USE OF GIS BASED MAPS FOR PRELIMINARY ASSESSMENT OF SUBSOIL OF GUWAHATI CITY.

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ABSTRACT: Guwahati, the major city in the north eastern region of India is growing rapidly in every aspect with major infrastructures like sports complex, educational institutions, hospitals, Flyovers, multiplex halls, etc. Determination of the subsurface soil condition is necessary to ensure the structural safety and serviceability of the above mentioned structures before any construction. Therefore contour maps of standard penetration test N value and shear wave velocity map using GIS platform will be of great help for such purpose. Contour maps of SPT N value at different depth and average contour map of N value of Guwahati city have been prepared. Standard Penetration Test (SPT) N values were taken from a data base of 200 boreholes upto 30 meter depth to prepare N-value contour map of Guwahati city. Other subsurface geotechnical information of Guwahati city like soil classification, depth to water level from ground surface are also presented in the form of GIS based maps in order to form a data base. The shear wave velocity profile is usually obtained by carrying out wave propagation tests in the field. But it is often not economically feasible to conduct these tests at all the sites. Therefore, a reliable empirical correlation between V_s and SPT-N would be of considerable advantage. This work has developed a regression equation between V_s and SPT-N value based on previous similar correlations. From the regression equation, the shear wave velocities are calculated for 1.5m interval upto 30m depth for all 200 locations based on the N values. Average shear wave velocities are then used to generate map on GIS platform.

INTRODUCTION

Geographical information systems (GIS) have developed over the years as a very important tool for graphic representation of geospatial data. Geotechnical, geologic and hydrologic data as represented on GIS based maps has put a great impact on civil engineering, especially in regards to how subsurface geospatial data is communicated with clients and with people at large. GIS has evolved as the principal technical communication medium over the last four decades because data represented in GIS formats can be widely and easily disseminated through the World Wide Web. This paper presents subsurface geotechnical information of Guwahati city in the form of GIS based maps in order to form a data base.

A regression equation between V_s and SPT-N value based on previous similar correlations had also been developed. From the regression equation, the shear wave velocities are calculated Based on the N values of the soil for 1.5m interval upto 30m depth for 200 bore holes. The average shear wave velocities for 30m depth for all locations had been determined and used to generate map on GIS platform.

BRIEF LITERATURE REVIEW

Many researchers internationally and within India, made attempts to correlate values of shear wave velocity (Vs) with SPT 'N' value. Iyisan (1996) [1] examined the influence of the soil type on SPT-*N* versus V_s correlation using data collected from an earthquake-prone area in the eastern part of Turkey. The results showed that, except for gravels, the correlation equations developed for all soils, sand and clay yield approximately similar V_s values. Jafari *et al* (2002) [2] presented a detailed historical review on the statistical correlation between SPT-*N* versus V_s. Matsuoka, Wakamatsu, Fujimoto, and Midorikawa (2005) [3] studied the soil of Japan and prepared average shear-wave velocity mapping using Japan engineering geomorphologic classification map. Maheshwari, Boominathan and Dodagoudar (2008) [4] studied the soil of Chennai and developed an empirical correlation between shear wave velocity and standard penetration test 'N' value for the soil of Chennai city. In this study, 200 data pairs (V_s and SPT-N) were employed in the assessments. Trivedi, Rao and Gupta (2009) [5] studied the soil of Ahmedabad city and prepared average shear wave velocity map for Ahmedabad soil sites. The shear wave velocity of soil in the Ahmedabad region was measured and mapped using the Multichannel Analysis of Surface Wave (MASW) technique. The test locations covered almost entire Ahmedabad region. The shear wave velocity of Ahmedabad soils were evaluated for 2 m depth interval up to 30 m depth. The average shear wave velocities for all locations had been determined and used to generate map on GIS platform. Rao (2012) [6] studied and estimated Shear Wave Velocity from Soil Indices. In situ Vs measured by cross-hole technique at six sites were compared with those evaluated using an existing empirical relation between N value, soil indices and shear wave velocities. A new, modified empirical relation for predicting Vs from N-Values and other soil indices has been proposed.. Shear wave velocity determination up to 30m depth for Guwahati city for this work has also been done using Rao (2012) equation. Ribeiro et. al. (2007) [7] studied the soil of Brazilian port site for geotechnical mapping and reports about N-value contour mapping at Brazilian port. Humyra et al. (2012) [8] studied the soil of Rajshahi for the preparation of SPT contour map of Rajshahi city area. In the study they used 21 soil reports of Rajshahi city prepared by civil engineering department of Rajshahi University of engineering and Technology.

