OBJECT

This document collects generic information on the use of water-soluble organosilane-based nanomaterials (**Terrasil and** Terrasil+) in the field of soil stabilization.

ABOUT OPTIMASOIL

OptimaSoil is a company founded in 2009 and specialized in the development and commercialization of Nanotechnology for different applications, providing added value of service, operation, quality and economy. The company **Zydex Industries** revolutionizes the market of polymers and nanotechnology, since its creation in 1997, its pillar is the development of ecological and sustainable chemicals for the sector of Agriculture, Textile Industry and Construction.

The application of nanotechnology in infrastructures such as roads, unpaved or rural roads, buildings, bridges or airstrips, both large and small scale, means an improvement in their useful life and cost savings, while nanotechnology means a reduction in medium to long term maintenance.

The technology offered by **OptimaSoil** is a fundamental pillar for the main private and public companies that require technological advances that allow constructions with less maintenance, more durable and less initial investment.

OptimaSoil is formed by several companies having its headquarters in Madrid and its delegations in Colombia and Mexico and Brazil, also collaborates and gives technical assistance in other countries such as Peru, Ecuador and Central America.

Additionally, **OptimaSoil** advises Zydex Industries on the development of new solutions and product improvements.

OptimaSoil has participated in congresses worldwide to expose the uses and advantages of nanotechnology, sharing the basic pillars of its applications in the field of sustainable roads, concrete protection, agriculture and waterproofing, applied to both large infrastructure and more specific projects, such as the coating of facades of public facilities, to reduce maintenance costs important to a municipality.

PARTICIPATION IN INTERNATIONAL CONGRESSES AND TECHNOLOGY AWARDS

The commitment to technology makes us be present in the most important congresses worldwide, some of the congresses with participation in recent years are

- Congress, The International Road Federation (IRF) which awarded in 2013 **the prize for the best technology "Nano Technology for Chemically Bonded Asphalt Binders".**
- 8th Mexican Asphalt Congress "Transformation in movement", August 2013
- Marico Innovation Foundation Congress awarded the **prize for the best innovation in 2014**
- Corasfaltos Congress, August 2014, Colombia
- National Asphalt Congress Lima (Peru), November 2014.
- Peruvian Association and National Concrete Congress 2014.
- World Congress of Asphalt 2015, March 2015.
- 9th Mexican Asphalt Congress "Preservation and Sustainability of Asphalt Pavements", August 2015.
- XX Colombian Congress on Pavement Engineering, September 2015.
- Infrastructure Congresses of the Colombian Chamber of Commerce
- Ibero-Latin American Congress (CILA) in Guadalajara (Mexico) 2019

TERRASIL AND TERRASIL +

Description

Terrasil is a waterproofing agent on a nanometric scale, reactive, permanent and soluble in water, which has its application in the field of soil stabilization understood as the improvement of mechanical and hydraulic properties and the maintenance of them against the passage of time and load.

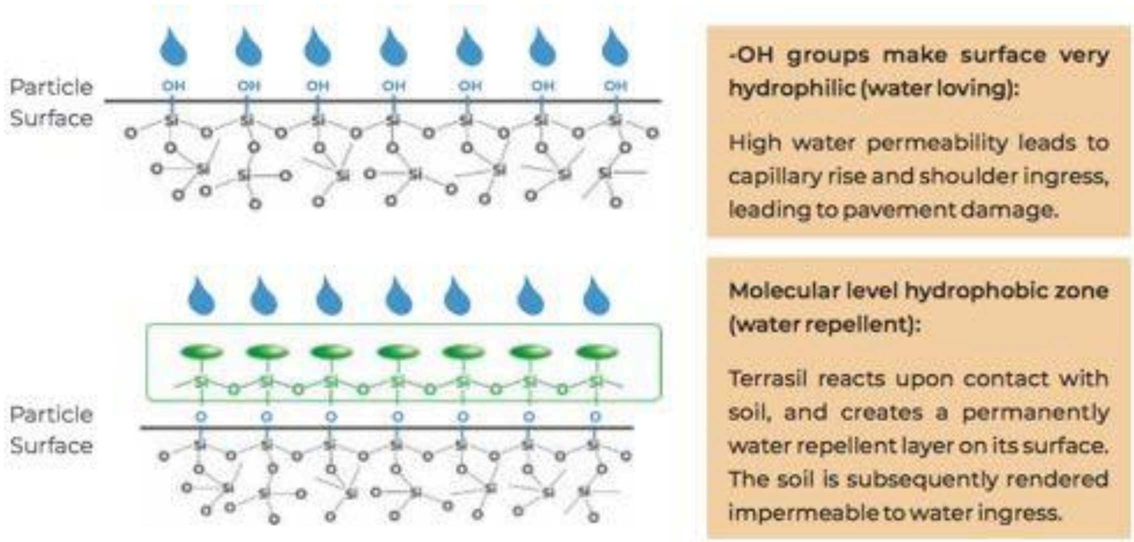
It is a fifth generation organosilane, reactive at room temperature, soluble in water and bitumen and hydrolytically stable. It provides permanent waterproofing to the aggregates, while improving compaction even with lower compaction humidity.

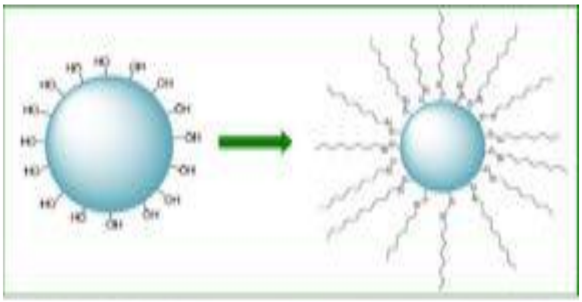
www.optimasoil.com
info@optimasoil.com

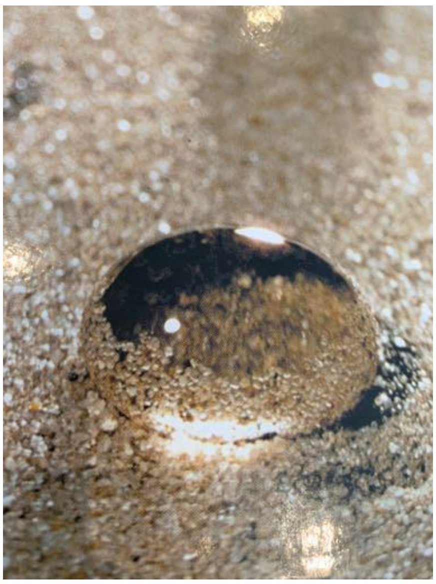
Working principle

Terrasil molecules are diluted in water at room temperature. When water enters Terrasil in contact with the soil, Terrasil molecules are attracted by the polar groups (Silanol Group) of the soil and remain attached until the water evaporates, at which time they form a chemical covalent bond by condensation. This bond (Siloxane) is extremely strong and does not reverse under conditions of humidity, ultraviolet radiation or temperature.

Once the aggregate is covered by hundreds of millions of hydrophobic molecules, the soil will be water repellent, which has a very important effect on the soil characteristics.



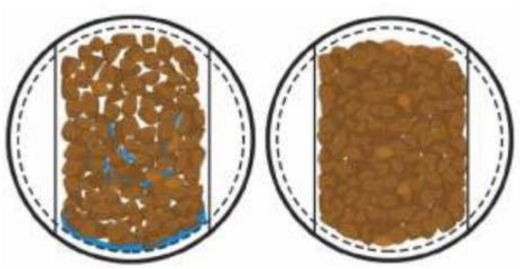




EFFECT ON MAXIMUM DENSITY AND COMPACTION

When Terrasil is added to the compaction water, an extraordinary lubrication of the soil particles is produced, which present less friction between them, improving the redistribution of the particles and the efficiency of the compaction effort.

In habitual conditions to obtain densities between 99-103% of the maximum density obtained in laboratory even in conditions of dampness slightly different from the optimal one from compacting.

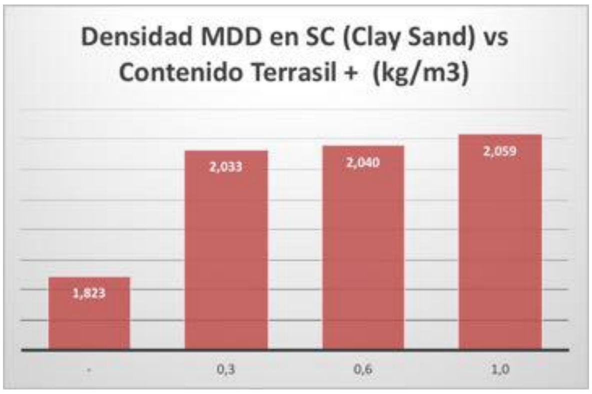


Control Treated

CONTROL DE DENSIDADES - METODO DEL CONO DE ARENA

N° DE CAPAS	UBICACIÓN DE LA PRUEBA	LADO DE ENSAYO	ESPSOR DE LA CAPA	CONTENIDO DE HUMEDAD OPTIMO	CONTENIDO DE HUMEDAD CAMPO	DENSIDAD MAXIMA	DENSIDAD CAMPO	% COMPAC.
Base Estabilizada	2039+120	Izquierdo	0.11	8.5	10.2	2.111	2.09	99.1
Base Estabilizada	2039+140	Derecho	0.10	8.5	10.5	2.111	2.08	98.3
Base Estabilizada	2039+160	Izquierdo	0.115	8.35	9.3	2.116	2.09	99.0
Base Estabilizada	2039+180	Derecho	0.10	8.35	9	2.116	2.12	100.0
Base Estabilizada	2039+210	Izquierdo	0.11	8.35	8.9	2.116	2.12	100.0
Base Estabilizada	2039+240	Derecho	0.11	8.35	9.3	2.116	2.10	99.0

Densities measured in the field, Obrainsa, Northern road section (2013)



Laboratory densities of different soil types with variations in Terrasil + content (0-1 kg/m3). Source: Zydex Industries Laboratory.

