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ROLE OF SLAG IN THE SUSTAINABLE CONCRETE ROADMAP 2015-2020 FROM A CONCRETE PRODUCER'S PERSPECTIVE

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Abstract

Contracts for concrete and concrete products contain more and more criteria on their environmental impact, although significant differences are seen between market segments. As an example we treat a residential building in this paper, in which concrete accounts for 25% of the total environmental impact of the total object. This building scores 4 out of 8 points in the Dutch BREEAM-NL sustainable construction code for new build. When we use slags in the concrete mix design to improve its environmental profile, we would strive to get one extra point in BREEAM for the building. By doing so, we need to replace 180 kg of the initial 310 kg cement in all concrete in the building. This example shows the significant impact of slags on the environmental profile of concrete, but also shows that even a high amount of slags utilisation (60% CEM replacement) potentially leads to only one additional point in the BREEAM-NL code, equalling to one credit.

Introduction

In today's practice a concrete producer is increasingly challenged to the environmental impact of his product. Country by country there are still significant differences, but in general terms in Europe it is clear that we are moving towards a commercial practice where contracts would require the producer to show the environmental impact of his product through a type of declaration and the modern contracts increasingly take the performance on this issue into account in determining who wins the contract.

In this paper we are going to use the current status in The Netherlands as a reference. By no means do we state that that practice should be exemplary or is in any way to be preferred. It represents a structure that has progressed quite far over the last few years and as such shows potentially a good picture of what the future may hold for all of us at some point in time.

We will demonstrate the affect of taking into account the environmental impact of concrete and concrete products on the producers operation and on the selection of the raw materials in the concrete mix design.

The Netherlands

In The Netherlands the building sector has chosen to work with a national database containing environmental performance data for basic raw materials (like cement, fly ash, slag, admixtures), as well as environmental product declarations (EPD) of building products. The database recognises three level of data quality:

1. Product data, supplier specific, reviewed
2. Product data, branch averaged, reviewed
3. Product data, not reviewed

In the category 3, data will be replaced by higher category data when these are available. When the category 3 data are used in calculations for building performance, they are used with a 30% penalty to account for any possible inaccuracy in the data.

The Dutch EPD format, as it is used in the national database, reports 11 environmental impacts.[1] An example for the Ready Mix Concrete (RMC) is shown in Figure 1.

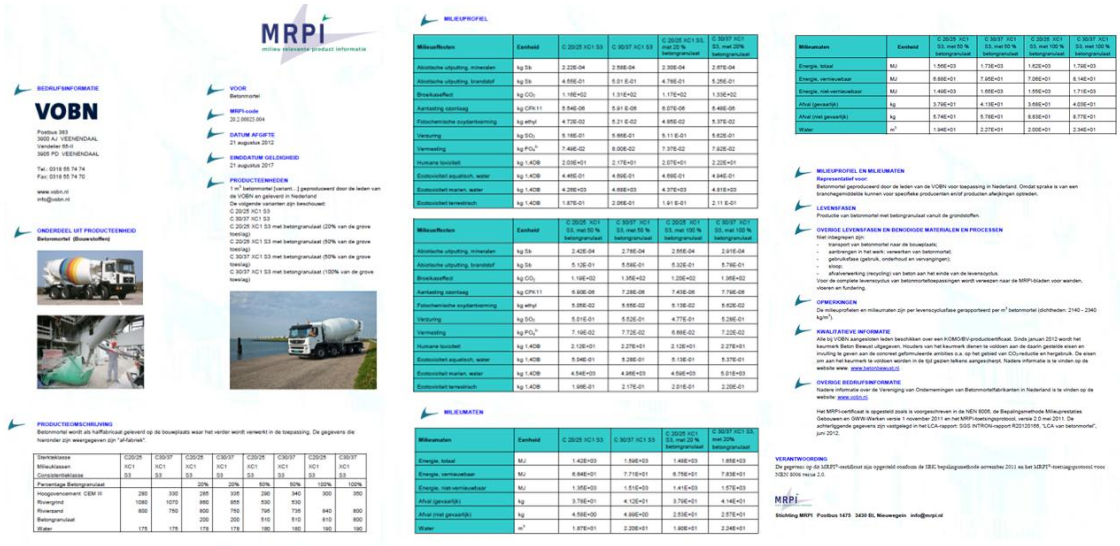

Figure 1: Example of the Dutch EPD format for Ready Mixed Concrete as provided by the VOBN[1]

