In situ shear wave velocity from multichannel analysis of surface waves (MASW) tests at six sites of Delhi Technological University.

Rajat Gautam[a], A.K. Shrivastava[b], Shubham Gupta[c], Vishal Sharma[d]

[a]Research Scholor, Civil Engineering Department, Delhi Technological University, Shahbad Daulatpur,Delhi 110042, India, rajatgautam1994@gmail.com
[b]Professor, Civil Engineering Department,Delhi Technological University,Shahbad Daulatpur,Delhi 110042, India, aksrivastava@dce.ac.in
[c]M.Tech student, Civil Engineering Department, Delhi Technological University, Shahbad Daulatpur,Delhi 110042, India, shubhamgupta_mt2k19@dtu.ac.in
[d]M.Tech student, Civil Engineering Department, Delhi Technological University, Shahbad Daulatpur,Delhi 110042, India, vishal_mt2k19@dtu.ac.in

A B S T R A C T

In the mid-1980s, the surface wave method was initially exhibited as an instrument for the geotechnical engineering field. This non-obtrusive seismic method of multi-channel examination of surface waves is prominently used to draw out the shear-wave velocity profile (variation of soil with respect to its depth). In an attempt to increase the sureness in the construed shear wave velocity (V_s) profile as a result of the ambiguity in the analysed dispersion characteristics, the multichannel method is used in this research to characterize six test sites on the campus of Delhi Technological University, Delhi. The multi-channel analysis of surface waves (MASW) method commenced from the traditional seismic survey method that engages twenty-four receivers positioned all along a linear survey track. The current study implies results from MASW survey at six sites within the DTU campus, for which the MASW data acquisition comprise of the use of a 24-channel PASI seismograph and 24 numbers of 4.5 Hz Vertical geo-phones set apart at 2 m each and source offset (2 m,4 m). The seismic power source was a steel sledgehammer (15 lbs). In order to develop and invert the surface-wave seismic data in addition to creating the one-dimensional depth versus Shear Wave Velocity (Vs) profiles WinMasw software was used. The mean shear wave velocity of the current study area is 285 m/sec. The mean shear wave velocity for Delhi city is in a range of 110 to 350 m/s.

Keywords:
MASW, Shear wave velocity.

1. INTRODUCTION

In an important range of geotechnical design applications, the measurement of the small strain shear modulus, G_{max} of a soil is essential. This normally involves strains of 10^{-3}% and less. As per the elastic theory, G_{max} may be estimated with the help of shear wave velocity using the below equation:

- $G_{max} = \rho*(V_s)^2$ (1)

where G_{max} is the shear modulus (in Pa), V_s is the shear wave velocity (in m/s), and ρ is the density (in kg/m^3).
Lately several authors (e.g., Kautmann et al. 2005 for narrow marine sediments; Harry et al. 2005 for fluvial aquifers; Donohue et al. 2003 and 2004 for very stiff Irish glacial and very soft clays and silts from central Ireland, respectively; and Park et al. 1999) have concluded that V_S (and henceforth G_{max}) can be easily acquired economically and reliably by the use of multichannel analysis of surface waves (MASW) technique.
The MASW technique has spawned substantial attention in the geo-physics society due to its non-obtrusive character and also due to the easiness of the process, Crice (2005) suggests that "MASW is the wave of the future because of the usefulness and interpretability of the data and the potential for dramatically higher productivity." The purpose of this study is to present the results of some MASW surveys conceded out during the autumn of 2019 at six well-characterized sites in Delhi Technological University.

2. Multichannel Analysis of Surface Wave

In order to master the difficulties related to the SASW method the Kansas Geological Survey (Park et al. 1999) announced the MASW technique in the late 1990s. This method uses multiple geophones bounded to a single multichannel recording seismograph. Its processing principles are basically the same to those which are typically used in the seismic reflection methods. The MASW technique has enhanced the characterization of dispersion relationship by sampling the spatial wave field with numerous geo-phones which lead to the upgradation of pre-existing seismic analysis methods. The prominent point of interest in this method is that it requires only one-shot to gather the data and also this method is capable of identifying and isolating noise. Crice (2005) demonstrate how MASW analysis data can be consistently interpreted by computer software without human intervention. Globally, research analysts have expressed that this method is precise for basic soil profiles. As the inversion interpretation in MASW can undergo the similar uniqueness difficulties as in SASW method, an experienced user is required for analyzing the complex soil profiles. For this study MASW method was utilized to gather and process the data for all six stations in the university. In general, the vertically polarized Rayleigh waves are kept in focused for the geotechnical surface wave surveys. In case of heterogeneous medium (or non-uniform) profiles, the wave-length (or frequency) of that Rayleigh wave majorly affect its propagation velocity. Short wave-length (or high frequencies) Rayleigh waves are usually affected by material closer to the surface when compared to Rayleigh waves with longer wavelengths (or low frequencies), which get affected at deeper depths. This phenomena of the dependence of the phase velocity in respect to frequency is called dispersion. Hence, by keeping a wider range of wavelength, dispersion curves are correlatedly produced by the mapping of phase velocities along with the respected frequency. After production of a dispersion curve, the next step involves the inversion of this curve using the software winMASW, which is developed by ElioSoft.

