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Influence of Coarse Demolition Waste Aggregates on Physical and Mechanical Properties of Concretes

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Influence of Coarse Demolition Waste Aggregates on Physical and Mechanical Properties of Concretes

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Abstract

Two series of concretes were prepared differing in the state of recycled gravels (RG) before being introduced to mix design. In the first one, the recycled gravels (RGC) were introduced at the saturated state while in the second they were incorporated at a dry state. For both series of concretes different replacement ratios of natural gravels (NG) by RG were selected (0%, 10%, 25%, 50%, 75% and 100%) and the binder dosage is maintained constantly. The super plasticizer dosages were adjusted in order to achieve the same consistency class of S4 ($18^{\pm 2}$ cm) and the compressive strength class of C35/45. First of all, the used gravels (NG and RG) were characterized by the sieving, the density, the water absorption, the porosity and the Los Angeles tests. The results point out that the RG are characterized by a low density and a significant capacity of water absorption than that of the natural ones. In addition, the fragmentation resistance of RG is lower than that of NG. The air content was measured. It appears that this property increases by the increasing of the replacement ratio. At the hardened state, the density, the water absorption coefficient, the porosity, the dynamical modulus of elasticity, the compressive strength and the tensile splitting strength were measured and experiments were conducted according to European standards. The density of the hardened concrete decreases and their porosity increases by increases of RG content. The mechanical properties at 28 days have been evaluated. It appears that they decrease by the increase of the substitution rate.

Keywords: Physical and mechanical properties, Recycled aggregate concretes, Recycled gravel.

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Introduction

The reuse of recycled aggregates from construction and demolition waste is a conceivable and beneficial solution for environmental preservation and effective utilization of the natural resources. Therefore, it is necessary to reuse waste concretes as recycled concrete aggregates (RCA) for new concrete structures. Therefore, the global market for construction aggregates is expected to rise 5.2% in reuse of RCA per year through 2015 to 48.3 billion metric tons [1]. According to World Aggregates Market, the global production of construction aggregates is forecasted to expand 5.8% per year to 53.2 billion metric tons through 2017 and this sale is estimated 66.2 billion metric tons by 2022 [2].

The Peter Craven [3] reports that according to the Frost and Sullivan 62% of construction, demolition and excavation waste in Europe was recycled in 2012 and it is targeted to arrive 70% through 2020. The C&DW in European Union takes accounts for approximately 25-30% of all waste generated in the European Union and it consists of concrete, bricks, gypsum and etc…, which can be used as recycled aggregates [4].

According to the review of the selected waste streams by the European Environmental Agency [5], the production of C&DW clearly depends due to some characteristics of industrials and institutional.

UNPG [6] and UNICEM [7] in 2008 report that, the production of aggregates is estimated to be 431 million tons, which 79% of this production are used in the civil engineering field and 21% in the building industry. Therefore, UNPG reports that, in France, 2.6 million tons of fresh concrete and 269 tons of demolished concrete are considered as waste and should be recycled, furthermore, in some regions, recycled concrete aggregates may cost between 20 - 30% less than the natural ones.

Given this background, a national project was initiated in 2012; named PN-RECYBETON [8] in order to use the recycled aggregates resulting from construction and demolished waste concrete to formulate new flow-able concrete structures. In 2013, a parallel project called ANR-VBD2012-ECOREB [9] has been launched to study the mechanical properties and the durability factors of mixtures developed in the framework of the national project.

The Aggregate represents about 70-80% of the concrete components, therefore, the re-utilisation of recycled aggregates to produce new concrete is a mean solution for achieving a more environment-friendly concrete.

Therefore, the researchers are increasing about the reuse of recycled concrete aggregates in concrete structures, most of them are focused on the effects of the partial or total replacement of natural gravels by recycled ones, on the physical and mechanical properties of recycled aggregates concrete. For example, the total substitution of the natural gravels by the recycled one can lead up to a 40% of reduction in compressive strength [10]. The studied carried-out by G. Wardeh et al. [11] underlined; however, that the 30% of RCA doesn't have any influence on the additional water of mixture, the compressive resistance reduces 14%. Ö. Çakır [12] is noticed that, the decrease of compressive strength is pronounceable at over 50% of the replacement level and the RCA content improves the tensile splitting strength. As well as, Tsung-Yueh Tu et al. [13] is pointed-out of the reduction of compressive strength for high performance concrete by the increase of recycled aggregate content. Moreover, the influence of recycled aggregates on recycled aggregate concretes was reported by S. Omary et al. [14], they observed that there are some relationships between recycled aggregate properties and recycled aggregate concretes properties.

This study was carried-out in an attempt to analyze the effect of the introduction state of coarse recycled aggregates from construction and demolition waste (C&DW) on the physical and mechanical properties of recycled aggregate concrete of concrete mixes.

Materials

To provide the concrete two types of aggregates that are used, the natural aggregates (NA) were furnished in three fractions; semi-crushed siliceous sand (NS 0/4) and two types crushed limestone gravels NG1 (4/10) and NG2 (6.3/10), respectively. The recycled concrete aggregates (RCA) were provided in a platform of recycling from construction and demolition waste which was classified as fine coarse aggregates (RG1 4/10) and coarse aggregates (RG2 10/20). The used aggregates were provided by PN-RECYBETON [8].

A Portland cement type CEM II/A-L 42.5 with a density of 3090 kg/m3 and a mineral addition of limestone filler (HP-OG) with a density of 2700 kg/m3 were used in the concrete mixes. The compressive strength of the cement at 28 days is about 51.8 MPa [8]. To obtain a high workability of all developed mixtures, a superplasticizer, MC Power-Flow 3140, was employed.

Experimental Method

The physical properties of NA and RG are determined via sieving, density, coefficient of water absorption and porosity tests.

