TECHNICAL REPORT ON THE SOIL INVESTIGATION FOR THE

ARGYLE INTERNATIONAL AIRPORT PROJECT,

SAINT VINCENT

06/09/2006

Contents

1 Introduction

The present report is the result of soil investigation that was done in the project area of the Argyle International Airport, in the island of Saint Vincent, with the objective of knowing the geo-mechanic characteristics of the soil in the site designated for the runway. As a result we hope to define the parameters for the design complying with an agreement that was made between the governments of the Republic of Cuba, the Bolivarian Republic of Venezuela and Saint Vincent and the Grenadines.

2- Geography of Saint Vincent

Saint Vincent is located within the southern part of the Lesser Antilles of the Caribbean. It is approximately 100 miles to the west of Barbados, 68 miles to the north of Grenada and about 190 miles to the north of Trinidad. Saint Vincent is the largest of 32 islands and cays that constitute the nation of Saint Vincent and the Grenadines. It is more or less of an oval form with 29 kms in length and 17.5 kms in width. The island consists of a central axial mountain range that begins in the north at the site known as La Soufrière, an active volcano 1178ms in height, and finishes in the south at the site known as St. Andrew, 736ms in height. This volcanic mountain range almost divides the island in two equal halves, an Eastern or windward side and a leeward side. The north-south center line of the island shows migration originating from the volcanic activity, with predominance of olivine, Scoria cones and basalts, product of the small explosive eruptions (Rowley 1978a).

The Eastern Caribbean is an example of a system of arc of islands formed on the extremes of the convergent plate (in other words, on a subjacent zone where two tectonic plates meet and the denser plate forces the lighter plate downwards). This is the main cause of the volcanic and seismic activity in the Eastern Caribbean. Most of the earthquakes that happen in the Eastern Caribbean are of tectonic or volcanic origin. The tectonic earthquakes are generated when the accumulated energy flows and produces the movement of the plates. The volcanic earthquakes are generated by the movement of magma within the lithosphere. The magma is less dense than the surrounding rocks, for such reason it rises to the surface, while the rocks move, in that way generating earthquakes. In fact, more than 75% of earthquakes happen in the limits of the convergent plates. The countries of the Eastern Caribbean are therefore very susceptible to earthquakes.

3- Geologic recognition

In the site, extrusive igneous rocks, represented by several events of lava flows of different composition, pyroclastic material and ash are visible. See Figure Nº1.

These volcanic materials come from the La Soufrière volcano located to the north of the island. The last registered eruptions were in 1902-03, 1971-72 and 1979.
Source: Seismic Research Unit, University of the West Indies.

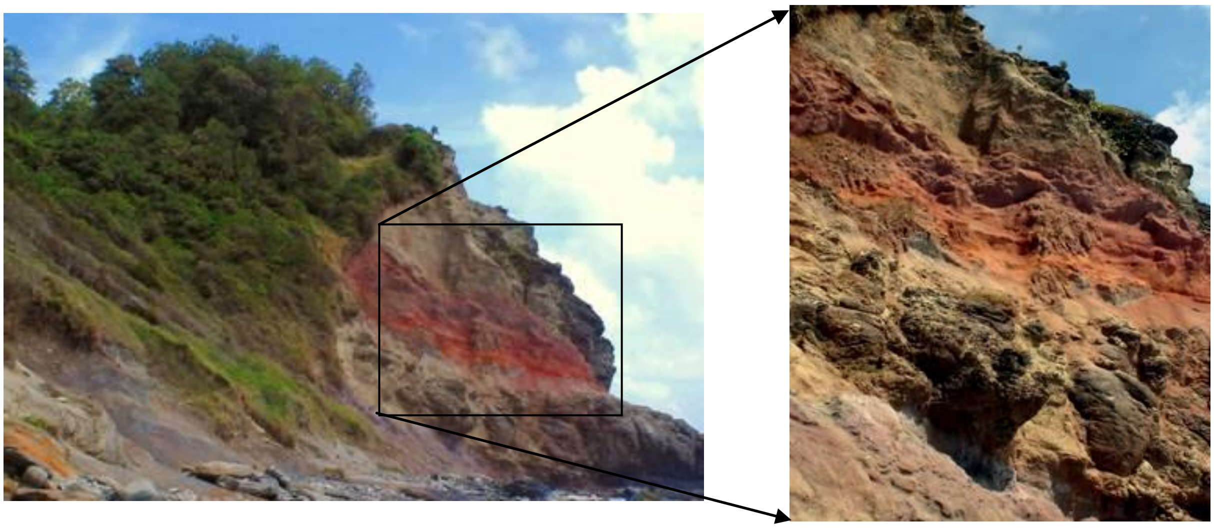


FIGURE Nº 1. *Embankment located to the Southeast of the island UTM coordinates, datum Pro. SAm 56, 20 P Norte 1455181 and East 701154. Take note of the five events of eruption and the differentiation of the material.*

According to the mineralogy of the hand samples taken in field and the perforations on the study site for the new International Airport, it can be concluded that the most common materials are:

- *Basalts and centimetric to plurimetric granular xenoliths*
- *Andesites*
- *Scoria*
- *Ash*

Basalts

In the eruptions that were registered, the flow structures and numerous vacuoles formed by the escape of the gases that was contained during the crystallization process stand out; these vacuoles gives it a high porosity, but they are not interconnected, therefore they do not contribute permeability to the rock. They are of a black color when fresh and grayish color when meteorized, fine to medium grained, micro/cryptocrystalline texture. In some eruptions the rock is greenish due to the olivine content. Between the observable minerals in the hand samples you have: Plagioclase, augite, amphibole, olivine and glass of a clear coffee color. See figures Nº 2 and 3.

FIGURES Nº 2 and 3. *Basalts of fine texture constituted of numerous irregularly distributed small crystals located in a mass of even finer crystals or glass.*

According to the geologic literature of the area these basalts are very common in the Southern areas of the island; this was substantiated in the fields, and to top it off, this material is being utilized as a heavy aggregate crushed stone N º 1.

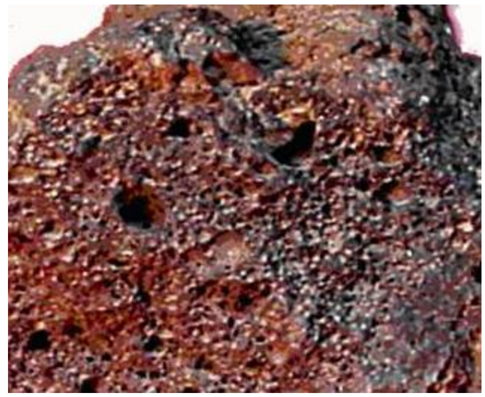
Andesite

Andesite arises in a massive form or in form of docks, porphyritic texture with crystals of plagioclase (white) and amphiboles (dark) and in smaller proportion some pyroxenes (dark), color black and white spots, when meteorized it is grayish. See figures Nº 4 and 5, the micro pores and the vitreous matrix are emphasized.

