

Conference Paper

Experimental Investigation on the Properties of a Recycled Aggregate Concrete Based on Waste of the Industrial Mineral Additions

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Abstract

This study investigates the possible effects of incorporating different industry wastes during manufacturing of concrete, with percentages ranging from 0% to 30%, and assesses the influence of these combinations (mineral additions and recycled aggregates) on the properties of a recycled concrete comprised of these two main constituents products. Recycled concrete samples with different combinations of mineral additions at various dosages were used to determine these properties in the fresh and hardened states. The "Design-expert" methodology was used to analyse the results after 7, 14 and 28 days, identifying correlations and the effects of the different variables. The results obtained showed the advantageous effect of incorporating the pozzolana and slag into the concrete mixture at dosages of 15% and 30%, they also demonstrated the low optimal percentage of marble fillers of 5%. These findings suggest that replacing clinker with industrial waste could limit the dust and CO₂ emissions into the atmosphere during concrete manufacture, offering environmental advantages as well as conserving the natural resources of aggregate recovery from C&D wastes.

Keywords: environmental concrete, mineral additions, recycled aggregate, design expert method.

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1. Introduction

The concrete is a building material that finds its field of use in almost all engineering sectors. Currently, the beneficial properties presented make of such product probably, the mostly used in the world today for its economic and technical advantages.

However, the intensive use of this material involves a large consumption of its components including essential aggregates for the production of concrete and represents approximately 70% of its total volume. They are produced and used in large quantities

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in all countries of the world, however, the natural resources are not sustainable, and extraction places continue to move away from the consumption sites, aggregates are materials whose price could be twice when transported at a distance of 50 Km [1].

In parallel, the rapid growth of urban agglomerations has caused a dramatic increase in quantities of by-products and wastes construction materials manufacturing industries. As a result, wastes are massively generated of demolition operations and renovation (C & D).

The by-products and waste that before had not been paid much attention and concern, began to be an economic and ecological problem in the late 20th century. The huge amounts that are produced continually immobilizing increasingly large areas for storage of waste and reducing the availability of land, besides the pollution with the environmental hazardous consequences [2].

To answer, first to the vital needs of the construction and on the other hand, the universal need to conserve resources and protect the environment, it has become essential to recover and recycle waste (inert) to produce recycled aggregates as an alternative to natural aggregates and reuse of by-product of the industry as a substitute additions in cement, to formulate a recycled concrete having performance (strength and durability) comparable to a conventional concrete [3].

The study undertaken here in is to highlight the possible effects of additions from different industry wastes, that are incorporated during manufacturing of concrete with percentages ranging from 0% to 30%; in order to assess the influence of this combination (mineral additions and recycled aggregates) on the properties of a recycled concrete based on these two products.

2. Experimental Study

2.1. Materials

The study concerned a concrete based on recycled aggregate; prepared with Portland cement CEM I / CRS N 42.5 MPa, delivered from Ain kebira plant in the Setif region (250 km east of Algiers). The original limestone crushed aggregates with a maximum dimension of 16 mm. the recycled aggregate were produced in a local site and prepared in the laboratory from an old concrete specimen with strength range between 25 to 35 MPa. This experimental program used the dune sand (0/5) as the fine aggregate; with a fineness modulus of 2.01, and the sand equivalent of 83 %.

Table 1 includes the physical and mechanical properties of aggregates used in this experimental study.

TABLE 1: Physical and Mechanical properties of aggregates.

Fraction	Bulk density (kg/m ³)	Specific density ρ (kg/m ³)	Hardness L _A (%)	Absorption A (%)
0/5	1413	2309	–	–
3/8 [CA]*	1202	2550	25	2.5
8/15 [CA]*	1331	2609	11	1.17
3/8 [RA]**	1179	2400	28.82	6.60
8/15[RA]**	1287	2572	26.5	4.38

(*) CA, refers to crushed aggregate.

(**) RA, refers to recycled aggregate.

2.2. Concrete mixtures proportions

The mixtures proportions are reported in Table 2.

TABLE 2: Concrete mixture proportions.