The aggregates were arrived in big-bags to the lab of L2MGC, to determine the size distribution of NA and RG, the sieving test was carried-out according to the standard NF EN 933-11 [15]. It has been seen that, natural gravels (NG) and recycled gravels (RG) are presenting almost the same grain-size distribution curves with slightly difference in the fines particles (

Figure **1.** *Grading Curves of NA and RCA*
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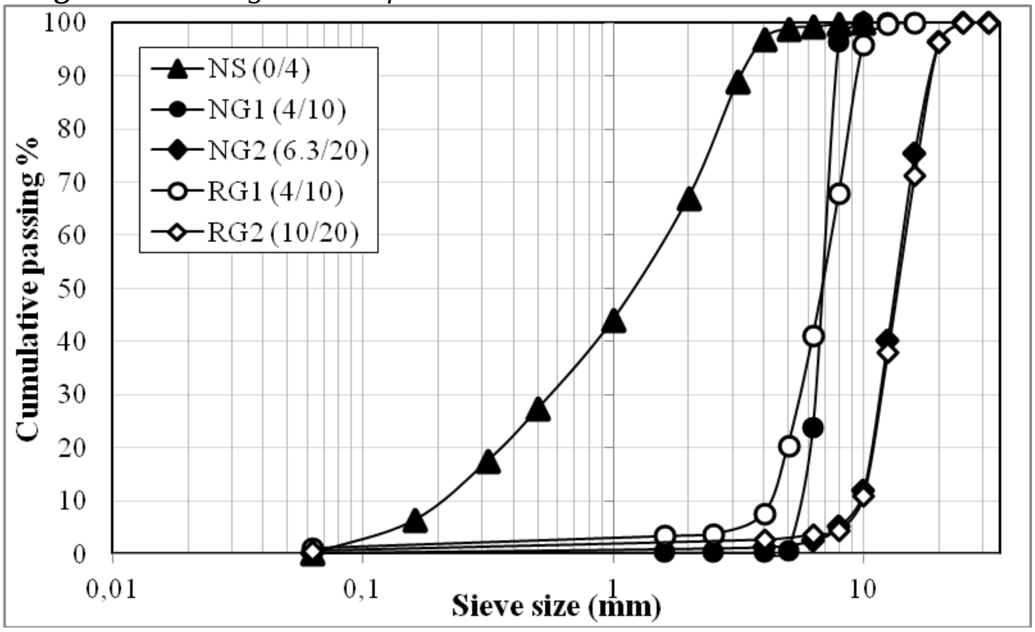
Figure 1. *Grading Curves of NA and RCA*



The density of NA and RG was performed by a pycnometer method according to the standard NF EN 1097-6 [16]. The moisture transport properties of treated aggregates were carried out by the water absorption coefficient (WA) test according to the standard NF EN 1097-6.

The mechanical resistance of NG and RG is determined by the Los Angeles test according to the standard NF EN 1097-2 [17] on the recommended fractions of [10-14 mm].

The Fresh concrete is tested by density and the air content. The air content of fresh concrete is determined by using an aerometer according to the standard EN 12350–7 [18].

At the hardened state, the compressive strength, the splitting tensile strength, the dynamic modulus of elasticity, the density, the porosity and the permeability tests were applied. The Compressive and splitting tensile strengths tests were performed using a servo-hydraulic INSTRON machine with a capacity of 3500 KN by imposing a stress rate of 0.5 MPa/sec and 0.05 MPa/sec, respectively. The dynamic modulus of elasticity was accomplished using E-Meter MKII device based on Resonant Frequency Testing method.

The water absorption capacity and the total porosity of hardened concretes were carried-out under the vacuum pressures according to the French standard NF P 18-459 [19].

Gas permeability was measured with a CEMBUREAU permeameter to record the gas flow. In order to obtain the representative values of permeability for each formulation, the test was conducted on three disc samples (15x5 cm). Each disc is subject to three different pressures (1 b, 3 b and 5 b), the apparent permeability was then calculated using Darcy's law and the Klinkenberg equation was used to calculate the intrinsic permeability.

For each experimental point the test was repeated at least 3 times.

Experimental Results

Characterization of Aggregates

To determine the apparent density (ρ_a), the bulk density (ρ_{rd}) and the particle density on a saturated-surface-dried basis (ρ_{ssd}), the NF EN 1097-6 standard was applied. The experimental results were summarized in

Table **1**. It can be pointed out that however the experimental apparent density is presenting approximately similar values for both types of aggregates, the bulk density and as well as the ρ_{ssd} are low for RCA than that of natural ones.

Table 1. *The Physical and Mechanical Properties of NA and RG*

Aggregates	$\rho_a \left(gr/cm^3\right)$	$\rho_{rd} \left(gr/cm^3\right)$	$\rho_{ssd} \left(gr/cm^3\right)$	WA24 (%)	LA (%)
RG1 (4/10)	2.61	2.32	2.45	$0.5^{\pm 0.1}$	-
RG2 (10/20)	2.59	2.26	2.40	$0.4^{\pm 0.1}$	$16.7^{\pm 0.6}$
NS (0/4)	2.65	2.56	2.59	$7.4^{\pm 0.1}$	-
NG1 (4/10)	2.76	2.72	2.73	$5.6^{\pm 0.2}$	-
NG2 (6.3/20)	2.75	2.72	2.73	$5.7^{\pm 0.2}$	$32.8^{\pm 0.6}$

The obtained results (

Table **1**) show that, the water absorption capacity of recycled gravels is significantly greater than that of natural ones. Compare to NG the ratio of between water absorption capacities of RG $\left(WA_{24h}^{RG1}/WA_{24h}^{NG1}\right)$ and $\left(WA_{24h}^{RG2}/WA_{24h}^{NG2}\right)$ are respectively, 11 and 14 times.

The relatively higher water absorption capacity and porosity of RA can be explained by the fact that the RA is coated by old cement paste which is characterized by a significant porosity [S. Omary et al., 2016].

The mechanical properties of RA are unfavorably affected by the presence of the old cement paste [S. Omary et al., 2016]. Indeed, the LA coefficient of RG is significantly greater than that of NG $\left(LA_{RA}/LA_{RA} \approx 2\right)$.

Concrete Mixture Design

In this study tow series of concretes were prepared differing in the state of recycled gravels before mix design. In the first one the recycled gravels (RG) were introduced at the saturated state, series S, while in the second they were incorporated at dry named series D.

The ratio of substitution is defined volumetrically by $r_v = V_{RG}/(V_{NG}+V_{RG})$: where V_{RG} presents the volume of RG in 1 m^3 of concrete and V_{NG} the volume of NG in 1 m^3 of concrete. Regarding to the equation, for both series of concretes different replacement ratios of natural gravels (NG) by RG were selected (0%, 10%, 25%, 50%, 75% and 100%).

The super plasticizer dosages were adjusted in order to achieve the same consistency class of S4 ($18^{\pm 2}$ cm) and compressive strength class of C35/45.

