Coventry University and
The University of Wisconsin Milwaukee Centre for By-products Utilization
Second International Conference on Sustainable Construction Materials and Technologies
June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.
Proceedings of Honouree sessions ed. T Naik, F Canpolat, P Claisse, E Ganjian,
ISBN 978-1-4507-1487-7 http://www.claisse.info/Proceedings.htm

Recycling of C&D Waste in Belgium: State-of-the-Art and Opportunities for Technology Transfer

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ABSTRACT

The state-of-the-art of using recycled materials in Belgium is reviewed and more recent steps and evolutions related to the quality assurance and certification of recycled materials are highlighted. Elements high on the agenda are whole-chain management (cradle to cradle) and the practice of selective demolition to prevent dangerous contaminations being mixed with the recycled aggregate to get cleaner materials, ready for use in high grade applications such as concrete.

Also, a testimony is given about a technology transfer project. From within the construction sector in Belgium, humanitarian help was given to the people of Kashmir following the devastating earthquake which struck the northern part of Pakistan. The specific objective of this project was to contribute in the short term to the rubble processing in Muzaffarabad and in the long term to the implementation of effective rubble waste management in the region.

RECYCLING: EVOLUTION FROM FIRST RESEARCH TO AN INDUSTRIAL SECTOR

Research

At the end of the 1970's, the first Belgian research on recycling of construction and demolition waste (C&D Waste) was executed, in order to develop the whole recycling process: from demolition techniques over crushing, sieving and sorting processes to the identification of applications for recycled materials. Besides the limited 'ad hoc' experiences of recycling of rubble of the Second World War in Belgium and Germany, large scale application of C&D Waste as construction material did not exist. Carlo De Pauw, the former Director-General of BBRI (Belgian Building Research Institute), published back in 1979 as young researcher his first insights in the matter stating that 'it is technically feasible to produce a 'regular' concrete with recycled concrete aggregates with a sufficient strength' [De Pauw 1980].

Applications in practice

In the following years, the pioneering role of BBRI was transferred from research to real practical applications. When a larger alternative to the Zandvliet lock in the Antwerp harbor was needed in 1982, it was decided to use recycled aggregates for the construction of the new lock. The recycled aggregates were in fact produced from the demolition waste of the old lock's embankment walls' demolition. This approach allowed for the first real industrial scale recycling plant to be set up in Belgium in 1986 (Herbosch-Kiere N.V.) and for the recycling of 200,000 tons of concrete aggregate in the concrete of the new Berendrecht lock, which still is the largest ship lock in the world (500 m long, 68 m wide and 17 m deep). The works were supported and monitored by BBRI and BRRC (Belgian Road Research Centre) to guarantee the technical quality.

Fig. 1. Overview of the Berendrechtlock (left) and the embankment wall during construction containing 200,000 tons of recycled aggregate (right)

This knowledge was later on also applied in other exemplary projects like BBRI's RecyHouse [RecyHouse] and the Centre for Sustainable Construction CeDuBo. RecyHouse is a European funded demonstration project (LIFE) demonstrating over 200 different applications of recycled materials in a regular house. In fact, all products used (besides some rare exceptions) contain a percentage of recycled material. Most of them were available on the market at the time of construction. The concrete skeleton of the RecyHouse is made with ready-mixed concrete in which a 100% replacement of the coarse aggregate by mixed C&D Waste (approximately 20% bricks & 80% concrete) was applied.

Fig. 2. RecyHouse: overview (l.) & section of a concrete beam, containing recycled C&D waste (r.)

The research and demonstration work helped to introduce recycling practices in the construction industry. Technical specifications, mainly developed by government bodies, defined for instance application fields. A regulation framework for secondary and recycled aggregates was published, both in Flanders and Wallonia. As a result, the recycling industry started to flourish. It all resulted in a steady annual increase of recycled aggregate production, which mainly found its way towards lower-grade applications in road construction.

