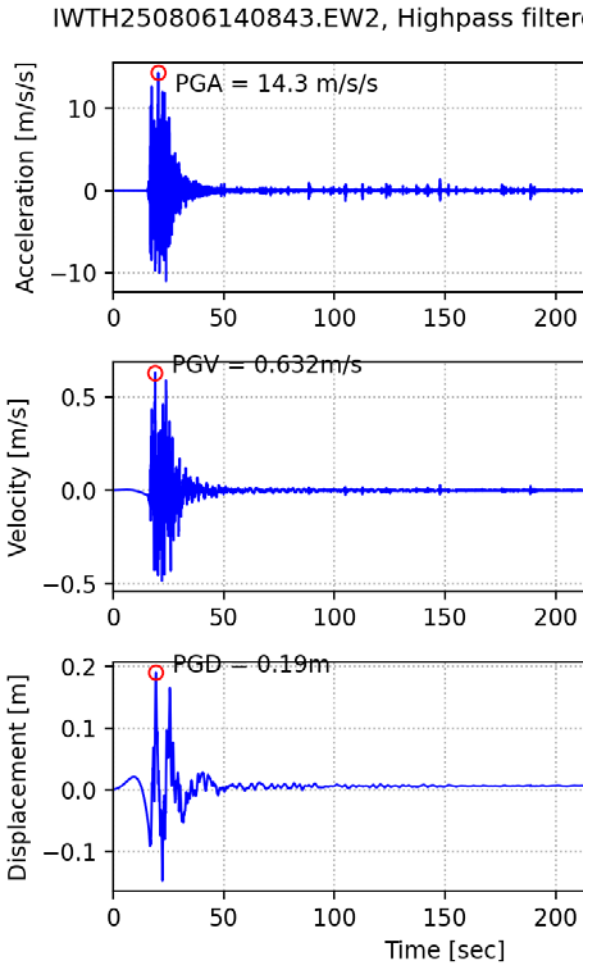
Table 2: relationship between rock materials with shear wave velocity

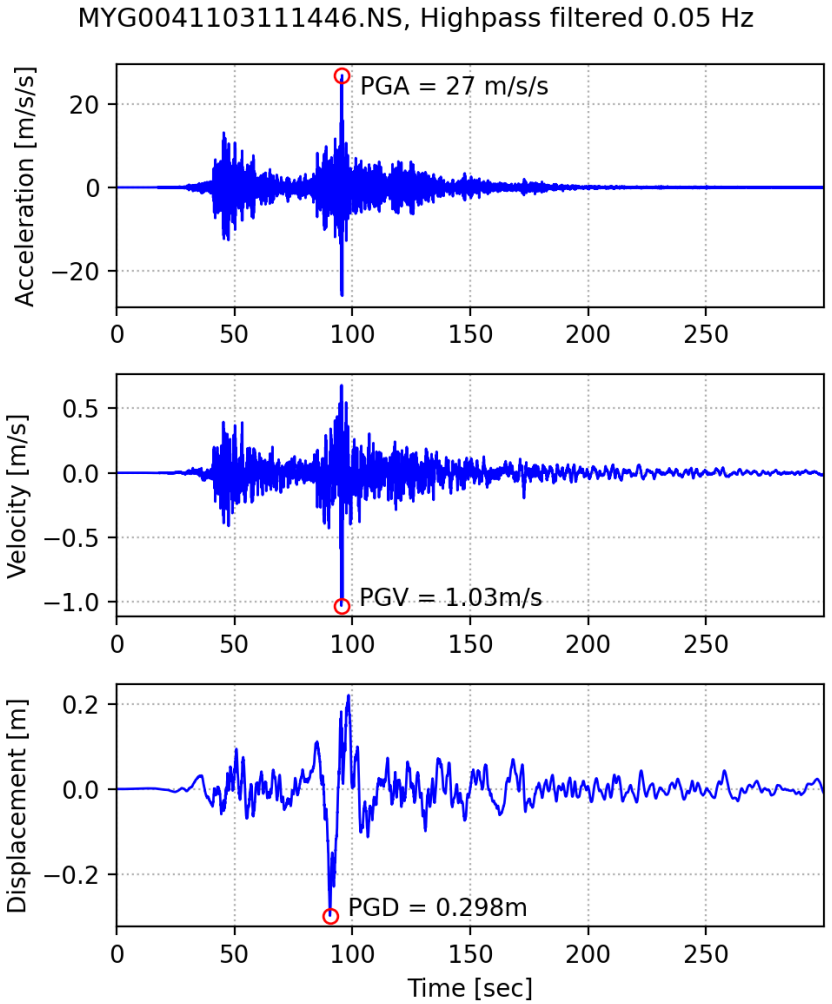
Rock Material Classification	Velocity of shear wave, Vs (m/s)
Very soft	84-107
Soft Soil	107-137
Moderately Soft Soil	137-183
Hard Soil	183-274
Very Hard Soil	274-366
Highly Wheatered Rock	366-610
Slightly Wheatered Rock	610-2743

