Field Training Report - Day 04 on

Site Characterization Of A Region By Implementing HVSR

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Content:

PREAMBLE

Embarking on Day 4 of our Winter Geophysical Field Training, our mission centered on Horizontal to Vertical Spectral Ratio (HVSR) exploration. Eager to unveil subsurface complexities beneath snowy landscapes, our team delved into uncharted territories. The snowy expanse became a canvas of possibilities as we aimed to decipher unique signatures through this innovative geophysical method. Day 4 unfolded as an exciting chapter of exploration, blending scientific curiosity with the challenges of winter terrain in our pursuit of understanding the intricate layers beneath.

SURVEY AREA

The survey area is situated in the Dhanbad district of the Jharkhand state, India, precisely in Baliapur, Dhanbad, with coordinates 24.8640° N, 87.1990° E. The designated base station for the survey is strategically positioned at 23°41’29’’ N, 86°31’25’’ E. These geographical coordinates serve as the anchor points for our exploration, providing a specific and essential reference for the conducted geophysical activities in this region.

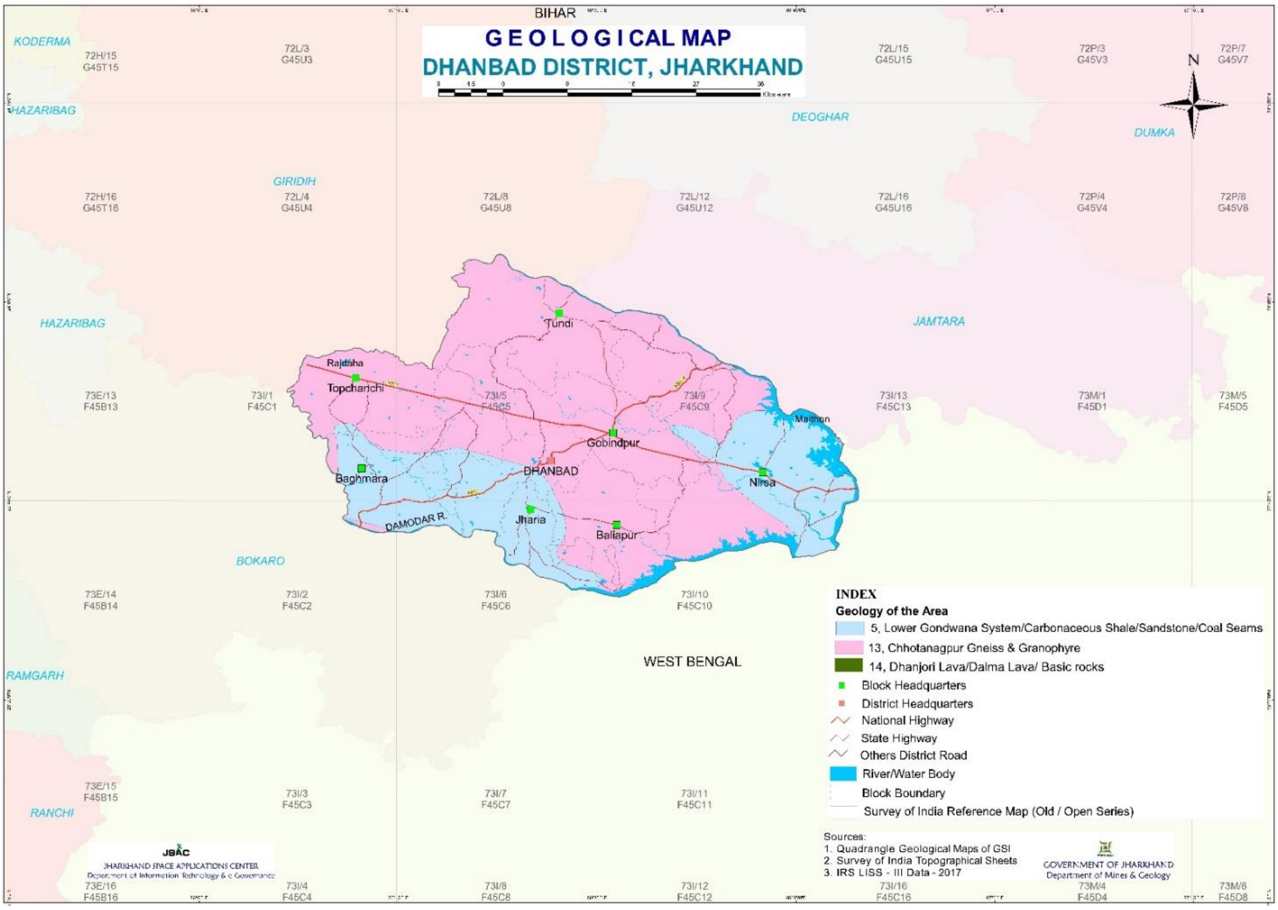


Fig: Geological Map of Dhanbad District, Jharkhand

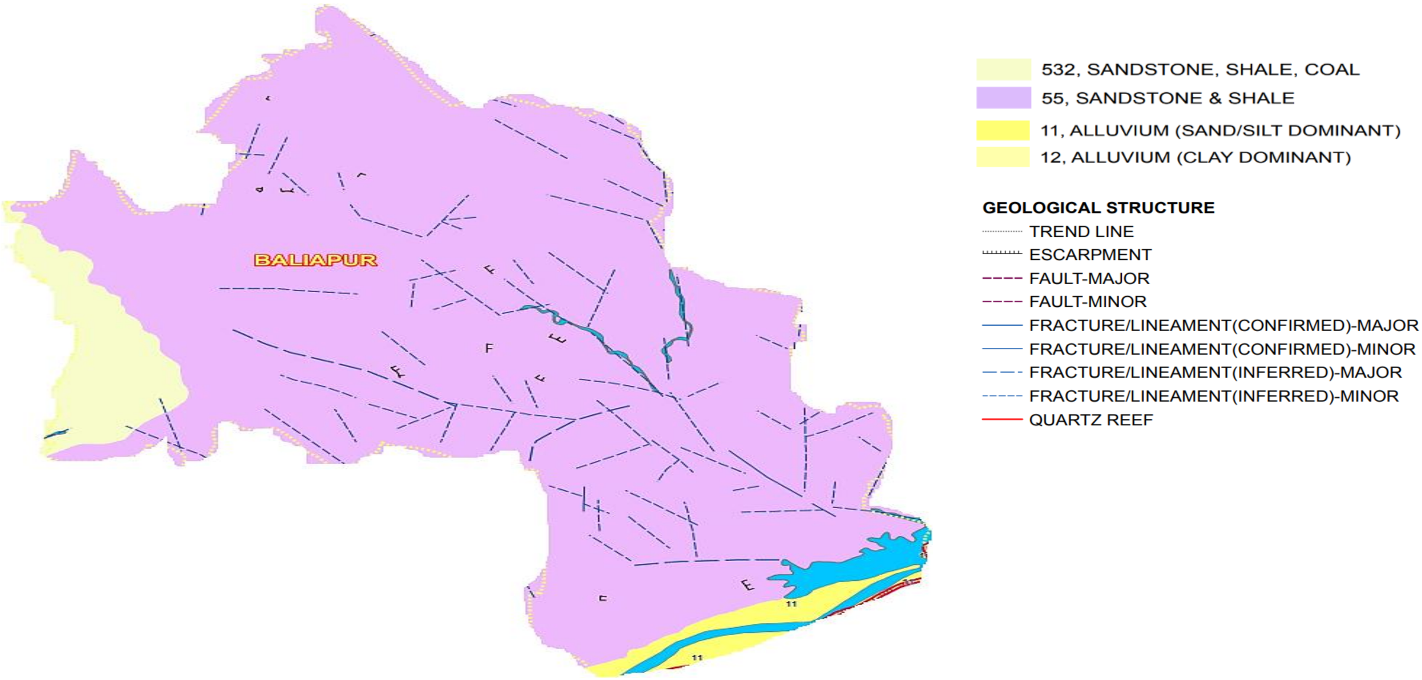


Fig: Geological Map of Baliapur

SURVEY: HVSR METHOD (HORIZONTAL - VERTICAL SPECTRAL RATIO METHOD)

INTRODUCTION

The Horizontal to Vertical Ratio approach is a commonly used instrument for investigating the amplification of ground motion. This concept encompasses a broad spectrum of ground motion amplitudes, ranging from subtle micro tremors to intense forceful motion.

