

Re-use of Sieve sand from demolition waste

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Abstract

Sieve sand originates from activities as sorting and/or breaking of demolition waste. In a breaking process the first step is a sieve step, to remove the fines. Next, the coarse material is broken and upgraded to a secondary raw material, which can be used as a coarse aggregate in concrete, or as a road construction material. The fine material (sieve sand) cannot be applied without due consideration. The sieve sand may be contaminated with Poly cyclic Aromatic Hydrocarbons (PAHs) to such an extent that, according to the Dutch Building Materials Decree, the sieve sand is not applicable as a granular building material.

For this reason Van Bentum Recycling Centrale ordered TNO to carry out a research into the possibilities of stabilising/solidifying the sieve sand in such a way that the PAHs are fixed (immobilised).

In the Building Materials Decree the organic contaminants are assessed on the basis of total concentration, in mg/kg. However, from an environmental point of view, not the total concentration, but the leaching is relevant. For this reason, the impact on the environment of the application of stabilised sieve sand has been assessed in terms of mg leached per square meter surface area by TNO.

The results of the leaching tests performed, show that even highly contaminated sieve sand (containing up to 1,000 mg/kg PAHs) can be sufficiently stabilised. Only 0.7 mg/m² (being 0.002 % of the total concentration) is being leached during the 64 days lasting Dutch diffusion test.

Introduction

In The Netherlands most of the demolition waste is being upgraded to a secondary raw material and re-used as a coarse aggregate in concrete, or as a road construction material. To obtain a material of high quality the demolition waste is sieved first, to remove the fines. This fine material (sieve-sand) should not be disposed of, but utilised, both from an economic and environmental point of view. On the other hand, it cannot be applied without due consideration. The sieve-sand may be contaminated with Poly cyclic Aromatic Hydrocarbons (PAHs) to such an extent that, according to the Dutch Building Materials Decree, the sieve-sand is not applicable as a granular building material (as will be explained in the next paragraph).

For this reason Van Bentum Recycling Centrale ordered TNO to carry out a research into the possibilities of stabilising/solidifying the sieve sand in such a way that the PAHs are fixed (immobilised). The intention is to use the stabilised sieve sand to heighten a piece of land for use

as an industrial area. The stabilised sieve sand has to be environmentally assessed as a monolithic material, on the basis of leaching.

In this paper the characteristics of sieve sand will be described first. Then a description will be given of the stabilisation process, that was used to immobilise especially the PAHs. After that the results of a leaching test on the stabilised sieve sand are given and the stabilised material is environmentally assessed. Finally the paper ends with some conclusions and a recommendation.

Sieve sand and its leaching characteristics

Sieve sand originating from a breaker of demolition waste, consists for the greater part of sand and small concrete and ceramic brick particles. Besides, it may also contain small particles of wood, roofing material or plastics. Though these kind of “physical” contaminants are relevant for the strength development of the stabilisation, environmentally the “chemical” contaminants are of more importance. The most critical chemical contaminants are PAHs and sulphate. The PAHs are present in tar-containing particles, originating from for instance roofing material, chimneys or tar containing asphalt concrete. The sulphate originates from mortar and plasterboard.

For the research, described in this paper, a sieve sand sample was used containing high concentrations of contaminants, as a worst case. Only the PAH content was measured. The sample contained 1000 mg/kg PAH (the 10 of the Dutch Ministry of VROM). This is much more than is allowed by the Dutch Building Materials Decree.

As for the environment, not the total content of contaminants in a material is important, but only that part of the contents that will leach out, in its application. For that reason in The Netherlands the environmental assessment of building materials is primarily based on leaching (at least for inorganic contaminants). Because of the fact that for organic components standardised leaching tests are not available yet, the assessment of organics is still based on total content. Nevertheless, in this paper also PAHs will be environmentally assessed on the basis of leaching. For this reason part of the sieve sand sample was leached in a column test for organic components, in accordance with the draft standard NVN 7344. In this column test, up to a liquid / solid (L/S) ratio of 10 l/kg, totally 0,26 mg/kg PAHs were leached. Even if the Dutch Building Materials Decree should assess the utilisation of granular (unbound) sieve sand on the basis of leaching (instead of total concentration), this sample of sieve sand would not be allowed to be utilised. The calculated immission of PAHs would be two times higher than the limit value of a category 2 application [1]. However, from an other investigation it follows that a sample with a lower total concentration of PAHs (490 mg/kg) has leaching characteristics that would allow it to be utilised as a category 2 construction material [2].

Not only the leaching of PAHs was determined, but also the leaching of inorganic contaminants. The leaching of the heavy metals that were investigated (for instance arsenic, barium, molybdenum and antimony) was far below the limit values of the Building Materials Decree (even the category 1 limit values). On the other hand, the leaching of sulphate was beyond the category 1 limit value, but below the category 2 limit value.

