Historical Case

Work: Industrial Pavement - Expansion of logistics operator warehouses, reinforced with multi-directional rigid geogrid.
Callao – Lima – Perú.

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Summary

The project was developed in the areas of expansion of the logistics operator Ransa, located on the coast of the port of Callao-Lima-Peru, which has covered an area of 71,829.0 m2. The foundation land is comprised of semi-loose silly sands with groundwater level of 0.60 - 1.00 mts.

An improvement of the sub-grade has been projected due to drainage problems of 0.40 meters of average thickness on the natural terrain, due to the current water table, which is 1.0 meters from the sub-grade projected; the sub-grade improvement system is composed of 0.30 mts rip-rap system and 0.10 mts sub-scratch crown, composed of geosynthetic system (Geotextile nonwoven + geogrid TX-140) multi-directional plus added; complemented by a sub-drain system that will control the maximum elevation height of the water which will be 0.50 meters below the projected sub-grade.

The projected flexible pavement is composed of a conventional hot asphalt mix layer of 0.06 mts plus granular materials (sub-base and granular base) reinforced with multi-directional geogrid (TX-160) in multi-directional geogrid (TX-160) in thickness of 0.54 mts, which has served as an optimization of a traditional flexible pavement with reduction of the granular base layers in the order of 30%.

The geogrid-reinforced pavement system, has been evaluated with load plate tests of 12 inch diameter, at 2 levels; one at the level of the projected sub-grade and one at the level of the reinforced base, the test carried out has aimed to , determine the combined reaction module (k_{76}), the composite CBR and the composite elastic module, at the sub-grade level and the reinforced reinforced granular base, in order to validate the parameters assumed by the structural design of the pavement.

From the results obtained, it has been determined that the use of multi-directional geogrid at the sub-scratch and granular base level, helps in reducing the variability of structural response to induced stresses on soft soils, thus reducing the risks of service failure in the time of use of industrial pavement, also validates the structural behaviour parameters assumed in the design of the projected pavement.

I. INTRODUCTION

In the world, in the area of pavement engineering, the development of the use of geosynthetics is widely used, for the benefits that are obtained with the inclusion of geogrids, geocells, geotextiles, drainage geo-composites in conventional pavement structure, be these flexible pavements, rigid pavements, articulated pavements and mixed pavements.

The benefit that is obtained, is due to the working mechanisms of the interaction of the geosynthetic-soil system, improving the deformation effort behavior of the built pavement; this improvement is reflected in the strength and rigidity of the reinforced layer, measured in resilience module and improving the performance of the resistance to the development of granular layer tying on soft soils, measured in the development of the pavement on the strip of the vehicle axle footprint.

It is also important to note that reinforced pavement systems reduce the high statistical variations (measured with the coefficient of variation C.V) of resistance behavior of the sub-grade and the granular layers that make up the structure flooring designed, whether these measured by in-situ CBR, load plate test, ffometric tests with FWD or HFWD.

TriAX multi-directional geogrids (TX-140 and TX-160) have been used for this industrial flooring project, as well as a type II nonwoven geotextile, granular materials and standard hot asphalt mixtures according to the requirements of the regulations (EG-2013).

Given the poor information of the response of pavement systems reinforced with geosintetics with on-site testing, and in the need for validation of the structural strength of the projected pavement, the conduct of response tests has been considered structural of the layers that make up the pavement in the construction stage, performing the load plate tests at the level of the finished sub-grade and at the level of the finished granular base, to determine the composite reaction module of the granular layers of the pavement and by correlation equations the CBR composed of the tested layers.

In this historical case, the results obtained from the plate tests carried out and the conclusions reached are reported.

II. PROJECT LOCATION

The industrial pavement corresponds to an extension of its areas of operations of the logistics operator of RANSA, which is located at Av. Nestor Gambetta, which is located near the coast line to the beach of Callao District, Callao Constitutional Province – Lima – Peru.

III.- FEATURES OF THE FOUNDATION AND THE PROJECTED SUB-RASANTE

The area of the project zone, presents problems of saturation of the foundation land by high ground level, silty sandy soils with low to medium densities and with high variability of strength resistance.

View of the conditions of the foundation land

The physical-mechanical properties of the laboratory foundation site are as follows:

CALICATA	*PROFUNDIDAD (m)*	*CLASIFICACIÓN SUCS*
C-1	*0.00-0.30*	*SM*
C-2	*0.00-0.30*	*SM*
C-3	*0.00-0.40*	*SM*
C-4	*0.00-0.30*	*SM*
C-5	*0.00-0.30*	*SM*
C-6	*0.00-0.30*	*SM*
C-7	*0.00-0.30*	*SM*
C-8	*0.00-0.30*	*SM*
C-9	*0.00-0.40*	*SM*
C-11	*0.00-0.40*	*SM*
C-12	*0.00-0.40*	*SM*