- Inversion of the dispersion curve produced a Vs profile to 767 m depth.
- The calculated Vs30 is 238 m/s, indicating relatively soft soil conditions.
- This profile forms the basis for site-response modelling.
- Shear-wave velocity controls site amplification and earthquake response.

Example of input excitation

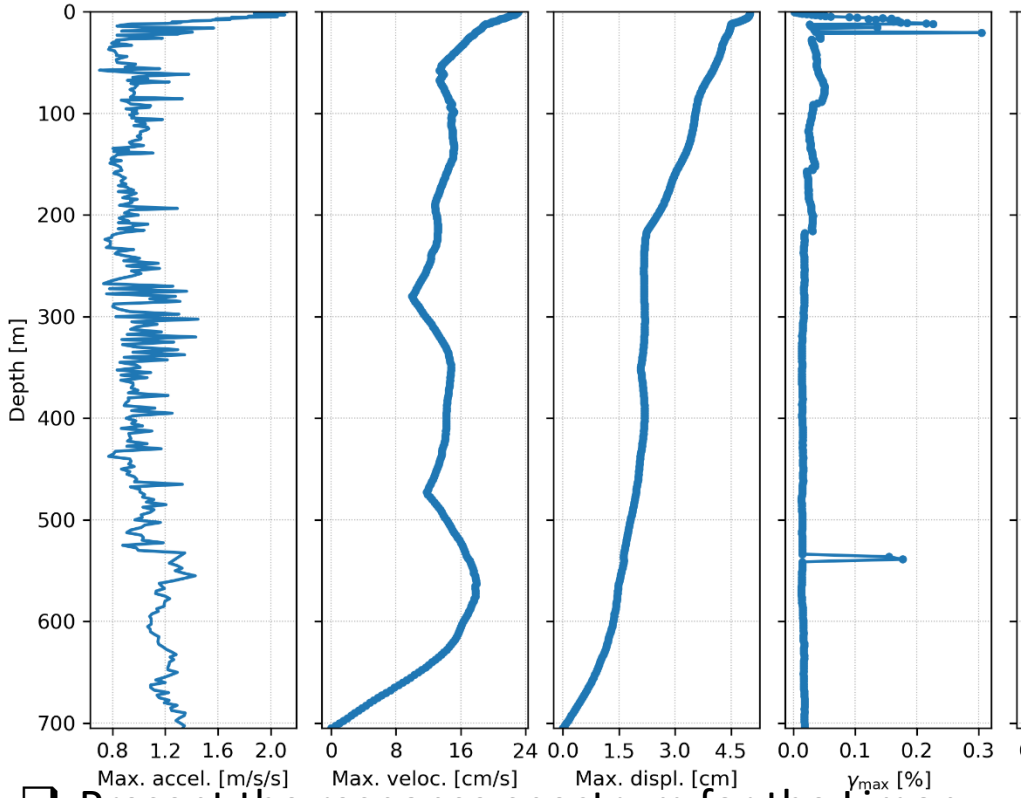






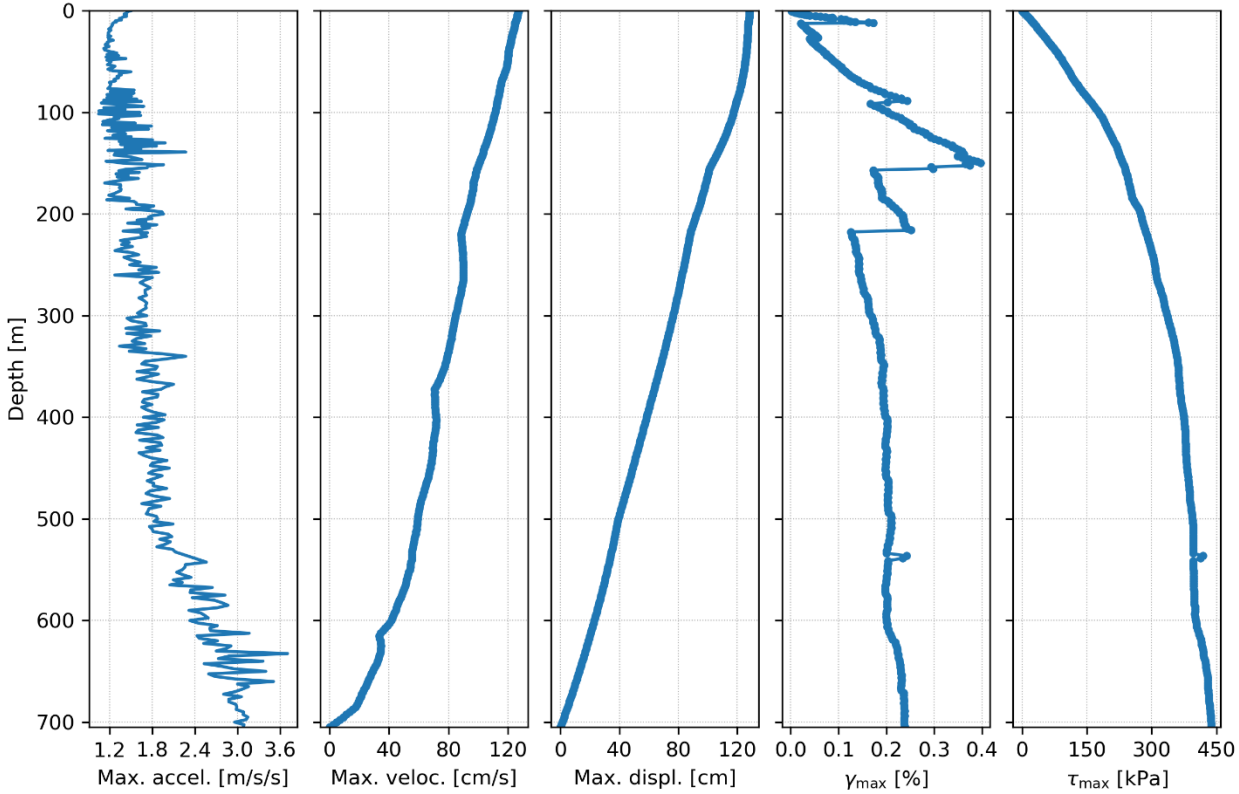
- ❑ This represents the bedrock motion before it is modified by the soil profile.
- ❑ It is the starting point for nonlinear site-response analysis.
- ❑ Input ground motions simulate realistic earthquake loading.