The role of the government

One of the main barriers for expansion of the sector in the 1990's was the lack of technical prescriptions. Thanks to a collective initiative, i.e. the set-up of a working group of LIN[1] - 'Hergebruik van Afvalstoffen' (Reuse of waste materials), several specific instructions for government example projects were drafted, allowing the use of secondary aggregates in road construction applications. This resulted in the uptake of technical prescriptions for recycled aggregates in the Standard Specifications for Road Constructions (SB250) in the Flemish region by 1996 [Ministerie van de Vlaamse Gemeenschap 1996].

Also in the Walloon region, initiatives were supported by the government in order to start up the recycling industry. With the input of the Walloon government, the organisation TraDeCoWall[2] was founded in 1991 in order to start recycling C&D Waste, to identify practical and reliable solutions for the management of waste originating from building and demolition sites and to develop valorisation options for those wastes [TraDeCoWall]. This initiative was later on also supported by the publication of Walloon technical specifications for public road works in which recycling was permitted in some areas (by MET, now in SPW[3]).

Besides the technical part, also the aspects of environmental protection were covered by authority initiatives. Following the Waste Decree of 1994, the OVAM[4] was responsible for the definition of the Strategic Waste Management Plan in 1995, in which the ambition of a 75% recycling rate of C&D Waste in Flanders by the year 2000 was defined. In 1997, the first version of VLAREA[5] regulation was published. The VLAREA regulates the administrative and chemical requirements (leaching, ...) for C&D Waste in order to be allowed for reuse in or as –amongst others- building materials. The VLAREA also implied a quality control and certification scheme for recycled aggregates, and was in this field the first legislation in Europe. In those days, the "COPRO" certification scheme emerged and allowed for the marketing of certified recycled aggregates.

Back in 1993, high grade applications such as recycled concrete with recycled aggregates were heavily debated. A LIN working group even prepared technical specifications for "recycled concrete" [Vyncke 1993], but notwithstanding the earlier positive demonstrations by BBRI, the market and government bodies were still reluctant. At the time the specifications were regretfully not approved.

STATE OF THE ART

Anno 2009, the Belgian recycling sector can be considered as grown up, with in the Flemish region 152 fixed locations (sorting of mixed C&D Waste, crushing of rubble, sometimes also mixing of lean concrete) and 42 mobile installations working under the COPRO-certification [COPRO 2009]. Since 2007, a second certification operator has entered the Belgian market, CertiPro, allowing for a QUAREA-label, which is declared to be equivalent to the COPRO-label by the competent regional authority. On the Walloon side, also about 40 recycling centers are active.

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[1] Department Environment and Infrastructure of the Flemish Community

[2] Société Coopérative pour le TRAitement des DEchets de COnstruction en WALLonie

[3] MET =Ministère Wallon de l'Equipement et des Transports, Walloon Ministry of Infrastructure and Transport, SPW= Service Public de Wallonie

[4] Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest – Public Waste Agency of Flanders

[5] VLAREA stands for the Flemish Regulation for Prevention and Management of Waste

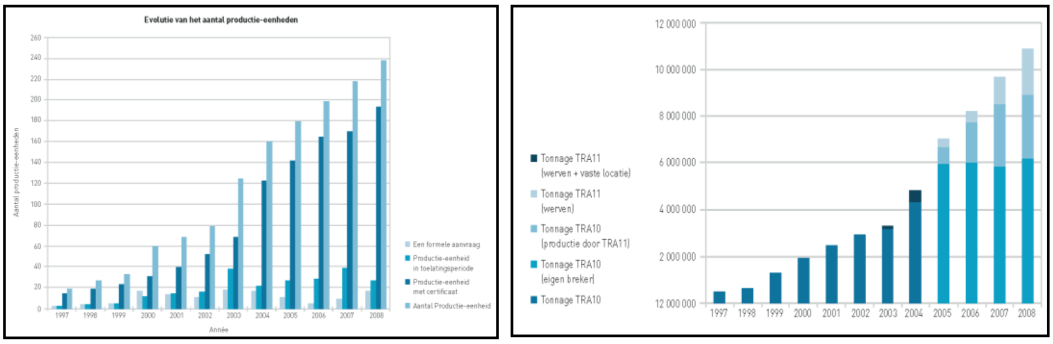

Fig. 3. Evolution of number of production units under COPRO-certification (l.) and total quantity of COPRO-certified recycled aggregates (r.) [COPRO 2009]

