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Site classification for strong motion stations in Gujarat, India using response spectral ratio

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ABSTRACT

We propose a site classification scheme of strong motion sites of Gujarat, India based on predominant period estimated from 5% damped mean H/V response spectral ratio following the site classification scheme of Di Alessandro et al. [1] which is an extended scheme of Zhao et al. [2]. The 23 strong motion sites in Gujarat were classified into seven classes based on predominant period of the sites. A total of 388 strong motion records from 223 earthquakes varying in magnitude between 2.5 and 5.6 are utilized for classification of the sites. Most of the records are from local earthquakes with hypocentral distance less than 50 km. Previous attempts to classify sites based on local site conditions and geology could not incarcerate the site characteristics and variability within the same geological conditions. The presented site characterization methodology is quick and inexpensive where for instance; sites with thick sedimentary column like basins can be identified quickly without invasive analysis. Also, this classification based on predominant period, which contains both velocity and thickness of resonant layers in its definition, is better than site classification based on Vs30 criteria which captures the site response for only 30 m. The site effects captured in this classification scheme can be utilized in the ground motion prediction equations developed for the region.

1. Introduction

Local site conditions strongly affect the ground motion modifying the amplitude, frequency and duration of the incoming seismic waves [3]. Therefore, the estimation of local site effects is very important in seismic hazard studies. Many researchers have proposed empirical and numerical techniques [4–9], but usually the national building codes [10,11] need simple parameters to account for site effects. Nowadays, the average shear-wave velocity of the first 30 m of the soils (hereinafter V_{S30}) is widely used to classify the sites [10,12] and in seismic microzonation studies. Also the next generation attenuation relationships (NGA), developed for active tectonic regimes, use the V_{S30} values to compensate the site effects [13–16].

Nevertheless, the use of V_{S30} is largely debated between seismologists and engineers, because the method has some advantages but also strong limitations. An estimate of V_{S30} is possible through direct geophysical (among others: multichannel analysis of surface waves, down- and crossholes, 2D-array microtremor measurements, reflection and refraction methods) and indirect geotechnical investigation (among others NSPT, DMST). However, these methods are often expensive and invasive; moreover, they require good practice during the surveys and experience on data interpretation to produce meaningful results. Also, the V_{S30} cannot completely reproduce the behavior of sedimentary covers more than 30 m thick, such as deep basins; in this case the ground motion predictions based on V_{S30} overestimate at short periods and underestimate at longer periods [17]. Yet, being an average velocity, V_{S30} is not able to take into account the effect of velocity reversal occurring in the first 30 m of subsoil [18].

Recently, significant advances in site-classification methodology have been made for sites occupied by strong motions around the world (in particular Japan, USA, Europe, Iran and India). These sites are often classified on the basis of different and not-unique parameters: V_{S30} values, soil type, thickness of the soft sedimentary cover, geology and site natural period of resonance. Zhao et al. [2] first proposed a site-classification methodology based on the predominant period from average horizontal-to-vertical (H/V) response spectral ratios of about 5400 accelerograms recorded by 874 stations of the Japanese Strong Motion Network (K-net). This criterion is currently used in Japan for the seismic design of highway bridges [19,20]. The authors classified sites into four classes (SC-I to SC-IV) based on the fundamental period (Table 1). Fukushima et al. [21] extended Zhao's classification scheme using mostly a European dataset and partially some Californian and

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Table 1
Site classification criteria proposed by Zhao et al. [2], Fukushima et al. [21] and Di Alessandro et al. [1].

Zhao et al. [2]		Fukushima et al. [21]		Di Alessandro et al. [1]	
Site	**Description**	**Site**	**Description**	**Site**	**Description**
SC-I	$Tg < 0.2$ s	SC-1	$Tg < 0.2$ s	CL-I	$Tg < 0.2$ s
SC-II	$0.2 \le Tg \le 0.4$ s	SC-2	$0.2 \le Tg \le 0.6$ s	CL-II	$0.2 \le Tg \le 0.4$ s
SC-III	$0.4 \le Tg \le 0.6$ s	SC-3	$Tg > 0.6$ s	CL-III	$0.4 \le Tg \le 0.6$ s
SC-IV	$Tg > 0.6$ s	SC-4	Tg not identifiable and original rock site	CL-IV	$Tg > 0.6$ s
		SC-5	Tg not identifiable and original soil site	CL-V	Tg not identifiable/flat H/V
				CL-VI	Broad amplification/multiple peaks above 0.2 s
				CL-VII	Tg not identifiable/multiple peaks over period range

Table 2
Details of the sites and local site conditions.

