FINES EXTRACTED FROM RECYCLED CONCRETE AS ALTERNATIVE RAW MATERIAL FOR PORTLAND CLINKER PRODUCTION

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ABSTRACT
The use of recycled aggregates in concrete has an important impact on the final quality. They have their influence on the durability and strength development of the final concrete **[1]**. To upgrade recycled concrete aggregates, the attached mortar on the aggregates has to be cleaned away as much as possible which will generate low grade recycled sand. Valorising this low grade sand is crucial for the success of upgrading recycled concrete aggregates. To increase the quality of recycled sands, the fines (<63 µm) contents *[wt%]* have to be lowered to attain acceptable water demands to optimise their use in high end concrete. Within this study, different technical set-ups were used to remove the mortar fraction from the aggregates, and to separate the generated fines from the recycled sand. The relationship between the different separation techniques and the physical and chemical properties of the generated fines was studied to evaluate their fitness as Alternative Raw Material (ARM) for Portland clinker production. Furthermore numerical simulations were carried out to maximise the fines fractions as ARMs in Portland clinker meals based on which experimental clinkers were produced. The final clinkers were fully analysed and evaluated on possible mineralogical influences.

INTRODUCTION

Recycling of construction and demolition waste is a key item in the sustainable development of the construction business. Zero landfill as long term target announced in the latest WBCSD (World Business Council of Sustainable Development) report on Concrete Recycling, sends out a clear message. Access to natural aggregate sources will become more and more difficult, strict legislative waste management is limiting land filling of construction waste and green building initiatives are gaining public importance. Within The Netherlands, which has a very advanced recycling industry, twenty-five million tons of stony demolition waste was created in 2009 of which forty per cent existed out of concrete. Four million tons were already used as recycled concrete aggregate 4/32mm and another four million tons went to low strength concrete production and road works. Expectations for 2025, predict an increase to forty million tons of stony demolition waste of which sixteen million will exist out of concrete (Source: BRBS, The Netherlands). The overall quality of recycled concrete aggregates is generally lower than that of natural aggregates, due to the mortar that remains attached to the natural aggregates **[1]**. Studies on the use of recycled concrete aggregates in concrete show that the compressive strength **[1]**, drying shrinkage, creep **[2]**, shear resistance **[2]**, freeze and thaw resistance, abrasion resistance **[1]**, sulphate content **[1]** etc. can be improved, if the attached mortar can be separated better from the recycled aggregates. Some researchers even claim that only recycled aggregates with an attached mortar content of less than 44 per cent can be used for structural concrete **[1]**.

It's therefore quite challenging to improve overall quality of recycled concrete aggregates and to valorise one hundred per cent of the demolished concrete to avoid disposal by land fill. Several ways are already investigated to separate as much of this cement stone from the recycled aggregates as possible. Within this article a two stages crushing action by jaw and VSI (Vertical Shaft Impactor), were used to upgrade the recycled aggregates as much as possible. This has as consequence that more low grade sand is created which is unsuitable for high end concrete production. This is the weak spot in the upgrading of recycled concrete aggregates. Therefore different separation techniques were tested to improve this low grade sand quality by decreasing the filler content (<63 µm) to create an acceptable water demand and make it more suitable for high end concrete applications.

The innovative aspect is that different existing separation techniques are evaluated to create a fines fraction suitable as alternative raw material (ARM) for Portland clinker production. First, the use of the Advanced Dry Recovery (ADR) installation **[3]** developed by TU Delft for the separation of bottom ashes was studied, secondly an installation situated in the research department of the Centre Terre et Pierre (Tournai/Belgium) **[4]** was investigated and finally a static KHD separator **[5]** under lab conditions was used in the research department of KHD (Cologne/Germany).

The treated sands coming out of the three separation installations separated from their fines fractions were also evaluated on their water demand to determine whether or not they were suitable for high end concrete production. This technology could be interesting for demolition and recycling companies as well as for cement and concrete producers.