The recycling industry is processing about 11 million tons of C&D Waste into recycled aggregates in Flanders, which is good for a recycling ratio of over 90% [Cuperus 2007]. The Walloon region produces about 4-5 million tons of recycled aggregate. These amounts also include the amount of C&D Waste generated in Brussels (600,000 – 1 million ton). It can be estimated that 90% of the recycled aggregates are used as sub base and base layers in road construction. The other 10% is used in road-like applications on construction sites and about 100,000 to 200,000 tons is nowadays used as aggregate for structural concrete in the private market. This means that less than 1% of the recycled aggregate is used in high-grade applications.

The OVAM commissioned a study in 2008 to BBRI in order to investigate possibilities for stimulating high-grade recycling, i.e. the use of recycled aggregates in structural concrete [Vrijders & Desmyter 2008]. A stakeholder consultation revealed as main barriers:

1) Image of recycled aggregates
There is a lack of confidence in the recycled aggregate itself. A study by VITO for OVAM [OVAM 2006] investigated over 100 aggregates samples on environmental soundness; 11% passed one or more thresholds for composition (organic substances) or leaching (heavy metals, inorganic substances). Recycled aggregates are sometimes still regarded as waste with inherent risks and problems.
This is also due to the general condition of the recycling sector in Belgium. There is a strong competition between the recycling centers, mobile installations and some illegal practices. The climate does not always allow for large investments in better quality processes.

2) Doubts about the quality of recycled concrete aggregate
Since 2000, a ‘normative framework’ exists in Belgium to classify recycled aggregates for their end use: PTV 406 [COPRO 2000]. This technical prescription was elaborated in order to certify the technical quality of aggregates. Requirements were set on the composition and other aspects like resistance to fragmentation. This PTV however, was and is used for aggregates for road constructions, mainly foundations and sub foundations. In these applications, some impurities (1%) can be allowed without risks. This is considered to be insufficient to allow recycled aggregates in concrete. There was also a lack of information conceived during the interviews with stakeholders on what the real quality of the recycled aggregates is or should be.

However, the lack of standardization and knowledge doesn't mean that recycled aggregates cannot be used in concrete. There is enough scientific and practical evidence [Vrijders & Desmyter 2008, Desmyter et al 1999] to demonstrate the possibilities, despite the higher porosity and lower strength of the aggregate due to the attached cement and mortar.

3) Lack of confidence in concrete with recycled aggregates
In Belgium, the annex to the European standard on concrete (EN 206-1), NBN B15-001 [BIN 2004] does not mention anything on the use of recycled aggregates. This is in contrast to the neighboring countries, The Netherlands and Germany, where standards and other technical guidelines (CUR, DAFSTB) allow the use of recycled aggregates in concrete.
Only the Technical Prescription TRA 550 [CRIC 2004] allows since 2004 the use of recycled concrete aggregates in concrete. TRA 550 is used to obtain the voluntary 'BENOR'-quality mark, and allows for use of 20%m of recycled concrete aggregate in non-dangerous and interior applications of concrete (X0, XC1), limited to strength class C16/20. Due to the strong position of the BENOR-label on the market, concrete with recycled aggregates could only be used in a limited (private) market. Due to the lack of a normative document allowing for more ambitious applications, there is a lack of confidence in recycled concrete. However, some companies have by now established a well-working concrete production plant and are able to deliver concrete with recycled aggregates (up to 90% replacement) for private works.