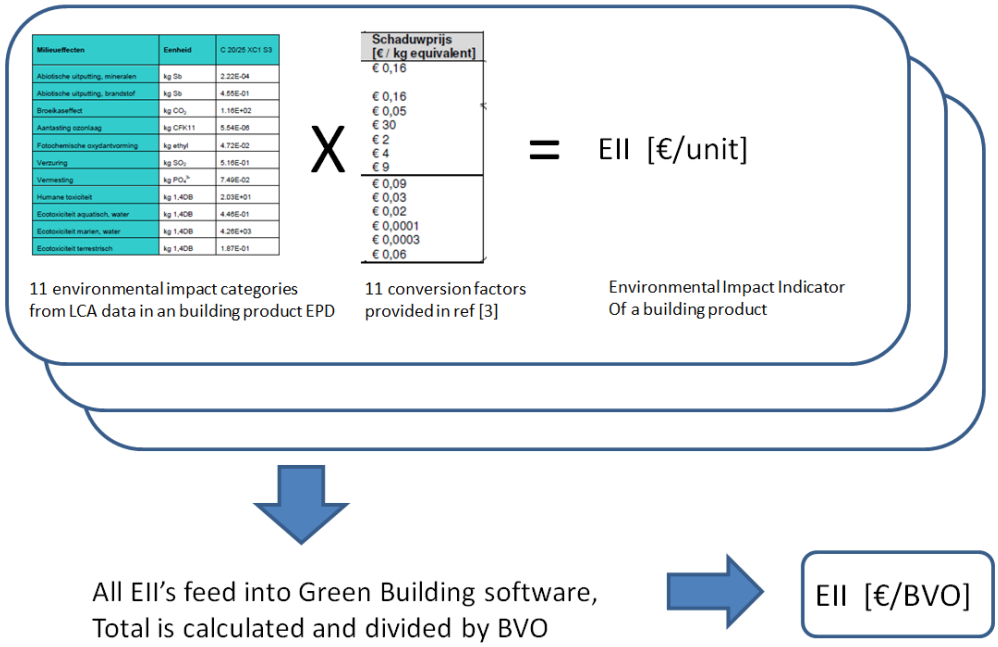

Figure 2: Schematic flow diagram to get from LCA data in a product EPD to the EII of a building product and from there to the EII of a construction work

The data in the national database are linked to commercial as well as to freeware software to calculate the environmental impact of a construction. For this calculation a range of conversion numbers is specified in a national technical report[2] that calculates the environmental impact indicator (EII) of a construction product from the LCA data given in the EPD, and from the EII's of all products the EII of a building is calculated. The process is schematically shown in Figure 2.

The Dutch building regulation requires that from the 1st January 2013 onwards for each construction, the total Abiotic Depletion Potential (ADP) and the Global Warming Potential (GWP) will be calculated. For this in practice the same software is used that calculates the total EII of the construction work and then these required two categories are reported separately.

Drivers for sustainable construction in different segments

The previous section has shown that the legislation in The Netherlands requires that the ADP and GWP of each construction should be calculated. However, that does not provide a further driver for innovation as such, since minimum performance levels are (not yet) set in our building regulations. If we use the same route as the energy performance coefficient, then it is to be expected that within a few years, when the

market is used for the calculation of the EII, the first minimum requirements will be given in the regulation.

A concrete producer with a view on near future will make sure he is ready for this. However, that is still not a way to be able to provide concrete (products) with environmental performance as added value.

For this, there are other drivers. We will handle the three major market segments one by one, explaining in short if there is a driver and where this driver comes from.

