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Evaluation of Construction and Demolition Wastes as Aggregates in Pervious Concrete

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ABSTRACT

Pervious concrete is a new type of product which allows rain water to pass through its mass due to its high porosity. To achieve this high porosity, coarse aggregates are mainly used with a little or no participation of fine aggregates. The present paper comprises an approach to the addition of demolition wastes as substitutes for coarse aggregates in pervious concrete. Initially the chemical compatibility of construction wastes was examined in relation to the requirements of standard EN 12620 for concrete aggregates. The mineralogical analysis of both construction wastes and limestone aggregates was examined through XRD. Finally, the porosity of these aggregates and the average diameter of the pores were measured. According to these results, it is concluded that the construction wastes have more porous than the limestone aggregates, which enhances their use in pervious concrete as the porous helps the desired property: water permeability.

INTRODUCTION

Continuous building construction, mostly arbitrarily, has caused a lot of damage to nature. More specifically, it affects the environment, directly or indirectly, during the entire life cycle of the buildings, as well as during the life cycle of their materials and components. Those environmental impacts can be local, such as production waste, or global, as climate change, resulting from all stages of the life cycle of construction: from the extraction and transport of raw materials, the construction phase, the operation and maintenance phase, and finally, the demolition. As the impact from the construction industry appears more often, the concepts of sustainable construction materials and technologies as well as eco-designing have become significant to our lives.

A typical example of environmental impact is the reduce of the absorption capacity of land due to continuous building construction which results to insufficient flood protection, and failure to provide drinking water. The trend in modern research effort is aimed to protect the environment while facing the problems arising from human activity. This is shown from the recent direction of research, including the concrete and cement industry, to the development of reasonable management of rainwater. The beginning of these efforts lies in the last decade in the U.S.A. with the designing and development of pervious concrete, a new type of product that has high porosity and allows rainwater to pass through its mass. There are only few reports of this product in Europe. The environmental benefits arising from the use of pervious concrete, are summarized to: i) the management of rainwater, ii) the prevention of flooding and iii) the enrichment of underground waters. The main challenge for the concrete industry is the requirement to design and synthesize a porous material that is water permeable unlike the so far principle to reduce the pores which facilitate the entrance of harmful materials for concrete. [ACI Committee 2008] [Alan Sparkman 2001][Liv Haselbach and Robert Freeman 2006] [Dale P. Bentz, 2008].

The term “pervious concrete” typically describes a zero slump, open-graded material consisting of portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water. The combination of these ingredients will produce a hardened material with connected pores , ranging in size from 0.08 to 0.32 in. (2 to 8 mm), that allow water to pass through easily. The void content can range from 18 to 35%, with low typical compressive strengths. The drainage rate of pervious concrete pavement will vary with aggregate size and density of the mixture, but will generally fall into the range of 2 to 18 gal./ min/ft2 (81 to 730 L/min/m2). [ACI Committee 2008] [Liv Haselbach and Robert Freeman 2006] [Dale P. Bentz, 2008].

Pervious concrete has been used in a wide range of applications, including: Pervious pavement for parking lots, rigid drainage layers under exterior mall areas, greenhouse floors to keep the floor free of standing water, structural wall applications where lightweight or better thermal insulation characteristics, or both, are required, pavements, walls, and floors where better acoustic absorption characteristics are desired, etc. Typically, unreinforced pervious concrete is used in all these applications because of the high risk of reinforcing steel corrosion due to the open pore structure of the material. [ACI Committee 2006] [ACI Committee 2008].

In this paper, in the frame of a relative PhD thesis, an approach to the addition of demolition wastes as substitutes for coarse aggregates in pervious concrete is examined. The reuse of these materials will reduce the environmental problems due to their landing and it will constitute one still alternative solution for the 500 million tons of construction and demolition wastes of Europe per year.

A lot of research work has been done with the use of recycled concrete as aggregate for new concrete production. The common reference point of all these research efforts is that the concrete containing recycled aggregates can be used in secondary applications since its quality is inferior to commonly produced concrete. Recycled Concrete Aggregates (R.C.A.) present a high porosity which, for the production of the conventional type of concrete, constitutes a disadvantage. However, for the production of pervious concrete, high porosity is the main desired quality. [Katz A.,2003] [Ryu J.S.,2002a] [Ryu J.S.,2002b] [Galbenis, 2008]

MATERIALS AND METHODS

The scope of the present paper is the exploitation of selected Construction and Demolition (C&D) wastes as substitutes for the conventional aggregates that are used in the concrete industry. The evaluation of this use has been reached through their chemical and mineralogical characterization compared with the conventional limestone aggregates. Also, to insure the main requirement (permeability) for the production of pervious concrete, the volume of the pores of these aggregates were tested with porosimetry N_2.

Chemical Characterization

Table 1 shows the chemical analysis of Construction and Demolition Wastes and limestone aggregates which were used. Comparing these results with EN 12620 "Aggregates for concrete" we see that the examined materials comply with all its requirements, and can be used as Recycled Concrete Aggregates (RCA).

Table 1. Chemical Compositions of C&D Wastes and Limestone Aggregates

%Element oxide	Limestone Aggregates	Construction and Demolition Wastes
CaO	52,8	44,7
SiO_2	1,16	20,1
Al_2O_3	0,67	4,72
Fe_2O_3	0,33	1,79
SO_3	200ppm	0,04
MgO	0,89	0,69
K_2O	940ppm	0,5
Na_2O	0	0,4
Cl^-	8ppm	0,18
TiO_2	260ppm	0,26
LOI	43,93	26,23

Mineralogical Characterization

In figures 1 and 2 there are shown the XRD patterns of limestone and C&D Wastes using the XRD Siemens D-5000. For both aggregates the mineral phase of Ca is $Ca,Mg(CO_3)_2$. As far as the C&D Wastes, the mineral phases of silicon oxide and feldspar are also observed.

