VOLUME REDUCTION OF CONTAMINATED CONCRETE

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ABSTRACT

During decommissioning activities of nuclear installations large amounts of contaminated concrete will have to be processed. All this concrete has to be treated and stored as radioactive waste, which implies major economical and environmental consequences.

Basic laboratory tests showed that the contamination is mainly concentrated in the porous cementstone. By separating this cementstone from the clean dense aggregate particles, a volume reduction of 60-70% was reached. The clean aggregate can be reused in concrete.

KEMA has developed, designed and constructed a pilot plant scale test installation for separation of aggregate from contaminated concrete. The separation is based on a thermal treatment followed by milling and sieving.

The results show that quartz and limestone concretes can be separated effectively. Verification tests are scheduled with contaminated concrete from decommissioning operations.

INTRODUCTION

In a nuclear installation, concrete in various building structures may get contaminated during operation. When the installation is withdrawn from service and eventually dismantled the contaminated concrete has to be conditioned and disposed off as radioactive waste. Global calculations indicate that per reactor about 3000 to 4000 tons have to be conditioned (1).

In normal quality concretes, the volume of the porous cementstone is approximately 30%, while the remaining part consists of dense aggregates such as quartz and limestone. Tests have shown that contamination primarily penetrates in the cementstone (see Fig. 1). Separation of the porous and dense components of concrete will therefore result in substantial volume reduction of radioactive waste. This is beneficial for economical and environmental reasons.

In the framework of a research project performed under the European Communities Program on Decommissioning, and the research program of the Netherlands electricity production companies, KEMA has developed, designed and constructed a pilot plant scale test installation for volume reduction of contaminated concrete. The findings obtained so far are presented in this paper.

CONCRETE CONTAMINATION AND ACTIVATION

In order to verify the assumption that mainly the porous cementstone is contaminated, concrete samples were prepared and supplied by nuclear power plants. The concrete samples were separated by grinding, sieving and washing. From these tests it could be concluded that more than 90% of the activity (due to Co-60) was concentrated in the cementstone (2).

Also the possible activation of concrete was tested. Therefore the various concrete components were subjected to a neutron fluence of 2.5×10^{23} n/m^2. Ordinary Portland cement and Portland blastfurnace cement were used for these tests. The tested aggregates were quartz, limestone and baryte. The results as presented in Table I show that because of their chemical composition, quartz gravel and limestone are less susceptible to activation than cements, while baryte shows the opposite.

From the tests it can be concluded that separation of contaminated concrete is effective. This is also true for activated quartz and limestone concretes (see Table I).

BASICS OF SEPARATION

Separation of concrete into its components gravel, sand and cementstone is based on the reduction of bond between the cement matrix and the aggregates. The bond can be reduced by temperature induced mechanical stresses. Two methods were tested in this research program. Cooling down by liquid nitrogen and heating up in an oven. The latter method has an additional chemical effect because of decompositioning of the cementstone. Typical results of both temperature treatments are presented in Table II in terms of the separation efficiency, Ed, defined as:

$$Ed = As / Ao \qquad \text{(Eq. (1)}$$

In this formula As stands for the amount of separated material < 1mm (cementstone and fine sand), whereas Ao represents the original amount of material < 1mm in the mix

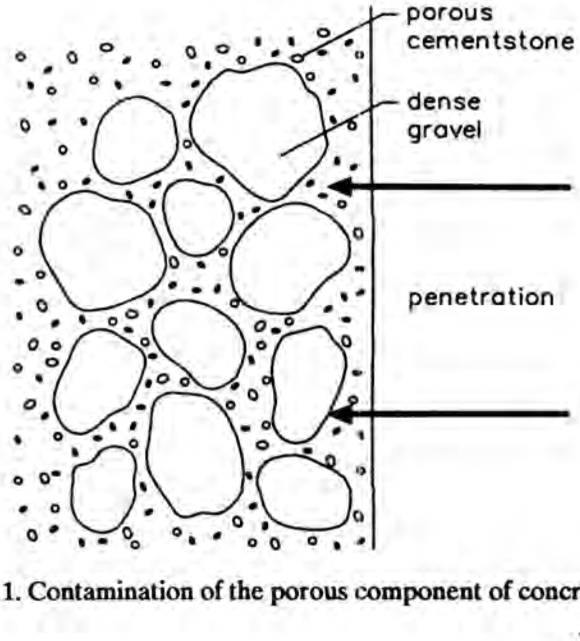

Fig. 1. Contamination of the porous component of concrete.

composition (3). It can be seen in Table II that heating up is more effective for separation.

