Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(6) (2019) 329-332
DOI: 10.22060/ceej.2017.12215.5148

Study and Comparison of Compaction Characteristics of Coarse Grained Soils using Ultrasonic Waves and New Designed Impact Hammer

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ABSTRACT: Obtaining physical and mechanical parameters of the soil has always been the primary challenge in the science of soil mechanics. These parameters are mostly obtained in laboratories or by field tests. In the present paper a hammer similar to Schmidt hammer is introduced which can be used to calculate soil parameters by its single impact. Such a novel hammer is termed RH impact hammer. The results of RH test are compared with that of ultrasonic tests. First, using the modified Proctor compaction test introduced in AASHTO standard, the modeling of the materials is done. In the continuation, the materials with known gradation range and based on the quality parameters such as compaction percent and natural and optimum moisture content are directly exposed to pressure waves of ultrasonic device and are simultaneously compact-metered with RH hammer. Without any field or laboratory experiments and only based on velocity and transmission time of waves and also using calibration plots and correlation formulas and base steel specimen. Readings are above 3 of the densities of more than 90% of the soil.

Review History:

Received: 2 December 2016
Revised: 19 April 2019
Accepted: 23 August 2017
Available Online: 26 August 2017

Keywords:

Ultrasonic Waves
Pressure Waves
RH Impact Hammer
Compressive Strength
Optimum Moisture

1- Introduction

In the soil engineering, most of the physical and mechanical parameters of soil are obtained through laboratory or field operations [1]. Such operations due to need for long time and high cost as well as high level of skill and precision to obtain acceptable results are more or less one of the existing challenges. Soil compatibility is one of the important and discussable topics among the physical parameters and characteristics of various soils [2]. In the first step of the paper, quality parameters of the soil (especially compression ratio) are obtained by the propagation velocity of the pressure waves detected by ultrasonic device. In the second step, the hardness of the soil is calculated by impact test in horizontal and vertical directions with RH hammer [3]. In the final step, comparing the results of ultrasonic device and RH hammer we can obtain the compression ratio of coarse-grained soil and determine and validate the relations between the results through correlation formulas [4].

2- Experiments by ultrasonic device

Modified Proctor compaction test in 4-inch-diameter mold (method C) on the soil specimen with 80% sand and 20% clay are done on several specimens with known moisture and specific weight [5].

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The soil specimens are constructed with different sizes and compressions and are removed from the mold and are directly exposed to the propagation of pressure waves of ultrasonic device in horizontal direction with maintained moisture and necessary surface conditions. The propagation speed of waves, v, and transmission time, t, are measured at least for ten times. In order to avoid the scattering and errors of transmitter and receiver waves a standard gel is used on the boundary surfaces of the specimens which are in contact with two probes of the device, Figure 2 [6].

Figure 1. Transmission of ultrasonic waves through the specimen

Each sample has certain moisture and specific weight that is a proper average over velocity and time reads from the device. In the continuation, having in hand four basic parameters including moisture percent, specific weight, average speed of propagating pressure waves and the transmission time of waves one can perform qualitative investigations on various samples in terms of moisture percent and compression. Figure 3 shows variations of speed of pressure waves in the samples as a function of dry specific weight variations. The figure is representing the ascending trend of pressure wave speed with specific weight increase [7].

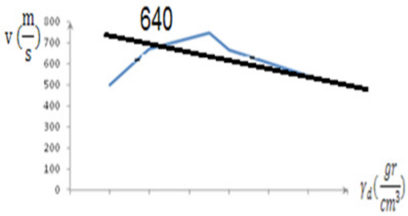

Figure 2. Variations of speed of propagating pressure wave vs dry specific weight variations

3- Experiments by RH impact hammer

In this section, a newly designed device termed RH impact hammer shown in Figure 4 is introduced. This hammer is designed based on the analog Schmidt hammer with softer internal spring and lighter internal mass so that smaller impact is applied on the soil surface. It can calculate parameters such as compression, specific weight and hardness of soil material surfaces by a sensor that is incorporated in its end so that applying a few impacts and reading the hammer numbers in horizontal and vertical directions the compression characteristics of the material can be obtained [8]. Parameters of the RH impact hammer are shown in Table 1.

