

The SmartCrusher Quarry 2020

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Introduction

The cement industry in 2000 was responsible for around 6% of the manmade CO₂ emissions worldwide and was at the time as polluting as all logistics together (all cars, ships and aircraft). Worldwide the production of 1 Kg CEM I (Portland cement) equals roughly 1 Kg CO₂ eq. This amount is largely caused by the raw material marl (CaCO₃) and the energy required to convert marl into clinker during the cement production process.

In the life cycle of concrete a phase can be distinguished in which the functional and / or functional lifespan of a (concrete) construction will no longer be sufficient, after which demolition will follow. In the current situation broken concrete, if it is even processed (recycled), is broken down further into smaller fractions of concrete with a maximum grain diameter of approx. 40 mm. These pieces of concrete, the so-called concrete rubble granulate; can be processed in road foundations and possibly with sufficient cleanliness in new concrete as a partial or complete gravel substitute.

An undesirable by-product of the traditional break from concrete rubble to granulate is that 40-50% is released as a fine fraction (0-4 mm) for which no valuable destination has been found to date.

Characteristic of this fine fraction is that it contaminates the crushing machines and that if this fine fraction is stored (under moist conditions) it hardens. Consequently, this fraction often has to be broken once more, which often leads to a very low to negative economic value.

Furthermore, it appears that if concrete rubble granulate is processed in concrete this often leads to a higher water requirement, which has to be compensated with more cement (BETONIEK November 2011). By using more cement, it does not contribute to a positive ecological or economic value. The strength can also be influenced by the fact that the cement stone, that is still present in the concrete granulate, is the weakest link when bearing a load. At higher replacement percentages (> 50%) material-technological changes also appear that are often perceived as undesirable in re-enforced, but especially in pre-stressed constructions. Among other things, the shrinkage and creep factors are negatively affected at higher percentages (CUR recommendation 112). This memorandum was written on the basis of a now proven and patented method for decomposing concrete rubble into the global constituent parts consisting of: cement stone, secondary sand and gravel. This technique is known as the **SlimBreken (SmartCrushing)** of concrete.

As described, this SmartCrushing technology leads to:

- The release of cement stone (including un-hydrated cement particles) as a very ecological and economic raw material for new cement and / or binder. This smart crushed cement is gypsum free (so does not have a binding time regulator) and can be used directly as a cement substitute, a raw material for new Portland cement, but also as an essential component for alternative cements, in addition to fly ash and blast furnace slag, for a new generation of geo binders. For this application a thermal cleaner is an excellent instrument. (See also Cement 4-2013; Smart crushing closes the material cycle)
- Clean and dry secondary sand and gravel with better properties than the original product.

The released cement stone (the reacted cement) is a perfect CO₂-free replacement for marl which can be used to halve the CO₂ emissions of CEM I (Portland cement) in existing cement plants! (marl = 100% CaCO₃ -> 56% CaO + **44% CO₂**).

When using the secondary (recycled from concrete) sand and gravel in new concrete, approximately 15% of cement can be saved for an equal strength compared to new sand and gravel, or with the same cement content more strength (+ 25%) can be obtained compared to a reference mixture.

This memorandum 'the SmartCrusher Quarry 2020' has been discussed (2007) in essential parts with the internationally recognized cement technologist Dr.ir. Mario R. de Rooij (senior researcher at TNO Building and Raw Materials and author of the special BETONIEK publication Cement Stone: Basis for Concrete).



(prognosis VROM 2005 see BETONIEK November 2011; Old concrete becomes young concrete)

This concrete rubble comes, among other things, from housing, roads, works of engineering, etc. Concrete quality used B17,5 – B22,5 (320-340 Kg/m³ and wcf 0,54-0,51)



In other words, less than a quarter of the strength of the constituent parts

Smart crushing is not breaking concrete into small pieces of concrete of a certain size, but breaking the concrete rubble through the weakest link (the cement stone). Smart crushing is loosening the gravel, sand and non-hydrated cement from the cement stone. Our own research showed that fully hydrated cement has less than 15 N / mm² compressive strength (10x less strong than the weakest gravel) and has a density of 1.8 - 2.0 Kg / l

What is new cement powder (CEM I)

Without going further into how this is made, CEM I is generally composed of 4 different cement minerals which after being processed with water into concrete contribute differently in strength. The chemical composition simulated in this article represents a cement from about 30 years ago.

The cement chemical story summarized as dry CEMI, CEM I with water and 30+ years of experience and (CEM I) cement stone after dehydration at about 500 ° C of heating

Cement minerals			The reaction of Cem I with water (H)			After dehydration		
before reaction with water and after dehydration								
C ₃ S	55%	-	2C ₃ S + 6H	→	C ₃ S ₂ H ₃ + 3 Ca(OH) ₂	shall C ₃ S ₂ H ₃	→	C ₂ S + CS
C ₂ S	15%	28%	2C ₂ S + 4H	→	C ₃ S ₂ H ₃ + Ca(OH) ₂	shall Ca(OH) ₂	→	CaO
C ₃ A	10%	16%	C ₃ A + 6H	→	C ₃ AH ₆	C ₃ A		
C ₄ AF	10%	-	C ₄ AF + 2Ca(OH) ₂ + 10H	→	C ₃ AH ₆ + C ₃ FH ₆	C ₃ A + C ₃ F		
C ₃ F	-	7%	C ₃ A + 3CaSO ₄ + 32H	→	C ₃ A _{SH} ₃₂	C ₃ A + SO ₂		
CS	-	19%						
C	-	21% = CaO						
		= quicklime						
<u>S</u>	2%	2%						

After 24 hours, C₃A_{SH}₃₂ will partly convert to C₃A_{SH}₁₄ (mono sulphate). In addition to the above, depending on cement grade (A, B or C) and water cement factor (WCF), new, un-hydrated cement will always remain.

