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Development of Recycled Aggregates In The Implementation of-the Concrete:Literature Review and Analysis of Research and Testing

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ABSTRACT
Civil engineering is rapidly evolving with the natural, political and environmental development. Due to a shortage of natural resources, to sustainable development and environmental certificationsrequirements, recycling of aggregates is increasingly valued.Research is done everywhere in the world (in 2016, more than a hundred doctoral subjects were proposed in this sense) in order to normalize the use of recycled aggregates, specify the domain and restrictionsof using concrete constructions design protocols based on recycled aggregates.Since the 80s, researches are based on the type of the recycled (concrete aggregates, remains aggregates , glass, rubbers…) and the percentage of it compared to natural aggregates to study the influence on the basic characteristics of concrete..
The main characteristics studied are the porosity of the concrete, the tensile strength and the compressive strength. In comparison with natural aggregates, concrete based on recycled aggregates has lower resistance values of approximately 20% but has better thermal characteristics than about 5% .These characteristics are basic for the dimensioning especially of the carrier elements so they are demanding bettertechnical and experimental studies to determine the optimum proportion of recycled aggregates for use in the preparation of concrete.
In Morocco, recycled aggregates, does not have any specific standards, and is used mainly in roads and pavements construction. Even if it's not normalized this use is not recent, in 1999 during the rehabilitation of the expressway road from Casablanca which was severely damaged on both channels, the authorities have opted for the reuse of aggregates instead of reloading the existing pavement with a new one.
The chosen alternative combinesthe replacement of existing material by a bituminous mixture and a cold instead reprocessing depending of differences of damage and requirement on the structural capacity for slow and fast lanes.This paper, part of my doctoral research, discusses different aspects of the problem beginning with a brief description of the advantages of recycling in all of the levels: social, economic… and a review of the international and national standards in terms of construction and demolition waste generated, recycled aggregates producedand their utilization in concrete. It also gives a benchmarking of the engineering properties of recycled aggregates and concludes by proposing some market opportunities and development paths and potential uses of recycled aggregates.
Keywords:Concrete blocks, Testing concrete material properties, Recycledaggregates,Construction and demolition waste, tensile and compressive strength.

I. INTRODUCTION

Most aggregates used in the construction field are natural aggregates from quarries. The conventional aggregates resources aremore and more depleted over the years and exploitation criteria are becoming more stringent, such as for the extraction of alluvial gravel.

The use of natural aggregates should be reserved for more noble uses where no alternatives exist.

Beside, road and urban infrastructure are aging quickly and will require repair or demolition works frequently. However, these works cause significant amounts of residues. These materials thus generated are increasingly costly to store and storage sites are also increasingly rare, not to mention that environmental standards greatly limit the opening of other disposal sites. So we must find suitable ways to reuse these types of material especially with the high consumption of natural aggregates.

The quantities produced and consumed of aggregates are not sufficiently recognized in Morocco unlike other countries especially in Europe. France, for example, consumed 379 million tonnes of aggregates in 2009 (3 million imported) including 300 Mt for civil engineering (79%) and 79 Mt for building (21%). Belgium, meanwhile, produced annually +/- 72 million tonnes of aggregates of all types. Recycled aggregates alone account for +/- 20% of the annual national production, which places Belgium at the head of European countries providing almost total recycling of inert waste from the construction sector.

II. ADVANTAGES OF RECYCLING AGGREGATES

In social terms

- An economy of natural resources;
- A reduction in the transportation of materials, thus reducing energy consumption and greenhouse gas emissions;
- A rapid implementation minimizes the inconvenience to residents;
- Reducing the amount of materials going to landfill.

In environmental terms

Complete recycling of concrete helps to minimize the CO2 impact because:

- For large agglomerations, the use of recycled aggregates will diminish some of the CO2 attributed to transport aggregates;
- Crushed concrete may capture CO2 in his carbonation process;
- Recovery of potentially usable fine after treatment in the production of a new cement or other hydraulic binder, has an impact on reducing CO2 production in cement plants.

On the economic level

In Europe, the deposition of clean concrete debris (not mixed with other components) in the recycler facilities is usually free while a landfill costs 15 to 30 € / t; asphalt deposited to a recycler will also be accepted free of charge while its landfill will cost between 130 and 170 € / t. Likewise, the use of recycled aggregates offers mostly a significant reduction in the cost of raw materials.

The average price change is then +/- 20 to 25% for aggregaterecycled (depending on quantities and transport linked to the geographical origin of goods).

Concrete example: CHAMELEON project - Call for Project 2007(new construction).

Specifications initially stated "the provision and implementation of a metaling with a thickness of 40 cm minimum for roads and slab on grade, gap-graded type III consists of porphyry rocks crushed caliber 32 / 56 "(tax-related environmental permits).