SOIL STUDY OF GUWAHATI CITY

A soil database from 200 boreholes was used for geotechnical subsurface investigation of Guwahati city. The soil database was from a project funded by the Directorate of Science and Technology, India for Microzonation of Guwahati City. In order to study the soil properties of Guwahati City, bore holes of30m depth were made in 200 locations covering an area of 262 sqkm. Standard penetration test was done at every 1.5m interval to determine the N value of the soil with depth. At some locations, SPT has been done to depths less than 30m due to refusal been encountered. Latitude and longitudes of typical boreholes were recorded using surveying and mapping Global Positioning System (GPS) receiver having accuracy up to 30 cm. Undisturbed and disturbed soil samples were collected to determine the engineering properties of the soils in the laboratory. From the undisturb samples, bulk unit weight, natural water content, and unconfined compressive strength of the samples were determined. In case of cohesive soils, liquid limit and plastic limit of the soils were determined. At depths where coarse sand, fine sand, silty sand or silty sand mixed with clay were encountered sieve analysis was done to determine the particle size distribution of the soils. The silt size and clay size for the silt-clay mixtures have not been determined.

Soil Classification

Soils in Guwahati mostly consist of alluvial deposits with alternating layers of both fined grained and coarse grained soils. There is a great deal of variation in the thickness of these layers. The fine grained fraction mostly consists of red, brown and gray coloured silty clay and clay of classification CL, CI and CH according to the Indian Standard soil classification system. In a few locations inorganic silt of classification ML and CL-ML and non plastic inorganic silts were also encountered. The coarse grained fraction is mostly of classification SP, SW, SC, SM, SP-SC. Gravel deposits were also encountered in certain bore holes. The soil classification at a depth of 6m is shown as a GIS based map in Fig.1.