FIGURES Nº 4 and 5 *Andesite arising in massive form and hand sample, take note of the fenocrystals of plagioclase, the fine matrix and flow textures*

Scoria

Rock conformed mainly of iron oxides, gray metallic lead color when fresh and reddish when meteorized of a spongy appearance. See figures Nº 6 and 7



FIGURES Nº 6 and 7. *Scorias showing its red and lead color due to meteorization and the spongy texture*

Ash or Pumites

Rock with very low density and great porosity, permeable, formed by volcanic ash accumulation in an ardent cloud, little consolidated, fine grain, smaller than four millimeters in layers of until 30cm, conditions of decomposed soft rock shows high plasticity and is extremely delineable*, difficult to sample as hand sample.*

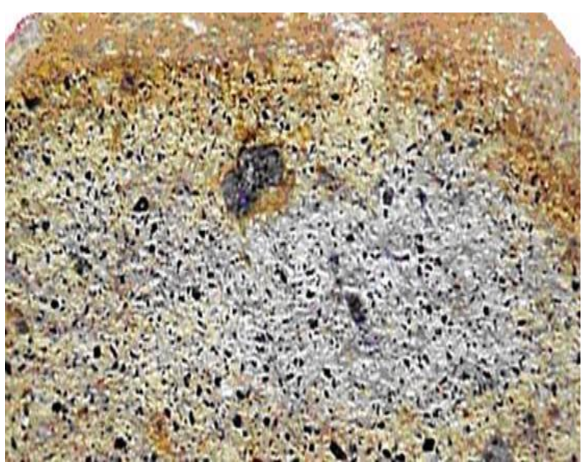


FIGURE Nº 8: *Pumite showing the vacuoles and its fine texture*

3.2- Seismicity of the area

The island of Saint Vincent is located in the arc of islands of the eastern Caribbean (See Figure Nº 9), where two tectonic plates converge, conforming a zone of subduction; when sufficient energy is accumulated, an elastic rebound takes place whose liberation of energy gives rise to earthquakes.

According to some authors the seismicity of Saint Vincent is intimately related to the volcanic activity consequence of the hitting of the two tectonic plates of the Caribbean and the Atlantic.

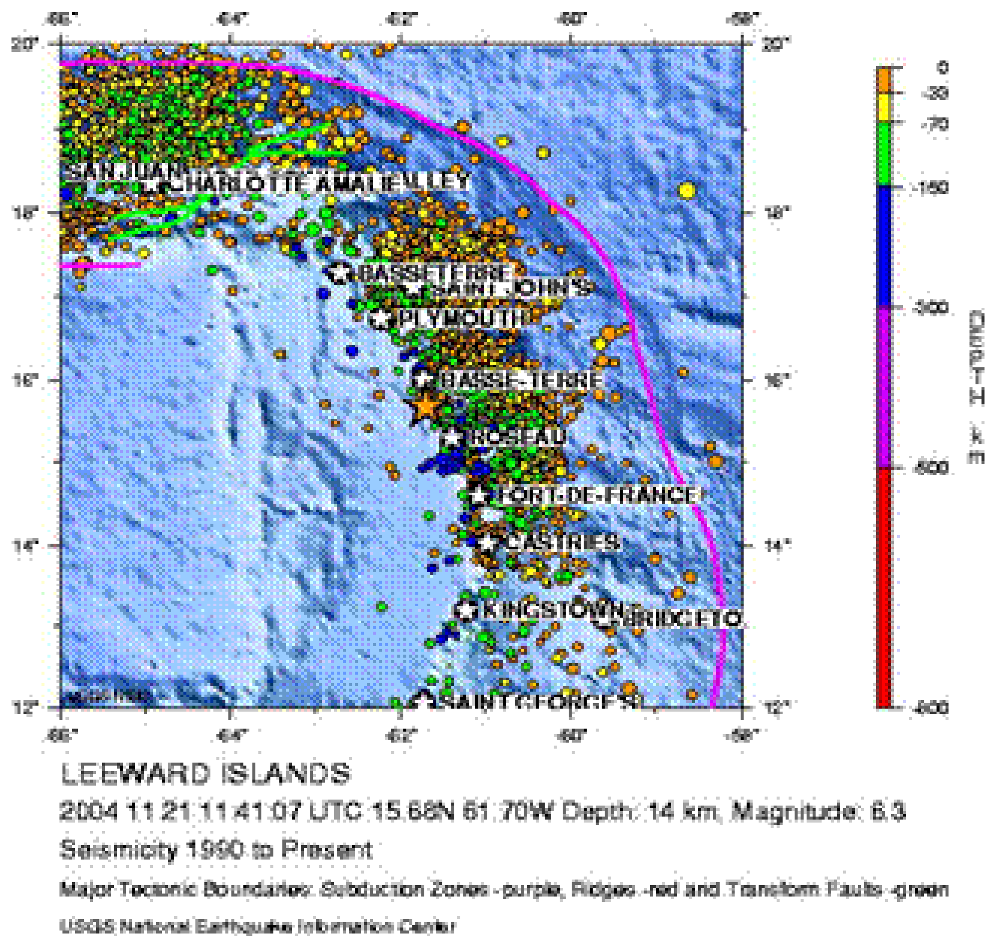


FIGURE Nº 9 *Historical seismicity of the arc of islands. Source USGS.*

In the threat map, done for Venezuela by INTEVEP, 1996, the arc of islands within the area is included with a horizontal acceleration Coefficient of 0.25g. See figure Nº 10.

In the location plan of the greatest earthquakes from 1969 made by FUNVISIS, 2004, the seismicity of the area can be observed. The information is being updated to include the area of the island of St Vincent and compliment this paragraph with numbers.

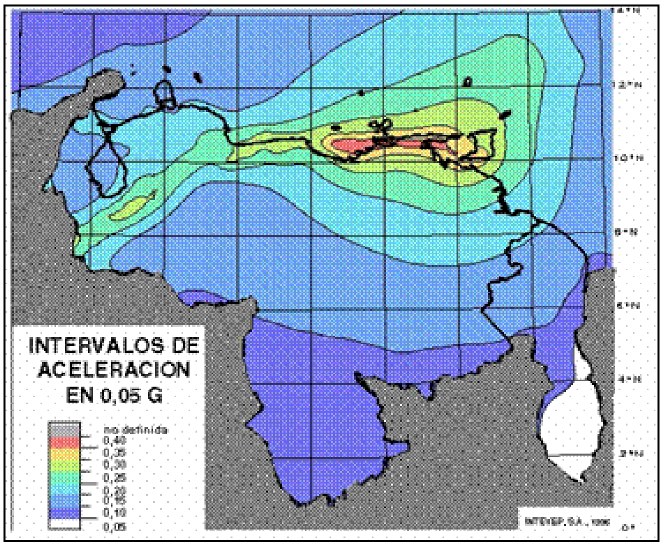


FIGURE Nº 10 *Map of seismic threat, INTEVEP, 1996*

<u>3.3- Geotechnical characterization of the rocks of the site</u>

According to the result of the perforations and the direct observation of the hand samples, the behavior of the material can be described as mixed, soil and rock depending on its origin and its mineralogical composition, on the basis of those observations and to the methods of field classification, the following was concluded:

- ***Resistance of materials:*** *The basaltic and andesites rocks, in fresh state, and on the basis of the Geo-mechanical classification of the amplified ISRM, 1977, they can generate resistance to compression within the order of 400 to 800 Kg/cm^2, nevertheless this resistance can lower in function to the degree of meteorization at ground levels in the range of 1-5 kg/cm^2.*

  The volcanic ash or pumitas rocks regularly generate unitary weights as low as $0.5 g/cm^3$ and specific weights from 0 to 1.0 g/cm3. These variations in resistance must be taken into consideration in the analysis of the field data because it induces important mistakes when analyzed statistically.

- ***Meteorization:*** *These rocks meteorize mainly to fine soil of medium to high plasticity and those of porphyritic texture can meteorize to sands of medium grains. In this type of rocks the meteorization is differential, reason why it is very common to find rocks in meteorized rock state hard and good conditioned RMdf next to rocks totally decomposed and soft or RDb.*

3.4- Behavior of the subsoil material in the perforations

On the basis of all that was said before, the following was concluded:

- *The nature of the material is volcanic and highly unstable chemically and mechanically.*
- *Its resistance to meteorization is differentiated by its origin and its mineralogical composition.*
- *Its resistance to penetration is in function of its degree of meteorization.*

Therefore we have in a same perforation, thicknesses of soil and rock bodies parallelly, with random and not zoned variations.