TECHNOLOGY/PROCESS

To make this investigation as realistic as possible, 282 tons 0/200 concrete material was recovered from a demolished concrete construction. The recycled concrete was crushed on a Nordberg LT 1213 impact crusher by which 53 wt% recycled 0/63 aggregates and 47 wt% recycled 0/8 sand out of the 0/200 concrete material were generated and separated by a Chieftain 400 power screen. The recycled 0/63 aggregates were crushed for a second time on a Magottaux VSI crusher 2400 to remove the attached mortar even more and to upgrade the recycled aggregates. This second crushing action decreased the recycled aggregates size to 0/14. The crushed material (0/14) delivered by the VSI crusher was homogenised with the recycled 0/8 sand separated after the first crushing action by a Chieftain 400 power screen which recompleted the recycled material to 100 wt%. Three separation installations were tested to generate the different fines fractions.

First, the Advanced Dry Recovery (ADR) installation was investigated. This installation is a sort of wind sifter that by the use of kinetic energy and air knifes, separates crushed recycled concrete in coarse aggregates, sand and fines (ARM/ADR) fractions **[3]**. A batch of 1.5 tons was sampled from the homogenised crushed material to serve as feed material for the ADR installation without drying, being the way the installation works in practice. The separation by the ADR installation generated three fractions: 34 wt% of a coarse fraction (0/14), 34 wt% of a 0/4 sand fraction and 32 wt% of a first fines fraction (ARM/ADR) which was in fact a sand 0/2.

Furthermore, the same homogenised crushed material as fed to the ADR installation was

inserted to a Chieftain 400 power screen which separated the recycled aggregates fraction or 9 wt% of the total homogenised crushed material from 91 wt% of a low grade recycled 0/6.3 sand fraction. This recycled 0/6.3 sand fraction served as feed for the CTP and the KHD installations. 1.5 tons of the 0/6.3 sand was sampled for each installation to investigate the separation phase.
The CTP (Centre Terre et Pierre) installation, situated in the research department of the Centre Terre et Pierre (Tournai/Belgium) **[4]**, consists out of a ball mill which is connected to a dynamic separator, that can be heated with a hot air stream. The ball mill wasn't filled with balls for this test, but was only used to throw the sand in the hot air stream which fed the dynamic separator with the entrained fine sand fraction. After the separation set at 250 µm, the fine sand fraction returned to the ball mill and the fines fraction (ARM/CTP) was recovered which represented 7 wt% of the total homogenised crushed material. The upgraded CTP sand fraction was recovered in the ball mill representing 84 wt% of the total homogenised crushed material. Comparable installations can already be purchased for industrial practice.

The static KHD separator **[5]** which is already used frequently for other processes on industrial scale was investigated under lab conditions in the research department of KHD (Cologne/Germany). The sand was first dried to a maximum humidity of 4 wt% before it was completely fed to the static separator which was also set at 250 µm. The separation generated a third fines fraction (ARM/KHD) and upgraded KHD sand representing 4.8 wt% and 86.2 wt% of the total homogenised crushed material.

The reason that the batch for the ADR installation **[3]** was taken before the power screen in contrast to the two other installations, is that the ADR installation should, by specification, be capable to separate also the coarse recycled 0/20 aggregates fraction from the sand and fine (ARM/ADR) fractions.

Schematic views of the complete processes which generated on the one hand, the ADR separation fractions and on the other hand, these of the CTP and KHD installations are presented in **figure 1** and **figure 2**.