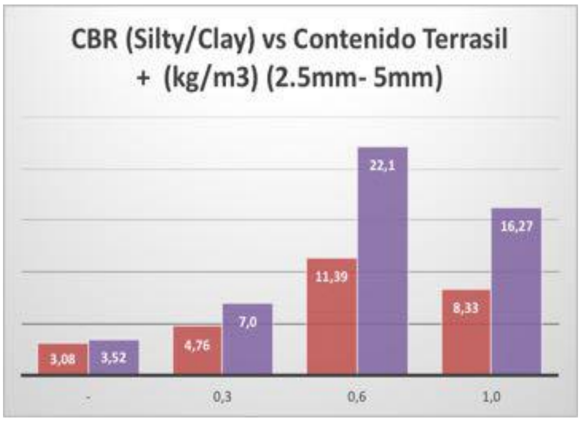
EFFECT ON GROUND BEARING CAPACITY - CBR -UCS- MR

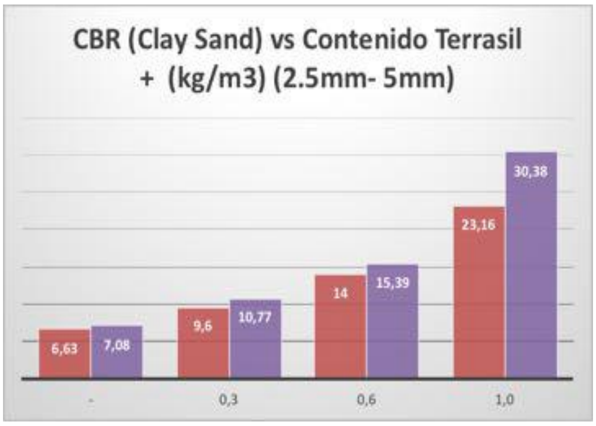
The reorganisation of the particles resulting from the increased initial lubrication, the higher density and the fact that moisture cannot easily spread, produces significant increases in the bearing capacity of the soil, demonstrated in several articles and in multiple tests, regardless of the measurement method used.

CBR (California Bearing Ratio)

Depending on the product dosage and the type of soil, the increases in the support capacity measured by the CBR test increase by between 200% and 400%, with the most extreme soils (CBR<4% and CBR>50%) showing the least gain.

In general, CBR increases with the healing time.





Laboratory densities of different soil types with variations in Terrasil + content (0-1 kg/m3). Source: Zydex Industries Laboratory.

DOSIFICACION DE LAS MUESTRAS CON DIFERENTES COMBINACIONES		NATURAL	TERRASIL 1Kg/m³	TERRASIL 0.5 Kg./m³ + 1% de cemento
PROCTOR	Máxima Densidad Seca	2.102	2.111	2.116
	Optimo Contenido de Humedad	8.78	8.5	8.35
C.B.R.	(100% M.D.S.) **0.1**"(4 días de curado)	52.5%	85.2%	110.2%
	(95% M.D.S.) **0.1**" (4 días de curado)	38.6%	68.3%	83.4%
	(100% M.D.S.) **0.2**" (4 días de curado)	73.2%	150.8%	171.8%
	(95% M.D.S.) **0.2**" (4 días de curado)	56.5%	129.4%	153.6%

Tabla 2. Resultados de CBR de suelos compactado en laboratorio

Muestra	CBR (0.1")	CBR (0.2")
Sin aditivar	5.4	9.9
Aditivada con 1 l/m³ de Terarasil	19.4	28.9
Aditivada con 0.5 l/m³ de Terarasil	63.1	60.8

Examples of CBR measures in projects Peru (Obrainsa) and Colombia (El Condor, report CL-026-14-126-01

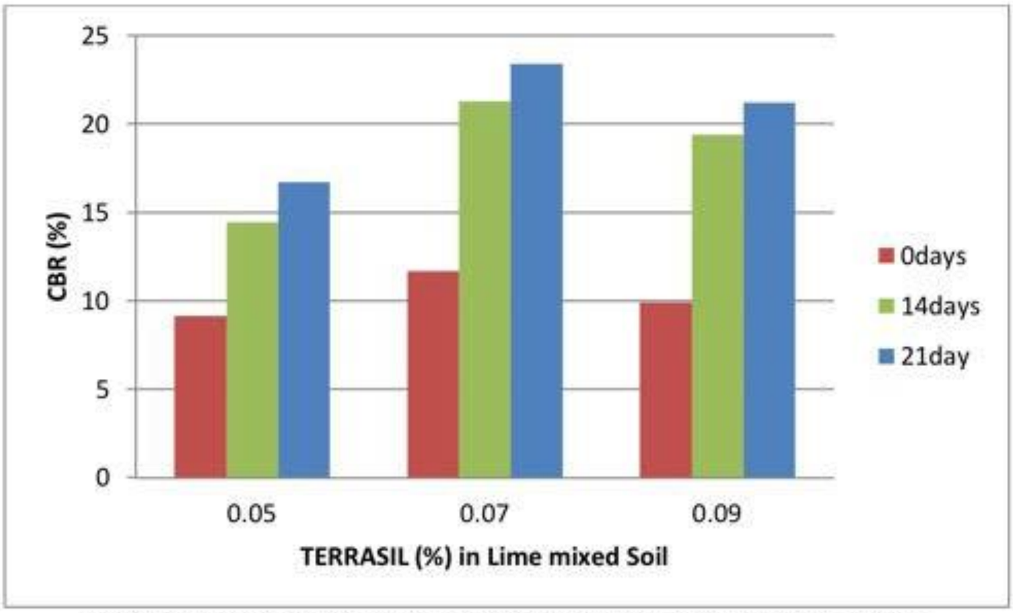


Fig 2: Variation of CBR values with Terrasil (%) at different curing period

Repercusión del tiempo de curado en un suelo tratado con Terrasil y cal (2%). Fuente: International Journal for Research in Applied Science & Engineering Technology (IJRASET) :Effect of Terrasil on Geotechnical Properties of Expansive Soil Mixed With Lime. Ajay Kumar Pandagre Rajesh Jain

Table-5 CBR Test Results (Tr. = Terrasil)

Sample	CBR (%)			
Curing (Days)	7	14	28	60
Untreated Soil	8	10	11	14
Soil+Cement	18	30	32	35
Soil+1% Tr.	25	24	21	25
Soil+1% Tr.+Cement	36	38	45	55
Soil+1.5% Tr.	39	29	35	40
Soil+1.5% Tr.+Cement	48	55	60	78
Soil+2% Tr.	36	29	60	76
Soil+2% Tr.+Cement	46	50	61	76

Effect of cure time on CBR in Terrasi and Terrasil samples with cement. TY - BOOK

Ravi Shankar, A.,B J, Panditharadhya 2017/12/1. Laboratory Investigation of Lateritic Soil treated with Terrasil and Cement

Resilient Module (Mr)

The effect on the resilient module of stabilization with Terrasil is very important and gains are obtained across the entire range of cyclic load confinement pressures even at reduced dosages of Terrasil (0.3-0.5 kg/m3)

Improvements in the resilient module have a significant impact on reducing thickness and improving track durability.

According to AASHTO criteria, any value above 40,000 psi (275 Mpa) for bases and sub-bases must be discarded for thickness reduction.

With Terrasil it is relatively simple to achieve these maximum values in sub-base and granular base.

RESILIENT MODULE IN SUBBASE

In the following case a Mr of 70 Mpa (10,000 psi) becomes about 270 Mpa (39500 psi) with 0.4 kg/m3 of Terrasil

Tabla 6. Resumen de datos Ensayo Triaxial

ENSAYO DE MODULO RESILIENTE PARA BASES Y SUB-BASES GRANULARES (TRIAXIAL DINAMICO)			
TIPO DE MATERIAL: Suelo Granular sin tratar al 100% de próctor			
SERIE No.	MODULO RESILIENTE ---> M_R (MPa)		
	P1	P2	PROMEDIO
1	59,42	75,78	67,60
2	69,12	82,36	75,74
3	75,45	87,26	81,35
4	79,12	87,99	83,55
5	83,97	91,19	87,58
6	55,15	68,77	61,96
7	61,87	73,94	67,91
8	71,33	82,68	77,00
9	79,32	89,59	84,46
10	86,55	96,51	91,53
11	55,05	70,44	62,74
12	63,07	75,12	69,09
13	72,53	83,40	77,97
14	81,28	91,69	86,48
15	88,92	99,21	94,06

Tabla 12. Resumen de datos Ensayo Triaxial

ENSAYO DE MODULO RESILIENTE PARA BASES Y SUB-BASES GRANULARES (TRIAXIAL DINAMICO)			
TIPO DE MATERIAL: Suelo Granular tratado con Terrasil al 100% del próctor			
SERIE No.	MODULO RESILIENTE ---> M_R (MPa)		
	P1	P2	PROMEDIO
1	254,64	264,23	259,44
2	296,84	295,02	295,93
3	309,70	303,90	306,80
4	317,65	313,20	315,43
5	333,90	319,79	326,85
6	242,89	262,66	252,78
7	272,53	281,05	276,79
8	299,71	296,79	298,25
9	320,78	310,25	315,52
10	334,65	321,59	328,12
11	246,79	258,46	252,63
12	277,84	279,72	278,78
13	300,38	295,39	297,88
14	320,23	309,94	315,09
15	340,82	324,47	332,65

