The International Journal of Engineering and Science (IJES)
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805
|| Pages || PP 21-26 || 2018 ||

# Engineering Characterization of Clayey Soil by Ultrasonic Pulse Velocity Tests

Nitesh Ashok Bhange, Pritiradheshyamnandagawali
*Lecturer, Department of Civil Engineering, Government polytechnic ,Bramhapuri*
*MTech Geotechnical Engineering, Ramdeobaba College of Engineering and Management , Nagpur*

***ABSTRACT:*** *Ultrasonic pulse velocity tests were performed on the clayey soil, while studying experimentally the relation between pulse velocity, dry density, water content and bulk density. Laboratory test specimens were prepared by compaction method in Proctor mould (100 mm dia.) and split mould (38 mm diameter). Then wave velocity was measured on each of the compacted specimen by adopting the direct transmission method. Unconfined compressive tests were also conducted on compacted samples of 38 mm diameter to establish the relation between compressive strength and pulse velocity. All soils tested exhibited an increasing pulse velocity with increase in dry density until the optimum water content. A rapid drop in pulse velocity was observed subsequently with decrease in density. This observation is in conformity with the findings of earlier various investigators. The parameters investigated were water content, soil type, dry density, compressive strength. The relation between velocity and density is linear for the soils tested. Unconfined compressive strength of the soil sample were correlated with velocity and are found to vary polynomialy with velocity. The empirical equations proposed in this study for predicting density, water content, compressive strength is encouraging.*
***KEYWORDS:*** *Bulk Density, Compressive strength, Dry Density, Ultrasonic pulse velocity test, water content, wave velocity.*

## I. INTRODUCTION

Soil is supposed to be most complex material regarding the various civil engineering projects. For determination of its index and engineering properties, particularly on field, we commonly use direct methods which are destructive tests as well. For ex. In-situ density is determined by sand replacement method, core cutter method which are destructive tests. However these methods are time consuming and frequently halt the construction. So, for quicker assessment, non-destructive methods are used. In this method some properties can be correlated with the another parameter, which can be measured easily. Non-destructive methods most commonly include nuclear density test, electrical resistivity and cone penetration test. However these methods are not as popular as conventional testing methods among the practicing engineers because of their less accuracy and practical difficulty in using them.

Soils are compacted in situ for various engineering activities such as the construction of embankments, pavements, hydraulic barriers, etc., In the constructed structure, the stress-strain and strength properties of the compacted soil are very important. Since these properties are functions of dry density and water content, specifications laid for the construction require, that each layer of soil to be compacted to some stated density at a particular moisture content. The minimum density and water content at which the soil is to be compacted at field is normally decided through the laboratory compaction test. But verifying the same at field is an important task. This is commonly carried out by direct measurement of in situ density through destructive tests such as sand cone replacement method, rubber balloon method, core cutter method and drive cylinder test. These tests are carried out in various layers of the compacted soils. However, these methods are time consuming and frequently halt the construction activities. For the quicker assessment, non-destructive methods are used. In the non-destructive methods, density and water content are correlated to a third parameter, which can be measured easily

Ultrasonic Pulse Velocity method hitherto used to assess the quality of concrete, asphalt, metals, etc., is being tried to predict some of the physical and engineering properties of soils by geotechnical researchers (Leslie (1950); Hardin and Richart (1963); Sheeran et al (1967); Sologyan (1990); Wang et al (1991) and Yesiller et al (2000)). Leslie was the first to investigate the relation between velocity and water content in silty clay and reported that maximum velocity occurs at maximum density and OMC. Hardin and Richart (1963) in their work on Ottawasand reported certain concepts of wave propagation in dry, partially saturated andsaturated sand. Among the investigators Sheeran et al (1967) made an extensive study on soils of three types, compacted by kneading and impact methods. The authors brought out certain relation between pulse velocity and compaction density which Yesiller et al (2000) later found consistent with their work Sologyan (1990) reported a similar study taking into account the microstructural properties of soils. The study by Wang et al (1991) brought out the effect of static compaction pressure on the variation of ultrasonic pulse velocity with water content. Recently, Ferreira and Camarini (2001) investigated the feasibility of assessing the strength of stabilised soil through pulse velocity.

