NovoCrete®

AUTARK
Energy & Infrastructure Solutions

Jobsite report

Road Building Project (Laterite Soil) in Jalan Pekoti Timur/Malaysia by using NovoCrete®

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Soil stabilisation with NovoCrete®

1. Situation

The NovoCrete® product series comprises two lines called NovoCrete® ST and NovoCrete® IM. The ST abbreviation stands for stabilisation, i.e. the additives line has specifically been developed for the production of base courses and frost blankets from natural soil. The individual products of the NovoCrete® ST line are usually only used together with hydraulic binding agents, i.e. cement in accordance with DIN EN 197-1. NovoCrete® ST is a whitish-grey powder composed of alkaline and alkaline earth elements and/or complex mineral compounds. According to the manufacturer, NovoCrete® ST promotes the cement hydration processes and inhibits the fulvic and carboxylic acids, which have negative impacts. Structural transformations and the additional new formation of minerals during cement hydration lead to an increase in pressure resistance and even allow for a stabilisation of humic soils.
Apart from increasing the pressure resistance, NovoCrete® ST supports the immobilisation of substances that are hazardous to the environment. These include both heavy metals and organic parameters that can permanently be fixed in the newly formed crystal structures. The advantages in favour of the application of the NovoCrete® system and the base course made from it include:

a) Reduction of excavation
b) Reduction of disposal costs for excavated soil
c) Reduction of transport costs
d) Reduction of environmental pollution
e) Reduction of building time
f) Reduction of building costs
g) Reduction of the thickness of the wearing courses
h) Soil with higher organic contents can be used for stabilisation
i) (Natural) soil can be converted to a base course and frost blanket
j) No use of pre-treated mineral ballast material
k) No anticapillary courses required since the NovoCrete® base course is watertight
l) NovoCrete® base courses can also be used without any wearing course for a certain period of time

Selected examples are intended to be used for explaining road building with the NovoCrete® ST additives line. The "Jalan Pekoti Timur Road Building Project" in Malaysia has been selected for this purpose. This road is an existing untarred road with a width of approx. 7m and a length of approx. 6.5 miles. The road leads through a palm plantation the palm fruits of which are cultivated for the production of bio fuels (bio diesel).
Due to the industrial production of the palm fruits, the road is primarily used by heavy-duty vehicles. When the road was built, the humic topsoil, i.e. the vegetation zone, was pushed away by means of bulldozers and graders and the natural laterite in the floor was compacted by means of smooth rollers. The road was used without any asphalt course, i.e. during the rainy season the natural laterite close to the surface became deeply soggy due to penetrating water so that the road was no longer passable for heavy-duty vehicles.

2. Laterites

Laterites develop from the intense chemical and partly also physical weathering of primary rocks in humid and warm climatic zones. Under these climatic conditions, the elements of iron and aluminium have the lowest solubility and accumulate in the clayey and sandy soils in the tropics and subtropics. Laterites are well-zoned soils with an eluviated horizon (A) on the top followed by a precipitation horizon (B) and the modified parent rock (C). In the (B) zone, the laterites have 2 often hard crusts of Fe ("ferricrete"), Mn ("mangcrete") or SiO ("silcrete") oxides and hydroxides. The crust formation is promoted by the rotating dry and humid seasons. The typical texture of lateritic soils comprises, for instance, concretions, banded crusts and oolites.

3. Soil analysis of the Jalan Pekoti Timur sample

The delivered soil sample was processed at the soil mechanics laboratory of GeoConCept.

3.1 Particle size distribution in accordance with DIN 18 123-4

At the laboratory, the particle size distribution of the fillings was determined on the won samples in accordance with DIN 18 123-4 and the natural water content was determined in accordance with DIN 18 121.
In accordance with the soil classification for constructional purposes, the delivered soil sample P1 is a poorly graded sand (DIN 18 196: SE) with a screen undersize of 0.61% below 0.063mm.

Sample	Natural water content W_n %	Inhomogeneity $U = d_{60}/d_{10}$	Reduction factor Cc	Share < 0.063 mm %	Soil classi-fication DIN 18 196
P 1	0.5	3.0	1.0	0.61	SE

Tab. 1: *Soil classification in accordance with DIN 18 196.*

3.2 Determination of the Atterberg limits in accordance with DIN 18 122

The Atterberg limits W_l and W_p of the soil sample indicated in table 2 were determined in accordance with DIN 18 122 Part 1. Furthermore, a soil classification in accordance with DIN 18 196 was carried out based on the determined values..