In the BETONIEK (March 1983) it is demonstrated that a concrete composed of Portland A cement with a wcf of 0.53 still contains about 40% new (un-hydrated)cement.

Temperature influences on cement stone and concrete:

≤ 105°C	evaporation of water from free capillary pores
150 – 300°C	evaporation of firstly physically and then chemically bound water from the CSH structure (Jennite and Ettringite)
300 – 400°C	further dissolution of CSH structure (tobermorite), oxidation of iron compounds (color from gray to pink red)
400 – 500°C	dissolution of Portlandite (Ca(OH) ₂) to quicklime (CaO)
573°C	conversion of crystalline α quartz to crystalline β quartz with a 5,7% increase in volume
≥ 700°C	decarbonation of CaCO ₂
1100 – 1375°C	melting of cement (Cem I melts at approximately 1350°C)

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To give an indication of how large this quarry can be, the Dutch prognosis. (The Netherlands is roughly 2% of the world market). In the Netherlands there will be around 22 Mio tons of concrete rubble in 2020. This means that if this 22 Mio tons will be **cleverly crushed** with a harvest of 100%, it will release:

- 17,6 Mio tons of secondary sand and gravel
- 4,4 Mio tons of cement stone - converted in a cement kiln this yields approx. 2.86 Mio tons of cement clinker.

As an example: ENCI Maastricht produced 0.86 Mio tons of cement clinker in 2007, which corresponds to a cement harvest of 6.6 Mio tons of cleverly crushed concrete rubble per year.

The cement kiln route

As a CO₂-free raw material for the cement kiln. Concrete rubble cement stone can therefore be seen as 'pre-baked bread', in which all ingredients are already present and which still has to be finished in the cement kiln. **The greatly reduced CO₂ emission by applying concrete rubble cement stone offers great advantages. The difference in CO₂ emissions compared to marl could even be called gigantic. If the concrete rubble cement stone would be heated using bio-fuels in the cement kiln, the CO₂ reduction can go up to almost 100%.**

In this way, the kiln operation of a cement plant can be CO₂ neutral.

Because concrete gravel cement stone also contains a small amount of gypsum (CaSO₃), the S-content, it is possible to work with bio-fuels that have a higher alkali content without giving rise to problems in the kiln operation of the cement factory. These alkalites, which can normally give rise to clogging in a cement kiln, are bound to alkali sulphate by this extra sulphate and leave the cement kiln as cement mineral. Making cement clinker is not the same as making a CEMI. After all, this clinker still has to be finely ground to CEM I.

The possibilities with the new un-hydrated cement

(with cement quality of 30+ years back)

- A. As pure cement with or without fly ash or blast furnace slag and a little bit of gypsum
- B. As a cement additive to be used as an initial binding accelerator (gypsum-free cement)
- C. Directly into the wind sieve at a cement factory after the cement mill (together with the ground cement to the cement silo)
- D. Back into the cement kiln as marl replacement

Separating unsaturated cement from cement brick after smart crushing is very simple, but this requires an extra operation and an extra silo. The hydrate is much finer (about 3 µm versus 60 µm) and much lighter (ρ1,8 to 2,0 versus 3,15 kg / m³) so that it can be separated easily by means of wind sieving (or similar).

If the cement kiln route is not chosen

Dehydration of cement stone will occur below 500 °C while the carbonation of CaCO₃ takes place above 600 °C. Carbonated cement stone can thus be made reactive without CO₂ being released and can therefore also be traded as reactively very good material. For example as an essential component / as an activator / as Ca source to make 'geobinder' cement with blast furnace slag and fly ash. (Cement 4-2014 Smart crushing closes the material cycle).

After 7 days a significant strength increase was visible and the 28 day compressive strength was also higher. This can, among other things, be applied for:

- Self-compacting concrete (ZVB) (SCC)
- Accelerator for blast furnace cement
- Activator of fly ash
- Eco concrete
- Ultra high strength concrete
- Production of a new CEM II cement

In short, both for reinforced and unreinforced concrete applications.

Due to the special particle size distribution (PSD), the released cement stone is very suitable as an improver of concrete mixtures, especially when working with super plasticizers. Because there is always more C₃A in this cement stone than in CEM I it seems ideal to serve as PCE (super plasticizer 'carrier') and it will be able to contribute particularly to the ability of concrete to be processed. Also with blast furnace slag, the high C₃A content in the cement stone will develop more and faster strength.

The CO₂ emission (CERs) calculation after clever crushing of concrete rubble

Currently the CO₂ 'price' is under strong pressure. Larger international market parties such as Shell and Akzo even claim that it must be increased to above € 25 / ton, which amounts to € 1 to € 2.50 / ton of concrete rubble. If the aforementioned 22 Mio tons of concrete rubble is cleverly crushed, this alone represents a value between € 22 million and € 55 million.

'Better than new sand and gravel'

The secondary sand and gravel released by smart crushing will retain a minuscule PH-etched transition zone, resulting in a much better initial and final strength when used again in concrete.

When concrete rubble granulate is used, small pieces of concrete, instead of gravel, yields little or no economic or ecological benefit. This is because the water requirement of the concrete to be made with it, is negatively affected. This high water requirement must then be compensated with -either- more super plasticizer -or- more cement which will immediately be expressed in a quantitative LCA approach.

Application of the sand and gravel released from smart crushing in new concrete, will have as a result that the water requirement will not increase. Due to the improved adhesion to the secondary sand and gravel, 1/3 more strength will be found after 7 days and 1/4 more strength will be found after 28 days compared to new sand and gravel (source: Kema Netherlands / circuit construction). This 'contribution' can also be interpreted as: for the same strength 15% less cement will have to be used.

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