Analysis of Surface waves by using MASW(NDT)equipment at Ramappa Temple, Warangal, Telangana State, India

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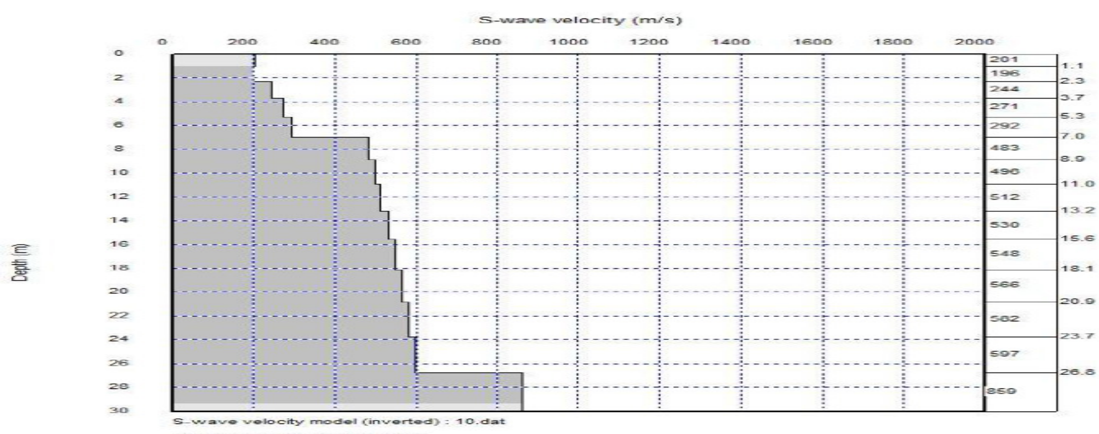
Abstract

In this study, the findings of the seismic site characterization carried out at the Ramappa temple and the thousand pillar temple, Warangal, Telangana, are presented. The site characterization activity was divided into two categories. The first one was the geophysical testing, which included Multichannel Analysis of Surface Waves (MASW) tests. The second category was the conventional geotechnical testing, which included standard penetration test and laboratory testing. In the MASW test, shear wave velocity profiles are obtained based on Rayleigh wave dispersion curves.

