

Putting recycled concrete into practice in Belgium: From case studies over chain management to standards and quality assurance

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Abstract

Although there has been extensive research and several demonstration projects in Belgium and abroad, the use of recycled aggregates in concrete is still limited in practice. Several barriers were identified: lack of practical experience, limiting standards and the need for specific quality assurance. The paper describes recent developments in Belgium, with focus on practical experiences and support of the professionals on the one hand, and development of standards and quality assurance schemes on the other. Practical experience is gained through 10 pilot projects using recycled aggregates in structural concrete for roads & buildings. The results show concrete with recycled aggregates on an industrial scale can fulfill all technical requirements. However, specific attention points are to be taken into account, as well in the design phase (applications, ambition levels), the preparation phase (quality of aggregates, ITT of concrete) as in the execution phase (finishing, curing ...). A step-by-step procedure to guide the process has been elaborated. Complimentary, research has been executed to reinforce the recycling chain, and to directly link the demolition of a building to the crushing and the quality of the recycled aggregate for use in concrete, in order to obtain a so called 'short & strong chain' in order improve confidence & to divide costs & benefits over the actors. A second development is the specific Belgian standardisation and certification framework, based on the European standard EN 206. Specific aspects of the Belgian approach are the implementation of the 'specificity of use'-principle, application of correction and safety factors on the calculation of the effective water-to-cement-ratio and the required quality of the recycled aggregates. To support the development of the standard, research is being executed in several Belgian laboratories. Results on aggregate quality (10 sources) and concrete performance (20%, 30%, 50% replacement) show the feasibility and the limits. Finally, a specific certification scheme for concrete with recycled aggregates is being developed. This procedure addresses requirements on the high-quality aggregates, specific initial type testing and factory production control schemes, practical implications on the concrete production plant (storage of aggregates, mixing procedure ...). The combination of the different developments will lead to the increased and responsible use of recycled aggregates in structural concrete in Belgium.

Keywords: recycled aggregate, concrete, practice, chain management, standardization, quality assurance.

Introduction

The recycling of construction & demolition waste in Belgium is considered a 'grown up', well-developed economic activity in an established market. However, only an estimated amount of 1% of the available recycled aggregate (which equals about 200,000 tons on 18 million tons each year) is currently used as aggregate for structural concrete [1]. Although there has been extensive research and several demonstration projects in Belgium and abroad,

the use of recycled aggregates in concrete is still limited, due to several barriers: lack of practical experience, limiting standards and the need for specific quality assurance.

However, in recent years, an evolution is ongoing to tackle these barriers.

- Practical experience is gained through pilot projects using recycled aggregates in structural concrete for roads & buildings. Pilot projects allow for evaluation of technical performance, as well as identifying important attention points throughout the realisation process (design, preparation, execution ...).
- Additionally, research is being executed on short and direct chain management, in order to improve confidence and to divide costs and benefits over the involved actors (demolition contractor, recycling plant, concrete producer, ...)
- On the other hand, the Belgian standardisation framework is changing, and will contain specific aspects on the use of recycled aggregates in concrete in the near future. To support this evolution, a specific certification scheme for concrete with recycled aggregates is being developed.

Practical experience

An important barrier for the use of recycled aggregate concrete is the lack of practical experience and well documented knowledge. In the past, several (large scale) demonstration projects were executed, like the demolition of a part of the Zandvliet lock and the construction of the Berendrecht lock and the RecyHouse (www.recyhouse.be). However, since technical documentation is lacking in most of the projects in the past, it is difficult to assess the long term performance of the recycled concrete, and thus to build up a dataset and confidence in the durability of the concrete.

Between 2013 and 2016, 10 pilot projects were executed using concrete with recycled aggregates, in order to demonstrate the possibilities and in order to learn from the practical experiences. The projects are varying in terms of application domain (roadworks: 3, industrial concrete floors: 5, building structures: 2) and thus in concrete composition and requirements. Most pilots opted to replace virgin aggregate by recycled concrete aggregate (8) or manufactured aggregates like slags (2); in only 1 project, alternative binders were used as way to reduce the environmental impact. The replacement ratio varies between 20% to 100% (of the coarse aggregate fraction). In all projects, the process was guided by BBRI and testing was done in the preparation phase and/or during the execution stage. The most important conclusions in terms of concrete performance are given below:

- The concrete with recycled aggregates had similar properties in fresh condition (slump, workability) as conventional concrete – besides the attention points noticed in §3.4: variance in slump & a faster drop in workability. Additionally, tests on fresh concrete showed that concrete with recycled aggregates can have a higher air content (a surplus of 1-2%). A possible explanation is the use of a specific type of superplasticizer that interacts with the concrete mix. This has a negative effect on the compressive strength, but can be beneficial for the frost-resistance of the concrete.
- In all projects, the required compressive strength was obtained. There was however a slight decrease (-5%) in compressive strength noticeable when a limited amount (<30%) of recycled aggregate was used, which became more clear (-10%) when replacing higher volumes (> 30%). This is in line with the vast amount of research available, e.g. [2].
- In none of the projects a significant difference was noticed between the carbonation of concrete with recycled aggregates and conventional concrete (test according to NBN EN 13295 on prisms 10x10x40).