Limon



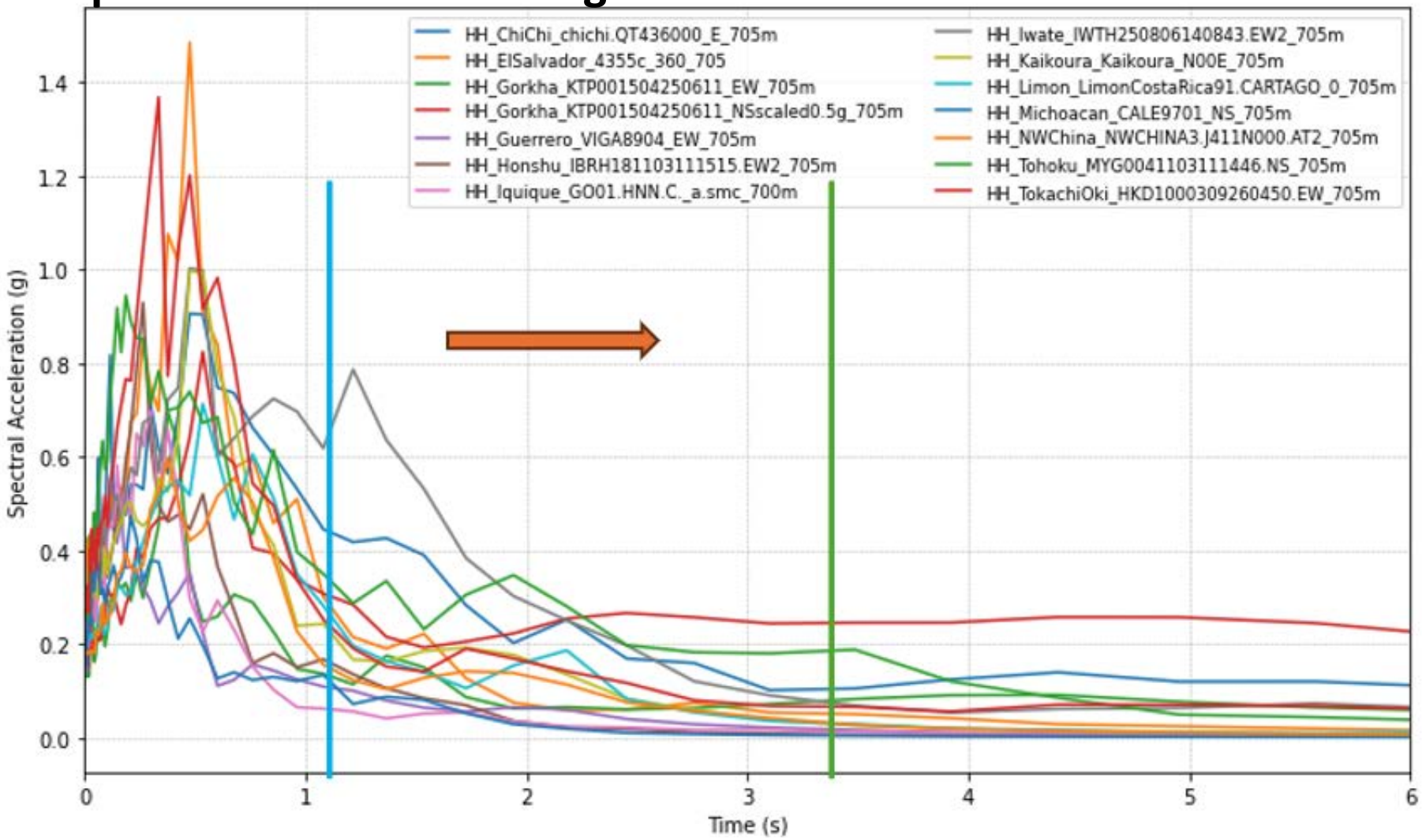
- Present the response spectrum for the Limon earthquake record.
- Compare the amplified surface motion with the input motion.
- Highlight how soil conditions modify the earthquake motion.
- Local soil significantly changes the amplitude and frequency content of ground motion.

Gorkha scaled 0.5g



- Present the scaled Gorkha earthquake results.
- Explain how scaling allows comparison with the design level of shaking.
- Discuss the resulting site-specific response spectrum.