The HVSR methodology has become widely popular as an inexpensive method for estimating the amplification of seismic ground motion at a location. It may be used with both ambient noise and weak motion recordings. A plethora of site amplification studies is documented in the gray literature. This approach has been lately used for many goals, including investigations of sedimentary basins, faults, cavities, and ultimately to assess the fundamental frequency of structures. The technique was first presented by Nogoshi and Igarashi in 1971 and later popularized by Nakamura in 1989.

Prior research has analyzed Nakamura's approach by examining the ellipticity ratio of Rayleigh waves. This technique shows a distinct peak at the fundamental S-wave resonance frequency when there is a significant difference in impedance. The process involves calculating the ratio between the Fourier amplitude spectra of the horizontal (H) and vertical (V) components of the ambient noise vibrations that are recorded at a single station.

- The popularity of Nakamura's technique:

  I. Cost-effective approach.

  II. Relevant for areas with little seismic activity.

  III. Only one seismic station is necessary.

  IV. There is a lack of consensus among researchers.

PRINCIPLES

- Nature of microtremor is debated.
  - No established theory on the kind of wave motions provided by microtremor surveys (Bard, 1999).
  - Specific mechanism causing wave amplification:
    1. Varies from site to site.
    2. Ambient noise of weak motions
  - Key Assumptions:

$$HVSR_B = \frac{H_B}{V_B} = 1$$

$$TF_V = \frac{V_S}{V_B} = 1$$

$$TF_H = \frac{H_S}{H_B} = \frac{H_S}{H_B} \times \frac{V_S}{V_B} \times \frac{H_B}{V_B} = \frac{H_S}{V_B} \times \frac{V_S}{V_B} \times \frac{V_B}{H_B} = \frac{H_S}{V_S}$$

$$TF_H = \frac{\sqrt{{H_{NS}}^2 + {H_{EW}}^2}}{V_S}$$

H=horizontal Vibration
V= Vertical Vibration

OPERATION

The technique consists in estimating the ratio between the Fourier amplitude spectra of the horizontal (H) to vertical (V) components of the ambient noise vibrations recorded at one single station.
The computation of the H/V ratio follows different steps:

1. record a 3-component ambient noise signal
2. select of the most stationary time windows (e.g., using an anti-triggering algorithm) in order to avoid transient noise
3. compute and smoothing of the Fourier amplitude spectra for each time windows
4. Average the two horizontal components (using a quadratic mean)
5. compute the H/V ratio for each window
6. compute the average H/V ratio

INSTRUMENTATION

1. The GEObit instruments **GEOtiny** compact digital seismometer was used to acquire the data of the H/V survey. The GEOtiny supports 10s-98Hz velocity seismic sensor.
2. Battery
3. GPS antenna
4. Measuring tape

Field Photos:-

The GEOtiny compact digital seismometer (short period 0,1-0.01 s) ,Ethernet Cable, Connecting Wire, and Battery

GPS

Field Arrangements, Methodology And Data Acquisition:-

1. First, we have to mark the profile taking the 10 meters step size along the profile line of the survey.
2. Then As per the above arrangement shown in above figure we have to set the instruments.
3. For arranging the instruments first, we have to set the GEOtiny along the true North.
4. Then we have to level the GEOtiny using the spirit level given at the top for the accurate readings.
5. Then We have to connect the GPS cable to the GEOtiny. After completion of the arrangements battery has to be connected. This would turn on the GPS Antenna which would take some time for the synchronizing, it provides the time and the location for the time series data recorded on the GEOtiny. Then we have to connect the Laptop with GEOtiny to confirm that data recording has started.
6. Then we have to leave the instrument for the 30-40 minutes for the acquisition for recording the ground vibration.
7. We have to repeat this process for six different positions along the survey line.