The components were introduced into the mixer by starting with coarse gravels, followed by fine gravels, sands, fillers, mix of water and super plasticizer. The mixing procedure proposed is summarized below:

0-1': Mixing of all dry components and saturated RCA
1 'to 1'30": Introduction of water + super plasticizer
1'30 " to 5': Mixing of mixes

The mix proportions of concrete are shown in Table 2. For all concrete mixes design, the total water-cement and water-binder ratios are maintained constant.

Table 2. *Mixture Proportions of Concrete*

Constituent (kg/m3)	Ref. Conc	Saturated recycled gravels (RG)					Dry recycled gravels (RG)				
	C35 0% GR	**C35 10% GR**	**C35 25% GR**	**C35 50% GR**	**C35 75% GR**	**C35 100% GR**	**C35 10% GR**	**C35 25% GR**	**C35 50% GR**	**C35 75% GR**	**C35 100% GR**
W_{total}	182	181	181	180	178	178	181	181	180	178	178
Water used for mixing	182	177	169	156	144	131	181	181	180	178	178
Cem II/A-L 42,5 N	294	293	293	291	288	288	293	292	291	287	287
Filler Calcaire	57	57	57	56	56	56	57	57	56	56	56
NS (0/4)	758	756	755	751	743	743	756	754	750	740	740
NG1 (4/10)	259	233	194	129	64	0	233	194	128	64	0
RG1 (4/10)	0	22	55	109	162	215	22	55	109	162	214
NG2 (6.3/20)	796	715	595	394	195	0	714	594	394	196	0
RG2 (10/20)	0	66	165	329	489	651	66	165	329	490	649
SP	1.95	2.27	2.38	2.74	3.83	4.46	1.94	1.78	1.53	1.20	0.95
$\rho_{theo.}$	2350	2328	2298	2245	2182	2138	2326	2294	2241	2176	2129
r_v (%)	0	10	25	50	75	100	10	25	50	75	100
W_{tot}/C	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
W_{tot}/b	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
$\rho_{at\ fresh\ state.}$	**$2360^{\pm10}$**	**$2325^{\pm16}$**	**$2286^{\pm7}$**	**$2271^{\pm17}$**	**$2252^{\pm6}$**	**$2225^{\pm7}$**	**$2341^{\pm13}$**	**$2310^{\pm22}$**	**$2261^{\pm19}$**	**$2232^{\pm12}$**	**$2157^{\pm57}$**
Slump (cm)	**$20^{\pm0.5}$**	**$20.1^{\pm0.3}$**	**$19.8^{\pm0.5}$**	**$19^{\pm0.8}$**	**$19.6^{\pm0.5}$**	**$18.9^{\pm0.3}$**	**$19.2^{\pm0.5}$**	**$18.8^{\pm0.8}$**	**$20.1^{\pm0.5}$**	**$19.3^{\pm0.3}$**	**$19^{\pm0.5}$**
Air content (%)	**$1.8^{\pm0.1}$**	**$2.0^{\pm0.1}$**	**$2.2^{\pm0.1}$**	**$2.7^{\pm0.2}$**	**$3.0\pm^{0.04}$**	**$3.7^{\pm0.2}$**	**$2.0^{\pm0.1}$**	**$2.4^{\pm0.1}$**	**$2.7^{\pm0.1}$**	**$3.4^{\pm0.1}$**	**$4.3^{\pm0.1}$**

The consistency of fresh concrete was determined by measuring the slump according to the method of the Abrams cone and it can be seen that for all mixtures the proposed consistency class (S4) was achieved (Table 2) by adjusting the quantity of super plasticizer that graphically illustrated in Figure 2. It can be point out that the dosage of the super plasticizer increases with the increases of substitution of NG by RG for the concretes with saturated RG (series S) due to decrease of mixing water. On the other hand, while the RG introduced at a dry state (series D) in the mixture, the quantity of super plasticizer decreases. After the measurement of air content and the quantity of the super plasticizer for every type of concrete, the mix proportions of concretes were corrected in order to obtain 1 m^3/m^3 by volume (Table 2).

Characterization of Concretes

The concretes at the fresh state the concrete were characterized by the density and the air content. The density at the fresh state was measured by samples with a specific volume that the results are summarized in Table 2 and it can be remarked due to low density of RG, the density of both series of concretes decrease with increases of RG content.

The air content of concretes was measured by aerometer according to the standard NF EN 12350–7 [17]. The obtained results regarding to the air content were graphically illustrated in Figure 3, it can be seen that there is a relationship between the air content of the concretes and the replacement ratio. The air content of both series of (S & D) concretes proportionally increases by increases of the replacement ratio, the relationship between these two parameters was established based on a strong correlation and it can be given by the expression Eq. (1):

$$a(\%) = 1.81e^{0.01 r_v(\%)} \quad \text{with} \quad R^2=0.98 \qquad \text{Eq. (1)}$$

The RG state (saturated & dry) doesn't have any significant effect on the fresh state, except the concrete with 100% of dry RG (C35-100%).

Figure 2. *The Superplasticizer by the Cement Weight*

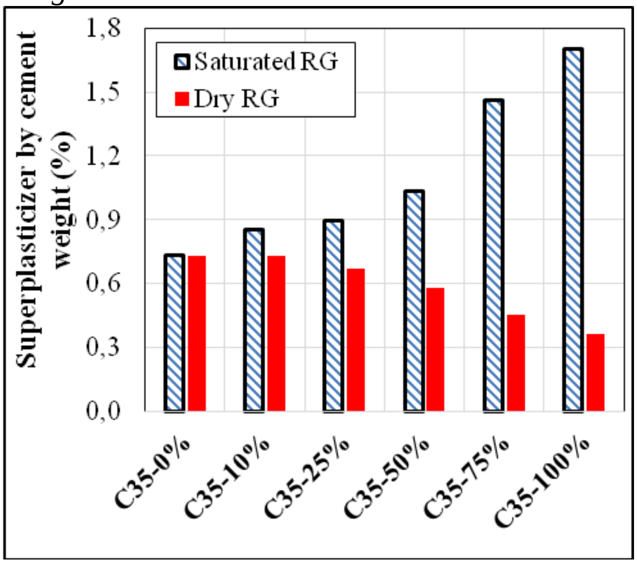
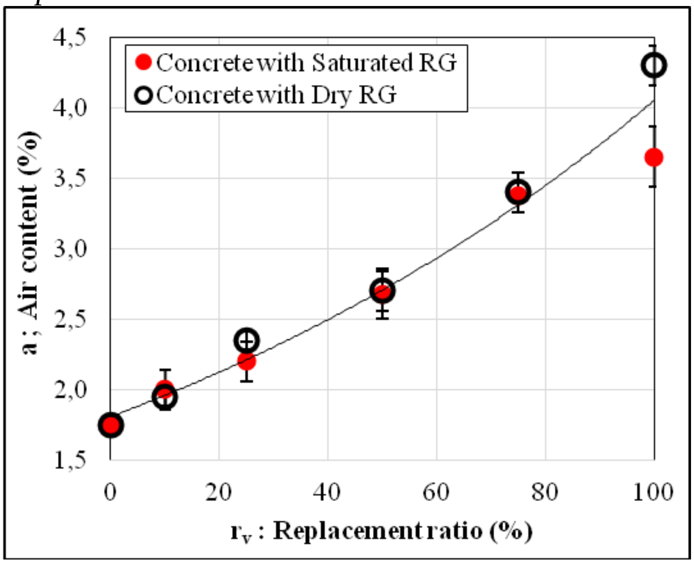


