IGP GEO ZT GmbH
3130 Herzogenburg, Josef Würtz - Gasse 24
1050 Wien, Schlossgasse 11
3430 Tulln an der Donau, Marc-Aurel-Park 3/1 Top 2
www.ig-prem.at
Ziviltechnikergesellschaft für Bauingenieurwesen

To
ADINOTEC AG
Hohenzollernstrasse 89
D-80795 Munich

1702_Adinotec_Perenium DX_gtst_englisch.docx

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-	-	Herzogenburg, February, 20th, 20I7

Betr.: **Soil improvement with hydraulic binder; product PERENIUM DX**

GEOTECHNICAL REPORT

CONCERNING THE SUITABILITY OF PERENIUM DX AS ADDITIVE

CONTENT:

1. GENERAL

The polymer PERENIUM DX was developed as additive for hydraulic binder treated soils (“polymer modified cement stabilisation”).

For verification of the mode of action of the polymer PERENIUM DX respectively to clarify how far the characteristics of hydraulic binder treated soils will be improved by adding the polymer PERENIUM DX, laboratory tests on a model soil were carried out.

In this connection IGP Geo ZT GmbH, Herzogenburg, was assigned by ADINOTEC AG, munich, for carrying out a geotechnical report concerning the suitability of PERENIUM DX as additive for hydraulic binder treated soils.

As basis for this report the Expert report on results of comparative tests of cement treates soils containing polymer PERENIUM DX, prepared by Nievelt Labor GmbH, Stockerau, on Dec. 18th, 2016, was used. It will be noted, that the laboratory test were carried out in closely coordination with our company.

In this report in a first step a summary of the results of the laboratory tests should be given.

After that a geotechnical evaluation of the test results will be prepared.

Finally possible fields of application will be presented, where the addition of the polymer PERENIUM DX as additive to hydraulic binder provides a technical and an economical advantage.

Introductorily it will mentioned, that the percentage data in the following chapters are throughout percentages per mass.

2. TESTS CARRIED OUT; TEST RESULTS

For verification of the mode of action of the polymer PERENIUM DX concerning the **change of strength properties and frost resistance** of hydraulic binder treated soils, comparative laboratory test were carried out.

All natural soils have inhomogeneity. Therefor the laboratory tests were carried out on samples of model soils, to increase the comparability.

The model soil is a mixture of 80 % quartz sand (product Siligrans) and 20 % quartz powder (product Microsil M300). The grain size distribution shows a sand content of 80 %, a loam content of 17 % and a clay content of 3 %. The model soil can be classified as silty sand (si SA).

As binder the cement type CEM II/B-M (C-L) 32.5 R was used. The dose of the binder was fixed with consistently 3.5 %.

As additive the polymer PERENIUM DX was dosed with 0 %, 2.5 % und 4.0 %, referred to the cement mass.

The mixtures for soil treatment with cement and the polymer PERENIUM DX were prepared in a compulsory mixer. The moisture content of the mixture was defined at 8 %. The test specimens (d=150 mm) were produced by means of the method of the proctor density in accordance with EN 13286-2:2012.

The following tests were carried out to determine the relevant strength properties and frost resistance of the cement treated soils:

- 7 and 28 day compressive strength values according to EN 13286-41:2003
- 7 and 28 day indirect tensile strength values according to EN 13286-42:2003
- Modulus of elasticity in the indirect tensile test according to EN 13286-43:2003
- Frost resistance of the cement treated soils - measurement of linear expansion in accordance with the technical regulation for tests of soils and rocks in the road construction (TP BF StB, part 11, Item 1)

The first three tests are relevant for the evaluation of the strength properties and the last mentioned test is relevant for the frost resistance of the cement respectively cement and PERENIUM DX treated soil.

In the following tables the test results are shown. In addition the percentage increase to the values of the cement treated soil without the polymer PERENIUM DX is stated in brackets.

- compressive strength

designation of the mixture	**7 day-strength** N/mm²	**28 day strength** N/mm²
cement	2,3	4,2
cement+2,5% PERENIUM	**2,6 (+10%)**	**5,1 (+20%)**
cement+4 % PERENIUM	1,9 (-21 %)	4,2 (+/-0)

- indirect tensile strength

designation of the mixture	**7 day-strength** N/mm²	**28 day strength** N/mm²
cement	0,10	0,30
cement+2,5% PERENIUM	**0,17 (+70%)**	**0,33 (+10%)**
cement+4 % PERENIUM	0,10 (+/-0)	0,27 (-10%)

- E-Modulus

designation of the mixture	**28 day strength** N/mm²
cement	228
cement+2,5% PERENIUM	**419 (+83%)**
cement+4 % PERENIUM	356 (+56%)

❍ frost resistance

designation of the mixture	**linear expansion** ‰
cement	23,2
cement+2,5% PERENIUM	**7,9 (-66%)**
cement+4 % PERENIUM	6,1 (-74%)

3. GEOTECHNICAL EVALUATION OF TEST RESULTS

In this chapter the geotechnical aspect of the test results, summarised in chapter 2 should be evaluated.