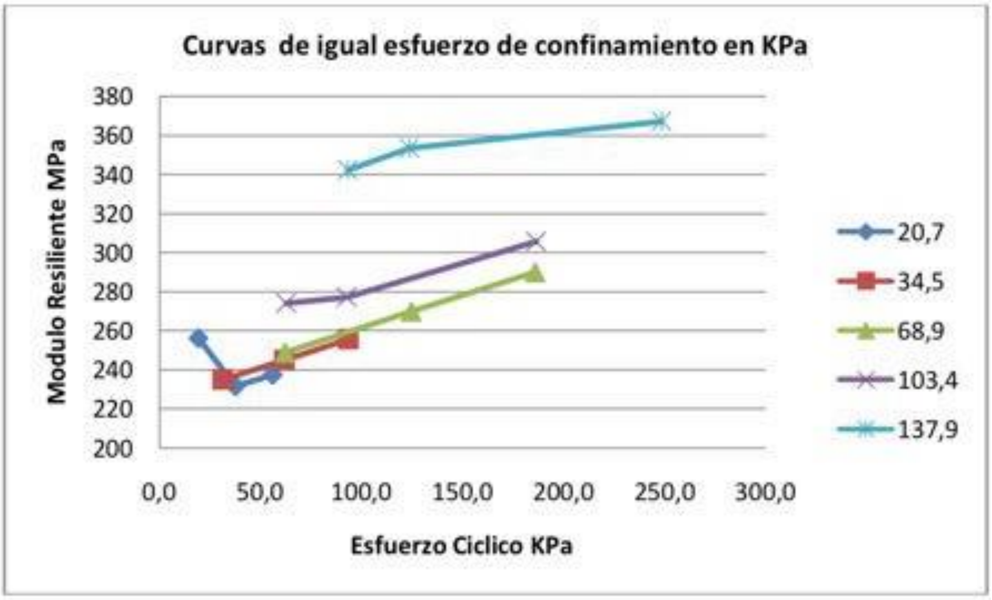
Source: Humberto Quitero: Mr de subbase Granular de Chingaza tests

EFFECT ON THE RESILIENT MODULE ON GRANULAR BASES.

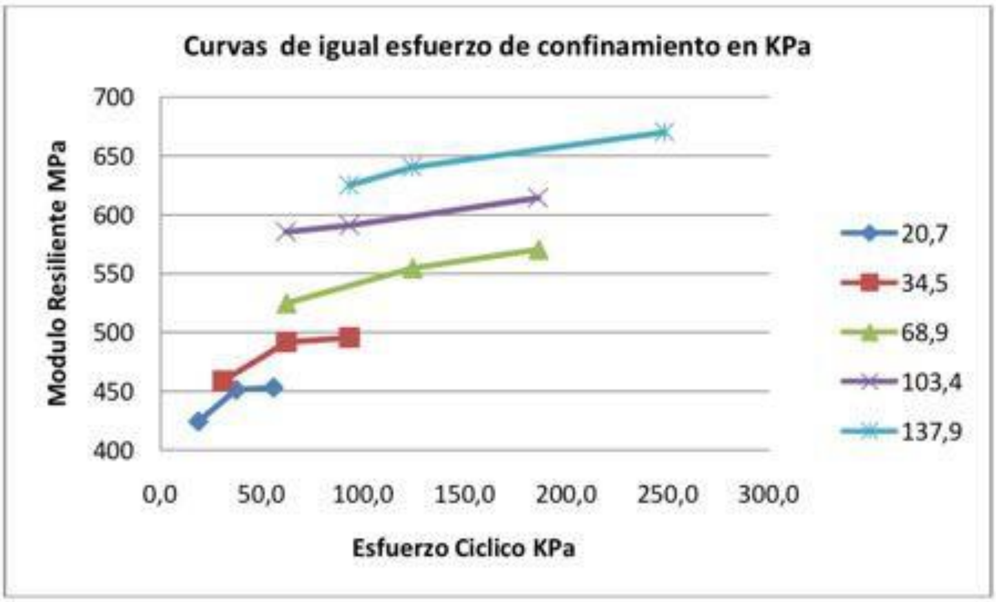
Terrasil significantly improves the resilient module (Mr) of the materials, e.g. granular base material.

It should be noted that although the module increase obtained with Terrasil is greater, the design is limited to Mr of 40,000 psi so it does not reflect the full potential of the solution.

Gráfica 9. Gráfica de datos Ensayo Triaxial **Suelo original (G-187-14-2 y -4)**



Gráfica 11. Gráfica de datos Ensayo Triaxial **Suelo con 0.3 Adit. (G-187-14-2 y -4)**

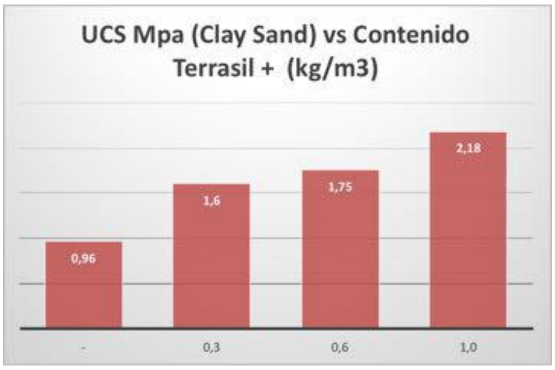


Source: Corasfaltos: Characterization of stabilized bases of Obrainsa

Unconfined Compression (UCS)

Since Terrasil is not a cementitious material, the unconfined compression test, especially in dryer, yields small increments (compared to cementitious stabilizers)

However, increases of at least 30-100% can be expected depending on the cohesive or non-cohesive nature of the material.



Source: Zydex Industries Laboratory

Improvements in unconfined compression values are also dependent on the curing time of the samples and are observed in both Terrasil and the combination of Terrasil with cement or lime.

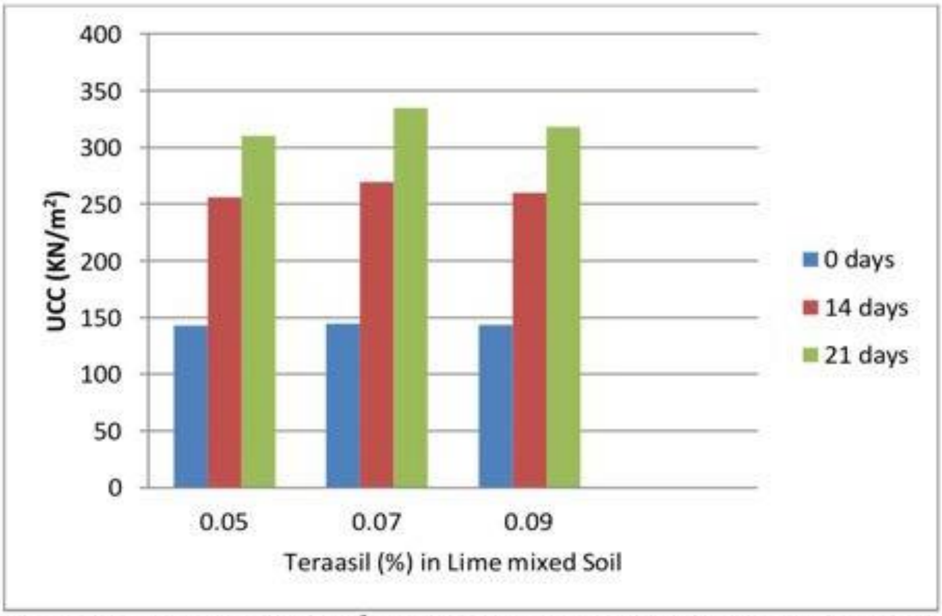


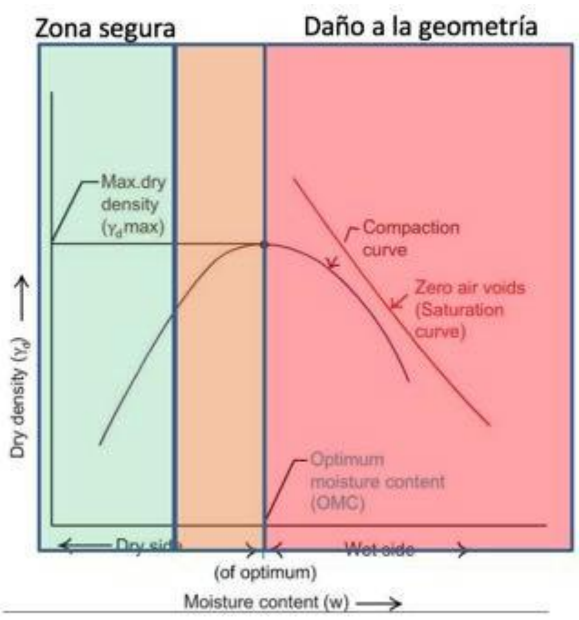
Fig 1: Variation of UCC (KN/m^2) values with Terrasil (%) at different curing period

Fuente: International Journal for Research in Applied Science & Engineering Technology (IJRASET) :Effect of Terrasil on Geotechnical Properties of Expansive Soil Mixed With Lime. *Ajay Kumar Pandagre Rajesh Jain*

EFFECT ON PERMEABILITY.

With low dosages of Terrasil, the matric suction of the soil and the permeability at saturation is reduced, so the soil will remain below the saturation humidity (unsaturated condition) throughout the life of the track.