4) Lack of extra incentives for high-quality recycling
There are no technical prescriptions allowing for the use of recycled aggregate in structural concrete, neither is there a technical guideline available.
The government has supported the use of recycled aggregates in road applications, also by allowing for demonstration and exemplary projects. When it comes to the use of recycled aggregates in structural concrete, there were fewer initiatives supported by the government to demonstrate and validate the possibilities.
Another role to be taken up by the authorities is the enforcement of current legislation and the tackling of illegal practices, in order to allow for a better functioning recycling market.

EVOLUTIONS

In the last couple of years, several steps were taken in order to preserve Belgium's leading position in the recycling of C&D Waste, as well on research level as on policy level and in practical implementation by the recycling sector.

Research

BBRI was one of the partners within the European IRMA-project (Integrated Decontamination and Rehabilitation of Buildings, Structures and Materials in Urban Renewal) dealing with contamination in buildings and management of recycling in large-scale urban demolition and construction projects. The IRMA-project has lead to a methodology for identification of contaminants (asbestos, PCBs, PAHs, mineral oil, other chemical substances) in buildings to be demolished: a pre-demolition assessment in 4 steps [Vrijders & Van Dessel 2007]:

1. historic records of the building: what materials were used, were there any incidents, what activities took place in and around the building
2. site visit: a verification on site is an absolute prerequisite in order to verify the suspicions identified in phase 1 and to visually assess the condition of the building and identify other possible contaminations.

3. sampling and testing: some contaminants (PCBs) might be invisible, some contaminations might be severe, others might be only superficial or even not relevant. Sampling and chemical testing are necessary at that moment, eg. to check the penetration depth of mineral oil in a concrete floor.
4. establishing a plan for selective demolition to produce a clean, uncontaminated fraction as large as possible and a limited, contaminated part that is kept apart to avoid contamination of the recyclable rubble.

Another part of the IRMA-project dealt with the management and optimal recycling of large quantities of C&D waste in an urban environment. BBRI was involved in a large case study, on which the established knowledge was applied: the demolition and recycling works for the new NATO headquarters in Brussels.

For the construction of the new NATO Headquarters, an army site containing over 60 buildings had to be demolished, resulting in 200,000 tons of inert waste. This huge amount of rubble had to be managed in an economical and environmental friendly way within the urban context of the city of Brussels. BBRI found this case a perfect example to implement the knowledge developed within IRMA. In order to maximise the economical benefit of the project the use of recycled materials in applications such as road foundations, concrete, … on the site itself was optimized. This leads to avoiding a lot of transport and primary resource use and thus minimizes hindrance and environmental impact of the works. The study was elaborated in cooperation with the governmental body Brussels Environment and Enviro Challenge.

In first instance, promising scenarios for recycling were developed. On the one hand, the choice had to be made to recycle on-site or off-site (or not to recycle at all). On the other hand, detailed on-site recycling scenarios had to be developed in order to assure that all inert material that originates on the site could be reused in future applications.

NATO's Project Management Team chose for full on-site recycling, based on a full scenario assessment by the IRMA City Concept's Expert Recycling Model. This assessment tool makes a comparison between the different scenarios in terms of economy (costs are the most important decision parameter for an owner/developer), logistics (timeframe, space available on site, hindrance for neighbours) and environmental impact (CO_2 emission, Fine dust or PM10, natural resource consumption …). Most important parameters in the evaluation are transport (distances and amounts of materials to be transported), costs and recycling percentage on site. Results showed that in this case, on-site recycling was the best solution. It could save up to 350,000 km of traffic and as such a lot of CO_2 emissions. A secondary effect was the avoided road congestion and hindrance for traffic. Also in terms of economics, the gain for on-site recycling was clear: over 50% cheaper compared to off-site recycling. The assessment of the boundary conditions showed that there were no restrictions due to the timeframe or storage space on site.

Additional to the scenario assessment, a tender specification on waste management and recycling was elaborated. This tender document is based on the principle that the final requirements are laid on the secondary aggregates, but that the demolition contractor is free to organise the demolishing works to his own insights. Important topics in the specifications are quality control, waste management and site logistics.