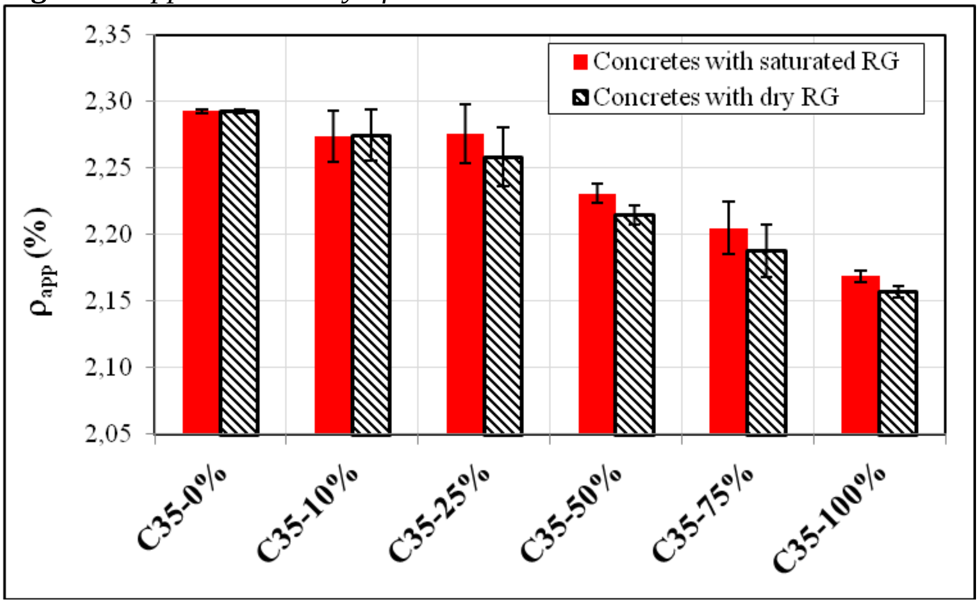
Figure 3. *The Air Content of Concretes versus Replacement Ratio*



At the hardened state, the physical properties of concretes were observed by the density, water absorption and total porosity according to the French standard NF P 18-459 [19]. The physical properties of concretes were carried-out on discs 15x5 cm which sawed from the cylindrical specimens of 15x30 cm after 28 days water cured.

The measurements of apparent density are displayed in Figure 4. However, there is no significant effect on density regarding to the state of RG (saturated & dry), the apparent density decreases by increases of the replacement ratio. Moreover, less than 50% of the replacement ratio (RG content) doesn't have significant influence on the concretes density.

Figure 4. *Apparent Density of Hardened Concrete*



The water absorption and total porosity of concretes are carried-out on specimens of 15x5 cm. The specimens are placed in an airtight container and vacuum is created until reaching a pressure of 25mbar. After 4 hours of vacuum the specimens are being submerged in water for 44 hours. The vacuum is maintained constant during submerging. The specimens are, then, weighed in the water (M_w) and in the air weighed (M_{air}) then dried at 80±5 °C until reaching a constant mass (M_{dry}). The porosity (n) as well as the coefficient of water absorption (WA) was calculated using Eq. (2) and Eq. (3)

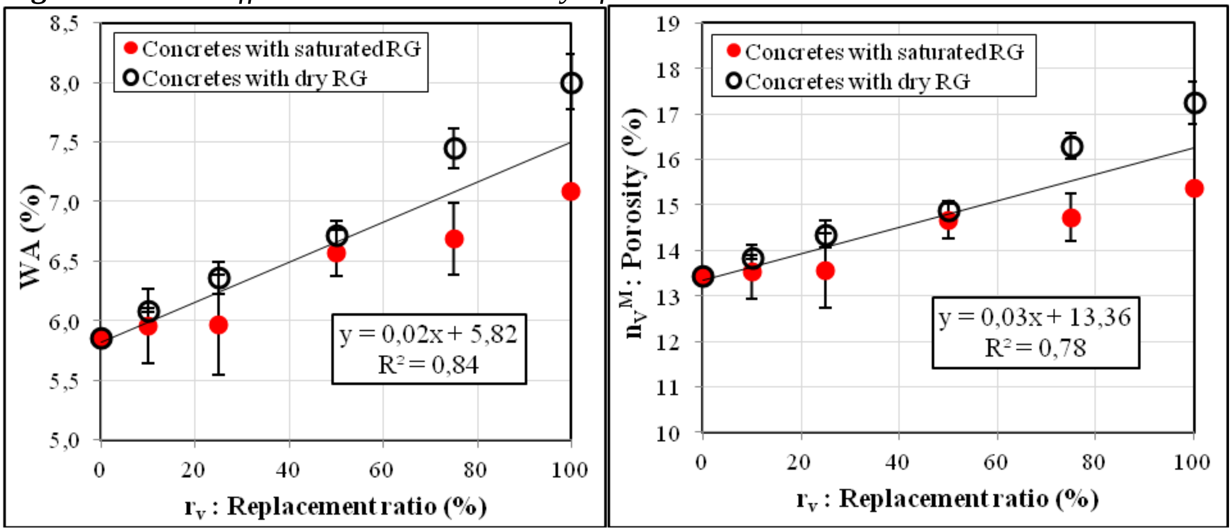
Coefficient of water absorption $$WA(\%) = \frac{M_{air} - M_{dry}}{M_{dry}} \times 100 \qquad \text{Eq. (2)}$$

Porosity $$n(\%) = \frac{M_{air} - M_{dry}}{M_{air} - M_W} \times 100 \qquad \text{Eq. (3)}$$

where M_{air} is a mass of samples at the saturated surface-dried state, M_{dry} is the mass of samples at oven dried state and M_w is the mass of concrete specimens in water.