Sample	w_n %	w_l %	w_p %	$I_p = w_l - w_p$	I_c	Consis-tency	Soil class DIN 18 196
P 1	2.1	21.5	10.4	11.1	1.75	fest1	TL

Tab. 2: *Soil classification in accordance with 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 = consistency index (0.0 – 0.5 very soft; 0.5 – 0.75 soft; 0.75 – 1.0 stiff; >1.0 semisolid)

According to the laboratory analyses carried out, the sample is a low-plasticity clay in accordance with DIN 18 196 (DIN 18 196: TL).

3.3 Proctor compaction test in accordance with DIN 18 127

In order to determine the optimum dry density and the optimum water content, each of the soil samples taken was submitted to a Proctor compaction test in accordance with DIN 18 127-P 100 X.

Sample	P 1	P 2
optimum dry density D_{Pr} 100% in g/cm³	1.848	1.868
W_{Pr} in %	7.7	13.0
Wet density in g/cm³	2.10	2.151

Tab. 3: *Results of the Proctor compaction tests in accordance with DIN 18 127.*

Based on a Proctor density of 1.848 g/cm³, an optimum dry density of 7.7% Pr was determined for sample P 1, while for sample P 2, a Proctor density of DPr = 1.868 g/cm³ was determined based on an optimum water content of W_{Pr} = 13.0%.

3.4 Testing the uniaxial pressure resistance in accordance with DIN 18 136

The pressure resistance tests were carried out on cylindrical test pieces with H = 120mm (approx.)/D = 100mm and contents of 10% NovoCrete® ST (180 kg/m³ <> 2% NovoCrete® ST Premix +98% CEMI 32.5 R). In accordance with the DIN 18 127-P 100 X Proctor compaction test, the test pieces were produced with a water content of approx. 10% (P 1) and 15% (P 2).

By analogy with "TP BF-StB Teil B 11.1 Eignungsprüfungen bei Bodenverfestigung mit Zement" [TP BF-StB Part B 11.1 Suitability tests with cement-based soil solidifications], the pressure resistance test was carried out on test pieces of 6 days of age in order to be able to determine the binding agent content required for soil stabilisation. The results of the pressure resistance tests can be seen from table 4.

Sample	NovoCrete® ST in kg/m³	Diameter in mm	Age Days	Rupture load k/N	Pressure resistance N/mm²	Corrective factor	Pressure resistance $N_{korr.}$/mm²
P 1a	180	100	7	26.6	3.39	1.25	4.23
P 2a	180	100	7	17.4	2.21	1.25	2.76
P 1b	180	100	14	30.1	3.83	1.25	4.79
P 2b	180	100	14	19.5	2.48	1.25	3.10
P 1c	180	100	28	50.7	6.46	1.25	8.08
P 2c	180	100	28	28.3	3.60	1.25	4.50

Tab. 4: *Ergebnisse der Druckfestigkeitsprüfung nach 7, 14 und 28 Tagen.*

3.5 Frost classes/frost test in accordance with TP BF-StB Part B 11.1

With respect to their frost susceptibility, the soils can be classified as follows.

Soil	Frost susceptibility class
Poorly graded sand (SE)	F1
Low-plasticity clay (TL)	F2

Tab. 5: *Frost susceptibility in accordance with ZTVE-StB 94*

F1 – no frost susceptibility
F 2 – low to medium frost susceptibility
F 3 – high frost susceptibility

In accordance with the technical testing regulations for "Suitability tests with cement-based soil solidifications", test pieces with a binding agent content of 10% and 28 days of age were submitted to a frost test of the NovoCrete® ST soil mixtures. For this purpose, test pieces with a height of h = 120mm and a diameter of d = 100mm were produced with an optimum water content according to the Proctor compaction test in accordance with DIN 18 127 and submitted to a frost test comprising 12 periods of alternating frost and thaw in accordance with TP-BF-StB Part B 11.1.
The change in length of the test pieces due to repeated stress through frost and thaw was determined. For this purpose, the prepared test pieces were alternately frozen and placed on an absorbent base for thawing and absorbing water at temperatures between +20 °C and -20 °C in accordance with TP BF-StB Part B 11.1 . The change in length TMI of each test piece is the difference between the medium values following the first and the last frost stress. It refers to the original length of the test piece before the first absorption of water. The referred change in length is determined with an accuracy of 0.01%.
The results of the frost test are summarised in table 6. No significant loss of mass, e.g. due to superficial weathering, occurred during the alternating frost/thaw stress. According to the obtained measuring results, the samples can be considered frost-resistant.

