NovoCrete®

AUTARK Energy & Infrastructure Solutions

Photo report

Construction of a link road between Cocobeach und Ntoum in Gabon by using the NovoCrete® technology

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Construction of a link road with NovoCrete®

1. Situation

For the "R 10 Ntoum-Cocobeach" road construction project in Gabon, a geotechnical test programme was drawn up in cooperation with the Gauff Engineering company, based in Libreville, in order to be able to make a statement about the applicability of the NovoCrete® procedure for the stabilisation of soils on site in view of the planned use of the road under the prevailing climatic conditions.

The test programme ought to be based upon the available results of the laboratory examinations carried out by the LBTPG (Laboratoire du Bâtiment et des Travaux Publics du Gabon, Rapport Géotechnique, 10 avril 2007) and by the GeoConCept GmbH company (qualification test report AZ 0207/1127).

In June 2007, the Gauff Engineering company based in Libreville entrusted the LBTPG laboratory with the realisation of NovoCrete® qualification tests which were carried out from 25 May to 12 June 2007 in Libreville under the guidance of a qualified geologist of the GeoConCept GmbH.
For the first part of the test program, 10 soil samples were taken from 19 excavated holes that were made up to a depth of about 60 cm over the 85 km long road section.

In a second step, the samples taken were examined in the LBTPG laboratory; simple soil-mechanical identification and compaction tests were carried out.

On the basis of the determined data, the scope of the test programme was limited, in the framework of a further step, to 1 laterite sample and 3 further different soil types.

With the help of the cement additive NovoCrete®, about 150 specimens were manufactured which served to determine the compressive strength as well as the tensile splitting strength at the age of 7 and 28 days as well as the compressive strength after 7 days, with 3 days of exposure to air and 4 days of immersion in water.

In the following, the results of the soil-mechanical examinations as well as the results of the strength tests realised on soil-binder mixtures at the age of 7 and 28 days are presented.

2. Related documents

The qualification test is based upon the following documents:

1. Results of the laboratory examinations
2. DIN 18196 "Earthworks and foundations - Soil classification for civil engineering purposes"
3. DIN 4022 "Classification and description of soil and rock"
4. DIN 18121 "Water content"
5. DIN 18122 "Soil, investigation and testing - Consistency limits"
6. DIN 18127 "Proctor test"
7. DIN 18136 "Determination of the unconfined compression strength"
8. ZTVE-StB 94 "Additional terms for technical contracts and guidelines for earthwork in road construction"
9. ZTVT-StB 95 "Additional terms for technical contracts and guidelines for road bases in road construction"
10. TP BF-StB, part B 11.1 "Qualification tests for soil stabilisation with cement", edition 1996
11. Leaflet for soil improvement and soil stabilisation with cement, edition 1984
12. DIN 1048 Sheet 1: Testing methods for concrete
13. NF P 98-232-1 "Essais relatifs aux chaussées ; Partie 1 : Essai de compression simple sur graves"
14. NF P 98-232-3 "Partie 3 : Essai de compression diamétrale sur les matériaux traités aux liants hydrauliques et pouzzolaniques"
15. NF P 94-093 "Essai Proctor normal-Essai Proctor modifie"
16. NF P 11-300 "Classification des matériaux utilisables dans la construction des remblais et des couches de forme"

3. Product description

NovoCrete® ST is a whitish-grey powder which is composed of alkaline and alkaline-earth elements or complex mineral compounds. According to the manufacturer's specification, NovoCrete® supports the cement hydration process and counteracts the negatively influencing fulvic and carboxylic acids.

Changes in the structure and the additional new formation of minerals during cement hydration lead to an increase in compressive strength and even allow stabilisation of humus-rich earth.

Besides the increase in compressive strength, NovoCrete® promotes the immobilisation of environmentally dangerous contaminants. This includes heavy metals as well as organic factors that can be fixed permanently in the newly formed crystal structures.