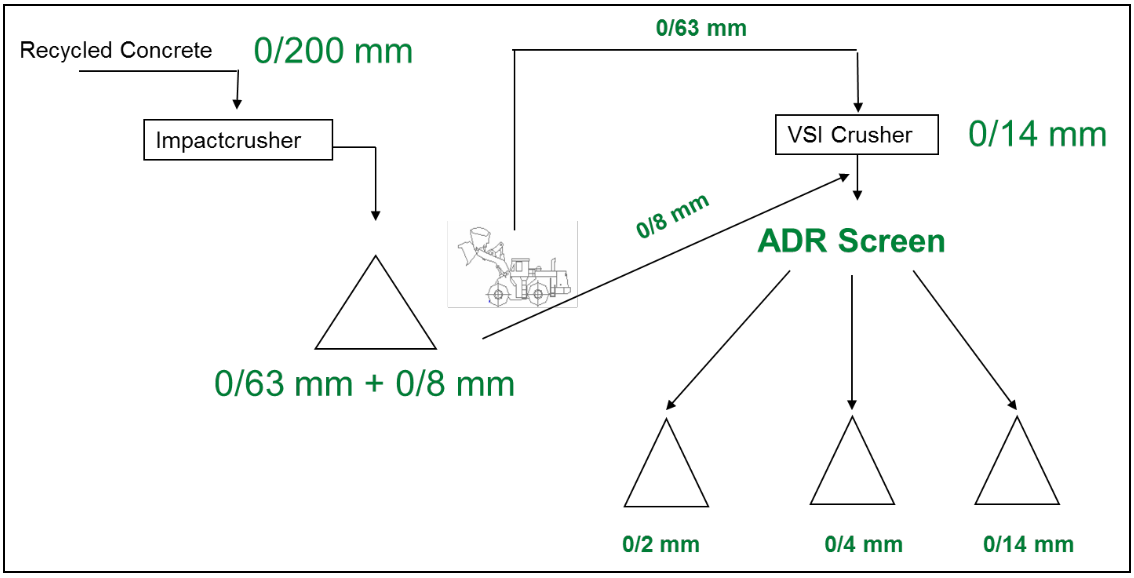

Figure 1 – Process view incorporating the ADR separation

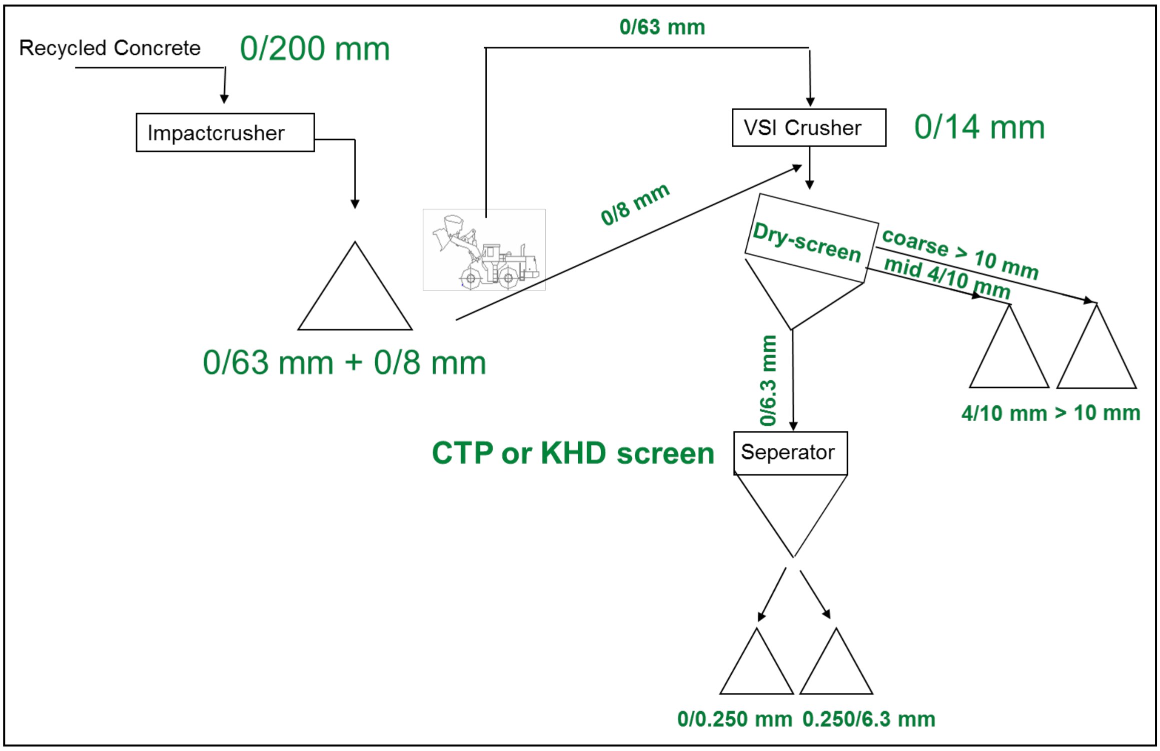

Figure 2 – Process view incorporating the CTP and KHD separation

INFLUENCE OF THE FINES REDUCTION ON RECYCLED CONCRETE SANDS

After being processed by the separation installations, three sand fractions were generated which had all a decreased filler (<63 µm) content compared to the sand fraction (7.8 wt%) separated on the Chieftain 400 power screen after the two stage crushing action: Ag/Sa04/ADR (6.9 wt%), Ag/Sa06/CTP (0.1 wt%) and Ag/Sa06/KHD (2.2 wt%). The filler content of aggregates which defines the amount *[wt%]* of particles passing through a sieve of 63 µm is an important parameter for aggregate producers. Higher filler content *[wt%]* implies a higher water adsorption *[wt%]*. Dry and wet screening are used in primary aggregates production **[6]** to decrease as much as possible the filler content *[wt%]*. Asphalt producers avoid high filler content *[wt%]* because they want to pursue an ideal ratio between filler and bitumen.

A method was developed by Sagrex Benelux to evaluate the water demand of a sand for concrete applications. By this method, sand is separated from its coarse particles on a 4 mm sieve to make an objective comparison possible. An amount of 3857 g of the sieved sand is weighed into a mixer bowl after which 500 g of water is added and mixed for 10 minutes. Next, 1285 g of a CEM III/A 42.5 N LA cement is dosed to the sand/water mixture after which the paste is mixed for another 10 minutes. After 5 minutes, extra water is added until a slump consistency between 50 and 75 mm is obtained or in other words consistency class S2 **[7]** is attaint. The final Water Demand (WD_{sand}) is calculated by:

$$WD_{sand} = (W_{Tot} – (\% \ WA * Sa4mm) – Cem * WD_{cem}) / Sa4mm$$

W_{Tot} = the total amount of water added (g)
% WA = Percentage of Water Absorption of the sand [8]

Cem = the 1285 g of cement added
WD_{cem} = 28.2 wt% which is the water demand of the used CEM III/A 42.5 N LA [9]