Fig. 4. Overview of the Demolition & Recycling Site showing the different products made on-site © NATO

This project resulted in a national spin-off, 'Ketenbeheer' (Chain Management), where the extra step towards high-value application of recycled aggregates as a gravel substitute in concrete will demonstrated through 5 demonstration projects. Other aspects addressed in the project include the environmental and technical pre-demolition assessment, expanded chain management (where the old building is considered as a source of resources and the quality of the materials is optimized and controlled throughout the recycling chain), quality assurance and concrete production.

Legislation, standardisation and quality assurance

In 2009, a new version of the Flemish legislation on waste management and recycling, VLAREA, was published. For C&D Waste the existing framework on environmental characterization was enlarged with two important concepts [OVAM 2009].

1. Total or Whole Chain management

"The list of environmental parameters to verify is limited to heavy metals (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn), extractable organohalogens (EOX), mineral oil and PAHs, on the condition that the recycled aggregates (except asphalt) comes from a recycling centre, subjected to a management system, approved by OVAM". This management system is at the moment being elaborated by the sector representatives and will contain the principle of 'chain management'. This means that a distinction will be made between suspicious and unsuspicious C&D Waste at the acceptance at the recycling centre, based on the origin of the waste. When the rubble was selectively demolished, no problems are expected. In the other cases, the waste can be suspicious and will be treated as such. Other aspects in the Chain Management System are adapted frequencies of testing, based on a statistical approach and the responsibility of each actor in the recycling chain.

2. Waste inventory before demolition

In order to allow for a correct price setting and a correct follow-up of (dangerous) waste streams, the VLAREA imposes since May 2009 that "for buildings with a (partially) different function than housing, and an enclosed volume over 1000 m³, a waste inventory for demolition has to be drawn up, before awarding the work to a contractor, by an architect or another expert. The owner of the urban development or building permit (in most cases the client) is responsible for this. The inventory should list all waste fractions that will come from the building, their type (dangerous, inert, ...), appearance and presence in the building and quantity.” This means that for industrial buildings (but also schools, shops, ...) of a certain dimension, a pre-demolition assessment must be executed to list all dangerous and other waste fractions. Based on the listed materials, the demolition contractors can all define their price offer based upon the same information, which should allow for a more fair competition in the market and a better follow-up of dangerous waste throughout the chain.

In the field of standardization things are moving as well. Since 2008, the European standard for Aggregates for concrete, NBN EN 12620, contains some explicit clauses for recycled aggregates. Besides aspects on chloride and sulphat content, a new identification test is included (NBN EN 933-11:2009) to assess the composition of recycled aggregates. For concrete, the Belgian annex to EN 206-1, NBN B15-001, is in revision and will contain some aspects on the use of recycled aggregates. The current draft version mentions the allowance for 20%v of recycled concrete aggregate, in exposure classes X0 and XC1, up to strength class C25/30. This means that recycled aggregate can be used in more common interior applications of structural concrete. The new NBN B15-001 will also define some quality requirements for the recycled aggregate itself (i.e. specific fit-for-use requirements), such as limits for grain size, composition (constituents), resistance to fragmentation, density …. It is expected that the new standards will lead to a specific approach for quality assurance and certification of concrete and recycled aggregates.

Practical solutions

Also in the practical field innovation continues. Frontrunner companies are now working on the practical application of colour sorting of mixed C&D Waste. Using optical scanning and air pulses, the pure red (clay) fraction can be separated from the grey (concrete) fraction. Both fractions can be used to close the loop: the bricks will be partially used in the production of new bricks, the concrete aggregate will serve as aggregate for concrete production.

Besides the stony fraction, solutions are developed for other C&D waste types as well. Instigated by the Flemish Authorities (OVAM) and a market demand, companies are taking initiatives to find recycling solutions for gypsum (boards, powders), autoclaved aerated concrete and bituminous materials (roof coverings). For gypsum, a recycling factory is built in 2008 nearby Antwerp, operated in partnership between the gypsum factory and a recycling specialist. The recycling solutions for the other fractions are in pilot scale testing and investigation of feasible collection schemes.