4. Excavated holes

From 25 June to 26 June 07, the LBTPG carried out altogether 19 excavated holes in the presence of the technical director of the Gauff Engineering based in Libreville. The kilometer point 0 was agreed to be the T crossing leading from Ntoum to Cocobeach. From the kilometer points (PK) already examined and sampled by the LBTPG laboratory, the GeoConCept company chose the following kilometer points in their letter dated 09 May 2007 for a qualification test with NovoCrete®: 20, 50, 55, 60, 65, 75 and 85 (7 excavated holes).

Further compaction points were selected by the client: PK 11.5; 16; 20; 45; 49.5; 54; 64.5; 69.5; 72.1; 74.5; 75.5; 76.7; 79.5 and 82.1.

At the different kilometer points indicated above, the excavated holes were used for soil identifications according to DIN 4022. A sample from the laterite soil was taken at PK 45; for the soil-mechanical evaluation of the subsoil, a 50 kg sample was taken at each of the following kilometer points: PK 20; 50; 51.7; 56.8; 61.9; 72.1; 75.5; 76.7 and 82,1.

The following table shows the thickness of the laterite layer as well as the soil identification for the different excavated holes.

LBTPG test designation (PK)	GPS-No.	Boring depth (cm)	Laterite thickness (cm)	Road bed, soil identification according to DIN 4022
11.5	022	65	45	Brown coarse clay, slightly argillaceous, semisolid
16	049	60	0	Brown coarse clay, semisolid
20	025	65	30	Yell.-br. coarse clay, red clay covering, stiffsemisolid
21.5	026	55	25	Yell.-br. coarse clay, slightly sandy, semisolid
45	027	60	60	Laterite sample
46.6	028	50	30	Brown coarse clay, semisolid
50		60	7	Li. brown coarse clay, fine gravel laterite inclusions
49.5	033	65	50	Yellow-brown coarse clay, lateritic, red-violet sandstone on the basis
51.7	034	60	30	Light brown silty fine sand of medium density
54	035	55	30	Yellow-brown coarse clay, grey and red clay layers, stiff, but plastic
56.8	036	55	20	Yellow-brown clay, red clay covering, stiff
61.9	037	80	40	Yellow-brown coarse clay, argillaceous, stiff-semisolid, laterite lumps
64.9	038	65	60	Red.-br. coarse clay, slightly argillaceous, stiff, lateritic
69.5	039	70	25	Reddish-brown clay, stiff
72.1	040	70	30	Upper 10 cm: clay, soft; under that: black argillite and mudstone
75.5	031	60	0	Light brown coarse clay, semisolid
76.7	042	60	0	Sand, very silty, of medium density
79.5	045	55	15	Green-grey clay, semisolid
82.1		60	0	Clay, silty, stiff-soft

Table 1: *Description of the excavated holes samples with indication of the laterite thickness*

The thickness of the road's surface course – in the framework of the soil-mechanical evaluations designated as very binding laterite gravel (GU*/GT*) – varies over the entire road section between 0 and 60 cm and amounts to an average value of 27 cm, if one takes into account the LBTPG results available at the point in time of the field study. The road bed of the laterite gravel as well as the road superstructure on the kilometer points without laterite gravel mainly consist of very plastic coarse clays and clays (UA or TA according to DIN 18 196) with a natural water content of > 30 %, semi-plastic clays (TM), as well as fine sands and very argillaceous sands (SU*/ST*).

5. Soil-mechanical examination

In the following, the samples taken at kilometer points PK 20; 45; 76.7 and 82.1 are described in detail, since, for every one of these, a qualification test was carried out in the LBTPG laboratory with NovoCrete®.
The PK 45 sample consists of a typical laterite gravel of the road section. The selection of the samples PK 20; 76.7 and 82.1 represent soil types from the road section in which the laterite gravel is missing or only exists as a 5 cm thick crust on the road bed.

5.1 State limits, Limit Atterberg according to NF P 11-300

For the classification of fine-grained soil types, the water content at the liquid and plastic limit were determined respectively for the samples PK 20 and PK 82.1. The right column of table 2 contains the classification of soils according to DIN 18 196.