Initially for this project, a series of perforations by percussion and rotation were prepared where the following was carried out:

- *Perforation method: perforations by the percussion and rotation method combined were done, whose determination is only made on site and at the moment at which the materials vary its resistance to penetration.*
  The method of perforation used was based on the ASTM-D1586 standards, that which allows you to find the relative resistance of the different formations of the soil quickly and simply. In this test, the number of blows needed to perforate 30cm (one foot) is counted that which represents one sample in the form of tube that was broken vertically and the number of blows (N) is correlated empirically with the resistence of the soil.
- *The taking of samples was continuous and very detailed trying, inclusively, to take samples in the washing zone.*
- *The distribution of the perforations were more frequent in the less sloped areas and distributed with higher frequency in the zones of lower slope and less in the hills, this is due to the fact that the topography is controlled by the meteorization differential, leaving the greater heights to the rocks with greater resistance and the flat and semi-flat zones to softer rocks.*
- *The depth of the perforations is based on the quality of the rock or soil as foundation material in each perforation reason why the depth is only decided according to the quality of the recovered material, and always considering to deepen 3 meters in relation to the height of the runway.*

4- Work Methodology

4.1 Field Work

The work in the fields was done by means of the exploration of the soil by methods of preliminary character, to elaborate the study referred to in the results of the laboratory tests, through the following activities:

1. ***Technical visits by the team to the field:*** *where the visual inspection was carried out with the purpose of observing the characteristics that the soil has, to later select the suitable sites where the sampling was done.*
2. ***Opening and closing of test pits:*** *the work in the field was realized by doing investigations in form of test pits up to a depth of 5.00 ms, where altered samples were taken so as to perform physical and mechanical tests.*
3. ***Perforations:*** *these were done with the aim of determining the characteristics, thickness and stratification of the subsoil materials and also to find its resistance to penetration. The perforations using percussion were done following the specifications of ASTM D1586 norm. This norm was chosen because it renders the best practical results and gives very useful information in terms of the subsoil when compared to the rest of the preliminary exploratory procedures. The utility and importance of this test are in the correlations made in the field and the laboratory in diverse soils, mainly in sands, that allows you to approximately relate the compactness, the angle of internal friction and in clays the value of the simple compressive strength, with the number of blows necessary, in this soil, for the standard penetrometer to penetrate the 30cms specified in the requirements. This was done with equipment for perforation that consists of:*

    - *Chisel type reels, continuous drills for superficial holes, with inner diameter of the drill of empty piston rod between 2.2" and 6.5". Manual drills with solid scoops with inner diameter of 2.2" and 6.5".*
    - *140 lbs Percussion hammer.*
    - *Divided spoon type Samplers.*
    - *Pipe for sampling with unions to connect the divided spoon samplers.*
    - *Heads and connected axis.*
    - *Tripod.*
    - *Monkey wrenches, retaining baskets, derrick of bars, mecate.*
    - *Bottles, spatulas, markers, chalk, metric tape.*
    - *Level and plummet.*

Once the perforation site has been located, the tripod is raised with the pulley connected to it. The level of the equipment was verified with a level. The mecate was passed through the channel of the pulley and it was supported, coiling it on the rotating cylinder of the machine approximately ¾ times in the counterclockwise sense. Later, the perforation tube was assembled, the sampler and the hammer head was joined on.

Once the equipment was assembled, the motor was put into operation; then the hammer with mecate was suspended until an approximate height of 1 m, leaving it to fall freely on the surface of the land. In the inner circle of the print left by the hammer, a hole of 15 cms depth and 10 cms diameter was opened; this was done with the aim of eliminating the layer of loose material.

The sampling was done with the sequence of operations indicated:

- *On the sampler the length that will be penetrated was marked with chalk, in this case three marks of 15cms each were done; that corresponded to the 15cms of repair and 30cms of normal penetration.*
- *The sampler set, bar and head was placed in the site that will be perforated in a vertical position and then the execution of blows with the hammer begun, suspending it until a height of 30" (0,76m) and dropping it freely on the head.*
- *The number of blows applied for each increase of 0,15m was counted.*
- *Additionally when rejection to the standard penetration was evident, rotating perforation with the injection of water was done.*

4. ***Geophysical soundings:*** *geophysical soundings were done in the study area of interest for the new Argyle International Airport. Parallel, the geological surveys of surface was done. The applied seismic methods were those of refraction and seismic reflection. In these methods, the time of propagation of the elastic waves, between the site where the seismic waves are generated and the different observing points of arrival. A series of sensors in straight lines at known distances were used, forming what is known as seismic laying or line of refraction or seismic reflection. At a known distance on the extreme of laying, in the point of detonation, generating seismic waves, with the aid of a hammer in some points and in others by the detonation of explosives, which caused vibrations in the land that were detected by each of the sensors in the laying.*

   The basic equipment consists of the sensors; the acquisition unit , where the movements of the land detected by each sensor are stored; the connection cables between the sensors and the unit of acquisition; the trigger cable, which is responsible to mark the moment in which the registry in the acquisition unit begins. The registries of each sensor have information of the movements of the land based on the time, that which are generated in order to register parameters for the design. These registries are analyzed in the refraction to obtain the time of arrival of the first waves from the detonation point to each sensor, and in the reflection to obtain data of the waves that are reflected in the different interfaces of the soil.

   Additionally, one of the applications of the refraction method, that will be obtained, is the determination of the depth to the base, and for the determination of the conditions (meteorization, fracturation) and competence of the rock in the places where the structures will located. The method uses the arrival of the first waves to the geophones, P waves, but also as the arrival of S waves, in such a way that the dynamic Poisson's ratio and other modules can be determined.

4.1. ***Selection of measurement sites:*** *The selection of sites for the realization of tests was oriented by the necessities of the project, for which 13 soundings were made, generating longitudinal and cross-sectional sections in the area of interest. For this, measurements were done in 11 sites in the zone of the airstrip and 2 outside this area with the intention of comparing the measurements with other soil deposits, and these other areas are additionally considered to be obstacles.*

4.2- Location of the test pits and perforations

The location of the test pits and perforations obeyed a trefoil distribution in the area of the runway (45m) and in some sites outside this strip considered of interest because of the diversity of the materials found, in order to be able to later correlate the results on the layout strip. It is important to mention that in the distribution of the investigation, the first variant for the location of the runway was considered, and later the definitive variant was taken into consideration.

Next is a table with a list of the coordinates and heights of the perforations that were done, their location is given with reference to the station of the layout and its distance with respect to the centerline indicating the direction, that is to say, right or left of the centerline. The separation between perforations corresponded basically to the topographic relief and was also influenced by the height of the runway.

During the second stage of the investigation, nine (9) perforations and nine (9) test pits were done to control the more critical zones like great embankments or great cuts. The sites considered to be most critical were in the area of the great embankment near to station 74+000, where two perforations were done, identified as: P2-10 and P2-11, revealing soils type A-2-4(0), with very low resistance to penetration. The additional perforations that were done during this second stage of investigation served to corroborated the type of soils found throughout the profile realized on the centerline of the track with a predominance of soils types A-2-4 and A-7-6.

