DETERMINATION OF THE OPTIMUM HUMIDITY FOR COMPACTING A FILLING MATERIAL USED IN FOUNDATIONS WITH CONCRETE WASTE CONTENT

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***ABSTRACT**: The fill material can be anything from waste to clay, gravel and is usually compacted to provide support and stability. The type of material can vary depending on the application area. For example, crushed stone can improve drainage around the foundation. Filling can also be used to insulate foundations or to improve drainage, being essential in the construction process of various structures or roads. Depending on the project, filling layers in construction can be a simple or complex operation that requires special equipment.*

It is vital to ensure that the filling material is properly compacted to provide a stable base. To determine this, in specialized laboratories, determinations of the optimal compaction moisture are made through the Proctor test. In this paper, we want to determine the optimal compaction moisture of a filling material containing concrete waste from construction and demolition.

***Keywords:** filling; constructions; optimal humidity; foundations;*

Introduction

Compaction is used for soils used as filling material for the foundations of various constructions to give them adequate properties for supporting them. Subtracts and layers of land roads are compacted to obtain a greater resistance to their compression and shear [1].

Soil compaction is the procedure by which a necessary mechanical energy is applied and adequate water content is added to the soil mass to reduce void volume expelling the air and water occupying the pores, thus increasing its density in order to improve the physical-mechanical properties of the soil [2]. The difference between a compacted and an uncompacted soil is shown in figure 1.

The dry specific gravity after compaction increases first as the water content increases. When the water content increases gradually and the weight of solids in the soil gradually increases, but beyond a certain water content, any increase tends to reduce the dry specific gravity because the water occupies the spaces that they could have been occupied by solid particles [3]. The water content it touches the maximum dry specific gravity is called the optimum compaction moisture [4]. Soil compaction allows improving the following properties:

- Increases ground support capacity;
- Reduces land settlements;
- Reduces swelling and contraction of the soil, because if there are voids, water penetrates and will help amplify these phenomena;

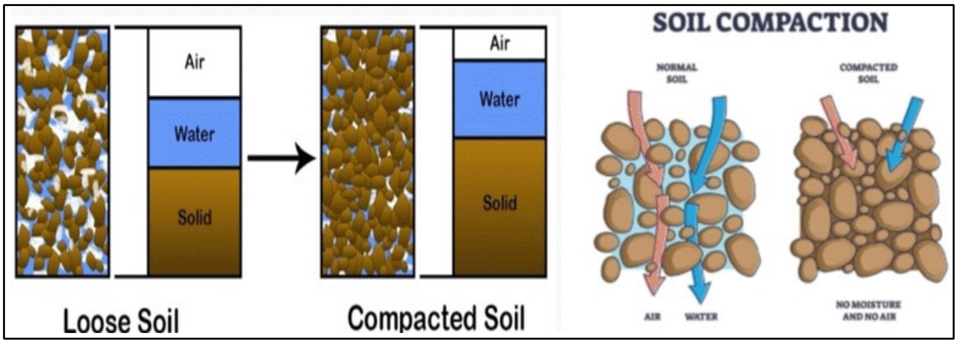

Fig. 1. The difference between compacted and uncompacted soils (5,6)

• Prevents the damage to the constructions above the foundations, by preventing the accumulation of water that favors the freeze-thaw cycle;

• Reduces the permeability of the soil, the leakage and penetration of water into its pores, water flows and drainage can be adjusted [7].

Figure 2 shows how proper compaction can ensure a longer life for various structures, eliminating future foundation problems:

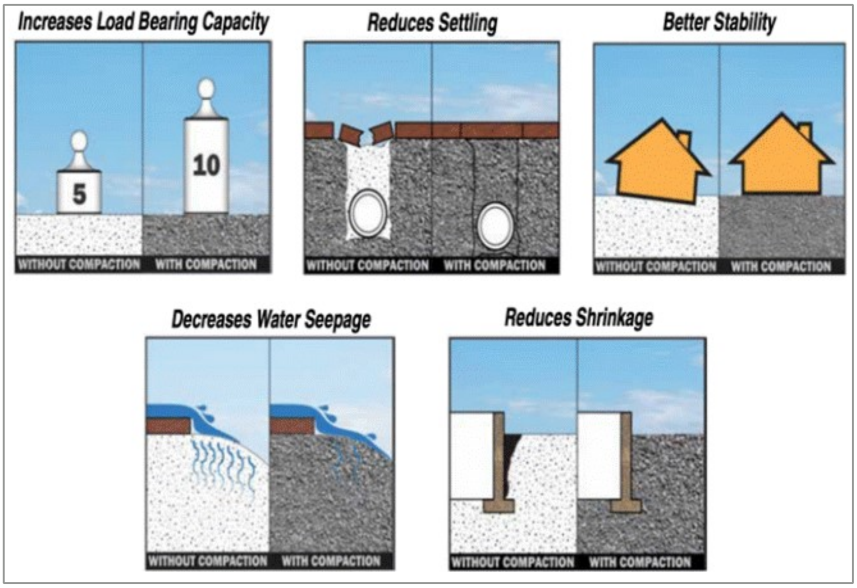

Fig. 2. Benefits of Soil Compaction(8)

Materials and methods

Soil compaction to achieve maximum dry density is required in many engineering projects. The relationship between the moisture content and the dry density of the soil is obtained following the Standard or Modified Proctor test. The Proctor Standard Test was developed by R.R.

Proctor in the 1930s as a means of evaluating compacted fill using the compaction equipment of that era [9], and since 1958, due to increases in truck and airplane traffic, compaction equipment has evolved and the Modified Proctor test appeared [10].

Laboratory determination of maximum dry density [MDD] and optimum moisture content [OMC] by the Proctor test requires considerable time and effort [11]. Recycled concrete aggregates, reclaimed asphalt, pavements, brick, recycled fine glass are some of the materials that are left behind when buildings or roads are demolished. Reusing concrete waste from demolished buildings as backfill material will help economic sustainability and environmental sustainability [12]. Concrete recycling plays a key role in both improving the sustainability of the construction sector and reducing the impact associated with the unprecedented exploitation of natural resources such as gravel and sand, among other minerals [13].

In order to create foundation soils with improved properties by compacting a mixture in optimal conditions, an important factor is the determination of the optimal compaction parameters [humidity and compaction density respectively]. The exact correlation between the compaction characteristics obtained in the laboratory and those in the field is achieved by the Proctor test [14]. Soil fills have traditionally been compacted to obtain a maximum dry density of the soil with a certain water content [15] called optimal compaction humidity which is determined in the laboratory by the Proctor test.

For performing tests according to the SR EN 13286-2:2011 standard [16] the automatic compactor Proctor UTS-0620 was used, this being used for compacting the filling material and the ventilated oven with thermostat UTD-1295, used for determining the humidity according to the SR EN ISO 17892-1:2014 standard [17], the equipment being presented in figures 3.

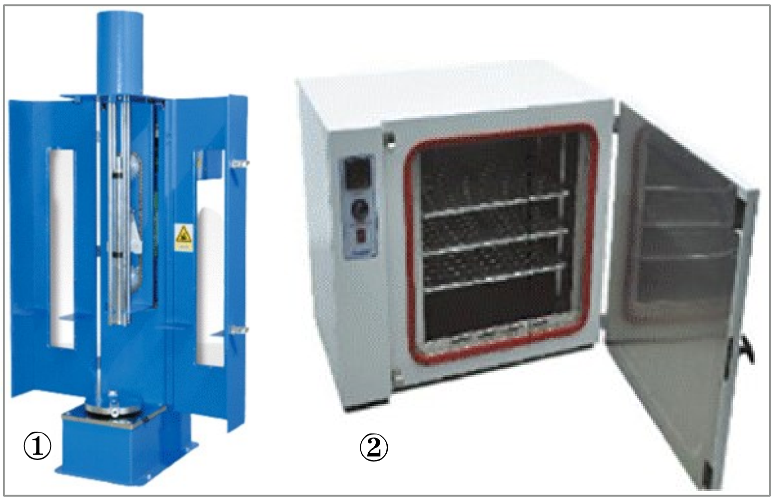

Fig. 3: 1- Proctor UTS-0620 automatic compactor (18)
2 - Ventilated oven with thermostat UTD-1295 (19)

Results and discussion

The principle of the Proctor test consists in the compaction with the same mechanical [L] specific compaction of soil samples with different humidity, aiming to obtain the highest possible density of the sample after compaction. Depending on the value of the specific mechanical work of compaction, two types of tests are distinguished: - the normal Proctor test, the method used in this work, in which: L= 0.6 J/cm^3 - the modified Proctor test in which: L= 2.7 J / cm^3. Table 1 shows the differences between the two methods.

