# USE OF RECYCLED PLASTIC BAG WASTE IN THE CONCRETE

**Youcef Ghernouti, Bahia Rabehi, Brahim Safi and Rabah Chaid**

Research Unit: Materials, Processes and Environment, University M'Hamed Bougara of Boumerdes. Algeria.

***ABSTRACT***

*The aim of this study is to explore the possibility of re-cycling a plastic bag waste material (BBW) that is now produced in large quantities in the formulation of concrete as fine aggregate by substitution of a variable percentage of sand (10, 20, 30 and 40 %). The influence of the PBW on the fresh and hardened states properties of the concrete: workability, bulk density, ultrasonic pulse velocity testing, compressive and flexural strength of the different concretes, has been investigated and analyzed in comparison to the control concrete. The results showed that the use of PBW improves the workability and the density, reduces the compressive strength of concrete containing 10 and 20 % of waste by 10 to 24 % respectively, which have a mechanical strength acceptable for lightweight materials, remains always close to reference concrete (made without PBW). The results of this investigation consolidate the idea of the use of PBW in the field of construction, especially in the formulation of concrete.*

***Keywords:*** *Waste, plastic, concrete, strength, valorization, density, workability.*

## 1. INTRODUCTION

The valorization of waste in civil engineering is an important sector to the extent that the products to be obtained are not subjected to rigorous quality standards too.

The valorization of waste affects two major impacts, environmental impact is solved by disposing of such waste and the economic impact is the use of that in industry or in the field of construction, this waste has the advantage of being available large quantity and low value (Hassani et al. 2005). The cementing materials, by their performance in terms of mechanical strength and durability dominate the market of construction materials. The addition of polymeric waste to concrete corresponds to a new perspective in research activities, integrating the areas of concrete technology and environmental technology.

Industrial and domestic waste has a significant percentage of polymeric materials in its constitution, which occupies a considerable volume on landfills. Therefore its recycling is interesting to research and development of technologies for minimizing the problems caused by this waste.

Several studies have been conducted on the use of plastic waste in concrete. The works of Rebeiz showed that the resins based on recycled PET can be used to produce a good quality of precast concrete (Rebeiz 2007). Many studies have been conducted on the use of scrap tire/rubber in mortar and concrete, and a research work has been published by Siddique a review paper (2008) on the use of recycled plastic in concrete (Siddique, Khatib & Kaur 2008). In the other study, Choi et al. (2005) investigated the effect of plastic waste (PET bottles) as aggregate on properties of concrete. The results obtained in this study showed that these wastes could reduce the weight by 2–6% of normal weight concrete and the compressive strength was reduced up to 33% compared to that of normal concrete. Sikalidis et al. (2002) investigated the utilization of municipal solid wastes (MSW) for the production of mortar. Batayneh et al. (2007) have shown, in their work, that the decrease of compressive strength was in function of increase in the content plastic content. For a 20% substitution of sand by the waste, the compressive strength was reduced up to 70% compared to that of normal concrete. Also, researchers [Remadnia et al.2009, Yazoghli-marzouk et al. 2007) have also studied the use of consumed plastic bottle waste as sand-substitution aggregate within composite materials for building applications. These authors showed that the density and compressive strength were decreased when the PET aggregates exceeded 50% by volume of sand. Also, It was found that the addition of plastic waste (fractions < 10%) in volume inside of cementitious matrix does not imply a significant variation of the concrete mechanical features.

The present study focused on the use of plastic fines aggregates resulting from the crushing of plastic bags waste rejected into nature and to find new ways of valorization in the field of construction. We will present, therefore, the fresh and hardened states properties of the concrete: workability, bulk density, ultrasonic pulse velocity testing, compressive and flexural strength of the concretes.

## 2. EXPERIMENTAL PROGRAM

### *2.1. Materials used*

In this study, the concrete is composed of crushed sand 0–5mm and two types of gravel 3–8mm and 8–15 mm, supplied by the quarry (Mascara, Algeria), a cement type CEM II 32.5 from the cement Chlef (Algeria). Specific gravities for the sand and coarse aggregate were 2.62 and 2.65, respectively. The sand has a fineness modulus of 2.55. The physical properties of sand and the plastic waste are listed in Table 1, its particle size analysis of sand and the plastic waste is represented in Fig. 1.
The recycled waste used is the plastic bag waste is obtained according to the following technological chain (Fig. 2).

