



# Strong ground motion analysis of Assam using H/V ratio method

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## Abstract

Strong ground motion data required for analysis were obtained from 26 locations of Assam through their respective strong ground motion monitoring station websites. Raw data obtained were then processed to obtain average Horizontal to Vertical ratio (H/V ratio) of the strong ground motion spectrum. The average H/V ratio was then plotted against their corresponding frequency in a wave like pattern. The resonant frequency of a particular location was indicated by the frequency corresponding to the first peak of the average H/V ratio spectrum. The resonant frequency was then plotted against sediment thickness measured from nearby borehole data in order to obtain an empirical relation. Also, a comparison was made in this regard with the obtained empirical equation with already established work. Moreover, in this paper, a new attempt was made to correlate resonant frequency with water table depth measured from borehole data. Likewise amplitude from the seismic waves was also plotted against sediment thickness and aquifer thickness data available from local boreholes. All these correlations showed a good fit with a little assessment about the seismic condition of the Assam being made.

**Keywords** Resonant frequency · H/V ratio method · Sediment thickness · Amplitude

## Introduction

Many researchers are showing promising improvement in engineering seismology. Earthquake study is gaining importance in recent years due to the increase in number of seismic activities throughout the world. Earthquake studies throughout the world have increased in number; however, earthquake prediction is still a tough task. Although earthquake cannot be completely predicted, minimization of damage to structures due to earthquakes is possible by implementing site-specific studies and designs. Proper ground motion studies can help us in developing more earthquake-resistant building design. The sediments present in Assam are capable

of causing local site amplification and in extreme cases may induce resonance, a condition where the natural frequency of the structure matches with that of the surface ground motion.

Different researchers used different methods to remove source and path effect (Andrews 1982; Iwata and Irikura 1986; Çelebi 1987; Field et al. 1990; Hough et al. 1991; Takemura et al. 1991; Kato et al. 1992; Tai et al. 1992; Kowada et al. 1998). One such method was H/V ratio method introduced by Nogoshi and Igarashi (1970) and modified later by Nakamura (1989) which uses both horizontal and vertical components of either an earthquake or surrounding vibration caused by manmade activities. This method is popularly known as one station method as it measures all the three components at the same station rather than two stations (i.e. one reference site and one observing site). It was inferred that horizontal component of strong ground motion showed larger amplifications in comparison with the vertical component at the resonant frequency. This large variation between both components induces peak at a particular frequency which corresponds well to the resonant frequency of that soil.

Several research materials are already available regarding H/V ratio method from the earthquakes and vibration caused by manmade activities for various sedimentary plains. Much theoretical explanation about H/V ratio method

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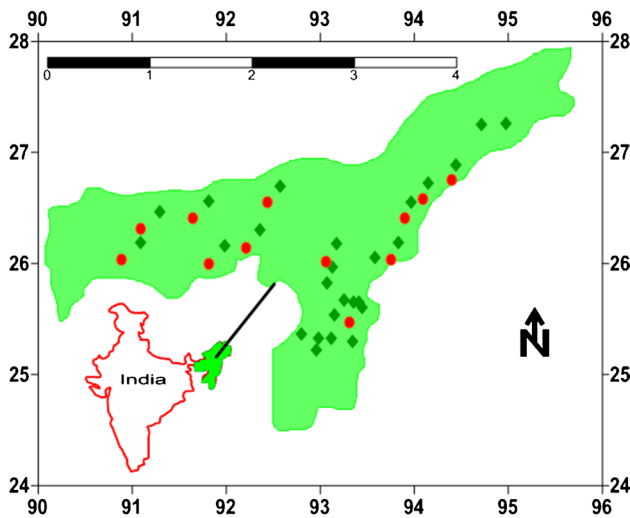
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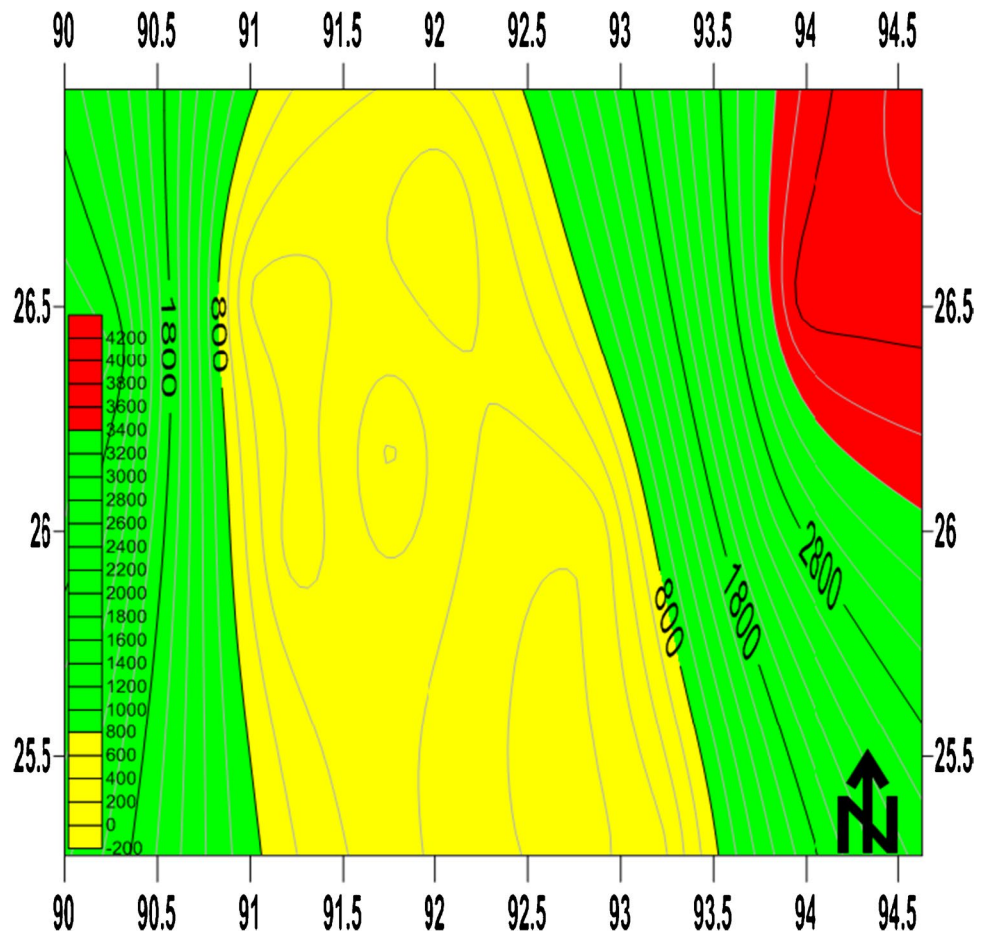