Site	Zone	Latitude (°N)	Longitude (°E)	Site geology
Anjar	Kachchh	23.11	70.03	Mesozoic rocks
Badargarh	Kachchh	23.47	70.62	Mesozoic rocks
Bela	Kachchh	23.87	70.8	Tertiary rocks
Bhachau	Kachchh	23.28	70.34	Mesozoic rocks
Bhutakiya	Kachchh	23.55	70.80	Mesozoic rocks
Chobari	Kachchh	23.51	70.34	Mesozoic rocks
Chitravad	Kachchh	21.11	70.53	Mesozoic rocks
Dayapar	Kachchh	23.65	68.87	Mesozoic rocks
Desalpar	Kachchh	23.74	70.69	Mesozoic rocks
Dudhai	Kachchh	23.32	70.13	Tertiary rocks
Fatehgarh	Kachchh	23.69	70.84	Tertiary rocks
Kandla	Kachchh	23.03	70.22	Quaternary
Khavda	Kachchh	23.92	69.77	Mesozoic rocks
Lakadia	Kachchh	23.34	70.57	Tertiary rocks
Lodrani	Kachchh	23.89	70.62	Tertiary rocks
Mandvi	Kachchh	22.83	69.36	Quaternary
Nakhatarana	Kachchh	23.34	69.27	Mesozoic rocks
Naliya	Kachchh	23.33	68.83	Tertiary rocks
Rapar	Kachchh	23.56	70.66	Mesozoic rocks
Suvai	Kachchh	23.61	70.49	Tertiary rocks
Vamka	Kachchh	23.42	70.42	Mesozoic rocks
Morbi	Saurashtra	22.84	70.89	Mesozoic rocks
Sipu	Mainland	24.39	72.29	Proterozoic rocks

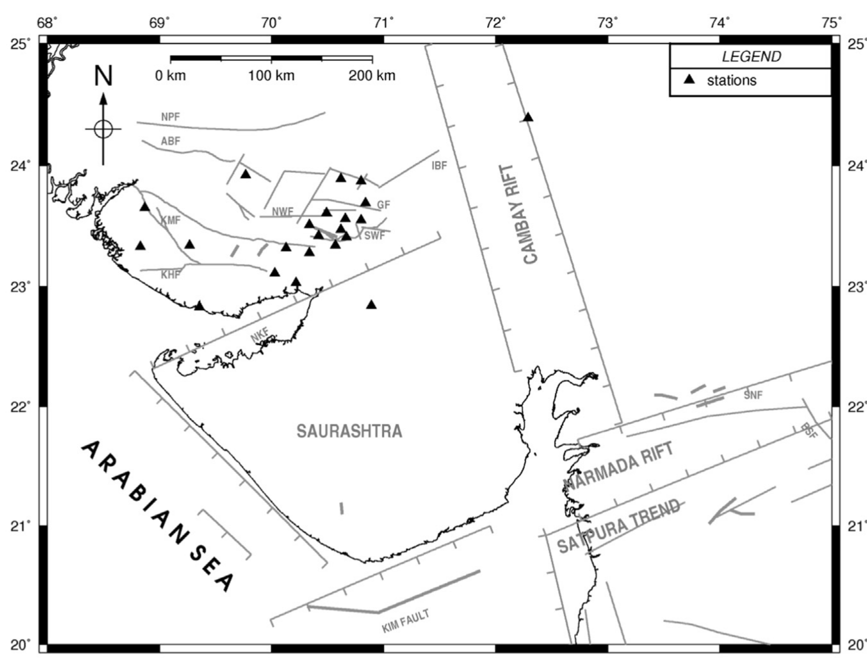

Fig. 1. Location of strong motion sites in Gujarat, India.