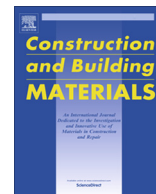




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## New sustainable technology for recycling returned concrete

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### HIGHLIGHTS

- The new technology transforms returned concrete into a granular material.
- After curing, the granular material can be used as aggregates for new concrete.
- Consumption of natural aggregate is reduced and no waste is produced.
- Concrete with 100% of new aggregates has been developed and marketed in Japan.

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### ABSTRACT

A new technology is presented for transforming returned concrete into a granular material that can be reused as aggregates for concrete. The new method is based on non-toxic, easy to use additives that are added directly into the drum of truck mixers containing returned concrete. The new method favours the preservation of natural resources, allows the reduction of waste and the cutting of costs, both for waste disposal and for aggregates supplying. A laboratory and full scale test program has been undertaken in Japan by GNN, a Japanese association of RMC companies, to implement and fully assess the new technology.

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### 1. Introduction

The production of construction and demolition waste (C&DW) is concurrent with the production of concrete, the second most consumed material, after water. It is estimated that roughly 25 billion tons of concrete are globally produced every year. Consequently, 510 million tons of C&DW are generated in Europe, about 325 million tons in the US and about 77 million tons in Japan. Given that China and India are now producing and using over 50% of the world's concrete, their waste generation will also be significant as their development continues.

Recycling and recovery of both hardened concrete and returned concrete is an important issue for concrete sustainability. Returned concrete is the unused unset concrete that comes back to the plant in the concrete truck as excess material. This can be small amount of concrete leftover at the bottom of the drum, or more significant quantities not used by the customer at the construction site. Typically, the amount of returned concrete generated by ready-mixed

deliveries can be as low as 0.4–0.5% of the total production. However, during peak periods, returned concrete can increase to 5–9%. Globally, it can be estimated that over 125 million tons of returned concrete are generated every year, confirming that it is a relevant part of C&DW and represents a heavy burden for the ready-mixed plants [1].

### 2. Current methods of processing returned concrete

Current methods of processing returned concrete include:

- (1) Discharging returned concrete at a location at the ready-mixed plant. Hardened concrete is then removed and stored before disposal to landfill or crushed to produce aggregates in recycling centres.
- (2) Production of concrete elements, such as blocks for breakwaters or retaining walls. This possibility is limited by local market conditions and opportunities for the block production.
- (3) Reclamation systems to reuse or dispose the separate ingredients, including the process water. The fines and cement materials are washed out and held as a slurry in suspension tanks. Coarser sand and aggregates are also extracted and

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stockpiled and can be reused for the manufacture of new concrete. This method requires significant capital investment and careful attention to proper practice [2].

### 3. The new method to recover returned concrete

So far, environmental impact, working complexity and capital investment have limited the possibility of achieving a high level of recycling. The new method presented in this paper is based on a new additive that transforms returned concrete, in few minutes and without the need of specific equipments, into a granular material that can be fully reused as aggregates for new concrete. The new technology permits the complete recycling of returned concrete without the generation of wastes and, through the saving of natural aggregates, the preservation of natural resources. Furthermore, the new technology is very easy to apply and it is not based on toxic substances. Finally, it permits economical benefits through the saving of aggregates and the cut of costs for waste disposal.

#### 3.1. Description of the new method

The new method consists of 4 steps:

Step 1 – Addition of superabsorbant polymer SAP (Part A) into the drum of the truck mixer containing returned concrete. The dosage of Part A is in the range 0.4–0.8 kg of SAP/m<sup>3</sup> of returned concrete, depending on water to cement ratio (W/C), type and dosage of cement and climate conditions. Most of the free mixing water is absorbed by the polymer and, after few minutes of mixing (2–3 min), returned concrete is transformed into a granular material made by a core formed by the original aggregates covered by a composite material made by cement paste, sand and the superabsorbant polymer, as shown in Fig. 1.

Step 2 – Addition of an ettringite forming compound (Part B), based on Aluminium Sulphate, and mixing for additional 2–3 min. The dosage of Part B is in the range from 4 to 8 kg/m<sup>3</sup> of returned concrete. The formation of ettringite crystals further consumes free water and consolidates, through a sort of “chemical sintering”, the fresh granular material, giving enough strength to be further processed.

Step 3 – Discharge. After Step 2, the granular material is discharged to the ground and stored in a stack, avoiding accumulation in tall piles to prevent excessive pressure over the bottom layers.



Fig. 1. Typical aspect of a fresh granular material after the addition of SAP.

The scheme of the operation of the new process for recovering returned concrete is shown in Fig. 2.

Step 4 – Curing. The bulk granular material needs to be cured like any concrete material. The only precaution in this step is to move the piles with a grab once or twice within the first 24 h, in order to break the weak bonds of hydrated cement paste among the grains and detach them each other. The optimum time for processing the material depends on many variables, such as the climate conditions, type and dosage of cement and water to cement ratio. If the granular material is left for longer time before moving, the bonds among the grains become stronger and it is necessary to spend more energy to break the lumps. Once the granular materials have been moved, there is no further risk of agglomeration and it can be stored as normal aggregate. In Fig. 3, the dependence of optimum processing time on concrete temperature is shown. This relationship has been obtained by VCCTL software (Virtual Cement and Concrete Testing Laboratory) developed by NIST (National Institute of Standard and Technology) and gives an idea how climate conditions are important in determining the optimum processing time.

### 4. Characteristics of the aggregates with the new method

The properties of the aggregates obtained by the new technology are related to those of the original aggregates and to the mix-design of the returned concrete. The composite layer of mortar that surrounds the core of the grains of the new aggregates influences their characteristics, both in terms of size and other physical/chemical properties. Fig. 4 shows the comparison between the cumulative aggregate distribution of the original aggregates (dotted line) and the recycled aggregates produced with the new process (solid line). The reduction of the fraction finer than 4 mm for recycled aggregates is due to the action of SAP, which agglomerates the finer particles (cement, sand and fillers) around the original aggregates.

The other physical–chemical characteristics of recycled aggregates cured for 28 days are shown in Table 1. Each value has been determined as the average of three measurements made on aggregates produced from different returned concretes. The density of the new aggregates is lower than the typical density of natural ones (typically higher than 2.6 kg/l) and it decreases with smaller size. This is due to the relative higher proportion of covering of the smaller aggregates compared to the larger ones.

For the same reason, water absorption increases with decreasing the size of new aggregates. Regarding the chemical characteristics of the new aggregates, both sulphates and chlorides comply

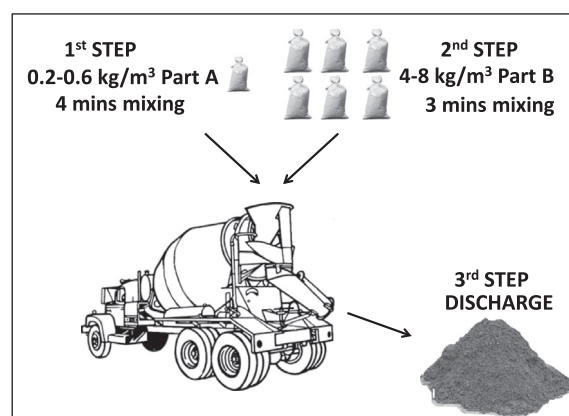


Fig. 2. Scheme of operation of the new process for recover returned concrete.

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