GEAR PROJECT - DIAGNOSIS OF THE CURRENT RECYCLING SITUATION IN SPAIN

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ABSTRACT

The GEAR Project aims the normalization of CDW recycled products and its uses in civil construction across the elaboration of the "Spanish Guide on Recycled Aggregates".

The first stage of the project consists of the accomplishment of a technical and statistical field study to characterize the situation of the Spanish Recycling Plants. This diagnosis study consists on the analysis of data from 65 Spanish recycling plants, chosen by their importance and location, products, production and uses. Our aim is that the final document proposed in this project reflects the reality of the Spanish recycling market, considering all its technical, scientific and environmental aspects.

The study, coordinated by the GERD (Spanish Association of the Recycling Industry), is under the responsibility of three Technological Centers (AIDICO, AITEMIN, INTROMAC) and four Universities (Universitat Politècnica de Catalunya, Universidad Politécnica de Valencia, Universidad de La Coruña y Universidad de Oviedo).

This document presents the results obtained in this stage of the GEAR Project, whose analyses refer both to the recycled aggregates production, marketing and control, and to the Spanish and European regulations and technical particular prescriptions currently in use.

1. INTRODUCTION

The Project "Spanish Guide on Recycled Aggregates" (GEAR Project) is a technical and scientific project subsidized by the Ministerio de Medio Ambiente, y Medio Rural y Marino, of Gobierno de España, within the framework of the National Plan of Scientific Research, Development and Technological Innovation.
Coordinated by the GERD (Spanish Association of the Recycling Industry), the GEAR Project possesses the direct participation of 24 CDW recycling companies of Spain, 4 universities and 3 technological centers.

Its principal aim is to elaborate the "Spanish Guide on Recycled Aggregates", a limited set of technical prescriptions offers referred to the principal applications of the recycled aggregate origin by CDW.

The first stage of the project consists on knowing the needs of the CDW recycling market and the characteristics of the recycled aggregate produced and commercialized in Spain. For such, the project did a diagnosis of the situation of RCD's recycling that consisted of:

To collect, in a systematic and scientific form, the technical information of the practical experience in Spain of manufacture process and utilization of recycled materials proceeding from the treatment of the CDW (production systems analysis and uses classification);

To characterize the materials and the recycled products commercialized nowadays in the recycling plants of Spain, across a statistical and comparative analysis of the information.

This document presents the diagnosis results obtained until now. The results indicate the existing trend in Spain of the recycled aggregates production, marketing and control. Also, it presents the characteristics of the commercialized products and contributes to identify the needs and possibilities of technological accomplishments on this sector.

2. DIAGNOSIS METHOD

The diagnosis consisted in collecting technical information from the Spanish CDW recycling plants, mainly considering the methods of production of recycled aggregates, the results of control tests conducted and the uses proposed by the companies. The collection of this information has been done during technical visits, applying specification sheets.

In order not limit the diagnosis to the situation presented by the 24 recycling companies participating on the project, a network of recycling companies interested on collaborating with the project was created (named in this document by recycling companies’ collaborators).

At the time of the elaboration of this article, the number of collaborating companies was 30 plus 35 recycling plants of the 24 participating companies. In total, 65 recycling plants have been analyzed in all the Autonomous Communities of Spain.

The visits have been carried out between April, 2008 and June, 2009. In order to complement the information, the recycling companies have executed a specific plan of tests for the Project defined by the Coordination. The planning of the tests and their frequency of accomplishments have been defined by the needs of the project and the conditions of production of each plant.

In order to fulfill this plan, all participants have received indications and specifications on how to correctly carry out tests plan so to guarantee its representativeness and strictness. The Table 1 presents the tests carried out in this stage of the project.
3. PRODUCTION SYSTEMS

The diagnosis of the production systems of the Spanish recycling plants has been carried out in static, semi mobiles and mobiles plants distributed all over Spain, as indicated in the Figure 2.
The production scheme of a recycling plant in Spain generally consists of all or some of the stages presented in the figure 3. The design criteria of a recycling plant can change a lot for each plant. It can recognize more than one line of production, trowels, previous sift, primary and/or secondary crushing, mechanical and/or manual classification, separation cabins, cleanliness by air and/or water and/or separation of ferric materials.

**Figure 3. Production flow of a Spanish type recycling plant.**

The selection and complexity of the recycling system used depends on the degree of the needs of the CDW processing, which comes determined by:

- The final application of the recycled material: the production process design of recycled aggregates for its application in concrete, for example, is different from the one destined to be applied in landfill or in road surfaces;

- The quantity of impurities contained in the CDW to be processed: the quality of the residue received in the plant will indicate the necessity to use the mechanisms of impurities elimination that will take place during the processing.
The summary of the diagnosis results of the Spanish recycling plants production systems is presented in the figure 4.