TABLE I

Results of Irradiation Tests (2.5×10^{23} n/m^2)

Component	Activity After 2y Decay (MBq/kg)
Cement:	
Portland	88
Portland blastfurnace	84
Aggregate:	
Quartz	5
Limestone	27
Baryte	122

TABLE II

Effect of Type of Temperature Treatment on Separation

Thermal treatment	Ed (%)
heating (650°C)	80
cooling (liquid N_2)	39

In an extensive research program important concrete and process variables on concrete separation were investigated (3, 4). This finally led to a setup for a separation plant as schematically presented in Fig. 2.

In Fig. 2, four main steps can be distinguished. In the first step concrete parts are crushed in order to extend the surface assessable for the subsequent treatments. By means of heating up, the bond between aggregate and cement matrix is reduced and in the next step separation is realized by mechanical forces in a turning mill. Then a selection has to be made between contaminated and clean material. In this program it was decided from preceding tests, to sieve the material over 1mm sieves. The material <1mm turned out to contain the powdered cementstone and consequently the contamination.

PILOT PLANT SCALE TEST INSTALLATION

The approach as presented in Fig. 2 formed the basis for the design of a pilot plant scale test installation for separation of contaminated concrete.

In order to be able to use standard components, a batch-wise process was developed. Much attention was given to dust-free operation, which resulted in the introduction of closed process containers and a filtering system connected to all individual components. In the process flow diagram of Fig. 3 the various components and the process are shown. An additional important feature of this installation is that the process parameters can be investigated in a wide range.

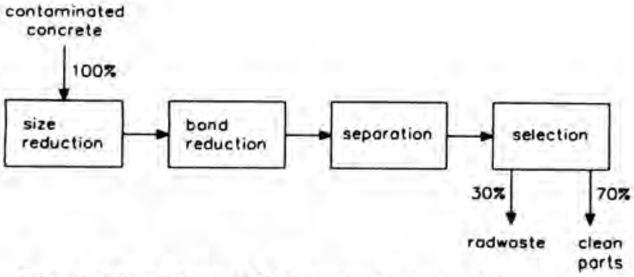

Fig. 2. Flow sheet of the concrete separation process.

In the jaw-crusher the input concrete is crushed to about 40 mm diameter parts, which are then transported in a specially designed closed process container to the electrical oven for a temperature treatment at about 650°C (925 K). After cooling down of the concrete, the mill (in vertical position) is loaded and then operated (in horizontal position). In the last step the milled material is led to the sieve unit, where the cementstone and fine sand <1mm is collected as radwaste in a storage drum. The material >1mm is also collected for possible reuse as concrete aggregate.

A top view of the installation as erected in the KEMA laboratories is shown in Fig. 4.

TEST-RUNS AND VERIFICATION

The first test-runs with the installation showed that some minor modifications proved to be necessary for dust-free operation. This mainly concerned the valve construction and operation of the process containers.

Well defined, not contaminated, concrete (150mm) cubes were made with maximum grain size of 31.5 mm. The 28 days compressive strength was about 40 N/mm^2. From the concrete composition and the sieve line of the quartz aggregate, the

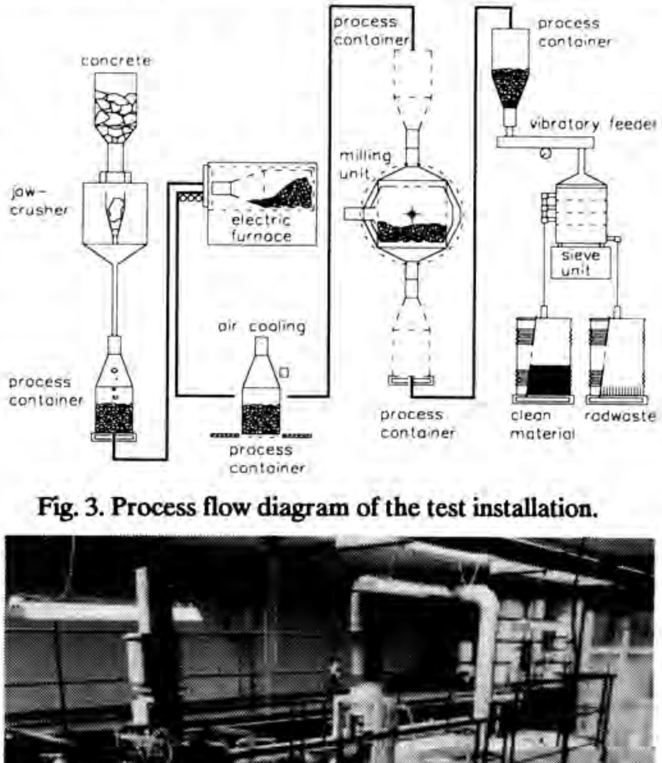

Fig. 3. Process flow diagram of the test installation.