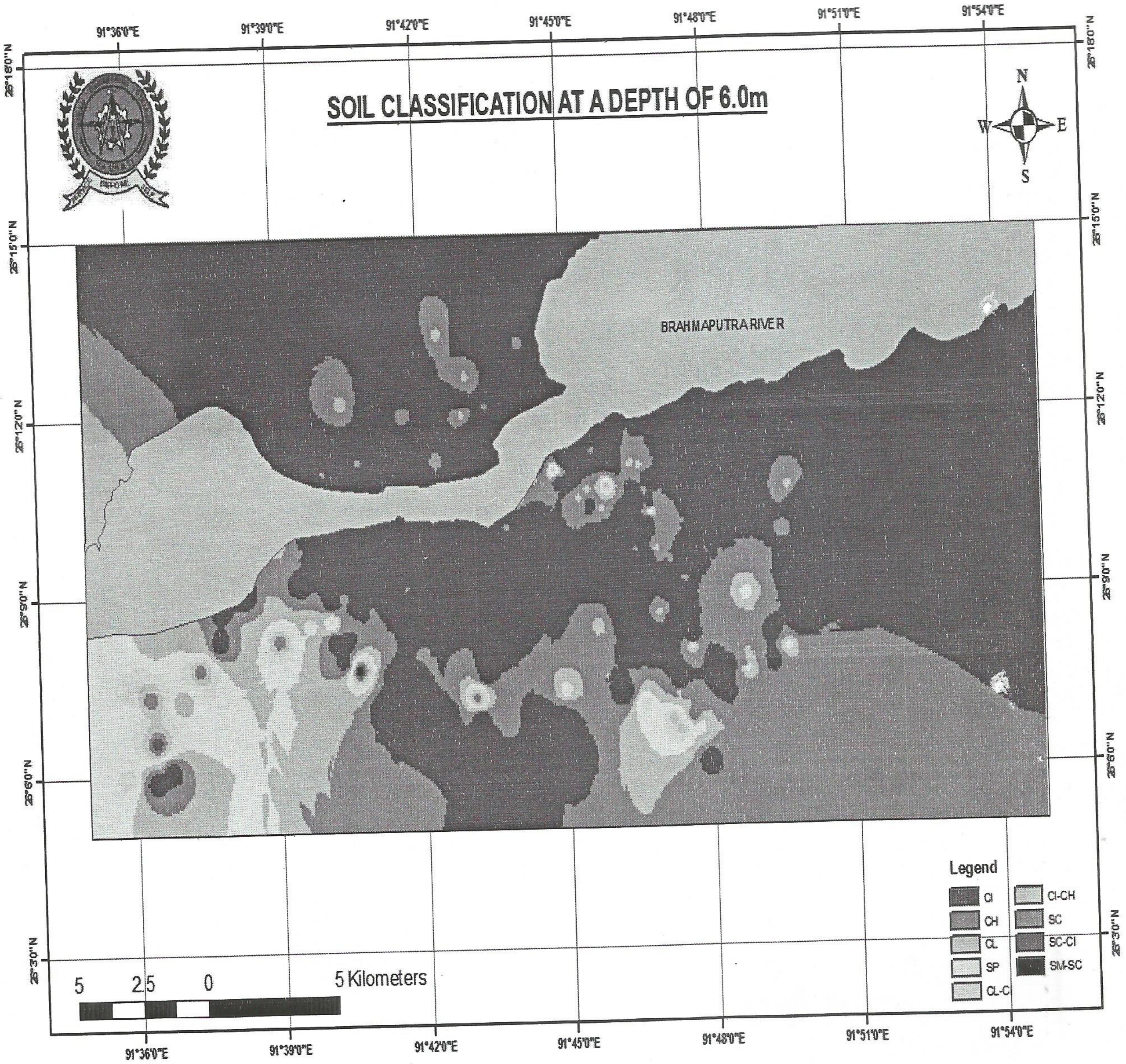

Fig.1 Soil classification map at 6m depth of Guwahati city.

Ground water level

Depth to the water table in the 200 bore logs was found to be within 0m to 6m meter of the ground surface. The depth to ground water level in Guwahati city is shown in Fig. 2. The map in Fig.2 indicates that in most of the locations in Guwahati city the water table is at a shallow depth. The water level fluctuation data obtained for the period 2001 to 2010 by the Central Ground Water Commission, India, shows the water level rise to be less than 2m and the fall of water level is also less than 2m in Assam.