2.1 Instrument:

Seismic data were recorded using the GEA24 seismograph, it is designed and assembled by P.A.S.I. srl, a leading company in Italy in the production of instruments for geology and geophysics. Gea24 consists of a control unit and two 12 channel seismic cables, equipped with 12 single take-outs and terminated with standard connectors Cannon NK2721C. Gea24 can be placed either at the ends or in the centre of the spreading, in the present study all tests were conducted while keeping the seismograph in the centre of two cables. Table 1 shows the technical specifications of the instrument used.

Table 1 – Technical Specification GEA24.

Number of channels	24 + trigger
Sampling Interval	ACTIVE: Up to 125 microsec on 24 channels
Acquisition Length	27500 samples @24 channels
Stackings	Unlimited
Trigger	Normally closed contact
Geophone Frequency	4.5 Hz
Noise Monitor	All channels + trigger
Data Format	SEG2, SAF
Operating Temperature	-30 - +80 C
Dimension	24 cm x 19 cm x 11 cm
Weight	2 Kg

2.2 Data Acquisition and processing:

Physical impacts via a metal mallet of 15 lbs. weight, on a square aluminum plate is utilized for creating the vital energy source for the geophones. For the current field work 12 or 24 geophones are orchestrated in a lined array spread out at 2 m spacing and are linked to the PASI seismograph, which made the absolute overview length of 24 m or 48 m respectively. Seismic power is spawned at 2 m, 4 m and 5 m distance from the last geophone. Ground setting of the geophones and the seismograph is shown in Fig 1. Totally 20 shots were taken at each specified location of the university. Likewise, to instate the recording a trigger geophone was utilized. Data for each shot is digitally recorded. The procured information is then moved for further investigation using the winMASW software. Table 2 depicts the accounts parameters for the field-testing during procurement process. The acquired seismic data of the sports complex and concert ground sites are shown in Fig 2. Shows the dispersion curves of the football ground and concert ground area.

Gained surface wave seismic information is further copied to the personal computer and is handled with the help of winMASW software. In order to filter recorded data for background noises, the data was first being processed by GeoGiga software. Mapping of dispersion curve (phase velocity versus frequency) is one of the most important steps for creating a precise shear wave speed profile. Inversion of this curve leads to the generation of shear wave velocity profile.

Table 2 – General MASW parameters.

Recording System	GEA24
Sampling Interval	500 s
Source	Sledge Hammer
Pre-Trigger	On
Geophone Frequency	4.5 Hz
Data Format	SEG2, SAF
Geophone Spacing	2 m
Stack Mode	Summation

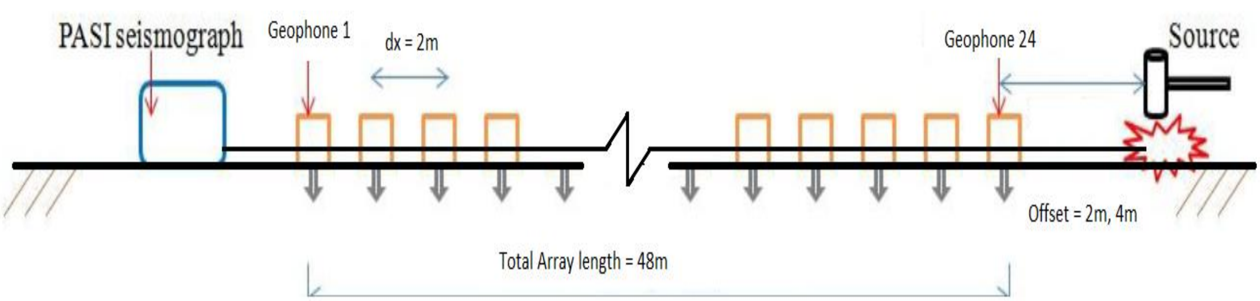
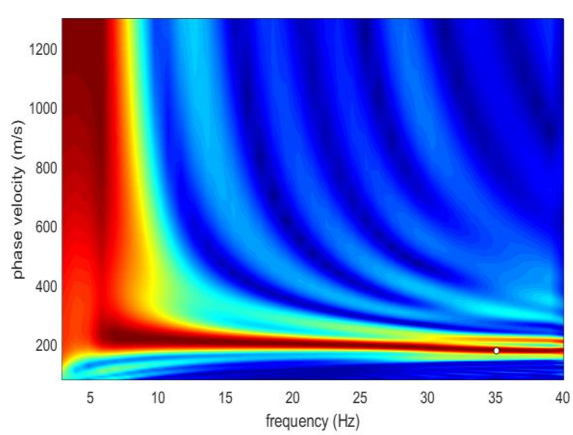