Sa4mm = 3857 g or the used sand for the test

Table 1 lists the final Water Demand (WD_{sand}) of each of the three treated sands as well as some specific physical properties. The indicated reference is a 0/4 sea sand.

Table 1: Influence of fines [wt%] on the water demand of the recycled sand

Sand		Reference sand	Chieftain 400 sand	ADR sand	CTP sand	KHD sand
Filler content (< 63 µm)	wt%	1.3	7.8	6.9	0.1	2.2
Absorption Water (EN 1097-6)	wt%	0.40	4.70	3.50	5.50	6.40
Absolute Density (EN 1097-6)	kg/m³	2650	2365	2374	2356	2360
Water Demand	kg/kg	0.084	0.167	0.129	0.070	0.088

The filler (<63 µm) content in recycled aggregates often originates from cement stone which explains the high water absorptions in comparison with natural sea sand. The water absorption **[8]** for the recycled ADR sand, although still higher than in reference sea sand, is lower than for both CTP and KHD sands. This is due to the fact that the ADR sand is cut below 2 mm demonstrated by the fineness of its fines fraction (ARM/ADR) presented in **figure 3**, extracting more of the cement stone than with the two other installations which are cut below 250 µm. Water absorption of sands has no influence on the W/C ratio **[7]** of concrete but is an important parameter for the production of concrete because it could requisite the pre-wetting of the sand fraction to maintaining concrete consistency **[7]**. The water demand of a sand is strongly influenced by the adsorption water **[8]** needed to wet the specific surface of the sand. An increasing filler content *[wt%]* increases the specific surface of a sand. Using sands with a high filler content *[wt%]* will have a big influence on the W/C ratio of high end concrete defined within a specific concrete consistency class **[7]**, making the concrete production very expensive and in some cases even impossible. Based on the water demand, sands out of the CTP and KHD installations are more suitable to produce high end concrete than the sand coming out of the ADR installation.

