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Use of plastic waste in sand concrete

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Abstract
This study investigated the utilization of two type of waste plastic (Polyethylene Terephthalate (PET) and Low Density Polyethylene (LDPE) used for bags manufacture) as a fibers and fine aggregates (powder) in sand concrete. Various volume fractions of sand (10%,20%,30% and 40%) were substituted by the same volume of plastic aggregates, and various amount of plastic fibers (0.5%, 1%, 1.5%,2%) were introduced by volume in sand concrete mixes.The physical and mechanical properties of the composites produced was studied.The results showedthat the use of plastic waste as partial replacement of sand contributes to reduce the bulk density,decrease the air content, causing a increase in compressive and flexural strength and especially for 10% and 20% of replacement. In addition, the reinforcement of the cementing matrix with plastic fibers induced a clear improvement of the tensile strength. This study insures that reusing waste plastic in sand concrete gives a positive approach to reduce the cost of materials and solve some environmental problems.

Keywords: Environment, waste, Recycling, Sand concrete, Plastic.

1. Introduction
In Algeria, as in many countries of the world, the amount of plastic waste is increasing and occupies a large part of solid waste. This type of waste is a serious problem for environment because of its non-biodegradable nature. Recycling of this type of waste to produce new materials like concrete or mortar appears as one of the best solution, due to its economic and ecological advantages.Previous studiesshowed that it waspossible to useplastic wastein mortar and concrete suchas polyethylene terephthalate (PET) bottle [1], polypropylene (PP) [2] , poly vinyl chloride (PVC) pipe [3], high density polyethylene (HDPE) [4], thermosetting plastics [5], shredded and recycled plastic waste [6], expanded polystyrene foam (EPS) [7], glass reinforced plastic (GRP) [8]and polycarbonate as an aggregate, a filler or a fiber [9]. Several authors [6, 7]explored the use of light aggregate based on polymeric waste, as a material in reducing the unit weight, the cost, the brittleness and the thermal insulation properties of building materials such as concrete or mortars. However, these aggregates exhibit a series of drawbacks, mainly due to their poor chemical compatibility with inorganic matrix. The in homogeneity between the two phases which causes defects in the internal structure of the inorganic matrix, can result in: (a) a reduction in fresh mortar workability, (b) a decrease in mechanical performances, such as strength and stiffness and (c) a worsening of thermal properties, such as a reduction of thermal degradation temperatures and fire resistance
This workaims to study thepossibility of usingwasteplastic bottles(PET-polyethylene terephthalate)andtanks (low densitypolyethylene-LDPE) in sand concretewithout any transformationexceptgrinding,to minimize the cost of the final material. The influence ofthe proportion ofwaste usedon the physical andmechanical propertiesof the new materialhas been studied andanalysed.

2. Experimental programme
2.1. Materials
Portland cement CEM II/A 42.5 from Ain El-Kebira Factory in Algeria was used throughout this study, with a density of 3100 kg/m^3. Natural dune sand (NDS) from Tamanrasset (south of Algeria) was used for all

mixes.The particle size distributionis shown inFigure1 and the physical properties are presented in Table 1. The X-ray Diffraction analysis of the sand used is presented in Figure 2and shows its siliceous nature. Ultrafine blast furnace slag with a specific surface of 3100 m^2/kg and specific density of 2.857 kg/m^3 are used.

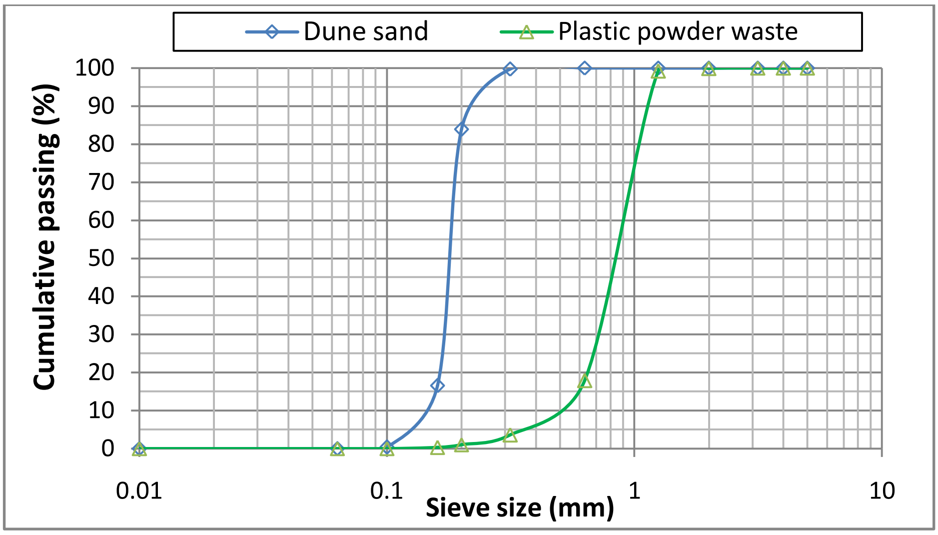

Figure 1: Particle size distribution of used sand and plastic powder waste.