CALICATA	PROFUNDIDAD (m)	CLASIFICACIÓN SUCS
C-13	0.40-1.40	SP-SM
C-14	0.50-1.00	SP-SM

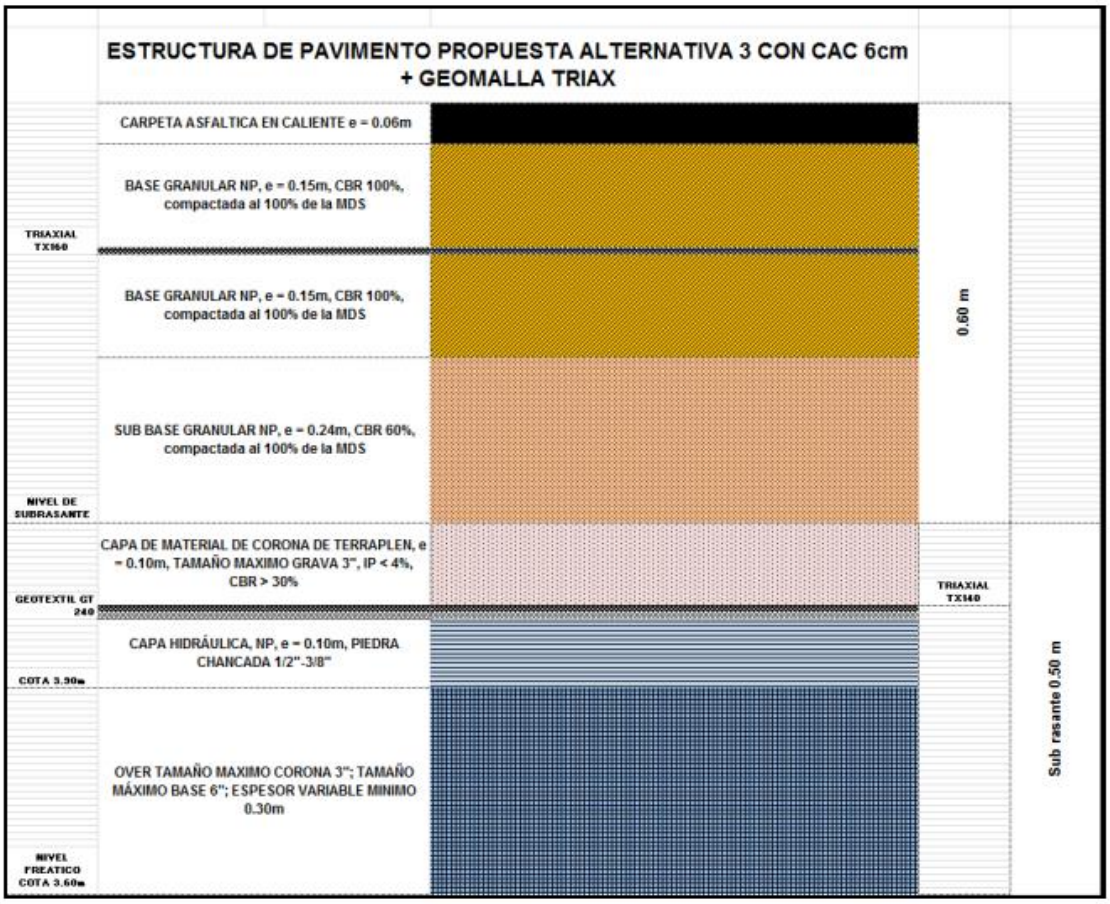
The adopted design CBR of the foundation ground is **13.3% to 95%** of the maximum dry density, taking into account that this is the laboratory density, the resistance of the foundation land in the field is much lower, because it was saturated and with d low on-situ ensities; it is therefore necessary to make an improvement of the foundation land with highly draining material and that breaks the capillary between the natural terrain and the projected pavement.

The projected sub-grade will be on top of the foundation allotment which will consist of a stone in thickness of 0.40 m. + a layer of sub-scratch crown wrapped with non-woven geotextile type I of 0.10 m. reinforced with multidirectional geogrid Triax TX-140. On the surface of the sub-grade, a design resiliency module of **Mr 11,965 psi** is being considered.

IV.- PROPOSED FLEXIBLE PAVIMENT STRUCTURE

The proposed flexible pavement has been designed for a design period of 20 years and with an ESAL equivalent traffic of 4.84 x 10^6

The typical section of the projected flexible pavement is as follows:



The assumed design parameters are as follows:

- Reliability (R) - 90 %
- Standard deviation - 0.45
- Initial PSI = 4.2
- PSI Final = 2.0
- WESAL = 4.84 x 10^6
- The Structural Number of the Pavement Required (SN req) - 3.58
- The Adopted Structural Number (SN adopt)- 3.87


V.- LOAD PLACE TEST RESULTS ANALYSIS

In the execution of the construction work of the proposed pavement with the use of geosynthetics, the validation of the resistances at the sub-grade level and finished granular base proposed in the structural design of the pavement have been carried out.