OBSERVATION TABLE OF THE TIME INTERVAL AND POSITION

Point No.	GMT time	clock time		lattitude	longitude
1	04:20:00	9:50	10:20:00	23.691190	86.52437
2	05:14:00	10:44	11:14:00	23.691093	86.524331
3	05:52:00	11:22	11:52:00	23.690089	86.524228

DATA PROCESSING

We are using the Geopsy Software to process the data

1. Importing the Data

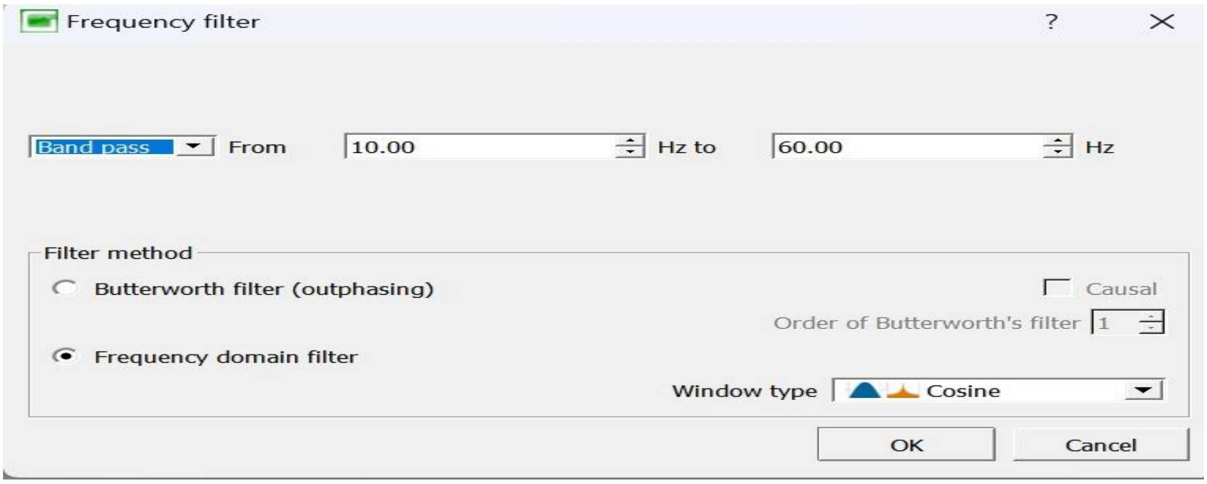
- Open the Geopsy software
- Import the HVSR data as by going to file and then import as signals
- Select all the 3 components of the data and then import the data

	ID	Name	Component	Start time	End time	Sampling frequency	Sampling period	N samples	Duration	Rec x	Rec y
1	1	GTN12	East	2023-12-05 04:17:52.927970	2023-12-05 04:49:17.187970	100	0.01	188426	31m24.260000s	-12345	-12345
2	2	GTN12	North	2023-12-05 04:17:52.927970	2023-12-05 04:49:17.187970	100	0.01	188426	31m24.260000s	-12345	-12345
3	3	GTN12	Vertical	2023-12-05 04:17:52.927970	2023-12-05 04:49:17.187970	100	0.01	188426	31m24.260000s	-12345	-12345