In an unsaturated condition, the soil behaves elastically, without suffering permanent deformation and, if the maximum acceptable load (designed from the Resilient modulus) is adequate, the treated soil layer will not be fatigued



Detail of area waterproofed with Terrasil

Source: Zydex Industries(USA)

Source: Optimasoil, presentation to Invias

In addition, absorption by capillary action and free swelling is reduced or eliminated. Provided that the floors have a free swelling of less than 20%, non-inflation can be achieved.

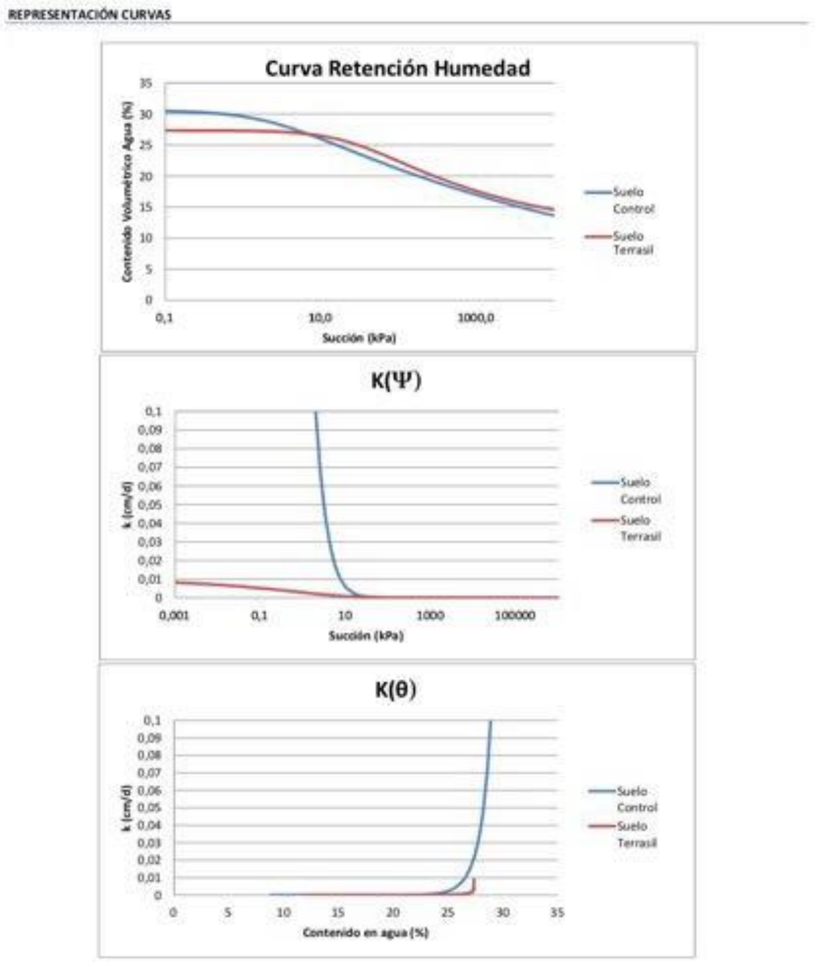
Source: Optimasoil, 8 hour capillary validation field test

Table 3. Permeability tests on local and treated soils

Soil type	Local soil	Soil treated with zycobond	Soil treated with Terrasil
Coefficient of permeability, k (cm/s)	9.77×10^{-7}	1.26×10^{-6}	Impermeable

PADMAVATHI, V., NIRMALA PETER, E. C., RAO, P. N., & PADMAVATHI, M. (2018). STABILIZATION OF SOIL USING TERRASIL, ZYCOBOND AND CEMENT AS ADMIXTURES. LATEST THOUGHTS ON GROUND IMPROVEMENT TECHNIQUES, 163-170.

In addition to the lower absolute permeability, the permeability values in all moisture ranges are practically zero until the saturation moisture is reached. Even in this case, the coefficient of permeability is very low and equivalent to 0.01 cm / day.



Variation in hydraulic properties (suction, permeability) . Source Lab Ferrer

EFFECT ON OTHER TRIALS

In addition to the tests mentioned above, we have extensive and varied information on the effect of Terrasil on soils evaluated under other methods that seek to solve specific problems of a route and that are briefly mentioned here:

Soil-cement durability test:

The durability test involves subjecting the samples to 12 wet-dry-abrasion cycles with a maximum loss of 2% of mass.

Soils treated with Terrasil and cement exceed 12 cycles while soils treated with Terrasil or cement alone cannot pass the test.

An untreated floor would not exceed the first cycle and a floor with cement would only exceed 4 cycles.

Table 4: Wetting and Drying test results for stabilized soil

Sample	No. of Cycle pass	Weight loss
Untreated Soil	Fail	-
Soil + 3% cement	4	-
Soil+3% Cement+0.75 kg/m³ (T) + 0.75 kg/m³ (Z)	12	<2%
Soil+ 0.75 kg/m³ (T) + 0.75kg/m³ (Z)	2	-

From the Table 4 it is found that stabilization of soil with 3% cement, Terrasil & Zycobond passes the criteria in wetting and drying cycle test where the loss of weight is less than 2%.

Source: PERFORMANCE OF NANO-MATERIALS STABILIZED SOIL FOR CONSTRUCTION OF PMGSY ROADS. Khusboo Arora1 & Dr. Pramod Kumar Jain2

Indirect traction

It is a test that is performed on cohesive materials or in the presence of cement.

In general, as Terrasil is not a cementing agent, it should not increase the indirect traction value. However, this effect has been observed in soils with Terrasil as well as in soils with Terrasil and cement and in soils with Terrasil and asphalt emulsion in low doses

Laboratory Investigation of Lateritic Soil treated with Terrasil and Cement

Table-6 IDT Test Results

Sample	IDT Strength (kPa)			
Curing (Days)	7	14	28	60
Untreated Soil	17	28	41	55
Soil+Cement	52	94	132	160
Soil+1% Tr.	69	85	67	75
Soil+1% Tr.+Cement	207	296	208	250
Soil+1.5% Tr.	63	86	88	101
Soil+1.5% Tr.+Cement	252	275	308	364
Soil+2% Tr.	41	61	75	77
Soil+2% Tr.+Cement	265	291	331	386

Ravi Shankar, A.,B J, Panditharadhya 2017/12/1. Laboratory Investigation of Lateritic Soil treated with Terrasil and Cement

In addition to the increase in indirect traction, a higher TSR (ratio of dry to wet traction) is observed

Stabilising Agent	SS60 anionic nano-modified emulsion (NME) with organo-silane and nano-polymer additives				Standard SS60 anionic emulsion without any additives			
% of stabilising agent added	0.7% per mass				0.7% per mass			
% of cement content	None				None			
Optimum Moisture Content (OMC) %	6.0				6.0			
Sample Diameter (mm)	150mm Φ Sample				150mm Φ Sample			
Test Performed	UCS (Dry)	UCS (Wet)	ITS (Dry)	ITS (Wet)	UCS (Dry)	UCS (Wet)	ITS (Dry)	ITS (Wet)
Test and curing Protocol	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b	Jordaan et al., 2017b
Test 1 (kPa)	2316	1901	192	197	2197	592	158	35
Test 2 (kPa)	2662	1913	173	161	2169	593	140	33
Test 3 (kPa)	2311	1955	172	114	2288	488	137	41
Average (kPa)	**2430**	**1923**	**179**	**158**	**2218**	**558**	**145**	**36**

Source: LABORATORY EVALUATION OF ROAD CONSTRUCTION MATERIALS ENHANCED WITH NANO-MODIFIED EMULSIONS (NMEs) I Akhalwaya and FC Rust

Stability and Flow Marshall.

A soil with good grading combined with cement (1%-3%), Zycobond and Terrasil will have a higher bearing capacity than an asphalt mix while maintaining its flexibility characteristics and excellent resistance to humidity.

These "Super Soil" layers can be used as a replacement for asphalt base layers and provide excellent road structure.

In these cases, we suggest testing Marshall's stability in water immersion at 60ºC and checking its durability over time.

Marshall Stability					
Sr no.	GSM(70:30) GSB: Soil (4-6) % CBR	Stability @ 60ºC (KN) & Flow Value (mm)			
		24 Hrs.	3 Days	7 Days	15 Days
1	GSM+ 1.6 kg/m3 TS + 2.0 Kg/m3 ZB + 3% Cement	34.3 KN - 1.08 mm	30.7 KN - 2.59 mm	28.3 KN - 2.85 mm	28.0 KN -2.9 mm

Source: Zydex Industries Soil Laboratory. Gujarat

In addition, fatigue tests such as the three-point beam bending fatigue test can be performed to ensure durability over time.

Flexural Fatigue Beam Test

Beam fatigue properties are important because one of the principal modes of failure is fatigue related cracking. Usually failure is defined as 50% loss in initial beam stiffness but after 2,560,000 cycles stiffness is still 80% of the initial stiffness which indicates that development of crack during fatigue is effectively resisted by the stabilized soil with nano- materials along with cement. This is because the nanotechnology based stabilizers works well with the combination of cement and makes the soil stiff, by forming highly stable water repellent alkyl siloxane bonds which improves the strength of the soil sub-grade. Therefore, the result shows that stabilized gravel road alone is sufficient considering the traffic loads in rural areas.

Table 5: Result of Beam Fatigue Test

Sample	Initial Stiffness	Stiffness Reached	No. of cycles
Soil+3% Cement+0.75 kg/m³ (T) + 0.75 kg/m³ (Z)	442	360	2,560,000

Source: PERFORMANCE OF NANO-MATERIALS STABILIZED SOIL FOR CONSTRUCTION OF PMGSY ROADS Khusboo Arora1 & Dr. Pramod Kumar Jain2

COMBINATION WITH OTHER PRODUCTS

Terrasil can be applied alone in combination with other products such as Lime, Cement or Polymers (provided they are cationic)

Cal

The combination of Terrasil with lime at low dosages produces excellent improvements in waterproofing and bearing capacity. In general, the addition of lime is recommended when the soil is very expansive or the bearing capacity is too low (< CBR 4) although often a combination of lime and Terrasil is more economical than a higher dosage of Terrasil.