Mix	Aggregate		C (%)	FM* (%)	PZ** (%)
	CA (%)	RA(%)			
BT	100	0	100	0	0
BR0	0	100	100	0	0
BR1	0	100	70	0	30
BR2	0	100	70	10	20
BR3	0	100	70	15	15
BR4	0	100	70	20	10
BR5	0	100	70	30	0

(*) FM refers to marble fillers addition.

(**) PZ refers to pozzolana addition.

3. Results and Discussion

The procedure in the following analysis and interpretation, after presentation of the results obtained in our study. In the coming sections all the properties in fresh and Hardened state are discussed.

3.1. Fresh state

3.1.1. Density

Figure 1 shows the change in the charge density as a function of different types of concrete (recycled and control). We note that different types of recycled concrete have a density less than that of the control concrete (BT). Indeed, BR0 has a density (2325 kg / m^3) 5% lower than the concrete witness BT (2398 Kg / m^3). This decrease can be attributed to the nature of the recycled aggregates (low density and high porosity) as reported by

On the other hand, the lowest value of density was recorded with the BR1 mixture (2250 kg / m^3) with 4% lower than BR0 and 7% than of BT. It is found that the substitution of cement by 30% pozzolana presents a negative effect on the density of concrete with pozzolana additions at high dosages.

Concretes (BR2, BR3, BR4 and BR5), a slight increase in density is observed (2273 , 2284 , 2310 and 2362 Kg / m^3), respectively, this as a function of the cement substitution rate by fillers of marble (10, 15, 20, and 30%) This shows the positive effect of fillers which act as micro-aggregate i.e decreases the porosity filling the voids and give the concrete a high compactness as shown by several studies, [4–6]. Fillers effect is remarkable in the case BR5 which gives a value of the density (2362 Kg / m^3) higher compared to the remains of different types of recycled concrete.

It is concluded that all recycled mixtures give a density lower in control concrete; except BR5 mixture (30% marble fillers) which shows a nearly similar density to concrete BT.

3.2. Hardened state

3.2.1. Compressive strength (R_c)

Figure 2, shows the variation of the compressive strength for different concretes (recycled and control) at 7, 14, and 28 days. It can be noted that the compressive strength of the control concrete (BT) is higher compared to other types of recycled concrete. The concrete BR0 (without mineral addition) has a development of similar strength to that of BT, and better strength compared to different concretes recycled with additions (marble fillers and pozzolana) Figure 2. At 28 days of age difference was recorded between 12% resistance BR0 (35.25 MPa) and BT (40.04 MPa), the replacement of crushed aggregates with 100% recycled aggregates, has affected the resistance because they present a