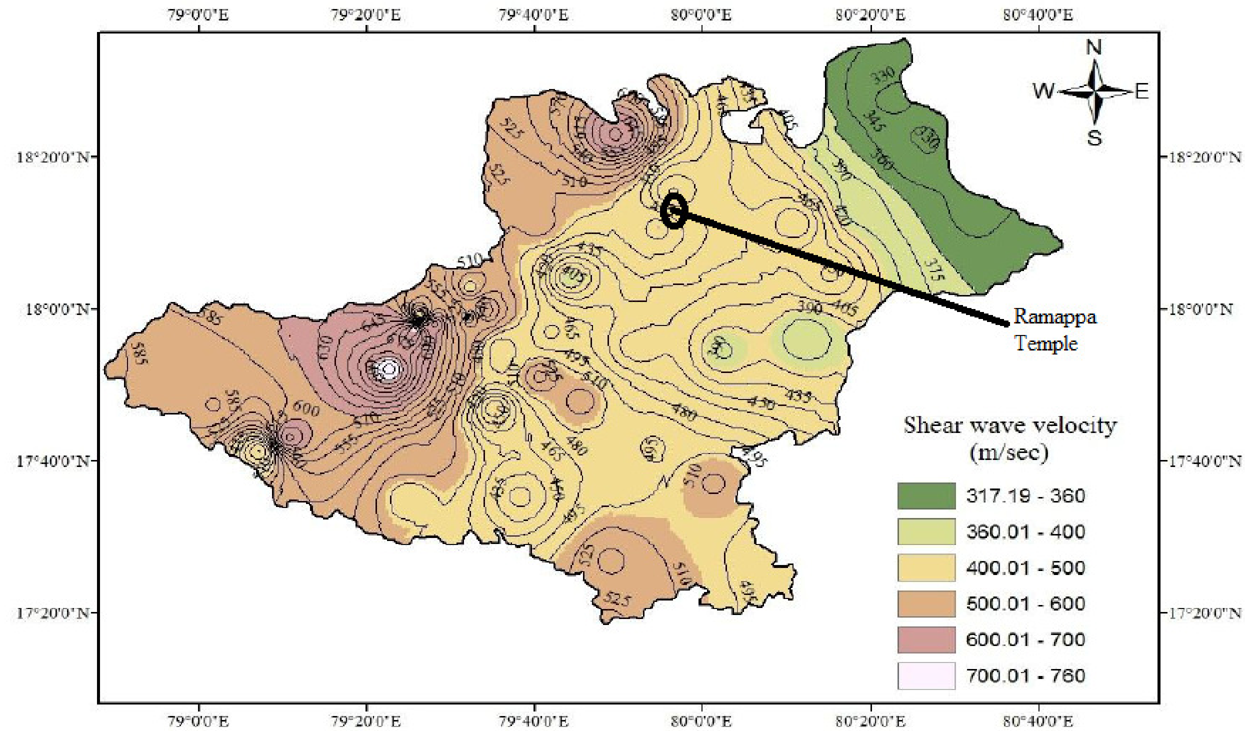
Seismic site characterization can be performed by various noninvasive methods (using both active and passive sources) which include spectral analysis of surface waves (SASW), multichannel analysis of surface waves (MASW), frequency-wave number (f-k), spatial autocorrelation (SPAC), refraction microtremor (ReMi), reflection/refraction, horizontal to vertical spectral ratio (HVSR), surface wave (SW) and microtremor array methods. Noninvasive methods are becoming more common for measuring Vs30. There are a number of methods that are currently in use and a number of methods that are being explored for future applications. The general procedure involves recording surface or body waves at the ground surface and resolving the subsurface structure or stiffness through forward or inverse modelling. Seismic tests involve the creation of transient and/or steady-state waves and the interpretation of their behavior from measurements made at one or more different locations. In many seismic tests, a source produces a pulse of waves whose times of arrival are measure at distance receivers. The source, which may range from a sledgehammer blow to the ground surface to a buried explosive charge, will generally produce P-waves, S-waves and surface waves.

The MASW test (Park et al., 1999) is commonly employed to estimate shallow S-wave structure. The frequency-dependent properties of Rayleigh-type surface waves can be utilized for imaging and characterizing the shallow subsurface. Most surface-wave analysis relies on the accurate calculation of phase velocities for the horizontally travelling fundamental-mode Rayleigh wave acquired by stepping out a pair of receivers at intervals based on the calculated ground roll wavelengths. Interference by coherent source-generated noise inhibits the reliability of shear wave velocities determined through inversion of the whole wave field. Among these non-planar, non-fundamental-mode Rayleigh waves (noise) are body waves, scattered and non-source-generated surface waves, and higher-mode surface waves. The degree to which each of these types of noise contaminates the dispersion curve and, ultimately, the inverted shear-wave velocity profile is dependent on frequency as well as distance from the source.