The experimental results of water absorption and porosity are presented graphically in Figure 5. It can be observed that the water absorption and porosity are distinctly increased by increases of substitution of NG by recycled ones for both series of concretes. The experimental results are in accordance with those of literature [20-23]. The concretes porosity can be attributed to the high porosity of recycled aggregates [14]. However, the introduction state of the RG to mix design doesn't have a pronounceable difference until 50% of RG content, the substitution rate more than 50% with dry RG leading with high porosity than that of saturated ones.

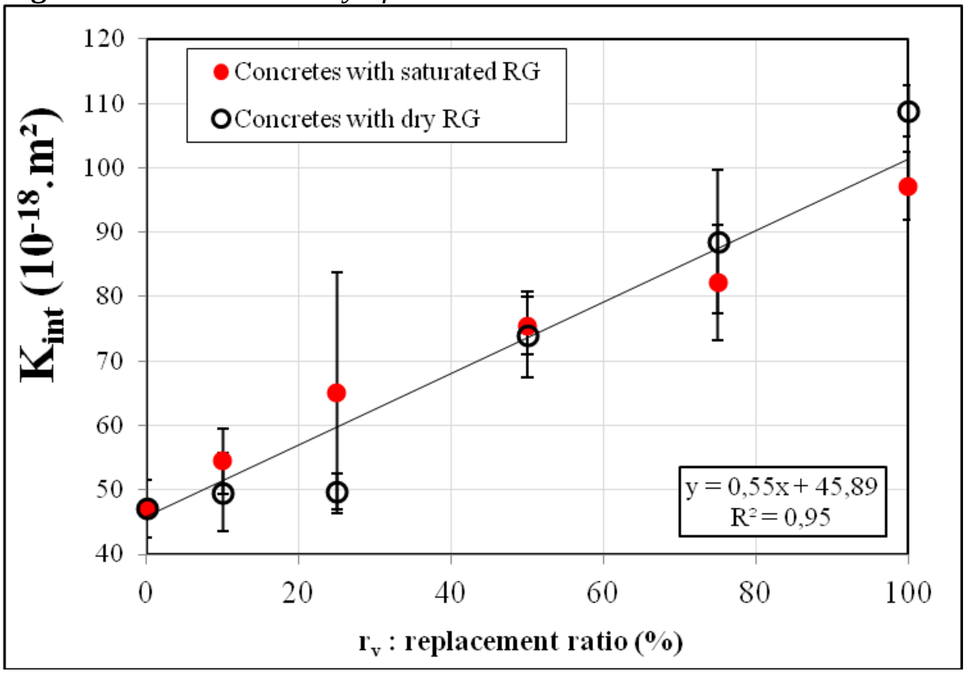
Figure 5. *WA Coefficient and Total Porosity of Hardened Concrete*



The measurement of the gas intrinsic permeability of concretes was characterized using the air permeability by the CEMBUREAU permeameter. The test was conducted on 3 discs of 15x5 cm. The specimens are dried in 80 C for 20 days and each disc is subject to three different pressures (1 b, 3 b and 5 b), the apparent permeability was then calculated using Darcy's law and the Klinkenberg equation was used to calculate the intrinsic permeability.

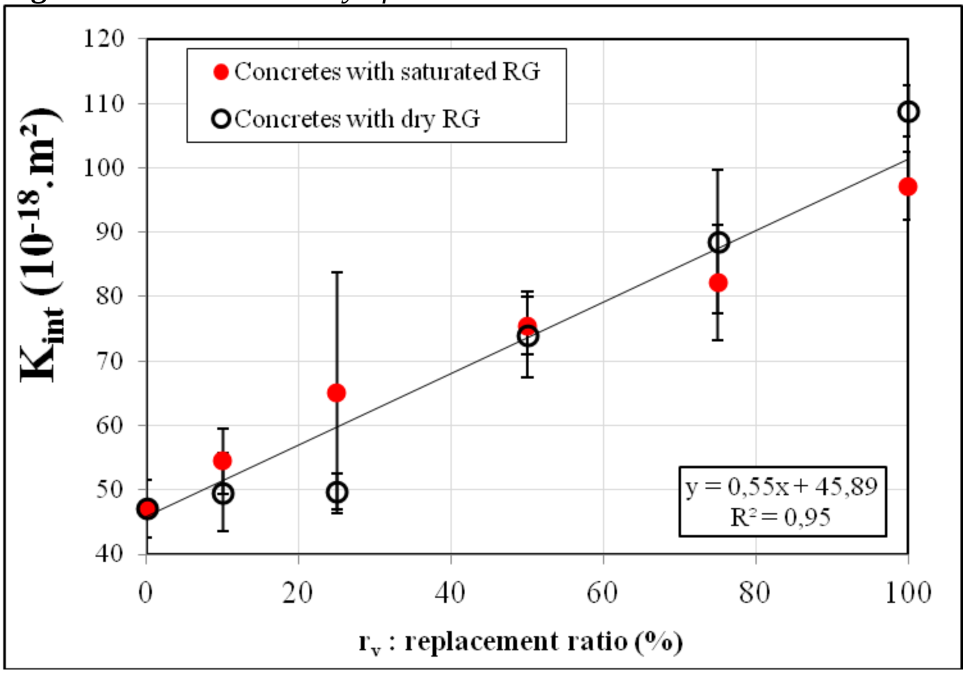
The experimental results of the permeability measurement were graphically displayed in

Figure 6. *Gas Permeability of Concretes*



. The intrinsic permeability increased as the content of recycled gravel increased, while the W_{tot}/b is constant for all concretes. Moreover, the state of RG doesn't have significant influence on permeability.

