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Geomechanical characteristics of controlled backfill soil for foundations, Pucallpa, Peru

Características geomecánicas del suelo de relleno controlado para cimentaciones, Pucallpa, Perú

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Article Data

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Abstract

The population growth in the city of Pucallpa, forces more and more projects to be executed on complicated soils, which in the past were rejected because of their bad characteristics, therefore, foundations on uncontrolled fills present very serious problems due to the heterogeneity of these materials, producing damages and reducing the life time of these buildings. The objective of this experimental investigation was to diagnose, by means of laboratory tests, the mechanical characteristics of controlled fill soils for foundations. The methods used were documentary analysis, laboratory studies and statistical processing using the Microsoft Excel program; the procedures performed for each soil test were guided and indicated by the manual of materials testing. The results for the controlled fill soil were: i) granulometry yielded a SUCS classification "SC (clayey sand)", AAHSTO classification "A-7-6 (clayey soils)" ii) compaction yielded a CBR at 100 % of the MDS of 14.00 % at 0.1" iii) shear strength yielded a friction angle at 25.01° and a cohesion of 0.00 kg cm^{-2}. The above indicates that the geomechanical characteristics of the controlled fill soil, the subgrade of the terrain according to the MTC is a good material for foundations in the city of Pucallpa, since it is a material with better physical and mechanical properties.

Resumen

El crecimiento poblacional en la ciudad de Pucallpa, cada día obliga más a que se ejecute proyectos sobre suelos complicados, que antiguamente fueron rechazados por sus malas características, por ello, las cimentaciones sobre rellenos no controlados presentan problemas muy graves por la heterogeneidad de estos materiales, produciendo daños y reduciendo el tiempo de vida de dichas edificaciones. El objetivo de esta investigación experimental fue diagnosticar mediante ensayos de laboratorio las características mecánicas del suelo de relleno controlado para cimentaciones. Los métodos empleados fueron el análisis documental, los estudios de laboratorio y el procesamiento estadístico por medio del programa Microsoft Excel; los procedimientos realizados para cada ensayo de suelo fueron guiados e indicados por el manual de ensayos de materiales. Los resultados realizados al suelo de relleno controlado fueron: i) la granulometría arrojo una clasificación SUCS "SC (arena arcillosa)", clasificación AAHSTO "A-7-6 (suelos arcillosos)" ii) la compactación arrojo un CBR al 100 % de la MDS del 14.00 % a 0.1" iii) la resistencia al corte arrojo un ángulo de fricción a 25.01° y una cohesión de 0.00 kg cm^{-2}. Lo anterior indica que las características geomecánicas del suelo de relleno controlado, la sub rasante del terreno según el MTC es un material bueno para las cimentaciones de la ciudad de Pucallpa, dado que es un material con mejores propiedades físicas mecánicas

Introduction

In Peruvian soils, Tarapoto is positioned in the most active seismic space on planet Earth, within the Circum-Pacific Belt, with 4 seismic zones[1]. Zone I, ground bearing capacity 0.78 kg cm^{-2}, located in the urban extension sector of the jurisdiction of Morales, in the district of Tarapoto covers the area of La Hoyada, Partido Alto, commerce and in the district of La Banda de Shilcayo. Zone II, bearing capacity of 1.86 kg cm^{-2}, located in the urban extension sector of the jurisdiction of Morales, parallel to the Cumbaza River on its right bank, in the district of Tarapoto covers the area of Sachapuquio, Pueblo Joven 9 de Abril, Punta del Este, Huayco neighborhood and in the district of La Banda de Shilcayo. Zone III, the portant capacity of the land 1.77 kg cm^{-2}, located in the jurisdiction of Tarapoto part of Atumpampa, airport area, AA. HH El Porvenir, Suchiche neighborhood, 10 de Agosto, 2 de Mayo, in the jurisdiction of La Banda de Shilcayo. Finally, in zone IV, the bearing capacity of the soil was 0.82 kg cm^{-2}. In the city of Tarapoto, the towns of Villa Universitaria, AA. HH Los Andes and Porvenir[1,2]. INDECI recommends foundations with external rectangular footings excavated to a minimum depth of 1.60 m, joined with slabs and/or foundation beams, in soils with clayey characteristics[2].