Sample	W_n [%]	W_l [%]	W_P [%]	I_P [%]	I_c	DIN 18 196
PK 20	33.3	53.0	27.7	25.3	0.78	UA/TA
PK 76,7	13.2	26.4	15.3	11.1	1.19	TL
PK 82,1	36.6	55.3	31.3	24.0	0.78	UA

Table 2: *Soil classification according to NF P 11-300 and DIN 18 196*

W_n - natural water content
W_L - water content at the liquid limit
W_P - water content at the plastic limit
I_P - plasticity index
I_C - consistency index (0.0-0.5 paste-like; 0.5-0.75 soft; 0.75-1.0 stiff; >1.0 semisolid)

After the laboratory examinations carried out at LBTPG, the soil samples PK 20 and PK 82.1 were identified in accordance with DIN 18 196 as very plastic clays resp. as very plastic coarse clays (DIN 18 196: TA/UA) with stiff to soft consistency. The PK 76.7 sample was classified according to DIN 18 196 as slightly plastic clay with a semisolid consistency.

5.2 Grain size distribution according to NF P 11-300

In the LBTPG laboratory, the grain size distribution of the samples of PK 45 (laterite gravel) and PK 76.7 were determined according to the applicable French standard. The following table shows a soil classification according to DIN 18 196.

Sample	Natural Water content W_n%	Coefficient of uniformity $U=d_{60}/d_{10}$	Coefficient of curvature Cc	Fraction < 0,080 mm [%]	Soil classification DIN 18 196
PK 45	14.8	-	-	27.7	GT*/GU*
PK 76,7	13.2	-	-	25.6	ST*/SU*

Table 3: *Soil classification according to NF P 11-300 and DIN 18 196*

According to the laboratory tests carried out, the laterite sample PK 45 was identified as very argillaceous or very silty gravel according to DIN 18196. The fine-grain fraction < 63 µm of the sample amounts to about 28 %.
After the elutriation of the fine fraction < 0.08 mm, the PK 76.7 sample was classified as very argillaceous or very silty sand according to DIN 18 196.

5.3 Proctor test according to NF P 94-093

For the determination of the optimum dry density and the optimum water content, a Proctor test according to NF P 94-093 was carried out for the samples PK 45; PK 20; PK 76.7 and PK 82.1 on soil-binder mixtures with the simple Proctor test. The soil-mechanical values of the samples determined with the help of the Proctor test are given in table 4 below.

Sample	PK 45	PK 20	PK 76.7	PK 82.1
Optimum Proctor density D_{pr} 100 % [g/cm³]	19.4	16.5	19.1	15.5
Optimum water content W_{opt} [%]	13.5	25.0	11.7	21.2

Table 4: *Results of the Proctor tests according to NF P 94-093*

6. Examination of the compressive strength [compression simple] according to NF P 98-232-1 and of the splitting tensile strength [traction par fendage] according to NF P 98-232-3

The approximate 150 specimens created from the PK 45; PK 20; PK 76.7 and PK 82.1 samples were also used to produce mixtures of PK 76.7 + 20 % PK 45.

The examination of the compressive strength (Rc, compression simple) was realised for cylindrical specimens (dimensions: H = 115 mm (ca.) / D = 100 mm) according to NF P 98-232-1 on soil-NovoCrete® mixtures at the age of 7 and 28 days in the LBTPG laboratory in order to be able to determine the binder content required for the soil stabilisation. In addition to the compressive strength without immersion in water, the compressive strength was also determined after 7 days, with 3 days of exposure to air and then 4 days of immersion in water. This test was meant to take into account the extreme climatic conditions in the tropics.

Furthermore, specimens of the age of 7 and 28 days were examined in order to determine their splitting tensile strength (traction par fendage) according to NF P 98-232-3. The breaking load was determined visually on the basis of the maximum deflection of the press' gauge needle.

The following table indicates the respective binder quantities used for the qualification tests of the soil samples. The annex lists the results of the strength tests.

