NEW SUSTAINABLE TECHNOLOGY FOR RECYCLING RETURNED CONCRETE

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ABSTRACT:
A new technology is available 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 admixtures 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.

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.

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. Typically, the amount of returned concrete generated by ready-mixed deliveries can be as low as 0.5% of the total production. However, during peak periods, returned concrete can increase significantly. 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 represent a heavy burden for the ready-mixed concrete industry.

2. CURRENT METHODS OF PROCESSING RETURNED CONCRETE
Current methods of processing returned concrete include:

(1) Discharging returned concrete at the ready-mixed plant. Hardened concrete is then removed and stored before disposal to landfill or crushed to produce aggregates for recycling.
(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 blocks production.

(3) Reclamation systems used to separate the 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 stockpiled and can be reused for the manufacture of new concrete.

This method requires significant capital investment and careful attention to proper practice.

3. THE NEW METHOD TO RECOVER RETURNED CONCRETE

So far, environmental impact, working complexity and capital investment have limited the possibility of achieving high levels of recycling. The new method presented here is based on a new admixture that transforms returned concrete, in only a few minutes and without the need of specific equipment, 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 waste and achieving the preservation of natural resources. 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 costs for waste disposal.

The new method consists of 4 steps:

Step 1 Addition of super absorbent polymer SAP (Part A) into the drum of the truck mixer containing returned concrete. Most of the free mixing water is absorbed by the polymer and, after few minutes of mixing, 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 super absorbent polymer, as shown in Figure 1.

Fig.1 Typical aspect of a fresh granular material after the addition of SAP
Step 2 Addition of an Ettringite forming compound (Part B) and mixing for additional 2-3 minutes. 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, avoiding tall piles to prevent excessive pressure over the bottom layers.

Fig 2 Freshly discharged material after the above process.

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 hours, in order to break the weak bonds of hydrated cement paste among the grains and detach them from each other. Once the granular materials have been moved, there is no further risk of agglomeration and it can be stored as normal aggregate.

Fig 3 Schematic diagram showing process.
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.

Figure 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.

Fig.4 Comparison between the size distribution of aggregates from the new process (solid line) and the original ones (dotted line)

The other physical-chemical characteristics of recycled aggregates cured for 28 days are shown in Table 1.

From this table, it can be seen that the density of the new aggregate is lower than the natural ones and it decreases with the 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 by decreasing the size of new aggregates. With regard to chemical characteristics of the new aggregates, chloride content is quite low and comparable with the original aggregates (0.0008% for the new aggregates compared to 0.0005% for the original aggregates), so there is no risk of corrosion associated with the use of the new aggregates. EN 12620:2008 sets the maximum limit of soluble sulphates in aggregates for concrete at 0.8 per cent, while the content in the new aggregates is 0.08 per cent, one order of magnitude lower. So, also for soluble sulphates content, there is no counter indication in the use of the new aggregates.

5. CHARACTERISTICS OF CONCRETE MADE WITH THE NEW AGGREGATES

Thirty per cent by weight of aggregates produced by the new process were used in substitution of natural aggregates for the production of new concrete, which was compared with a reference mixture prepared with natural aggregates. Both mixes were characterized by the same dosage of cement (CEM 32.5R II/A-LL, 320 kg/m3), W/C = 0.55 and consistency class (S4 according to EN206-1). The characteristics of hardened concrete are compared in Table 2.

These results indicate that the density of concrete made with recycled aggregates is from about 3 to 5 per cent lower compared to control concrete, as a consequence of the lower density of the recycled aggregates in comparison with the natural ones. Nevertheless, this reduction of the density does not affect the mechanical strength, as confirmed by the results of Table 2.
Water permeability tests, made according EN 12390-8, showed a remarkable reduction of water penetration for concrete with 15% and 30% of new aggregate in substitution of natural ones, in comparison with control concrete made with natural aggregates, as shown in Table 3.

Table 3 – Water permeability of concrete with different levels of substitution of new aggregates

<table>
<thead>
<tr>
<th>Type of concrete</th>
<th>Amount of penetrated water (g)</th>
<th>Depth of penetration (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% subst. (control)</td>
<td>35</td>
<td>7.8</td>
</tr>
<tr>
<td>15% substitution</td>
<td>23</td>
<td>6.0</td>
</tr>
<tr>
<td>30% substitution</td>
<td>15</td>
<td>3.6</td>
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</tbody>
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The reason for these improvements seems to be due to the better Interface Transition Zone (ITZ) of concrete containing the new aggregates, as shown in Figure 5b for concrete with 30% substitution.

Figure 5a shows that the ITZ between aggregate and cement paste of control concrete and is characterized by higher porosity (darker colour) compared to that of the concrete made with 30% new aggregates Figure 5b.
The durability of concrete made with 30% substitution was further assessed for resistance to chloride penetration and freeze thawing. The concrete made with 30% substitution was found to be frost resistant and chloride penetration found to be similar with no appreciable difference as shown in table 4.

<table>
<thead>
<tr>
<th>Type of concrete</th>
<th>Chloride penetration (mm)</th>
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<tbody>
<tr>
<td></td>
<td>7d</td>
</tr>
<tr>
<td>0% subst. (control)</td>
<td>9.5</td>
</tr>
<tr>
<td>30% substitution</td>
<td>9.3</td>
</tr>
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6. CONCLUSIONS

(1) The new technology permits to recover returned concrete by transforming it in a granular material and to prevent the production of wastes, both liquid and solid

(2) The granular material, once hardened, can be used for the production of concrete, in partial substitution of natural aggregates.

(3) Concrete made with 30 per cent by weight of the aggregates of the new technology in substitution to natural aggregates had the same compressive strength, compared to similar concrete.

(4) From the economical point of view, the cost of the additive, dosed at 6.5 kg per cubic meter of returned concrete, is fully paid back by the production of 2.4 Tons of new aggregate that may be fully reused for concrete production. Furthermore, all the costs for landfilling of returned concrete are completely eliminated

(5) The proposed technology offers many advantages from environmental, social and economical point of view and represents an interesting progress in the field of concrete sustainability.

References:

NEW SUSTAINABLE TECHNOLOGY FOR RECYCLING RETURNED CONCRETE (Full Version)

by Giorgio FERRARI

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Full technical and safety data may be downloaded from www.mapei.co.uk

Video demonstration viewable on you tube at https://www.youtube.com/watch?v=2EE6GgzM4vo