

Estimation of site response beneath seismic stations in the vicinity of Jaitapur region (Ratnagiri district, Maharashtra), India, using H/V Spectral Ratios

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ABSTRACT

Jaitapur village (16.59°N, 73.35°E) in Ratnagiri district, Maharashtra, India, is the site of a proposed Nuclear Power Plant that lies within the Konkan Plains of the Deccan Volcanic Province. The region has not experienced any moderate to large earthquakes ($M_w \geq 5.5$) during the last five decades, except for a few moderate events ($M_w \approx 5.0$) occurring more than 75 km from the Koyna–Warna seismic zone. At the request of the Nuclear Power Corporation of India Limited (NPCIL), a local seismological network was operated by CSIR–National Geophysical Research Institute (CSIR-NGRI), Hyderabad, from November 2004 to February 2012. In this study, ambient noise data recorded during January 2012 at six seismological stations (Mervy, Madban, Dassure, Mutat, Kharepatan, and Oni), were analysed using the Horizontal-to-Vertical Spectral Ratio (HVSr) technique to estimate the site response characteristics. The predominant resonance frequencies at these sites range from 1.5 to 6.0 Hz, with amplification factors between 0.6 and 9.0. Using an average shear-wave velocity of 350 m/s for the laterite and weathered basalt layer, the thickness of the near-surface geological layer was estimated to vary from approximately 17.5 m to 58.3 m. The results indicate significant spatial variability in site response across the region, reflecting lateral heterogeneity in the near-surface geology. These findings provide preliminary constraints on local site effects, which are important for seismic hazard assessment and infrastructure planning in and around the Jaitapur region.

Keywords: HVSr, Site response, Predominant frequency, Laterite, Jaitapur, Konkan plains, Deccan Volcanic Province.

INTRODUCTION

The 65 Ma Deccan Volcanic Province represents one of the largest continental flood basaltic eruptions on Earth, covering about 500,000 km² of western and central India (Widdowson and Cox, 1996). The basaltic sequence consists of multiple lava flows, separated locally by intertrappean sedimentary beds comprising limestone, shale, conglomerates, and sands. The region is structurally influenced by NE–SW and NW–SE trending lineaments, with fewer NNE–SSW features.

Historically, the Deccan volcanic region has experienced several damaging earthquakes in the past, including the 1967 Koyna (M_w 6.3), 1993 Killari (M_w 6.4), 1997 Jabalpur (M_w 5.8), 1956 Anjar (M_w 6.0), and 2001 Bhuj (M_w 7.7) events. The Killari and Bhuj earthquakes alone caused nearly 30,000 fatalities. Jaitapur (Figure 1) became an important location for seismic investigations following the proposal to establish a ~10,000 MW Nuclear Power Plant. At the request of NPCIL, CSIR-NGRI installed a micro-seismological network around Jaitapur in November 2004, which operated until February 2012. The network consisted of six stations: Mervy, Madban, Dassure, Mutat, Kharepatan, and Oni, equipped initially with short-period and later with broadband seismometers (Figure 1).

The stations are located between 16°–17°N and 73°–74°E along the Konkan coast bordering the Arabian Sea. Continuous waveform data recorded by this network were used in the present study to evaluate site response characteristics beneath each station using ambient noise measurements. Although the area lies close to the Koyna–Warna seismic zone, no events with magnitude greater than 2.0 were recorded during the

network operation period (CSIR-NGRI internal communication to NPCIL).

METHODOLOGY

Horizontal to vertical spectral ratio (HVSr)

The horizontal to vertical spectral ratio (HVSr), was popularized as Nakamura’s method (Nagoshi and Igarashi, 1971; Nakamura, 1989), who demonstrated that the ratio between horizontal and vertical ambient noise records is related to the fundamental frequency of the soil beneath the site and hence to the amplification factor. It can be represented as:

$$HVSr = \frac{\sqrt{H_{NS}^2 + H_{EW}^2}}{V}$$

Where the vertical, east-west, and north-south components of the waveform are denoted by V, H_{EW}, and H_{NS}, respectively.

It is generally accepted that the HVSr technique is effective in identifying the fundamental (natural) resonance frequency of a site. However, there is still debate regarding the extent to which the amplitude of the HVSr peak can be directly related to site amplification. Under idealized conditions dominated solely by fundamental-mode Rayleigh waves, the HVSr amplitude could theoretically increase indefinitely at the site resonance frequency, depending on subsurface properties. In realistic field conditions, however, the coexistence of additional vertical motion components at the same frequency constrains the amplitude of the HVSr peak. From this viewpoint, the peak amplitude primarily reflects the relative contribution of fundamental-mode Rayleigh waves within the ambient vibration wavefield (Ohmachi et al., 1991).