Cement

The combination of Terrasil and cement provides tensile strength and increased bearing capacity while protecting the cement from attack by moisture, carbonation, and etringite formation. The use of Terrasil is highly recommended in soils with sulphates that are going to be stabilized with cement.

Polymers (Zycobond)

The use of reactive polymers such as Zycobond further improves waterproofing and provides a more elastic interface between cement and aggregate particles, providing greater durability from reduced rigidity.

APPLICATION MODES

Terrasil is a liquid product that is supplied in different types of packaging, the most widely used being the 20-litre container.

Terrasil dissolves in water (with the recommendation that the water has a maximum solid residue of 1000 ppm) forming a transparent solution with a viscosity identical to that of water itself, so it can be watered or dosed by spraying with any equipment that can pump water or even by gravity (irrigation tanks, personal application equipment, hoses, soil stabilization equipment etc...)

There are several ways to apply the product depending on the benefit you want to obtain.

Waterproofing irrigation:

This technique consists of applying a solution of 1 part Terrasil in 300 parts of water and watering until a compacted soil is saturated.

When evaporation curing occurs, the treated soil will behave as a waterproof (but breathable) membrane that will prevent water permeability either by gravity or by capillarity, becoming an excellent protection of the infrastructure.

This solution can also be applied on asphalt roads whose ageing causes cracks and damage to the base layer due to moisture.

Sealing irrigation on compacted track. San Pedro de Urabá (Colombia)

Sealing irrigation on asphalt mix. India

Display of waterproofing effect. Spain and Peru

Wet stabilization.

To improve the structural capacities of the soil, according to the parameters mentioned above, the Terrasil product is applied like any other wet stabilization, adding Terrasil to the water used for compaction.

The process can be carried out with a specific stabilizing equipment or with a motor grader.

Afterwards, mixing and compacting are carried out.

DOSAGE

The dosing process will be as follows:

1. Calculate the content of Terrasil to be contributed to the soil (kg/m3): Ct (Terrasil content per m3)

   This parameter is usually 0.3kg/m3 to 2 kg/m3

   Example: Ct= 0.4kg/m3

2. Calculate the water to be supplied to the soil at all times (difference between the optimum moisture content for compaction (OMC) and the moisture content in-situ.

   Ha= Moisture content (per m3)

   Example: Optimum moisture content =14

   Moisture in-situ = 8% Moisture

   to be supplied =6% (HA%)

   Density = 2000 g/cm3 =d

   *Ha= HA% * d = 120 litres*

3. Calculate the dissolution ratio of Terrasil in the compaction water:

   Ratio = Ha/Ct = 120/0.4 = 300

   This means that 1 litre of Terrasil is added to the tank for every 300 litres of water. This ratio is usually between 1:50 and 1:600

EXAMPLE OF CONSTRUCTION PROCESS ON EXISTING SOIL

Scarification of existing soil by 15 cm.

*Escarificación de 15 cm del existing material.

Addition of dry stabilizers (lime or cement)

If necessary, spread the calculated amount of dry lime or cement.

Filling of the irrigation tank with water and contribution of the stabilizer in the calculated dosage.

Watering of the solution of Water and Terrasil on the material.

*Terrasil+ watering on previously scarified material

Mixing of the material to be stabilized

Levelling and profiling, pumping and natural gutters

Compaction until the project density is reached.

DESIGN METHODOLOGIES AND TEST DATA BANK

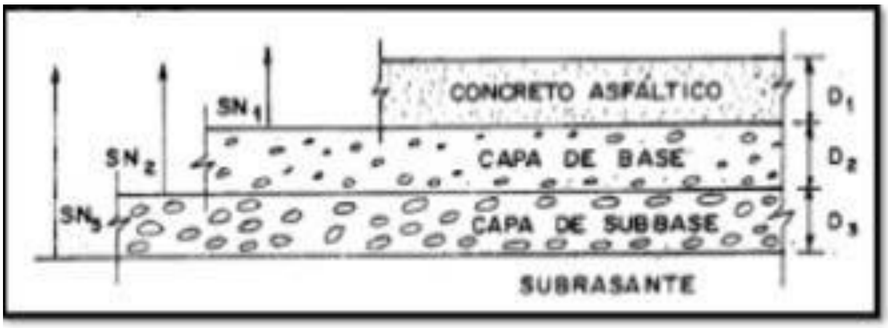
Optimasoil has the test reports referenced in the document and many more that are not mentioned, in order to keep the document short.

Optimasoil always suggests the realization of the relevant trials for the specific project to evaluate the impact of Terrasil at different dosages and suggest the best option for the specific design.

We suggest making alternative designs with Terrasil to check that there are reductions in cost and improved durability for the specific case of the project (local costs, design criteria and specific limitations)

EXAMPLE AASHTO DESIGN

In the case of the AASHTO design methodology, the structural coefficients of the layer (derived from the increase in the resilient module) and the drainage coefficient (drainability coefficient) are mainly affected, which has a significant impact on the resulting structural number and, therefore, on durability.



$$SN = a_1 \cdot D_1 + a_2 \cdot D_2 \cdot m_2 + a_3 \cdot D_3 \cdot m_3$$

a1, a2, a3 = coeficientes estructurales de las capas: superficial, base y subbase, respectivamente

d1, d2, d3 = espesores (en centímetros) de las capas: superficial, base y subbase, respectivamente

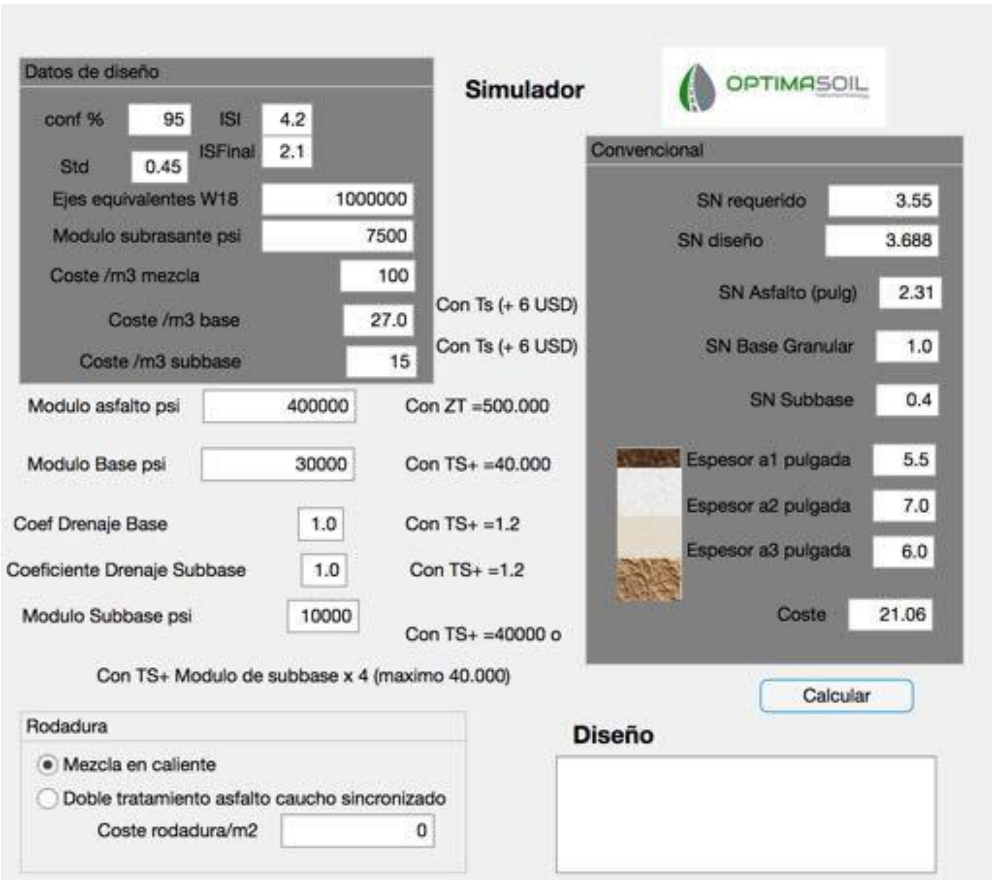
m2, m3 = coeficientes de drenaje para las capas de base y subbase

Por example, para a vía rural, designed to support 1 million ESALs in the design period, there are savings important when using the improved and waterproofed floors

Conventional design:

The conventional design with hot mix asphalt obtains a structural number of 3,688 at a cost of 21.06 USD/m3

Parámetro	Value
Number of equivalent axes	1.000.000
Difference in service level	2.1 (4.2-2.1)
Std. confidence/deviation	95%-0.45
subgradeVariación estacional del value	No
Subgrade resilient module	7500 psi