From these investigations it can be concluded that highly contaminated sieve sand should not be utilised as such, from an environmental point of view. According to the Building Materials Decree, the total concentration of PAHs is too high (even though this is environmentally less relevant). Nevertheless, also an assessment based on leaching indicates that this sieve sand

should not be used as such, because of the leaching of PAHs. Besides, the leaching of sulphate exceeds the limit value of a category 1 application. Therefore stabilisation is a must.

Stabilisation of PAH-containing sieve sand

A research has been carried out to find the best binding agent for the stabilisation / solidification of the sieve sand, described in the previous paragraph. Four different agents were tested in two addition percentages (5% and 10%):

- blast furnace slag cement;
- geo-cement (a cement produced from secondary raw materials);
- a mixture of blast furnace slag cement and an additive;
- a special cement, specifically developed to bind high concentrations of organic components.

Three criteria were used in finding the best binding agent. First of all the mechanical strength after 28 days of hardening had to be beyond 5 MPa. The specimens with 5% binding agent added, did not fulfil this criterion. Of the specimens with 10% binding agent 3 kinds had a pressure strength of more than 5 MPa. The only one that did not, was geo-cement.

The second criterion was the leaching of PAHs from the stabilised material, determined by means of the diffusion test (tank leaching test). The leaching of PAHs of the remaining three types of specimens differed from 0.7 mg/m² surface area (blast furnace slag cement with additive) to 3.6 mg/m² (special cement).

The third criterion was the price of the binding agent. The blast furnace slag cement was much less expensive than the special cement. Concerning the additive, this was little more expensive than the blast furnace slag cement itself, but the mixture performed better than the cement as such, so the mixture of blast furnace slag cement and the additive was chosen as the best binding agent.

In the experiments mentioned in the following paragraphs, stabilised sieve sand was investigated, that was mixed up with 9% blast furnace slag cement and 1% of an additive. The material was compacted well in cubes of 10 * 10 * 10 cm. After 28 days of hardening the density of the material was 1900 kg/m³. The pressure strength was 6 MPa.

Leaching of PAHs from stabilised sieve sand

The leaching characteristics of a stabilised, monolithic material are in The Netherlands determined by means of the diffusion test (or tank leaching test). This test is standardised for inorganic components (NEN 7345). In this standardised test the specimen (or product) is immersed in five times its volume leachant, consisting of demineralised water, beforehand acidified to a pH of 4 with nitric acid. This leachant is renewed at 0.25, 1, 2.25, 4, 9, 16 and 36 days after the start of the test. At 64 days the test is finished. The eight eluate fractions are filtered, measured (pH and conductivity), conditioned and analysed on relevant components. From the analysis results for each component the quantities leached at the eight different times are calculated (expressed in mg/m² surface area). These emissions are then plotted against time (on a double logarithmic scale). If the leaching indeed is diffusion controlled, this should yield a straight line with a regression coefficient of 0.5. If so, a diffusion coefficient can be calculated from the leaching data. This diffusion coefficient can be used to predict a diffusion controlled leaching (emission) in course of time by extrapolating the leaching with time.

In the research, described in this paper, the leaching behaviour of all inorganic components, mentioned in the Building Materials Decree, was investigated. Only a small number of components could be detected (Ba, Cu, Mo, Ni, Sb, V, Zn, Cl, SO₄). The results (emissions) are given in table 1.

In the Building Materials Decree the organic components are assessed on the basis of total concentration, in mg/kg. However, from an environmental point of view, not the total concentration of a contaminant in a building material is important, but its leaching from the building material. For this reason, the impact on the environment of the application of stabilised sieve sand has been assessed in terms of mg leached per square meter surface area by means of the diffusion test. In principal this test was performed in accordance with NEN 7345, but additionally, some pre-cautions were taken to prevent the degradation and/or the absorption of leaching PAHs. The pre-cautions were:

- The leaching vessel was made of glass and covered to avoid evaporation of the more volatile PAHs.
- The leaching vessel was packed in aluminium foil, to prevent degradation of PAHs by ultra-violet radiation of sunlight.
- The eluates were filtered in teflon filter devices, by means of pressure filtration, to avoid absorption of PAHs in the device.
- The eluates were put in brown flasks in between the time of sampling and the time of analysis, again to avoid degradation of PAHs.

The leaching of PAHs, determined in this way (according to NEN 7345, with additional pre-cautions), proved to be diffusion controlled, on the analogy of the inorganic components. The diffusion coefficient was very low ($1,5 \cdot 10^{15}$ m²/sec). The emission in 64 days was 0.68 mg/m².