One of the important aspects for the geotechnical characterization of tropical soils is to establish their properties, considering the variation with respect to depth[3]. Soil profiles have five factors that determine their formation, differing from one place to another[4].

In the districts of Yarinacocha, Campo Verde and Callería, in the jurisdiction of Ucayali, Peru, an area of about 25000 ha, 7 different soil classes have been recognized: Restinga, Cashibococha, Barrizal, Colina, Yarinacocha, Aguajal and Campo Verde. Morphologically, the 3 main ones have typical A/C profiles, Aguajal, Colina and Yarinacocha have typical A/Bw/C profiles, and finally Campo Verde is typical A/Bt/C, the volumetric density varies from 1.20 to 1.71 g cm^{-2}/[5].

The soils of the city of Pucallpa belong to the jurisdiction of the Peruvian jungle, so they are classified as clay soils. Therefore, the controlled fill material was evaluated for use in the foundations of the project. Backfills are artificial deposits that are differentiated by their nature, such as compactable soils, without foreign elements, and by the conditions under which they are placed[6].

In line with the above, some authors have developed research works about foundations on fill soils, Moreira Montigue[7], mentions in his comparative analysis of deep foundations with reinforced concrete piles in soft vs. sandy soils, to reduce subsidence in a 10-story building through laboratory tests, allowed to know the geomechanical characteristics of the foundation soils of each site. The pile designed for the foundation of the structure in Canton Manta, was 10.0 m long and 0.45 m in diameter with a capacity of 60 t.

Maldonado Gutierrez & Vargas Garcia[8], indicate in their manual for the monitoring, control of a "deep foundation and construction of subtraction piles Kelly type" through the implication of the subject of study that works as a support for their administrative and technical employment. The compendium of consultation produced is appropriate to mention, the various processes of deep foundation elaboration procedures, the limitations of projects such as structures, limitations that point out the soil study and the dangers that originate the project.

Rosas González & Sanginés García[9] point out from their geotechnical design of balanced foundations for a residential building in zone II of the state of Mexico. In addition, once the characteristics of the type of soil in which the building will be located have been verified, the most appropriate solution is to opt for the use of a rigid reinforced concrete caisson placed at a depth of 5.86 m. This solution would comply with the limit states of failure, with a resistant load capacity of qR = 69086 kPa and a service load Qult = 126 kPa.

Escobar Trujillo[10], in his design of foundations and soil studies in the mini-sports complex of the Ampas-Huari Public Works Center, noted that after construction, deficiencies were detected in the columns on the west side of the mini-sports complex (overturning and settlements), thus it was necessary to evaluate the foundations and the area of soil in depth to establish the design parameters of the foundations.

Huamani Sacha & Ichpas Torres[11] carried out their foundation design for residences by soil classes in the urban sector of the district of Seclla-Angaraes, they point out that in this district there is population growth, which does not lead to housing constructions without technical direction, which present an inadequate foundation design, all this would be due to lack of economy and lack of professional services, adding to a history of unstable soil for lack of study and design of foundations, with time even more failures are presented.

Teniente Pauccar[12], developed a comparative study in the definition of the admissible capacity through Meyerhof and Terzagui methods, for the design of a shallow foundation according to soil properties of Inquilpata in the jurisdiction of Anta, performed excavation for calicata (open pit) randomly, obtained characteristic parameters of their soils and Cusco region, the experiments that were made, characterization and shear strength. All this because of the relief of the place that is disadvantageous, because of the high slope in the area, causing the descent of boulders is of great consequence.