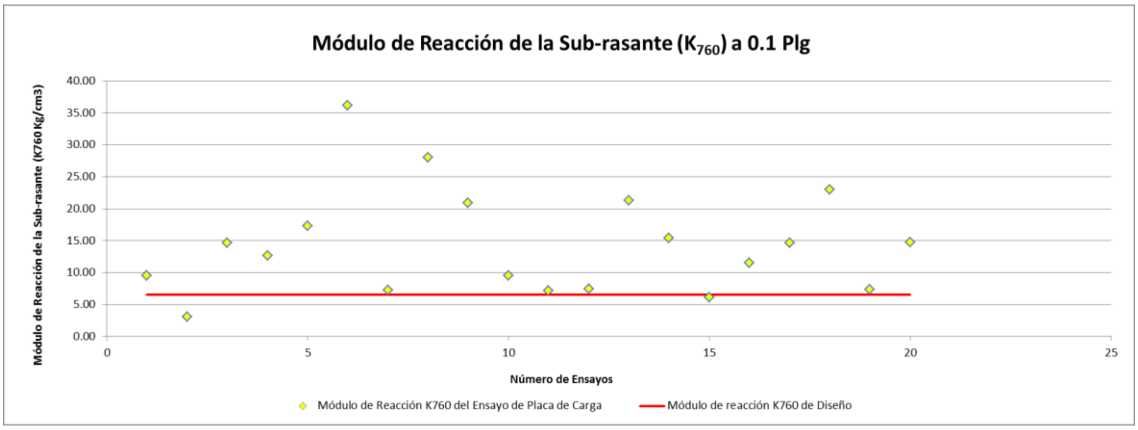
The test performed to determine the stiffness of the pavement is the static load plate test (ASTM D-1194), which has been used to determine the layer reaction module for 0.1 inch and 0.2 inch, the initial elastic module and the equivalent Layer CBR according to the existing correlations (PCA, FAARFIED, NAPTF).

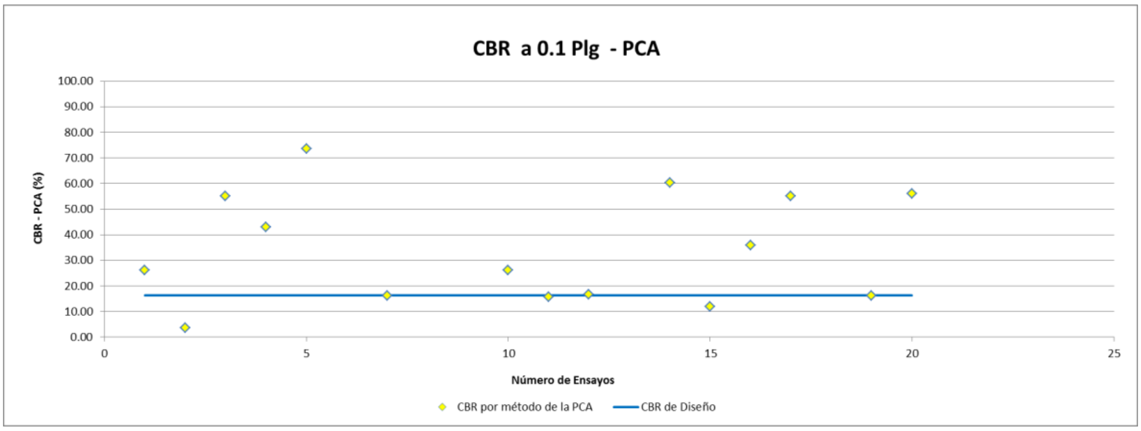

The results of the load plate tests at 0.1 inch. and 0.2 inch. are as follows:

SUB-GRADE LAYER

Analysis at 0.1 Inch of deformation

Test	$K_{30\ cms}$	0.1 plg	$K_{30.5\ cms}$	F.C	$K_{76.2\ cms}$		Radio Placa	µ	Es		CBR		
					Kg/cm2/cm	pci	30 plg	Arena	Kg/cm2	psi	PCA	FAARFIELD	NAPTF
1	5.50	0.25	21.65	0.4417	9.56	345.51	76.20	0.30	1,041.60	14,811.57	26.15	31.50	24.41
2	1.78	0.25	7.01	0.4417	3.10	111.87	76.20	0.30	337.26	4,795.80	3.64	7.40	5.74
3	8.42	0.25	33.15	0.4417	14.64	529.04	76.20	0.30	1,594.88	22,679.15	55.07	54.44	42.19
4	7.30	0.25	28.74	0.4417	12.69	458.66	76.20	0.30	1,382.71	19,662.10	42.91	45.32	35.12
5	9.94	0.25	39.13	0.4417	17.28	624.48	76.20	0.30	1,882.58	26,770.29	73.60	67.36	52.20
6	20.80	0.25	81.89	0.4417	36.17	1,306.88	76.20	0.30	3,939.80	56,024.00	267.72	173.87	134.75
7	4.18	0.25	16.46	0.4417	7.27	262.69	76.20	0.30	791.91	11,260.90	16.19	22.16	17.17
8	16.14	0.25	63.54	0.4417	28.07	1,014.04	76.20	0.30	3,056.97	43,470.08	171.80	125.53	97.28
9	12.00	0.25	47.24	0.4417	20.87	753.90	76.20	0.30	2,272.76	32,318.64	102.31	85.79	66.49
10	5.50	0.25	21.65	0.4417	9.56	345.51	76.20	0.30	1,041.60	14,811.57	26.15	31.50	24.41
11	4.10	0.25	16.14	0.4417	7.13	257.58	76.20	0.30	776.51	11,041.98	15.64	21.60	16.74
12	4.25	0.25	16.73	0.4417	7.39	266.99	76.20	0.30	804.90	11,445.62	16.66	22.62	17.53
13	12.22	0.25	48.11	0.4417	21.25	767.79	76.20	0.30	2,314.62	32,913.84	105.62	87.82	68.06
14	8.88	0.25	34.96	0.4417	15.44	557.93	76.20	0.30	1,681.96	23,917.44	60.44	58.29	45.17
15	3.52	0.25	13.86	0.4417	6.12	221.19	76.20	0.30	666.82	9,482.14	11.99	17.77	13.77
16	6.60	0.25	25.98	0.4417	11.48	414.61	76.20	0.30	1,249.92	17,773.89	35.96	39.81	30.85
17	8.43	0.25	33.19	0.4417	14.66	529.68	76.20	0.30	1,596.80	22,706.52	55.19	54.52	42.26
18	13.20	0.25	51.97	0.4417	22.96	829.39	76.20	0.30	2,500.32	35,554.61	120.88	96.97	75.15
19	4.20	0.25	16.54	0.4417	7.31	263.96	76.20	0.30	795.75	11,315.63	16.33	22.29	17.28
20	8.50	0.25	33.46	0.4417	14.78	533.99	76.20	0.30	1,609.79	22,891.23	55.98	55.09	42.70
				Mínimo	3.10	111.87			337.26	4,795.80	3.64	7.40	5.74
				Máximo	36.17	1,306.88			3,939.80	56,024.00	267.72	173.87	134.75
				Promedio	**14.39**	**519.78**			**1,566.97**	**22,282.35**	**64.01**	**56.08**	**43.46**
				Desvest	8.24	297.72			897.51	12,762.64	64.67	41.31	32.01
				Coeficiente de vaciación	**57.28**	**57.28**			**57.28**	**57.28**	**101.03**	**73.66**	**73.66**
				Nivel de Confianza	**75.00**	**75.00**			**75.00**	**75.00**	**75.00**	**75.00**	**75.00**
				Zcrítico	0.674	0.674			0.674	0.674	0.674	0.674	0.674
				Parámetro de Diseño	**8.83**	**318.98**			**961.61**	**13,674.08**	**20.39**	**28.22**	**21.87**
				Parámetro de Diseño Asumido	6.5	234.85					**16.3**	**16.3**	**16.3**