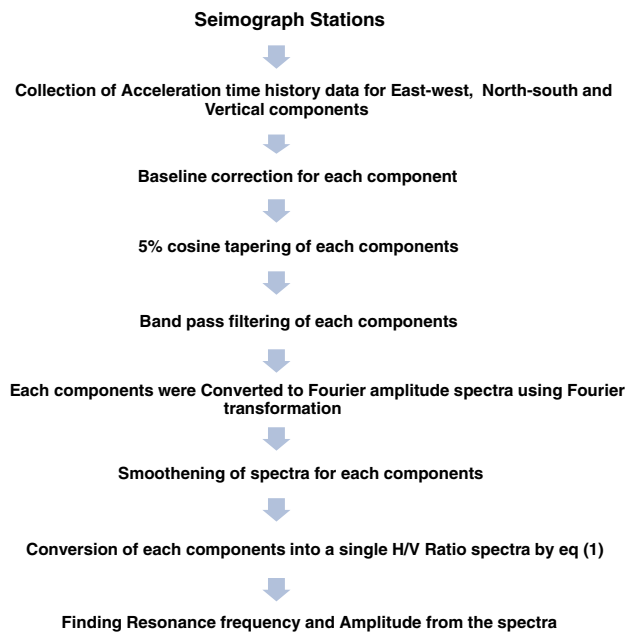
**Fig. 1** Study area map of Assam (red dot indicates borehole locations; green diamonds indicate strong motion sites)

is available in literatures (Field and Jacob 1993; Lachet and Bard 1994). Chávez-García et al. (1990, 1996), Bour et al. 1998, and Bard 1999 tested the reliability of H/V ratio by

comparing it with other conventional techniques. Ibs-von Seht and Wohlenberg (1999) first established an empirical relationship between resonance frequency and sediment thickness using H/V ratio. Later, many researchers set foot in the footsteps of Ibs-von Seht and Wohlenberg 1999 and established relationship between resonance frequency and sediment thickness using H/V ratio from ambient vibrations (Delgado et al. 2000; Parolai et al. 2001 2002; Hinzen et al. 2004; Birgören et al. 2009; Fnais et al. 2010; Dinesh et al. 2010; Özalaybey et al. 2011; Paudyal et al. 2013; DelMonaco et al. 2014; Biswas et al. 2014; Khan and Asif Khan 2016, Anthiraikili 2020). Using H/V ratio from earthquakes, Natarajan and Rajendran (2017) studied site response of an earthquake affected area in Bhuj, India. Talha Qadri et al. (2015) showed that H/V ratio can be used to study site classification and seismic microzonation. Later, Harinarayan and Kumar (2018) and Anbazhagan et al. (2019a, b, c) used H/V ratio from earthquakes to classify sites based on resonance frequency and shear wave velocity. Recently, Anthiraikili and Das (2021) proved that seismicity is associated with water and established empirical relationship for seismic parameters with aquifer parameters using H/V ratio from earthquakes or strong ground motion.

**Fig. 2** Contour map showing distribution of sediment thickness in Assam (red: high sediment thickness area, green: intermediate sediment thickness, yellow: low sediment thickness area)





**Fig. 3** A brief description of the entire methodology

In this study, resonance frequency was obtained using H/V ratio method from 26 locations of Assam, and based on it, a site classification for Assam has been proposed. Then, the resonance frequency values were correlated with sediment thickness and water table depth obtained from borehole data for certain regions of Assam. Relationship of amplitude with sediment thickness was plotted as a cluster graph. This amplitude is an inevitable content in the strong ground motion due to its usage in differentiating strong ground motion from weak ground motion. Anthirakili and Das (2021) have already proved that the strength of seismic signals was drastically reduced by aquifer thickness. Hence, a correlation was attempted for amplitude of strong ground motion with aquifer thickness to see whether the presence of groundwater controls the strength of seismic signals.

## Seismicity of the study area

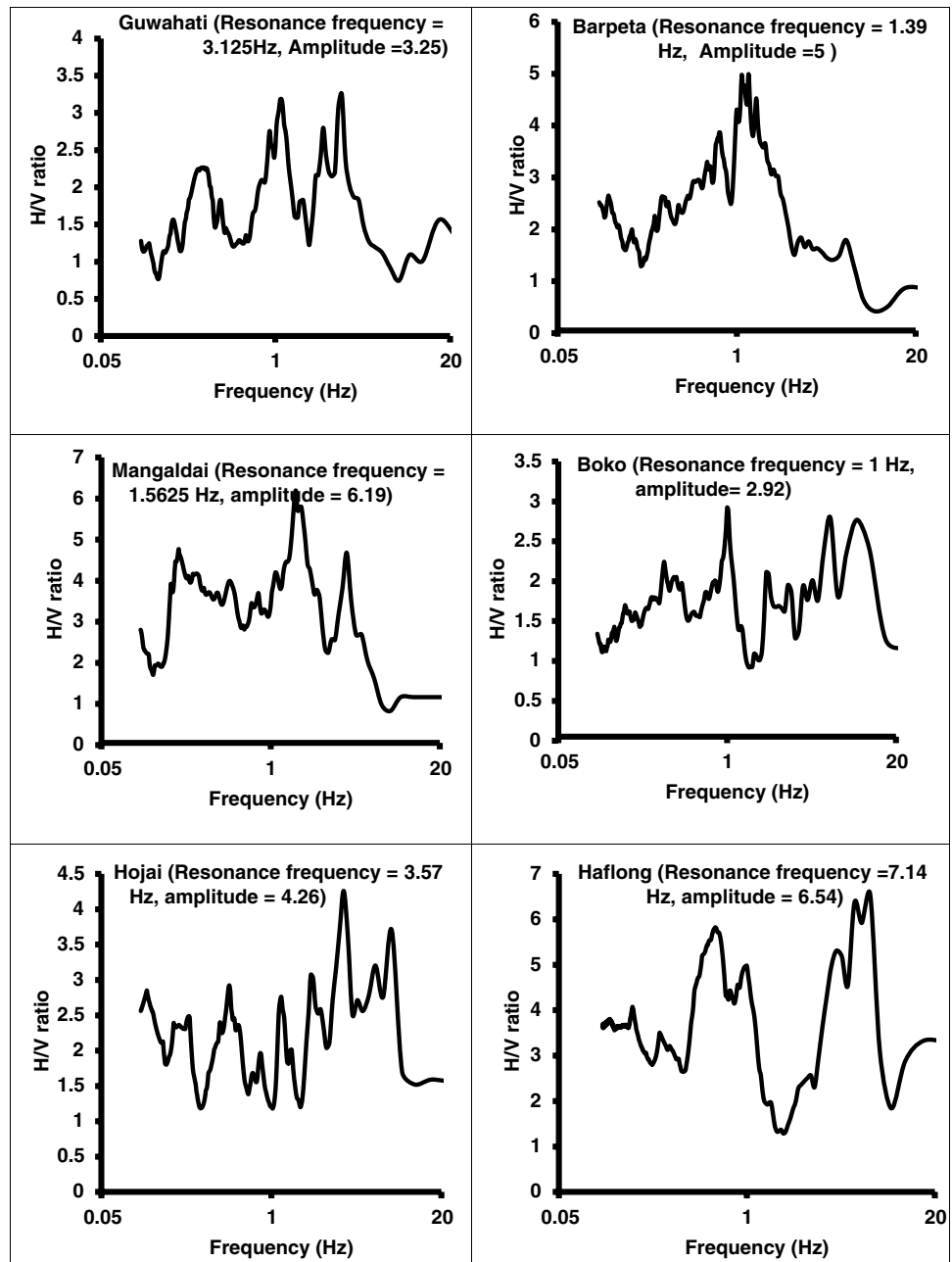
Assam, a state in India (Fig. 1), is one of the high hydrocarbon potential zones. Major rock types that prevail here are harzburgite, lherzolite, dunite, pyroxenite, and mafic rocks (Roy et al. 1975). The tectonic features of Assam include three tectonic phases—earliest cretaceous to Eocene, intermediate Oligocene, and Pliocene phase. During cretaceous to Eocene phase, block faults were developed as a result of detachment of Indian plate from Antarctica plate and by the further drifting of Indian plate towards Eurasian and Burma plate (Saha 2012). The sedimentation during this age occurred in order to counter balance the load created by slow

subsidence along longitudinal extensional fault (Sahoo and Gogoi 2011). The sedimentation during this Eocene period occurred in a passive margin setup with fault controlled continuous sediment (Sahoo and Gogoi 2011). It was during this same geological age that the basement of Assam basin started sloping towards south east (Saha 2012; Sahoo and Gogoi 2011).