The vast majority of civil engineering works begin in the soil, which is a fundamental part of a structure[13]. The soil where any type of construction will be founded must seek ways to densify the soil and increase its resistance[14]. Soil is one of the most important resources, its formation is a complex process that involves physical, chemical and biological changes of the original rock[15]. Texture determines the proportion of mineral particles of different sizes present in the soil[16]. According to Crespo Villalaz[17], the concept of soil, as mineralized natural particles that can be found relatively separated in small sets of masses and that may contain air, organic matter and even water. He also mentions the types of soil, gravelly materials, which over time accumulate loosely in fragments of stones, with dimensions less than 2 mm. For the Silt, grains of fineness, with almost null plasticity, can be inorganic similar to that found in the quarry or organic silt, which can be obtained in the river and lakes, presenting these plastic characteristics, finally, he mentions, clay, solid compounds with diametrically smaller dimension and whose bodies present the characteristic of becoming with plasticity when meeting or mixing with water. According to Ramos[18], sand is a type of loose fragmented soil from rocks that can be obtained from lakes, rivers or volcanic deposits. The mechanical properties of the soil consist of modifying the characteristics in order to increase bearing capacity and shear strength, decrease settlements, both absolute and differential, and reduce or eliminate the risk of liquefaction in the event of earthquakes or major vibrations[13]. The physical properties of a soil determine to a large extent its stiffness, bearing strength, specific weight, size, shape, roughness, sieving method, natural moisture, plasticity, liquid and plastic limits[19]. The soil in Peru is very varied, and over the course of time multiple factors can occur that affect its stability, such as earthquakes. A clear example is the earthquake of May 31, 1970, which generated liquefaction in large areas of Chimbote, Ancash. According to this phenomenon, the information available in Peru is very scarce, and it is necessary to carry out studies of the phenomena in different areas of Peru[20].

With an increasingly urban society, without contact with nature, we lose sight of the importance of soils for our survival[21]. There are a large number of techniques that could be used at this level of condition, but their choice and capacity of resolution depend directly on the characteristics of the building, the needs of improvement that the land requires for its correct functionality. The construction of buildings, every day forces more and more the recognition of the fillings and their treatment, the compactness of these, usually is very low, with very high pore indexes, being in general very open structures[22]. There are many kinds of fillings and all of them are dangerous for the stability of buildings[23]. The technical standard for buildings (NTE) E.050 was extended, incorporating the classification of fills by their nature into: selected materials (SM), unselected materials (USM), by the conditions of placement: controlled fills (CF) and uncontrolled fills (UCF)[24]. Foundations on UCF pose very serious problems due to the heterogeneity of these materials[25]. The settlements that can occur in foundations built on UCF can occur in three ways: in compressible fills under a foundation load, in fills subjected to their own weight, in natural soils below the fill[26]. Such is the case that, currently, there are many buildings of noble material, built in a backfill area, which present damage due to structural misalignment caused by settlements, which represents a social problem, undoubtedly apart from the engineering problem[27].

Important buildings in the area have been resolved by means of deep foundation solutions, soil improvement and reinforcement techniques such as controlled fills, offering an alternative solution to foundations in this type of terrain. For this reason, CF are those that are built with selected materials, generally of the granular type[6]. The characteristics that a selected soil must meet in order to be considered as fill must follow the methods mentioned in the E. 0.50 standard. The methods used in its conformation, compaction and control, depend mainly on the physical properties of the material[6].

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The selected soils used for the construction of the controlled fills must be compacted as follows[6]: When 30 % or less of the soil is retained in the ¾" mesh. i) When more than 12 % of fines are present, it shall be compacted to a density greater than or equal to 90 % of the maximum dry density (MDD) of the Modified Proctor compaction test in all its thickness. ii) If less than 12 % of fines, it shall be compacted to a density not less than 95 % of the MDD of the Modified Proctor compaction test in all its thickness. iii) When more than 30 % of the soil is retained in the ¾" mesh. iv) If the percentage of fines is less or equal to 15 %, it shall be compacted to a relative density of not less than 70 %. v) The use of soils with more than 15 % of fines shall not be recommended, unless the compaction and control methods are supported.