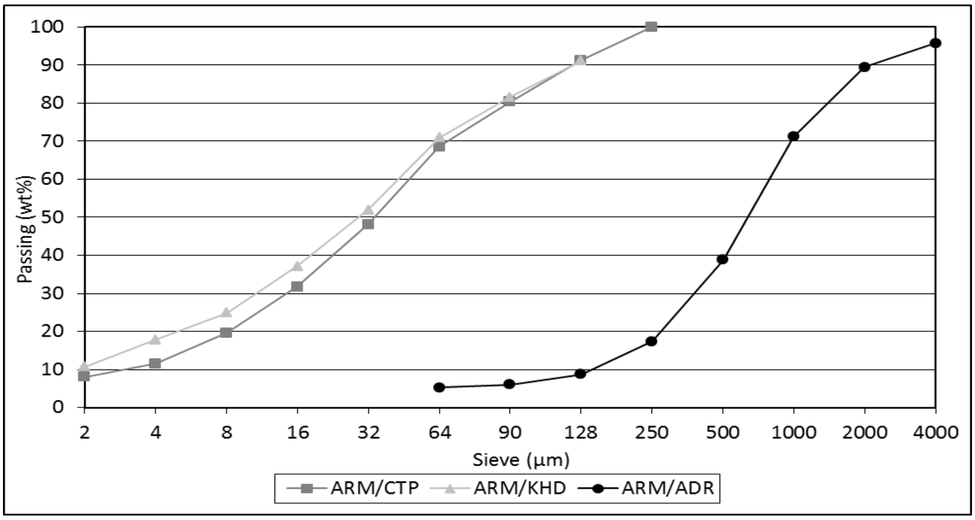

Figure 3- Passing's [wt%] for ARM/ADR, ARM/CTP and ARM/KHD measured by laser diffraction (µm)

SIMULATION AND ARTIFICIAL PORTLAND CLINKER PRODUCTION

When investigating the fitness of alternative raw materials for Portland clinker production, it's very important to not lose track with the real manufacturing process itself. Simulations of clinker compositions or production of artificial Portland clinkers on lab scale often deliver specific properties which can't be generalized for clinker production in practice. On the other hand, it isn't possible to perform all investigations immediately on industrial scale. Realistically simulating clinker production on lab scale is quite difficult because of the specific construction of a clinker kiln. A good theoretical simulation and/or artificial clinker production setup which identifies and tries to incorporate the unique properties of a real clinker kiln, is therefore necessary. Limitations have to be defined which could prevent undesirable effects on the clinker kiln as well as prevent insufficient clinker quality based on the cement standards **[9] [10] [11]**. These limitations **[12-13]** have to be taken into account while making simulations which will serve to produce artificial lab clinkers.

Table 2 - Chemical and mineralogical limitations on the final clinker

Clinker		Antoing	Lixhe
Cl	(wt%)	x < 0.08	x < 0.08
SO_3	(wt%)	x < 1.4	x < 1.2
Na_2Oeq	(wt%)	x < 1.2	x < 1.2
MgO	(wt%)	x < 4.0	x < 4.0
MgO/Fe_2O_3		x < 1.40	x < 1.40
DoS-factor		80 < x < 120	80 < x < 120
LSF_MgO		97.0	97.0
C_3A	(wt%)	7.4	6.7
LiqSimple	(wt%)	19.2	22.7
SR		3.2	2.6

(DoS = 77.41•SO3 / (Na2O+K2O•0.658))

Within this investigation, two real clinker kilns were simulated: CBR Antoing and CBR Lixhe, all belonging to the Heidelberg Cement Benelux group. A simulation program based on linear equations calculated raw meal compositions for each kiln in line with specific chemical and mineralogical limitations (**Table 2**).

The simulated raw meal composition slightly deviates from the real composition, to obtain the same mineralogical settings without taking into account the ashes of the fuels that in reality will be used to heat up the raw meal in a clinker kiln.