Fig. 1 – Field Layout Plan.

a.



b.

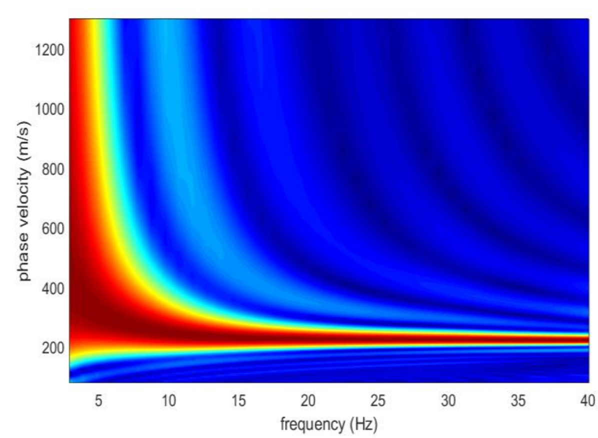


Fig. 2 – Dispersion Curves a) Football ground b) Concert ground.

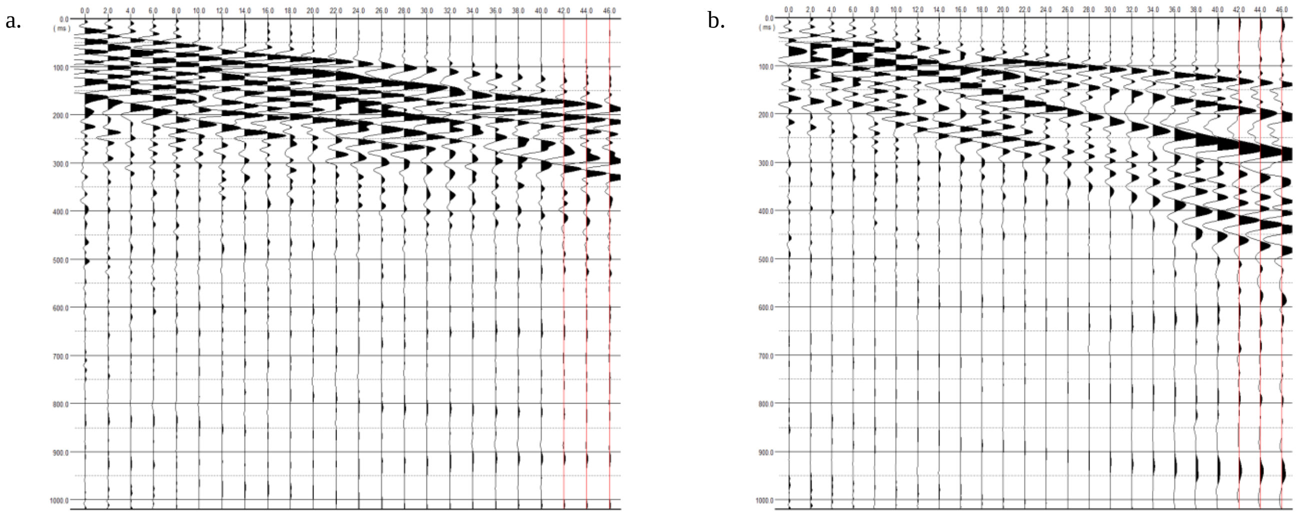


Fig. 3 – Seismic Data a.) Football ground b.) Concert ground.

2.3 Field testing program:

The in-situ tests were performed out in Delhi Technological University at 6 different sites locations by using either 12 or 24 geophones for the estimation of one-dimensional shear wave velocity profiles. Totally 30 tests were conducted to carry out a comprehensive site categorization of the university.