Table 1. Parameters of the impact hammer

value	Parameter
30 N/m	Spring constant
50 g	Internal mass
8 cm	Maximum stretch
4 cm	Maximum compression

The process of the impact hammer can be briefly explained such that it is first contacted with the soil surface and then with the graphical interface the execution command is generated. Application of pressure on the hammer, an impact is imposed on the soil surface using its internal weights. The resistance and voltage sensors of the hammer calculate the value of the inserted impact. The value is converted to standard output by electric circuits. The standard output is given to microcontroller unit with ADC convertor and the microcontroller calculates the compressive strength using the sensor results and finally compressive strength is shown on the LCD display by microcontroller.

As shown in Figure 4 impacts in the horizontal direction is applied to the soil sample. It is worth noting the mentioned method is already calibrated with other reference experiments such as direct shear, sand bottle and modified Aashto density tests on soil.

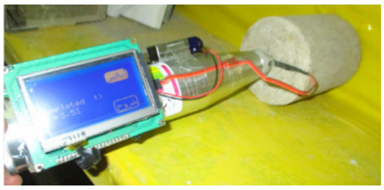

Figure 3. RH impact hammer on the compressed soil

As indicated in Figure 5 and Figure 6 the results of RH impact hammer (N_H, N_V) increase with compression ratio growth unless for moisture percent higher than optimum value for which decreasing behavior is seen.

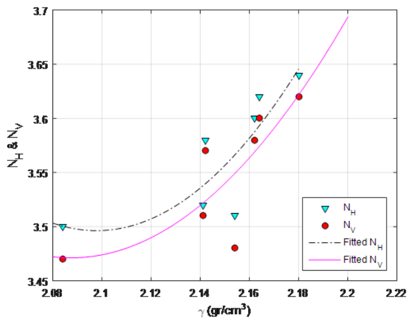

Figure 4. N_H and N_V vs special weight

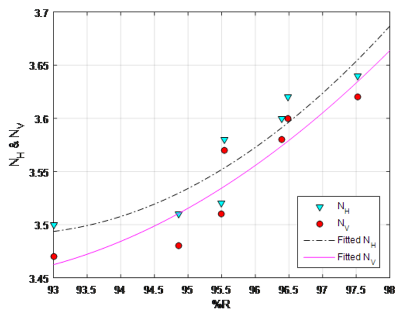

Figure 5. N_H and N_V vs compression

4- Comparison of experiments

Comparing experimental results of ultrasonic and RH impact hammer and using correlation relations for compression, speed of pressure wave, horizontal and vertical hammer results we will be able to estimate other parameters only with one of the obtained parameters. Figure 7 shows relation between horizontal number of RH impact hammer and speed of pressure wave[9].

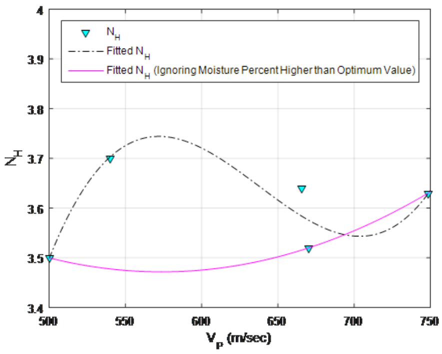

Figure 6. Horizontal number vs speed of pressure wave

5- Conclusions

In the present paper the physical and mechanical parameters of the soil were calculated by two different methods. In the first method ultrasonic and pressure waves were used and in the second one a new designed device called RH impact hammer was incorporated. This hammer has a high similarity to the Schmidt hammer and enables the calculation of parameters such as compressive strength of soil by means of internal sensors. For similar conditions and materials, one can find physical parameters like compression, porosity, horizontal and vertical reads of RH hammer, specific weight and moisture percent (to some extent) of the soil samples through correlation formulas and fitted curves.

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Please cite this article using:

H. R. Saba, B. Halimi, S. Jafari Mehrabadi, S. Saeedi Jam, Study and Comparison of Compaction Characteristics of Coarse Grained Soils using Ultrasonic Waves and New Designed Impact Hammer, *Amirkabir J. Civil Eng.*, 50(6) (2019) 1033-1042.

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