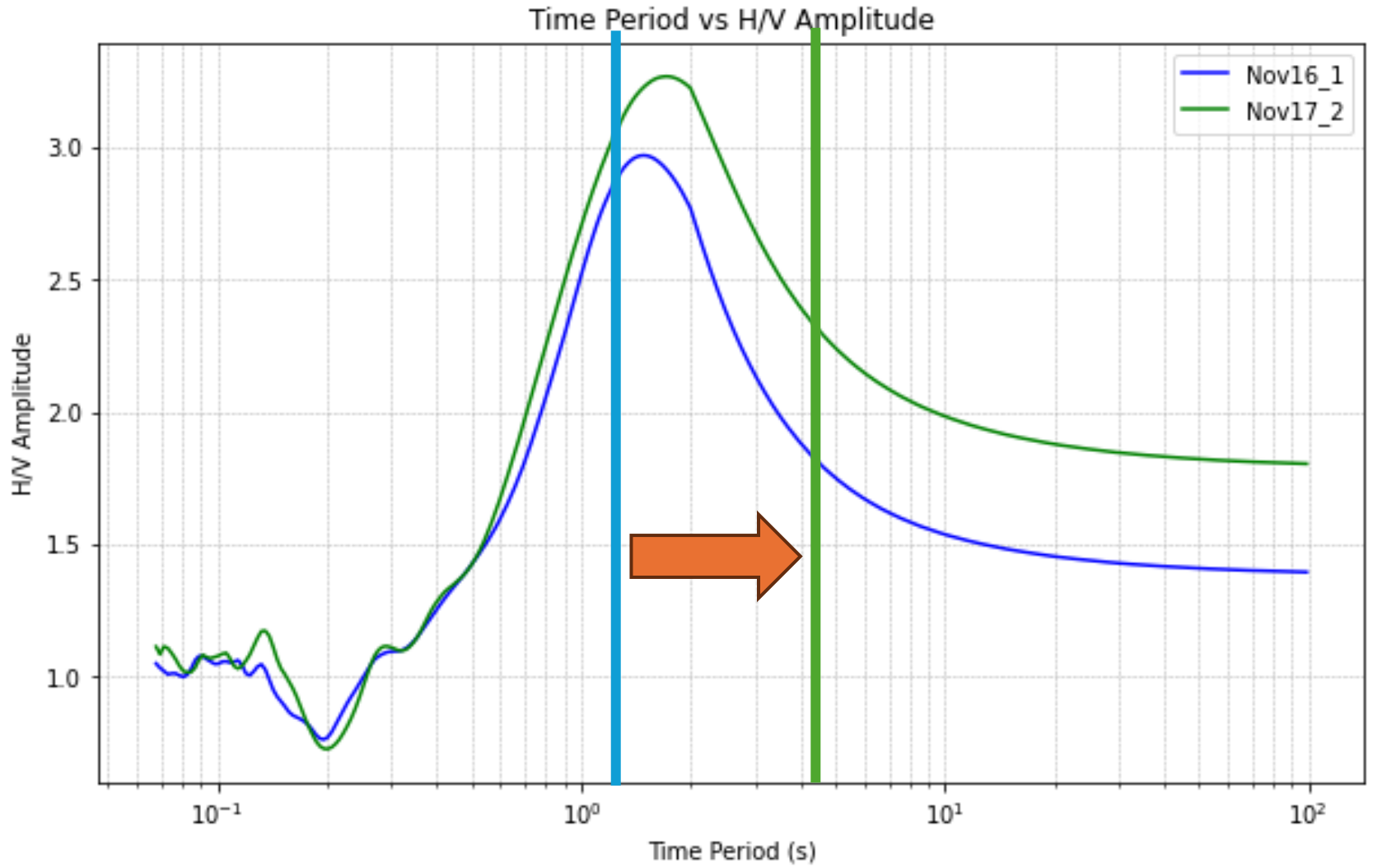
The time period is shifted, so that the time period is shifted to lower spectral acceleration range.



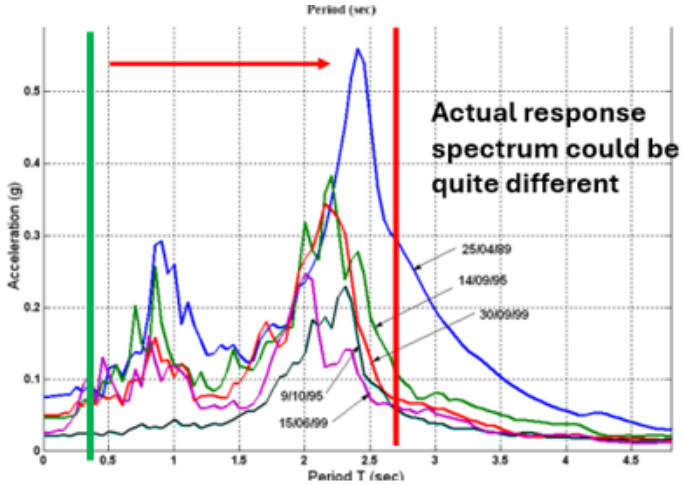
ACTUAL response spectrum for BTCC

- Base isolation increases the natural period of the structure.
- The period shifts from approximately 1.1 s to 3.7 s.
- This moves the structure away from the dominant resonance region of the ground.
- Period shifting is the main mechanism by which base isolation reduces seismic forces.