TEST PITS / PERF.	***COORDENATES***		***HEIGHT (m)***	***LOCATION***	***DEPTH (m)***
	EAST	**NORTH**			
CC-1	491396,432	1453236,512	83,600	-2+15.0 (10m left)	4.40
CC-3	491403,921	1453251,355	79,494	-2+13.0 (22m left)	5.00
CC-4	491445,609	1453262,253	60,372	-0+6.00 (14m right)	6.50
CC-5	491412,880	1453325,612	58,309	4+0.00 (40m left)	1.20
CC-86-A	491474,072	1453170,403	69,866	-8+4.00 (22m left)	1.50
CC-86	491482,714	1453173,142	65.343	-8+0.00 (80m left)	5.00
P-86	491478,922	1453136,542	67,644	-10+10.0 (90m right)	22.0
P-81	491550,007	1453083,675	55,940	-14+0.00 (170m right)	18.0

Table No. 1. *Location of perforations y test pits*

TEST PITS / PERF.	*COORDENATES*		*HEIGHT (m)*	*LOCATION*	*DEPTH (m)*
	EAST	**NORTH**			
CC-81	491544,469	1453021,539	56,403	-14+10.0 (174m right)	2.30
CC-84	491600,027	1453031,590	52,220	-14+20.0 (240m right)	4.60
CC-85	491551,195	1453131,582	49,058	-8+10.0 (160m right)	3.50
CC-82	491503,828	1453219,574	50,273	-2+6.00 (82m right)	4.40
CC-83	491456,834	1453324,936	45,956	98+8.00(146m right)	4,25
P-5	491491,140	1453376,628	49,040	10+16.0 (16 m right)	23.0
CC-6	491490,277	1453473,261	54,080	20+6.00 (20m left)	3.90
CC-7	491523,319	1453457,202	46.312	20+0.00 (18m right)	3.20
CC-8	491560,444	1453504,839	46,308	26+0.00 (36m right)	3.40
CC-9	491566,959	1453617,876	49,020	36+8.00 (cent line)	3.10
CC-10	491639,826	1453696,180	39,725	46+6.00 (40m right)	4.10
CC-11	491625,543	1453730,047	43,939	48+16.0(18m right)	3.70
P-11	491623,607	1453760,821	44,50	52+0.00 (cent line)	15.0
CC-12	491675,318	1453768,81	41,117	54+0.00 (50m right)	4.65
CC-13	491624,855	1453793,930	39,853	54+14.0 (6m left)	4.50
CC-14	491669,984	1453818,025	30,377	58+10.0 (26m right)	4.75
CC-15	491693,932	145388,671	17,280	64+10.0 (26m right)	-
CC-16	491727,948	1453863,001	18,560	64+10.0 (cent line)	3.80
CC-17	491675,835	1453907,258	19,897	66+16.0 (cent line)	-
P-18A	491686,193	1453933,346	13,010	70+8.00 (cent line)	9.70
CC-50 / P-21	491749,744	1454202,337	44,769	98+0.00 (32m left)	6.00/19.62
P-18	491684,363	1453967,390	13,210	74+0.00 (12 m left)	15.0
P-19	491696,067	1453977,220	13,340	74+10.0 (4 m left)	7.65
CC-49	491716,791	1454267,004	48,175	96+2.00 (92 m left)	3.20
CC-20	491745,869	1454053,510	12,24	84+0.00 (14m right)	3.80
CC-20A	491783,920	1454100,233	20,142	88+18.0 (30 m right)	3.40
CC-20B	491795,651	1454206,607	54,902	100+0.00 (6 m right)	3.60
P-73	491765,705	1454258,473	53,678	104+0.00 (40 m left)	18.80
CC-74	491861,075	1454189,029	55,544	100+8.00 (73m right)	5.00
CC-75	491842,479	1454212,536	53,497	102+6.00 (48 m right)	4.80
CC-76	491930,312	1454183,538	61,156	102+6.00 (140m right)	4.30
CC-22	491906,406	1454225,949	48,125	104+10.0 (100 m right)	4.90
CC-77	491844,989	1454243,810	47,011	104+12.0 (140 m right)	4.20
CC-22A	491838,367	1454252,951	46,711	106+0.00 (30 m right)	3.40
CC-23	491846,198	1454353,298	30,935	104+14.0 (cent line)	4.25
CC-24	491886,082	1454343,593	25,822	106+0.00 (cent line)	3.35
CC-25	491879,478	1454426,214	19,143	124+10.0 (cent line)	4.20
CC-26	491914,373	1454525,201	12,181	134+0.00 (6 m right)	3.00
CC-27	491952,638	1454513,955	11,031	134+0.00 (45 m right)	2.60
P-28	491953,180	1454656,132	11,963	148+0.00 (4 m left)	6.00
CC-29	491991,350	1454741,050	17,630	156+10.0 (cent line)	3.65
CC-30	492076,860	1454799,487	10,897	164+14.0 (60m right)	2.80
CC-30A	492079,326	1454821,516	12,706	166+10.0 (54 m right)	1.60
CC-37	492091,246	1454942,595	24,485	178+12.0 (22 m right)	2.80
CC-38	492145,715	1455016,337	20,789	188+0.00 (26 m right)	3.40
CC-40	492127,752	1455102,531	14,096	194+14.0 (cent line)	3.75
CC-39	492122,786	1455088,234	13,499	194+0.00 (cent line)	4.00
CC-41	492278,713	1455281,111	8,951	216+16.0 (76 m right)	2.20

Cont. Table No. 1. *Location of perforations y test pits*

TEST PITS / PERF.	COORDENATES		HEIGHT (m)	LOCATION	DEPTH (m)
	EAST	NORTH			
CC-41A	492317,414	1455290,974	7,76	220+0.00 (110m right)	3.00
CC-65/P-65	492384,736	1455781,977	35,18	268+0.00 (cent line)	4.80
P-66	492324,662	1455825,882	40,08	270+0.00 (70 m left)	29.61
CC-67	492307,898	1455858,485	34,60	272+10.0 (50 m left)	3.60
CC-68	492349,982	1455840,476	33,34	272+0.00 (50 m left)	3.00
CC-69	492397,674	1455825,669	26,84	272+10.0 (cent line)	4.80
CC-70	492365,005	1455869,444	24,37	274+14.0 (50 m left)	3.40
CC-61	492357,938	1455726,032	22,71	262+2.00 (cent line)	2.40
CC-62	492305,272	1455774,129	27,82	264+6.00 (70m left)	4.10
CC-63	492320,970	1455730,970	19,38	260+10.0 (40 m left)	3.50
CC-60	492335,124	1455672,311	9,51	256+0.00 (cent line)	3.30
CC-59	492305,868	1455591,131	15,82	248+0.00 (cent line)	4.60
CC-58	492284,760	1455518,347	18,59	240+0.00 (cent line)	4.50
CC-41-B	492249,393	1455424,810	9,66	230+0.00 (cent line)	1.15
P-42	492313,942	1455366,234	8,89	226+10.0 (80 m right)	11.50
CC-71	492341,162	1455412,766	15,88	232+0.00 (90 m right)	3.60
CC-72	492332,963	1455401,847	13,64	230+10.0 (86 m right)	3.30
CC-43	492350,661	1455450,002	16,85	268+0.00 (cent line)	2.80
CC-44	492386,299	1455542,510	8,57	246+0.00 (86 m right)	2.90
CC-44A	492393,462	1455620,903	5,76	262+16.0 (64 m right)	3.20
CC-46	492412,704	1455675,587	6,11	258+10.0 (85 m right)	1.90
CC-80	491828,935	1454161,93	47,840	96+6.00 (52 m right)	3.50
CC-88	491824,604	1454302.514	39,502	110+0.00 (cent line)	4.15
CC-30 B	492036,998	1454863,669	14,249	170+0.00 (cent line)	3.80
P-111	492266,634	1455490,623	18,924	236+16.0	21.60
P-90	492250,566	1455439,237	10,374	234+14.0	24.75
P-35	492016,152	1454812,812	12,890	164+0.00 (cent line)	6.00
P100	492131,379	1455237,608	30,29	PRESTAMO	15.00
P/CC 103	492001,527	1455243,805	49,72	PRESTAMO	14.00
P105/CC105	492091,318	1455217,347	43,10	PRESTAMO	18.00
CC101	492127,914	1455256,456	38,20	PRESTAMO	4.20
CC102	491974,422	1455316,677	48,00	PRESTAMO	3.50
CC109	492149,923	1455259,202	30,00	PRESTAMO	3.20
CC104	492018,837	1455175,111	30,36	PRESTAMO	3.20
CC106	491902,653	1455278,156	56,87	PRESTAMO	5.75
CC107	492089,739	1455185,563	39,75	PRESTAMO	2.80
CC108	492079,408	14551145,658	20,86	PRESTAMO	2.50
CC106-REST	491526,646	1454781,744	39,17	PRESTAMO	5.75
CC108-PREST	491588,080	1454755,239	40,34	PRESTAMO	4.55
CC109-PREST	491695,134	1454771,829	35,86	PRESTAMO	3.20
CC110-PREST	491578,329	1454717,974	29,18	PRESTAMO	3.50
CC90	491714,716	1453753,334	43,02	230+0.00 (cent line)	2.50
CC91	491748,401	1453755,130	40,73	PRESTÁMO	2.50
CC92	491752,414	1453807,571	32,68	PRESTÁMO	2.50
CC93	491773,314	1453835,414	24,35	PRESTÁMO	1.85