Sample	DIN 18 196	Binder content (%)	Binder content (kg/m³)
PK 45 Laterite - GPS 027	GU*/GT*	5.0	97
PK 45 Laterite - GPS 027	GU*/GT*	10.0	190
PK 20 Argillaceous coarse gravel - GPS 025	UA/TA	11.0	180
PK 76,7 - Silty sand - GPS 042	TL	10.0	190
PK 82,1 - Argillite - GPS 046	UA	11.6	180
PK 76,7 (80%) + PK 45 (20%)	TL	10.0	190

Table 5: *Soil classification according to DIN 18196 and binder content of soils*

6.1. Laterite gravel PK 45

6.1.1 Compressive strength and modulus of elasticity

For the laterite gravel, classified as GU*/GT* according to DIN 18 196, test series with a binder content of 5 % and 10 % were carried out for the cement additive NovoCrete®. The binding agents used were Portland cement CEM I 42.5 R from China and an NovoCrete® premix (mixture of cement and pure NovoCrete®: 50:50). The addition of the NovoCrete® premix corresponds to 2 % of the dry cement additive.
The specimens were manufactured with the optimum water content determined in the framework of the Proctor test according to NF P 94-039X.

For the verification of the results determined at the LBTPG laboratory, some PK 45 specimens were sent to Germany. These specimens were submitted to tests carried out at the Baustoff- und Bodenprüfstelle [Inspection authority for construction material and soil] in Wetzlar on the day agreed upon (after 7 and 28 days) in order to determine the compressive strength without immersion in water as well as the modulus of elasticity.

The average results of the compressive strength test determined for the Gabon specimens are given in tables 6 and 7. Table 8 shows the average results of the compressive strength test with immersion in water.

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compressive strength [N/mm²]
PK 45	GU*/GT*	5.0	100	7	3.17
PK 45	GU*/GT*	5.0	100	28	3.88
PK 45	GU*/GT*	10.0	100	7	3.69
PK 45	GU*/GT*	10.0	100	28	4.98

Table 6: *Average compressive strength in N/mm² after 7 and 28 days; determined at the LBTPG laboratory*

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compr. strenght [N/mm²]	E-Modulus [N/mm²]
PK 45	GU*/GT*	5.0	100	7	2.56	470 - 540
PK 45	GU*/GT*	5.0	100	28	3.31	460 - 530
PK 45	GU*/GT*	10.0	100	7	3.09	420 - 510
PK 45	GU*/GT*	10.0	100	28	4.22	430 - 550

Table 7: *Average compressive strength in N/mm² after 7 and 28 days; determined in Germany*

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compr. strenght [N/mm²]
PK 45	GU*/GT*	5.0	100	7	1.27
PK 45	GU*/GT*	10.0	100	7	2.34

Table 8: *Average compressive strength in N/mm² after 7 days with immersion in water; determined at the LBTPG laboratory*

6.1.2 Splitting tensile strength

In addition to the compressive strength test, a splitting tensile strength test [traction par fendage] was carried out at the age of 7 days according to NF P 98-232-3. The average results are given in table 9.

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Splitting tensile strength [N/mm²]
PK 45	GU*/GT*	5.0	100	7	0.33
PK 45	GU*/GT*	10.0	100	7	0.64

Table 9: *Average splitting tensile strength in N/mm² after 7 days; determined at the LBTPG laboratory*

In case of a binder content of 5 %, the splitting tensile strength values of the laterite sample amount to 0.33 N/mm² after a curing time of 7 days. As could be expected, the splitting tensile strength value increases, when the dosage of the binding agent is increased. Accordingly, the splitting tensile strength values almost doubles in case of 7 days of curing and a binder content of 10 %.

The higher splitting tensile strength, the higher the bending tensile strength. Concerning the dynamic load bearing capacity, an increased bending tensile strength has a positive effect on the service life of a hydraulically bound base course, since the crack sensitivity of the base course is also greatly reduced. Only the reduction of the crack sensitivity also allows a reduction of the asphalt thickness, since, otherwise, the cracks occurring would destroy the surface course.