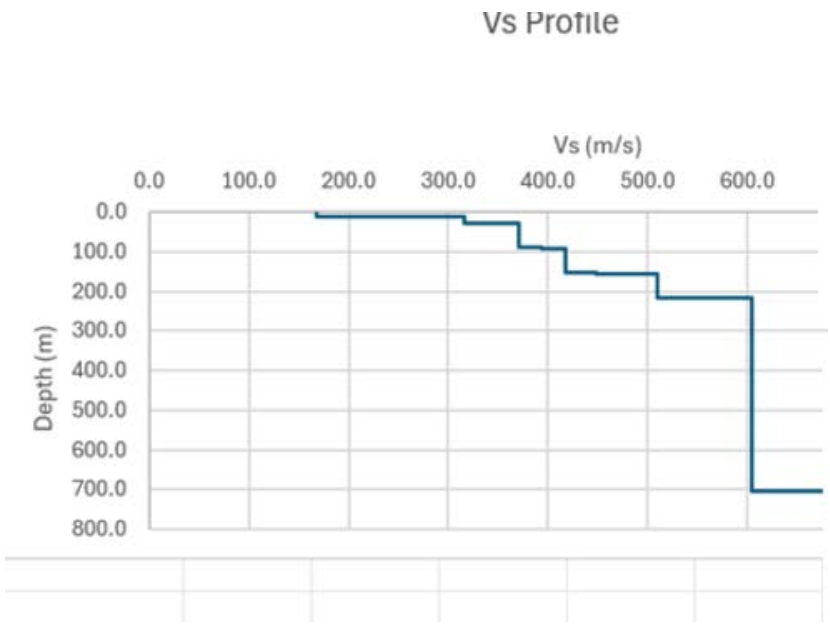
The time period is shifted away from resonant period of the ground through base isolation from (i.e. time period of 1.1 s to 3.7s.



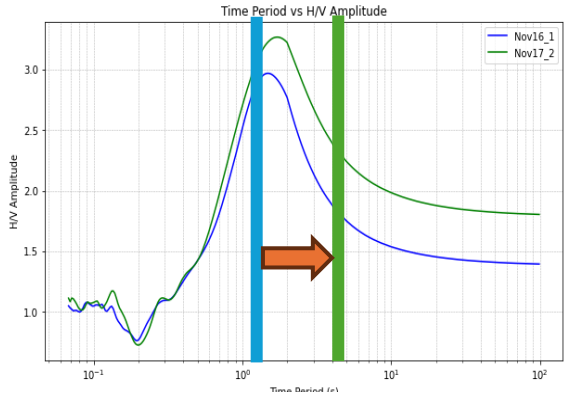
Key messages

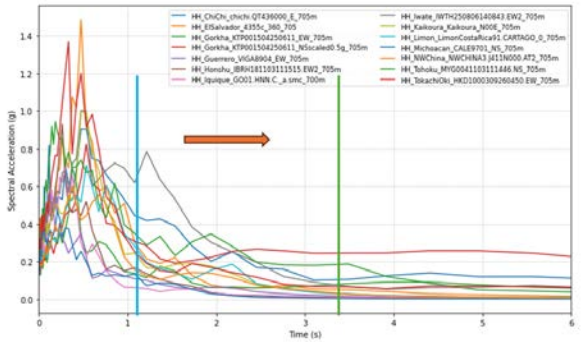


Suitability of base isolation depends on site rsponse



The microtremor survey can provide inputs for simulating site response





The HVSR curve and site specific response spectra can be used to decide the suitability of base isolation

- ❑ Suitability of base isolation depends on site response.
- ❑ Microtremor surveys provide valuable input for site-response analysis.
- ❑ HVSR curves and site-specific response spectra help engineers evaluate whether base isolation is appropriate.
- ❑ Site characterization should always precede base-isolation design.

Motivation → Method → Results