All raw materials were first crushed in a Siebtechnic Disc mill. The different raw materials were brought together in dosages *[wt%]* calculated for the different raw meals by the simulation program.
The calculated dosages to achieve 500 g of raw meal were brought together in a vessel used for the analysis of the micro-Deval abrasion resistance. This procedure was used to homogenise as good as possible the raw meal before it was thermally treated in a furnace. Before sintering, the different raw meal compositions were first granulated on granulation plates (5 mm holes).
Artificial clinker production was performed by sintering the raw meal in an electric high temperature static furnace (Carbolite BLF1800) to 1450 °C at a constant heating rate of 10 °C/min. The hot clinker meals were maintained for 1h at 1450 °C after which they were immediately air-cooled to room temperature by open air to form the final clinker.

PHYSICAL AND CHEMICAL EVALUATION OF THE SEPARATION FRACTIONS

The limited chemical variation of the ARM is very important for its suitability as raw material in Portland clinker production. Because the chemical composition of the clinker meal has to be fixed to guarantee optimal clinker reactivity by the formation of predefined quantities of mineralogical complexes, a big chemical variation of one or more raw materials could disrupt severely the Portland clinker process. Up to this moment, a big collection of fines fractions couldn't be collected. However, a homogenisation phase adapted to the chemical variation of the recycled fines will be crucial based on the small batch of ten fines fractions that were already collected in the last two years (**Table 3**).

Table 3 – Average, minimum and maximum values of individual chemical compounds out of ten recycled fines fractions

ARM		Minimum	Average	Maximum
CaO	(wt%)	18.50	25.12	29.92
SiO_2	(wt%)	41.55	48.15	62.50
Al_2O_3	(wt%)	2.99	5.50	9.27
Fe_2O_3	(wt%)	1.50	2.70	4.06
K_2O	(wt%)	0.70	0.86	1.30
Na_2O	(wt%)	0.12	0.39	0.69
SO_3	(wt%)	0.97	1.47	2.71
MgO	(wt%)	0.39	1.25	2.61
LOI 975°C	(wt%)	3.64	13.61	19.89

The fact that in the Benelux, cement can be composed out of clinker, slag, fly ash and limestone filler in varying dosages, indicates that the chemical variation of the recycled fines could be quite big. Also the origin as well as the mineralogy of the used aggregates can influence the chemical composition as well as the chemical variation of the recycled concrete fines. On the other hand, this study aims primarily to investigate how different separation techniques could influence the chemistry and therefore the suitability as ARM for Portland clinker production. The presented chemical composition in **table 4**, demonstrates that different separation techniques can generate fines with different chemical compositions starting from the same material.

Table 4 - Chemical composition of ARM/ADR, ARM/CTP and ARM/KHD

ARM		ARM/ADR	ARM/CTP	ARM/KHD
CaO	(wt%)	15.14	24.38	22.99
SiO_2	(wt%)	64.07	44.78	44.61
Al_2O_3	(wt%)	4.80	6.02	5.86
Fe_2O_3	(wt%)	2.74	3.22	4.06
K_2O	(wt%)	0.87	0.89	0.97
Na_2O	(wt%)	0.49	0.39	0.48
SO_3	(wt%)	0.76	1.23	1.24
MgO	(wt%)	1.02	1.38	1.44
LOI 975°C	(wt%)	9.39	16.68	17.40

Comparing **table 4** with **figure 3**, gives a clear relationship between the particle size distribution of the recycled concrete fines (ARM) and their chemical composition. The finer the fines are cut from the rest of the recycled aggregates, the higher the CaO content *[wt%]* becomes and the more suited they are for Portland clinker production. Based on the chemical composition, fines fractions out of the CTP and KHD installation are more suitable for Portland clinker production than the ones coming out of the ADR installation.