2. Preprocessing of the Data

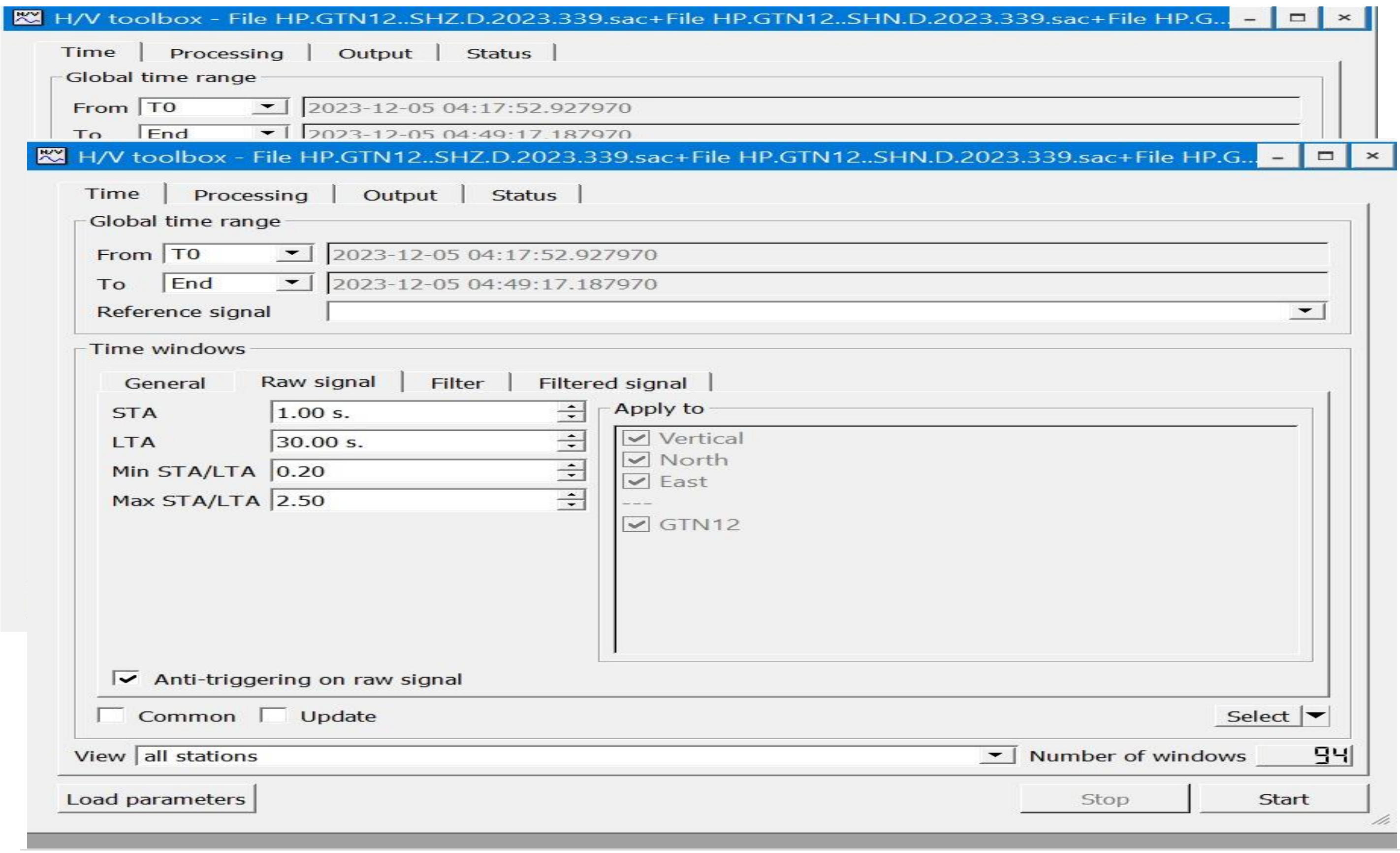
- After loading the data go to the visualization box to visualize the data
- This step is need to ensure that whether we need to apply filter to the data or not
- Now to remove the effects of higher frequency component we do filtering of data-