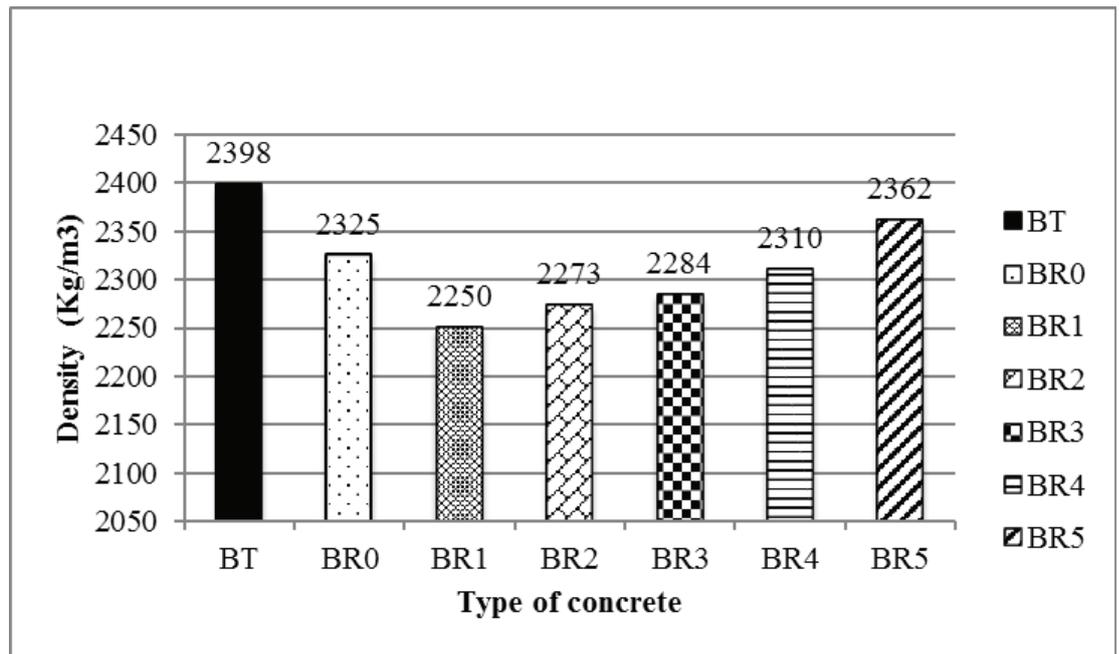


Figure 1: The variation of the bulk density for different concrete types (recycled, controls).

lower hardness of 50 % compared to crushed aggregates, as shown in the los Angeles test most of the increase in the W / C ratio (due to the demand for additional water when making recycled concrete) makes porous and less dense concrete, which affects the mechanical performance. Another Parameter to be taken into account, the presence of old mortar and dust bothers cement hydration and hydrate formation and contributes to the reduction of resistance. The results are correlating with those found by other studies [10].

The Substitution of 30% of cement with mineral additives (marble fillers and pozzolana) is not beneficial, as illustrated in Figure (8), we note that these concretes have lower resistance to BR0 (without additions) at different ages (7, 14, and 28 days).

At 7 days, results show that BR1 gives the lowest value (12.83 MPa), was recorded a fall of 56 % compared to BR0 (27.5 MPa) and 60% vis- à-vis BT (31.5 MPa). On the other hand there is a move up resistance concretes (BR2, BR3, and BR4), (17.35 MPa 19.26 MPa and 24.61 MPa) respectively; following the increase in the marble fillers rates (10%, 15% and 20%) respectively.

It is noted that the pozzolan has a negative effect on the resistance young age high percentages (20% and 30%), its action is manifested in the long term, as described in several studies [11], while the marble fillers brings an advantageous effect on the mechanical response by improving the physical properties (high compactness), which explains the increasing evolution of resistance depending on the dosage of fillers to a percentage (20%)

In general, it can be concluded; that the substitution of an amount of the cement by the additives in the case of recycled concrete always give a compression resistance (Rc) below the concrete BT, on the other by the concrete BR4 (10% pozzolan, and 20% of fillers marble) and concrete BR5 (30% marble fillers) show resistance (Rc) close to recycled concrete without mineral additives.

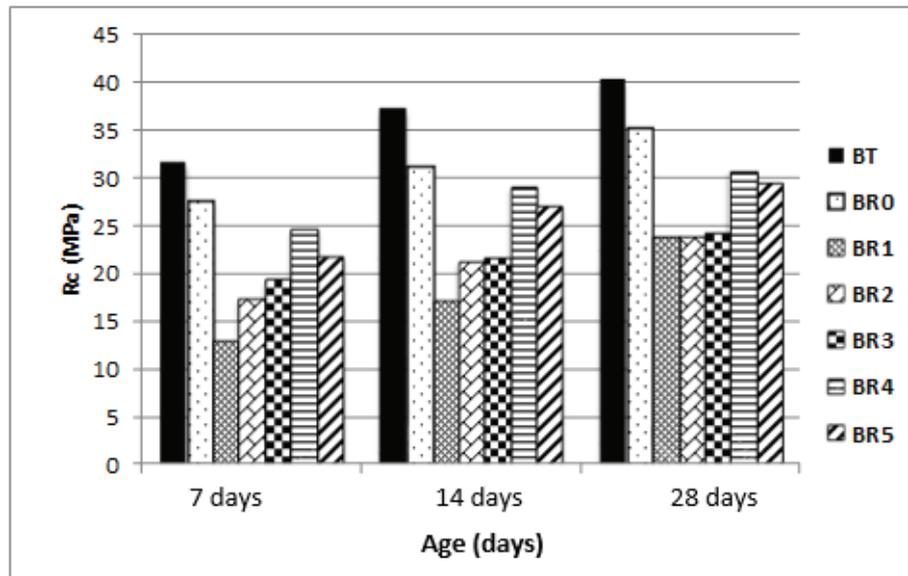


Figure 2: The variation of Compressive strength (Rc) for different concrete types (recycled, control) at 7,14 and 28 days.