Figure 6. *Gas Permeability of Concretes*

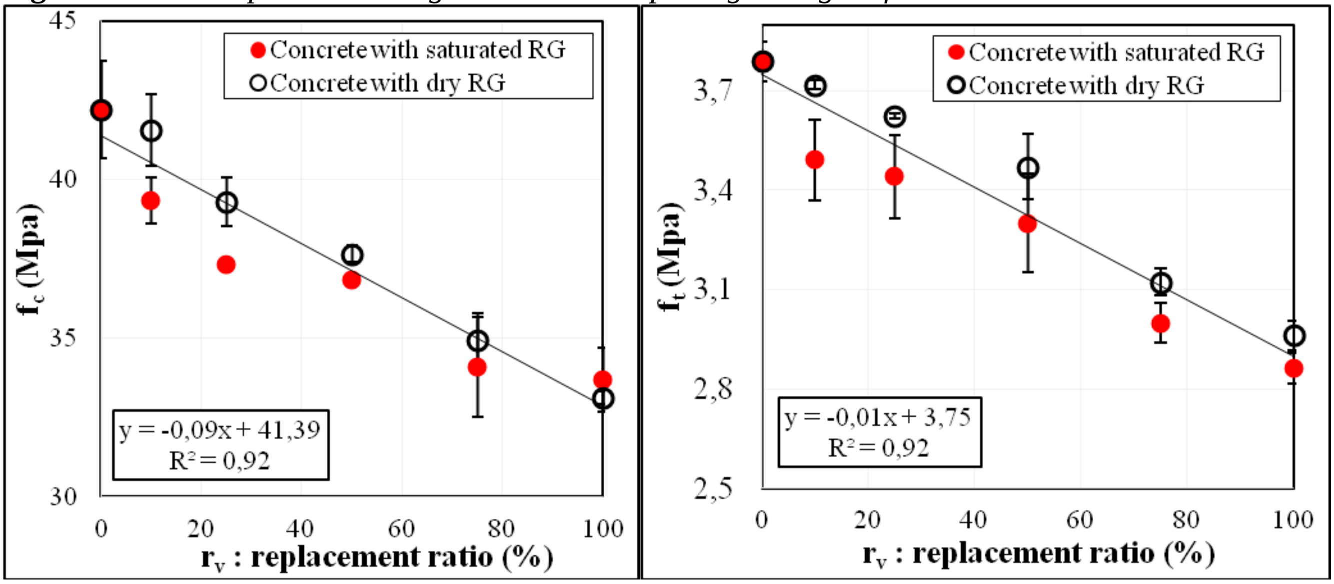


The mechanical properties of concretes are characterized by compressive strength, tensile splitting strength and dynamic modulus of elasticity. The tests were carried-out on cylindrical specimens 11x22 cm after 28 days water cured.

The compressive and tensile splitting strengths were performed using a servo-hydraulic INSTRON machine by imposing a stress rate of 0.5 MPa/sec and 0.05 MPa/sec and the dynamic modulus of elasticity was accomplished using E-Meter MKII device based on Resonant Frequency Testing method.

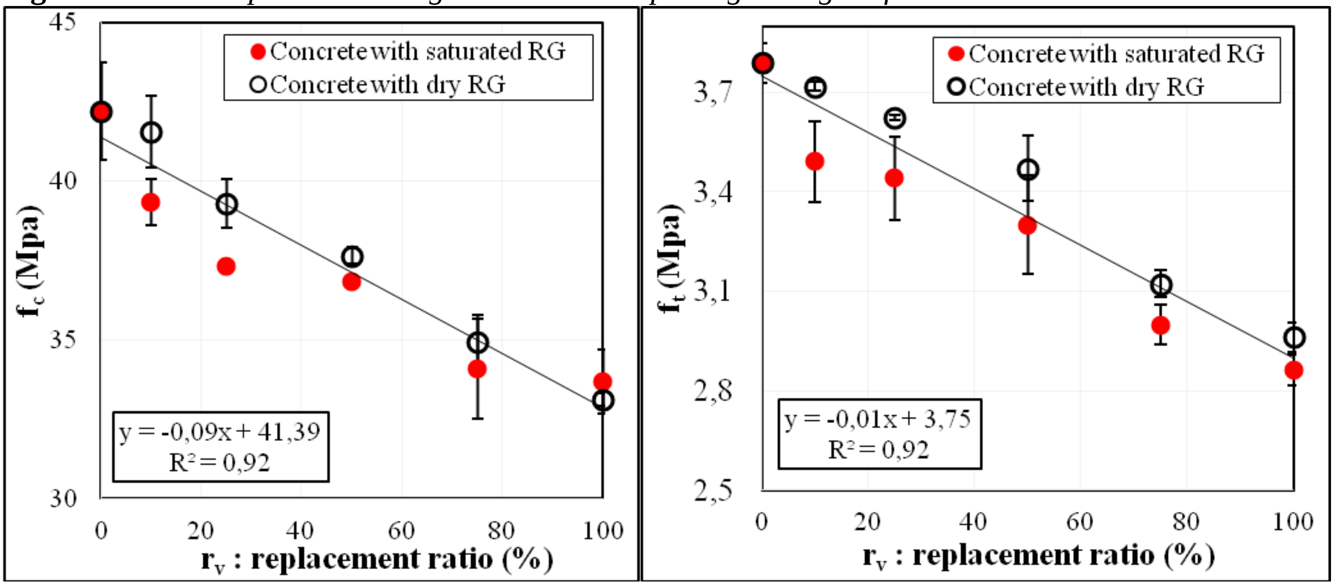
The experimental results of compressive strength are illustrated in

