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NEHRP soil classification and estimation of 1-D site effect of Dehradun fan deposits using shear wave velocity

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ABSTRACT

Shear wave velocity of the near surface soil at nearly 50 sites in the sub Himalayan mountain exit covering Doon fan deposits, was determined using Multi-channel Analysis of Surface Waves (MASW), a seismic reflection technique. Based on the average shear wave velocity of the upper 30 m soil column, sites in the Dehradun fan are predominantly classified as class 'D' (180–360 m/s). Similarly, sites located on the northwestern, eastern and southeastern sides of the fan deposit have shear wave velocities (in the upper 30 m soil) greater than 360 m/s, thereby classifying them as class 'C' (360–760 m/s) in accordance with NEHRP provisions. Some of the sites towards the southwestern side of the fan deposits had average shear wave velocities less than 180 m/s and could be classified as soil class 'E'. One dimensional site effects, including amplification and dynamic period were calculated for the majority of the sites. However, some of the representative suite of sites across the north–south profile of Dehradun fan has been discussed here. Although the attenuation is greater on the southwestern side of the Dehradun fan deposits (i.e. thicker, low velocity sediments) and the sites had been classified as class 'D' and 'E' but the site amplification tends to be greater in the northern and northwestern part of the city due to large impedance contrast with in the near surface soils.

1. Introduction

Shear wave velocity is one of the key parameters in construction engineering, since the elastic properties of the near surface material are of fundamental importance in engineering and site response studies. Dehradun city, which is located in the intermontane valley within the Siwalik foreland basin, has a variety of geomorphic units. Earlier no subsurface data was available to assist the understanding of the subsurface sedimentary architecture of these units, however, present efforts of deriving shear wave velocity profiles down to a depth of 30–40 m will help sedimentologists in understanding the sedimentary architecture and basin evolution. The data will be useful for the prediction of the ground motion response to earthquakes in areas where significant soil cover overlays the firm bedrock and the information can be used to derive the stiffness factor of any site.

As a result of significant earthquakes such as those that have affected Mexico City (1985), San Francisco (1989), Los Angles (1995) and Ahmedabad (2001), it has become apparent that the structure of the unconsolidated materials of young sedimentary basins can have a profound effect on the spatial distribution of ground amplification and dynamic site period, resulting in large variation in the severity of damage to buildings, transportation corridors and other lifeline infrastructures. The Dehradun city has witnessed a lot of damage during the 1905 Kangra, 1991 Uttarkashi and 1999 Chamoli earthquakes. So the city of Dehradun is in a critical situation because, i) it has a high seismic potential due to its proximity to the active seismic source zones in the western and eastern part of the Dehradun region (Mahajan et al., 2002), ii) the location of the Main Boundary Thrust is close to the north of the city, iii) the existence of Mohand Thrust (Raiverman et al., 1984) to the south, and iv) the growing urbanization of the city and variation in thickness of sediments from north to south. Based on the current seismic hazard status of the Dehradun city and its surrounding Garhwal Himalaya, the most likely source of high amplitude ground motions in the area will be from a significant earthquake in the Garhwal seismic zone (Fig. 1) (Khattri et al., 1989; Mahajan et al., 2002).

The objective of this shallow subsurface study is to derive a shear wave velocity map of Dehradun city and to understand the one dimensional site effect, including the amplification and dynamic period of different sites within the Dehradun city itself.

2. Geological and geomorphological setting

Dehradun city (Doon valley) is located in the broad intermontane depression, in the Siwalik foreland basin of Garhwal Himalaya (Fig. 1). The Doon valley is a crescent shaped longitudinal, synclinal valley bounded in the North by the Main Boundary Thrust (MBT), dividing the pre-Tertiary rocks from Tertiary rocks. The southern margin of the Doon valley is marked by a sudden break in topography defined by the