Table 1. physical properties of sand and the plastic waste

| | Sand | Plastic bag waste waste |
|---|---|---|
| Apparent density, Ad (g/cm$^3$) | 1.45 | 0.53 |
| Specific gravity, SG (g/cm$^3$) | 2.56 | 0.87 |
| Visual equivalent, VES (%) | 80 | - |
| Finesse modulus, Fm | 2.5 | 4.7 |

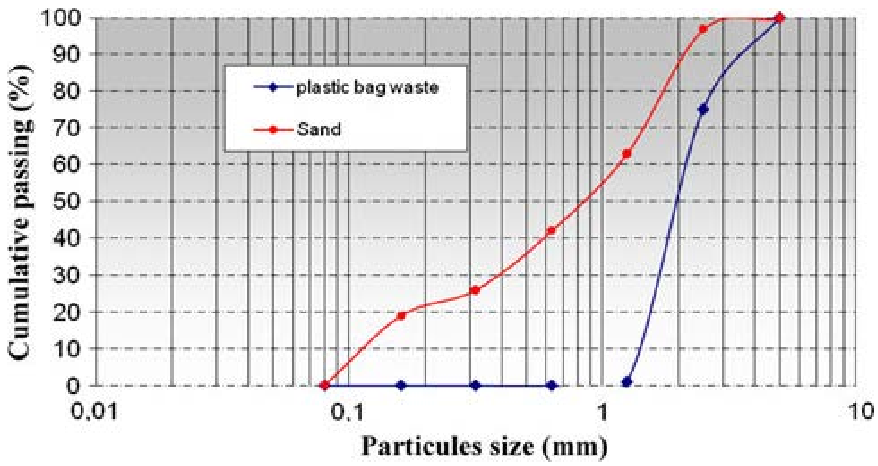


Figure 1. Particle size distribution of sand and waste.