Cont. Table No. 1. *Location of perforations y test pits*

4.3- Lithology of the perforations and test pits

The soil indices properties were taken based on the test pits made on the layout, near to the centerline of the runway. With the purpose of constructing the lithologic profile on the center line, the results of each perforation and test pit up to a distance of 25 ms from the center line were correlated.

The average depth of the test pits is 3.50ms and the average depth of the layer of vegetation is 50cms.

The presented lithologic profile specifies the lithology of the definitive variant, constructed based on the results of extracted soil from the perforations and test pits, and is presented in Annex 1. In this profile it is appreciable that the predominant soil classifications are A-2-4, A-2-7 and A-7-6 throughout the layout.

Presented in Annex 2 is the detail of the lithologic columns of some characteristic perforations and test pits, that complemented the definition of the profile, and are of importance, due to their location, for the design of vitally important structures for the project, as is the case of perforation 90 that is found on the banks of the river close to station 230+0.00. In this lithologic column, one can see the variation of disintegratable rock with alluvial and mass of sand from the river bed, observing the heterogeneity of the materials, necessary to be considered in the design of the structure that will be projected in this site.

Perforations 18 and 19 are also presented with their columns and one can see that although they are close, perforation 18 has a predominance of clayey materials and perforation 19 has a predominance of sandy materials. These perforations are bordering station 74+0.00 in a valley area.

In the second round of investigation, nine (9) perforations were done where all the materials displayed a degree of very variable density, generally characterized by a number of blows SPT of around 10 with few cases up to 40 in first 5,00m,. Only in depths greater than 8,00m was rejection encountered (more than 80 blows). The highest values were found to correspond with the ashes of a blackish color below the levels previously mentioned. Generally, underneath the ashes, the formation of basalt and andesites within a clayey matrix was found, in which the SPT tests have generally indicated rejection, nevertheless these pyroclastic flows, are almost always observed to be affected by an intense fracturing of tectonic origin.

4.4- Hydrogeology

4.4.1- On site permeability tests

In order to determine the coefficient of permeability of the soil, three perforations were done; P28, P35 and P111. In these perforations the permeability measurement was done until a depth of 3.00 m, and the values obtained appear in the following table, where the permeability obtained in each site is specified.

PERF.	*COORDENATES*		*Test Intervals*	k_f *(cm/seg)*	*Observations*
	ESTE	NORTE			
P-35	492016,152	1454812,812	0,00 – 3,00 m	$3{,}12 \times 10^{-5}$	*Low permeability*
P-111	492266,634	1455490,623	0,00 – 3,00 m	$3{,}47 \times 10^{-6}$	*Low permeability*
P-28	491953,180	1454656,132	0,00 – 3,00 m	$1{,}16 \times 10^{-5}$	*Low permeability*

Table No. 2. *Measurement of permeability*

As you can see, a low permeability was registered in all three of the perforations, typical of fine sands, soils of the A-2 group. According to, Valle Rodas, 1975, these soils of the A-2 group, which were the soils that were found in the sites of the perforations, are poorly graded mixtures of gravel, sand, lime and clay, which provoke low to medium permeability.

4.4.2- Detection of water levels

During the execution of perforations and test pits water levels were detected, that is presumed to have originated from filtrations of the land, nevertheless, they were localized, and they appear in the following table.

PERF.	COORDENATES		Water Level Depth. (m)
	EAST	NORTH	
CC-30	492076,860	1454799,487	1,40
CC-27	491952,638	1454513,955	2,15
P-90	492250,566	1455439,237	2,00
CC-40	492127,752	1455102,531	3,80
CC-39	492122,786	1455088,234	2,90
CC-60	492335,124	1455672,311	2,50

Table No. 3. *Registered water levels*

In the perforation 18-A, the water table was detected at 6,80m being influenced by the sea level, having registered the highest values between 6.80 – 7,00m. Different measurements were made during different days and the lowest values registered are close 9,10m.

4. 5- Methodology- Laboratory work

With the aim of determining the physical-mechanical characteristics of the subsoil that define its behavior, the laboratory tests were done following standardized norms. The samples that were taken to the laboratory were selected in such a way that the most important levels are those that appear as the results of the group of samples.

The altered samples were chosen directly during the revision of the samples that were in the boxes of each sounding. The unaltered samples were sampled in the layers of clayey type materials. The laboratory tests that were conducted are mentioned next:

- *Visual examination of the samples*
- *Test for the determination of the percentage of humidity (ASTM D2216)*
- *Test of consistency limits (ASTM D4318)*
- *Test of granulometry (ASTM C136)*
- *Test to determine the specific weight with pycnometer (ASTM D854)*
- *Test of modified compaction (Cuban Norm of 2004)*
- *Test of natural Density (Cuban Norm 156:2002)*
- *CBR Test (ASTM D1883)*
- *HRB System of classification (ASTM D3282)*

5- Tests Results

The test pits were divided in groups in order to generate the results in sectors of the work area, therefore test pits and perforations were located on the layout and on the elevations studied as future soil reserves. In a general sense, the study area dispose of a type of soil that is generally a clayey sand of medium-low plasticity, especially when it refers to the ash, nevertheless it is evident that the characteristics of the materials could be modified by the actions of perforation. As for the mechanical characteristics, these are very variable according to the levels shown and, above all, depending on the alteration of the samples, because of the perforation. Due to these considerations, it was decided that the test results are considered as "intervals", rather than "points", and the interpretation of the same results, was done in correlation with the results of the investigations in field (SPT tests).

The test pits that were done on the runway strip are included on the layout, that which generates results of soils that are predominantly of the A-2-4, A-2-7 group type.

Test pits were done in the area of the taxiways, where there was an average layer of vegetation of 50 cms and the soils found there are characterized as being of the A-2-4 and A-7-6 groups. In the case where excavations are necessary in this area, these soils can be used in the first layers of fill. In the second stage of the investigation, additional test pits and two perforations were done, that which registered values of penetration between 15 and 40 up to 5,50m of depth. From this value the penetration resulted to be greater than the rejection.