3.3. Correlations for mechanical characteristics

3.3.1. Correlation between the compressive strength (Rc) and the ultrasound velocity (V)

Figure 3 shows the relationship between the compressive strength (Rc) and the ultrasound speed (V). Wide dispersion was noted with a correlation coefficient R^2 equal to 0.4951. It can be noted that the strength is proportional to the speed of ultrasound and that the correlation is linear type: $Rc = a (V) + b$. Previous research on the concrete base of crushed aggregates [15, 16] propose linear correlations between strength and ultrasonic velocity. The correlation proposed from this study is of the form:

$$Rc = 54.777(V) - 227,65 \tag{1}$$

$$R^2 = 0.4951.$$

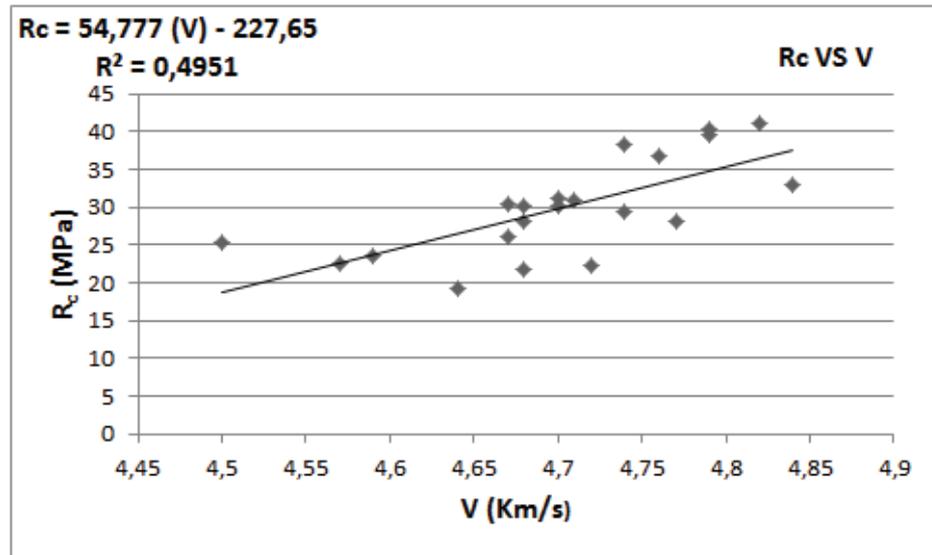


Figure 3: Correlation of the mechanical resistance (Rc) and the ultrasound velocity (V).

3.3.2. Correlation between compressive strength (Rc) as a function of (Is)

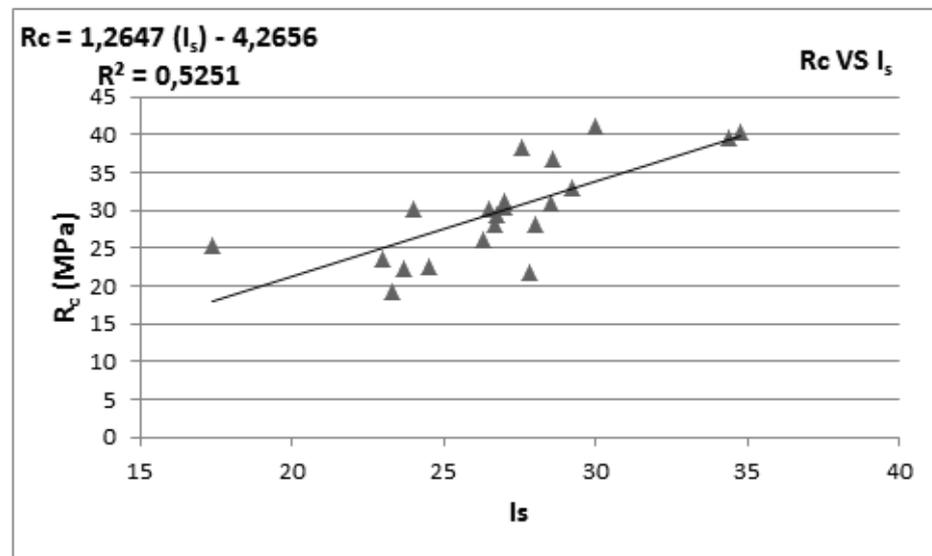


Figure 4: Correlation between the compressive strength (Rc) and the rebound number (Is)