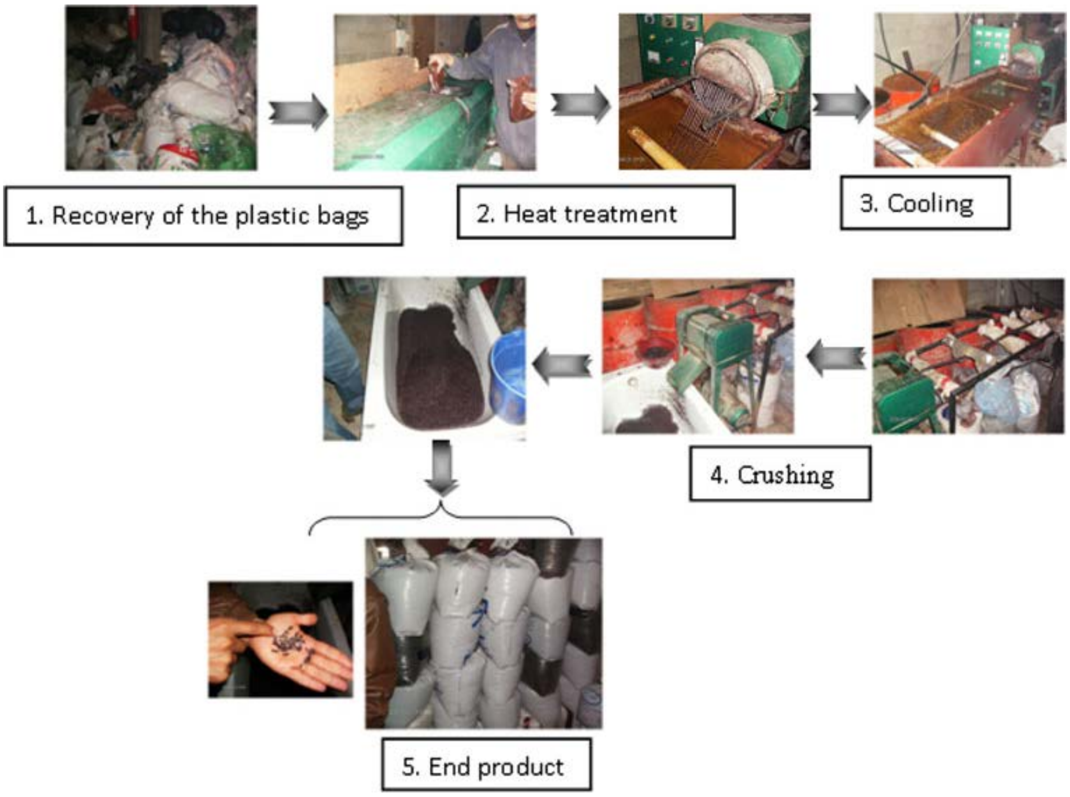


Figure 2. Stages of obtaining waste of the plastic bags.

### *2.2. Formulation of Concrete's*

The concrete composition was determined by Dreux Gorisse method.
The plastic bag waste was introduced by substitution of a variable percentage of sand such as: 10, 20, 30 and 40 % and that, to better see their influence on the mechanical physic properties of the concrete. The different composition of concrete's studied and their notations are presented in Table 2.

Table 2. Mix proportions of the concrete's (kg/m$^3$).

| Materials (kg) | Reference concrete (RC) | Concrete with plastic bag waste | | | |
|---|---|---|---|---|---|
| | | CPBW10 | CPBW20 | CPBW30 | CPBW40 |
| | | 10% | 20% | 30% | 40% |
| Cement | 400 | 400 | 400 | 400 | 400 |
| Water | 190 | 190 | 190 | 190 | 190 |
| Sand | 467 | 420.3 | 373.6 | 326.9 | 280.2 |
| PBW | 0 | 16.25 | 32.5 | 48.75 | 65 |
| Gravel 3/8 | 276 | 276 | 276 | 276 | 276 |
| Gravel 8/15 | 1064 | 1064 | 1064 | 1064 | 1064 |

### *2.3. Preparation of specimens*

After mixing concrete, the molds (cylindrical and prismatic) are met in three phases. For each phase, a vibration of the mold was carried out using a mobile stripe for 20s. For each series, three cylindrical specimens (160x320mm) and three prismatic specimens (70x70x280mm) were prepared by using the same composition. After demolding, the specimens were deposited in a water vat for 28 days.

### *2.4. Tests on fresh concrete*

It is important to understand and quantify the ease with which the concrete to implement. The consistency and workability of all the concrete mixtures was determined through slump tests. The slump tests were performed according to NF P 18-451. The vertical distance between the original and displaced positions of the centre of the top surface of the concrete was measured and reported as the slump.

### *2.5. Tests on hardened concrete*

The tests have been performed to determine the mechanical properties were compressive and flexural strength. The test results were reported as the average of three tested specimens in the respective testing. From each concrete mixture, 70 x 70 x 280 mm beams, and 160 x 320 mm cylinders has been casted for the determination of flexural and compressive strength test respectively.

### *2.6. Compressive strength test*

Cylinder compressive strengths has been determined at 28 days in accordance with NF EN 12390-3.The specimens were loaded under a monotonic uni-axial compressive load up to failure by using an MATEST hydraulic testing machine with the capacity of 3000 kN. The loading rate was approximately 0.6MP/s. The higher tray is fixed and the lower support is mobile. Before testing, the faces of the specimen were suffered with a surfacing machine, to ensure parallelism and flatness of the faces of support.

### *2.7. Flexural strength test*

Flexural strength test was carried out using a simple beam with three-point loading method at 28 days of curing age, conforming to NF EN 12390-5. The specimens were subjected to bending tests with a concentrated load at the centerline in order to verify their behavior. The bending tests were performed by test machine of 60 kN maximum load, with a loading rate of 0.05MPa/s.