Table 5 - Compositions of the different clinker meals

	CRM+ARM	Quantity (wt%)		CRM+ARM	Quantity (wt%)
Antoing/Reference	Poor limestone	55.25	Lixhe/Reference	Tufa	79.44
	Rich limestone	37.50		Loam	6.63
	Fly ash	6.38		Fly ash	12.34
	Iron carrier	0.87		Iron carrier	1.59
	ARM	0.00		ARM	0.00
	Sum	100.00		Sum	100.00
Antoing/ADR	Poor limestone	38.13	Lixhe/ADR	Tufa	78.44
	Rich limestone	51.81		Loam	0.00
	Fly ash	7.11		Fly ash	13.31
	Iron carrier	0.84		Iron carrier	1.61
	ARM/ADR	2.11		ARM/ADR	6.64
	Sum	100.00		Sum	100.00
Antoing/CTP	Poor limestone	34.78	Lixhe/CTP	Tufa	75.24
	Rich limestone	53.22		Loam	0.00
	Fly ash	6.57		Fly ash	11.23
	Iron carrier	0.81		Iron carrier	1.53
	ARM/CTP	4.62		ARM/CTP	12.00
	Sum	100.00		Sum	100.00
Antoing/KHD	Poor limestone	33.22	Lixhe/KHD	Tufa	75.46
	Rich limestone	54.51		Loam	0.00
	Fly ash	6.65		Fly ash	11.39
	Iron carrier	0.73		Iron carrier	1.35
	ARM/KHD	4.90		ARM/KHD	11.80
	Sum	100.00		Sum	100.00

CLINKER FEED CALCULATIONS AND PREPARATIONS

The compositions of the different reference and alternative raw meal compositions after simulation are presented in **table 5**. The alternative raw meals were calculated to maximise the use of the three ARMs. By maximisation of the ARMs in the alternative raw meals of CBR Lixhe, loam which acts as a SiO_2-source, is completely replaced. CBR Antoing which uses no real SiO_2-source receives its required SiO_2 of its two limestone sources, especially the poor limestone. The dosage of poor limestone was decreased but on the other hand, the dosage of rich limestone was increased by lack of sufficient CaO *[wt%]* in the ARMs. The limiting factor for the maximisation of the ARMs is the SiO_2 *[wt%]* of the raw meal itself by which the ARM with the highest SiO_2 *[wt%]* will be dosed the least.

CHEMICAL AND MINERALOGICAL EVALUATION OF THE FINAL CLINKERS

The chemical analysis of the final clinkers presented in **table 6** shows that the alternative raw material compositions partly prepared out of the different ARMs, were properly assessed by the simulation program and have a comparable chemical composition as their reference. Because the fines, ARM/CTP and ARM/KHD have similar physical and chemical properties as well as comparable raw meal dosages, it was decided to only make artificial lab clinkers partly based on ARM/CTP and ARM/ADR. The Bogue equations applied to the chemical composition **[14]**, predicted the expected mineralogy of the reference and alternative final clinkers as presented in **table 6**.

Table 6 - Chemical analysis and Bogue calculations of the Final Clinkers

Clinker		Ant/Ref	Ant/ADR	Ant/CTP	Lxh/Ref	Lxh/ADR	Lxh/CTP
CaO	(wt%)	65.90	66.31	66.53	66.28	66.41	66.21
SiO_2	(wt%)	22.27	22.62	22.75	21.93	22.37	22.49
Al_2O_3	(wt%)	4.14	4.08	4.00	4.40	4.21	4.15
Fe_2O_3	(wt%)	3.02	2.88	2.83	4.21	4.03	3.96
K_2O	(wt%)	0.59	0.39	0.39	0.21	0.12	0.15
Na_2O	(wt%)	0.17	0.16	0.17	0.20	0.15	0.16
SO_3	(wt%)	0.89	0.62	0.53	0.12	0.14	0.20
MgO	(wt%)	1.73	1.74	1.64	1.28	1.29	1.33
TiO_2	(wt%)	0.25	0.25	0.24	0.30	0.27	0.26
P_2O_5	(wt%)	0.21	0.20	0.20	0.24	0.23	0.24
Cl	(wt%)	-	-	-	-	-	-
LOI 975°C (O_2)	(wt%)	0.48	0.31	0.35	0.39	0.40	0.45
DoS-factor		123.42	115.20	96.17	27.47	47.33	59.85
Alite (C_3S)		66.84	66.45	66.97	67.52	66.24	65.02
Belite (C_2S)		13.44	14.73	14.72	11.95	14.17	15.44
Aluminate (C_3A)		5.86	5.94	5.81	4.54	4.34	4.30
Ferrite (C_4AF)		9.19	8.76	8.61	12.81	12.26	12.05

The XRD analysis with Rietveld refinement of the final clinkers presented in **table 7**, shows mineralogical weight percentages that are comparable with those calculated by the Bogue equations but nevertheless have significant differences.
The alternative clinkers of CBR Antoing, both attained DoS-factors between 80 and 120 resulting in identical alite *[wt%]* for both Bogue and XRD.