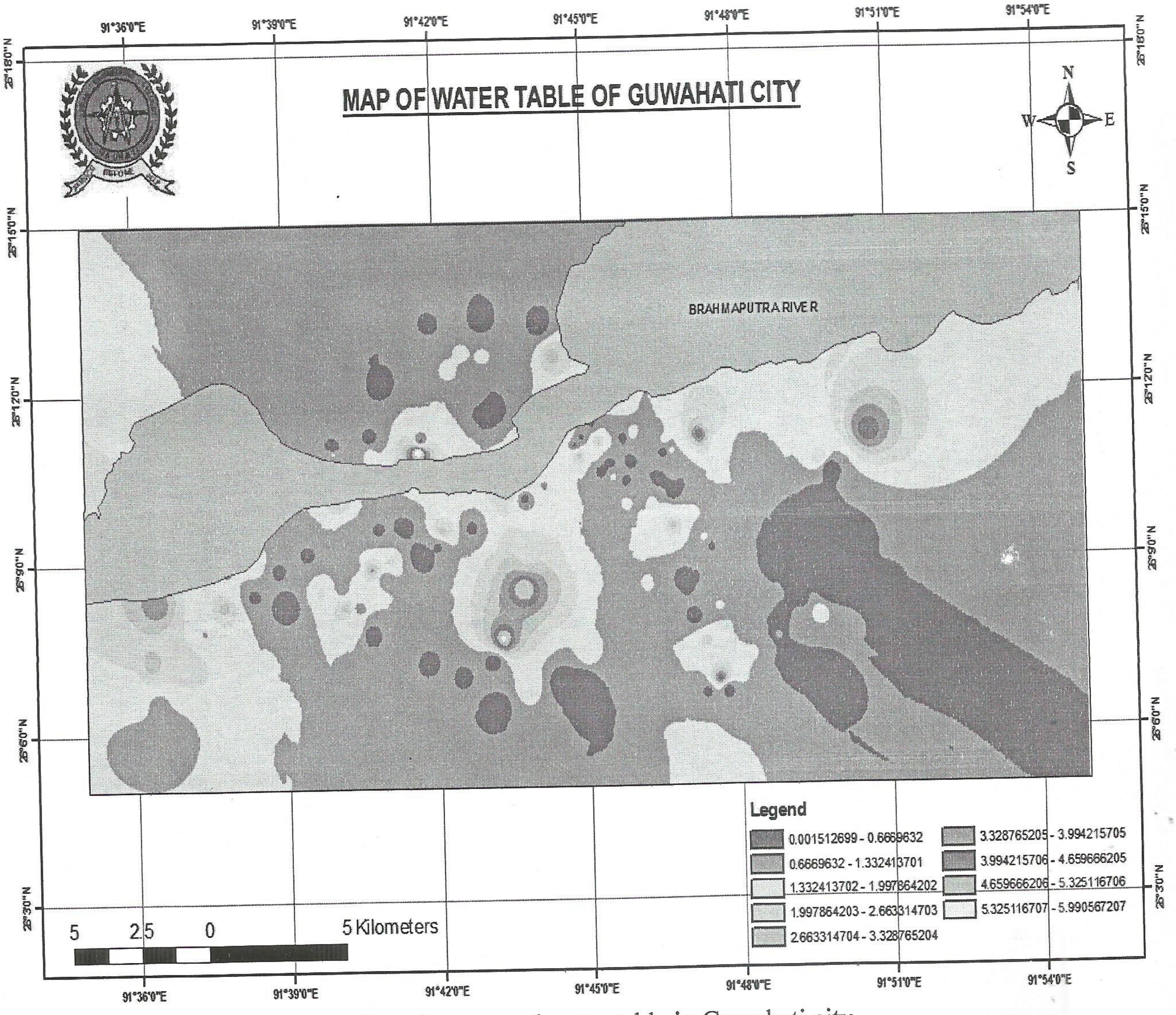

Fig.2 Depth to ground water table in Guwahati city.

Average N value for 15m depth

In the 200 bore holes, standard penetration test was done at every 1.5m interval to determine the N value of the soil with depth. At some locations, SPT has been done to depths less than 30m due to refusal been encountered. SPT-N value of the soils varied from 4 to > 50 (refusal). The average standard penetration resistance upto 15m depth at all the bore holes was computed by the following expression as suggested by International Building Code [IBC, 2003].

$$N\ avg = \sum_{i=1}^{n} di \,/\, \sum_{i=1}^{n}\left(\frac{di}{Ni}\right) \qquad (1)$$

Where d_i = thickness of each layer.

N_i = SPT N- value at i^{th} layer.

n = total no layers.

Figure 3 shows the spatial distribution of average N-value calculated for 15m depth for Guwahati city.