During Oligocene, the upliftment and erosion occurred north of Brahmaputra River with most of the faults being reactivated (Saha 2012). Geological investigation of this age shows coarser clastic sediments which prove the fact that receding of sea water has occurred as a result of tectonic upliftment during this age (Sahoo and Gogoi 2011). Later, alluvial soils were deposited within quick time with rapid sedimentation and fault growth from Miocene to Pliocene (Sahoo and Gogoi 2011). If the supply of sediments is too heavy to accommodate the subsidence created, then in such cases the sedimentation along with fault is created (Goswami et al. 2008). Also, the sediments began to unwrap from foredeep basin towards the region away from the central part of Assam basin and created forebulge (Sahoo and Gogoi 2011). With increase in sediments away from the central part of the basin, the basements started to dip further south east with successive faulting, and hence sedimentation increased in south east direction than the central part of the basin (Saha 2012). The alluvial plains from central part of Assam towards periphery vary in thickness from 2000 to 7000 m (Saha 2012). The distribution pattern of sediments in Assam basin can be seen in Fig. 2. Also, Assam is bounded by three thrust from all sides with one thrust being the most prominent among them all—the Himalayan main frontal thrust which is active from Miocene age to present day.

Some of the earthquakes that have caused damage in this region are 1869 Cachar earthquake, 1897 Shillong plateau earthquake, 1923 Meghalaya earthquake, 1930 Dhubri earthquake, 1943 Hojai Assam earthquake, 1947 Arunachal Pradesh earthquake, 1950 Arunachal Pradesh-China border earthquake, 1954 and 1957 Arunachal Pradesh earthquake, 1984 Silchar earthquake, 1985 Tipi earthquake, and 1988 Manipur-Myanmar border earthquake. Even some of the earthquakes had their epicenter at Assam like 1869, 1943, and 1984 earthquakes. It is worth here to note that during 1957 Arunachal Pradesh earthquake, the source of rupture caused shaking in most parts of Assam including a town named Dhubri located some 450 km away from Arunachal Pradesh. Similarly, an 1869 earthquake which had its epicenter at Cachar in Assam created strong shaking in Cherrapunji, a town located some 280 km away. So from previous history of earthquakes in and around regions of Assam, it can be understood that heavy sedimentation had remained as a causative factor for amplification of some earthquakes which had their origin in Assam. Even earthquakes outside

**Fig. 4** Showing resonance frequency plots of various strong motion sites in Assam



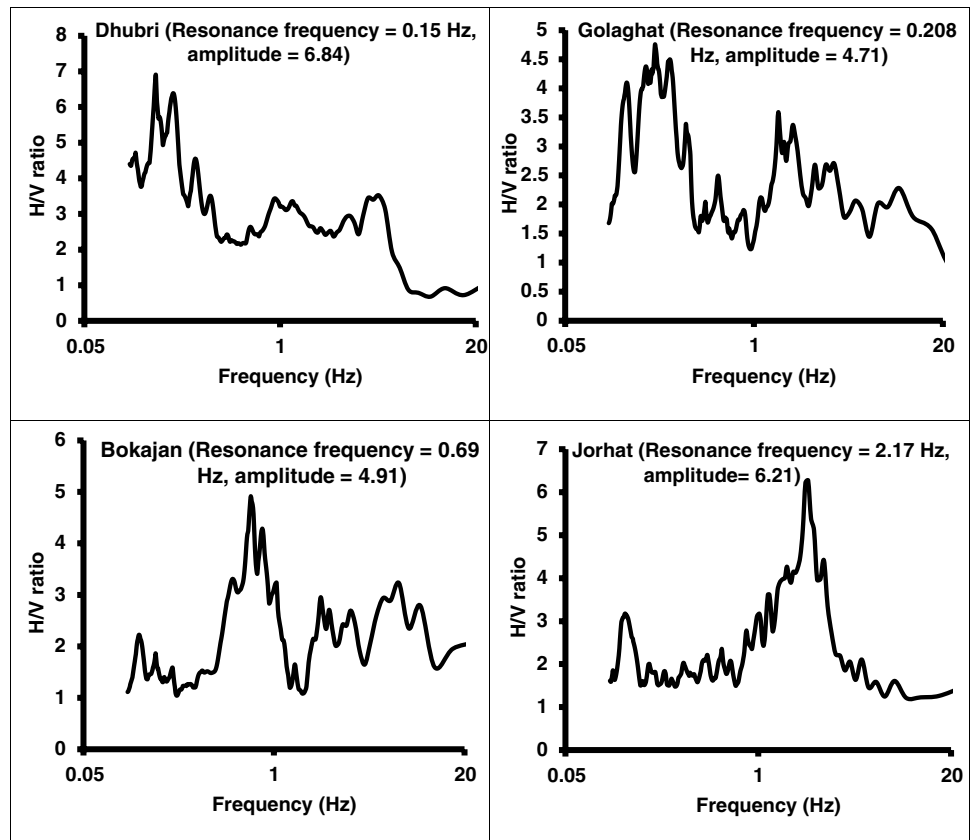
the epicenter of Assam have caused strong shaking in Assam due to the same reason.

### Strong ground motion readings

Strong ground motion or earthquake vibration differs from weak ground motion or ambient vibrations in terms of amplitude and magnitude. Strong ground motion does have larger amplitude, while weak ground motions have smaller amplitude, but both of them show identical resonance frequency irrespective of the amplitude values (Horike et al

2001). In terms of magnitude, values less than 3 are considered weak ground motion, while values greater than that are taken as strong ground motion. The strong motion recording stations in Assam (Fig. 1) are spaced at regular intervals in such a way that at least two to three stations can record the same event. The seismographs installed in these strong motion sites are built with Guralp CMG 3 T 120-s triaxial broadband sensors and Guralp CMG-DM24 24-bit digitizers with external GPS and a data storage device. The sensor used in this instrument has the potential to measure frequency within the range of 0.02 to 50 Hz and has same character in all its three axes. Data are recorded in

Fig. 4 (continued)



continuous mode at the rate of 100 samples per second. These strong motion stations have so far recorded more than 4000 local earthquakes with an error of 1–2 km in latitude and longitude and 4–5 km in depth. The data used in the present study were carefully selected for magnitude ranging from 3.5 to 8 between 2009 and 2017 including all the three components of ground motion (i.e.) east–west, north–south and vertical direction. The strong ground motion data from earthquakes used in the present study were obtained from [www.strongmotioncentre.org/vdc](http://www.strongmotioncentre.org/vdc) and from the Department of Earthquake Engineering, Indian Institute of Technology, Roorkee (IITR) website (Mittal et al. 2012). The above mentioned websites act as portal for Indian strong motion sites providing acceleration time history data from different earthquakes in pictorial format which are digitized. Later, these digitized values were used as input for initial processing.