6.2 Qualification test for the soils at kilometer points PK 20; PK 76.7 and PK 82.1

6.2.1 Compressive strength

For the samples taken at the kilometer points PK 20; PK 76.7; PK 76.7 + 20 % PK 45 and PK 82.1, compressive strength tests were carried out at the age of 7 and 28 days according to NF P 98-232-1. The related soil groups according to DIN 18 196 as well as the binder contents used are given in the following table 10. Furthermore, the respective samples were also submitted to compressive strength tests after 7 days with immersion in water. For this, the samples were at first exposed 3 days to air and then stored for 4 days under water. Table 11 indicates the results of the compressive strength test with immersion in water.

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compr. strenght [N/mm²]
PK 20	UA/TA	11.0	100	7	2.04
PK 20	UA/TA	11.0	100	28	3.40
PK 76.7	TL/ST*	10.0	100	7	3.44
PK 76,7	TL/ST*	10.0	100	28	5.77
PK 82.1	UA	11.6	100	7	1.15
PK 82.1	UA	11.6	100	28	1.82
PK 76.7 + 20 % PK 45	TL	10.0	100	7	2.76
PK 76.7 + 20 % PK 45	TL	10.0	100	28	4.67

Table 10: *Average compressive strength in N/mm² after 7 and 28 days; determined at the LBTPG laboratory*

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compr. strenght [N/mm²]
PK 20	UA/TA	11.0	100	7	1.87
PK 76.7	TL/ST*	10.0	100	7	2.97
PK 82.1	UA	11.6	100	7	0.98
PK 76.7 + 20 % PK 45	TL	10.0	100	7	2.38

Table 11: *Average compressive strength in N/mm² after 7 days with immersion in water*

6.2.2 Examination of compressive strength and modulus of elasticity in Germany

For the following samples, the compressive strength and modulus of elasticity were determined at the age of 28 days in the framework of tests carried out in Germany. The results are listed in the following table.

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Compr. strenght [N/mm²]	E-Modulus [N/mm²]
PK 20	UA/TA	11.0	100	28	2.89	260 - 310
PK 76.7	TL/ST*	10.0	100	28	8.08	840 - 910
PK 82.1	UA	11.6	100	28	2.56	290 - 300
PK 76.7 + 20 % PK 45	TL	10.0	100	28	4.97	780 - 900

Table 12: *Average compressive strength and modulus of elasticity in N/mm² after 28 days*

Sample	DIN 18 196	NovoCrete®-cement-mixture in %	Diameter [mm]	Age [days]	Splitting tensile strength [N/mm²]
PK 20	UA/TA	11.0	100	7	0.35
PK 20	UA/TA	11.0	100	28	0.37
PK 76.7	TL/ST*	10.0	100	7	0.52
PK 76.7	TL/ST*	10.0	100	28	1.00
PK 82.1	UA	11.6	100	7	0.22
PK 82.1	UA	11.6	100	28	0.28
PK 76.7 + 20 % PK 45	TL	10.0	100	7	0.55
PK 76.7 + 20 % PK 45	TL	10.0	100	28	0.89

Table 13: *Average splitting tensile strength in N/mm² after 7 and 28 days*

7. Geotechnical recommendation

According to the strength tests carried out after 7 and 28 days on the soil-binder mixtures for selected soil types from the Ntoum-Cocobeach road section, a soil stabilisation by means of the special binding agent NovoCrete® is possible.

According to ZTVT-StB 95, a compressive strength (after 28 days) of 3.5 N/mm² is required for specimens of the construction material mixture in case of hydraulically bound base courses.

The minimum binder quantities indicated below for cement/NovoCrete® solely refer to the soils examined at the respective kilometer points.
The following tables contains the sample designations with their distance to kilometer point 0, the average strength values after 28 days for the compressive strength, the modulus of elasticity (maximum value of the tests on mixtures with a dosage of 10 % carried out in Germany) and the splitting tensile strength of soil-NovoCrete® mixtures.