In early 2000s, the MASW method came into popular use among the geotechnical engineers. The term ―MASW originated from the publication made on Geophysics by Park et al. who had been utilizing the seismic reflection method—long used in the oil industry to image the interior of the earth for depths of several kilometers. Called the high resolution reflection method, it was used to image very shallow depths of engineering interest.
MASW method analyzes dispersion properties of seismic surface waves (fundamental-mode Rayleigh waves) propagating horizontally along the ground surface directly from impact source to vertical receivers. Shear wave velocity information is typically presented in 1-D (depth) or 2-D (depth and surface location) format. The fundamental framework of the MASW method is based on the multi-channel recording and analysis approach long used in seismic exploration surveys that can discriminate useful signals against all other types of noise.
MASW is a recently developed seismic method that deals with relatively lower frequencies and shallower investigation depth ranges than do conventional high-resolution seismic methods. It provides shear-wave velocity (*Vs*) information of near-surface materials in a highly cost effectively manner. Because of the relatively significant value of this (*Vs*) information in most geotechnical engineering projects and also because of the relatively simple in-field operation and data processing.
The Ramalingeswara temple (Ramappa temple) of Warangal district is a famous monument that attracts visitors from far-off places and is a very good example of artistic pursuits and achievements of Kakatiyadynasty.Ramappa Temple, being such a significant monument is built on sand in its foundation and is very susceptible to earthquake damages. And the investigations to be carried around the temple also call for the need of non-destructive methods with the least disturbance to the temple's foundation, unlike conventional boring methods.Hence MASW turns out to be the best method that can be used under these conditions. Many number of MASW tests were conduct in the surroundings of Ramappa temple and based on the data acquired average shear wave velocity of the ground under the Ramappa temple is calculated as 433.6m/sec.

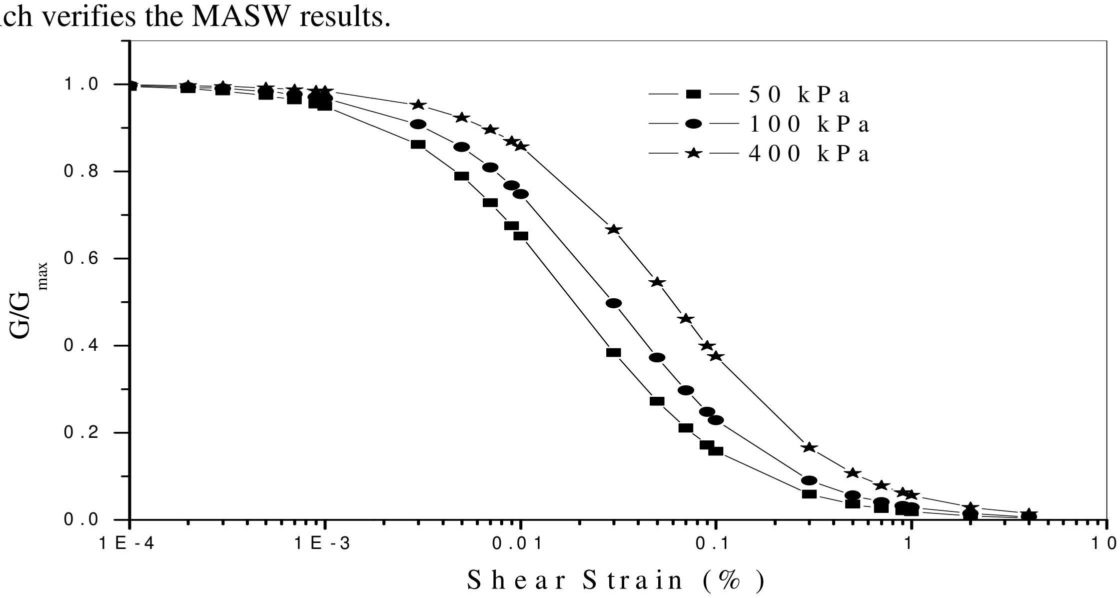


Typical Shear wave velocity profile of site at Ramalingeswara temple



Average shear wave velocity (Vs30) of depth 30 m variation across Warangal District.

In order to verify the results obtained by the MASW, laboratory tests are conducted on the soil samples. Laboratory tests mainly involved cyclic triaxial test in which dynamic properties of the soil can be found. These dynamic soil properties are useful in the seismic ground response analysis. Shear modulus obtained by this test (G_{max}) gave us a shear wave velocity of 380 m/sec which verifies the MASW results.



Modulus Reduction Curves for Different Confining Pressures