Test piece with 10% NovoCrete® ST	Height H_1 before 1st absorption of water mm	Height H_2 after 1st frost mm	Height H_1 after 12th frost mm	Δl (H - H) mm	ref. Δl $\frac{\Delta l}{H_1}$
P 1d	121.036	121.36	121.49	0.175	0.001
P 2d	121.06	123.06	124.03	0.97	0.007

Tab. 6: *Results of the frost test*

4. Soil stabilisation by means of NovoCrete®

A binding agent quantity of 180 kg/m³ of NovoCrete® ST should be used for stabilising and/or solidifying the natural soils (DIN 18 196: SE, TL). In order to achieve the required bearing capacity, the binding agent must be added to the natural soil down to a depth of 0.30m. A summary of the work process is given below:

1. Prepare the rough subgrade approx. 2-3 cm below the height of the later finish subgrade.

2. Apply the NovoCrete® ST binding agent to the soil to be stabilised at a mixing ratio of 180 kg/m³. Based on a mixing ratio of 180 kg/m³ of NovoCrete® ST and an incorporation depth of 0.30m, approx. 54 kg/m³ will be needed. A rotary cultivator should be used for sinking the binding agent into the soil.

3. The existing soil partly is sensitive to water. Therefore, the first sinking process should be carried out without adding water and down to a max. depth of 0,20m. Water should only be added during the second mixing process through the WR® 2500 rotor. The second mixing process will have to be carried out in a way that ensures a minimum layer thickness of 0.30m.

4. According to the obtained results, the optimum water content W for the tested soil samples is 7.7% or 13% respectively. During the stabilisation phase, the water content will have to be increased by approx. 2% depending on the used NovoCrete® ST system.

5. Following the homogenisation of the NovoCrete® ST soil mixture, evenly distribute the loosened soil by means of a laser-controlled grader or bulldozer.

6. Subsequently, dynamically compact the NovoCrete® ST soil mixture with a smooth roller (weight > 8 tons) with activated vibration. Make sure during the compacting work to observe a 50% overlapping of the individual transitions.

7. Subsequently, form the finish subgrade by means of a laser-controlled grader or a bulldozer.

8. Finally, statically compact the base course again by means of a roller. A rubber-tyred roller (weight > 12 tons) should be used for this purpose in order to ensure that negative reliefs are also compacted.

9. In order to prevent the water contained in the soil from evaporating, add an evaporation protection to the compacted surface of the base course, i.e. fully wet the surface with a sufficient amount of water.

When processing NovoCrete® ST, make sure that the time between the first incorporation of the binding agent and the formation of the finish subgrade does not exceed 3 to 4 hours; therefore, the base course should be solidified in several steps. At the age of 28 days, static moduluses of deformation of 300 to 400 MN/m^2 can be expected on the base course and frost blanket thus created based on empirical values.

Fig 1: *Supply of NovoCrete® ST-Premix in bags of 25kg.*

Fig 2: *Spreading the cement supplied in bags of 50kg (CEM I 32.5 R).*

Fig 3: *Laying the NovoCrete® ST additive.*

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Fig 4: *Manual distribution of the NovoCrete® ST additive over the spread cement.*

Fig 5: *Incorporating the NovoCrete® ST cement mixture into the natural lateritic soil with a WR® 2500. Before, the mixture was irrigated by means of a road tanker driving ahead.*

