

Contaminated soil - cement stabilization in a demonstration project.

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Abstract

Public Works Rotterdam has carried out a feasibility study on the application of contaminated soil-cement stabilization layers (ref. 1). Conclusion was that contaminated soil can be beneficially used as a soil-cement stabilization in a road construction. As a follow-up, a full scale demonstration project (1.000 m²) was realized in 1995: a (sub)base of a soil-cement stabilization layer with soil that should have been landfilled (ref. 2). Samples of the soil-cement layer have been tested on both environmental and physico-mechanical aspects.

Conclusions were that the base is environmentally safe and no isolating provisions are required. The compressive strength is sufficient according to the standard of 1.5 N/mm². However, the need for licences and an environmental impact assessment and the procedure time involved will be the bottle-neck for the on-site immobilization of (hazardous) waste materials in constructions.

Introduction

In the city of Rotterdam large quantities of polluted soil are excavated as a result of soil sanitation and/or infrastructural works. The policy aims of the government and the municipality of Rotterdam are in the first place the beneficial use, secondly to clean and thirdly to landfill the polluted soil, depending on the type of soil combined with the type and content of contaminants.

In infrastructural works, the base is mostly constructed of primary sand - cement stabilizations. The question was whether the (clean) sand could be replaced by polluted, sandy soils.

The policy of beneficial use of the municipality of Rotterdam is being implemented by stimulating the use of contaminated soil in infrastructural works. Public Works Rotterdam has carried out a feasibility study on the application of contaminated soil-cement stabilization layers (ref. 1). Conclusion was that contaminated soil can be beneficially used as a soil-cement stabilization in a road construction. The question was whether the immobilisation of strongly polluted soil is executable on a full-scale project.

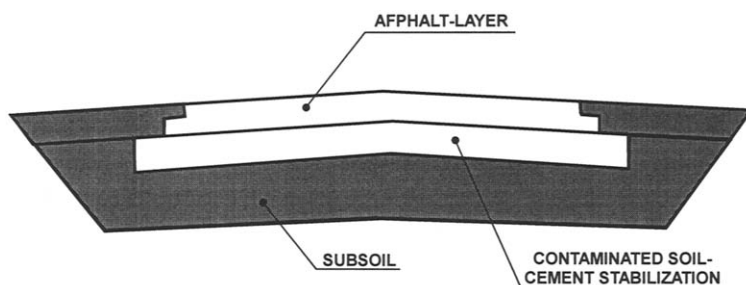
In 1993 the national government started a tender-program on immobilization: Technology 2000 - Immobilization. The goal of this program is to stimulate the development and implementation of immobilization techniques on 22 selected hazardous materials, including non cleanable polluted soil.

As a follow-up of the feasibility study and within the framework of the program Technology 2000 - Immobilization, a full scale demonstration project was realized in 1995: a (sub)base of a soil-cement stabilization layer with soil that should have been landfilled (ref. 2). The stabilization is the base of the temporary storage site of DOP-NOAP, a landfill for polluted soil in Rotterdam. The goals of this project were:

- * the demonstration and testing of the beneficial use of polluted soil immobilized with cement as a road base.
- * to check the feasibility and practical aspects of the immobilization process.

- * to determine the performance of the soil/cement stabilization under practical use.

Figure 1 shows a cross-section of the construction.



Methods and materials

The project consisted of the following steps (see figure 2):

- 1) the selection of a batch of polluted soil, which has to be landfilled (physical and environmental criteria)
- 2) the characterisation of environmental and physical quality of the soil
 - *content of contaminants and leaching behaviour
 - *grain-size, pH, organic matter
- 3) the determination of the optimal cement addition.
- 4) the determination of practical aspects of the construction
 - *mixed in place
 - *mixed in plant
- 5) the sampling of cylinders after execution and hardening
- 6) the determination of environmental and physical quality of the soil/cement stabilization
 - *compressive strength, durability.
 - *leaching behaviour

In order to landfill the polluted soil, a large number of batches are registered at the Soil- and Residuebank of Rotterdam. Some of these batches are suitable for immobilization. As a result of the feasibility study some initial criteria were derived for the selection of batches of soil.

- * organic matter < 10% dry weight
- * fines (< 2 μm) < 5% dry weight
- * moisture content < 10%

The batch which best met these criteria, was selected and stored at the site. Then samples were taken in order to characterize the batch and several tests were carried out in the laboratory. The leaching of the soil has been determined according to NEN 7343.

One of the most important questions was the optimal addition of cement and the question whether other additives had to be added. The physical tests were carried out according to the Dutch RAW-standards. After 28 days of hardening, the compressive strength of the proctors was determined. If they met the standard (5.0 N/mm²), the proctors were tested in the tank leaching tests (NEN 7345), to determine the leaching of the immobilized product.