Fig. 4. Top View of the KEMA test installation.

amount of cementstone and sand < 1mm can be estimated. The findings are given in Table III.

TABLE III
Data of Concrete Mix used for the Test-Runs

Component	Amount
1. Portland cement	320 kg/m^3
2. quartz sand < 1mm	450 kg/m^3
3. formed cementstone (calculated)	400 kg/m^3
cementstone and sand < 1mm (2+3)	850 kg/m^3
fine material ratio*	35%
* (850/2400)x100%	

It was calculated that the amount of fine material < 1mm was 35% of the total mass of concrete. The specific mass of the concrete was taken as 2400 kg/m^3.

Nine test-runs were executed, in which the concrete parts were subjected to temperatures in the range of 650-700°C (925-975 K) for 3 to 4.5 hours. The milling time was set between 1 and 2 hours. After sieving over 1 mm, the amount of "clean" material proved to be 63%, and the amount of "contaminated" residue was 37% (standard deviation 3%). Because of crushing of some aggregate particles during operation, this ratio of 37% is slightly higher than theoretical value as given in Table III.

It can be concluded from the results that by separation the original amount of "contaminated" concrete was reduced to 37% of the input material.

The residue has to be conditioned as radwaste. As part of this research project, methods for solidification are being studied by Taywood (5). Important is that the volume is kept as low as possible. This seems to be feasible by the addition of hydration activators to the mixture of powdered cementstone and sand.

The test installation will be further optimized by tests with not contaminated concretes. In the summer of 1993 the installation will be shipped to an ongoing decommissioning project in Germany for verification tests with radioactive contaminated concrete. The findings will be reported by the end of 1993.

Operation of the test installation as described in this paper shows that volume reduction of contaminated concrete by separation is an interesting option. For large scale operations, however, modifications are necessary for instance in the direction of an integrated continuous process. The economical benefits are dependent on many factors such as costs of disposal of contaminated concrete and the definition of radwaste especially the corresponding release levels. In the discussions in Europe the release levels vary somewhere between 0.1 and 10 Bq/g.

Based on rough estimations a cost-benefit analyses was made for concrete separation installations having capacities of 1 and 2 m^3 contaminated concrete per day. The investment costs were calculated by extrapolation of the costs of the test-installation. The results of the analyses are presented in Fig. 5. It can be seen that after 2 to 5 years operation the benefits become dominant.

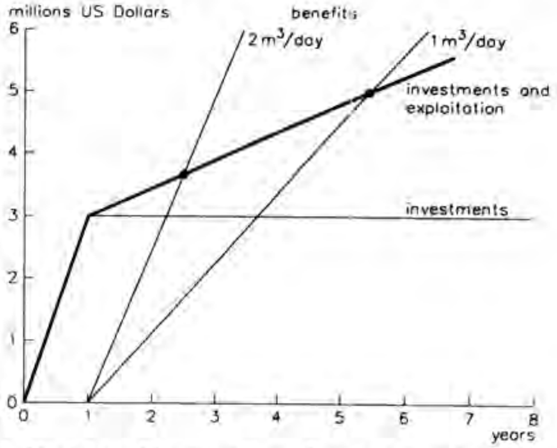

Fig. 5. Cost-benefit estimation of concrete separation plants with capacities of 1 m^3 and 2 m^3 concrete.

CONCLUSIONS

Contamination of concrete is mainly concentrated in the porous cementstone and not in the dense aggregates like quartz gravel and limestone.

Depending on the concrete composition, volume reduction of 60% to 70% can be reached of material that has to be treated and stored as radioactive waste.

Concrete can be separated in contaminated and clean parts by means of a process based on heating, milling and sieving over 1 mm.

The KEMA test installation showed that separation is feasible on small scale. Verification, however, is necessary by processing radioactive contaminated concrete.

Full scale concrete separation seems beneficial for economical and environmental reasons.

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