Fig 6: *Homogenised NovoCrete® cement/soil mixture before compaction.*

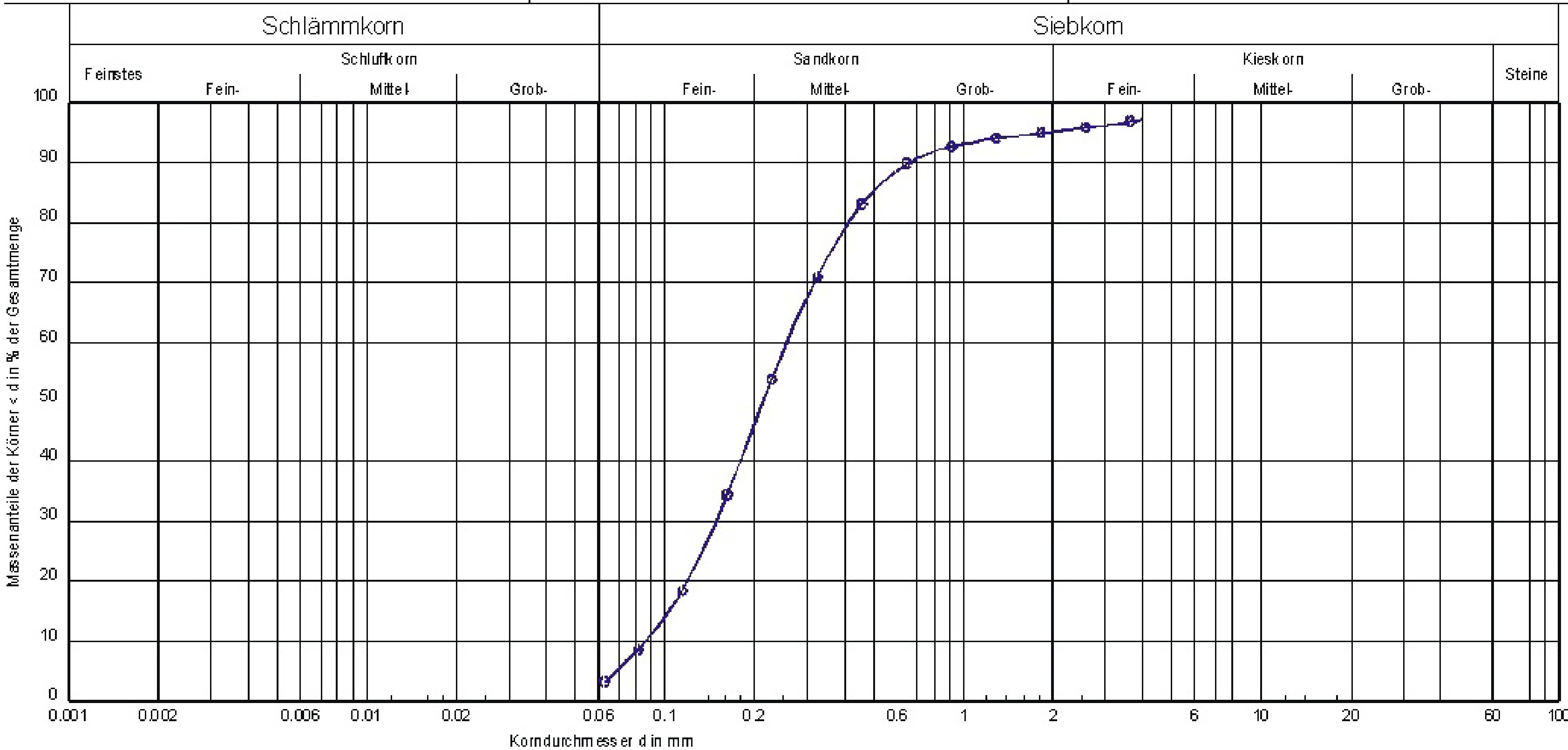
Fig 7: *Forming the finish subgrade by means of a grader, while the right side of the road has already been compacted*

Fig 8: *Dynamic compaction of the NovoCrete® base course with a smooth roller.*

Fig 9: *Bearing capacity measuring by means of a falling weight deflectometer (FED) on the road covered with an asphalt course of 5cm.*

Annex 1:
Particle size distribution in accordance with DIN 18 123-4

GeoConCept GmbH Am Sportplatz 15 35641 Schöffengrund Tel.: 06445 / 612 43 - 0 Bearbeiter: Dipl.-Geol. F. Hohmann Datum: 07.04.2006	Körnungslinie Jalan Pekoti Timur Road Malaysia	Prüfungsnummer: 0406 / 979 I Probe entnommen am: unbekannt Art der Entnahme: gestört Arbeitsweise: trocken



ezeichnung:	Laterite	Bemerkungen: SE	Bericht: AZ 0406 / 979 Anlage: 1
odenart:	fS, mS, gs'		
iefe:	0,0 m - 0,40 m u. GOK		
[m/s] (Hazen):	$8.7 * 10^{-5}$		
ntnahmestelle:	Jalan, Malaysia		
U/Cc	3,0/1,0		