## II. ULTRASONIC PULSE VELOCITY (UPV)

In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing. However, when ultrasonic testing is conducted with an Electromagnetic Acoustic Transducer (EMAT) the use of couplant is not required.

There are two methods of receiving the ultrasound waveform: reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Using the couplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces.

**Fig-1. Velocity determination**

**2.1Capabilities of UPV in Soil**

1. The relation between velocity and water content in-silty clay can be studied.
2. Certain concepts of wave propagation in dry, partially saturated and saturated sand can be reported.
3. Certain relation between pulse velocity and compaction density can be obtained.
4. A similar study can be done by taking into account the micro structural properties of soils.
5. The effect of static compaction pressure on the variation of ultrasonic pulse velocity with water content can be studied.
6. The feasibility of assessing the strength of stabilised soil through pulse velocity can be find out.
7. Velocity and compressive strength can be correlated.
8. Velocity and secant modulus can also be correlated.
9. By measuring the wave velocity, the shear modulus (G), Young's modulus (E), and Poisson's ratio (ν) can be determined for the strain level of $10^{-4}$%.
10. Interrelationship between relative density of soil and ultrasonic pulse velocity can also be established.

## III. MATERIAL, SAMPLE COLLECTION AND PREPARATION

3.1 Soil

Soil is considered by the engineer as a complex material produced by the weathering of the solid rock. The formation of soil is as a result of the geological cycle continually taking place on the face of the earth. The cycle consists of weathering or denudation, transportation, deposition and upheaval, again followed by weathering and so on. The sample is collected from the Nagpur.region,

3.2 Sample preparation

Soil sample as received from the field is dried in the air. The clods broken with a wooden-mallet to hasten drying. The organic matter, like tree roots and pieces of bark is removed from the sample. Similarly matter other than oil, like shells is separated from the main soil mass. A noting is made of such removals and their percentage of the total soil sample is noted when samples are taken for estimation of organic content, lime content etc., total sample is taken for estimation without removing shells, roots etc.

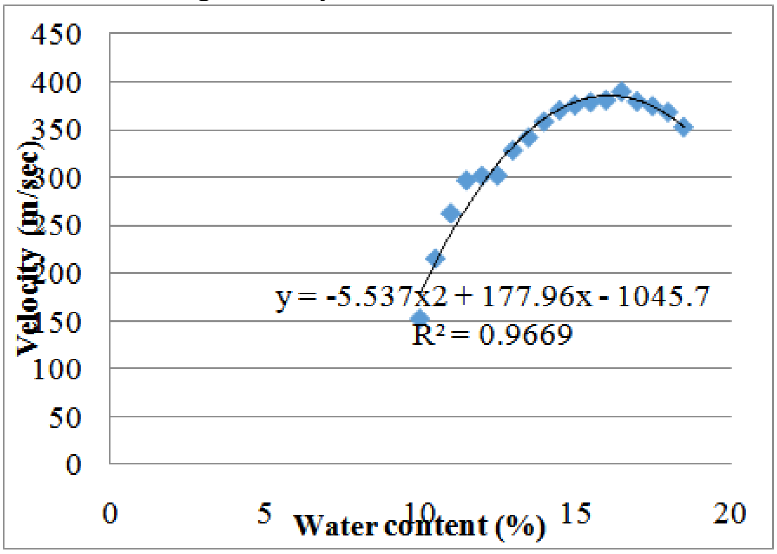
3.3 Properties of Soil Sample and Testing