After initial processing, the acceleration time series record of the data was processed using Seismosignal software. Each component was base-line corrected by the software for anomalous trends, later tapering it with a 5% cosine window and then band-pass filtering it. Band pass filter is a special filter which permits only signals within desired frequencies without changing the original information content of the signal. Later, the values for each component were converted to Fourier amplitude spectra and smoothed using

Konno and Ohmachi (1998) smoothing constant value of 40. Finally, the average spectral ratio of the Fourier transformed horizontal (east–west, north–south) to vertical component (i.e.) H/V ratio was obtained using the equation (Delgado et al. 2000):

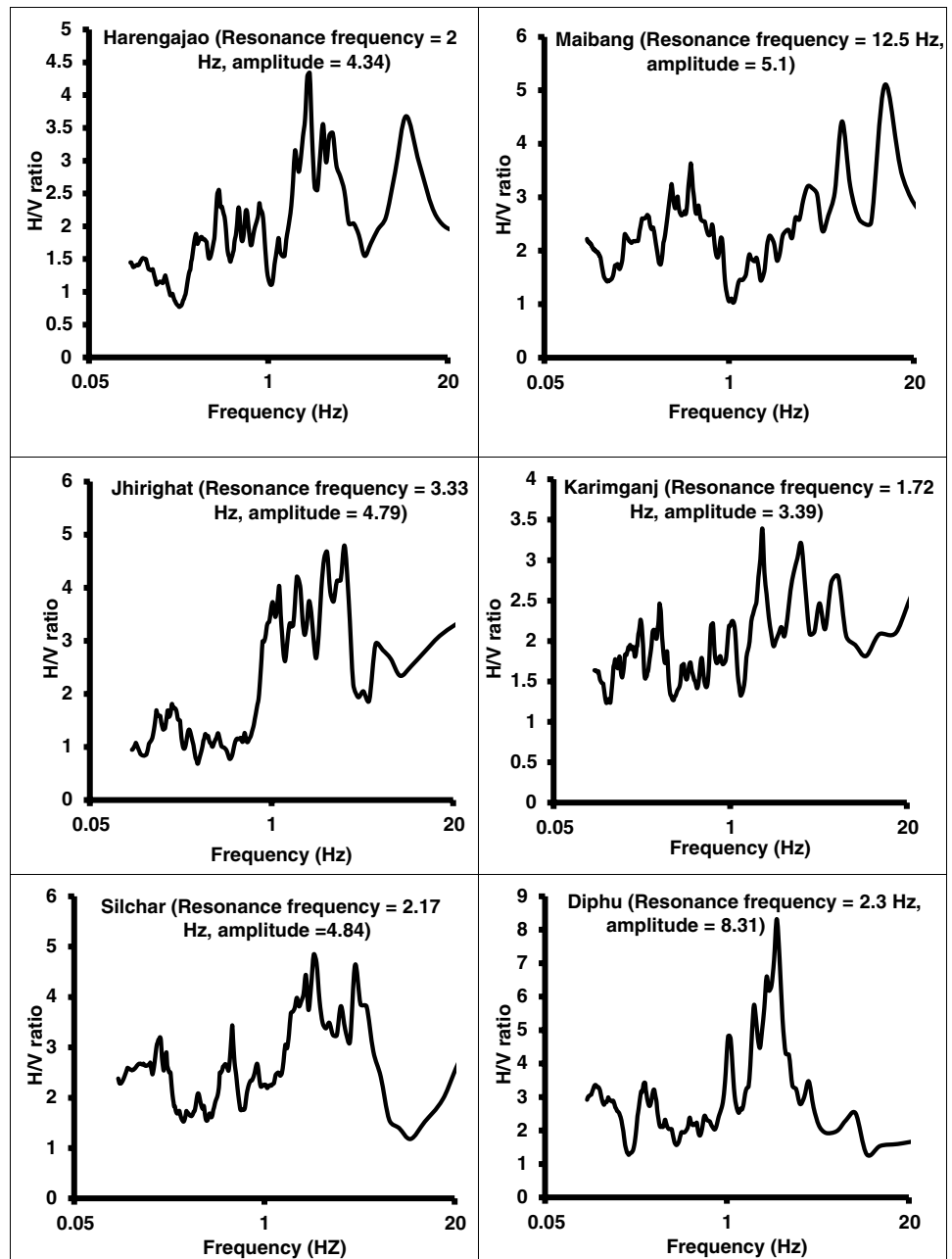
$$H/V = \sqrt{(F_{NS}^2 + F_{EW}^2)/(2F_V^2)} \quad (1)$$

Here,  $F_{NS}$ ,  $F_{EW}$  and  $F_V$  are the Fourier amplitude spectra in the north–south (NS), east–west (EW) and vertical (V) direction, respectively. The software plots the H/V ratio derived from the above equation against their respective frequency in a graphical pattern. The frequency corresponding to the first peak of the H/V spectrum plot will be taken as the resonant frequency of the site (Field and Jacob 1993; SESAME 2004; Bonnefoy-Claudet et al. 2006). The entire methodology has been described as a flowchart in Fig. 3. The resonance frequency curve for all sites in Assam is provided in Fig. 4.

## Results and discussion

The borehole details used for the correlation were obtained from deep borehole studies conducted by ONGC for the purpose of oil exploration and some drills

Fig. 4 (continued)



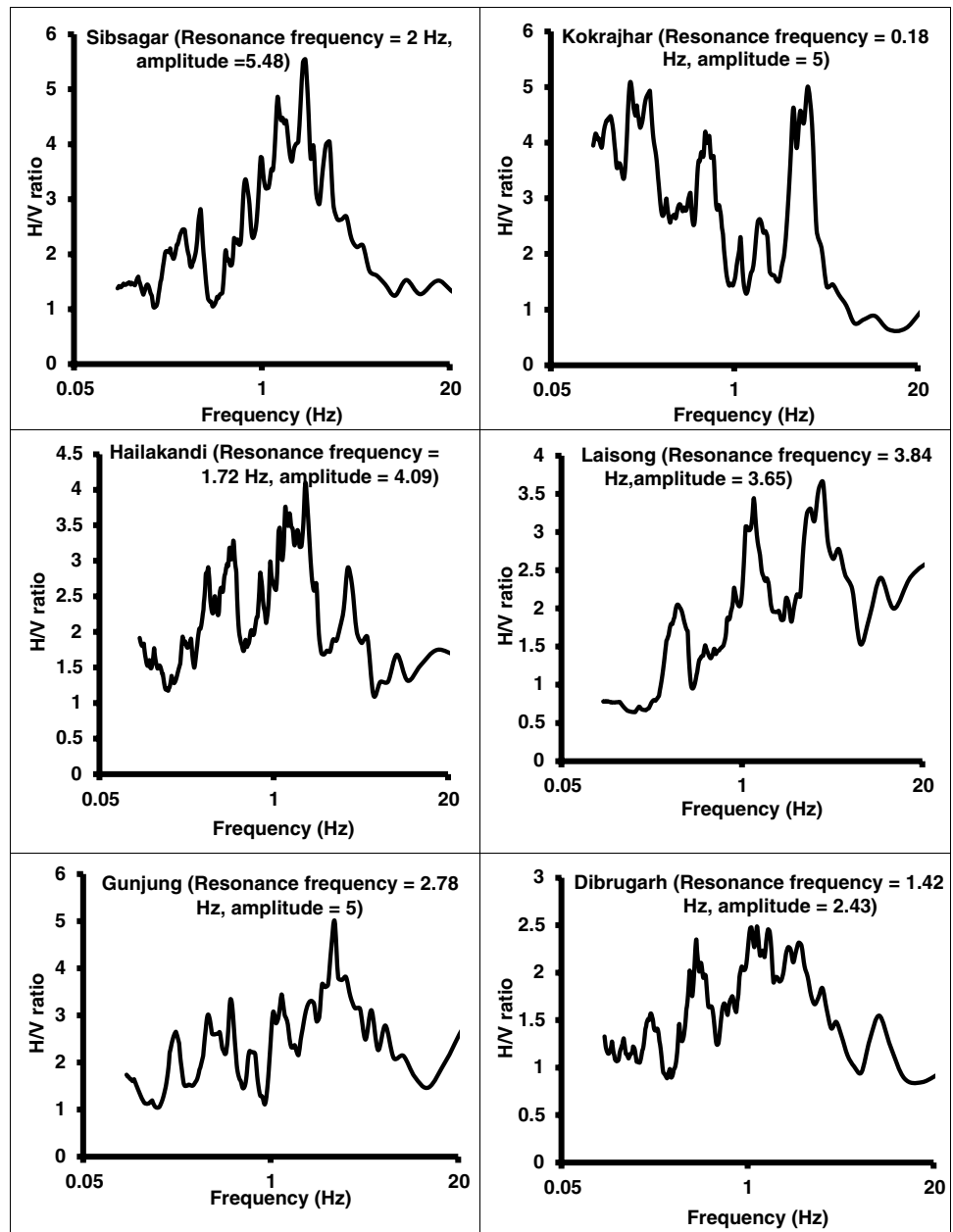
conducted by CGWB to study ground water condition. All the boreholes near the sites did not reach bedrock, but many of them reached groundwater level. The boreholes that have reached bedrock level have been used in the present study for the purpose of correlation with strong ground motion parameters.