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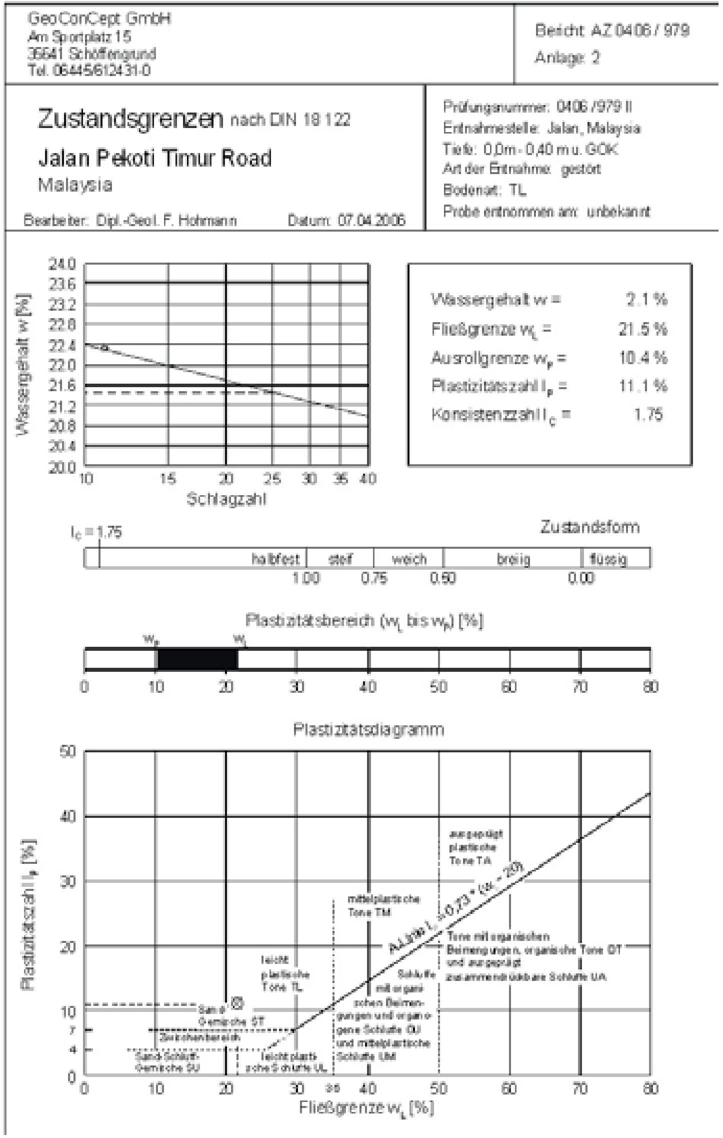
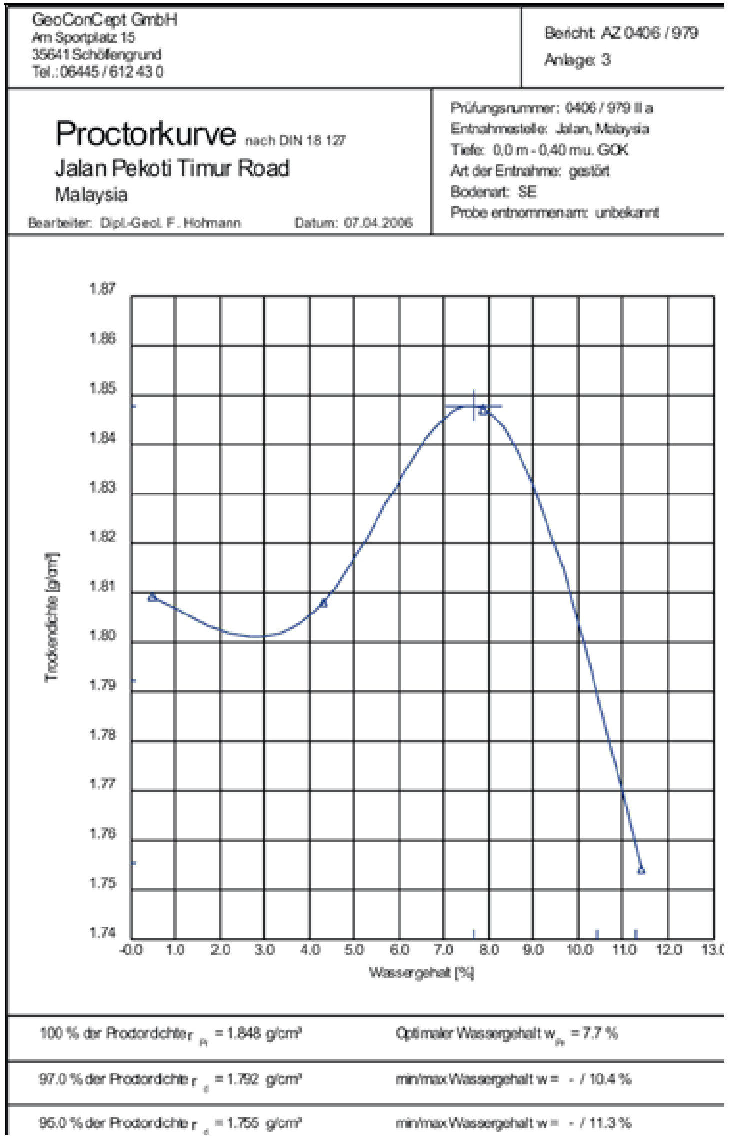