Way of working. The material sample is inserted into the cylinder in layers of approximately equal thickness. The blows required to compact a layer must be applied uniformly over the entire surface of the layer of material in the cylinder, with the Proctor may, by free fall and without interruption. The weight of the compaction sleeve is 2.5 Kg for the normal Proctor test. For a determination point, the material to be compacted in the cylinder is placed in layers of approximately equal thicknesses [minimum three layers], which are each compacted evenly, with a number of 25 blows of the may for the normal Proctor.

Table 1. Differences between normal Proctor and modified Proctor

CYLINDER SIZE	THE MAXIMUM SIZE OF THE PARTICLE	NUMBER OF LAYERS	NUMBER OF LAYERS	NUMBER OF STRIKES PER LAYER/ THE WEIGHT OF MAY	NUMBER OF STRIKES PER LAYER/ THE WEIGHT OF MAY
d(mm)	Dmax(mm)	NORMAL PROCTOR	MODIFIED PROCTOR	NORMAL PROCTOR	MODIFIED PROCTOR
100	7.1	3	5	25/2.5	25/4.5
150	20			70/2.5	70/4.5
200	31.5			30/15	80/15

Preparation of samples. The amount of material prepared for a sample is spread on the work table or in a tray, approximately 5 Kg of dry material, samples shown in figure 3-2.

After adding the water, homogenization of the moisture is ensured by manual mixing or with the help of a mixer. The metal cylinder with extension ring is prepared and weighed [m^2].

Before introducing the material required for a new layer, the surface of the compacted layer is scarified with a laboratory knife, to achieve their union. The upper level of the last compacted layer must exceed the edge of the cylinder, but not by more than 5 mm, so that after removing the extension ring the material can be leveled with a knife at the level of the cylinder.

Brush off the fallen material on the base plate and weigh the material cylinder [m1]. The material is removed from the cylinder with the help of a piston, and at least three samples are taken to determine the average humidity of the material. Figure 4 shows the sequence of the stages of the normal Proctor test and Figure 5 shows the stages of determining the humidity of the compacted soil.

The humidity is determined according to known standards [SR EN ISO 17892-1:2014] and the value is taken as the average of the three determinations. A maximum of three compactions are performed on a sample of material.

The amounts of water that are added to the material samples for successive compaction tests are those corresponding to an increase in humidity by 1...2% for non-cohesive soils and by about

Fig. 4. Material samples subjected to the normal Proctor test

Fig. 5. Stages of the normal Proctor trial

Fig. 6. The stages of determining the compact soil unit

3...4% for cohesive soils. The compaction test is carried out 6-10 times, the moisture content of the material varying in a range of 10-24%. Figure 7 shows the differences between the initial material compacted with natural moisture and the material compacted with the addition of 50 ml of water.

soils, a moisture less than the optimum moisture is needed to provide maximum bearing capacity, for pavements on expansive soils, optimum moistureis ideal. During the execution of various constructions [roads, highways, airport runways, parking lots, various buildings], frequent sampling

Figure 7. The differences between the initial material compacted with natural moisture and the material compacted with the addition of water

Table 2. Shows the results of the normal Proctor tests performed on several samples with the same composition of the filler material but different humidity

Initial soil test	Initial soil sample	Initial soil sample + 50 ml water	Initial soil sample + 100 ml water	Initial soil sample + 150ml water	Initial soil sample + 175ml water	Initial soil sample + 200 ml water
Humidity(%)	6,21	8,22	11.31	14,17	15.9	17,8
Density (g/cm^3)	1,71	2,02	2,32	2,47	2,4	2,36
The weight of the sample(g)	1752,3	1905,6	2023.4	2137.1	2102,6	2023,1

The determination ends after two or three compaction trials, from the trial at which the total mass of the cylinder of compacted material has begun to decrease.

Conclusions

The soil mixed with different aggregates or waste that can replace aggregates used as filling material must meet different criteria for the various uses. For example, for an earth dam, the ideal density of the soil is slightly above the optimum moisture so that it is plastic and can deform during settlement, for roads built on non-expansive is performed to control the quality of the material. The importance of Proctor tests is particularly important in order to obtain the highest possible density of the bearing soil at optimal compaction humidity. As can be seen in the results obtained, the density of the material used in the tests is influenced by the increase in its humidity.

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