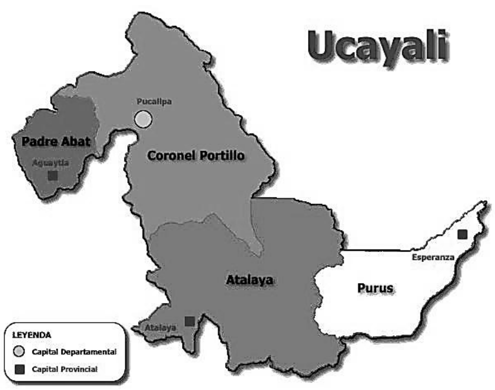
Compaction controls should be carried out on all compacted layers, at a necessary rate of one control for every 250 m^2 at most in the project to be carried out[6].

The objective of the research was to diagnose by means of laboratory tests the geomechanical characteristics of CF soil for foundations in Pucallpa-Peru, since jungle soils cause damage to buildings over time, reducing their life span if they are not replaced by compacted and controlled fills. The structure of a building is supported and achieves stability through its foundations[28]. These studies were carried out where the seismic zoning is different and the mechanical properties of the fill soil show different values, performing an analysis linked to the characteristics of the Amazonian soil.

Materials and methods

Study area. The city of Pucallpa is located in the department of Ucayali in central eastern Peru on the banks of the Ucayali River. It is in the middle of the Amazon jungle at 154 meters above sea level. The climate is tropical and warm all year round[29]. The project consists of 1052 m^2 of land.

Figure 1 Reference map of the city of Pucallpa, Ucayali, Peru



Abbreviations. AA. HH: Human Settlement, INDECI: Instituto Nacional de Defensa Civil, C.P: Village Center, NTE: Technical Standard for Buildings, MS: Selected Materials, USM: Unselected Materials, CF: Controlled Filling, UCI: Uncontrolled Infill, MDD: Maximum Dry Density, NBR: National Building Regulations, CS: Clayey Sand, SUCS: System Unified Classification System, AASHTO: American Association of State Highway and Transportation Officials, CBR: Californian Bearing Ratio, OMC: Optimum Moisture Content, MTC: Ministry of Transportation and Communications.

Obtaining and selection of the material. The soil used was obtained from the "Piedras, Ripio y Arenas" quarry located at Jr. Mariano Melgar Mz. 143A Lt.04 Yarinacocha Pucallpa. The selection of this soil will be granular (gravel and sand particles), with a not excessive clay content and totally free of degradable or aggressive elements[30], therefore the quality of the fill material will be established in accordance with the tests carried out in the laboratory.

Geomechanical characteristics. Study of the way in which rocks and soils are altered, until they occasionally end in failure, in reaction to variations in temperature, stress, pressure and other environmental indicators[31].

Foundation. That section of the structure responsible for transferring loads to the ground[32].

Method. The processes employed in the development are described: Documentary analysis "involves the thorough review of the contents of documentary sources, so that the characteristic information foundations were obtained from books, undergraduate theses and scientific articles, classifying, analyzing and organizing them according to the position of the objectives of the study"[33]. The laboratory studies involve carrying out tests in compliance with the indications of the MTC according to the materials testing manual, which is one of the technical documents of a normative nature that governs at the national level and is mandatory[34], as well as the tests of granulometric analysis (MTC E 107), modified Proctor compaction (MTC E 115), CBR (MTC E 132) and direct cut (MTC E 123), with the purpose of knowing the mechanical properties of the material. The data analysis is hypothetical deductive, based on exploration and statistical processing of quantitative information. Likewise, it was ordered and classified in Excel tables for analysis and study in order to be able to draw conclusions. Therefore, Bernal Torres[34] indicates that "it consists of a procedure that starts from assertions as hypotheses and seeks to refute or falsify such hypotheses, deducing from them conclusions that must be confronted with the facts".