Conventional design AASHTO. Optimasoil® Fountain

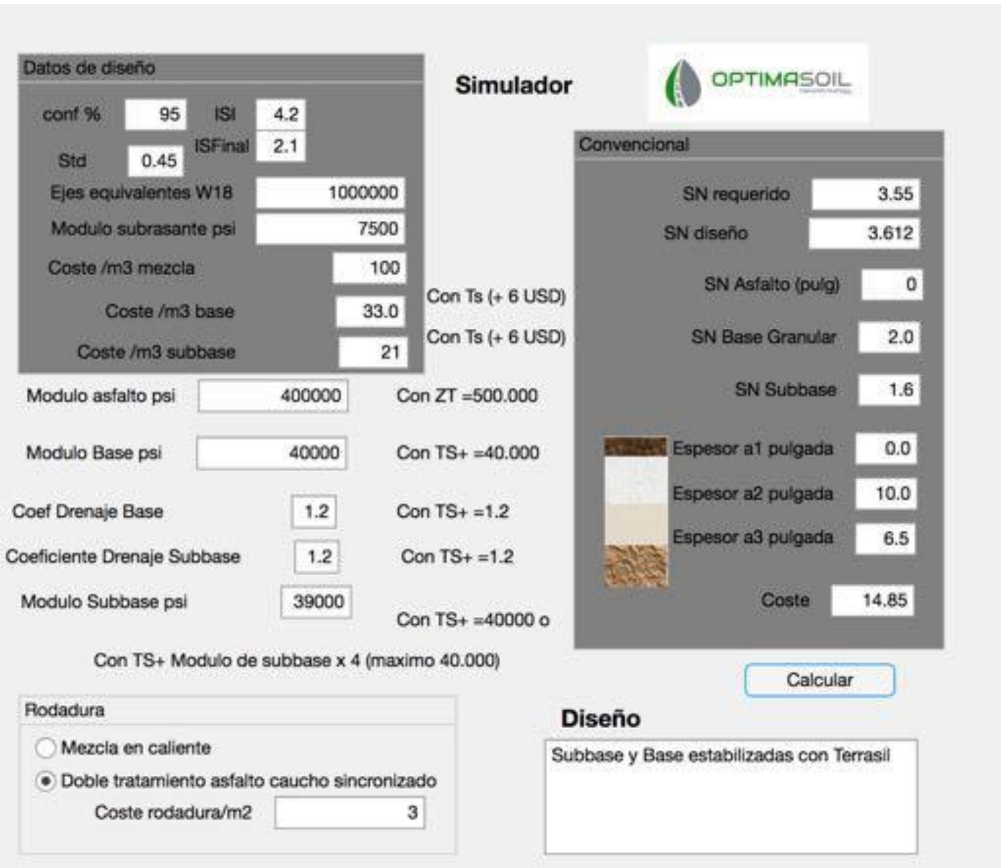
Conventional design, with cold tread and soil stabilized with Terrasil

The waterproofing allows to increase the drainage coefficient from 1 to 1.2 (conservative) and to increase the subbase and base modules up to the maximum allowed by the standard (275Mpa) (reference: Chingaza Granular Subbase Test and Obrainsa Granular Base Characterization)

The new design allows for cost savings while maintaining durability.

Capacidad de Drenaje	% de tiempo en el que el pavimento está expuesto a niveles de humedad próximos a la saturación.			
	Menos del 1 %	1 a 5 %	5 a 25 %	Más del 25 %
Excelente	1,40 – 1,35	1,35 – 1,30	1,30 – 1,20	1,20
Bueno	1,35 – 1,25	1,25 – 1,15	1,15 – 1,00	1,00
Regular	1,25 – 1,15	1,15 – 1,05	1,00 – 0,80	0,80
Malo	1,15 – 1,05	1,05 – 0,80	0,80 – 0,60	0,60
Muy malo	1,05 – 0,95	0,95 – 0,75	0,75 – 0,40	0,40

Fuente: AASHTO, Guide for Design of Pavement Structures 1993.



OTHER IRC DESIGN METHODOLOGIES:

37-2012 (INDIA)

Other methodologies also show a reduction in costs

Material	CBR at 5 mm penetration	Total Thickness (mm)	Cost (Rs)
CL Soil	6.64%	547 mm	9271686
CL Soil + 0.041% Terrasil	10.82%	405 mm	8708166

Table 4 :thickness design is calculated as per IRC: 37 – 2012.

Fuente Scientifically Surveying the Usage of Terrasil Chemical for Soil Stabilization

South Africa (D1884)

The alternative design for a road (D1884) with Terrasil proved to be more economical and yielded a higher value in the heavy traffic simulator (7 million axles vs 3.5 million axles)

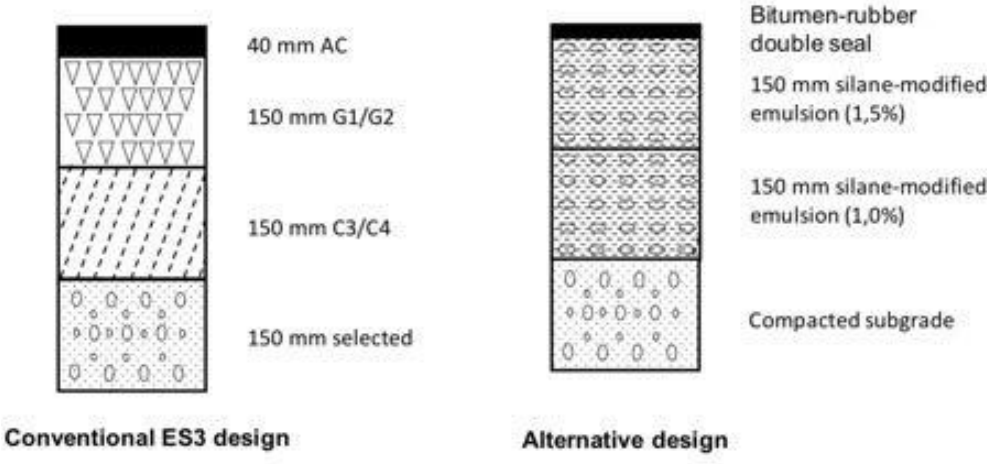


Fig. 1. Conventional and alternative designs for the D1884

TABLE III. CALCULATED DAMAGE COEFFICIENTS

Wheel load (kN)	Total traffic repetitions	Repetitions for the slope calculation	Rut (mm)	d	E80s (HVS)	E80s (d = 4.2)
40	321,350	229,800	0.63	1	321,350	321,350
60	372,600	169,350	0.9	1.63249	722,287	2,045,626
80	96,882	83,500	1.1	2.26461	465,542	1,780,611
80 (wet)	155,649	133,400	4.738	3.69547	2,016,485	2,860,700
TOT E80s					3,525,664	7,008,287

Fuente: Evaluation of a nano-silane-modified emulsion stabilised base and subbase under HVS traffic

FC Rust ,I Akhalwaya Council for Scientific and Industrial Research , GJ Jordaan

University of Pretoria and Tshepega Engineering (Pty) Ltd, Pretoria , L du Plessis

Gauteng Department of Roads and Transport

PUBLICATIONS AND SCIENTIFIC ARTICLES

The use of Terrasil, Terrasil +, Zycosoil and other versions of organosilanes manufactured by Zydex Industries for soil stabilization has been evaluated and documented in a growing number of scientific articles, including and by way of example the following references:

PATEL, Nandan A.; MISHRA, C. B.; PANCHOLI, V. V. Scientifically surveying the usage of Terrasil chemical for soil stabilization. *International Journal of Research in Advent Technology*, 2015, vol. 3, no 6, p. 77-84.

RAGHAVENDRA, T., et al. Stabilization of Black Cotton Soil Using Terrasil and Zycobond. *International Journal of Creative Research Thoughts (IJCRT)*, 2018, vol. 6, no 1, p. 300-303-300-303.

PANDAGRE, Ajay Kumar; JAIN, Rajesh. Experimental Study on Index Properties of Black Cotton Soil Stabilized with Terrasil. *International Research Journal of Engineering and Technology (IRJET) e-ISSN*, 2017, p. 2395-0056.

ADERINOLA, Olumuyiwa S.; NNOCHIRI, Emeka S. Stabilizing lateritic soil using terrasil solution. *Selected Scientific Papers-Journal of Civil Engineering*, 2017, vol. 12, no 1, p. 19-28.

CLEMENTE PANCHANA, Lissette Nathaly; RAMÍREZ BAQUERIZO, Jairo Omar. *Comparative analysis of the stabilization of material from La Negrita quarry using cement, terrasil, zycobond*. 2019. Licentiate thesis. La Libertad: Peninsula de Santa Elena State University, 2019.

MARKET ROOMS, Dante. Soil stabilization with the addition of cement and Terrasil Additive for the improvement of the base from Km 11+ 000 to Km 9+ 000 of the Puno-Tiquillaca-Mañazo road. 2018.

RODRÍGUEZ VINCES, Diego Israel. *Comparative analysis of the compaction and humidity of the natural subgrade and the subgrade using biodegradable chemicals (terrasil), of the ecological path of the Quevedo canton, province of Los Rios*. 2016. Licentiate thesis. Technical University of Ambato. Faculty of Civil and Mechanical Engineering. Degree in Civil Engineering.

THOMAS, ANSU; RKTRIPATHI, LKYadu; ROY, SUDEEP. Soil Stabilisation Using Terrasil. *International Journal of Earth Sciences and Engineering-ISSN*, 2016, p. 0974-5904.

SHIRAHATTI, Pavankumar N.; KALLIMANI, P. M.; RAJASHEKHAR, M. S. Application of geo-textile and terrasil chemical to reduce permeability of soil. *International Journal for Scientific Research & Development (IJSRD)*, 2016, vol. 4, no 06.
GAYATHRI, M.; SINGH, P. N.; PRASHANTH, M. G. Soil Stabilization using Terrasil, Cement and Flyash. *i-Manager's Journal on Civil Engineering*, 2016, vol. 6, no 4, p. 31.

PANDAGRE, Ajay Kumar; RAWAT, Ashutosh. Improvement of Soil Properties Using Nonchemical-Terrasil: A Review.