### Seismic site classification

If we take into account the seismic analysis of Assam region, we can see that not much literature talks about

the seismic site classification of Assam. Out of few, Anbazhagan et al. (2019a, b, c) used best of five empirical methods as a means of site classification based on resonance frequency for 167 strong ground motion stations in India's Himalayan region including Assam. Another author, Harinarayan and Kumar (2018) prepared site classification using resonance frequency values for the nearby strong motion sites in India excluding Assam as per National Earthquake Hazard reduction Program (NEHRP) system of site classification (available in my previous paper) considering 30 m as overburden

Fig. 4 (continued)

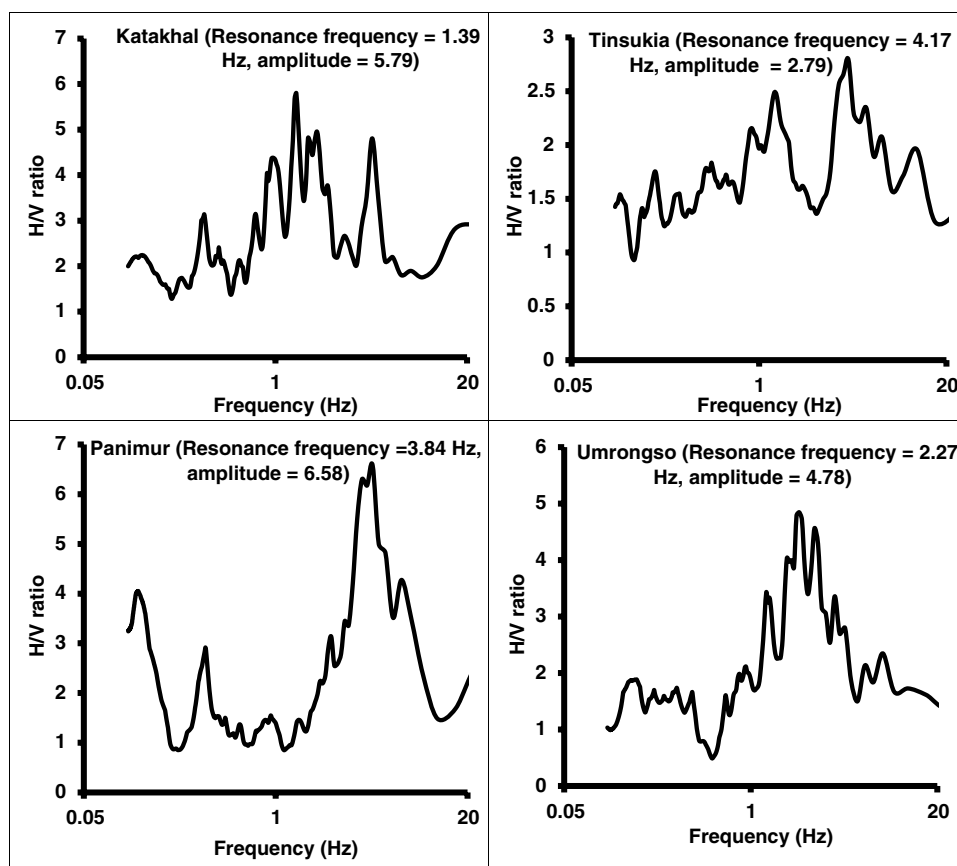


thickness. In the present study, a site classification as per NEHRP regulation has been proposed for Assam based on resonance frequency values obtained from strong ground motion, and the result has been tabulated in Table 1. According to the present classification, 2 sites belonged to class B, 6 sites to class C, 10 sites to class D and 8 sites to class E. Further analysis shows that maximum sites belonged to class D and class E, characteristics of stiff soil and soft soil respectively. Very close to class D and class E, class C presents a category that pertains to soft rock and dense soil as per the current study. All these results finally say that Assam is a region of soil, and not rocks which match with the local geology

observed by Central Groundwater Board (CGWB). In the absence of fewer reports about site classification in this region, the above statement can be taken as a validation for our data.

The spectral curves of different sites were classified as site A, B, C, D, E and analyzed to study the pattern of curves. From careful comparison of spectral curves devoid of site A, two sites from site B (Fig. 5a) showed double peaks within 10 Hz. Spectral curves of site C (Fig. 5b) showed maximum peak within 1 Hz. For site D (Fig. 5c), spectral patterns were equally distributed with all graphs displaying peak frequency of 2 Hz. For site E (Fig. 5d), the case was different with some of the

Fig. 4 (continued)



site exhibiting peak before 1 Hz, while some other site exhibited peak after 1 Hz. The comparison between various site classes from Assam has been depicted in Fig. 6. Thus, from site class comparison, it can be seen that all sites exhibited maximum amplitude around 3 to 4. Sites C, D and E almost exhibited equal curves, while site B exhibited curve quite different from other site classes. Maybe, the presence of more spectral curves for site B would have changed the scene as only limited data were available for analyzing site B.

As a next step in the analysis, comparison of our result with previous studies from Himalayan region has been carried out. The present study in Himalayan regions about seismicity are from Walling and Mohanty (2009), Mahajan et al. (2012), Mittal et al. (2012), Rawat et al. (2014), Haloi and Sil (2015), Mundepi et al. (2015), Chopra et al. (2018), Harinarayan and Kumar (2018) and Anbazhagan et al. (2019a, b, c). Out of them, three prominent authors who have given site classification for Himalayan region are Mittal et al. (2012), Anbazhagan et al. (2019a, b, c) and Harinarayan and Kumar (2018). Out of these three authors, both Harinarayan and Kumar (2018) and Anbazhagan et al. (2019a, b, c) have given site classification based on site A, B, C, D and E. While Harinarayan and Kumar (2018) have given site

classification for sites in Himalayan region devoid of the present study region, Anbazhagan et al. (2019a, b, c) is the only author who has given site classification for the Himalayan region including our present study area. For the present study, we have used site classification given by Anbazhagan et al. (2019a, b, c) and Harinarayan and Kumar (2018) for comparison with our present site classification. The comparison of our site class with both these authors has been given in Fig. 7a, b, c, d. It can be seen that except for site B, the other three site classes coincided with the results of Harinarayan and Kumar (2018). Amplitude in spectral curves measured by Anbazhagan et al. (2019a, b, c) seems to be low in value compared to Harinarayan and Kumar (2018) and our present study. The usage of low amplitude values from surrounding Himalayan region by Anbazhagan et al. (2019a, b, c) might have decreased his amplitude values when compared to high amplitude values of Assam.