A small elevation located adjacent to the platform area was investigated, towards the southwest of the same (CC106-PREST, CC108-PREST, CC109-PREST, CC110-PREST, – see location in the table No.1), giving as result soils of the groups A-2-7 and A-7-5, in a study of 2.90 m depth, with an average depth of the vegetation layer of 45cm. These are appropriate materials for the construction of embankments compacted to 98% minimum, of its maximum dry density. However, the minimum degree of compaction can be greater than the CBR obtained according to the project.

Additionally, the natural and loose densities in all the soils were determined, with the objective of knowing the changes of volume that they will experience when being excavated or compacted. The different types of soils experienced the changes of volume that are presented at continuation:

- From natural state to excavated state: 1.567
- From loose state to the state when it is compacted at 0.95 of its maximum dry density the value is: 1.256

In annex 3 appears the graph of the design CBR for the runway, where it is observed that the definitive value is 15%.

5.1- Mt. Coke Elevation

The area located in the stations -12+0.00 to 50+0.00, includes the approach area and head 02, zone of cut. The soils present in this elevation are of the A-2-6 and A-2-7 type, displaying high values of plasticity, LL greater than 25% and plastic index greater than 6. A material characterized to be A-1-B was found, only in the area that faces Stubbs Bay, nevertheless it is advisable to indicate, that of all the perforations that were done in this area (81, 83, 86) rock nuclei with dimensions suitable for testing were obtained, the compression test was done to these rocks and the average values obtained, in the area where the rock was found to be less fractured, are in the order of magnitude of 600kg/cm^3, which means that the superficial soil is limy sand, but the base *rock is more of a basaltic volcanic rock of high resistance. From what has been observed during the perforations, this basaltic rock is found to be embedded in the clayey sand matrix. For the soil profile of this elevation an average CBR of 35.93% was obtained. The samples for the physical and CBR tests correspond to the most weathered part of the elevation; where the bulldozer was able access.*

The material studied from this cut can be used in the fill areas up to sub-grade level, compacted up to 95% of its maxima dry density, with which a CBR greater or equal to 15% can be achieved. The following is a table with the summary of the values obtained from the tests.

VALORES DE PROCTOR Y CBR (ELEVACIÓN MT. COKE)

PROCTOR					VALORES C.B.R.								
					56 GOLPES			25 GOLPES			10 GOLPES		
PERF(P) CALIC.(CC)	Prof(m)	w ópt(%)	γ h	γ d	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)
CC3	0,25-5,00	9,30	2295	2100	10,90	2056	78,00	10,70	1933	31,20	13,80	1770	11,00
CC4	0,30-2,20												
CC4	2,20-5,00	11,30	2243	2015	10,30	1983	48,40	10,30	1862	28,70	9,90	1739	8,20
CC5	0,50-2,70	20,00	2052	1710									
CC5	2,70-4,50	14,10	2123	1861	12,20	1889	92,50	11,90	1732	23,80	12,80	1607	10,40
CC81	0,30-2,50	11,80	2245	2008									
CC84	0,30-4,60	13,10	2153	1904	14,80	1905	23,60	16,40	1853	30,00	15,50	1798	25,40
CC85	0,25-3,50	11,30	2308	2074	11,00	2098	78,70	11,10	2061	64,40	11,40	1931	42,30
CC86	0,40-5,00	10,70	2258	2040	12,00	2051	45,90	11,50	1980	37,50	12,30	1870	42,30
VALORES PROMEDIO		**12,70**	**2210**	**1964**	**11,87**	**1997**	**61,18**	**11,98**	**1904**	**35,93**	**12,62**	**1786**	**23,27**
VALOR MÁXIMO		**20,00**	**2308**	**2100**	**14,80**	**2098**	**92,50**	**16,40**	**2061**	**64,40**	**15,50**	**1931**	**42,30**
VALOR MÍNIMO		**9,30**	**2052**	**1710**	**10,30**	**1889**	**23,60**	**10,30**	**1732**	**23,80**	**9,90**	**1607**	**8,20**

NOTA: LOS VALORES RESALTADOS Y SOMBREADOS SON LOS CONSIDERADOS PARA EL DISEÑO

Table No. 4. *Proctor y CBR Values (Mt. Coke Elevation)*

5.2- Cut Elevation station 98+0.00 to 114+0.00

The soil found in this elevation up to 4 meters of depth, are of the A-2-7 group. It can be excavated with bulldozer. According to perforations No. 21, 73 and 77, from 4 ms, the occasional use of explosives will be required because of the presence of pyroclastic larva such as basalts, andesites, etc, of great resistence, nevertheless the use of this method will be substantiated in the result of the seismic refraction. The material from this excavation is recommended to be used in the filling of the airstrip area un to the sub-grade levels, compacted to 95% of its maximum dry density, since the plasticity exceeds the LL of 25% and PI of 6. The average CBR value of this cut is 16.83%.

VALORES DE PROCTOR Y CBR (ESTACIÓN 98+0,00 - 114+0,00)

		PROCTOR			VALORES C.B.R.								
					56 GOLPES			25 GOLPES			10 GOLPES		
PERF(P) CALIC.(CC)	Prof(m)	w ópt(%)	γ h	γ d	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)
CC20-A	2,10-3,40	34,5	1841	1275									
CC22-A	2,10-3,40	31,5	1841	1400	30,6		6,9	30,4	1237	21,8	30,5	1361	34,8
CC-49	0,30-3,20	25,5	1722	1372	22,4	1255	3,8	22	1291	4,8(*)	22,2	1340	6,7
CC-50	1,10-3,70	22	1881	1542	21,4	1506	51,2	21,6	1352	24,9	21,5	1255	10,5
CC-74	0,20-3,20	32,8	1876	1413	32,9	1163	0,5	32,7	1279	1,6 (*)	32,7	1379	2,8
CC-74	3,20-5,00	35,2	1816	1343	32,7	1379	2,8	32,7	1279	1,6 (*)	32,9	1163	0,5
CC-75	0,40-1,90	32,2	1904	1440	32,2	1427	21	32,2	1331	5,9	32,3	1246	0,3
CC-76	0,45-4,30	27,6	1951	1529	27,6	1249	0,7	27,7	1335	2,2 (*)	27,1	1480	3,2
CC-83	3,50-5,50	30	1885	1450									
CC61	0,40-2,40	29	1939	1503	28,5	1508	65,6	29,4	1393	31,2	29,5	1254	3,3
CC63	0,90-3,50	32	1740	1450									
CC65	1,75-4,80	25,8	1902	1512	26,9	1507	23	26,3	1480	9,5	26,7	1435	5,5
CC68	0,30-3,00	27	1989	1570	26,2	1519	33,2	26,3	1405	15,2	26	1296	0,3
CC69	070-4,10	30,5	1890	1448	31,1	1449	35,3	31	1361	9,3	30,9	1279	2,5
VALORES PROMEDIO		**29,32**	**1872**	**1459,38**	**28,41**	**1396,20**	**22,18**	**28,39**	**1340,27**	**16,83**	**28,39**	**1317,09**	**6,40**
VALOR MÁXIMO		**35,20**	**1989**	**1570,00**	**32,90**	**1519,00**	**65,60**	**32,70**	**1480,00**	**31,20**	**32,90**	**1480,00**	**34,80**
VALOR MÍNIMO		**22,00**	**1722**	**1343,00**	**21,40**	**1163,00**	**0,50**	**21,60**	**1237,00**	**5,90**	**21,50**	**1163,00**	**0,30**

NOTA: LOS VALORES RESALTADOS Y SOMBREADOS SON LOS CONSIDERADOS PARA EL DISEÑO, Y LOS VALORES CON (*) SON DESPRECIADOS.