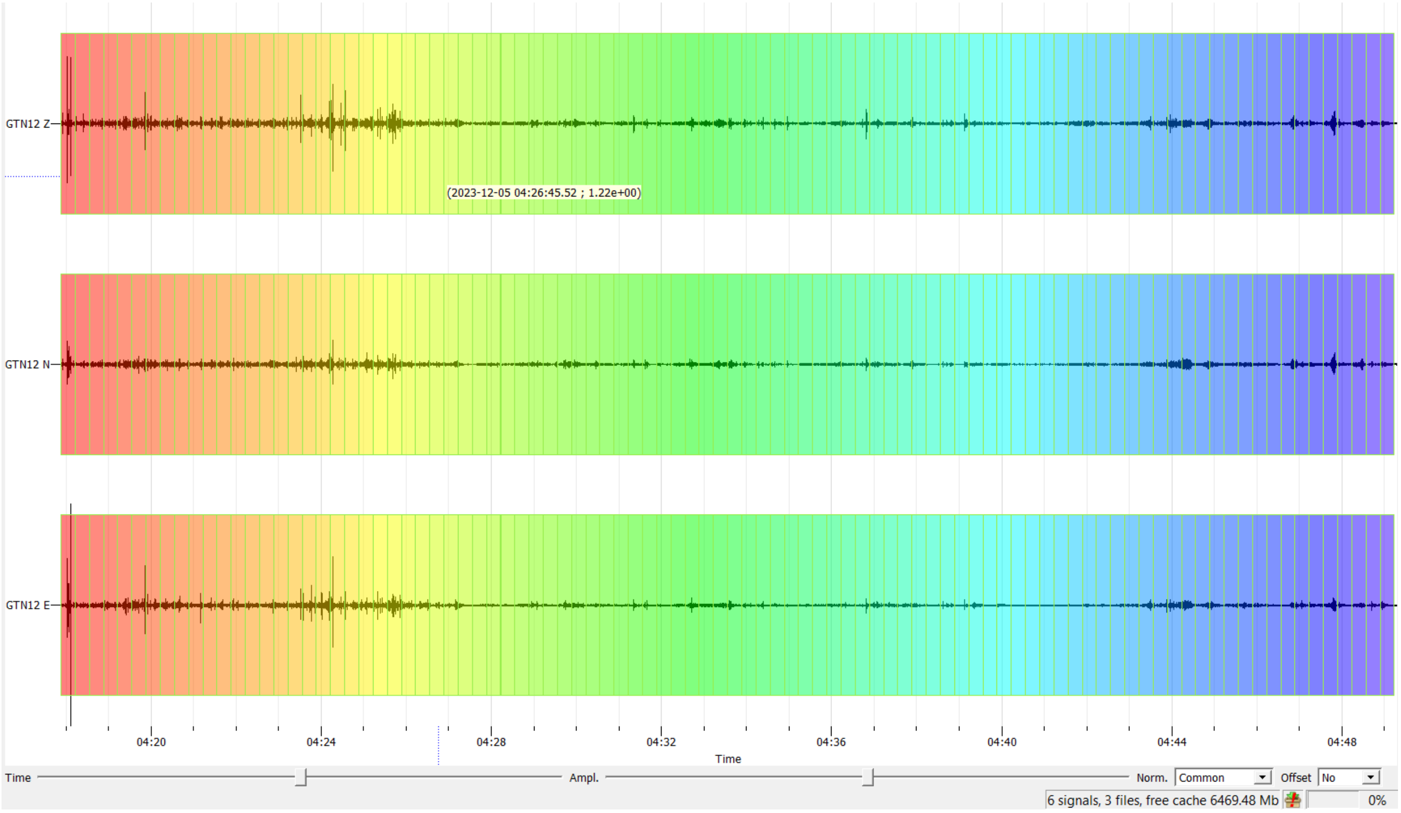
- ➢ Filter type= Bandpass (10-60Hz) ; Cosine filter applied



- After doing the filtering of the data divide the whole data into small windows.

  - ➢ Window duration=20 s
  - ➢ STA = 1 s
  - ➢ LTA = 30 s
  - ➢ Min STA/LTA = 0.20
  - ➢ Max STA/LTA = 2.50
  - ➢ No. of windows created=94