Procedure. The steps are described in detail: It began in the quarry with 200 kg of material to be transported to the laboratory of materials mechanics, the material was dried in the open air, dry preparation of the sample was made for the granulometric analysis, the soil sample was quartered to choose two diagonal quarters, a significant sample of soil was weighed to proceed to wash it through mesh No. 200, it was placed in the oven at 110±5° C. It was sieved in meshes of different openings by means of a mechanical sieve shaker and finally the material retained in each mesh was weighed, the modified Proctor type compaction was performed establishing the test method according to the granulometry data, the appropriate compaction mold was selected according to the method, the mold, base and extension collar were assembled, the condition and calibration of the balance and manual piston were checked before starting, a significant sample of soil was weighed to moisten it in a container at different percentages of water content, the specimen was compacted in 5 layers of the same thickness and each one with 56 blows, the collar and base plate were flushed and removed from the mold, the mold was weighed plus the compacted soil, the compacted material was removed from the mold, a soil specimen was obtained to determine the water content, as for the CBR test, the same procedure of the modified Proctor was performed until compaction for the three CBR molds, then the 2 overloads were placed in each mold, the 3 molds were soaked in a tub of water for 96 h, the reading of the expansion was taken for 4 days, then the molds and their overloads were taken out to drain it for 15 min, it was taken to the press and placed in the central hole of the annular overload, the penetration piston and the rest of the overload was added, then the needles of the measuring dials were placed at zero and began to penetrate the mold at a uniform speed of 1. 27 mm every 30 s, and finally, the mold was disassembled and a sample was taken from its upper part to determine its humidity. Finally the direct shear test was performed by assembling the shear box with the frames aligned and blocked, a layer of grease was applied between the frames, the test sample was introduced with great care, the loading device was connected and the dial was adjusted to measure the deformation, the water reservoir was filled allowing drainage, the force was applied to each of the samples, the normal deformation readings were recorded at appropriate times and finally the normal deformation readings were plotted vs. time.

Results

Table 1 Diagnosis of the geomechanical characteristics of the controlled backfill soil

	Summary of laboratory tests			
	Granulometry	**Proctor**	**CBR**	**Direct cut**
Backfill soil	The soil is a SC according to the SUCS system, by the AASHTO system it is an A-7-6, clay soil.	The maximum dry compacted density is 1.57 g cm^{-3} and the optimum moisture content is 8.55 %.	The CBR (0.1") at 100 % MDS is 14.00 % and the CBR (0.2") at 95 % MDS is 7.04 %.	The angle of friction is 25.01°, cohesion is 0.00 kg cm^{-2} and moisture density is 2.028 g cm^{-3}.
Status	Well	Well compacted soil	Good	Well compacted soil

Table 1 presents a summary of the results of the tests performed on the CF or engineering soil, obtaining a SUCS and AASHTO classification, a CHO of 8.55 %, a CBR at 0.1" at 100 % of its MDD of 14 %, a friction angle of 25.01° and a cohesion of 0.00 kg cm^{-2}.

Table 2 and Figure 2 present the results of the sieving grain size of the fill soil showing 74.33 % sand and

25.67 % silt and clay, so that it has a soil classification according to the SUCS systems a CF and AASHTO an A-7-6. In addition, the granulometric distribution curve shows the percentages passing through each sieve and the nominal maximum size of the soil at 0.84 mm.

Table 2 Results of sieving grain size and classification of the soil

Sieve	Diámeter (mm)	Retained weight (g)	Partial retained percentage	Cumulative retained percentage	% go to
3"	76.200	0.00	0.00	0.00	100.00
2"	50.800	0.00	0.00	0.00	100.00
1 1/2"	37.500	0.00	0.00	0.00	100.00
1"	25.400	0.00	0.00	0.00	100.00
3/4"	19.050	0.00	0.00	0.00	100.00
3/8"	9.525	0.00	0.00	0.00	100.00
N°4	4.750	0.00	0.00	0.00	100.00
N°10	2.000	0.00	0.00	0.00	100.00
N°20	0.840	0.66	0.05	0.05	99.95
N°30	0.590	3.14	0.23	0.28	99.72
N°40	0.420	55.08	4.11	4.39	95.61
N°50	0.297	475.54	35.49	39.88	60.12
N°60	0.250	145.54	10.86	50.74	49.26
N°100	0.150	185.54	13.85	64.59	35.41
N°200	0.075	130.54	9.74	74.33	25.67
Fondo	0.020	343.96	25.67	100.00	0.00
Total		**1340.00**	**100**	**Sieving results**	
SUCS Classification:				Gravel (4.75 - 75mm)	0
SC				Sand (0.075 - .75mm)	74.33
Clayey sand, a mixture of sand and red clay.				Silt and clay (< .075)	25.67
AASHTO classification:				Classification: Sands	
A-7-6				**Types of sand**	
Clay soils				Total weight:	996.04 g
				Coarse sand:	58.88 g
				Fine sand:	937.16 g
				Classification	Fine sand