PADMAVATHI, V., et al. Stabilization of Soil Using Terrasil, Zycobond and Cement as Admixtures. En *International Congress and Exhibition" Sustainable Civil Infrastructures: Innovative Infrastructure Geotechnology"*. Springer, Cham, 2018. p. 163-170.

MEERAVALI, Karumanchi; RUBEN, Nerella; RANGASWAMY, Kodi. Stabilization of soft-clay using nanomaterial: Terrasil. *Materials Today: Proceedings*, 2020.
RAGHUWANSHI, Anand Kumar; BHARGAVA, Saurabh; GUPTA, Pallavi. Improvement of Black Cotton Soil with Cement & Flyash Treated With Terrasil. 2016.

MULLA, Afreen Abulkasim; GUPTHA, K. G. Comparative Study and Laboratory Investigation of Soil Stabilization Using Terrasil and Zycobond. En *Sustainable Construction and Building Materials*. Springer, Singapore, 2019. p. 757-769.

ALI, MOHAMMED SUFIYAN, et al. STABILIZATION OF SUBGRADE SOIL USING SAND, CEMENT AND TERRASIL CHEMICAL AS AN ADDITIVE. 2019.

SINGH, Sandeep. Microstructural Analysis of Clay after Treatement with Terrasil–A Nano Chemical.

RAJU, VR Prasada. A Study on Geotechnical Properties of Expansive Soil Treated with Rice Husk Ash and Terrasil.

OLANIYAN, O. S.; AJILEYE, V. O. STRENGTH CHARACTERISTICS OF LATERITIC SOIL STABILIZED WITH TERRASIL AND ZYCOBOND NANNO CHEMICALS.

SOIL, PAVEMENT BY USING SUBGRADE. ECONOMIC ANALYSIS OF FLEXIBLE PAVEMENT BY USING SUBGRADE SOIL STABILISED WITH ZYCOBOND AND TERRASIL.

GARCÍA CASTILLO, Ximena Alexandra, et al. *Comparison of the effects of different subgrade stabilization methods on clays from Bogotá*. 2015. Licentiate thesis. Bogotá-Uniandes.

PATEL, Nandan A., et al. Subgrade Soil Stabilization using Chemical Additives. *International Research Journal of Engineering and Technology (IRJET) e-ISSN*, 2015, p. 2395-0056.

OBREGÓN VÁSQUEZ, María Fernanda, et al. Analysis of the viability of stabilization processes with chemicals in tertiary roads, based on economic and environmental evaluation, taking as a reference (case study) Pilot Test Antioquia 2015, and its applicability in the tertiary roads that connect with the cocoa route (Santander).

CALDERON, Christopher; ANGEL, Michael. Ionic stabilization of soil with terrasil in road maintenance and conservation contracts. 2015.

EWA, D. E.; EGBE, E. A.; AKEKE, G. A. Effects of Nano-Chemical on Geotechnical Properties of Ogoja Subgrade.

ROY, Souvik; SARKAR, Dipankar; PODDER, Protyay. Laboratory Evaluation of Cement Stabilized Modified Base Course Layer Treated With Nano Materials.

ROY, Souvik; PATIDAR, Aman; SARKAR, Dipankar. A Feasibility Study of Replacing Conventional Base Course Layer in Flexible Pavement with Locally Available Materials.

GIRIDHAR, V.; KUMAR, P. Suresh Praveen; JYOTHIRMAYEE, S. An Experimental Study on Strength Characteristics of Expansive Soil Treated with Zycobond.

PANDOR, Vishala. Stabilization of Black Cotton Soil Using Chemical Additive. 2017.

RUALES, Franco Rojas; FLORES, Patricio Romero; VINUEZA, Cesar. METHODOLOGY FOR THE DESIGN OF LOW-COST MICRO SURFACING FOR SANDY ORGANIC SILT TYPE SOIL (OL).

KUMAR, Rakesh; ADIGOPULA, Vinod Kumar. *A Correlation Between LWD Backcalculated Moduli with Dynamic Cone Penetrometer Test Results for Subgrade Layer*. 2017.

WARDANI, Sri Prabandiyani Retno, et al. THE INTEGRATION OF CLIMATE CHANGES ADAPTATION AND MITIGATION IN SUSTAINABILITY CONCEPT. In *PIARC INTERNATIONAL SEMINAR*. 2014. p. 1-13.

KUMAR, Rakesh; ADIGOPULA JR, Vinod Kumar; GUZZARLAPUDI, Sunny Deol. Stiffness-based quality control evaluation of modified subgrade soil using lightweight deflectometer. *Journal of Materials in Civil Engineering*, 2017, vol. 29, no 9, p. 04017137.

JORDAN, Christopher S.; DANIELS, John L.; LANGLEY, William. The effects of temperature and wet-dry cycling on water-repellent soils. *Environmental Geotechnics*, 2015, vol. 4, no 4, p. 299-307.

MANITEJ, PENUMALLA; NAIDU, K. RAMI. EFFECT OF CALCIUM EXCHANGE CAPACITY ON THE PROPERTIES OF BLACK COTTON SOIL.

BECERRA SANTILLÁN, Anthony César Fernan; HERRERA GONZÁLES, Alfredo Emmanuel. STABILIZATION OF CLAYS, SANDS AND ASSERTED, USING THE CEMENTS PACASMAYO VIAFORTE, MOCHICA AND QHUNA; LAMBAYEQUE. 2018. 2019.

QUACKENBOSS, John S., et al. *Waterproof roadbed construction*. U.S. Patent No 8,348,547, 8 Ene. 2013.

STRENGTH, INVESTIGATION OF MECHANICAL. GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES.

SHEHATA, Hany; POULOS, Harry (ed.). *Latest Thoughts on Ground Improvement Techniques: Proceedings of the 2nd GeoMEast International Congress and Exhibition on Sustainable Civil Infrastructures, Egypt 2018–The Official International Congress of the Soil-Structure Interaction Group in Egypt (SSIGE)*. Springer, 2018.

REINOSO, ING ADRIAN XAVIER QUILAMBAQUI. *"EVALUATION OF URBAN ROAD DESIGN USING ORGANIC RESINS TO INCREASE THE CAPACITY SUPPORT OF THE TRACK STRUCTURE"*. 2017. Doctoral thesis. UNIVERSITY OF CUENCA.

ÁLVAREZ MONTOYA, Manuel Santiago, et al. *Chemical stabilization of soils in road infrastructure projects in Antioquia*. 2015. Doctoral Thesis. University EIA.

DAS, Bibhuti Bhusan; NEITHALATH, Narayanan (ed.). *Sustainable Construction and Building Materials: Select Proceedings of ICSCBM 2018*. Springer, 2018.

FAPOHUNDA, C. A.; AMU, O. O.; BABARINDE, O. F. EVALUATION OF GEOTECHNICAL AND STRUCTURAL PERFORMANCE OF CEMENT-STABILIZED SOIL WITH SAW DUST ASH (SDA). 2019.

APPLICATION EXAMPLES

Currently, Terrasil is used in several countries and in some of them it is directly specified by the transport department.

As an example of the different applications, some projects are mentioned:

KARJAN ROAD (INDIA)

This road connects two small towns, which are subject to torrential rains during 4 months of the year.

The road built with Terrasil maintains its properties while the control road had to be rebuilt several times.

The full report can be found in the annex. Karjan Road

LUNDA NORTE WATERFALL (ANGOLA)

Project data

Project: Stabilization of subgrade material 65 KM , 10 mts wide, 25-30 cm thick Laterites (sandy reddish silt material)

Customer:	ODEBRECHT ANGOLA (2013)
Length:	65 km
Wide:	10 meters
Depth:	25-30 cm
Material:	Laterites (sandy-loamy rijizo)

Location

The section was developed in Lunda Norte

Laboratory studies and test section

According to the previous laboratory study and test section executed, 150 m long x 10 m wide and 25-30 cm thick, the material to be stabilized (red silty sand or laterite), for the application of the Catata-Luvua, Lunda Norte work, 1 kg/m3 of Terrasil was used, in a thickness of 25-30 cm, in the subgrade layer.

The solution determined for the finished track section would be as follows:

Existing material.

Subgrade layer stabilized with Terrasil 25-30 cms. Sub-base

layer.

Base layer.

Primer irrigation. Hot mix

asphalt.

The main characteristics of Terrasil in the Catata-Luvua Lunda Norte project were the following:

- It will improve the available project material. Laboratory tests were carried out to check the parameters under study. Improvement of CBR, unconfined compression,...
- The proposed dosage to achieve the improvements is 1 Kg/m3 of Terrasil, therefore the importance of previous laboratory studies.
- It can be combined with cement or lime if necessary.
- It reduces the permeability of the material, which is very important in areas of high rainfall and torrential rain, such as the project area.
- Reduces swelling and expansiveness.
- Improves densities. Two-point improvement in on-site compaction.

Terrasil is not corrosive and does not produce leachate in the soil.

CONSTRUCTION PROCESS.

Placement of material to be stabilized


- 25-30 cm thickness of laterite material to be stabilized

Filling the tank with water and product according to the initial calculations


*Filling the tank with the previously established solution.

Watering with Terrasil

*Terrasil watering on previously extended material.

Homogenisation of the material

*Preparation of the material to be stabilized

*Leveling and profiling of the surface

Compaction

*Roller compaction

Surface regularity

*Final profiling and refining with a motor grader

Definitive compaction

*Compaction required in project.