Non-residential construction

In this segment it has been reported recently[3] that commercial office buildings with a green building certificate provide higher rent, higher occupancy and reduced operational costs. This insight has ensured in a short period of time (within a year) that almost the complete development portfolio of newly build commercial office buildings in the conceptual design phase has now a sustainable building certificate. In The Netherlands this mostly comes down to BREEAM-NL.[4] In BREEAM-NL sustainable material use accounts for about 14% of the credit points. This provides a strong driver for sustainable concrete (products) as a value added product.

Residential construction

For new build the market in The Netherlands for residential buildings is largely in the commission of the building corporations. However, due to recent developments this percentage is expected to drop in the coming years. The rest of the market is built for private owners. For building corporations, with normally a strong social commitment and clear environmental policies, sustainable construction certainly has a value. Although not as strongly defined in commercial terms as in the non-residential sector (above), it is still there and this is reflected in the contracts that are on the market. For private ownership sustainable construction only accounts for high energy efficiency, and thus a low energy bill. In this part of the market sustainable material use has no added value.

Infra structural work

In this sector the national government is by far the biggest customer and sets the norm. Rijkswaterstaat in The Netherlands has developed the dubocalc method[5] that takes into account the environmental performance of the products. This method is harmonised with BREEAM-NL code for new build, and is also connected to the national database. Increasingly Rijkswaterstaat brings contracts to the market where the performance on the EII plays an important role. All major contractors have embraced programs to ensure that the EII of the solutions they propose are competitive. Sustainable use of materials in infra structural projects plays an even

more dominant role than in buildings. However, the driver for Rijkswaterstaat to be willing to reward good performance on EII in contracts is not financially driven, like in the Non-residential construction segment. Thus, in practice it is proven to be less effective for a producer to be able to create an added value.

Concrete in the BREEAM-NL system

In the BREEAM-NL MAT 1 credit, the EII of a complete building object (*e.g.* house, office, *etc*.) is expressed in the unit Euro/m^2. For this benchmark numbers are provided in the BREEAM code for residential and non-residential buildings as 1.1 Euro/m^2 and 1.3 Euro/m^2 respectively. With the MAT 1 credit 8 points can be gained, depending on how much lower the building object scores compared to these benchmark numbers.

In Table 1 a summary of the MAT 1 score for a residential building is given. In Table 2 the scores on the different environmental indicators are given. Concrete is used in the foundation, inner walls and floors. Concrete accounts for 0.16 Euro/m^2 BVO in this construction, being 22% of the total. This building with the EII of 0.72 scores in MAT 1, a total of 4 points out of the possible 8. To get to 5 points the EII needs to drop to 0.66. If we would like to provide that improvement completely in our concrete, our EII of the supplied concrete would need to decrease 38%.

Table 1: EII for a residential building, used for the calculation of the MAT 1 credit in BREEAM-NL

	EII Euro/m^2 BVO per year
Foundation	0.08
Outer walls	0.19
Inner walls	0.06
Floors	0.05
Roof	0.05
Installations	0.28
Stairs and Sanitation	0.01
Total	0.72

BVO=Bruto Vloer Oppervlak (in dutch), Gross Floor Area, in this case 202 m^2

Table 2: Data showing how the EII is built up from the 11 Environmental impact categories

Environmental effect	EII [Euro]	Absolute effect	Unit
Climate Change	62	1245	Kg CO_2 eq.
Ozone Depletion Potential	0	0	Kg CFC-11 eq.
Human Toxicity	56	624	Kg 1.4-DB eq.
Sweat water Aq. Ecotoxicity	0	11	Kg 1.4-DB eq.
Marine Aq. Ecotoxicity	0	0	Kg 1.4-DB eq.
Terristic Ecotoxicity	0	6	Kg 1.4-DB eq.
Photochemical Oxidation	1	1	Kg C_2H_4 eq.
Acidification	19	5	Kg SO_2 eq.
Eutrophication	5	1	Kg PO_4 eq.
Abiotic depletion mineral	1	6	Kg Sb eq.
Abiotic depletion fossil Energy	1	7	Kg Sb eq.
Total	146		

Optimised concrete mix design and the role of slags

There have been some good indicative studies showing how the environmental impact of a concrete mix in general is built up.[6] In this study we make use of the software tool that was developed by INTRON on request of the CUR committee B-88.[7] This software tool is commercially available through the CUR. We will show several screen shots of the software tool though these are in Dutch.