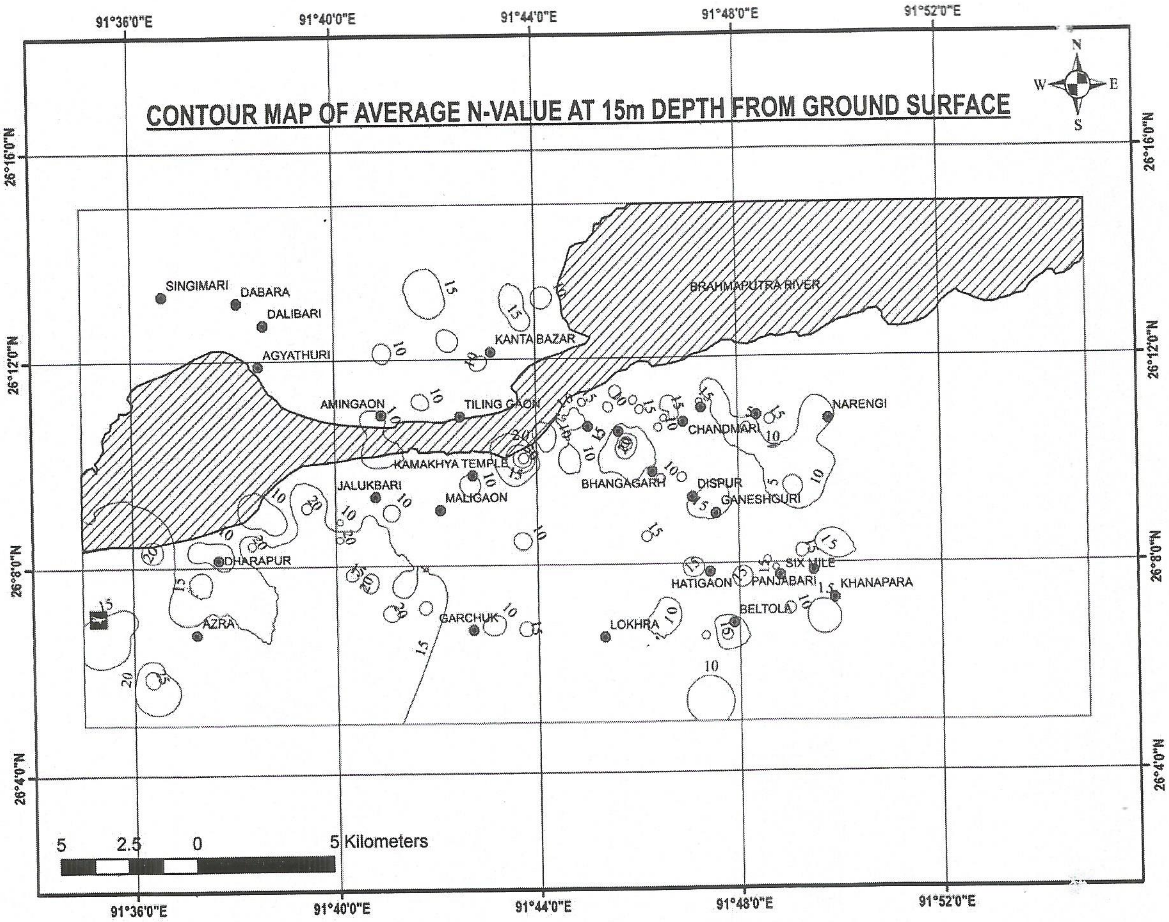

Fig 3. Spatial distribution of average N-value for 15m depth for Guwahati city.

Shear wave velocity

Shear wave velocity (Vs) is the most commonly used parameter used in shallow soil geophysics for soil characterization. It is required for solution of design earthquake motions, soil-structure interaction and wave amplification. Cross-hole logging technique and Multi channel analysis of surface wave (MASW) test gives reliable measure of in situ shear wave velocity. These tests are expensive, requiring two closely spaced boreholes, special recording equipment and skill in identifying shear wave arrivals on a seismic record. However many empirical relations are proposed connecting Vs and Soil indices. Most of these equations are based on the relation between Vs and N-value. Empirical relations for estimating the low-strain Vs using different combinations of soil indices such as N-value, depth, geological age and soil type are available. This paper uses dataset obtained from published literature globally. These are shown in Table 1. These independent correlations are established for various sites from the world. The relationship of the 26 empirical correlations are in form of $Vs = AN^B$ as shown in Table 1