Sample	Kilo-meters*	Binder content	Compressive strength [N/mm²]	Splitting tensile strength [N/mm²]	E-Modul [N/mm²]
PK 45	44.313	5.0 % (≈ 97 kg/m³)	2.46	0.22	495
PK 45	44.313	10.0 % (≈ 190 kg/m³)	4.46	0.57	940
PK 20	15.241	11.0 % (≈ 180 kg/m³)	3.40	0.37	260 - 310
PK 76.7	75.067	10.0 % (≈ 190 kg/m³)	5.77	1.00	840 - 910
PK 82.1	80.431	11.6 % (≈ 180 kg/m³)	1.82	0.28	290 - 300
PK 76.7 + PK 45	75.067	10.0 % (≈ 190 kg/m³)	4.67	0.87	780 - 900

* (T crossing point 0) Ntoum to Cocobeach

Table 14: *Distance to kilometer point 0 and strength test results for the samples examined at the LBTPG laboratory*

On the basis of the available strength results for laterite gravel with the designation PK 45 (44.313 km from T crossing Ntoum), classified as GU*/GT* according to DIN 18 196, as well as on the basis of the interpolation of the uncorrected compressive strength results at a binder content of 5 % and 10 %, it is possible to use a minimum binder quantity of 7.5 % in order to meet the requirements according to ZTVT-StB 95. Given the determined optimum dry density of 1.94 g/cm³, this corresponds to a binder dosage of about 150 kg/m³.

In view of the high requirements concerning the type and use of the road leading from Ntoum to Cocobeach, particularly concerning the long exposition to heavy axle loads (> 160 kN) for the transport of wood and concerning other influences, it was empirically proved that a milling depth of at least 0.30 m must be observed for the stabilisation of the road with NovoCrete®. It is thus possible to guarantee that the requirement concerning the service life of the road can be met. Falling short of the planned milling depth is only possible, if the ground can permanently assure a high bearing capacity.

This means that, in case of a milling depth of 0.30 m, about 45 kg/m² of cement/NovoCrete® are to be spread for the laterite gravel.

As regards the binder dosage defined here, it must be noted that, in case of laterite gravel variations due to deviating soil-mechanical characteristics on the road section, the binder dosage must be adapted or increased accordingly or a laterite of the same or a higher quality must be worked in.

According to the results of the qualification test concerning the stabilisation of the soil at PK 20 (15.241 km from T crossing Ntoum), classified as very plastic coarse clay or clay according to DIN 18 196, a minimum binder quantity of 11.0 % (≈ 180 kg/m³) ought to be used. In case of a milling depth of about 0.30 m, 54 kg/m² must be spread.

For the very binding sand (ST*/SU*) at PK 76.7 (75.067 km from T crossing Ntoum), the binder quantity can be reduced thanks to the good strength results achieved in the tests. However, it is recommended to take into account a minimum binder quantity of about 8 % (≈ 150 kg/m³). The Cocobeach soil with the designation PK 82.1 (80.431 km from T crossing Ntoum) is conditionally suitable for the stabilisation with NovoCrete®. Here, the soil should be replaced by laterite gravel.

Furthermore, if possible, a pure Portland cement CEM I should be used for the compaction works, since the proportion of clinker reacting in this cement with the NovoCrete® additive amounts to 100 %. The cement types used in Gabon are probably composite cements in which the reactive clinker proportion was replaced by granulated cinder or other additives. Moreover, the classification of the domestic cements (CPJ 35 and CPJ 45) does not correspond to internationally applicable standards (EN 197-1). If, however, a domestic cement is used for the soil stabilisation, it ought to have better characteristics than the Portland cement CEM I 32.5 R. In order to achieve higher initial strengths for premature loading of the NovoCrete® surface course due to heavy trucks, as we see it, a CPJ 45 cement should be used.