We have defined a reference concrete mix that is commonly used in the production of elements for residential buildings.

For this mix design we can calculate the EII with the CUR'88 tool, the result is shown in Figure 4. This is the EII for 1 m^3 of this concrete mix. From the output we can see the contribution of the different environmental effects, as well as how this is built up by the contributions over the different process stages (raw materials, transport, process and end of life). The CUR'88 tool has been specifically designed for concrete engineers to facilitate the mix design for sustainable concrete mixes.

Mengselgevens van 1 m^3 beton

Grondstofcategorie	*Identificatie toegepaste grondstof*	Databron	*Hoeveelheid [kg/m^3]*	*Aandeel [%]*	*Data kwaliteit*
Bindmiddel 1	cement	MRPI	310	13,7	Cat. 2
Toeslagstof 1 (primair fijn)	zand 0-4	Cat. 3	985	43,6	Betondatabase
Toeslagstof 1 (primair grof)	kalksteen	Ecoinvent	700	31,0	Cat. 3
Toeslagstof 1 (secundair grof)	betongranulaat	Betondatabase	90	4,0	Cat. 3
Vulstof 1	vliegas		170	7,5	
Hulpstof 1	superplast	Betondatabase	2,6	0,1	Cat. 3
	Totaal		2.258		

Figure 3: Reference mix design

Milieuprofiel NL (Conform NMD)

	Eenheid	Totaal	Productie grondstoffen	Transport naar betoncentrale/ betonfabriek	Processen betoncentrale/ betonfabriek	Finale afvalverwerking
uitputting van abiotische grondstoffen	kg Sb eq	3,6E-04	2,1E-04	8,3E-05	2,2E-05	4,1E-05
uitputting van fossiele energiedragers	kg Sb eq	9,0E-01	3,1E-01	3,3E-01	1,3E-01	1,2E-01
broeikaseffect	kg CO_2 eq	1,8E+02	9,8E+01	4,8E+01	1,7E+01	1,6E+01
ozonlaagaantasting	kg CFC-11 eq	1,2E-05	2,5E-06	6,7E-06	6,7E-07	2,5E-06
fotochemische oxidantvorming (smog)	kg C_2H_4	8,6E-02	3,6E-02	3,5E-02	1,9E-03	1,3E-02
verzuring	kg SO_2 eq	7,7E-01	3,7E-01	2,9E-01	2,6E-02	8,2E-02
vermesting	kg PO_4^{-3}eq	1,3E-01	4,0E-02	6,6E-02	6,7E-03	1,9E-02
humaan-toxicologische effecten	kg 1,4-DB eq	3,6E+01	1,1E+01	1,3E+01	6,8E+00	5,1E+00
ecotoxicologische effecten, zoetwater	kg 1,4-DB eq	1,1E+00	2,4E-01	5,6E-01	5,8E-02	2,0E-01
ecotoxicologische effecten, zout water	kg 1,4-DB eq	7,4E+03	2,8E+03	2,6E+03	1,1E+03	8,4E+02
ecotoxicologische effecten, bodem	kg 1,4-DB eq	5,0E-01	1,2E-01	1,0E-01	2,2E-01	4,8E-02
milieukostenindicator (MKI)	***EUR***	€ 17,53	€ 8,18	€ 5,71	€ 1,75	€ 1,89

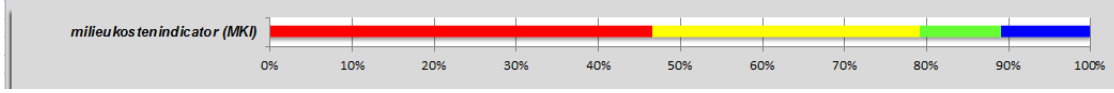

Figure 4: The EII (MKI in Dutch) built up by the environmental impact effects and by process phase (red: raw materials, yellow: transport raw materials to concrete plant, green: concrete plant process, blue: end of life scenario concrete)

With the CUR'88 tool we can now replace part of the cement by GGBS and see the effect on the EII of the concrete mix. Table 3 shows the results. As we have shown earlier, if we want to make such an improvement that we would get one extra point in the BREEAM MAT 1 score for the object, we need a reduction of the EII of 38%. If we would want to obtain this by replacement of CEM I with GGBS we need to replace 180 kg (of the original 310 kg). If we could replace the CEM I completely with a CEM III (averaged Dutch CEM III as it is in the national database) we would have almost the same result, with an EII of 17.53. These calculations are only to demonstrate the impact because the resulting mixes are not of practical relevance.