### Relating resonance frequency with sediment thickness

Relating resonance frequency with sediment thickness is not a new concept according to seismologist. Various



**Table 1** Showing site class for each site from Assam for the present study (column 3) along with site class given by Anbazhagan et al. 2019 for the same region (column 4)

S. no	Location	Site class based on resonance frequency from present study	Site class given by Anbazhagan et al. (2018)
1	Guwahati	C	D
2	Barpeta	E	E
3	Mangaldai	D	D
4	Hojai	C	C
5	Haflong	B	B
6	Dibrugarh	E	E
7	Umrongso	D	D
8	Panimur	C	B
9	Harengajao	D	D
10	Laisong	C	B
11	Maibang	B	B
12	Gunjung	D	C
13	Jhirighat	C	C
14	Tinsukia	C	C
15	Golaghat	E	E
16	Karimganj	D	D
17	Bokajan	E	E
18	Silchar	D	D
19	Katakhal	E	E
20	Diphu	D	D
21	Hailakandi	D	E
22	Jorhat	D	D
23	Sibsagar	D	D
24	Dhubri	E	E
25	Kokhrajhar	E	E
26	Boko	E	E

studies relating resonance frequency versus sediment thickness cover are available in the literature (Ibs-Von Seht and Wohlenberg 1999; Delgado et al. 2000; Parolai et al. 2001; Parolai et al. 2002; Hinzen et al. 2004; Birgören et al. 2009; Paudyal et al. 2013; Özalaybey et al. 2011; Sarfraz Khan and Asif Khan. 2016; Fnais et al. 2010; Biswas et al. 2014; and DelMonaco et al. 2014). Among them, Seht and Wohlenberg (1999) are the pioneer of this research.

The general empirical relationship between resonant frequencies of a soil layer with its sediment thickness is established through a relationship (Seht and Wohlenberg 1999):

$$H = a(f_r^{-b}) \quad (2)$$

Usually, the resonant frequency found out from peak value of spectral ratio was correlated with sediment thickness cover to obtain a non-linear regression fit of Eq. (2).

By performing non-linear correlation based on Eq. (2), the following equation was established:

$$H = 388 * (f_r^{-1.08}) \quad (3)$$

Non-linear fitting of curve (Fig. 8) showed negative trend of graph as sediment thickness values decreased with increase in resonant frequency with  $R$  value of 0.79. To validate the present equation, it was compared with equation established by other authors both outside India (Fig. 9) and inside India (Fig. 10) to find whether the present equation is in agreement with other researcher's findings. As expected, negative trending curve was produced by the comparison graph revealing the fact that resonance frequency decreases with increasing sediment thickness and vice-versa. Thus, the present equation agreed with results published by other researchers.

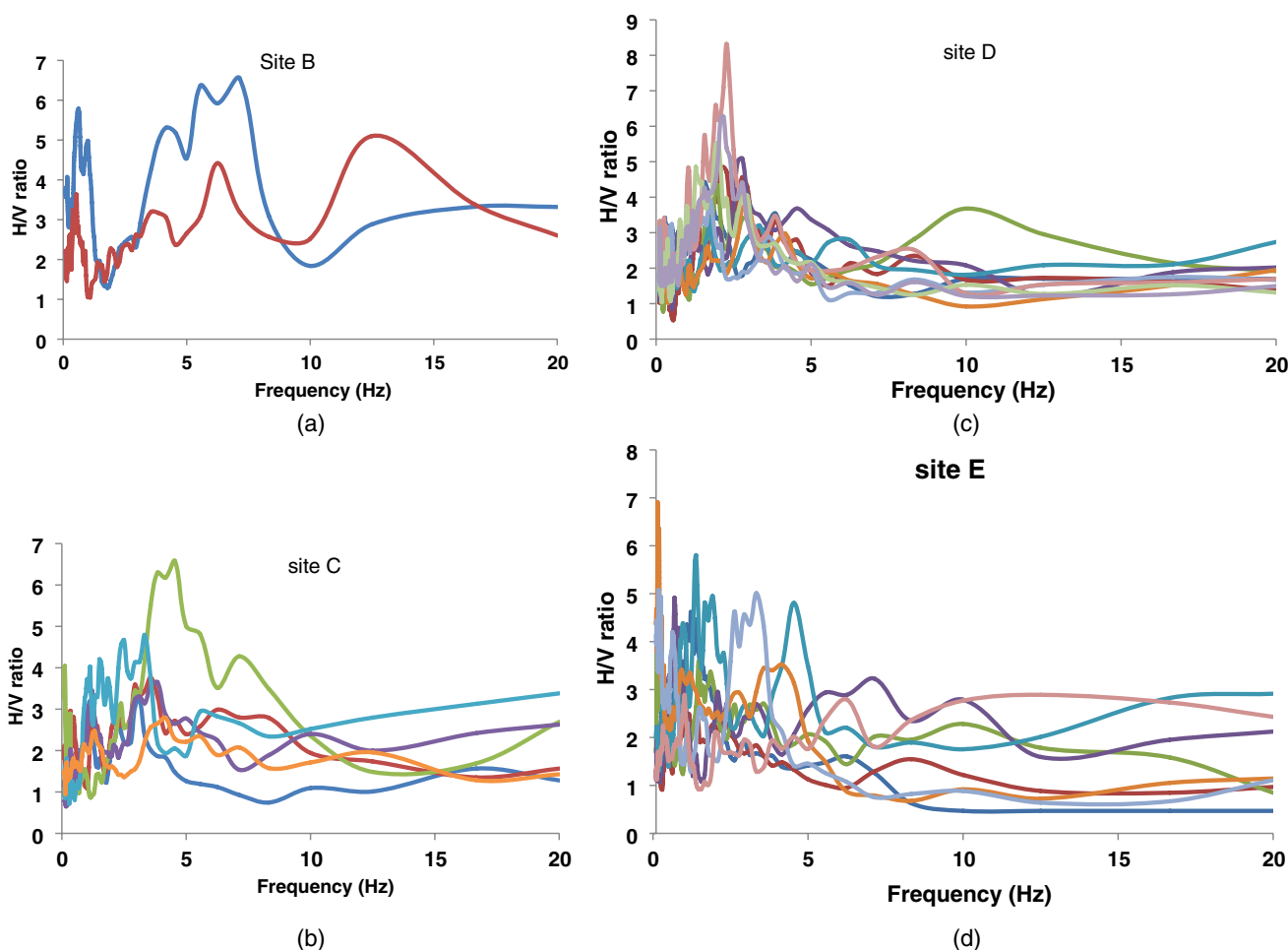
### Relating resonance frequency with water table depth

There are many views regarding the correlation between strong ground motion and groundwater table depth. It is said that the groundwater drops suddenly when the seismic event is occurring within short hypocentral distance (Wang and Manga 2009). But still the relationship between ground water table and seismic ground motion recordings is unexplored. In this section, we have attempted to find a relationship between resonant frequencies with ground water table depth. Also, we would like to emphasize that this is the first attempt to correlate resonance frequency with ground water table depth in Assam.