Given the framework conditions mentioned above, the author of this site report recommends that an at least 5 cm thick asphaltic concrete layer be applied as surface course on the NovoCrete® base course. This asphalt layer has to be glued to the NovoCrete® base course by means a pressure-sensitive adhesive or primer. Experience has shown that this type of construction avoids deformations in the asphalt layer resulting from shearing forces.

By means of the Weslea for Windows 3.0 programme (U.S. Army Corps of Engineers: Waterways Experiment Station, Layered Elastic Analysis method; Van Cauwelaert, et. al., 1989), a service life calculation was made for a laterite-containing base course stabilised with NovoCrete® under a 5 cm thick asphalt layer, for a varying road bed strength (binding soils). This programme makes it possible to simulate loads, tensile stresses and dislocations in the road body. The calculation was based upon a service life of 20 years, the crossing of 100 3-axle-trucks per day with an axle load of 13 t (= 130 kN) or 16 t (=160 kN), a soil strength under the base course varying between 10 and 25 MPa and a 0.30 m thick NovoCrete® base course. The results are shown in the following table.

Simulation	NovoCrete-base course thickness cm	Axle loads in kN	E-Modulus of the soil in MPa	Fatigue	Damage (Fatigue)	Rutting	Damage (Rutting)
1	30	130	10	0	0.0	508029	4.31
2	30	130	15	0	0.0	807656	2.71
3	30	130	25	0	0.0	1450241	1.51
4	30	160	10	0	0.0	241785	9.06
5	30	160	15	0	0.0	387293	5.65
6	30	160	25	0	0.0	702932	3.12

Table 15: *Results of the simulation calculation with the Weslea programme*

In case of an axle load of e.g. 130 kN and a load capacity of the ground of 25 MPa, about 810,000 crossings are possible without a deformation occurring. On the basis of the calculations made, a minimum thickness of the NovoCrete® base course of 0.30 m should not be fallen short of for axle loads of 130 kN. Given an axle load of 160 kN and the road structure described above, it takes about 703,000 crossings until the first deformation occurs. If axle loads of 160 kN are expected, a minimum base course thickness of 0.35 m must not be fallen short of.

In general, the following is applicable: the higher the bearing capacity of the ground, the higher the number of crossings until the first dislocation presents itself in the road's superstructure.

The operating sequence is briefly described below:

1. The binding agent NovoCrete® ST must be applied to the soil to stabilise in the mixing ratio defined before. The milling of the binding agent into the soil should be realised with the help of a large mill, e.g. of the WR® 2500 type, since, for this machine, the addition of water can be realised directly by the robot.

2. The determined optimum water content of the soil sample is given in table 4. During the stabilisation phase, the water content must be increased to about 2 % above the optimum value subject to the NovoCrete® ST system used.

3. After the homogenisation of the NovoCrete® ST-soil mixture, the aerated soil should be evenly spread by means of a laser-controlled road grader or bulldozer.

4. Then, the NovoCrete® ST-soil mixture can be dynamically compacted with the help of a vibratory roller (weight > 10 t). During the compaction works, one has to make sure that a 50 % overlap is observed.

5. Afterwards, the ground can be levelled by means of a laser-controlled grader or bulldozer.

6. In the end, the base course surface should again be statically compacted by means of a road roller. This compaction should be carried out by means of a rubber wheel road roller (weight > 12 t).

7. In order to avoid any evaporation of the water contained in the soil, the compacted surface of the base course must be covered with an evaporation protection, i.e. the surface must be completely moistened with a sufficient quantity of water. Due to the climatic conditions at site, one has to pay particular attention to the subsequent treatment of the soil-binder mixture after stabilisation works (irrigation and keeping the soil moist).

Jobsite report: Construction of a link road

As regards the use of NovoCrete® ST, one has to bear in mind that its pot life from the first placing of the binder up to the fine levelling of the ground is limited to 3-4 hours.

If the geological framework conditions, the processing guidelines and the axle loads described above are met and complied with, a service life of 20 years can be expected for the road body of the "R 10 Ntoum-Cocobeach" road project in Gabon, if the NovoCrete® ST additive system is used.

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