Table 1. Correlations of SPT 'N' value and shear wave velocity

Researcher	correlation
Kanai (1966)	$Vs = 19N^{0.6}$
Ohba and Toriumi (1970)	$Vs = 84N^{0.31}$
Imai and Yahimura (1970)	$Vs = 76N^{0.33}$
Fujimara (1972)	$Vs = 92.1N^{0.337}$
Ohsaki and Iwasaki (1973)	$Vs = 81.4N^{0.39}$
Imai and Yoshimura (1975)	$Vs = 92N^{0.329}$
Imai *et al.* (1975)	$Vs = 89.9N^{0.341}$
Imai (1977)	$Vs = 91N^{0.337}$

Ohta and Goto (1978)	$Vs = 85.35N^{0.348}$
Seed and Idriss (1981)	$Vs = 61.4N^{0.5}$
Imai and Tonouchi (1982)	$Vs = 97N^{0.314}$
Imai and Yoshimura (1990)	$Vs = 76N^{0.33}$
Yokota *et al.* (1991)	$Vs = 121N^{0.27}$
Kalteziotis *et al.* (1992)	$Vs = 76.2N^{0.24}$
Athanasopoulos (1995)	$Vs = 107.6N^{0.36}$
Sisman (1995)	$Vs = 32.8N^{0.51}$
Iyisan (1996)	$Vs = 51.5N^{0.516}$
Jafari *et al.* (1997)	$Vs = 22N^{0.85}$
Kiku *et al.* (2001)	$Vs = 68.3N^{0.292}$
Hasancebi and Ulusay (2007)	$Vs = 90N^{0.309}$
Hanumantharao and Ramana (2008)	$Vs = 82.6N^{0.43}$
Lee and Tsai (2008)	$Vs = 137.153N^{0.229}$
Dikmen (2009)	$Vs = 58N^{0.39}$
Uma Maheswari *et al.* (2010)	$Vs = 95.64N^{0.301}$
Tsiambaos and Sabatakakis (2011)	$Vs = 105.7N^{0.327}$
Anbazhagan *et al.* (2012)	$Vs = 68.96N^{0.51}$

By averaging shear wave velocities at different N- values from the above 26 correlations, simple linear power regression analysis as what had been agreed by researchers was carried out to develop a relationship between shear wave velocity and standard penetration resistance.

This relationship is given as

$$Vs = 74.639xN^{0.3876} \qquad (2)$$

for which $R^2 = 0.99$

Rao (2012) proposed an empirical relation for predicting Vs from N-Values and other soil indices . The relation is as follows

$$Vs = 68.79xN^{.171}xH^{.199}x$$

$$(1.0 \text{ for Alluvium or } 1.303 \text{ For Diluvium})x \qquad (3)$$

Coefficient for soil type

where H = thickness of soil strata. The coefficient for soil type are given in Table 2

Table 2: coefficient for soil type

Type of soil	Coefficient for soil type.
clay	1.0
Fine sand	1.086
Medium sand	1.066
Coarse sand	1.135
Sand and Gravel	1.153
Gravel	1.448

Using equation (2) and equation (3), shear wave velocities were determined for the 200 bore holes at 1.5m interval upto 30m depth using the N- value of the soil. According to Kiku *et al.* (2001) [9] the top 30m of surface soil stratum greatly influence the ground motion characteristics and site amplifications. Average shear wave velocity at 30m depth or V_{S30} is therefore taken as a representative indicator in the National Earthquake Hazards Reduction Program (NEHRP) and International Building Code (IBC). V_{S30} is also used in hazard assessments including microzonation study and site characterization.

The average shear wave velocity for the depth H of soil is referred as V_H . The average shear wave velocity up to a depth of H (V_H) is computed as follows:

$$Vavg = \sum_{i=1}^{n} di \,/\, \sum_{i=1}^{n}\left(\frac{di}{Vi}\right) \qquad (4)$$

Where $\sum d_i$ =cumulative depth in m.