The contractor in charge of the work proposed as an alternative the use of recycled aggregates type debris mixed with the same characteristics as the original product specifications.

This choice validated by architects allowed the operation of +/- 4.200 m3 of recycled aggregates - is +/- 6.500T savings of noble natural aggregates. From an economic point of view, the choice of mixed recycled aggregates has reduced the cost of +/- 2.5 € / m3 considering the quantity ordered and transportation (ie +/- 1 € / m2 for a thickness of +/- 40 cm). At the project level, it is an economy of +/- € 10,500 which was carried!

III. STANDARDS AND NORMATIVE FRAMEWORKS

Morocco:

Moroccan standards institute (IMANOR) is responsible for the management of standardization, certification and related activities in accordance with international standards.

In the domain of building and public works construction 26 standardization committeesare dedicated and have approved 2057 standards until the end of May 2016. Among the main standards directly related to recycled aggregates:

- *NM 10.1.008 (2007)*: Concrete: Specification, performance, production and conformity.
- This standard specifies that the aggregates recovered from wash water or fresh concrete can be used as aggregate for concrete.

The proportion of unsorted added recovered aggregates must not be greater than 5% of the total amount of aggregate. When amounts greater than 5% are added, they must be of the same type as the primary aggregate used in concrete and must be sorted, separated gravel and sand, and must meet the requirements of theNM10.1.271.

The standards specifying the technical characteristics of concrete depending on its composition are:

- *NM10.1.313*: Tests for mechanical and physical properties of aggregates: Method for Determination of bulk density and inter-granular porosity.
- *NM10.1.004:* Tests for geometrical properties of aggregates - Determination of particle size - size analysis by sieving.
- *NM10.1.271*: Aggregates for hydraulic concretes: definitions, specifications, compliance.
- *NM10.1.314:*Lightweight Aggregates - Lightweight aggregates for concrete and mortar
- *NM10.1.273*: Tests for mechanical and physical properties of aggregates Determination of particle density and water absorption coefficient.
- *NM10.1.060*: Testing fresh concrete - Sampling.
- *NM10.1.061*: Testing fresh concrete - Test sagging.
- *NM10.1.062*: Testing fresh concrete - Test Vebe.
- *NM10.1.063*: Testing fresh concrete - Degree of compactability.
- *NM10.1.064:* Testing fresh concrete - spreading test in shock table.
- *NM10.1.065:* Testing fresh concrete - Density.

- *NM10.1.066:* fresh concrete testing - Air content - Method of compressibility.
- *NM10.1.067:* Testing hardened concrete - Shape, dimensions and other requirements for specimens and molds.
- *NM10.1.068:* Testing hardened concrete - Making and curing specimens for strength tests.
- *NM10.1.051:* Testing hardened concrete - Compressive strength of test specimens.
- *NM10.1.052:* Testing hardened concrete - Tensile strength by splitting specimens.
- *NM10.1.072:* Testing hardened concrete - concrete volume weight.

In France, the normative contextclass concrete gravel recycled into six categories (GR0-Sol, Sol GR1-, GR2, GR3 and GR4) and following clues (B, E, M) according to their origin: B (Gravel recycled from concrete), E (recycled asphalt gravel) and M (mixed recycled gravel).

These geotechnical characteristics are used to classify in the category F7 of the NF P 11-300 (1992) and even integrate the E or D categories of the standard XP P 18-540 aggregates 1997.

So following these serious GR0-Sol standardsis used as backfill and GR1-sol as form layer and trench. For GR2, GR3 and GR4, they are used in sitting pavement as GNT.

France (1)

Reference Standard	**NF P 11-300**		**XP P 18-540 et NF P 98-129 (GNT A)**		
	F 72	**F 71**			
recycled gravel Category	GR0	GR1	GR2	GR3	GR4
granularity	uncalibrated	D<80 mm	D<31,5 mm	D<20 mm	D<20 mm
Hardness	unspecified	LA 45 MDE <45	LA < 45 MDE <45 LA+MDE <80 soit E	LA < 40 MDE <35 LA+MDE <65 soit E+	LA < 35 MDE <30 LA+MDE <55 soit D
Cleanliness	unspecified	VBS <0.2	(ES> 50 ou MB < 2.5) soit b	(ES> 50 ou MB < 2.5) soit b	(ES> 50 ou MB < 2.5) soit b
sulfates	according to specification	SS b < 0.7%			

The other standards that specify the characteristics of recycled aggregates are:

- *EN 1097- 2 / P 18-650-2:* Tests for mechanical and physical properties of aggregates - Part 2: Methods for determination of resistance to fragmentation
- *NF EN 1097-1 / P 18-650-1:* EN 1097-1 - Tests for mechanical and physical properties of aggregates - Part 1: determination of the resistance to wear (micro-DEVAL).
- *NF EN 933-9:* Tests for geometrical properties of aggregates - Part 9: Qualification fine - Test methylene blue.
- *XP P 18-581***:** Aggregates - Elements definition, compliance and coding: soluble sulfate content.
- *NF P 11-300:* Classification of usable materials in the construction of embankments and form layers of road infrastructure - Execution of earthworks.
- *EN 933-11:* Tests for geometrical properties of aggregates. - Part 11: Classification test for recycled gravel constituents (classification index: P18-622-11). This standard is based on visual sorting. It enables a classification of products according to weight or volumetric contents.