### *2.8. Ultrasonic pulse velocity test.*

The principle is to measure the propagation time (t) of longitudinal waves in concrete, issued by the issuer probe. Knowing the distance(s) travelled by the waves, it is possible to derive a velocity (v) equal to (l/ t) in m/s. The procedure consists in placing sensors on the concrete surface coated with a thin layer of petrolatum; this layer will prevent unwanted waves, as described in ASTM C597-97. Measurements are recorded on digital screen at the time of stabilization

## 3. RESULTS AND DISCUSSION

### *3.1. Fresh properties*

#### *3.1.1. Fluidity of concrete's*

We sought in this study to know the influence of the plastic bag waste (PBW) on the workability of concrete. The obtained results of the slump value of different concrete compositions are given by the histogram of figure 3. It was observed according these results, that more waste content increases the fluidity of concrete improves, that is favorable for concretes. This improvement can be attributed to the fact that plastic particles have an outer smoother surface than that of the sand Batayneh et al. (2007). The plastic cannot absorb water, therefore an excess of water which improves the workability.

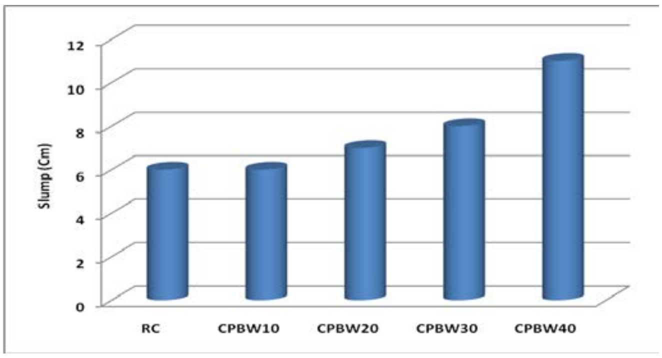


Figure 3. Evolution of slump test value of all mixtures as function of content plastic bag wastes

### *3.1.2. Bulk density*

Figure 4; give the bulk density of concrete as a function the content difference of plastic wastes, after 28 days of water maturation of the samples. The bulk density has decreased considerably for all concrete's with the content of replacement of sand by plastic waste that also becomes than lighter with 40% of plastic waste. The substitution of sand by plastic waste reduced the bulk density of all mixtures with increasing the waste plastic ratio, because the density of plastic is lower than that of sand by 70%. This observation was already verified by several authors (Baboo et al.2012, Ferreira et al.2012). This decrease in bulk density concrete's is probably due to the substitution of a heavier material (sand) by the lighter material.
Up to 40% of the waste, the bulk density of concrete's was reduced to 11.5%. The mortars with 40% of plastic waste, the bulk density were 2100 kg/m$^3$. This result has been proved by several authors [5]. Indeed, as an example, the results obtained by Al-Manaseer et al. (1997) showed that density of concrete was reduced by 13% for concrete Containing 50% of plastic waste as aggregate. The image shown in Fig. 5 (Safi et al. 2013) show the good distribution of plastic waste in the mortar mixes. This distribution has favored to obtain a lighter density. It should also be noted that this distribution of plastic waste in matrix of mortar favored also the reduction of voids between granular [Siddique, Khatib & Kaur 2008, Sikalidis et al. 2002, Ferreira et al. 2012, Avila & Duarte. 2003).

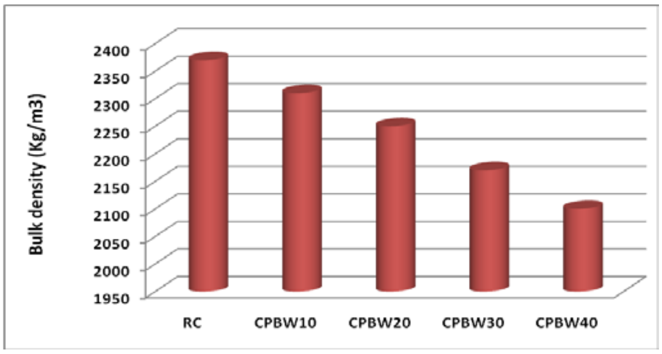


Figure 4. Evolution of bulk density of all mixtures as function of content plastic bag wastes