In the beginning of the survey it is extremely fundamental to choose the source recipient configuration which incorporate number of receivers, distance between receivers, source increment and all out total study length. Configurations settings used while the present study is summarized in Table 2. A number of trial tests with different configurations were conducted before fixing up these parameters. From the preliminary tests it was prominently seen that greater (max of 4 m) receiver spacing i.e. larger survey spread preferably generates higher resolution of data.

Table 3 – MASW test parameters at each site.

Site	Station Code	No. of Geophones	Geophone Spacing(m)	Source receiver offset(m)
Concert ground	A	24	2	2,4
Football ground	B	24	2	2,4
Administration ground	C	24	2	2,5
Mechanical area	D	24	2	2,5
Faculty Residential area	E	12	2	2,5
Lake area	F	12	2	2.5

3. Research site

Delhi Technological University (DTU), is a well-known public university situated in the vicinity of New Delhi, India. It was first established as the Delhi Polytechnic in the year 1941 and was later re-informed as Delhi College of Engineering (DCE), since 1963 the college has been under the government of the National Capital Region since 1963. DTU is amongst those few engineering colleges of India which were established before independence of India. The university is spread over a campus area of 164 acres. Six different arenas (Concert ground, Football ground, Administration ground, Mechanical area, Faculty Residential area and Lake area) bounded within DTU were chosen in a way to include every essential areas of the university to perform MASW survey. Locations of the six sites surveyed are shown in Figs. 4. The tests were performed in a way at a time so that there was minimal noise due to traffic or other human activities.

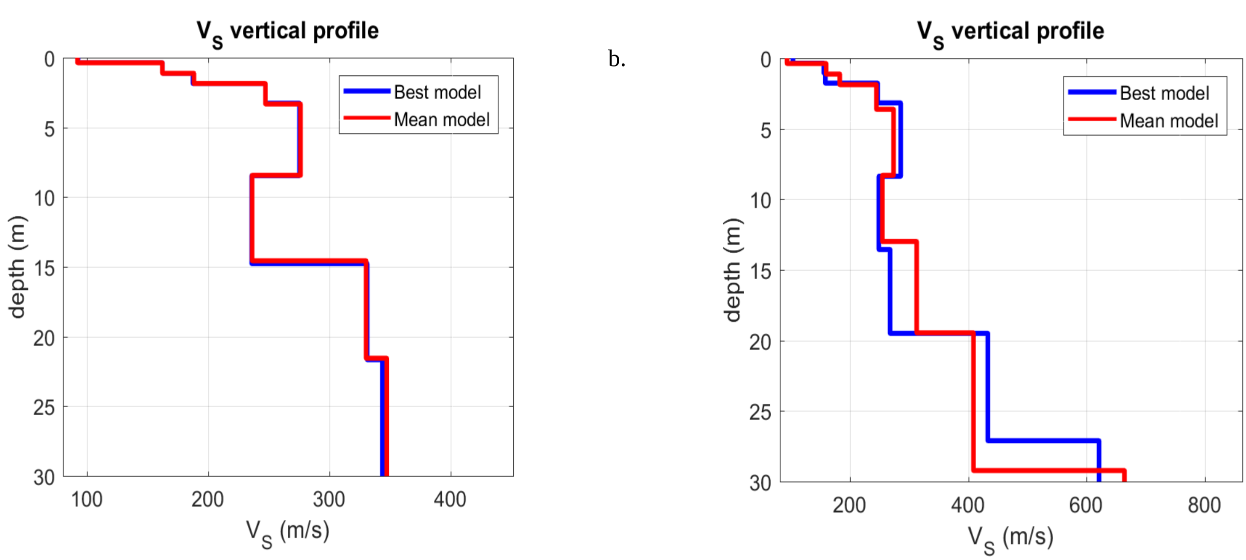
a. b.

Fig. 4 - (a) Delhi Technological University; (b) Delhi.