Recycled aggregates for concrete are subject to the same requirements as natural aggregates. The standards are:

- NF EN 13139:Aggregates for mortar
- NF EN 12620:Aggregates for hydraulic concretes
- EN 13055-1:Light aggregates for concrete, mortar and grout.

Studies are conducted to characterize the concretes made of artificial aggregates but to date no standard specifies the use of recycled aggregates for concrete production.

Brussels (2)

In Brussels, the references relating to the use of construction and demolition waste for recycling and exploitation are:

- Decree of 16 March 1995 the Government of the Brussels-Capital Region concerning the mandatory recycling of certain construction and demolition waste.
- This order requires the contractor to recycle debris (the stony and sandy fraction of construc-

tion and demolition waste). Recycling is mandatory or by the entrepreneur himself is a specialized company for recycling.

- The contractor is exempt from the obligation to recycle if it can establish that within 60 km of the location of works, no recycling facility of the type of debris which he rid exists.
- Ministerial Circular of 9May 1995 on the reuse of debris in road and infrastructure works.
- This ministerial circular completes the specifications and allows the use of recycled materials for various applications, subject to compliance with technical conditions specified in the circular.
- CE Marking: In order to be placed on the market, any granulate must carry the CE mark, which means that it meets the minimum requirements of the European standards "aggregates" (EN 12620, EN 13043, EN 13139, EN 13242).
- In order to obtain the CE marking of their products, manufacturers must carry out the tests specified in the specification and implement a functional system of internal control of production.
- Marking BENOR: The BENOR marking comes from voluntary, it is awarded to a product or a traditional building material meets the requirements of standards

Belgian or requirements / specifications:

The BENOR marking is granted only if the product or building material meets the preliminary tests which it is subject and ongoing internal quality control factory production.

Certification bodies are responsible BENOR brand management and are responsible for the publication of the Technical Specification (PTV).

These technical specifications relating to products and building materials are in compliance with NBN: Belgian standards published by the Belgian Institute of Standardization IBN)

- PTV 411 - Consolidated Aggregates. This
- technical specification conforms to BS EN 12620 standards BS EN 13043, BS EN 13139, BS EN 13242.
- PTV 406: Aggregates recycled - aggregates of concrete debris, mixed debris, masonry debris and asphalt debris - crushed and grave stones.

This technical requirement established categorization of recycled aggregates (aggregates of concrete debris, masonry debris, mixed debris and asphalt debris) based on existing standards which set the specifications. It highlights the codification of aggregates from fragmentation, separation, screening and possibly washing debris from construction and demolition works and can be used provided they meet a series of conditions contained in the legislation.

IV. BENCHMARKING STUDY ON EXPERIMENTAL MADE FOR DETERMINING THE QUALITY OF A CONCRETE AGGREGATE RECYCLED

1. Characteristics of the aggregates

a. Density

Tests done by Gomez Soberon JMV (3)on recycled aggregates materials Class MR-2 (with a nominal size of 20-5mm) show an average value of gross density of 2.3 knowing that in Quebec, natural aggregates, which are generally of calcareous origin has a value of 2.67.

b. Absorption capacity

Testing, by Gomez-Soberon J.M.V (3), shows that the absorption is between 5.54% and 6.02% compared to natural aggregates that have a value not exceeding 1%.

2. Physical and mechanical properties of concrete

a. Absorption and porosity

According to Gomez-Soberon J.M.V (3) testing of mercury injection in concrete GRB shows a significant volume of large pores. Analyses of the mixed concrete and concrete aggregate 100% recycled confirm that the porosity depends on the percentage ofrecycled aggregates and more exactly of the cement paste on the aggregates.

These tests also confirm that the total porosity depends on the age. It passes from 19% in 7 days 15% in 90 days.

b. Workability and durability

In the research paper "Recycled aggregates moistened: behavior of fresh and hardened concrete" by: Meftah Houria and Nourredine Arabi (4), attempts have been made to detect the influence of the substitution rate of dry recycled graves, pre-wetted and water saturated oneson handling.