| Clayey soil Sample | Properties of Clayee soil | | | | Ultra Sonic Pulse velocity Length of sample= 0.133m, diameter of sample= 0.1m | |
|---|---|---|---|---|---|---|
| | Water content (%) | Bulk density Y=w/v (kN/m²) | Dry density Yd= Y/(1+w) (kN/m²) | Compressive strength (kN/m²) | Time (usec) | Velocity = Length/Time (m/sec) |
| 1 | 10.00 | 17 | 15.45 | 55.02 | 876.03 | 151.82 |
| 2 | 10.52 | 17.5 | 15.83 | 61.73 | 620 | 214.51 |
| 3 | 11.11 | 17.7 | 15.93 | 81.13 | 508 | 261.81 |
| 4 | 11.53 | 17.9 | 16.03 | 91.71 | 449 | 296.21 |
| 5 | 12.00 | 18.1 | 16.16 | 91.79 | 442 | 300.9 |
| 6 | 12.50 | 18.2 | 16.18 | 97 | 441.42 | 301.3 |
| 7 | 13.04 | 18.4 | 16.28 | 98.56 | 406 | 327.58 |
| 8 | 13.51 | 18.5 | 16.3 | 98.58 | 390 | 341.02 |
| 9 | 14.20 | 18.7 | 16.37 | 100.52 | 372 | 357.52 |
| 10 | 14.80 | 19 | 16.55 | 101.42 | 360 | 369.44 |
| 11 | 15.15 | 19.3 | 16.76 | 105.22 | 355 | 374.64 |
| 12 | 15.62 | 19.5 | 16.87 | 105.89 | 352 | 377.84 |
| 13 | 16.00 | 19.7 | 16.98 | 107.15 | 350 | 380 |
| 14 | 16.66 | 19.9 | 17.06 | 109.89 | 342 | 388.88 |
| 15 | 17.24 | 19.1 | 16.29 | 110.11 | 351.26 | 378.63 |
| 16 | 17.64 | 18.7 | 15.9 | 112.35 | 355.76 | 373.84 |
| 17 | 18.18 | 17.9 | 15.15 | 112.95 | 361.88 | 367.52 |
| 18 | 18.75 | 18.9 | 15.92 | 120 | 378 | 351.82 |

**Table 1 : Properties of Soil Sample and Testing**

## IV. DEVELOPMENT OF CALIBRATION CURVES

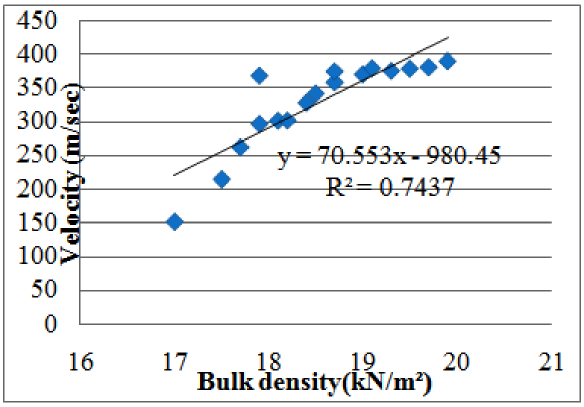
**Fig-1 Velocity- water content relation**




Observations

We can see that it resembles like compaction curve.The velocity water content relationship indicates that, the pulse velocity increased with water content up to water content close to OMC.Beyond OMC the increase in water content showed a reduction in pulse velocity for the soil tested.The relation between velocity and compaction water content follows the typical characteristic relation density and water content (proctor,

1933) and is found to be valid with the same compactiveefforts.Leslie (1950) had also reported that maximum velocity occurs at maximum density and OMC.



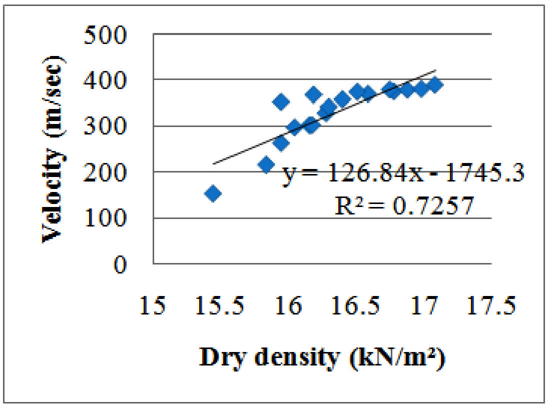




**Fig-2 Velocity vs. bulk densityFig-3 Velocity- dry density relation**

Observations

- The relation between these two parameters are analyzed.
- For a given soil, the velocity increased with increase in density.
- Ultrasonic waves are propagating with the velocity under different water contents irrespective of dry or wet side of compaction and soil type, which shows that the density and water content have cumulative effect on velocity.
- Since the relation between density and velocity is linear , the results of the tests are combined for this soil sample to arrive at an empirical relation between the two parameters.
- The linear relation obtained through regression analysis between velocity and density is given in following equation,

$y = 126.84\,x - 1745.3$……(1)

$R^2 = 0.7257$………………..(2)

- The correlation coefficient ($R^2$ = 0.7257) for the above equation which shows reasonable association between the two parameters investigated
- The above equation can be used to determine the density of compaction , if velocity is known or vice versa.