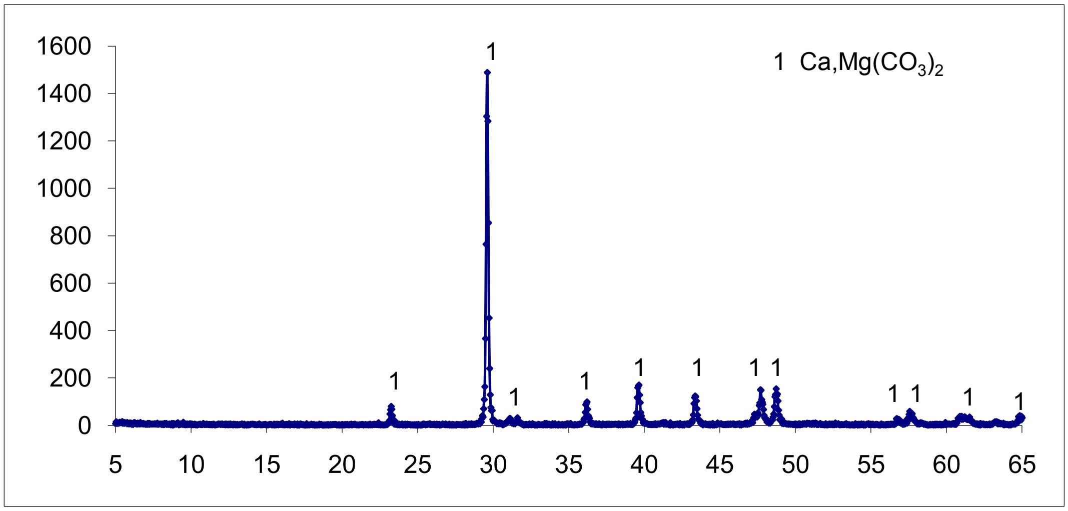

Fig. 1. XRD pattern of Limestone Aggregates

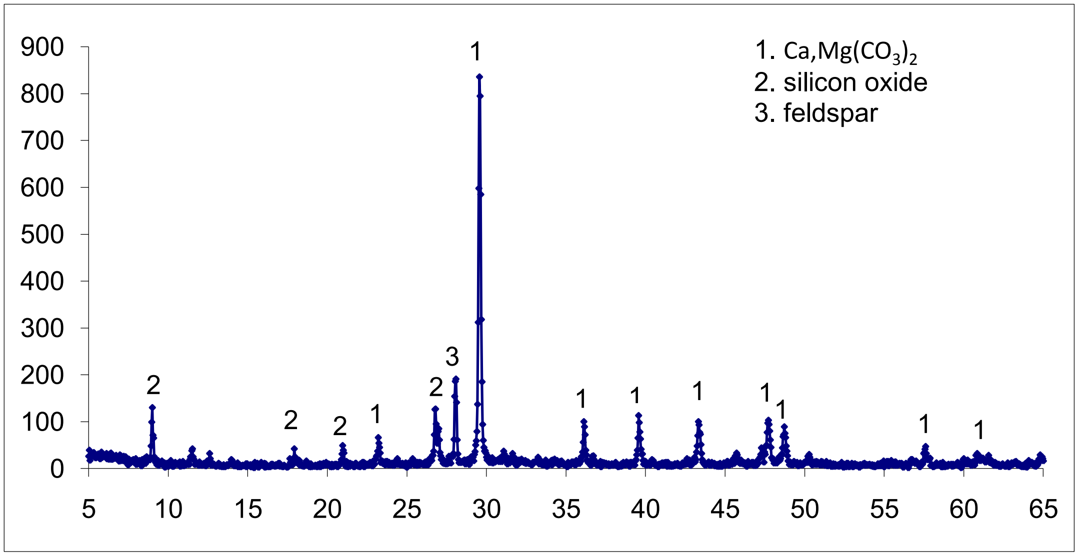

Fig. 2. XRD pattern of C&D Wastes (RCA)

Porosimetry Analysis

Using Nitrogen Porosimetry (N2) method the pores size of the aggregates was compared. The results of the surface area and pore size analysis was determined by NOVA 2200e and are shown in table 2.

Table 2. Surface area and pore size analyses

	Limestone Aggregates	C&D Wastes
Surface Area S_{BET} (m^2/g)	0,406	4,850
Pore Volume V_p (cm^3/g)	0,001	0,013
Average Diameter of Pores d_p (A)	98,522	107,216

These results are an indication that C&D Wastes are more porous materials than limestone aggregates. More specifically the volume of their pores is 10 times over the volume of the limestone's pores. The reason for such results may be attributed to the presence of attached cement mortar with the C&D Wastes. The carbonization and the cracks in the cement mortar that have occurred over the years cause weaknesses to the surface of the recycled concrete, which increase the water absorption and permeability.

CONCLUSIONS

The attempt to evaluate Construction and Demolition Wastes as concrete aggregates in pervious concrete gives promising results. C&D Wastes comply with EN 12620 for concrete aggregates and have more porosity than the conventional limestone aggregates. Although the high porosity is a disadvantage for the production of the conventional type of concrete, it is the desired quality for pervious concrete. All these indicate that C&D Wastes can be proved very promising materials to substitute natural aggregates for producing pervious concrete as they insure water permeability.

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