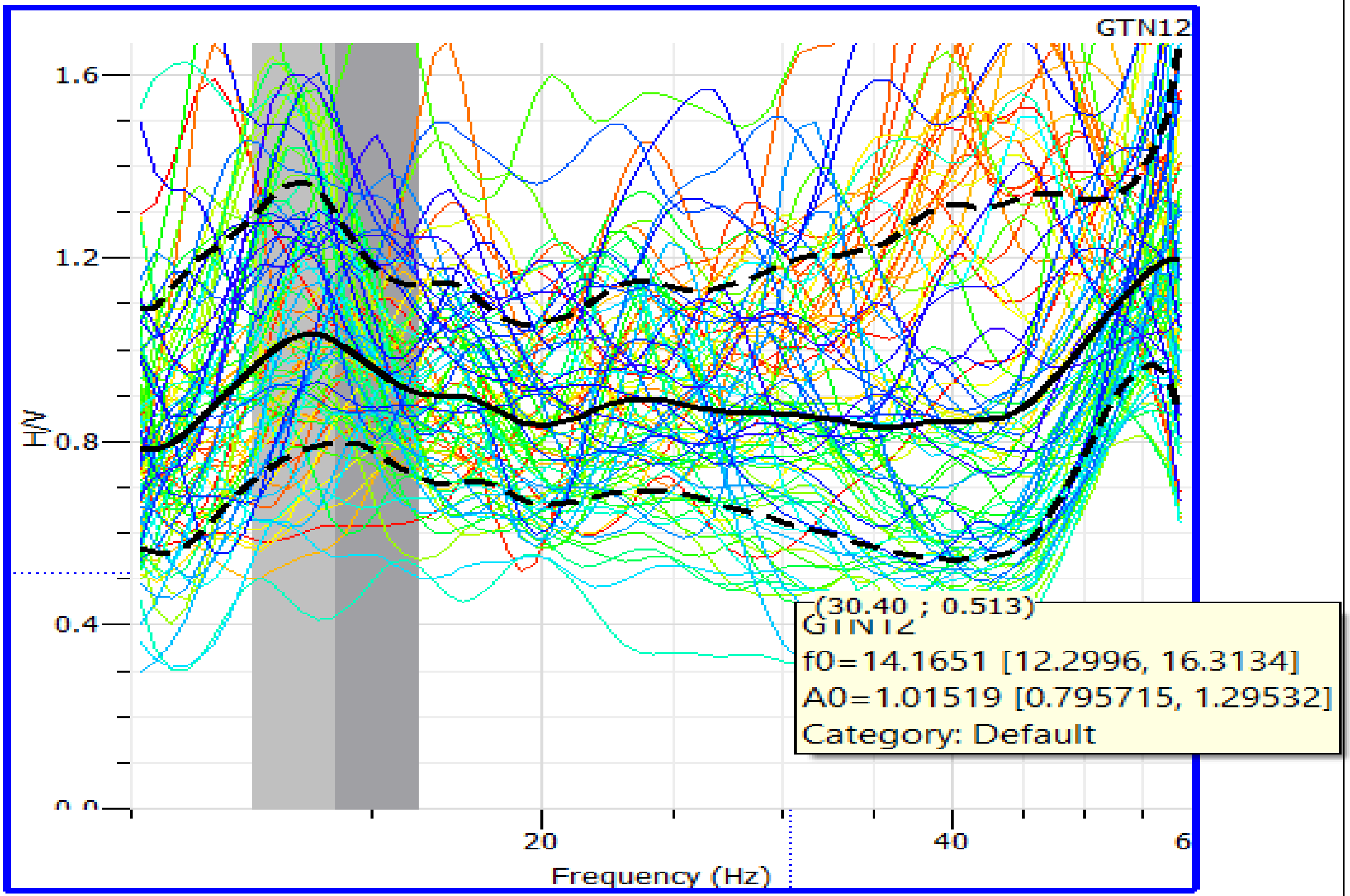


3. **HVSR Curve Computation and Frequency Analysis**
    - Use the Icon H/V to compute the HVSR Curve for each window
    - After computing the HVSR curve for each window plot them and correspondingly do the frequency analysis
- Identify resonant frequencies in the HVSR spectrum.
- Use methods like Fourier analysis to determine dominant frequencies.
- Understanding these frequencies helps reveal subsurface geological features and structures.

<u>OBSERVATIONS</u>

- Here we are considering the processing of first location in Geopsy Software.
- We have sliced the total time window of 30 min into equally spaced stationary time windows of 20sec length.
- Each and every time windows are represented by different color.
- Now after plotting the H/V vs f we can see each color curve represents the amplitude spectrum of each color time window
- The mean value of all the colored curves is represented by a black solid line and average Standard deviation ($\mu \pm \sigma$) about the mean is represented by black dashed lines.

- Here we see dominant frequency is at 14.1651Hz with an amplitude of 1.01519 Width of the resonant peak is (Frequency Range of Predominant Frequency: Min=12.2996 Hz, Max= 15.3134 Hz)



CONCLUSION

The soil's natural frequency at 14.1651 Hz suggests the presence of Tertiary or older rocks, characterized by hard sandy rocks and gravel. Identified as a type IV class I soil, the surface sediments are notably thin, predominantly composed of hard rock.

With a natural period of 0.07 seconds, considerably shorter than the typical range of 2-10 seconds for large buildings, our geological region appears suitable for constructing multi-storey buildings. The conclusion drawn is that structures and significant infrastructure developed here are unlikely to face seismic hazards or earthquake activities, ensuring a level of safety for construction projects in this area.