This shows us that a green building certification scheme like BREEAM-NL provides a direct incentive to a producer of concrete building products to consider the mix design from an environmental impact point of view. Of course there are many more considerations that will determine the final mix design used in specific products for specific applications. However, it is very well imaginable that when this green building certification schemes become widely adopted, there will be an increasing interest in the use of supplementary cementitious materials like slags.

Table 3: Effect of replacement of CEM I with GGBS on the EII of 1 m^3 concrete mix

Kg CEM I replaced with GGBS	EII [EUR/m^3]
0	29.08
20	27.76
40	26.44
60	25.13
180	17.23

Sustainable Concrete roadmap 2015-2020

To be ready for a future where the environmental impact of building products will be a normal aspect to take into account in the building practice, CRH sustainable Concrete Centre has decided to implement a Sustainable Concrete Roadmap. This is an option based approach where, depending on which scenario plays out, certain measures can be implemented to be ready to react to changing market situations. As a global player CRH experiences the differences in focus, stage and speed of these developments over different regions of the world. We recognise that Europe is, at this moment, the leading region when it comes to putting the environmental performance into the commercial building practice.

The building industry is certainly not the only industry recognising the importance of environmental impact assessment. To illustrate this, recent publications by PUMA on their environmental profit & loss account statements are a good example.[8] The following has been taken from the PUMA web site:

"The unprecedented PUMA Environmental Profit and Loss Account has been indispensable for us to realise the immense value of nature's services that are currently being taken for granted but without which companies could not sustain themselves," said Jochen Zeitz, Executive Chairman of PUMA and Chief Sustainability Officer of PPR. "At PPR HOME, we view the PUMA EP&L as an essential tool to help drive PPR's sustainability development across its Group of brands because analysing a company's environmental impact through an E P&L and understanding where environmental measures are necessary will not only help conserve the benefits of ecosystem services but also ensure the longevity of our businesses. The results of the PUMA E P&L underpin the urgency for a paradigm shift in the way we all currently do business and I have been pleased to also see that the release of PUMA's first results has generated widespread interest among governments, corporations, NGOs and academics."

The way forward

So what is going to happen next, one might ask? We have the CUR'88 tool available, providing us with an easy tool to use to get fundamental insight in assessing the environmental impact and how it is influenced by concrete mix design. The CUR committee B-88 is now working on the next phase of the tool, which will make it possible to do the assessment for a complete concrete building product, including reinforcement and other materials. With these tools concrete producers can assess their products and evaluate the impact of innovative new product designs. Commercial contracts for BREEAM-NL certified constructions as well as

Rijkswaterstaat contracts already provide an incentive for products or solutions with reduced EII. Competition will do the rest. To enhance our tool box we would need more knowledge on the use of supplementary cementitious materials and their effect on durability, strength and other performance criteria of concrete so that we can put those valuable raw materials to optimal use.

Abbreviations

EII	Environmental Impact Indicator, we mean the Dutch indicator (Milieu Kosten Indicator)
BVO	Gross Floor Area of a residential building, in Dutch Bruto Vloer Oppervlak
SBK	Stichting Bouw Kwaliteit, Dutch institution that maintains the National Environmental Database
CUR	Dutch knowledge institution for the construction and infra
BREEAM	Building Research Establishment Environmental Assessment Method [www.bre.co.uk]
RMC	Ready Mixed Concrete
EPD	Environmental Product Declaration
CRH	Cement Roadstone Holding [www.crh.com]
GGBS	Ground Granulated Blast furnace Slag

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