Table 3 presents the results of dry density between the ranges of 1.54 to 1.57 g cm^{-3} and moisture percentage of the 4 compacted specimens through the modified proctor test. Figure 3 shows the top of the curve, with results at 100 % compaction for the MDS of 1.57 g cm^{-3} and the optimum moisture content of 8.55 % of the controlled backfill soil for foundations in Pucallpa, Peru.

Table 4 and Figure 4 show the results of the penetration resistance, obtaining the percentages of CBR at 0.1" and 0.2" of each mold, with 56 blows the CBR is 15.07 % and 20.37 %, with 25 blows the CBR is 7.35 % and 9.33 % and finally with 12 blows the CBR is 5.78 % and 6.15 %. Also, the CBR at 100 % of its MDS of 14.00 % at 0.1" of the controlled fill soil is found in the figure.

Figure 2 Grain-size curve of the fill soil-Pucallpa

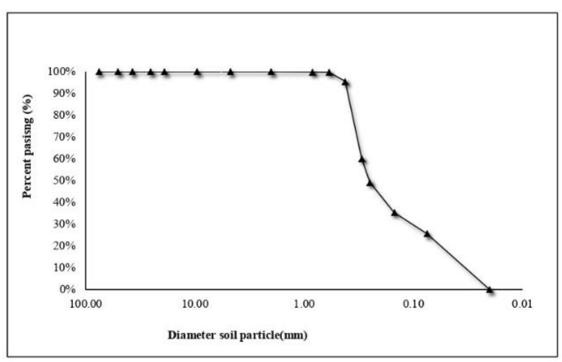


Figure 3 compaction curve maximum dry density vs CHO of backfill soil

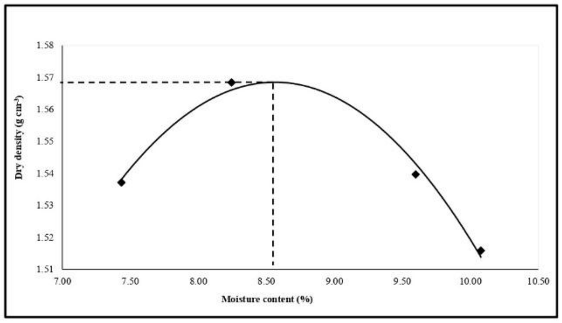


Figure 4 CBR. curves at 0.1" and 0.2" from the backfill soil

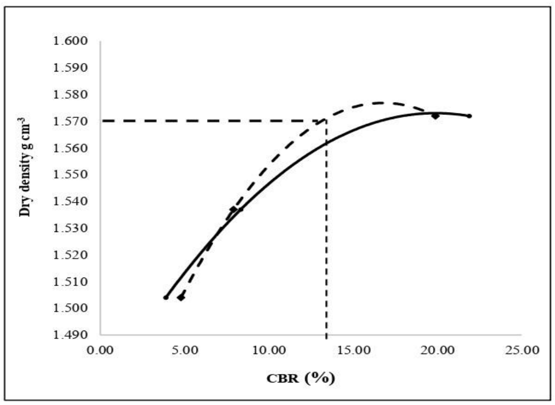


Figure 5 Shear stress vs. vertical load curve of the direct shear test

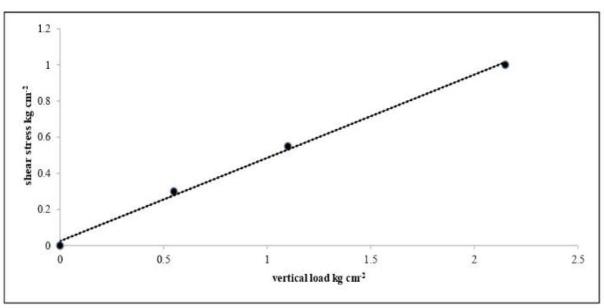


Figure 5 shows the results of the shear stress ratio and the vertical load of each sample, obtaining the friction angle of 25.01°, also obtained from the shear stress ratio and the lateral displacement was the moisture density of 2.028 g cm^{-3}, and finally the main result was the cohesion of 0.00 kg cm^{-2} of the controlled backfill soil for foundations.