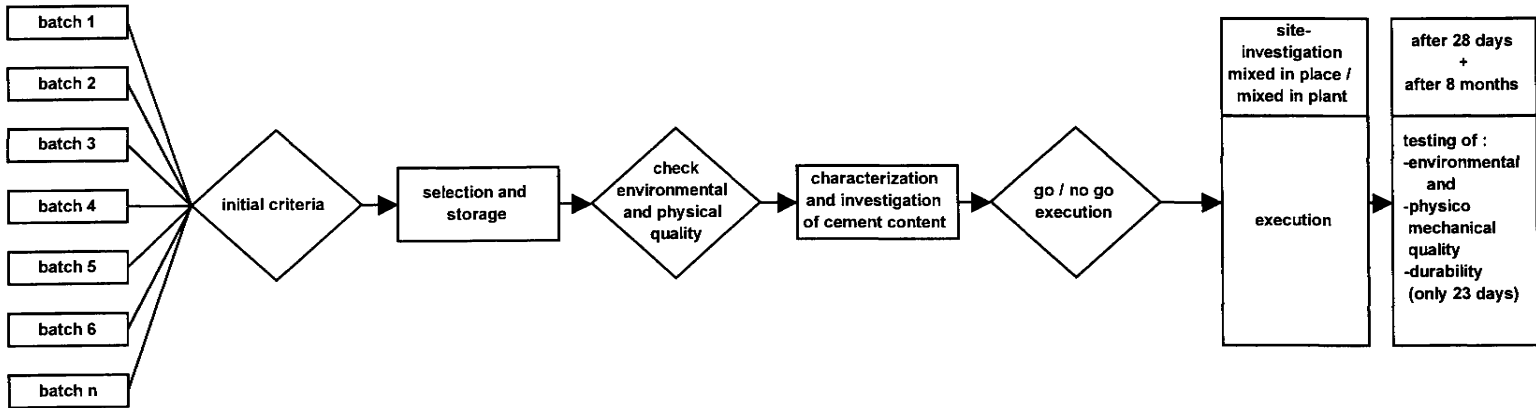


Figure 2: The scheme of the project

When a batch is qualified as suitable and a large scale infrastructural work is planned, the go/no go decision can be made. The local geology of the site determines the method of realisation ('mixed in place' or 'mixed in plant'). After the realisation samples were taken in order to determine the environmental and physico-mechanical quality of the immobilized product.

After respectively 28 days and 8 months of hardening, samples (cylinders) were taken out of the base. The cylinders were tested on both physico-mechanical and environmental aspects. Compressive strength, durability and leaching of the cylinders were determined after 28 days. After 8 months the compressive strength and leaching of the samples were determined again. Durability is defined as the resistance against wetting, drying and freezing and is investigated by wet-dry and freeze-thaw cycles. The cylinders were exposed to wet/dry and freeze/thaw -cycles, according to Dutch RAW-standards. After those cycles the compressive strength has been measured again.

Results and discussion

Characterisation of the batch

A batch of about 500 tons of soil, contaminated with heavy metals, mineral oil and poly aromatic hydrocarbons (pah's) and supposed to be landfilled, was selected for the base. In table 1, the results of the most critical components are shown. In the national Dutch legislation for the use of raw and secondary materials (Bouwstoffenbesluit, the Dutch Building materials Decree) criteria for the use of soil are included. For both granular and immobilized materials standards on content and leaching have been developed.

Table 1: environmental quality

component	content		Leaching	
	Range	Trigger value	L/S=10	Trigger value
Copper (mg/kg)	95,2 - 181	87,5	0,0660	0,58
Lead (mg/kg)	46,5 - 125	325,5	0,0500	1,6
Zinc (mg/kg)	124 - 274	278,0	0,327	3,3

According to the mentioned legislation for beneficial use, the soil is not suitable because of the high content of copper and the presence of oil and pah's. However, for immobilized soil and/or other materials, there aren't any standards for the content of heavy metals (and other anorganic components). On the other hand, the products or materials have to meet the standards for leaching for these anorganic components. For the organic components, no leaching tests have yet been developed, so the standards are based on the content of these components.

From table 1 can be concluded that the leaching of copper, lead and zinc meet the standards for unisolated application. The addition of cement should be sufficient to produce a product which is environmentally safe.

Next, the physico-mechanical aspects of immobilization were determined. The results are presented in table 2.

Table 2: physical quality and demand of cement

Moisture content	17,6 % 21,6 %
Fineness modulus (test 18)	1,50 1,90
pH-test 10% cement (test 23.2)	12,11 12,13
Suitability test (test 22.1)	
10 % cement	1,6 N/mm ²
10 % cement	1,6 N/mm ²
10 % cement	1,5 N/mm ²
Determination content of cement (test 22.2)	
8 % cement	2,7 N/mm ²
10 % cement	5,0 N/mm ²
12 % cement	3,7 N/mm ²

The optimal content of cement is derived from the results in table 2 and the feasibility study with several batches of polluted soil (ref. 1). In the feasibility study an empirical relation between moisture content and cement content has been observed. It is concluded that the water-cement ratio should be 1:1. The moisture content of the batch was in the range 17,6 - 21,6%, so, according to the feasibility study the cement-content should be about 19%. The standard for the compressive strength of proctovs is 5,0 N/mm². From table 2 a cement-content of 10% was deduced. In the demonstration-project, the mean of these two contents, 14,5% of cement, was used.