Especially the effect of the addition of the polymer PERENIUM DX toward the strength properties of the cement treated soil on the one hand and the frost resistance on the other hand should be analysed.

❍ strength properties

The test results concerning the **compressive strength** show, that the addition of 2.5 % PERENIUM DX, referred to the cement mass, leads to a significant increase of the strength. After 7 days it is 10 % und after 28 days 20 %. The 7 day value of 2.6 MN/m^2 remains, by addition of the polymer PERENIUM DX, only just under the requirements for cement-stabilised base course according RVS 08.17.01. In this standard the required value is 3.0 MN/m^2. By increasing the cement dose this value also can be reached.

A higher dose of the polymer PERENIUM DX remains however without any positive impact to the compressive strength. The reached values are nearly the same as the values which result without addition of PERENIUM DX.

The indirect tensile strength increase with the addition of 2.5 % PERENIUM DX short time about 70% after 7 days and long-term about 10 % after 28 days.

A higher dose of the polymer PERENIUM DX remains however without any positive impact to the indirect tensile strength. The reached values are about 10 % below the values which result without addition of PERENIUM DX.

The **E-modulus,** who is applicable for the deformation behaviour, increases with the addition of 2.5 % PERENIUM DX% strongly. The value is 83 % higher, and therefore the deformability is significant lower. This has a very positive effect to the bearing capacity.

A higher dose of the polymer PERENIUM DX leads to a slightly lower increase about 56 % to the values, which result without addition of PERRENIUM DX.

In **summary** the addition of 2.5 % PERENIUM DX is the optimum in technical and economical point of view.

This dose of the polymer PERENIUM DX leads to a very positive effect toward the carrying and the deformation behaviour of the cement treated soils. Due to the higher carrying behaviour, a reduction of the thickness of the soil exchange and the base course can be effected.

On the other hand the lower deformability has a positive effect concerning the dimensioning of the asphalt respectively concrete road surface. According to this, the thickness of the asphalt layers and concrete paving slab can be reduced. In case of the concrete slab (factory halls) also the reinforcement content can be reduced.

The lower deformability should be quantified for the road construction in the course of a test field. There static and dynamic load plate tests should be performed to receive the relevant deformation modulus E_{v2} and E_{vd} for road construction.

- <u>frost resistance</u>

The frost resistance will be exorbitantly improved with the addition of PERENIUM DX. The frost heave is reduced by adding 2.5 % PERRENIUM DX about 66 % and by adding 4.0 % PERENION DX about 74 %. The improvement from 2.5 % to 4.0 % is however low.

The received values of 7.6 ‰ respectively 6.1 ‰, are only little above the limit value for binder treated fine and mixed grain soils of 1 ‰ (according ZTV-StB), although the model soil has a high silt/clay content of 20 %.

The limit value for frost-proofed aggregates according ÖNORM B 4811:2013, point 5.4, of 10 % (15 mm for sample height of 150 mm) is noteworthy undercut.

Therefore the samples with addition of the polymer PERENIUM DX are frost proofed at least for streets of the secondary road network.

4. POSSIBLE FIELDS OF APPLICATIONS

In this chapter a geotechnical evaluation due basis of the test results and an outlook on possible fields of applications for PERENIUM DX should be presented.

For the possible fields of applications the improvement of the carrying and the deformation behaviour on the one hand and the increase of the frost resistance otherwise have to be taken into consideration.

The possible fields of applications are below-mentioned.

- Rehabilitation of secondary roads with frost damages

In the secondary road network a lot of streets exist, who have no structure state of the art. That leads to ongoing frost damages, which usually will be temporary rehabilitated. A total rehabilitation is only provided, when the local damages reach a too large extend.

In this connection the addition of PERENIUM DX to the cement treated soil offers the possibility, to stabilise the existing subgrade of the roads. With this measurement the bearing capacity can be increased to the requirements of the standards. PERENIUM DX offers the additional

advantage, that the subbase becomes frost resisting. According to this, frost damages in the future can be minimised.

Furthermore the existing subbase materials can be reused. Therefore the material requirements and the disposal of materials fall away. Due to the removal of the transportation, the construction time and the environmental impact can be minimised.

- Construction of the secondary roads/agricultural and forest roads/parking areas/areas of operations

Due to the increase of the frost resistance of the subsoil by adding the polymer PERENIUM DX, the thickness of the frost protection layer can be reduced respectively only the mechanic stabilised base course (20 cm) is necessary.

In addition the increase of the bearing capacity of the subgrade and the reducing of the deformability enable the possibility of optimising the thickness of the asphalt layers.

- factory buildings

In factory buildings often monolithic or double reinforced concrete slabs are realised.

By stabilising with hydraulic binder and addition of PERENIUM DX on the one hand the deformability can be reduced and otherwise the frost resistance can be reached.

To that effect the thickness of the frost protection layer can be reduced respectively only the mechanic stabilised base course (20 cm) is necessary.

The increase of the bearing capacity also enables an optimised dimensioning of the concrete slab in the building due to a stiffer bedding of the slab.