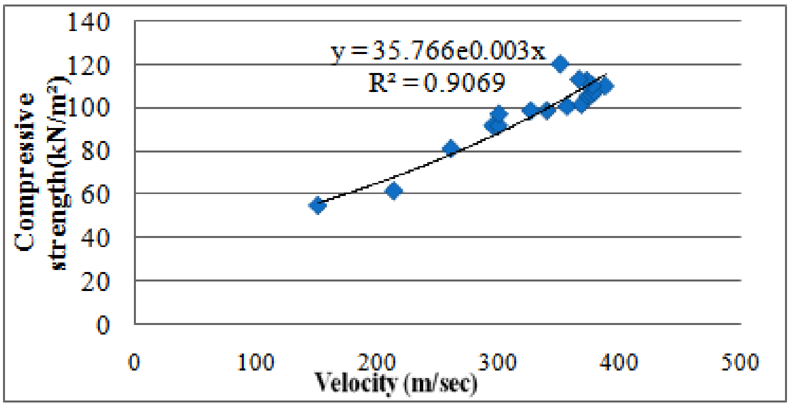



**Fig Variation of velocity with compressive strength.**

Observation

Unconfined compressive strength measured on the soil samples are related with velocity of propagation of ultrasonic waves as both of them are functions of density and moisture content. independently.

- The compressive strength increases exponentially with increase in velocity.
- Exponential curve fitting resulted in the following equation,

$y = 35.766e^{0.003x}$….. (3)

$R^2 = 0.9069$…..…..(4)

## V. VALIDATION OF THE EQUATION ARRIVED

The equations presented below can be combined appropriately to arrive at the density of compaction and compaction moisture content, if the velocity is known. For example eq. A and B can be used to determine water content and density, if ultrasonic pulse velocity of the clayey soil is known. The maximum variation in the calculated water content is 5.06%. The maximum variation in the dry density is obtained as 3.19%. Unconfined compressive strength and the ultrasonic pulse velocity have been determined on the same soil at various water content. Eq. (C) has been used to calculate the compressive strength with pulse velocity arrived from the experiments.

Equations which are obtained from fig-2 as follow,

$V = -5.537 \times (wc)^2 + 177.96(wc) - 1045.7$ (A)

Equations which are obtained from the fig 3 is as follow,

$V = 126.84 \times (Yd) - 1745.3$ (B)

Equations which are obtained from the fig 4 is as follow,

$qu = 35.766e^{0.003v}$(C)

Where,
V = Ultrasonic pulse velocity (m/sec)
wc = Water content (%)
Yd = Dry density (kN/m²)
qu = Compressive strength (kN/m²)

### 4.1 Variation between experimental & calculated compressive strength data

**Table 2** : Experimental and Empirical data variation

| Sr. No. | Experimental data | | Empirical equation | |
|---|---|---|---|---|
| | Compressive strength | Velocity | Compressive strength | % variation |
| 1 | 55.02 | 151.8 | 56.39 | 2.49 |
| 2 | 61.73 | 214.5 | 68.06 | 10.25 |
| 3 | 81.13 | 261.8 | 78.44 | 3.32 |
| 4 | 91.71 | 296.2 | 86.97 | 5.17 |
| 5 | 91.79 | 300.9 | 88.2 | 3.91 |
| 6 | 97 | 301.3 | 88.31 | 8.96 |
| 7 | 98.56 | 327.6 | 95.56 | 3.04 |
| 8 | 16.3 | 341.02 | 16.45 | 0.91 |
| 9 | 98.58 | 341 | 99.48 | 0.91 |
| 10 | 100.52 | 357.5 | 104.53 | 3.99 |
| 11 | 101.42 | 369.4 | 108.33 | 6.81 |
| 12 | 105.22 | 374.6 | 110.03 | 4.57 |
| 13 | 105.89 | 377.8 | 111.09 | 4.91 |
| 14 | 107.15 | 380 | 111.83 | 4.37 |
| 15 | 109.89 | 388.9 | 114.84 | 4.50 |
| 16 | 110.11 | 378.6 | 111.36 | 1.14 |
| 17 | 112.35 | 373.8 | 109.77 | 2.30 |
| 18 | 112.95 | 367.5 | 107.71 | 4.64 |