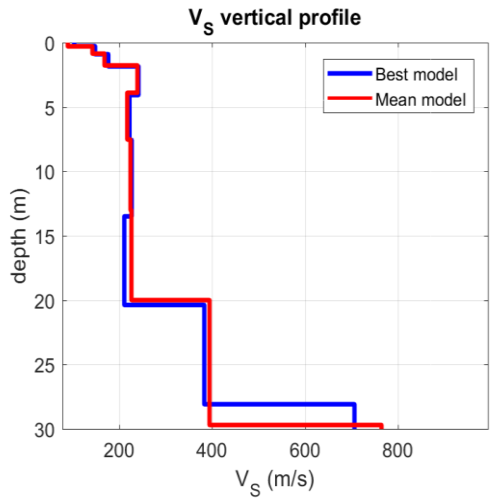
4. Results &Discussion

The obtained shear wave velocity for the specified locations in the study area are shown in table 4. Rao (2004) in his study concluded that the shear wave velocity of soil for the Delhi region is ranging from 110 to 350 m/s. Shear wave velocities of all the specified locations in the university premises were within the range. For the site classification according to NEHRP (National earthquake hazard reduction programme) and for analysing dynamic properties of soil shear wave velocity in an important mechanical parameter. It has been estimated during this study that the overall shear wave velocity at various location of Delhi Technological University is 285 m/s which indicates that the area of study falls under the site class D. There is presence of stiff soil beneath the surface as per NEHRP site classification. So, precaution should be taken while designing any new structures. Also taking readings by MASW gives the true nature of soil stratigraphy and subsurface profile for further investigations as per NEHRP soil classification

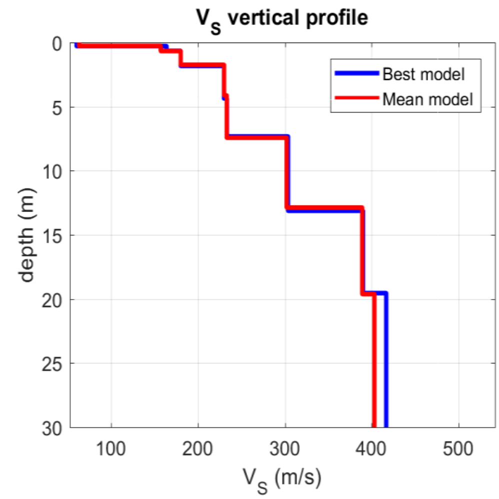
a. b.



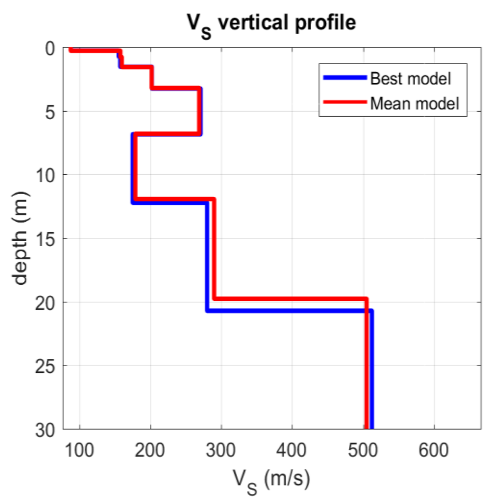
c.



d.



e.



f.

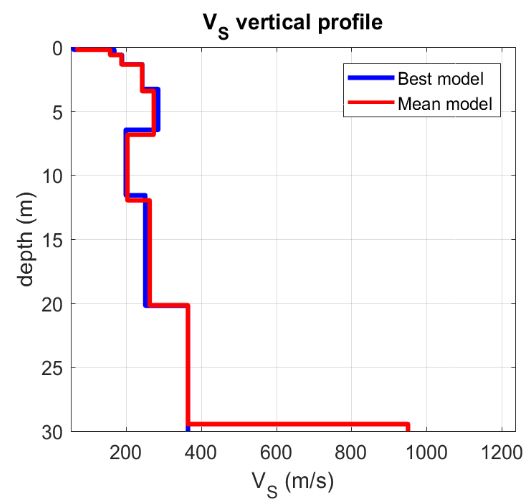


Fig. 5 - (a) Station A, (b) Station B, (c) Station C, (d) Station D, (e) Station E, (f) Station F.

Table 4 – Average V_s at various site.

Site	Station Code	V_s (m/sec)
Concert ground	A	253
Football ground	B	266
Administration ground	C	315
Mechanical area	D	276
Faculty Residential area	E	310
Lake area	F	290

5. Conclusion

As MASW is a non-obstructive technique which prominently allow us to the estimate the Vs ground profile, therefore subsequent estimation of shear waves profile is possible in a period productive and financially savvy way contrasted with the invasive technique helpful for Construction Project work. As seen the average shear wave velocity of Delhi Technological University, ground-test site is 285 m/s which indicates that the area of study falls under the site class D according to NEHRP site class. Subsurface profile and top of bedrock are determined using this MASW method compared to conventional methods which requires more time and cost. The MASW method saves time and cost for the investigation and proves useful for construction project work.

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