TECHNOLOGY TRANSFER

On the morning of 8th October 2005, a devastating earthquake, measuring 7.6 on the Richter scale, struck the northern part of Pakistan (NWFP[6] & Kashmir), causing the death of 75,000 people. 400,000 houses were destroyed, resulting in an additional 3.5 million persons being homeless.

A joint initiative from the Belgian building sector (Construction Confederation and BBRI), Ingenieurs zonder Grenzen (Engineers without Frontiers) and the Belgian Government (Federal Department of Foreign Affairs, Foreign Trade and Development Cooperation) was set up to give humanitarian help to the people of Kashmir and Muzzaffarabad, the epicentre of the earthquake. After the first aid phase, supported by the UN, the Red Cross and Artsen Zonder Grenzen (Doctors without Frontiers), people returned to their villages, and the

[6] North-West Frontier Province

reconstruction of the towns could begin. However, before construction could start, the rubble needed to be processed. Given the estimated amount of rubble (6 million m³), this was a very challenging task: the area is mountainous, transport is difficult to organize, disposing waste causes environmental and safety risks. For example, disposal next to the river causes risks for flooding; dumping rubble in a hilly environment may cause collapsing and landslides.

Following a humanitarian mission of members of the Brussels Capital Region Parliament, a technical mission was established. For more detailed information, see [BBRI 2009]. Given the experience and expertise gained throughout 25 years, also in disaster planning [De Pauw & Lauritzen 1994], Belgium could serve as an ideal technology transfer partner in using recycled material from building rubble in roads and constructions. The specific objective of this project was to contribute in the short term to the rubble processing in Muzaffarabad and in the long term to the implementation of effective rubble waste management in the region.

A team of 3 BBRI experts travelled to Islamabad in 2006 to explore the region, visit several communities and talk to representatives of organizations involved to the initiatives of reconstruction: authorities, humanitarian organizations and contractors. It became clear that technology transfer was an absolute necessity in order to facilitate the sustainable redevelopment of the area. Focus was from the beginning on as well the 'soft' aspects (estimates, training, education) as on the 'harder' aspects (equipment, tools, …). It's no use to learn or demonstrate something that can't be applied in practice afterwards, due to lack of machinery. The financial support of the Belgian Government (FOD Foreign affairs, Foreign Trade & Development Cooperation) and a supplementary grant of the Government of the Brussels Region was obtained and together with the local partners ERRA ('Earthquake Reconstruction and Rehabilitation Authority') and MCM ('Municipal Cooperation Muzaffarabad'), a project was set up to provide in:

1) The installation and running up of a recycling plant in Muzaffarabad, donated by the Belgian Government.

It was believed that for the Kashmir region, recycling waste in concrete should not be the first option to be promoted because it requires a far more elaborated quality control and because the most important thing to do in the first place is to clear up the debris quickly and efficiently and to give it a useful destination. Therefore, more common applications with a 'proven service record' for several years are aimed at aggregates for roads and simple building blocks. Doing this the proper way, would also lead to increased employment. For future business opportunities however, higher grade recycling could be envisaged as well.

A mobile crusher was considered to be the first important thing to get to the area. Offers were investigated by a Technical Committee (with experts from the VVS[7], TraDeCoWall and the project partners), which lead to the purchase of a mobile plant, delivered by a company, active on the Pakistani market.

2) Training of Pakistani plant managers

In order to ensure a good functioning of the recycling plant a technical training session was organized at the headquarters of the crusher producer in the United Kingdom. A delegation of 6 Pakistani, accompagnied by a BBRI representative, were educated and got their first hands-on experience to work with the mobile crusher. Additional visits to BRE, construction

[7] Flemish Union of Recycling Companies

sites and recycling plants were organized, in order to show the recycling activities in practice.

A strategic visit or master training was also organized for the decision makers of ERRA in Belgium. Visits were paid to the Belgian authorities dealing with waste and recycling in order to learn about waste management policy. Also recycling installations and applications sites were visited, to show possibilities and attention points for managing the impacts of recycling plants on the environment and resources.