## VI. CONCLUSION

In this study soil specimen were tested and pulse velocities were measured by direct transmission method. The parameters investigated were water content, soil type, dry density, compressive strength. Based on the results following conclusions are drawn.The relation between velocity and water content established an identical relation to that of a typical compaction characteristic curve of proctor (1933) and is also in comparison with the observations reported by Yesiller et al (2000) and T. Senthilmurugan, K. Ilamparuthin. The relation between velocity and density is linear for the soils tested.Unconfined compressive strength of the soil sample were correlated with velocity and are found to vary exponentially with velocity.The empirical equations proposed in this study for predicting density, water content, compressive strength is encouraging.

### 6.1 Limitations

Though the findings of this study are encouraging and support the use of ultrasonic pulse velocity technique as another method to access the quality of compaction, strength of soil, it has the following limitations:

1. The equations proposed in this study need field investigations.
2. Direct transmission adopted in this study cannot be extended to the field compacted soils without sampling.
3. The effect of microstructure variation of compacted soil on velocity is not considered in this study.

Despite the limitations brought out in this study, this technique can be continued to assess the adequacy as an auxiliary method to investigate the compaction and mechanical properties of soils.

## REFERENCES


[1]. David M Weidinger, Louis Ge, and Richart W stephenson "ultrasonic pulse velocity tests on compacted soil"
[2]. David m. Weidinger , "Laboratory analysis of small strain moduli In compacted silts"
[3]. Dessislava Z slavova, David M Weidinger, Adam F Sevi and louisGe "Evaluation of compacted silt characterization by ultrasonic pulse velocity testing"
[4]. En.m.wikipedia.org/Ultrasonic_testing
[5]. Hardin, B.O., Richart, F.E. (1963). "Elastic Wave Velocities in Granular Soils." J. Soil Mech. and Found. Engg., ASCE, 89(1), 33-65
[6]. IS 2720 (part 5) 1985, Plastic limit test and liquid limit test
[7]. IS 2720 (part 2) 1973, Plastic limit test
[8]. IS 2720 (part 10) 1999, Unconfined compressive strength
[9]. IS 13311(part1)1992 Non destructive testing (Ultrasonic pulse velocity )
[10]. K.Kumar, "Relative density and ultrasonic pulse velocity inter-relation of pilani soil" naziYesiller, "ultrasonic testing for compacted clayey soil"
[11]. Leslie, J. R. (1950) "Pulse Techniques Applied to Dynamic Testing", ASTM, 50, 1314-1323
[12]. T. Senthilmurugan, K. Ilamparuthin "study of compaction characteristics and strength through ultrasonic method"
[13]. Yesiller, N., GokhanInci and Carol Miller. J. (2000). "Ultrasonic Testing for compacted Clayey Soils". Advances in Unsaturated Geotechnics, 54- 68
[14]. Sheeran, D.E., Baker, W.H. and Krizek. R.J. (1967). "Experimental Study of Pulse Velocities in Compacted Soils". Highway Record No. 177, Highway Research Board, 226-238
[15]. "Soil mechanics and foundations" B.C Punmia, PN10,62,442
[16]. Sologyan, A.I., (1990). " Survey of Methods and Means for Determining Soil Density in the Fields." Soviet J. Nondestructive Testing, Plenum Publishing Corp.,25(7), 480-486
[17]. Yesiller, N., GokhanInci and Carol Miller. J. (2000). "Ultrasonic Testing for compacted Clayey Soils". Advances in Unsaturated Geotechnics, 54- 68