The French National Project Recybéton, to bring the concrete world into circular economy

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Abstract

France is currently producing about 17 Mt/year of demolished concrete, most of this material being used in road subbase courses or embankments. However, this flow should increase in the near future, although less and less new roads are to be built. Another 20 Mt of mixed demolition materials, a good part of it being concrete or natural rock is also available. Therefore there is a duty both for the society and the planet to make the best use of this resource, in order to preserve the natural resource and to avoid waste material landfill.
Based on this reality, a national project, partially sponsored by the Ministry of Ecology, was set in 2012, gathering 47 partners among which representatives of all construction stakeholders.
The paper aims at presenting the main outputs of the project, which will produce various deliverables: a scientific book (to be published), a guide (under preparation), a number of proposals to adapt standards and regulations, and, last but not least, five experimental constructions, including a parking lot, a bridge, various buildings and industrial constructions.

Keywords: recycling, recycled concrete, recycled concrete aggregate, national project, experimental construction site.

Introduction

After two years of preparation and meetings, the most important actors of the French construction sector decided to launch in 2012 a national project about “Recycling concrete into concrete” called Recybéton [1]. The stakes were numerous, all pushing toward this direction: i) need to preserve the natural aggregate sources given the difficulty to open new quarries, ii) future increase of the flow of construction & demolition materials generated by the cities, iii) need to ultimately suppress all landfill in the country, iv) need to decrease transportation distances for both social and environmental reasons, and, finally, v) need for the concrete industry to catch up as compared to competing materials, some of which being more advanced into the circular economy. This paper gives a brief overview of the work done by more than 100 researchers and practitioners, spending a budget of about 5 M€ in 5 years.

Main outputs

Material processing

Most of the project aimed at developing the use of recycled concrete aggregate (RA) into new

concrete, with a replacement rate ranging from 0 to 100 %, for both coarse and fine aggregates.
Recycled concrete aggregates are generally used "as obtained" through the sole process of crushing and sieving (plus removal of the steel reinforcement). As-obtained ordinary recycled aggregate display a low density and a high porosity, as compared to natural aggregates. Before batching fresh recycled concrete (RAC), pre-saturating is advised to avoid early workability losses generated by water absorption. Otherwise the process of recycled concrete production does not differ from the one of natural aggregate concrete (NAC). Finally, numerous techniques are available to perform *selection* – sorting the undesirable particles in a mixed demolition material – *detection* – on-line identification of the presence of such a phase – or *fracturation* – debonding the cement matrix from the original virgin aggregates. A review was performed on these techniques.
The possibility of using fine recycled aggregate as a supplementary cementitious material was also investigated. When grounded with the clinker (to make a blended cement) or to the concrete, the product performs as a filler, with sometimes a tendency to degrade the fresh concrete slump retention (a problem which can be solved through the use of a set retarder). As a raw material, it was tested at a replacement rate of 15 %, producing industrially a "good" CEM I cement. Unlike the previous processes, this one is currently allowed by the cement standard EN 197-1, so that the only obstacle is the availability, for cement factories, of a consistent, close and large enough source of recycled fine aggregate.

Recycled materials and structures

The impact of incorporation of recycled aggregate into concrete was investigated in a quite comprehensive way. The effect is minor on strength (only noticeable at high replacement rate), but all deformability properties evolve towards more strains in recycled aggregate concrete: E-modulus, shrinkage, creep. The flexural fatigue strength is also affected with a trend to more scatter in the results.
The behavior of structural elements - columns and beams of various dimensions were tested - is in line with the material properties: higher deflections in beams, higher buckling risk for columns, contribution of concrete to shear resistance depending on its tensile strength, as the bond between steel and RAC. Therefore no significant increase of crack width is observed in loaded reinforced RAC pieces.
In terms of durability, incorporation of RA increases the total porosity of concrete. This microstructural modification entails an easier transport of gas, water and alien species through RAC. However carbonation is only affected in the lower strength range of the mixes. Also, durability can be adjusted by lowering the water/binder ratio. Depending on the origin of RAs, they can be frost-sensitive, overcoming their use in RAC if the risk of freeze-thaw is present.

Sustainable development

The available national resource in RA was investigated. A total of 17 Mt was identified, to which another 20 Mt of cement treated or untreated NA have to be added. These materials are currently devoted to road and embankments, but can be partly redirected to the concrete business. In terms of Life Cycle Analysis, the positive points deal with the saving in non-renewable resource and the avoidance of landfill. Regarding carbon footprint, two key aspects must be examined: the transportation distances, which can be shorter for RA as compared to NA, and the cement content of RAC, which tends to increase for large

replacement rates. Finally, leaching of RA or RAC does not seem to release significant amount of pollutants when exposed to water, unlike other types of waste materials.

Standards and regulations

Recybéton is preparing proposals to extend the range of possible uses of RAC in France (EN 206/CN, Eurocode 2 etc.). Possible incentives to favor the process are also studied [2].

Dissemination, among which demonstration sites

A number of seminars are organized and will be continued in order to disseminate the results of the project. A scientific book is being completed [3] and will be published by the end of this year, a guide is also being processed, addressing all relevant categories of stakeholders involved in the construction world. Finally, five different experimental sites were carried out (see photographs in Appendix), showing how easy is the process of recycling concrete into concrete.

Conclusion

After 5 years of collective work, the French construction community has increased its awareness about recycling concrete into concrete. Most technical problems were addressed, and none of them appear to be a roadblock. All the tools will be available to improve significantly the sustainability of the concrete world, using at least partially a resource which represents about 30 % of the current aggregate consumption in concrete. Let's hope that the efforts undertaken will be paid off by a gradual change in the current practices, as it is already the case in more advanced countries.

Acknowledgements

The Recybéton project gratefully thanks the Ministère de l'Environnement, de l'Energie et de la Mer/Direction de la Recherche et de l'Innovation for its direct financial support, and the Agence Nationale de la Recherche for having sponsored the Ecoreb project, connected with Recybéton.

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Wall in Genevilliers (92)	Sidewalk, same location
	
Archive building in Mitry-Mory (77)	Construction of the same