Figure 4. Summary results of the production systems diagnosis: (A) CDW entrance control, (B) CDW piles forms, (C) Separation systems, (D) Cleanliness systems, (E) Production Systems, (F) Production lines quantity.

The major offer of mixed recycled aggregate and concrete recycled aggregate are in a continuous granulometry fraction where the minimum diameter of the aggregate is equal to 0 mm and the maximum diameter area is higher than 4 mm, popularly so-called in Spain “todo uno”. The other commercialized fractions are qualified in the following categories:

Fine fraction: recycled aggregate with minimum diameter equal to 0 mm and maximum diameter up to 4 mm;

Medium fraction: recycled aggregate with minimum diameter greater or equal to 4 mm and maximum diameter smaller or equal to 80 mm;

Coarse fraction: recycled aggregate with minimum diameter greater or equal to 30 mm;

The figure 5 relates the offer of recycled aggregate by its composition, its popular fraction category and the Autonomous Community in which it is produced. It is possible to observe that mixed recycled aggregate is offered in almost all regions.
4. RECYCLED AGREGGATES CHARACTERIZATION

This chapter presents and analyzes the results obtained by the characterization of the recycled aggregates produced in the diagnosed recycling plants.

All the tests were carried out using mixed recycled aggregate produced in the plants (fraction “todo uno”). In special cases, where the plant does not produce this type of product, the tests were carried out using produced concrete aggregate.

The composition analysis (PrEN 933-11) indicated that the recycled aggregate is composed principally by three elements (unbound aggregate, concrete and mortar elements and ceramic and masonry elements), and its presence is very variable (figure 6).

Nevertheless, the detailed analysis of each composition results indicates that the recycled aggregate always has a predominant element among the mentioned three elements. This behavior can influence the material characteristics because:

The presence of unbound aggregates in relevant quantity improves the recycled aggregate properties;

The presence of concrete aggregate in relevant quantity can imply low density, major absorption, high Los Angeles coefficient, etc, due to the adhered mortar existent in the concrete recycled aggregate;

The presence of ceramic aggregate, due to the ceramic matrix characteristics, can imply low density, high porosity and water absorption, and a high Los Angeles coefficient. The ceramic matrix characteristics allows establishing a certain parallelism with the lightweight aggregate.

In that way, the other recycled aggregates’ properties were analyzed in general and by categories defined by the predominant element of the analyzed sample. This classification shows three principal categories:

RA-ua: the aggregate set originated by the crushing, sifted and processing of CDW in recycling plants, in which the predominant element is the unbound aggregate.
RA-cm: the aggregate set originated by the crushing, sifted and processing of CDW in recycling plants, in which the predominant elements are the materials originated from concrete and mortar.

RA-ce: the aggregate set originated by the crushing, sifted and processing of CDW in recycling plants, in which the predominant elements are the materials originated from ceramic and masonry residues.

This procedure intends to check if a classification by categories defined by the recycled aggregate’s predominant material will be useful in order to define the expected characteristics of a certain recycled aggregate and also intends to indicate quality levels of the material by ranges of composition. The summary of the obtained results is presented in the figure 7.

The classification RA-ua presents a low variation range of water absorption, whereas the aggregates samples with classification RA-cm and RA-ce present growing variations, respectively. In addition, the samples classified as AR-ua present a water absorption average minor than the aggregates samples classified as RA-cm, which, in turn, present an average absorption minor than the aggregate samples classified as RA-ce (figure 7A).

All analyzed samples present high maximum and minimum range values of content of fines. That behavior is attributed to the fact that the analysis, in many cases, has been done in samples of the pre sift material produced in the plant, which is characterized for presenting a high amount of fine. The identified average value is very similar for the three types of analyzed classifications. It is important to highlight that most of the analyzed samples have presented a content of fine (material above the sieve 0.063 mm) not higher than 5%, for the three types of analyzed classification (figure 7B).

The recycled aggregate samples with classification RA-ce present the highest flakiness index average of the three categories presented. The variation range indicates a clear growth when the sample present ceramic aggregates (figure 7C). This behavior is generated because of:

the ceramic material trend to break in fewer cubic forms.

the CDW original morphology. Ceramic residues originally possess narrower and tipper morphologies that in many cases bypass the crushing hopper. This problem is less evident in plants with primary and secondary crushing that produce more cubic aggregates.
Figure 7. Average and maximum and minimum ranges values of analyzed properties in recycled aggregates samples by general and by category: (A) Water absorption, (B) Content of Fine, (C) Flakiness Index, (D) Los Angeles Abrasion, (E) Soluble sulphates in water, (F) Soluble sulphates in acid, (G) Gypsum Content, (H) Organic Pollutants.