EXAMPLES OF THE USE OF ZYDEX TECHNOLOGY IN ROADS

Year	Country	Customer	Project	Type
2010	India	Gujarat Government from	Karjan Road	Stabilization and asphalt mixing
2013	Peru	Obrainsa-Odebrech	Consortium of the northern (Ayabaca) road	Stabilization and slurry
2015	Peru	Copisa (SELCAS consortium)	Moyobambda	Stabilization and slurry
2017	Peru	Cosapi/Mota Engil	Vizcachane Consortium	
2014	Colombia	Government of Antioquia	Granada - Sancarlos	Stabilization of in-line pathways paving
2016	Colombia	Chia Municipality from	Main road of Chia (Cundinamarca)	Stabilization and slurry
2017	Colombia	CCC Lozada Civil Construction	Mocoa	Stabilization and slurry
2016	Colombia	CCC Lozada Civil Construction	Bogota City Hall	On-site recycling and hot mixing
2016	Colombia		ViaUramita-Small	Intravenous stabilization paving
2014	Nigeria	Enugu (airport)		Piston extension landing
2016	India	Rural Road, Sector19, Gandhinagar, Gujarat		

2019	Colombia	Chingaza Aqueduct	Access road to the aqueduct	Stabilization of the road paving
2016	Mexico	SCT	Campeche, new cohabitant	Stabilization of the road paving
2020	Colombia	IMMAC	Agricultural shopping centre	Stabilization of an agricultural shopping center
2018	Madagascar	Tamave		Street Stabilization Madagascar
2017	Ecuador	ProvinceDal Azuary, Ecuador		
2017	Spain	Badajoz City Council	ParkingSan Cristobal	

Other projects with Zydex Technology

Año	***País***	***Empresa***	***Vía***	***Mezcla***	***Tn or PK***
2014	*Colombia*	*Paving*	*Medellin Bogota Highway ...*	*MDC-1 and MDC-2*	
2014	*Colombia*	*Murcia y MurciA, S.A.*	*Via Bogota Villavicencio*	*MDC-2*	*42.000 Tn*
2015	*Colombia*	*Paving*	*Parques del Rio in Medellin..*	*MDC-1 and MDC-2*	
2015	*Colombia*	*Murcia y Murcia, S.A.*	*Various*	*MDC-2*	*42.000 Tn*
2015	*Colombia*	*KMA*	*Córdoba - Sucre Road Concession*	*MDC-2*	*305.150 km*
2016	*Colombia*	*Paving*	*Several...*	*MDC-1 and MDC-2*	
2016	*Colombia*	*Murcia y Murcia, S.A.*	*Various*	*MDC-2*	
2016	*Colombia*	*KMA*	*Ruta Caribe Mutata Road Concession*	*MDC-2*	*324.00 km*
2014	*Ecuador*	*Asphalt EP*	*Inner basin streets*	*Asphalt folder*	*15Km*

2014	Ecuador	Manabi Builds EP	Bahia-San Isidro Portoviejo internal roads Portoviejo-Montecristi Portoviejo side road Ruralles roads in the province of Manabi	Rolling Rolling Rolling	20Km 8Km 25Km 5Km 100Km
2014	Ecuador	Provincial Gold Council	Rural roads in the province	Filming	22Km
2014	Ecuador	Municipality of Machala	Internal streets of Machala	Filming	60Km
2014	Ecuador	Manabí builds EP	Bahia - san isidro Portoviejo internal roads Portoviejo-Montecristi Portoviejo side road Rural roads in the province of Manabí	Rolling Rolling Rolling Rolling Rolling	20Km 8Km 25Km 5Km 100Km
2014	Ecuador	Provincial Gold Council	Rural roads in the province	Filming	22Km
2014	Ecuador	Municipality of Machala	Internal streets of Machala	Filming	60Km
2014	Ecuador	Building company missing	Western track section 3	Filming	8Km
2014	Ecuador	Consermín	Cuenca - Gualaceo	Filming	22Km
2014	Ecuador	Road builder	E35 - pucará	Filming	15Km
2014	Ecuador	Asphalt and concrete	Gualaceo -Limón section 1	Filming	30Km
2014	Ecuador	Carvallo Construction Company	Sands - santa rosa	Filming	25Km
2014	Ecuador	Ormazabal Valderrama Construction	Streets of Guayaquil	Filming	5Km
2014	Ecuador	Obraciv	Streets of Ibarra and Tulcan	Filming	15Km
2014	Ecuador	Hidrobo Estrada Construction Company	Gualaceo - lemon section 2	Filming	30Km
2014	Ecuador	LPG Road EP	Catacocha - Pindal	Double surface treatment	25Km
2014	Ecuador	Angos & Sons Construction Company	Pineapples - Advanced County - Middle of the World	Rolling Rolling	35Km 20Km
2014	Ecuador	Julimarti Construction Company	Manabi's support roads build	Filming	40Km
2014	Ecuador	Public company Emuvial EP	Internal streets of Santa Elena	Filming	6Km
2015	Ecuador	Alvarado Ortiz Construction Company	Internal streets of Ambato Interoceánica de Quito T-1	Filming Base and Wheel	25Km 8Km

2015	Ecuador	Lozada Construction Company	Inter-Oceanic Section 3	Filming	5Km
2015	Ecuador	Ocampo Construction Company	Internal streets of Quito	Filming	20Km
2015	Ecuador	Hidalgo and Hidalgo Construction	Quevedo Road Ring Section 1	Filming	12Km
2015	Ecuador	Herdoiza Crespo Construction Company	North Pan-American	Filming Base and Wheel	70Km
2015	Ecuador	Municipality of azogues	Internal streets of azogues	Filming	12Km
2015	Ecuador	Basin Municipality	Inner basin streets	Filming	10Km
2015	Ecuador	Fopeca Constructions	Quevedo Road Ring Section 2	Filming	12Km
2015	Ecuador	Cevallos Hidalgo Construction	Internal streets of Santo Domingo	Filming	9Km
2015	Ecuador	Municipality of Loja	Internal streets of Loja	Rolling, bases	15Km
Yea r	Country	Company	Via	Type of	Tn or PK
2015	Ecuador	Santa Rosa Municipality	Internal streets of Santa Rosa	Filming	18Km
2015	Ecuador	Inductroc	Streets of Guayaquil	Filming	20Km
2015	Ecuador	Constructora Verdú	Pifo - Tumbaco	Filming Base and Wheel	10Km
2014	Peru	Moro SRL	Streets of Lima - the olive trees	Filming	15Km
2014	Peru	JMK contractors	Piura - Sechurra	Filming	12KM
2014	Peru	Obrainsa	Quilca - Matarani	Filming	22Km
2015	Peru	T and r contractors	Lima - Streets of San Juan	Filming	10Km
2015	Peru	Delheal SAC	Lima - Streets of Victory	Filming	32KM
2015	Peru	JMK contractors	Lima - Yellow Line	Filming	42KM
2015	Peru	Lirsa centre	Huancayo - la Oroya - Cerro de Pasco - Lima	Filming	120Km
2016	Peru	TDM asphalts	Trujillo - Via Evitamiento	Filming	25Km
2013	Peru	Obrainsa	Northern Road Consortium	Stabilization	
2014	Mexico	Jorge Enrique Mercader	Cancun- Tulum	SMA	20 km

2014	Mexico	Emulsions Bay Area Asphalt	Quintana Roo	Various	15000 tons
2015	Mexico	Bay Area Asphalt Emulsions	Tulum-Felipe Carrillo Puerto	Discontinued, AMAAC Protocol	12 km
2015	Mexico	Jorge Enrique Mercader	Quintana Roo	Various	15000 tons
2015	Mexico	ASF Pavements	Veracruz Airport and Streets, Veracruz State	Various	12500 tn
2015	Mexico	TRABISA	Veracruz Airport and Streets, Veracruz State	Ultra-thin	12 km
2015	Mexico	Samuel Lom	State of Veracruz	Rolling and Bases	5000 tons
2013	Spain	AM Alonso	Toledo	Rolling, Intermediates and Bases	5000 tons
2013	Spain	Riojana de Asfaltos	Rioja	Rolling, Intermediate and Bases	4000 tons
2013	Spain	Ishmael Andres	Rioja	Rolling, Intermediate and Bases	30.000 t
2014	Spain	Pavasal	Valencia	Rolling, Intermediate and Base	25.000 t
Yea r	Country	Company	Via	Mix	Tn or PK
2014	Spain	Elsan	Alarpardo ,streets	Rolling, Intermediates and Bases	5000 tons
2015	Spain	Riojana de Asfaltos	Rioja	Base	12.000 t
2015	Spain	Sorigue	Lleida	Filming	2000 t
2015	Spain	Pavasal	Valencia	Rolling, Intermediate and Bases	30.000 t
2015	Spain	Ishmael Andres	Rioja	Rolling, Intermediates and Bases	30.000 t
2018	Spain	Caterpillar	Malaga	Stabilization with Terrasil	
2015	Spain	Asphaltomers	Huesca	Filming	15.000 t
2014	Europe*	Pzedsiq Enterprises o Road and Bridge GODROM	Lublin	Rolling, Intermediate and Bases	6000 tons
2014	Europe*	Lemminkainen Sverige AB	Sweden	Rolling, Intermediates and Bases	5000 tons
2014	Europe*	The company's Road Construction Department DROGOPOL - ZW Sp. z o. o	Polynia	Rolling, Intermediate and Bases	18.000 t

2014	*Europe**	*Nynas AB*	*Sweden*	*Rolling, Intermediates and Bases*	*25000 tons*
2014	*Europe**	*Other companies*	*Europe*	*Rolling, Intermediate and Bases*	*50.000 tons*
2014	*Europe**	*PEAB (Nynas AB)*	*New Motorway Section of E4 bypassing City Centre of Sundsvall*	*Rolling (SMA 16) Intermediasy Bases*	
2014	*Europe**	*PEAB (Nynas AB)*	*Sundsvall Municipality*	*Filming*	*12000 tons*