Table No. 5. *Proctor y CBR Values (Station 98+0,00 – 114+0,00)*

5.3- Elevation to the left of station 200+0.00 (Argyle Hill)

This elevation is located to the left of station 200+0.00, at a distance of approximately 20 meters from the center line towards the left. Three perforations were done in this area, which are 100, 103 and 105. In perforations 103 and 105, the soil have an average depth of 8 meters, covered by a layer of vegetation with 25cms of depth, from this depth (8m) very fractured rock was found.

The soil found in the first 7–8 meters is classified to be from groups A-7-6 to A-2-4, which can be used for the construction of embankments in the first 2 meters, being placed above this other material of better physical – mechanical characteristics and can be excavated with tournapull and bulldozer.

5.4- Elevation station 260+0.00 to 274+0.00

This elevation includes the area at the end of the runway. Soils of the group A-2-4 were found, giving only one soil sample of the A-2-6 group at a depth until 1,70m. The A-2-6 soils are very located according to the investigation done and does not characterize the studied cut area. The A-2-4 material can be used for filling. An average CBR 16.30% was obtained.

The excavations in this area can be done with tournapull (moto scraper) and bulldozer.

VALORES DE PROCTOR Y CBR (ESTACIÓN 260+0,00-274+0,00)

		PROCTOR			VALORES C.B.R.								
					56 GOLPES			25 GOLPES			10 GOLPES		
PERF(P) CALIC.(CC)	Prof(m)	w ópt(%)	γ h	γ d	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)	W (%)	γ d (kg/m3)	C.B.R.(%)
CC-61	0,40-2,40	29	1939	1503	28,5	1508	65,6	29,4	1393	31,2	29,5	1254	3,3
CC-63	0,90-3,50	32	1740	1450									
CC-65	1,75-4,80	25,8	1902	1512	26,9	1507	23	26,3	1480	9,5	26,7	1435	5,5
CC-65	2,80-4,80												
CC-68	0,80-2,60	27	1994	1570	26,2	1519	33,2	26,3	1405	15,2	26	1296	0,3
CC-69	1,70-4,80	30,5	1890	1448	31,1	1449	35,3	31	1361	9,3	30,9	1279	2,5
VALORES PROMEDIO		**28,86**	**1893**	**1496,60**	**28,18**	**1495,75**	**39,28**	**28,25**	**1409,75**	**16,30**	**28,28**	**1316,00**	**2,90**
VALOR MÁXIMO		**32,00**	**1994**	**1570,00**	**31,10**	**1519,00**	**65,60**	**31,00**	**1480,00**	**31,20**	**30,90**	**1435,00**	**5,50**
VALOR MÍNIMO		**25,80**	**1740**	**1448,00**	**26,20**	**1449,00**	**23,00**	**26,30**	**1361,00**	**9,30**	**26,00**	**1254,00**	**0,30**

NOTA: LOS VALORES RESALTADOS Y SOMBREADOS SON LOS CONSIDERADOS PARA EL DISEÑO

Table No. 6. *Proctor y CBR Values (Station 260+0,00 – 274+0,00)*

5.5 Second stage of Investigation

During the second preliminary stage of investigation, a series of perforations were done only in localized sites in order to define with more precision the profile presented in the first stage. The location of the test pits and perforations appears in the following table.

Later, the summary tables of the tests and the classification of soils that were found appear, where one can see that up to the depths of the test pits, on average 3,50-4,00m, the soils vary, being soils A-2-7, A-7-6, A-2-7, A-2-4. However, at greater depths reached with the perforations, depths greater than 5,00m, the soils are more homogenized being in their majority soils types A-2-4 and A-7-5.

CALICATAS Y PERFORACIONES SEGUNDA ETAPA				
TEST PITS / PERF.	***COORDENATES***		***HEIGHT (m)***	***DEPTH (m)***
	ESTE	**NORTE**		
CC2-1	491821,135	1454959,124	27,024	4,00
CC2-2	492074,486	1455020,226	24,324	4,00
CC2-3	491967,241	1454880,083	15,070	4,00
CC2-4	492070,420	1454582,488	7,505	4,00
CC2-5	491994,622	1454602,061	8,247	4,00
CC2-6	491627,405	1454620,591	27,555	4,00
CC2-7	491607,639	1454543,659	35,873	4,00
CC2-8	492031,127	1454649,180	8,951	4,00
CC2-9	491840,956	1454097,764	30,325	4,00
P2-01	491525,998	1453459,537	46,150	10,00
P2-02	491487,004	1453431,011	50,248	9,70
P2-03	491796,561	1454186,053	51,331	14,65
P2-04	492068,402	1454793,687	10,993	9,80
P2-05	491945,946	1454562,606	9,806	10,00
P2-10	491780,185	1453924,886	9,879	8,00
P2-11	491834,609	1453896,840	8,670	6,50
P2-12	492074,486	1455020,226	24,324	9,70

Table No. 7. *Location of perforations y test pits, second stage*

CALICATA	**PLASTICIDAD**		**Gs**	**PROCTOR**		**CBR(%)**	**H.R.B.**
	LL	**IP**	**adim.**	**W(%)**	**((g/cm3)**		
CC2-01	49	14	2,65	35,00	1342,00	12,00	**A-2-7(1)**
CC2-02	46	7	2,39				**A-5(2)**
CC2-03	60	24	2,30				**A-7-5(13)**
CC2-04	54	18	2,61	39,00	1272,00	5,40	**A-7-5(3)**
CC2-05	52	24	2,36				**A-7-6(6)**
CC2-06	NL	NP	2,74	17,00	1590,00	15,00	**A-2-4(0)**
CC2-07	49	16	2,27	30,00	1407,00	21,00	**A-2-7(1)**
CC2-08	53	25	2,37				**A-7-6(5)**
CC2-09	52	19	2,39	30,00	1366,00	15,00	**A-2-7(2)**

Table No. 8. *Summary of test from the test pits*

PERF(P)	Ident.	Prof(m)	PLASTICIDAD		PASANTES			Gs	
			LL	IP	10	40	200	adim.	H.R.B.
P2 01	M-6-8	2,55-4,00	NL	NP	99	72	25	2,70	**A-2-4(0)**
	M-9-10	4,00-5,00	NL	NP	98	71	21	2,75	**A-2-4(0)**
P2 02	M-2-3	0,55-1,50	40	11	96	70	23	2,75	**A-2-6(0)**
	M-4-9	1,55-6,50	76	20	99	85	52	2,49	**A-7-5(9)**
	M-10-12	7,55-9,70	75	19	97	60	36		**A-7-5(2)**
P2 03	M-11	8,0	NL	NP	63	33	17		**A-2-4(0)**
	M-12-18	9,55-14,65	NL	NP	71	37	21	2,53	**A-2-4(0)**
P2 04	M-4,5,6	2,50-3,50	32	11	96	74	27	2,79	**A-2-6(0)**
	M-7	3,50-4,00	37	16	99	77	24		**A-2-6(0)**
	M-8-15	4,00-	53	23	98	86	43	2,68	**A-7-5(3)**
P2 05	M-5-8	2,05-4,00	NL	NP	98	74	24		**A-2-4(0)**
	M-9-10	4,05-5,00	30	9	97	60	7		**A-2-4(0)**
	M-11-15	5,55-9,80	NL	NP	92	62	16		**A-2-4(0)**
P2 10	M-3,4	1,05-2,05	31	10	96	65	17	2,71	**A-2-4(0)**
	M-5-11	2,50-5,50	NL	NP	94	58	13	2,72	**A-2-4(0)**
	M-12-17	5,55-7,93	NL	NP	98	81	17	2,76	**A-2-4(0)**
P2 11	M-3-6	1,05-1,50			98	73	27	2,78	**A-2-4(0)**
	M-7,8	3,05-3,50	NL	NP	92	61	16		**A-2-4(0)**
	M-9-13	4,05-6,50	36	11	96	59	20	2,78	**A-2-6(0)**
P2 12	M-2-3	0,55-1,50			98	73	32	2,77	**A-2-6(0)**
	M-6-10	2,50-5,00	31	10	98	75	18	2,71	**A-2-4(0)**
	M-11-15	5,55-9,70	NL	NP	95	59	14		**A-2-4(0)**