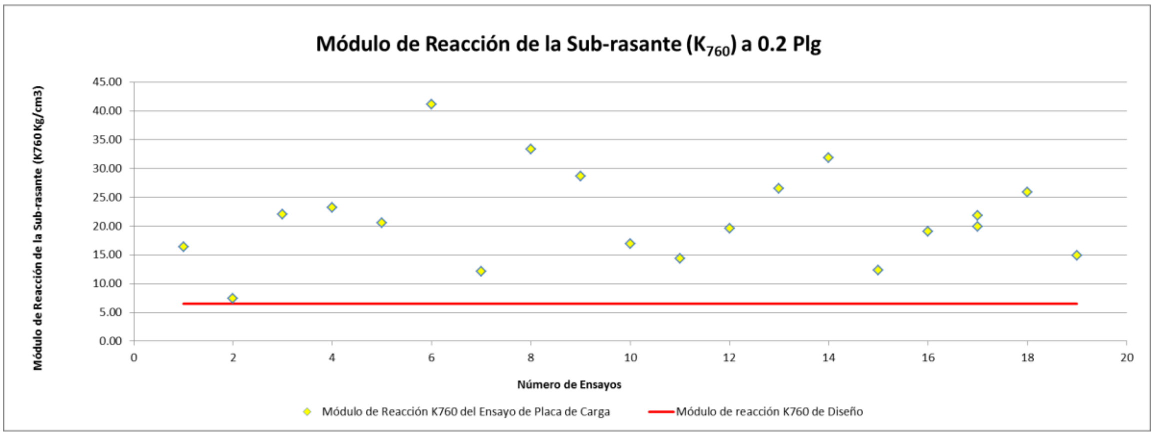


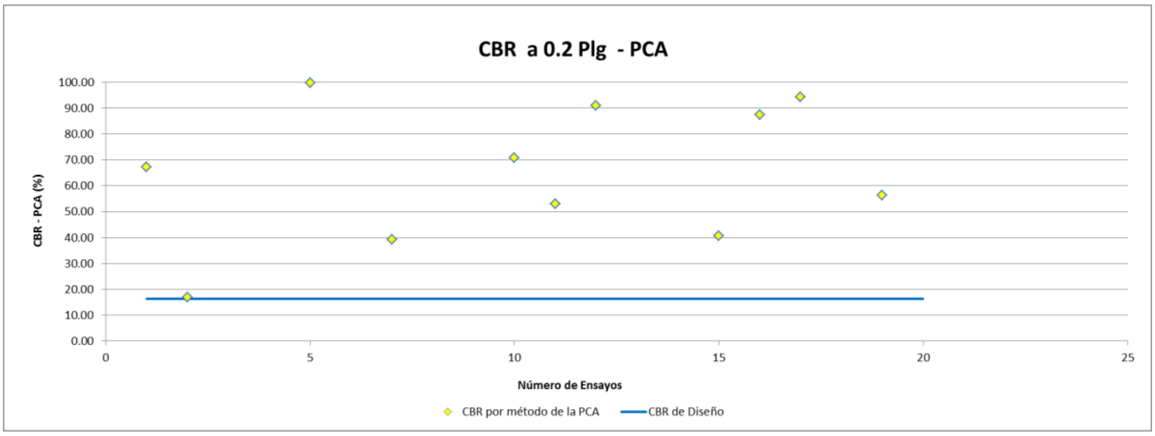


SUB-GRADE LAYER

Analysis at 0.2 Inch Deformation

Test	$K_{30\ cms}$	0.2 plg	$K_{30.5\ cms}$	F.C	$K_{76.2\ cms}$		Radio Placa	μ	Es		CBR		
					Kg/cm2/cm	pci	30 plg	Arena	Kg/cm2	psi	PCA	FAARFIELD	NAPTF
1	18.86	0.51	37.13	0.4417	16.40	592.56	76.20	0.30	1,786.36	25,402.02	67.15	62.97	48.80
2	8.55	0.51	16.83	0.4417	7.43	268.59	76.20	0.30	809.71	11,514.03	16.83	22.80	17.67
3	25.27	0.51	49.74	0.4417	21.97	793.80	76.20	0.30	2,393.04	34,028.99	111.96	91.66	71.04
4	26.72	0.51	52.6	0.4417	23.23	839.44	76.20	0.30	2,530.63	35,985.62	123.46	98.48	76.33
5	23.64	0.51	46.54	0.4417	20.56	742.73	76.20	0.30	2,239.08	31,839.75	99.67	84.16	65.22
6	47.30	0.51	93.11	0.4417	41.13	1,485.94	76.20	0.30	4,479.61	63,700.02	335.11	205.03	158.90
7	13.86	0.51	27.28	0.4417	12.05	435.36	76.20	0.30	1,312.47	18,663.26	39.17	42.39	32.85
8	38.30	0.51	75.39	0.4417	33.30	1,203.15	76.20	0.30	3,627.08	51,577.11	231.67	156.35	121.17
9	32.96	0.51	64.88	0.4417	28.66	1,035.42	76.20	0.30	3,121.44	44,386.82	178.18	128.94	99.93
10	19.44	0.51	38.27	0.4417	16.90	610.75	76.20	0.30	1,841.20	26,181.93	70.79	65.46	50.74
11	16.45	0.51	32.38	0.4417	14.30	516.75	76.20	0.30	1,557.83	22,152.36	52.85	52.82	40.94
12	22.45	0.51	44.19	0.4417	19.52	705.23	76.20	0.30	2,126.02	30,232.02	91.04	78.74	61.03
13	30.54	0.51	60.12	0.4417	26.56	959.46	76.20	0.30	2,892.43	41,130.33	155.95	116.92	90.61
14	36.63	0.51	72.11	0.4417	31.85	1,150.80	76.20	0.30	3,469.28	49,333.14	214.33	147.67	114.44
15	14.14	0.51	27.83	0.4417	12.29	444.14	76.20	0.30	1,338.93	19,039.54	40.56	43.49	33.70
16	21.93	0.51	43.17	0.4417	19.07	688.95	76.20	0.30	2,076.95	29,534.20	87.40	76.42	59.22
17	22.90	0.51	45.08	0.4417	19.91	719.43	76.20	0.30	2,168.84	30,840.91	94.27	80.79	62.61
18	29.80	0.51	58.66	0.4417	25.91	936.16	76.20	0.30	2,822.19	40,131.49	149.39	113.28	87.80
19	17.05	0.51	33.56	0.4417	14.82	535.58	76.20	0.30	1,614.60	22,959.65	56.27	55.31	42.86
17	25.10	0.51	49.41	0.4417	21.82	788.53	76.20	0.30	2,377.16	33,803.22	110.67	90.88	70.43
				Mínimo	7.43	268.59			809.71	11,514.03	16.83	22.80	17.67
				Máximo	41.13	1,485.94			4,479.61	63,700.02	335.11	205.03	158.90
				Promedio	**21.38**	**772.64**			**2,329.24**	**33,121.82**	**116.34**	**90.73**	**70.31**
				Desvest	8.14	294.18			886.86	12,611.13	77.23	44.19	34.25
				Coeficiente de vaciación	**38.07**	**38.07**			**38.07**	**38.07**	**66.39**	**48.71**	**48.71**
				Nivel de Confianza	**75.00**	**75.00**			**75.00**	**75.00**	**75.00**	**75.00**	**75.00**
				Zcrítico	0.674	0.674			0.674	0.674	0.674	0.674	0.674
				Parámetro de Diseño	**15.89**	**574.22**			**1,731.06**	**24,615.74**	**64.24**	**60.92**	**47.21**
				Parámetro de Diseño Asumido	6.5	234.85					**16.3**	**16.3**	**16.3**