Figure 4 shows the relationship between the compressive strength (Rc) and rebound number (Is). A wide dispersion was noted as a very low correlation coefficient $R^2 = 0.5251$; the correlation obtained is linear. Research [16–18] conducted on the correlation between the compressive strength and rebound number have a linear relationship. The correlation proposed from this study is of the form:

$$Rc = 1.2647(Is) - 4.2656 \tag{2}$$

$$R^2 = 0.5251$$

3.3.3. Correlation between the mechanical resistance (Rc) and the dynamic elastic modulus (Ed)

A proportional relationship between the dynamic elastic modulus and strength of linear type was found, the correlation coefficient is of the order of 0.5485.

The correlation proposed from this study is of the form:

$$R_c = 0.9627(E_d) - 5.08011 \tag{3}$$

$$R^2 = 0.5485$$

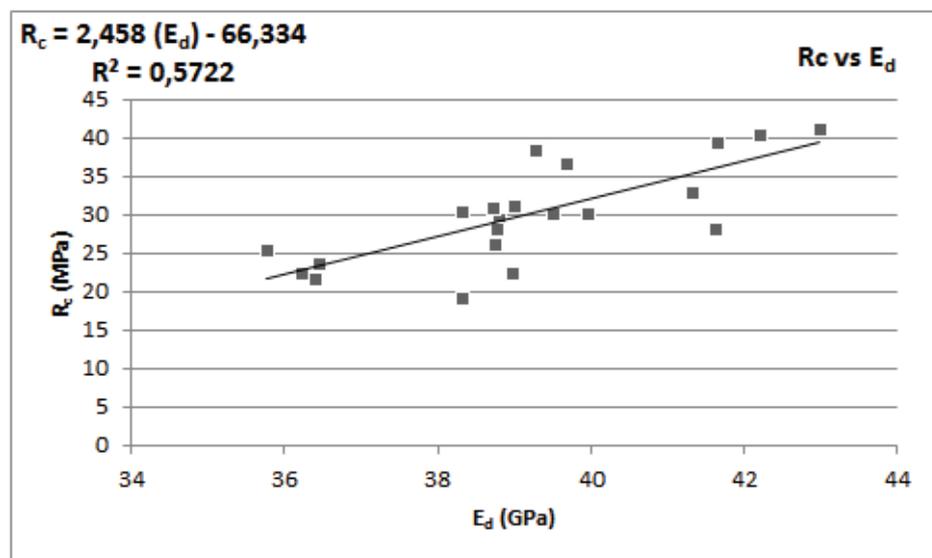


Figure 5: Correlation between compressive strength the dynamic modulus of elasticity.

4. Conclusion

The results obtained through the study of the effect of mineral additives (marble fillers and pozzolan) on the properties of a local recycled concrete; allow us to draw the following conclusions:

The dosage of 30% by pozzolana reduces remarkably the density for fresh and cured (BR1 mixture) compared to the recycled concrete without mineral additions (BR0), which shows the negative role of the pozzolan addition on this property.

The percentage of 30% marble filler addition gives densities at fresh and hardened state slightly higher (mixture BR5) in comparison with the concrete without mineral additions (BR0) but closer to the witness concrete values (BT).

The compressive strength (R_c) at different ages 7, 14 and 28 days of all the recycled concrete is lower than that of control concrete one.

The substitution of cement with 30% pozzolan negatively affects the compressive strength (R_c). However, recycled combined mixtures at 10%, pozzolan and 20 % marble fillers and 30% marble fillers alone provide mechanical responses closer to that of control concrete without mineral additions.

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