Table No. 9. *Summary of test from the perforations*

Correlating the values obtained in this complement of test pits and perforations with those obtained in the first stage of preliminary investigation, useful parameters to be consider in the designs appear next, based on existing tabulations of typical values. This way, the value of the modulus of elasticity in the soils encountered can be estimated, those which are soils types A-2-4, A-2-6, A-2-7 and some of soils type A-7-5, in general, consistent limy and clayey sand soil.

a. *Correlation between the SPT penetration test and the relative density of limy sands found: The values registered in the penetrations that were done oscillate up to depths of 5,00m with values less than 30 blows, reason why taking propose references by Terzaghi and Peck, one can consider that the A-2-4 soils found throughout the study area have a moderately compact relative density, with an internal angle of friction close to 30°. (see referential tables)*

N	DENSIDAD RELATIVA DE LA ARENA
0 – 4	Muy suelta
4 – 10	Suelta
10 – 30	Medianamente compacta
30 – 50	Densa
> 50	Muy densa

Tabla Nro.10. *Proposed correlation by Terzaghi and Peck (Relative N-Density)*

DENSIDAD RELATIVA	N	ϕ
Muy floja	< 4	< 30
Floja	4 - 10	30 – 35
Compacta	10 - 30	35 – 40
Densa	30 - 50	40 – 45
Muy densa	> 50	> 45

Table No. 11. *Correlation between the SPT penetration test and the angle of internal friction of the sand, proposed by Terzaghi and Peck.*

b. Correlation between the SPT penetration test, the consistency of the clays and the resistance to simple compression: in soils type A-7-5 that were found, the number of blows until depths of 5.00 registered values up to an average of 20 and greater at greater depths, for which reason one can say that the clayey soils of the area have a very compact consistency with resistances close to 200kN/m^2.

N	CONSISTENCIA DE LA ARCILLA	RESISTENCIA A COMPRESIÓN SIMPLE (kN/m^2)
< 2	Muy blanda	< 24
2 – 4	Blanda	24 – 49
4 – 8	Media	49 – 98
8 - 15	Compacta	98 – 196
15 - 30	Muy compacta	196 – 392
> 30	Dura	> 392

Table No. 12. *Correlation between the SPT penetration test, the consistency of the clays and the resistance to simple compression, proposed by Meyerhof.*

c. *In relation to the Poisson module, you have that the soils that were encountered can take on values between 0,25 a 0,30.*

SUELO	υ
Arcilla saturada	0,4 – 0,5
Arcilla no saturada	0,35 – 0,40
Arcilla arenosa	0,2 – 0,3
Limo	0,3 – 0,35
Arena densa	0,2 – 0,4
Arena gruesa	0,15
Arena fina	0,25
Roca	0,1 – 0,4

Table No. 13. *Typical values for Poisson module.*

6- Conclusions and Recommendations

- *In the layout three types of fine clayey soils of the A-7-6 type appear basically, sand gravel mixtures with lime of the A-2-6 group type and soils type A-2-4.*
- *The layer of vegetation have an average depth of 0,50m.*
- *The soils that will serve as foundation are classified as A-2-4 and A-2-7, they are additionally characterized by their good superficial draining, satisfactory result due to the topography of the area.*
- *In the cut sections the product materials of the excavations must be used for the construction of embankments up to the sub-grade levels, compacting it to 95% of its maximum dry density.*
- *The different types of soil found experience changes of volumes from natural to loose a change of 1.567 and from compacted to loose a change of 1.256 at 0.95 of its maximum dry density. In relation to the determination of the natural density, it should always be done so as to compare with the typical values of design, and it is recommended to choose the most critical in order to work with certain factor of safety. For such reason it was calculated and left to the designer to decide which to use.*
- *It is important to mention that an isolated result does not say anything about the soil, only the correlation of all the results with the observation on site is what defines the lithology, for such reason in the profile you find correlated depths depending on the location of the investigations, which define therefore the soil, that which will be considered as the type of soil found, and is that which should be considered as soil of the site.*
- *The filtration water is not represented in the lithologic columns, for that reason it is only mentioned in tables, since this water is influence by the gradient at the time*

of digging the test pit, it is only represented when one is certain of the level of the water table.

- *The soils classified as A-2-6 and A-2-7, can be used to fill the embankments that will be constructed, and not in layers of the sub-base and base of the pavement structure.*
- *According to the technical assignment received the 15/10/06, the value of the CBR support capacity for the sub-base and/or base layer of 50%, has not been achieved by any of the materials from the reserve and cut areas of the layout in the investigation. In the excavations done with bulldozer, the last 30cm of the surface of the sub-grade level will be compacted to its maximum dry density. Where the excavation is done with explosives, the last 50 cm beneath the sub-grade level must be replaced, to ensure that this thickness of material is compacted to its maximum dry density.*
- *To do the excavations until a depth 5,50m, in the runway strip, from station 10+000 to station 272+000, you should use tournapull or motor scrapers.*
- *The compacting of the fillings must be carried out using mixed compactors: vibratory – landfill and vibratory - smooth tires.*
- *A design CBR of 15% is recommended for pavement*
- *The slope recommended for the embankments based on the materials from the site is 1,5:1, since natural embankments have been observed to be totally stable with even negative slopes. It is important to guarantee the terrace in the slopes with heights that they do not surpass 7,5m and berms close to 3,00m.*

- *The use of vaults is recommended to span the Yambou river bed, designed as tri-articulated curved prefabricated structures of reinforced concrete, with its geometry and dimensions defined by the hydraulic engineer. The idea of the vault as a way of spanning the river bed is supposed to change the structural material by structural form, being the work by means of compressions a lot more efficient than the work by means of flexion, due to the fact that it uses all the resistant capacity of the section. These vaults are structures composed of voussoirs equivalent to a half-section of the arc with variable width in function of the dimensions of the element. The base can be supported on a previously built foundation "in situ", each half being sustain in its key against the other, which makes it is independently stable during its assembly, thus not needing of any proppings. This makes it possible for a team of workers to mount between 15 and 20 lineal meters per day, only needing two cranes in the assembly of the first pieces and one in the rest. Geometry should be designed and calculated specifically for the hydraulic conditions present in the site, on the basis of the anti-funicular means of loads.*

- *For the protection of the embankments, the TERRATREL systems are recommended, those which are walls with areas that can be used for vegetation in the slope, using metallic frame works of high adhesion ("Tierra Armada" type) for the reinforcement. These systems tend to protect the soil from the impact of rain drops, reduce the speed of the drainage of the water by increase of rugosity* *and increase the infiltration by holes made by roots, animals, etc. In general, the vegetation must be formed by selected species, susceptible to sustaining itself and to grow in the local conditions, since the same species from the region offer an innate guarantee. Another important function is the control of the water content in the superior layers of the soil, thanks to the evapo-transpiration of the plants. When one talks about the improvement in the appearance that is obtained with the vegetation, one can comment that the effect is not only confined to the appearance, but to many other aspects, like the insulating effect, for the noises, that can be obtained with some types of vegetation, which can have greater interest in urban and residential zones.*

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ANNEX 1.

Longitudinal Lithologic Profile on the center line of the Runway

ANNEX 2.

Lithology of the perforations and test pits

ANNEX 3.

Graphical design CBR.

ANNEX 4.

Results of compression tests of rock nuclei

ANNEX 5.

Summary Table of perforations