Our knowledge about the ground water table depth of Assam comes from the boreholes drilled for the purpose of ground water exploration by the Central Ground Water Board. We fitted this water table depth with resonant frequency values obtained using H/V ratio method to obtain a non-linear fit of equation (Fig. 11). The equation thus obtained was.

$$\text{Water table depth} = 0.626 \times (\text{Resonance frequency}) + 1.023 \quad (4)$$

$R$  value of 0.89 indicates that there is a significant relationship existing between resonant frequency and water table depth. This linearly trending curve indicated that water table depth is more in areas with high resonant frequency. Wang and Manga (2009) earlier have stated in their paper that there is a strong relationship existing between low-frequency and co-seismic groundwater level change which states that low-frequency excitation causes increase in pore pressure than high-frequency excitation leading to a change in ground water level (Wang et al. 2003; Wong and Wang 2007). Wang et al. (2003) have



**Fig. 5** **a** Plot showing spectral curves for different sites in Assam with site class B. **b** Plot showing spectral curves for different sites in Assam with site class C. **c** Plot showing spectral curves for different

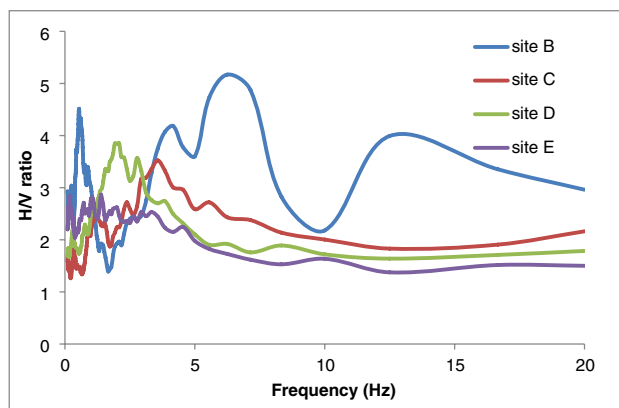
sites in Assam with site class D. **d** Plot showing spectral curves for different sites in Assam with site class E

also said that fundamental frequencies lower than 1 Hz are strongly correlated with hydrological changes. From strong ground motion analysis, it can be said that Assam is an area with high frequency with most of the frequencies greater than 1 Hz. High frequency of strong ground motion in Assam does not make it an area of high liquefaction potential zone, but what makes it a potential candidate for liquefaction is their aquifer with shallow water table.

**Relating amplitude with sediment thickness**

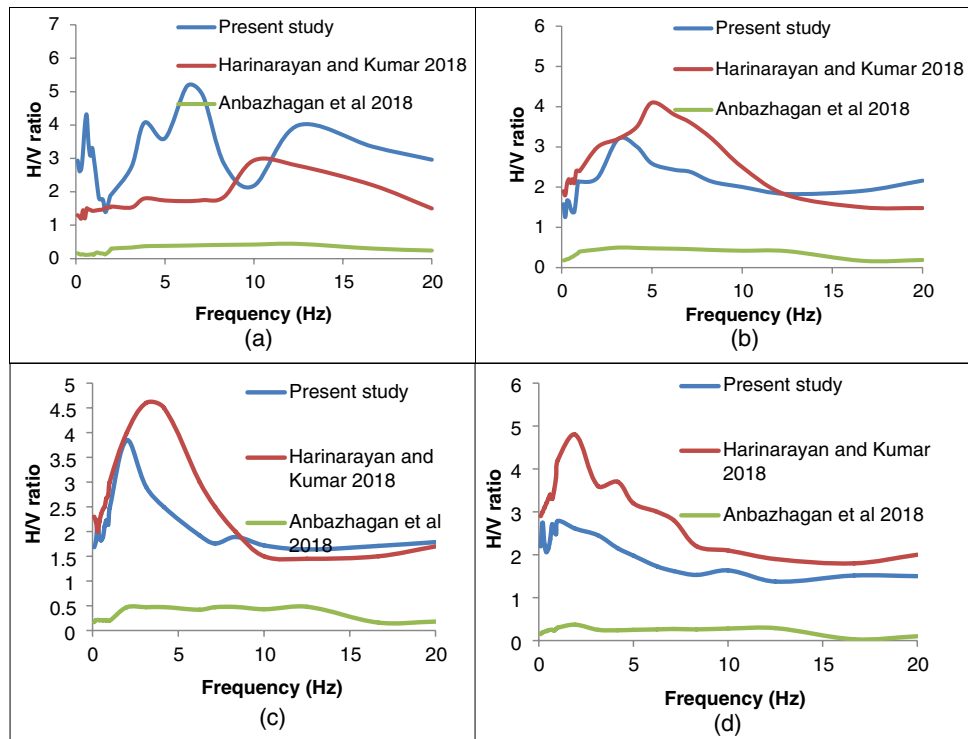
Amplitude which is an indication of strength of seismic signals is another important parameter very less used in the correlation study of strong ground motion. It is an already known theory that amplification of seismic waves becomes much pronounced in soft soil sediments (soil with more sediment deposition) known as site effect. Thus, it can be seen that amplification is related

to sediment thickness, and the same concept interested us in studying how far the theory holds true in the present study area. Not much authors except Parolai et al. 2001



**Fig. 6** Plot showing comparison of various site classes in Assam

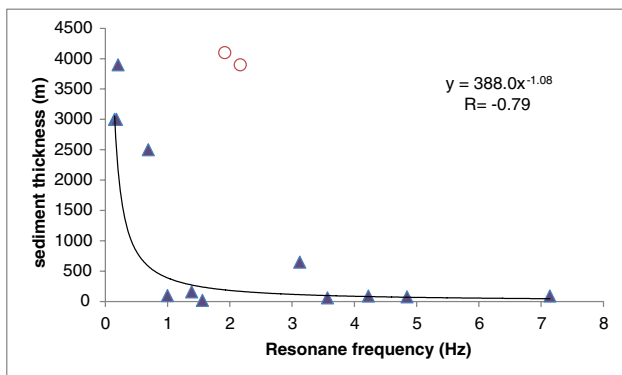
**Fig. 7** Plot showing comparison of the present study with previous studies from Assam and its neighboring region for various site classes: (a) for site B, (b) for site C, (c) for site D, (d) for site E



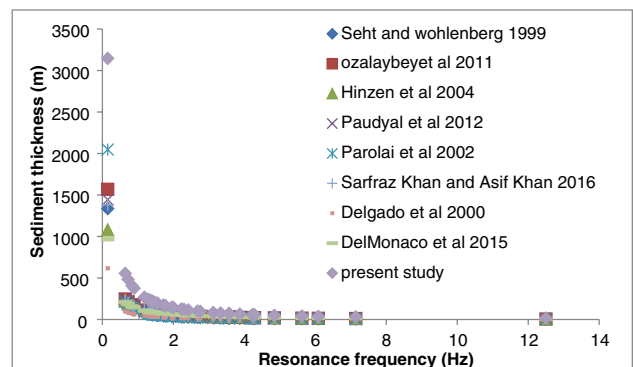
and Micenko (2019) have presented relationship between amplitude and sediment thickness in their papers. Apart from this, more literature studies pertain to relationship between resonance frequencies with sediment thickness. Even Micenko (2019) studied relationship between amplitude and sediment thickness based on a very handful of data. Since this relationship lacks more literature, we had no option to compare our data with previous studies. As said in the previous section, the sediment thickness data for the present study comes from boreholes drilled by CGWB. Thus, the plot of sediment thickness data with amplitude values of our strong ground motion study produced a linearly trending equation:

$$\text{Sediment thickness} = 1023 * (\text{amplitude}) - 3369 \quad (5)$$

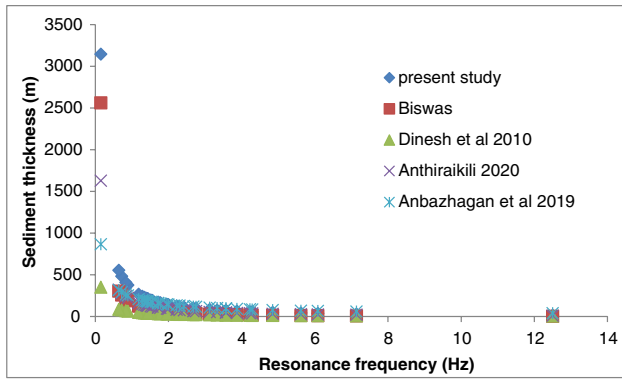
The graph thus plotted (Fig. 12) produced a good fit of equation ( $R=0.699$ ) with positive trend as expected. A graph was plotted for amplitude against sediment thickness in the form of cluster graph (Fig. 12) which resulted in increase of sediment thickness with increase in amplitude. From the same graph, two categories of sediment thickness was observed in the study area (one between 20 and 650 m and the other one between 2500 and 4100 m). Moreover, the plotted graph showed more sediment thickness in areas where the spectral curves produced maximum amplification proving the theory that amplification increases with high sedimentation and vice-versa. Thus, in the



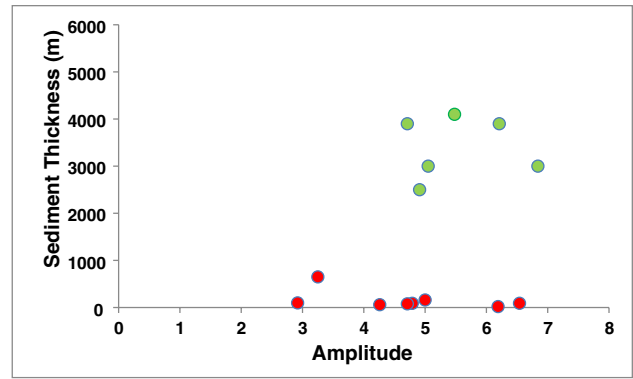
**Fig. 8** Correlation plot for resonance frequency with sediment thickness



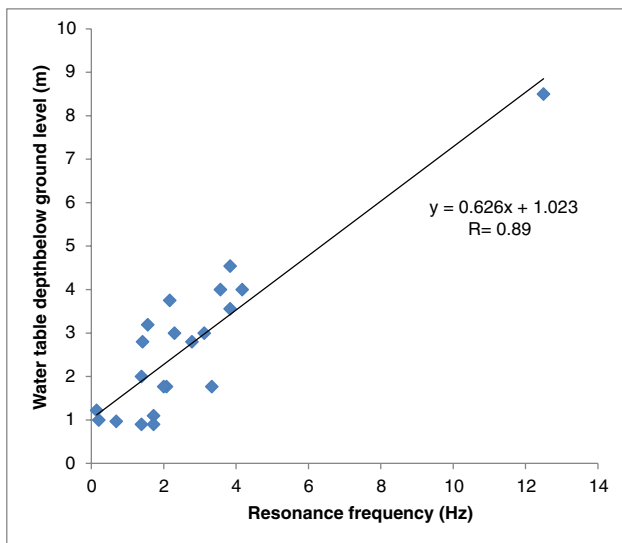
**Fig. 9** Comparison plot for the present equation with other equation established for soils abroad



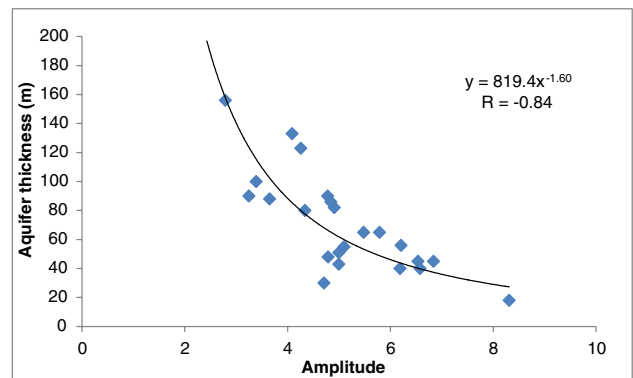
**Fig. 10** Comparison plot for the present equation with other equation developed by Indian authors under Indian condition



**Fig. 12** Cluster plot showing variation of amplitude with sediment thickness (red circles indicate sediment thickness between 20 and 650 m; green circles indicate sediment thickness between 2500 and 4100 m)



**Fig. 11** Correlation plot for resonance frequency with water table depth



**Fig. 13** Correlation plot for amplitude with aquifer thickness

study area, the amplitude values are much higher as expected, so that if an earthquake occurs in such areas, it is capable of causing strong ground motion in areas even at a larger distance (on an average 500 km).

**Relating amplitude with aquifer thickness**

Relating amplitude with aquifer thickness is not a new concept according to other field of science like aeronautics, but it is a new concept according to seismology. The review of literature showed that there are no correlation studies available at present that relate amplitude with aquifer thickness. An attempt was made in this paper to correlate aquifer thickness from local borehole studies with amplitude of the H/V spectrum by plotting these

two parameters as a non-linear graph. An equation was obtained in this endeavor by correlating amplitude with aquifer thickness as follows:

$$\text{Aquifer thickness} = 819.4 \times (\text{Amplitude})^{-1.6} \quad (6)$$

From Fig. 13 for the above graph, a high *R* value of 0.84 was observed with negatively trending plot. Also, from the above graph, it can be observed that amplitude of H/V ratio from strong ground motion analysis decreases with increase in aquifer thickness. The outcome of the above result indicates the importance of aquifer thickness in determining the amplitude of the seismic waves. In locations where aquifer thickness is more, less amplitude was observed and vice-versa thus proving the fact that strong ground motion signals are affected by the local ground water condition. Thus, in Assam, the thickness of aquifer seems to have confined the strength of seismic signals in certain areas. However, to know more exactly about the relationship between aquifer thickness and amplitude of seismic signals more studies throughout the world have to be carried out.

## Conclusion

Strong ground motion data for 26 locations of Assam were available in web portal as a pictorial format. Data available in this portal were used to find resonance frequency and amplitude for 26 locations of Assam. A seismic site classification has been proposed based on resonance frequency details collected from strong motion sites in Assam. Also, we compared our site classes with other studies from Assam and its nearby region which produced good match. Also, the amplitude values of the present study are almost consistent with nearby Himalayan region and are higher in value. Further, an empirical equation was established relating sediment thickness with resonant frequency which showed good agreement with the previous results. As a further step of analysis, resonance frequency from strong ground motion studies of Assam were correlated with ground water table depth to see how the ground water condition influences the strong ground motion. An additional parameter of strong ground motion (i.e.) amplitude was plotted as a cluster graph against sediment thickness. Apart from that, a correlation of amplitude with aquifer thickness was attempted which produced non-linear equation with good fit. Thus, it can be concluded from the above study that these correlation studies established good relationship between strong ground motions and geological conditions. Also, it is interesting to note that the above analysis leads to the fact that the high amplitude of this study area along with its shallow water table may make Assam a potential candidate for liquefaction and hence structural damage.

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## Declarations

**Conflict of interest** The authors declare no competing interests.

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