V_i = Shear wave velocity at i^{th} layer

V_{S30} is calculated for all the 200 bore holes using equation (4). Figure 4 shows the average shear wave velocity upto 30m depth (V_{S30}) of Guwahati city according to equation (2). GIS based map of V_{S30} of Guwahati city according to the equation of Rao (2012) is shown in Figure 5. Shear wave velocities according to Rao (2012) is found to be higher than that obtained by equation (2) with the percentage variation between the two methods varying from 38% to 61%. This high percentage deviation is because equation (2) is a correlation between Vs and N –value obtained from various correlations throughout the world which are site specific whereas equation (3) incorporates the thickness of the soil strata and soil indices which are not incorporated in equation (2).

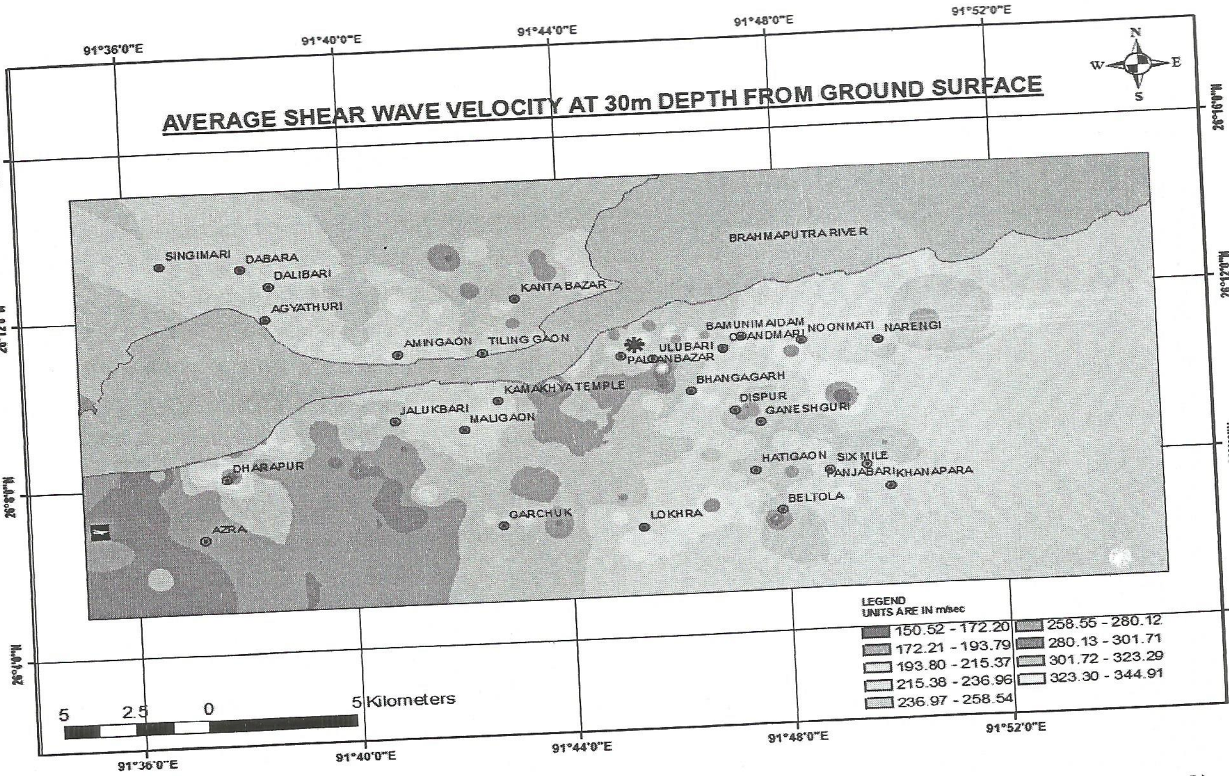

Fig.4: Mapping of average shear wave velocity for Guwahati region (Map developed by eqn. 2)