Discussion

Table 1 shows the diagnosis of the geomechanical characteristics of the fill soil, which was corroborated by laboratory tests[3,7,12], important data such as soil type, CHO, CBR at 100 % of the MDS, friction angle, cohesion and wet density, with all these results the soil is classified as a good subgrade and fill material to build or design foundations. Clarifying that the characteristics of each soil depend on several factors, the most important of which are the type of rock that originated them, their age, relief and climate[12].

Table 2 and Figure 2 refer to the importance of the granulometry of the backfill soil and its physical properties in order to identify its nature, as well as the classification[9] by the SUCS system is SC called clayey sand with a mixture of sand and red clay and by the AASHTO system it is A-7-6 called a clayey soil. In addition, the granulometric curve shows the percentages of soil passing through the different sieves[35] in order to determine the maximum size of the fill material.

Table 3 and Figure 3 show how the relationship between water content and dry unit weight[35] was determined through the modified Proctor compaction test; the data obtained are a reference for on-site compaction quality control, which seeks to eliminate any type of settlement caused by the structure[10]. The compaction curve also shows the CHO at 100 % of the MDS of the backfill soil.

Table 4 and Figure 4 show percentages of the capacity of the material at 0.1" and 0.2", from which characteristic parameters[12] were obtained, such as the resistance of this soil to gas loading. In addition, according to the range established by the MTC, it is categorized as a good subgrade for placing RC or engineered material.

Figure 5 shows the determination of the direct shear test of the backfill soil, under consolidated drained conditions, which seeks to determine the admissible capacity according to the soil characteristics to indicate which provides greater structural safety[12], provided that the characterization of the material and the test are carried out adequately[25]. As we know, shear strength is closely linked to suction pressure[3], such data allow foundation calculations to be made.

Table 3 Determination of the maximum dry density in the compaction test

Compaction test - Proctor M. - ASTM D 1157								
Density Determination								
Specimen N°:	M-1		M-2		M-3		M-4	
Layer Number	5		5		5		5	
N° of strokes for layer	56		56		56		56	
Weight Empty mold (g)	6685		6650		6690		6685	
Mold Weight + Wet Sample (g)	11500		11600		11610		11550	
Weight of compacted wet sample (g)	4815		4950		4920		4865	
Volume Mold (cm^3)	2915.70		2915.70		2915.70		2915.70	
D. Wet ($g\ cm^{-3}$)	**1.65**		**1.70**		**1.69**		**1.67**	
Determination of Moisture Content								
Container	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
Weight Container (g)	25.20	25.56	25.06	24.10	25.06	24.10	25.06	24.10
Weight Vessel + Wet Sample (g)	60.72	60.74	68.30	61.50	45.68	52.58	46.10	52.50
Weight Vessel + Dry Sample (g)	58.42	58.15	64.95	58.70	43.90	50.05	44.10	50.00
Water Weight (g)	2.30	2.59	3.35	2.80	1.78	2.53	2.00	2.50
Dry Sample Weight (g)	33.22	32.59	39.89	34.60	18.84	25.95	19.04	25.90
Cont. humidity (%)	6.92	7.95	8.40	8.09	9.45	9.75	10.50	9.65
W medium (%)	7.44		8.25		9.60		10.08	
Dry density ($g\ cm^{-3}$)	**1.54**		**1.57**		**1.54**		**1.52**	