In dry recycled graves and based on replacement rates and the setting time of the slump test, decreased maneuverability was seen . Subsidence of the Abrams cone at T = 0 are much lower compared to sagging fixed in the formulation, indicating a probable absorption by recycled aggregates of a part of the mixing water.

The loss of maneuverability increases during the period between 15 and 30 min, with is justified by a maximum mixing water absorption reached during this period.After 30 minutes, the loss of maneuverability seems to decrease with the hypothesis that water has returns to the mortar after it has migrated into recycled aggregates in the first 30 minutes.

For recycled aggregates previously pre-wetted and completely saturated with water, the workability of the concrete is much better than in the case of use of completely dry recycled aggregates. It becomes too soft plastic with high rate of recycled particles.

Thus, the use of a pre-wetting or water saturatedrecycled aggregates provides appropriate handling for implementation without hampering fresh concrete with recycled aggregates and without high riskingstiffening of cement paste after 60 minutes of waiting after mixing.

c. Sagging and abrasion resistance

Testing for impact resistance and abrasion resistance has been made by Gomez-Soberon J.M.V (3), taking into account two time: 10-20 mmand 5-10 mm.

The percentage of abrasion was 31.8% in the first time and 26.6% in the second.

These values resemble natural aggregates values of limestone parts but largely exceed 10% which is the value taken generally by reference.

These higher values are justified by the presence of residual mortar that comes off during the test.

d. Tensile strength and compressive strength

According to Gomez-Soberon JMV (3), when replacing natural aggregates by recycled aggregates, resistance oftraction, compression strength and the Young's modulus at 28 days are lower than those of concretes common to 28 days with the respective values of 10.8% , 11% and 11.5%.

Meftah Houria and Nourredine Arabi (4) detailed theretesting resultson concrete for various rates of substitution and different states (dry, pre-wetted ..)

For resistance to compression, testing essentially shows that the ultimate compressive strength is reached for all the mixtures at 28 days previously admitted to the formulation.

Note also that for gravel substitution with the recycled rates is 20% and 40%, we notice improvements on the the compressive strength are noticed compared to natural gravel 100%.

Beyond 40% recycled rate, resistances decrease. This is probably due to the intrinsic characteristics of recycled aggregates.

Comparison based on the condition of the gravel shows that dry recycled gravel seems to give the best resistance to compression compared to pre-wetted or saturated with water ones.

In the analysesof the tensile strength, a similarity is noted to the compression strength is recorded. The best resistance s raised for 20% of the recycled graves. The tensile strengths obtained perfectly reflect good resistances obtained by compression, indicating a homogeneous distribution of the components in the volume of concrete.

e. Young’s modulus

According to Gomez-Soberon J.M.V (3), when replacing natural aggregates by recycled ones, the Young’s modulus E at 28 days is lower than for the ordinary concrete at 28 days with a percentage of 10.1%.

Thesetests also confirm that E for the GRB concretes with x a value of 26.6 GPa does not dependent on the age of the test tube unlike the Young's modulus for ordinary concrete.

3. Thermal characteristics of concrete

According Gomez-Soberon J.M.V (3) and in correlation with the porosity, the thermal characteristics of GRB concrete are better than those of a natural concrete (They are inversely proportional to the porosity:17% against 14%).

V. CONCLUSION

There is a real potential for using recycled aggregates in the building construction industry, civil engineering and road works.Just like natural aggregates, recycled aggregates meet standards and strict regulations guaranteeing the quality and performance-based product knowledge.

There are no list highlighting opportunities for aggregate use by custom, nevertheless sector by identifying the possible uses of niches and conditions laid down - among them we notefor example for structural concrete Building you can use a rate of up to 20% for domestic concrete and non-aggressive environment (following restriction standard BENOR). but for concretes not BENOR certificate, there is no asking usage restriction except 'the art of the rule’. For non-structural concrete there is no usage restriction except the 'good use'. The use of soil preparation (formwork bottom) / slabs ... etc can be optimized.

In another point of view, most international environmental certifications applied to buildings reveal the criteria for Green building including analyzing the types of materials, their origin and their intrinsic characteristics (BREEAM , LEED…).

Among these points of analysis, the use of recycled aggregates is a positive approach to improving the final score of certification.Among developing trails to open the market, we identifya changing regulatory and normative frameworkallowing a wider use of recycled aggregates and a changing practice on the part of public administrations particularly at the specifications of taxation with the need to focus on the systematic use of recycled aggregates or where the technical requirements allow.

The imposition of a minimum percentage depending on the application could be a good approach (already applied in particular the Netherlands).In view of this work, it is important to complete this study by the analysis of the behavior of these concretes vis-à-vis the shrinkage and creep, the sustainabilityas carbonation and chloride diffusion coefficient,environmental study as carbon footprint and also aprice analysis;

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