Figure 7. *The Compressive Strength and Tensile Splitting Strength of Concretes*



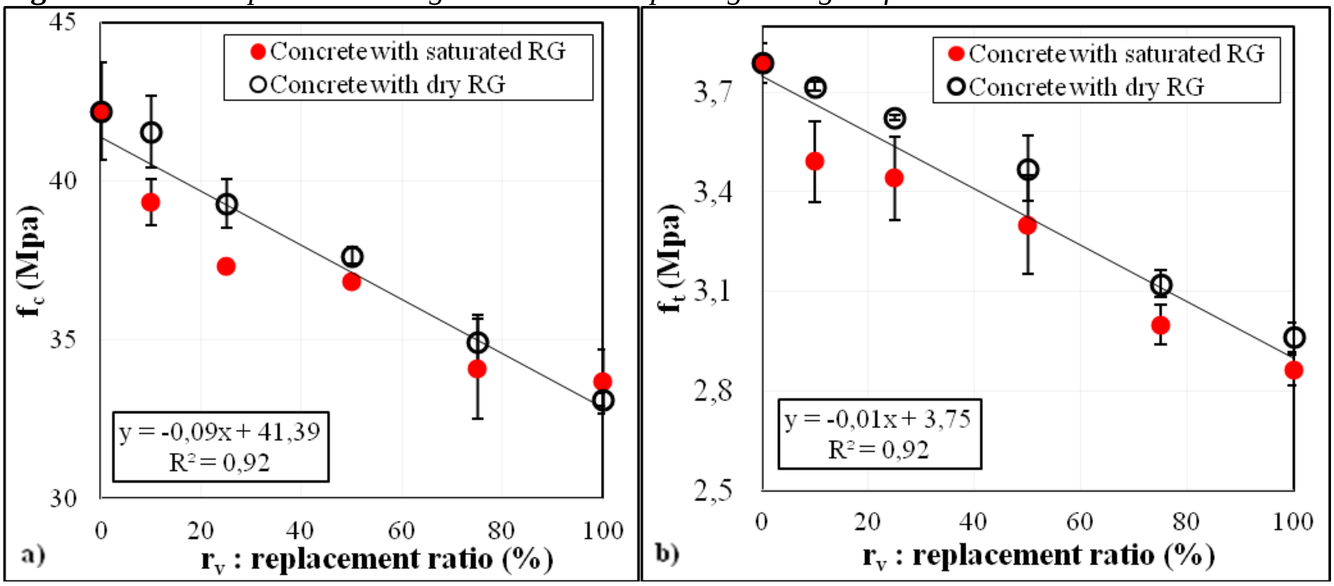
a, it can be seen that there is a linear relationship between compressive resistance and replacement ratio of NG by recycled ones, based on a strong coefficient of correlation. However, the concretes with saturated and dry recycled gravel present the similar approaches; the compressive strength concretes decreases as the replacement ratio increases. It can be attributed to the low resistance of gravels to fragmentation due to the presence of old cement paste in RG reported by Omary et al. [14]. As well as, the tensile splitting strength proportionally decreases by the increases of the RG in concretes, the concretes with saturated RG presents lower strength than that of concretes with dry RG ones (

Figure 7. *The Compressive Strength and Tensile Splitting Strength of Concretes*



b). Indeed, the experimental results are in agreement with those of the literature ones [21, 24-27, 29].

Figure 7. *The Compressive Strength and Tensile Splitting Strength of Concretes*

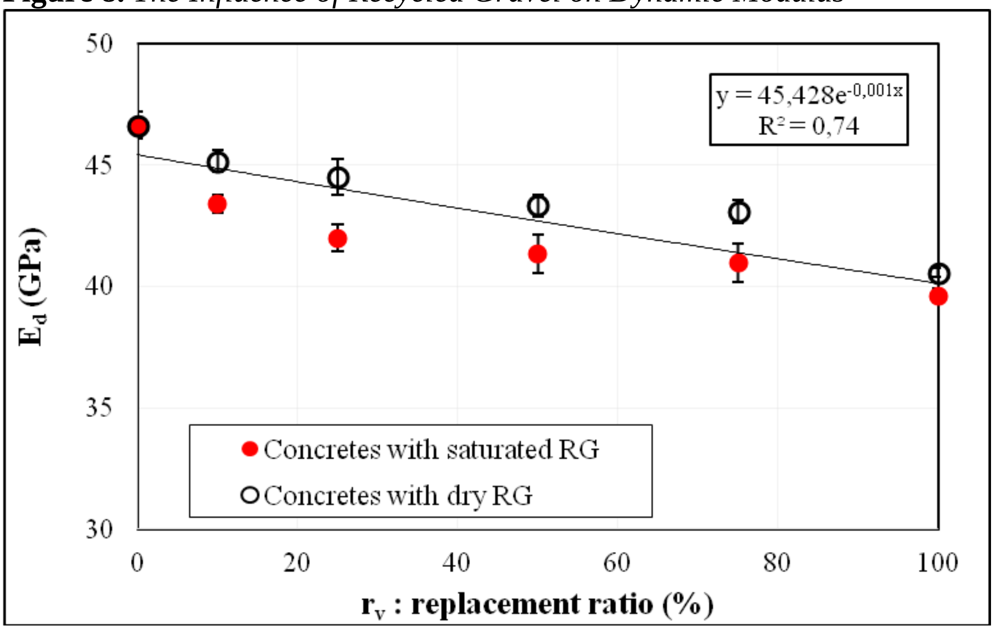


The experimental results of dynamical modulus of elasticity (Ed) are given in Figure 8. It can be concluded that, the Ed decreases when the RA is used. This relationship can be more pronounceable with a high replacement ratio of NG by RG, which can be described by Eq. (4):

$$E_d(Gpa) = 45.4e^{-0.001r(\%)} \quad \text{with} \quad R^2=0.74 \qquad \text{Eq. (4)}$$

Moreover, it can be seen that the concretes with the dry state of RG present slightly higher dynamic modulus elasticity than that of concretes based on the saturated ones. The experimental results are in accordance with those of literature ones [22, 28-30].

Figure 8. *The Influence of Recycled Gravel on Dynamic Modulus*



Conclusions

This work is related to the influence of recycled gravel introduction state (saturated and dry) to mixture design and their effects on physical and mechanical properties of concretes. Therefore, tow series of concretes were prepared differing in the state of recycled gravel before mix design; in saturated state and dray state. For both series of concretes different replacement ratios of natural gravel by recycled one were selected, respectively, 0%, 10%, 25%, 50%, 75% and 100%. The super plasticizer dosages were adjusted in order to achieve the same consistency class of S4 (18±2 cm) and compressive strength class of C35/45. The recycled gravel that used in this study was provided from waste construction materials. These aggregates are used for preparation of concrete for building structure applications. Based on the experimental results the following remarks can be withdrawn:

- At the fresh state, however, both series of concretes present the same behavior, there is a relationship between the air content of concretes and the replacement ratio. The air content of both series of (S & D) concretes proportionally increases by increases of the replacement ratio and the relationship between these two parameters was established on a strong correlation.
- At the hardened state, the physical and mechanical properties of concretes were affected by the substitution of natural gravel by recycled ones.