Table 4 Determination of CBR - Penetration resistance

California Bearing Ratio Test			
Determination of density and compaction humidity			
Mold N°	**1**	**2**	**3**
Number of layers	5	5	5
Hits for layer N°	12	25	56
Mold Weight + Wet Soils (g)	14265	14570	14760
Weight Mold (g)	8040	8175	8125
Weight Wet Soil (g)	6225	6395	6635
Vol. Mold (cm^3)	3852	3852	3852
Densidad Húmeda ($g\ cm^{-3}$)	**1.616**	**1.66**	**1.722**
Capsula N°	**1**	**2**	**3**
Capsule Weight + Wet Soil (g)	79.78	91.12	97.88
Capsule Weight + Dry Soil (g)	75.86	85.98	91.6
Water Weight (g)	3.92	5.14	6.28
Capsule Weight (g)	25.2	25.56	26.34
Dry soil weight (g)	50.66	60.42	65.26
Moisture content (%)	**7.74**	**8.51**	**9.62**
Dry density ($g\ cm^{-3}$)	**1.50**	**1.53**	**1.571**
Determination of expansion			
Mold height (cm)	127	127	127
Weather (h) / N° Mold	**I**	**II**	**III**
0	0.00	0.00	0.00
24	0.30	0.29	0.10
48	0.70	0.38	0.11
72	0.90	0.365	0.11
96	1.60	0.400	0.13
Expansion (%)	**1.260**	**0.310**	**0.10**

Table 4 Determination of CBR - Penetration resistance (continued)

Determination of density and compaction humidity								
Penetration		Pressure	Penetration		**II**		**III**	
pulg.	mm	pulg. (kg cm^{-2})	Dial (kg)	Pressure (kg cm^{-2})	Dial (kg)	Pressure (kg cm^{-2})	Dial (kg)	Pressure (kg cm^{-2})
0.000	0.00		0.0	0.0	0.	0.0	0	0.0
0.025	0.64		6	0.3	15	0.8	16	0.8
0.050	1.27		24	1.2	36	1.8	60	3
0.075	1.91		52	2.7	69	3.5	125	6.4
0.100	2.54	70	80	4.1	101	5.2	208	10.6
0.150	3.81		109	5.6	159	8.1	343	17.5
0.200	5.08	105	127	6.5	193	9.8	422	21.5
0.250	6.35		144	7.3	219	11.2	463	23.6
0.300	7.62	133	161	8.2	234	11.9	481	24.5
0.400	10.16	161	193	9.8	255	13.0		
0.500	12.70	182	219	11.1	280	14.3		
CBR a 0.1" (%)			**5.78**		**7.35**		**15.07**	
CBR a 0.2" (%)			**6.15**		**9.33**		**20.37**	

The method of this investigation is ideal for determining averages and trends, making forecasts, verifying relationships and acquiring absolute results for large populations[36].

Finally, it is concluded that the geomechanical characteristics of the RC soil for foundations in the city of Pucallpa comply with the parameters established in Standard E. 0.50[6] and the National Building Regulations.

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Conflicts of interest

The authors declare that there is no conflict of interest with the research conducted.

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Ethical considerations

The following ethical bases are considered: Principle of justice, expressing that all the studies for the execution of the mentioned project will be with equal treatment and that they will be considered at the moment of making the decision, without ever forgetting the recognition of intrinsic values. Principle of autonomy, where the authorization of the municipality will be obtained, where the laboratory and field tests will be carried out, respecting its autonomy, in compliance with the right to be informed about the purpose of the research. Principle of beneficence and non-maleficence, expressing that the research work will not cause any negative impact, risks or physical or psychological damage to any element of the sample that participates in the resolution of the instrument, as it is a work of visual inspection, rather, it will be positive in relation to the social field, since it will allow knowing the problems to later analyze, evaluate and make decisions seeking the common good for all.

Research limitations

We, the authors, declare that there were no limitations of any kind in the research carried out.

Authors' contribution

Sleyther Arturo De la Cruz-Vega, contributed in the execution of the experimental phase, collection of statistical data, review of results, discussion, statistical analysis and final revision of the article generated. *Esther Noemi Noel-Cornelio*, contributed in the execution of the experimental phase, collection of statistical data, administration of resources for the development of the research, literature review for material and methods.

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