For the Los Angeles Abrasion (Figure 7D), it is observed that:

- the concrete recycled aggregate presents a maximum and minimum range ampler than the one of the unbound material. This behavior is probably due to the adhered mortar presence on the concrete recycled aggregate that disperse off the material during the test;

- the ceramic recycled aggregates presents a maximum and minimum range ampler than the one of the concrete, probably because of the fragility of some types of ceramic materials.

When comparing charts 7E and 7F, it is noticed that the soluble sulphate content in water does not differ from the soluble sulphate content in acid for aggregates qualifiers as RA-ua. The
ones with classifications RA-cm and RA-ce, respectively, present a relevant rise of identified sulphates, when the analysis process is fulfilled in acid. This behavior is attributed to the fact that the recycled aggregate can contain a high amount of sulphates:

in concrete recycled aggregate, because, added to the original sulphate from the natural aggregates, there are sulphates from the adhered mortar and from impurities as gypsum, when the original residue comes from building.

in ceramic recycled aggregate, where sulphates presence is due to their presence as mortar and gypsum, and to the original sulphate from clays that cause efflorescence.

In both cases (classifications RA-cm and RA-ce), the method of sulphates content in acid allows identifying better those pollutants' presence.

Results reached in these tests showed coherence with the results presented in the gypsum content tests. Classifications RA-cm and RA-ce present maximum and minimum ranges higher than the classification RA-ua (Figure 7G).

Finally, recycled aggregates qualifiers as RA-ce have presented organic pollutant content until 2% (Figure 7H). The aggregates with classification RA-ua and RA-cm have not presented relevant humus content. This behavior is a reflex of the origin of the CDW used as a raw material in the production of the samples (qualifiers as RA-ce are recycled aggregates originated mainly from construction residues, while qualifiers as RA-ua and RA-cm are recycled aggregates originated mainly from demolition residues).

5. RECYCLING MARKET SITUATION IN SPAIN

This chapter presents the data analysis of works done in Spain in the 2008 with recycled aggregates with the aim of identifying the commercial trend of these materials in a specific time interval. Among the participant recycling companies, the project collected basic information of product and type of application of all works fulfilled during this period. The overall sum is a total of 566,510 marketed tons.

The most frequently used recycled product has been the mixed recycled aggregate in the fraction, popularly so-called “todo uno” (near 47% of the marketed ton total in 2008), followed by the concrete recycled aggregate, also in the fraction popularly so-called “todo uno” (near 18% of the total) (figure 8).

Between works fulfilled in 2008, near 82% of the total marketed tons have mostly been used as unbound aggregates for bases, esplanades, fillings, repairs of roads, urbanizations, gardens, etc. However, it is important to highlight that there exist information from relevant works with recycled aggregates used for concrete, pre fabricated elements and gravel and soil cement, so much as experimental as practice character.
6. CONCLUSIONS

The majority of the analyzed recycling plants are considered static even that present mobile equipments. The most identified classification systems have been sieves, magnetic separation, selection cabins and blowers. The improvement need is identified in the processes of the CDW control entrance and in the production quality control.

The recycled aggregate composition is the key point to determine its characteristics and properties, as well as its behavior or its response to efforts. The heterogeneous character of the recycled aggregate can be significantly reduced by defining composition categories with maximum and minimum ranges of the principal elements of the recycled aggregates.

The most offered recycled product is the mixed recycled aggregate in the fraction popularly so-called “todo uno” (near 47% of the total of produced ton in 2008), followed by the concrete recycled aggregate, also in the “todo uno” fraction (near 18% of the total). Its main use in the civil construction is as an unbound aggregate for bases, esplanades and fillings.

The application studies of recycled aggregates that will be proposed by the project will not be limited to the analysis of the existent natural aggregates’ norms. The main goal should be the feasibility of the use of recycled aggregate, considering its own characteristics and needs. The European Regulations for Recycled aggregates will be considered as well as the hands-on experience of the sector in Spain.

Based on the diagnose results, the GEAR Project will work in the following research lines of use of the recycled aggregates produced in Spain: roller compacted concretes, no structural concretes, pre fabricated elements, fillings / drainages, aggregates for roads bases and gravel and soil cement. The maximum number of possibilities of applications will be considered for each field. Splitting of a few basic properties that condition the work execution, no type of recycled aggregate will be rejected.

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