Figure 5. Samples containing PBW

### *3.2. Hardened properties*

### *3.2.1. Mechanical Strength*

The flexural and compressive strength are tested at 28 days. Each mechanical property value presented in the following of the article is the average value obtained from tests performed on three specimens. The evolution of the compressive and flexural strength of concrete's is represented in Figures 6 and 7 respectively.
We notices a reduction in the mechanical strength according to the increase in percentage of plastic bag waste in the concrete, but remains always close with this last for the case to the percentages 10 and 20 % when we recorded a fall of compressive strength at 28 days of about 10 and 24 % respectively. This result is considered better compared to those obtained from the work mentioned in the review paper published by the author's Saikia et al. (2012). Indeed, in this paper, compared to control mixes, up to 72% reductions in compressive strength were observed for concrete prepared by replacing natural aggregate at the replacement level of 20% (Ferreira et al.2012, Saikia et al. 2012). This fall of strength must mainly with:
• The substitution of the sand by waste which is less resistant.

• Low roughness of waste which returns adherence between the grains and cement paste and the circular shape of waste which increases the void volume in the mortar which reduces the compactness

The reduction in the compressive strength of concrete might be due to either a poor bond between the cement paste and the plastic bag wastes or to the low strength of this plastic wastes. However, the fracture surface of concrete prismatic showed that most of plastic waste are not pulled out and remain stuck in the specimens.

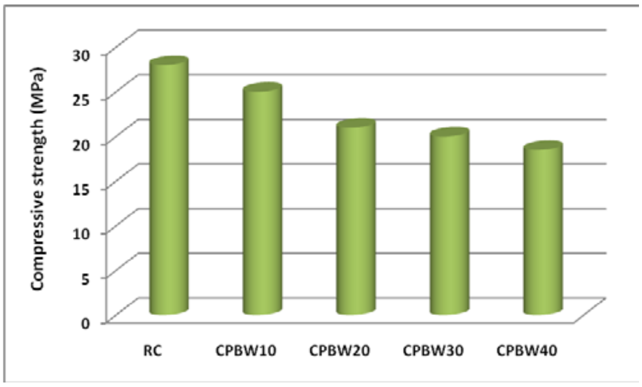


Figure 6. Evolution of compressive strength of all mixtures as function of content plastic bag wastes

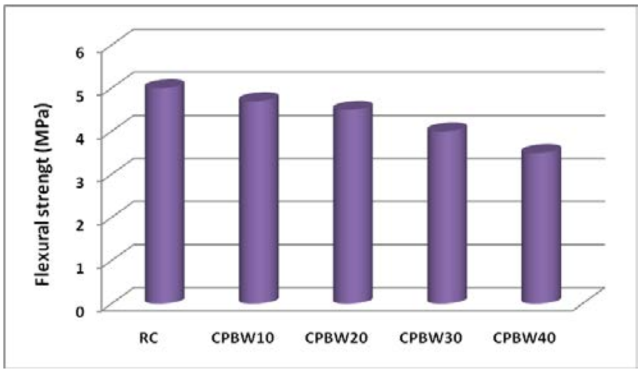


Figure 7. Evolution of flexural strength of all mixtures as function of content plastic bag wastes

### *3.2.2. Ultrasonic pulse velocity*

The obtained results of the Ultrasonic pulse velocity of different concrete compositions are given by the histogram of figure 8. It is noted that the speed of sound is much higher for concrete which contains a low percentage of waste, which is the case of the reference concrete (0% waste). It is noted that the waste plastic concrete compactness decreases which decreases the speed of sound. This decrease is due to the regular circular form of waste which increases the volume of voids.