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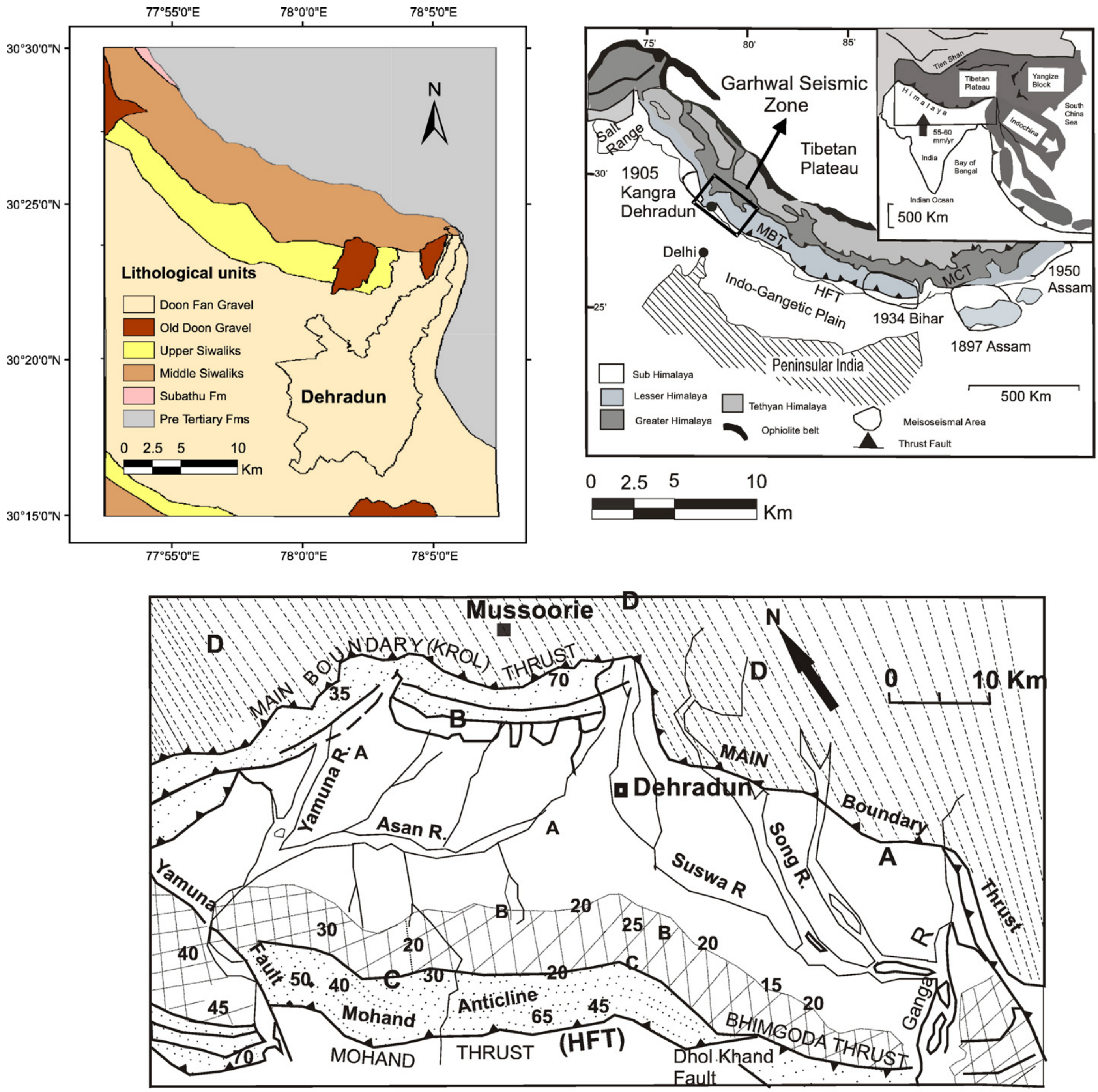

Fig. 1. Location map with regional geology and tectonics of Dehradun region (after Thakur, 1995). a—Doon Fan, b—Upper Siwalik Group, c—Middle Siwalik Group, and d—Pre-Tertiary rocks. Inset (right) shows regional map indicating the Garhwal seismic zone (modified after Wesnousky et al., 1999).

Himalayan Frontal Thrust (HFT), locally known as the Mohand Thrust (Thakur, 1995) where the rocks from the Siwalik Group are overriding the recent alluvial sediments towards the south (Fig. 1). The Doon valley is primarily underlain by piedmont fan deposits, locally known as Doon Gravels, which overlay the Siwalik rocks. These Gravels consist of gravel beds which become coarser with depth, with occasional clay lenses and mudstone layers that resemble the Upper Siwalik conglomerates (Auden, 1936). The geological investigations have revealed that these gravels are absent in northern part of the city where the middle Siwaliks are exposed (Fig. 1). The northwestern part of the city along the Tons River is marked by the enrichment of lime in the gravel beds making them compact similar to boulder beds and also facilitating the development of karst topography in the region. The depth of this cemented layer varies from 20–25 m in this area.

Geomorphologically, the Dehradun area can be differentiated into two major geomorphic surfaces identified as the Hilltop Surface (Residual Hill) and the Piedmont Surface (Singh et al., 2004). The latter had been further divided into the Middle Doon Surface (MDS) and the Lower Doon Surface (LDS) (Nossin, 1971; and Nakata, 1972). The Hilltop surface consists of thick boulders and gravel beds with boulders as large as 2 m occurring near the flat crest of the residual hills in the northernmost part of the city. Both the piedmont surfaces (LDS and MDS) comprise of less consolidated and weathered gravel