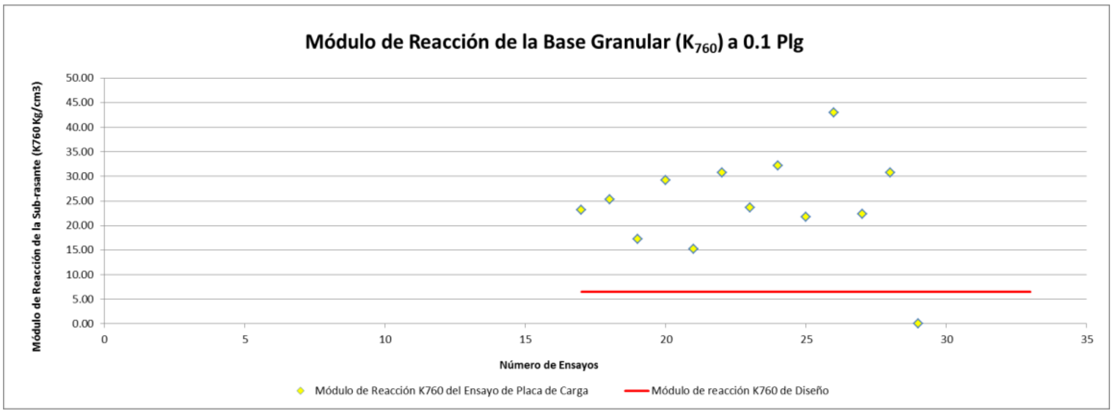


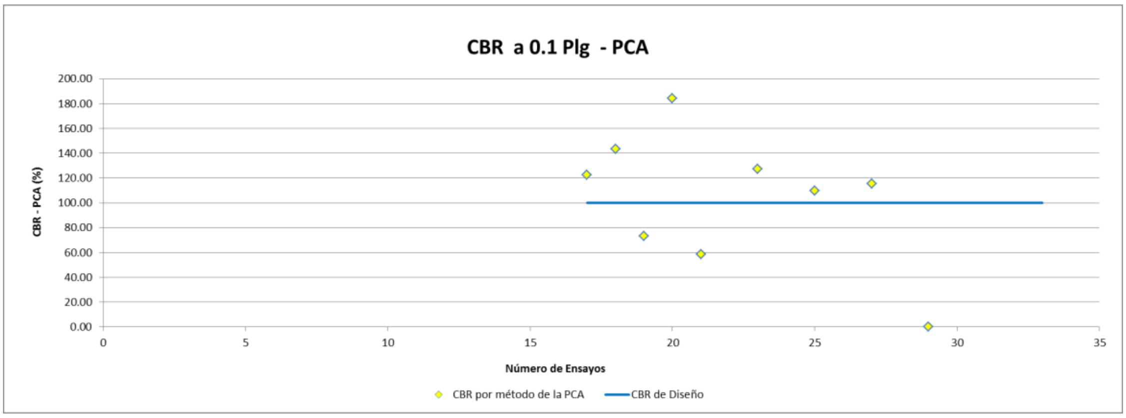


COURSE BASE LAYER

Analysis at 0.1 Inch Deformation

Test	$K_{30\,cms}$	0.1 plg	$K_{30.5\,cms}$	F.C	$K_{76.2\,cms}$		Diametro Placa	µ	Es		CBR		
					Kg/cm2/cm	pci	30 plg	Arena	Kg/cm2	psi	PCA	FAARFIELD	NAPTF
17	13.30	0.25	52.36	0.4417	23.13	835.61	76.20	0.30	2,519.09	35,821.43	122.48	97.91	75.88
18	14.55	0.25	57.28	0.4417	25.30	914.13	76.20	0.30	2,755.79	39,187.38	143.30	109.87	85.15
19	9.90	0.25	38.98	0.4417	17.22	622.08	76.20	0.30	1,875.36	26,667.67	73.11	67.03	51.95
20	16.80	0.25	66.14	0.4417	29.21	1,055.53	76.20	0.30	3,182.06	45,248.84	184.27	132.16	102.42
21	8.72	0.25	34.33	0.4417	15.16	547.87	76.20	0.30	1,651.65	23,486.43	58.55	56.94	44.13
22	17.70	0.25	69.69	0.4417	30.78	1,112.18	76.20	0.30	3,352.85	47,677.52	201.92	141.34	109.54
23	13.60	0.25	53.54	0.4417	23.65	854.45	76.20	0.30	2,575.86	36,628.71	127.34	100.75	78.08
24	18.50	0.25	72.83	0.4417	32.17	1,162.29	76.20	0.30	3,503.92	49,825.72	218.09	149.56	115.91
25	12.50	0.25	49.21	0.4417	21.74	785.34	76.20	0.30	2,367.54	33,666.39	109.88	90.41	70.07
26	24.70	0.25	97.24	0.4417	42.95	1,551.85	76.20	0.30	4,678.31	66,525.51	361.53	216.78	168.00
27	12.84	0.25	50.57	0.4417	22.34	807.05	76.20	0.30	2,432.97	34,596.82	115.25	93.63	72.56
28	17.70	0.25	69.69	0.4417	30.78	1,112.18	76.20	0.30	3,352.85	47,677.52	201.92	141.34	109.54
				Mínimo	15.16	547.87			1,651.65	23,486.43	58.55	56.94	44.13
				Máximo	42.95	1,551.85			4,678.31	66,525.51	361.53	216.78	168.00
				Promedio	**26.20**	**946.71**			**2,854.02**	**40,584.16**	**159.80**	**116.48**	**90.27**
				Desvest	7.52	271.56			818.66	11,641.37	81.58	43.13	33.43
				Coeficiente de vaciación	**28.68**	**28.68**			**28.68**	**28.68**	**51.05**	**37.03**	**37.03**
				Nivel de Confianza	**75.00**	**75.00**			**75.00**	**75.00**	**75.00**	**75.00**	**75.00**
				Zcrítico	0.674	0.674			0.674	0.674	0.674	0.674	0.674
				Parámetro de Diseño	**21.13**	**763.55**			**2,301.84**	**32,732.18**	**104.78**	**87.38**	**67.72**
				Parámetro de Diseño Asumido	6.5	234.85					**100**	**100**	**100**