Table 7 - Mineralogical analysis by XRD of the Final Clinkers with ARM/ADR and ARM/CTP

Clinker		Ant/Ref	Ant/ADR	Ant/CTP	Lxh/Ref	Lxh/ADR	Lxh/CTP
Alite (C_3S)	(wt%)	64.52	66.56	65.90	65.04	57.56	66.34
Belite (C_2S)	(wt%)	19.73	18.45	19.74	14.93	24.22	15.81
Aluminate (C_3A)	(wt%)	1.79	1.85	2.25	3.68	3.04	3.41
Ferrite (C_4AF)	(wt%)	12.86	12.50	11.63	15.87	14.43	14.83
Free Lime (CaO)	(wt%)	0.23	0.11	0.07	0.23	0.34	0.51
Periclase (MgO)	(wt%)	0.39	0.26	0.25	0.18	0.22	0.05
Arcanite (K_2SO_4)	(wt%)	0.32	0.07	-	0.07	-	-
Aphthitalite	(wt%)	-	0.10	-	-	0.09	-

For the alternative clinkers of CBR Lixhe, DoS-factors were lower than 80 which resulted in alite *[wt%]* measured by XRD lower than alite *[wt%]* calculated by Bogue for the alternative ADR clinker of Lixhe.

The reason for this difference can be found in the DoS-factors of the alternative clinkers of CBR Lixhe. Although all raw meals were designed to have DoS-factors between 80 and 120, the clinkers of CBR Lixhe didn't achieve this goal. The lower the DoS-factor, the bigger the difference between the alite *[wt%]* measured by XRD and the alite *[wt%]* calculated by Bogue became. This is a normal phenomenon described extensively by Taylor **[14]** and the reason for the introduction of the DoS-factor in the Portland kiln process. The lower the DoS-factor, the less SO_3 *[wt%]* will be available to combine the free alkali which otherwise would increase viscosity of the melt, decreasing alite formation.

The reason for this deviation is the difference in volatility of alkali and SO_3 in a static lab furnace compared to a real clinker kiln **[12-13]**. Because ARM/CTP consists out of a bit more SO_3 *[wt%]* than ARM/ADR, the DoS-factor was apparently still sufficiently high in the alternative CTP clinker of CBR Lixhe to have comparable alite *[wt%]* in XRD analysis and Bogue calculation. Nevertheless, it can be concluded that in the case DoS-factors are maintained between 80 and 120, the investigated ARM wouldn't influence the mineralogy of the clinker in a negative way.

CONCLUSIONS

Using fines extracted from recycled concrete as alternative raw material for Portland clinker production is a way to make the upgrading of recycled aggregates economically and ecologically more feasible. Furthermore, it is a way to get in line with the Cement Sustainability Initiative **[15]** as key action in the sustainable development of the cement industry. Nevertheless, the possible energy gain coming from the lowered decarbonation energy as well as the decrease in inorganic CO_2-emission, will be quite small. The reasons are the small replacement capacity of these ARM in function of the limestone due to their high SiO_2 *[wt%]* and the presence of limestone coming from the aggregates or limestone fillers used in the recycled concrete. Also, the physical and chemical bound H_2O, which will be significantly present in the recycled fines, will consume energy during evaporation, making energy gain by using these fines in Portland clinker production negligible. On the other hand, no major influence on the mineralogy of the final clinker was demonstrated by using recycled fines as alternative raw material. The way these fines fractions are generated, will have a direct impact on the particle size distribution, the chemical composition and the generated quantity of the ARM and therefore also on their intrinsic properties as ARM. The smaller the fines fractions are cut from the sand fraction, the better they are suited as ARM for Portland clinker production. To make these fines useful on industrial scale, a homogenisation phase adapted to the chemical variation of the recycled fines will be crucial. The way these fines fractions are separated also influences the final quality of the treated sand fraction and therefore also its practical use in concrete as well as in asphalt applications.

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