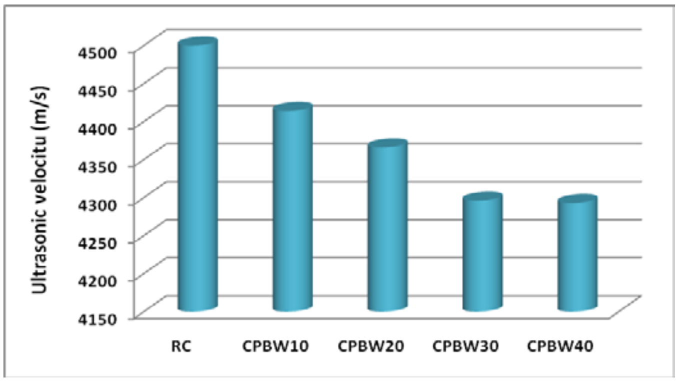


Figure 8. Evolution of ultrasonic velocity of all mixtures as function of content plastic bag wastes

## 4. CONCLUSION

This study investigates the valorization of plastic bag waste as fine aggregate in field of construction. The effects of an incorporation of this waste on the physic mechanical properties of the concrete have been analyzed. The following main conclusions can be drawn:
-The bulk density has decreased considerably for all concrete's with the content of replacement of sand by plastic waste that also becomes than lighter with 40% of plastic waste. -Being given that the concrete must have good workability, fluidity is significantly improved by the presence of this waste.
-A reduction in the mechanical resistance according to the increase in percentage of plastic bag waste, which remains always close to the reference concrete, when we recorded a fall of compressive strength at 28 days about 10 and 24 % or the concrete's containing 10 and 20 % of waste respectively.
Finally, PBW aggregates can be used successfully to replace conventional aggregates in concrete without any long term detrimental effects and with acceptable strength development properties.

## 5. REFERENCES

Al-Manaseer AA, Dalal TR, 1997, 'Concrete containing plastic aggregates', *Concrete International*, vol. 19, no. 8, pp. 47–52.

Avila AF, Duarte MV, 2003, 'A mechanical analysis on recycled PET/HDPE composites', *Polym Degrad Stabil*, vol.80, no. 2, pp. 373–82.

Baboo R, Tabin-Rushad S, Bhavesh KR, Duggal SK, 2012, 'Study of waste plastic mix concrete with plasticizer', *International Scholarly Research Network, ISRN Civ Eng*, pp. 1–5.

Batayneh M, Marie I, Asi I, 2007, 'Use of selected waste materials in concrete mixes', *Waste Management,vol.* 27, no. 12, pp. 1870–1876.

Brahim S, Mohammed S, Djamila A & Madani M, 2013, 'The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties', *Construction and Building Materials, vol.* 43, pp. 436–442.

Choi YW, Moon DJ, Chumg JS & Cho SK, 2005, 'Effects of waste PET bottles aggregate on the properties of concrete. *Cem Concr Res*, vol. 35, pp. :776–81.

Ferreira L, Brito JD & Saikia N, 2012, 'Influence of curing conditions on mechanical performance of concrete containing recycled plastic aggregate. *Constr Build Mater*, vol. 36, pp. 196–204.

Hassani, A, Ganjidoust, H, & Maghanaki, AA, 2005, 'Use of plastic waste (poly-ethylene terephthalate) in asphalt concrete mixture as aggregate replacement. *Waste Management & Research*, vol. 23, pp. 322–327.

Rebeiz KS, 2007, 'Time-temperature properties of polymer concrete using recycled PET. *Cem Concr Compos*, vol. 17, pp; 603–608.

Remadnia A, Dheilly RM, Laidoudi B & Queneudec M, 2009, 'Use of animal proteins as foaming agent in cementitious concrete composites manufactured with recycled PET aggregates. *Constr Build Mater*, vol. 23, no 10, pp. 3118–23.

Saikia N & Brito JD, 2012, 'Use of plastic waste as aggregate in cement mortar and concrete preparation', *a review. Constr Build Mater*, vol. 34, pp. 385–401.

Siddique R, Khatib J & Kaur I, 2008, 'Use of recycled plastic in concrete: a review' *Waste Manage*, *vol.* 28, pp. 1835–1852.

Sikalidis CA, Zabaniotou AA & Famellos SP, 2002, 'Utilization of municipal solid wastes for mortar production, *Resour, Conserv Recycl*, vol. 36, no. 2, pp.155–167.

Yazoghli-marzouk O, Dheilly RM & Queneudec M, 2007, 'Valorization of postconsumer waste plastic in cementitious concrete composite' Waste Manage, vol. 27, no. 2, pp.1870–1876.