Practical aspects of realisation

The most easy way to realize the soil-cement stabilization layer is the mixed-in-place technique. Because of the instable subsoil at the site, it was not possible to get a proper mixture and condensation of the soil-cement. By using the mixed-in-plant proces, it was possible to get a good mixture of soil, cement and water. Next, the mix was put into the site and rolled with a road-roller and covered with an asphalt layer. The area of the soil-cement stabilization is about 1.000 m².

Physico-mechanical and environmental aspects

The results of the physico-mechanical tests are displayed in table 3. According to Dutch standards the compressive strength of cylinders should at least be 1,5 N/mm². From tabel 3 it can be concluded that the compressive strength of all samples meets this

standard. From our experiences with traditional sand-cement stabilizations, the distribution in the results is in the same order of magnitude. After wet-dry and freeze-thaw cycles, the cylinders keep their strength, so the sustainability is judged to be good.

Table 3: physico-mechanical aspects

physico-mechanical aspect	average		median	minimum		maximum	
	28 d	8 m	28 d	28 d	8 m	28 d	8 m
Volumic weigth (kg/m ³)	2000 (n=16)	1972 (n=3)	1998	1933	1935	2079	2000
Comp.strength (N/mm ²)	3,1 (n=16)	4,7 (n=3)	2,8	1,6	3,0	6,2	7,1
After freeze/thaw-cycles (n=8)							
- comp. strength	3,5	2,9	1,6			8,2	
- volumic weigth	2013	2007	1960			2090	
After wet/dry-cycles (n=8)							
- comp. strength	4,5		3,2	1,9		7,8	
- volumic weigth	1944		1919	1835		2043	

The environmental research consisted of tank leaching tests. After 28 days and after 8 month 3 samples were tested. These tests should be carried out for a period of 64 days, according to NEN 7345. As the granular soil already met the leaching standards, the leaching was tested for control. Most of the leaching of the components takes place in the first 4 days. A test for the period of 4 days normally gives a sufficient indication of the leaching behaviour. In table 4 the results of the leaching tests are given. The leaching is much below the trigger values. The base is environmentally safe and no isolating provisions are required.

Table 4: environmental aspects, range of leaching in mg/kg

	Cupper	Lead	Zinc
sample after 28 days (leaching during 4 days)	1,93 - 2,66	1,92 - 3,26	1,89 - 1,92
sample after 28 days (leaching during 64 days)	4,96	3,26	3,24
sample after 8 month (leaching during 4 days)	3,10 - 4,36	1,74 - 1,81	1,74 - 1,94
triggervalue reuse (leaching during 64 d)	51	120	200

Legislation

In the Dutch legislation, the Environmental Management Act, a licence is required for the treatment of waste-materials. For the treatment of hazardous waste, an Environmental Impact Assessment has to be submitted. In that way, the on-site immobilization of waste materials in case of the beneficial use in infrastructural works, also needs a licence.

In this demonstration project the environmental licence to perform the project was no obstacle, because it was part of a larger project which already demanded a licence. In following immobilization projects, permission can be an obstacle because of the long procedure time and the large amount of information which should be submitted. In many cases an environmental impact assessment study will be demanded.

Costs

The costs of the soil-cement stabilization are comparable to the costs of a standard sand-cement stabilization and a base of granular, broken debris (so-called 'Repak'). The positive gain of the beneficial use of the contaminated soil are the costs of disposal in the landfill (about 80 Dutch Guilders a ton, which do not have to be paid). The negative gains are the costs of additional cement, additional handling, environmental and physico-mechanical research. The differences in costs of the soil-cement stabilization layer are about $f 1,-/m^2$ in relation to repak and $f 40,-/m^2$ in relation to sand-cement. Soil-cement is the economical most beneficial option.

The use of cement is a critical aspect for an economic advantage. A lower content of cement will give a substantial reduction of the costs. The cement content in the soil-cement stabilization is 4 to 6% more than in a regular sand-cement stabilization.

In case of a small batch of polluted soil the costs of environmental and physico-mechanical research are relatively high. The use of contaminated soils for a cement stabilization in a (road-) base seems to be economical beneficial when the total amount of soil is at least 500 tons.

Conclusions

The conclusions of the project were:

- The leaching of metals is in accordance with Dutch standards. The base is environmentally safe and no isolating provisions are required.
- The compressive strength is sufficient according to the standard of 1.5 N/mm². The distribution in the results is equal to those of sand-cement stabilizations. The durability is judged to be good.
- Considering the costs of landfilling, a minimal batch size of 500 tons of soil is economical beneficial, when it is used in infrastructural works.
- The site, including its base, is still in use, and no problems are being encountered.
- In future projects a critical review on the optimal content of cement is recommended. The results of standardized tests in a laboratory with each batch of soil are preferable to the use of the empirical relation of the water-cement ratio.
- The need for licences and an environmental impact assessment will cause problems for the on-site immobilization of hazardous materials in constructions. Certification of processes and contractors (quality management) are recommended as important alternatives.

References

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