Environmental assessment of PAH-leaching

In table 1 not only the emissions (in terms of mg/m² product surface area) are given, but also calculated *immissions*, in terms of mg/m² soil surface area. These immissions are calculated in order to be able to compare the leaching test results with the limit values of the Building Materials Decree. These limit values (Maximum Allowable Immissions into the soil), are based on the principle of “Marginal Burdening” of the soil. This means that the upper meter of soil may not be contaminated by leaching from building materials in there application by more than 1% of the target values for soil. The Building Materials Decree distinguishes two categories of applications, one without provisions to prevent rain water from coming into contact with the building material (Category 1) and one with those provisions (Category 2). These provisions can be a non-permeable clay liner or a plastic liner.

Table 1: Leaching characteristics of stabilised sieve sand

Component	Emission (calculated) in mg/m ²	Immission Cat. 1 application in mg/m ²	Immission Cat.2 application in mg/m ²	Max. Allowable Immission in mg/m ²
As	< 0.33	< 1.5	< 0.5	435
Ba	16*	170	54	6300
Cd	< 0.07	< 2.2	< 0.7	12
Co	< 0.67	< 7	< 2.2	300
Cr	< 0.33	< 3.4	< 1.1	1500
Cu	0.6	6.3	2.0	540
Hg	< 0.66	< 1.5	< 0.5	4.5
Mo	1.4	3.6	1.1	150
Ni	1.1	11	3.6	525
Pb	< 0.67	< 7.0	< 2.2	1275
Sb	0.38	4.0	1.3	39
Se	< 0.66	< 1.5	< 0.5	15
Sn	< 1.3	< 3.0	< 1.0	300
V	5.1	49	15	2400
Zn	10	100	33	2100
Br	< 66	< 370	< 120	300
Cl	2400*	4100	1300	30000
CN	< 20	< 150	< 47	75
F	< 66	< 690	< 220	14000
SO ₄	51000*	85000	27000	45000
PAHs	0.68*	7.1	2.3	15

* = calculation based on a diffusion coefficient

From table 1 it can be learned that the calculated immissions for most inorganic components are below the maximum allowable immission values, even for a category 1 application, except for SO₄. For the anions Br and CN this is no sure, because the analysis techniques are not able to determine such low concentrations yet. The sulphate immission for a category 1 application is higher than the limit value, whereas the calculated immission for a category 2 application is still below the limit value. So, the stabilised sieve sand should be considered a building material that can be utilised in category 2 applications only (because of the leaching of sulphate).

Also for PAHs immissions have been calculated, even though the Building Materials Decree does not give a maximum allowable immission for PAHs (because the Building Materials Decree assesses PAHs on the basis of total content). So, to be able to assess PAHs on the basis of leaching, a "maximum allowable immission" for PAHs had to be derived. This was done, starting from a target value of soil for PAHs of 1 mg/kg and following the same route as was done in the Building Materials Decree for inorganic components. In that way a maximum allowable immission of 15 mg/m² was calculated for PAHs.

The leaching of PAHs is very low, compared with the total amount. Only 0.002% of the PAHs present in the stabilised sieve sand are leached during the 64 days lasting diffusion test.

From table 1 it can be learned that, if PAHs would be assessed on the basis of leaching, the stabilised sieve sand would not have any problems to fulfil the criteria, even for a category 1 application.

The results of this leaching research show that the stabilisation process is capable to decrease the leaching of PAHs to such an extent that that it can be considered harmless to the environment. This is in contradistinction to the conclusion of an assessment on the basis of total content of PAHs. For this reason it is highly recommended to environmentally assess organic components in building materials on the basis of leaching, on analogy to inorganic components.

Conclusions

- Highly contaminated sieve sand may not be utilised, neither if assessed on the basis of total content of Poly cyclic Aromatic Hydrocarbons (PAHs), nor if assessed on the basis of leaching of these PAHs.
- This highly contaminated sieve sand (containing up to 1,000 mg/kg PAHs) can be stabilised well by adding 9% of blast furnace slag cement and 1% of an additive. Only 0.7 mg/m² (being 0.002 % of the total concentration) is being leached during the 64 days lasting Dutch diffusion test.
- If the stabilised material has to be assessed on the basis of total content of PAHs the material may not be utilised still (not the presence has been effected, but its mobility).
- However, if the stabilised sieve sand would have to be assessed on the basis of leaching, the material could be utilised in a category 2 application (because of the relatively high leaching of sulphate). The leaching of all other components (PAHs inclusive) is below the limit values of category 1 applications.

Recommendation

It is highly recommended to environmentally assess organic components in building materials on the basis of leaching (on analogy to inorganic components) and not on the basis of total content.

Literature

- [1] Zijlstra, R.K., and E. Mulder, Comparison of the shake test (CEN) and the column leaching test (NEN), TNO report No. TNO-MEP - R96/450 (in Dutch), December 1996.
- [2] Zijlstra, R.K., and E. Mulder, Determination of the leaching of PAHs with the column leaching test, TNO report No. TNO-MEP - R96/400 (in Dutch), November 1996.