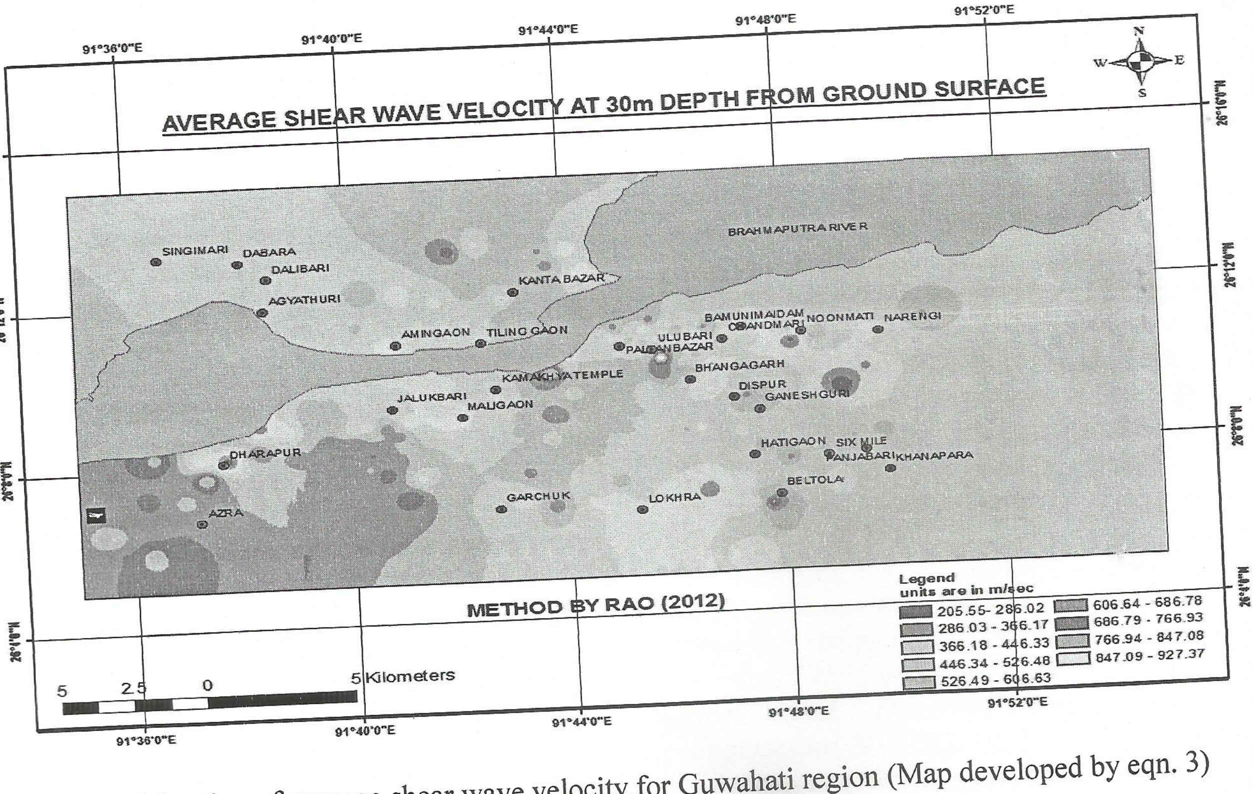

Fig.5: Mapping of average shear wave velocity for Guwahati region (Map developed by eqn. 3)

CONCLUSIONS

This paper presents subsurface geotechnical information of Guwahati city in the form of GIS based maps in order to provide the database for preliminary assessment of subsoil of Guwahati city. GIS based maps of soil classification at 6m depth, depth to ground water table, N-value contour map and average shear wave velocity map (V_{S30}) have been developed. Though this GIS based maps have many inherent shortcomings, yet it can be used for preliminary foundation design and foundation design of low cost structures for which detailed subsoil investigations are not done.

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