Annex 2:
Determination of the Atterberg limits in accordance with DIN 18 122



Annex 3:
Determination of the Proctor density in accordance with DIN 18 127

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Am Sportplatz 15
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Tel.: 06445 / 612 430

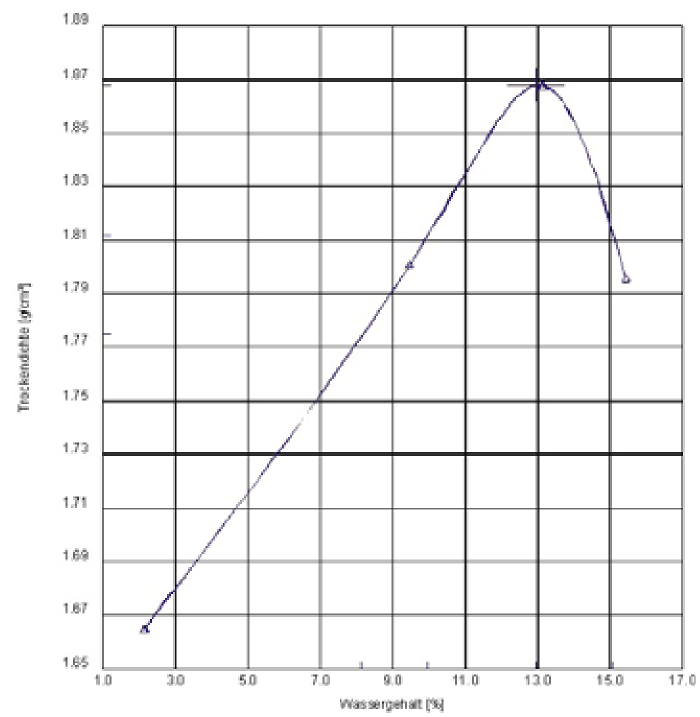
Bericht: AZ 0406 / 979
Anlage: 3

Proctorkurve nach DIN 18 127

Jalan Pekoti Timur Road
Malaysia

Bearbeiter: Dipl.-Geol. F. Hohmann — Datum: 07.04.2006

Prüfungsnummer: 0406 / 979 III b
Entnahmestelle: Jalan, Malaysia
Tiefe: 0,0 m - 0,40 mu. GOK
Art der Entnahme: gestört
Bodenart: TL
Probe entnommen am: unbekannt



100 % der Proctordichte r_{Pr} = 1.868 g/cm³	Optimaler Wassergehalt w_{Pr} = 13.0 %
97.0 % der Proctordichte r_d = 1.812 g/cm³	min/max Wassergehalt w = 9.9 / 15.1 %
95.0 % der Proctordichte r_d = 1.775 g/cm³	min/max Wassergehalt w = 8.1 / - %