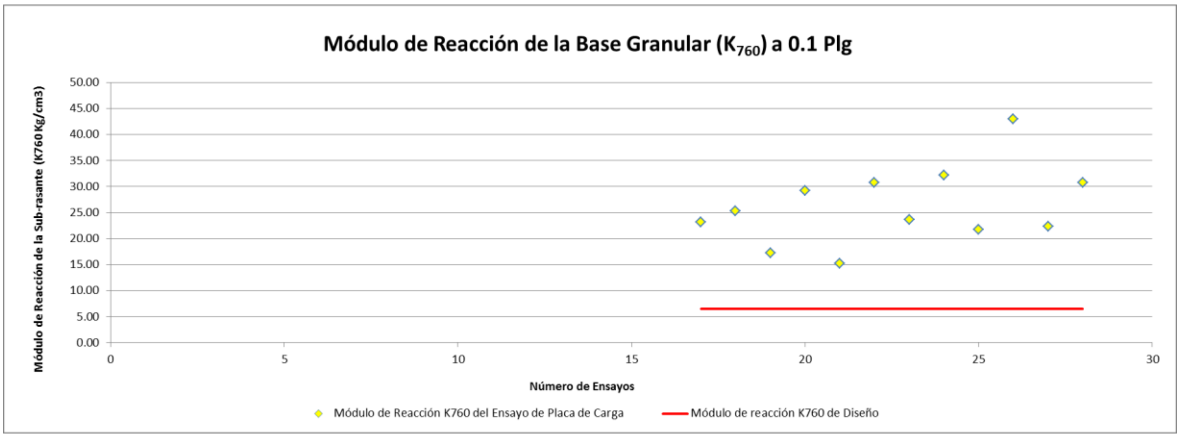


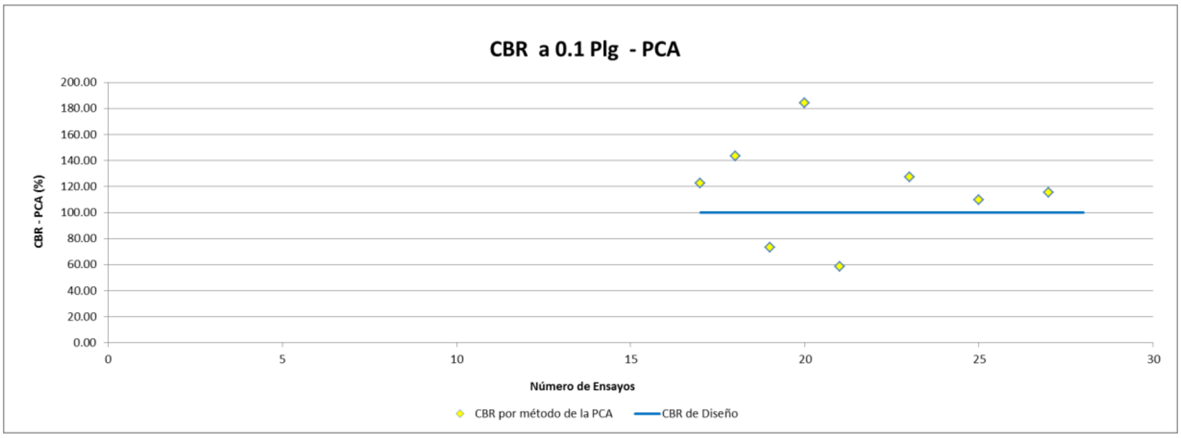


COURSE BASE LAYER

Analysis to 0. 2 Inch Deformation

Test	$K_{30\ cms}$	0.2 plg	$K_{30.5\ cms}$	F.C	$K_{76.2\ cms}$		Radio Placa	μ	Es		CBR		
					Kg/cm2/cm	pci	30 plg	Arena	Kg/cm2	psi	PCA	FAARFIELD	NAPTF
17	33.90	0.51	66.73	0.4417	29.47	1,064.94	76.20	0.30	3,210.44	45,652.48	187.16	133.68	103.60
18	35.20	0.51	69.29	0.4417	30.61	1,105.80	76.20	0.30	3,333.61	47,403.87	199.89	140.30	108.73
19	25.70	0.51	50.59	0.4417	22.35	807.37	76.20	0.30	2,433.93	34,610.50	115.33	93.68	72.60
20	39.40	0.51	77.56	0.4417	34.26	1,237.78	76.20	0.30	3,731.48	53,061.68	243.46	162.15	125.67
21	24.10	0.51	47.44	0.4417	20.95	757.10	76.20	0.30	2,282.38	32,455.47	103.07	86.26	66.85
22	42.60	0.51	83.86	0.4417	37.04	1,338.32	76.20	0.30	4,034.58	57,371.75	279.08	179.25	138.92
23	35.85	0.51	70.57	0.4417	31.17	1,126.23	76.20	0.30	3,395.19	48,279.57	206.39	143.63	111.31
24	40.10	0.51	78.94	0.4417	34.87	1,259.80	76.20	0.30	3,797.88	54,005.79	251.08	165.86	128.55
25	32.14	0.51	63.27	0.4417			76.20	0.30					
26	54.30	0.51	106.89	0.4417	47.21	1,705.86	76.20	0.30	5,142.58	73,127.43	426.57	244.78	189.71
27	36.00	0.51	70.87	0.4417	31.30	1,131.01	76.20	0.30	3,409.62	48,484.81	207.93	144.42	111.92
28	42.65	0.51	83.96	0.4417	37.09	1,339.92	76.20	0.30	4,039.39	57,440.16	279.66	179.53	139.14
				Mínimo	20.95	757.10			2,282.38	32,455.47	103.07	86.26	66.85
				Máximo	47.21	1,705.86			5,142.58	73,127.43	426.57	244.78	189.71
				Promedio	**32.39**	**1,170.38**			**3,528.28**	**50,172.14**	**227.24**	**152.14**	**117.91**
				Desvest	7.20	260.31			784.73	11,158.92	87.81	43.28	33.54
				Coeficiente de vaciación	**22.24**	**22.24**			**22.24**	**22.24**	**38.64**	**28.45**	**28.45**
				Nivel de Confianza	**75.00**	**75.00**			**75.00**	**75.00**	**75.00**	**75.00**	**75.00**
				Zcrítico	0.674	0.674			0.674	0.674	0.674	0.674	0.674
				Parámetro de Diseño	**27.53**	**994.80**			**2,998.98**	**42,645.56**	**168.01**	**122.95**	**95.29**
				Parámetro de Diseño Asumido	6.5	234.85					**100**	**100**	**100**





The following can be determined from the analysis of load plate test results (tables at 0.1 inch. and 0.2 inch.) :

At the projected sub-grade level:

- The equivalent CBR and/or the initial elastic module equivalent at the sub-grade level are greater than the CBR and resiliency module assumed in the design; the greater penetration, the greater the resiliency module.
- The existence of a high variability of the CBR response and/or combined sub-rasante resilience module, given the high variability of the loose and saturated foundation land.
- It has field data of the values that are obtained from an improvement of the sub-scratch with the use of stones and geosynthetics, which can serve as inputs for future designs.

At the projected Granular Base level:

- The equivalent CBR and/or initial elastic module equivalent at the granular base level is greater than the CBR and resilience module assumed in the design; the greater penetration the greater the resilience module, being the factors of improvement of module in ratio of the 30% higher.
- The coefficient of variation of the resiliency modules dropped to an average level.
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VI.- CONCLUSIONS

- The sub-scratch crown improvement system with the proposed use of geostitics, improves the behavior of the pedraplen used, reducing the coefficient of variation of the reaction module of the composite sub-grade.
- The resistance values of the layers that make up the pavement built with the inclusion of geosynthetics, are according to the values assumed at the design stage.
- The equivalent reaction modules and the equivalent initial elastic module are larger than those assumed in the design.
- The structural number of the pavement built, is greater than the structural number of the design pavement of the project.
- The statistical improvement factor for the inclusion of geosynthetics, at the level of granular materials in the pavement is in the order of 20 % to 30 %.
- The Coefficient of Variation of the pavement response at the level of the sub-scratch at the granular base level, decreases as the pavement is built with the use of geogrids.
- From the results obtained, the risks of point failure due to the inclusion of geogrids are reduced.
- The behavior of the pavement by "performance design" tread, increasing the life of the pavement is improved.

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