- The frost-thaw resistance was measured according to 12390-9 - slab test method. In general, the resulting mass losses after 28 or 56 cycles clearly show:
 - o The influence of air entraining agent. The compositions with air entrained perform much better. The influence of the use of air entraining agent is much bigger than the use of recycled aggregates.
 - o The influence of the use of recycled aggregates is only visible when higher replacement ratios were applied: below 50% replacement of the coarse fraction, no clear differences were noticed between conventional concrete and RCA-concrete. Replacement up to 100% resulted in higher mass losses and thus a less frost resistant concrete.
 - o The concrete compositions for roads (lower W/C, air entrained) all perform well, even with 100% recycled aggregate. Although, the water absorption rate of the concrete (which is used as a proxy to frost resistance) is higher than allowed by Flemish specifications (6.5%). This probably has to do with the lower volume mass and the higher air content entrapped by the recycled aggregates

An important result of the pilot projects was the elaboration of a technical specification document. This report is meant as a practical guidance document, complimentary to the standards and existing certification schemes, allowing parties in practice to make arrangements on the use of recycled aggregates in concrete for buildings or road works. It describes the whole production chain, from demolition to the production of qualitative aggregates and concrete, as well as the actual placement on site. In each of the steps, a technical description is given on relevant criteria & information, and practical recommendations are given to realise the desired requirements & criteria.

Short & strong chain management

Two important factors for success in using recycled aggregates in concrete are the elevated quality of the recycled aggregate, and a stable provisioning of aggregates in a continuous productions process (no supply shortage), especially if the concrete producer is another company than the recycling company. A possible solution for both aspects, is the development of a cooperation model between different actors in the recycling chain: the demolition contractor, the concrete recycling company (crusher) and the concrete producer. In a traditional model, all 3 parties have barriers (see table). In a short and strong chain, all 3 parties could have shared benefit & profit, if they agree to take a more holistic approach. This would mean that the demolition contractor does some 'cherry picking', by selecting the buildings, structures and parts of the structure that are high-quality concrete and can be selectively demolished, so the recycling company can crush these separately and make high quality recycled aggregates out of them. The origin of the concrete debris is known, which elevates the confidence in the recycled aggregate.

Table 1. Overview of barriers & potential benefits in short chain management

Actor	Barriers	Potential benefits
Demolition contractor	Work more selectively costs more time & money	Lower disposal fee at crusher
Recycling Company	Unsure sources of concrete, quality control & improvement necessary	Fix supply of high level concrete debris, fix client for high level RCA
Concrete company	Uncertain supply (volume & quality)	Replacement of virgin aggregate at lower cost

This approach was hypothetically tested in a Belgian case study with 4 actual companies using their figures for costs & revenues. The results show that there might be a mutual benefit for all 4 parties involved, as long as the central actor (recycling company) is willing to distribute the benefits.

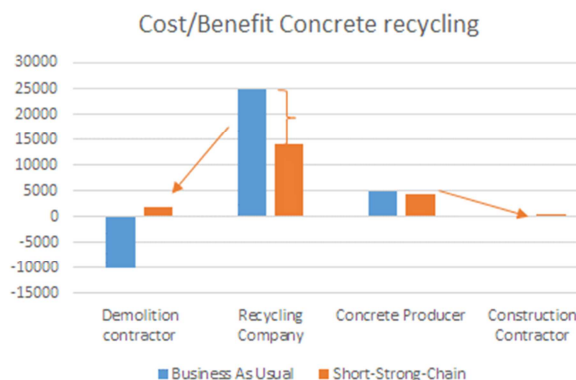


Figure 1. Illustration of shared cost & benefit in a short & strong chain

The next step is implementation of this model in practice, and evaluate the boundary conditions (volumes, transport distances ...).

Quality assurance

The new Belgian complement to EN 206, NBN B15-001, will normally allow for the use of 20, 30 and 50% of coarse recycled concrete aggregates in new concrete, up to C30/37 and in conditions with rain & frost (without deicing salts). Quality assurance plays an important role in the Belgian construction sector. Most (public) clients require the “BENOR label” as proof that the concrete delivered on site is conform to the Belgian concrete standard. A specific technical prescription document exists for this third party certification. However, this scheme is not developed for concrete using recycled aggregates. A working group is now developing these specific requirements, with special attention for the following aspects.

First of all, the quality of the recycled aggregates should be guaranteed & certified as well. In addition to the requirements of NBN B15-001, the maximum diameter of the aggregates is limited to 20mm. This is done to avoid carbonation tests on the concrete level. Also specific requirements are laid on the storage and processing of the recycled aggregates, in order to avoid contamination with other fractions, and in order to guarantee a controlled humidity environment (to take into account in the mixing process).

A distinction is made between concrete types and families. There are the ‘basic’ or standard concrete types on the one hand, requiring the same quality control aspects as conventional concrete without recycled aggregates, expanded with specific ITT tests for each concrete composition in terms of compression strength and workability. On the other hand, the application domain where durability is an issue, more tests are required in the initial phase, specifically on carbonation resistance and frost-thaw resistance of the concrete with recycled aggregate.

Conclusion

The use of recycled aggregates in concrete in Belgium is on the rise. The combination of the different developments – as well in the field and in terms of business models, as in terms of

standardisation and quality control - will lead to the increased and responsible use of recycled aggregates in structural concrete in Belgium.

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