3) Organization of workshops to foster technology transfer on recycling and waste management

Finally, in May 2008 a workshop was organized in Muzaffarabad to finetune the existing practice and to instigate future developments on new building products with recycled aggregates, quality control, policy, …. This workshop was combined with the official handover of the installation, at that moment consisting of the mobile crusher expanded by a secondary impact crusher, a sieving installation, conveyor belts, a concrete mixer and a block production plant. An important remark to this story is that a new law was voted in May 2008 by the local Muzaffarabad government, forbidding the disposal of rubble of any type in the Neelum River. This illustrates the evolution of the humanitarian project to a protection of the environment and natural resources.

Fig. 5. Overview of the Recycling Plant Lay-out in Muzaffarabad

Fig. 6. Concrete block machine & concrete blocks produced & quality control

CONCLUSIONS

In 30 years, the Belgian recycling sector evolved from pioneering research work to a grown up industry, where continuous improvement steps are still made, thanks to the combined efforts of research, authority initiatives and companies taking the lead initiative. The recycling rate of 90% of C&D waste is maintained and even improved, by elements as chain management, higher-grade applications, legislation on waste inventory and pre-demolition assessment, solutions for other fractions and exemplary projects.

This experience and expertise has also proven to be a valuable basis for development of a humanitarian project in Pakistan, following the earthquake of 8/10/2005. Not only 'soft knowledge' was transferred in the transition aid project, but also hardware (working technology and installations) were delivered. An extra was the growing attention for protection of the environment and natural resources.

REFERENCES

BBRI (2009). "Belgian Transition Aid Support Project: Kashmir Recovery Recycling Rehabilitation: Installation of a recycling plant at Muzaffarabad", *www.wtcb.be/go/kashmir* .

BIN (2004). "NBN B 15-001 : Aanvulling op NBN EN 206-1 – Beton – Eisen, Specificaties, eigenschappen, vervaardiging en conformiteit", 3e uitgave, 26p.

CRIC (2004). "TRA 550 – Toepassingsreglement Beton, versie 2.1".

COPRO vzw (2009). "Jaarverslag 2008", www.copro.eu.

COPRO vzw (2000). "PTV 406, Puingranulaten". 2nd version appeared in 2003.

Cuperus, G. (2007). "Recycling of C&DW in Europe" FIR Interforum 2007.

De Pauw, C. (1980). "Kringloopbeton". *WTCB Tijdschrift*, 1980 nr 2, blz. 2-15

De Pauw, C. and Lauritzen E. (1994). "Disaster Planning, structural assessment, demolition and recycling", *E&FN Spon*, 176p.

Desmyter J. and Blockmans S. and De Pauw P. (1999). "Puingranulaten en gerecycleerd beton: nieuwe resultaten en ontwikkelingen. Deel 2: Gerecycleerd beton (onderzoek)." *WTCB Tijdschrift*, 1999 nr3 p. 11-19.

Ministerie van de Vlaamse Gemeenschap (1996). "Standaardbestek 250 voor de wegenbouw".

OVAM (2009). "Vlaams Reglement inzake Afvalvoorkoming en –Beheer (VLAREA). Laatste versie 13.02.2009".

OVAM (2006). "Screening van de milieuhygiënische kwaliteit en kwaliteitsopvolging van puingranulaten"

RecyHouse, EU LIFE project, www.recyhouse.be

Tradecowall, www.tradecowall.be

Vrijders, J., and Desmyter J. (2008). "Een hoogwaardig gebruik van puingranulaten stimuleren", *BBRI for OVAM*.

Vrijders J. and Van Dessel J. (2007). "Inventarisatie van contaminanten in te slopen gebouwen", *WTCB-Dossier*, 2007 nr1, 10p.

Vyncke J. (1993). "Hergebruik van bouw- en sloopppuin als granulaat in beton voor gebouwen en kunstwerken. (Van Normen & Reglementen)". *WTCB Tijdschrift*, n.4. p.39-44.