

# DISPERSION IMAGING AND SUBSURFACE PROFILING USING PASSIVE ROADSIDE MASW SURVEY

## Abstract

Passive methods of Multichannel Analysis of Surface wave (MASW) utilizes surface waves generated from natural (microtremors) or cultural sources (tidal or traffic) to determine the subsoil profile in terms of Shear wave velocity ( $V_s$ ). Passive Roadside survey aims to record the surface waves generated from traffic-originated sources by employing 1-D linear array and, hence, is a more suitable method in congested urban areas. In roadside survey, the road surface irregularities such as the potholes or speed inhibitors serve as sources of surface wave as the vehicles pass over them. However, the field data acquisition and corresponding processing for dispersion imaging is complicated in passive roadside survey owing to the unknown numbers and locations of sources. The objective of the present research is to critically examine various parameters controlling the resolution and quality of dispersion imaging of passive roadside data, so that robust and confident  $V_s$  profile can be obtained, irrespective of site and test conditions.

An extensive experimentation programme of passive roadside survey was conducted at three sites inside and around IIT Guwahati campus. Site 1 was selected inside IIT Guwahati campus beside the cricket field, Site 2 is a road stretch from IIT Guwahati to Amingaon market, and Site 3 is a road stretch of the National Highway NH 31. The roads at each of these sites comprise different volumes of traffic comprising light, medium and heavy traffic, respectively. The raw field records from all the three sites have been critically analyzed for wavefield propagation and arrival, frequency-amplitude spectra, wavefield contamination and their respective effect on the resolution of dispersion imaging. The quality of raw field records in a passive roadside survey is not controllable by the investigator. It is found that even without existence of major surface sources on the road, traction of heavyweight vehicles produces significant energy, much greater than conventionally used sources in active survey. At sites with medium to heavy traffic volume, wavefield contamination is a major problem in obtaining a cleaner record. At such sites, it is necessary to cautiously record field data with smaller recording time, in the range of 1-5 s, to avoid wavefield contamination.

Receiver array length and acquisition time significantly affect the resolution of dispersion image. Thicker energy band and poor resolution in lower frequency band of dispersion image is found to be the outcome of utilizing shorter arrays. Irrespective of the site conditions, a short receiver array of length 23 m is found to be insufficient to produce dispersion image with sufficient resolution. With longer arrays of 46-92 m, the resolutions of dispersion images is found to be enhanced. At site with heavy traffic volume, raw field records from longer receiver array suffers severe contamination that resulted in poor resolution dispersion image. The ratio between longest measurable wavelength to the receiver array length is found to be approximately in the range of 0.6-1. Further, the highest ratio between the depths of investigation to longest wavelength has been found to be 0.4. The acquisition or recording time is largely influenced by the volume of the traffic and numbers of existing sources on the road surface. For site with light to medium traffic volume, acquisition time between 2.8-21.8 s have been found to be sufficient. Smaller recording time is effective during raw data acquisition at site with heavier traffic volume.

Implementing optimum processing parameters during dispersion analysis is critical in obtaining high-resolution dispersion image. Setting optimum frequency and velocity range during dispersion analysis, by discarding contaminating energy bands, helps in enhancing dispersion image resolution. An appropriate selection of azimuthal quadrants allow identifying directions of major wavefield sources, making energy computation along azimuth axis accurate and resulting in a dispersion image with superior resolution. Offline distance of receiver array controls the dispersion imaging process and adoption of appropriate processing scheme. An inline processing (IP) scheme for a closely situated source results in a broader energy band in the dispersion image and overestimated phase velocity in the extracted dispersion curve. Offline cylindrical (OC) or Offline plane (OP) scheme is found suitable for the cases of intra-line sources, which automatically incorporates the planar or cylindrical wave propagation through the receiver array depending on the offline distance between the array and the centreline of the road. Vertical stacking is an advantageous method for enhancement of dispersion image resolution especially in passive MASW survey. In most of the field situations, minimum 10 numbers of vertical stacking is required for high-resolution dispersion image. A new approach to vertical stacking is proposed to obtain a superior quality dispersion image when there are only a few numbers of good quality field records available.

The lowest frequency point on a dispersion curve controls the maximum achievable investigation depth. However, upon extending the selection of dispersion curve in lower frequency part, the corresponding Root-Mean-Square (RMS) value increases, which is a sign of deviations of the soil profile from its true scenario. Therefore, it is found that depending on the requirement of depth of investigation, the selection of dispersion curve should be limited in its lower frequency part to avoid deviation between measured and actual soil profile. The density of dispersion points, for representing the dispersion curve within a selected frequency range, affects the stability of inversion and the reliability of obtained  $V_s$  profile. It is found that to obtain a reliable  $V_s$  profile, the frequency interval of dispersion points for the extraction of dispersion curve should be 0.5 Hz or lesser. Adoption of higher number of earth layers in the initial earth model is observed to give more stable and reliable  $V_s$  profile. For a depth range of 18-30 m, the number of layers in the initial earth model to be used should be 7 or more.

Passive roadside surveys involve complex source characteristics with multiple source existence having varying azimuthal characteristics. In the study, the influence of source location in terms of intra-line and outer-line positioning of sources, existence of multiple numbers of strong sources of wavefields, and the effect of offline distance of receiver arrays on the resolution of dispersion image is highlighted. The intra-line source produces a dispersion image with better resolution, particularly in lower frequency band, attributed to the ability of recording stronger low frequency components of surface waves. Multiple sources shows marginal effect on the resolution of dispersion imaging until there is no contamination on the raw records by mutual interferences. Usability of roadside survey vastly depends on the accommodated offline distance. Based on the present study, to have recognizable dispersion image, the highest offline distance that can be adopted has been found to be 15 m. Based on the close comparison of results of Passive Roadside MASW survey with those of conventional surveys, the efficacy and applicability of the adopted Passive Roadside MASW technique in identifying subsurface characteristics utilizing the vehicular movement on the roads is suitably established. Finally, from the present research, a robust set of guidelines have been provided which would aid in a good field and analysis practice to conduct Passive Roadside MASW survey to obtain meaning subsurface  $V_s$  profiles.

**Keywords:** *Passive Roadside MASW survey, Data acquisition, Resolution of dispersion image, Vertical stacking, Shear wave velocity profile*