    - Results point out that, however, there is no visible difference in physical properties regarding to the state of RG (saturated & dry), and the apparent density decreases by increases of the replacement ratio. On the other hand, the water absorption, as well as, the porosity increased as the RG content increased.
    - There is a significant effect of RG on the permeability. The permeability of the concretes based on recycled gravel (r_v=100) is 2 times greater than that of the natural aggregate concrete (r_v=0). Moreover, the state of RG (saturated & dry) doesn’t have a significant influence on permeability.
    - Arguably, the compressive strength and tensile splitting strength of concrete decrease while, the RG content increases. Moreover, the concretes with saturated RG presents lower strength than that of concretes with dry RG ones.
    - Through establishing the relationship between the Young modulus and concrete substitution ratio based on a strong coefficient of correlation. Therefore, the modulus increases by increasing of RG content. Moreover, it can be seen that the concretes with the dry RG present slightly higher dynamic modulus elasticity than that of concretes based on saturated RG ones.

References

[1] Freedonia. *World construction aggregates*. Freedonia Jan-2012. http://bit.ly/2kP8Krg.

[2] Mark S. Kuhar. *A NEW STUDY PREDICTS THE NORTH AMERICAN AGGREGATES MARKET WILL BE A GLOBAL AREA OF GROWTH THROUGH 2017.* World Aggregates Market. Rockproducts. February 2014. http://bit.ly/2llJqen.

[3] Peter Craven. *Are Current EU C&D Waste Recycling Targets an Obstacle to Growth?.* Waste management world 02/2015. http://bit.ly/2lZCW8a.

[4] Waste-Construction and Demolition Waste (CDW). *European commission 2014.* http://bit.ly/1ERulE1.

[5] European Environmental Agency, Review of Selected Waste Streams. *Technical Report N.69, Copenhagen, Denmark:* European Environmental Agency, 2002.

[6] UNPG, Union Nationale des Producteurs de Granulats, France: http://www.unpg.fr/.

[7] UNICEM, L'Union nationale des industries de carrières et matériaux de construction, France: http://www.unicem.fr/.

[8] P. N. RECYBETON, Complete recycling of concrete, France: http://www.pnrecybeton.fr/, 2012.

[9] ECOREB, Ecoconstruction par le Recyclage du Béton, France: http://ecoreb.fr and http://bit.ly/2lBNLMZ, 2013.

[10] C. J. Zega, Y. A. Villagran-Zaccardi and A. A. Di-Maio. *Effect of natural coarse aggregate type on the physical and mechanical properties of recycled coarse aggregates.* Materials and Structures, vol. 43, no. DOI 10.1617/s11527-009-9480-4, pp. 195-202, 2010.

[11] G. Wardeh, E. Ghorbel and H. Gomart. "*Mix Design and Properties of Recycled Aggregate Concretes: Applicability of Eurocode 2,*" International Journal of Concrete Structures and Materials, vol. 9, no. 1, pp. 1-20, 2015.

[12] Ö. Çakır. *"Experimental analysis of properties of recycled coarse aggregate (RAC) concrete with mineral additives,"* Construction and Building Materials, vol. 68, pp. 17-25, 2014.

[13] T. T-sung-Yueh, C. Yuen-Yuen and H. Chao-Lung, *"Properties of HPC with recycled aggregates,"* Cement and Concrete Research, vol. 36, pp. 943-950, 2006.

[14] Safiullah Omary, Elhem Ghorbel & George Wardeh. *Relationships between recycled concrete aggregates characteristics and recycled aggregates concrete properties.* Construction and Building Materials Volume 108, 1 April 2016, Pages 163-174.

[15] N. F. E. N. 933-11, *Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution—sieving method.,* Cedex-France: AFNOR, 2009.

[16] N. F. E. N. 1097-6, *Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption.,* Cedex-France: AFNOR, 2014.

[17] N. F. E. N. 1097-2, *Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation.,* Cedex-France: AFNOR, 2011.

[18] NF EN 12350–7, *Testing fresh concrete-Part 7: Air content — Pressure methods.* Cedex-France: AFNOR, AVRIL 2012.

[19] N. F. P18-459, *Concrete — Testing hardened concrete — Testing porosity and density,* Cedex-France: AFNOR, 2010.

[20] K. Amon, *"Properties of concrete made with recycled aggregates from partially hydrated old concrete,"* Cement and Concrete Research, vol. 33, pp. 703-711, 2003.
[21] D. Soares, B. J. De, J. Ferreira and J. Pacheco, *"Use of coarse recycled aggregates from precast concrete rejects: Mechanical and durability performance,"* Construction and Building Materials, vol. 71, pp. 263-272, 2014.
[22] M. A. Mohamed, W. George and G. Elhem. *Influence de la valorisation des microfibres vegetales su la formulation et la resistance aux cycles de gel-degel de BAP* [Influence of the valuation of plant microfibers on the formulation and resistance to BAP freeze-thaw cycles], France, University of Cergy-Pontoise-L2MGC, 2011, p. EA4114.
[23] J. R. Correia, B. J. de and A. S. Pereira, *"Effects on concrete durability of using recycled ceramic aggregates,"* Materials and Structures, vol. 39, no. 2, pp. 169-177, 2006.
[24] C. S. Poon, S. C. Kou and L. Lam, *"Influence of recycled aggregate on slump and bleeding of fresh concrete,"* Materials and Structures, vol. 40, no. DOI 10.1617/s11527-006-9192-y, pp. 981-988, 2007.
[25] M. V. G. S. Jose, *"Porosity of recycled concrete with substitution of recycled concrete aggregate An experimental study,"* Cement and Concrete Research, vol. 32, p. 1301-1311, 2002.
[26] R. M. Chakradhara, S. K. Bhattacharyya and S. V. Barai, *"Influence of field recycled coarse aggregate on properties of concrete,"* Materials and Structures, vol. 44, pp. 205-220, 2011.
[27] N. K. Bairagi, R. Kishore and V. K. Pareek, *"Behaviour of concrete with different proportions of natural and recycled aggregates,"* Resources, Conservation and Recycling, vol. 9, no. 1-2, pp. 109-120, 1993.
[28] D. Zhen-Hua and P. Chi-Sun, *"Properties of recycled aggregate concrete made with recycled aggregates with different amounts of old adhered mortars,"* Materials and Design, vol. 58, pp. 19-29, 2014.
[29] M. V. G. S. Jose, *"Porosity of recycled concrete with substitution of recycled concrete aggregate An experimental study,"* Cement and Concrete Research, vol. 32, p. 1301-1311, 2002.
[30] S. Manzi, C. Mazzotti and M. C. Bignozzi, *"Short and long-term behavior of structural concrete with recycled concrete aggregate,"* Cement & Concrete Composites, vol. 37, p. 312-318, 2013.