Table 1: Physical properties of sand

Properties	Dune Sand
Apparent density(kg/m^3)	1400
Bulk density (kg/m3)	2560
Water absorption (%)	2.66
Sand equivalent (%)	80.50
Fineness modulus	0.84
Compactness (%)	0.55
Porosity (%)	0.45

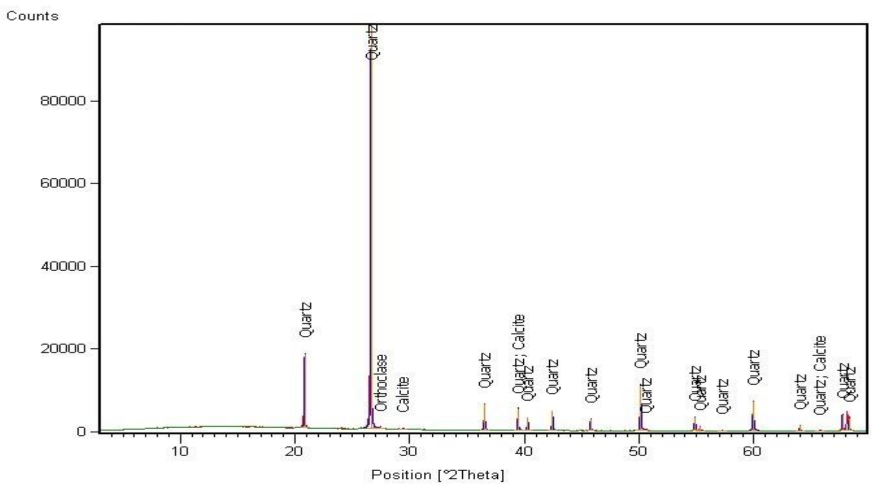

Figure2: X-ray diffractogram analysis of sand

Polyethylene terephthalate(PET) fibers and Low Density-Polyethylene (LDPE) powder,as shown in Figure 3, are used in this study.The PETfibers with 40 mm of length and 0.5 of thicknesswere obtained by mechanical

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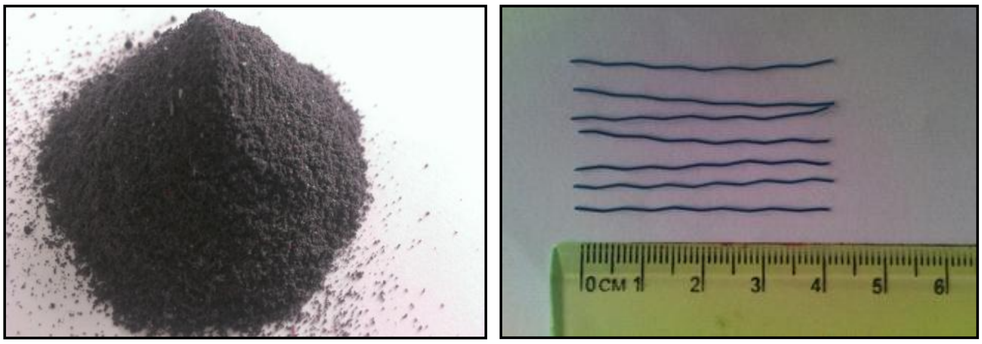
cutting of lateral sides of PET bottles. The bottlenecks and the bottom of the bottles were discarded. The uniformity of fibers is ensured, especially for the dimensions length and width, by fine adjusting executed in a semi-automatic cutting machine. The LDPEpowder with 2 mm maximum size was obtained from oldbleu jerry-can waterafterhaving beencollected,washed,compressed, and crushed.The physical and mechanical properties of plastic waste used are presented in Table 2.



LDPE plastic powder PET plastic fibers

Figure3: General aspect of plastic waste used.

Table 2: Physical and mechanical properties of plastic waste.

Properties	Plastic powder	Plastic fibers
Diameter (mm)	1.5	0.5
Length (mm)	/	4
Apparent density(kg/m^3)	350	950
Bulk density (kg/m3)	450	1230
Fineness modulus	2.8	/
Young’s modulus (MPa)	1900	2400
Tensile strength (MPa)	45	60
Melting point(°C)	135	260

Apolycarboxylate superplasticizer (Medafluid 104) produced by GRANITEX group (Algeria) with solid contents of 35% was used for all mixes. The mixing water used for the different mixes is the distribution drinking water, free of impurities with a pH equal to 7.9.

2.2. Concrete mixes design

SABLOCRETEdesign method [10], with 350 kg/m^3 of cement, 1200 kg/m^3 of sand, 230 kg/m^3 of fillers, 0.86 of water/cement ratio of and1% of plasticizer was used for optimizing the composition of sand concrete.Four volume fractions of sand (10%,20%,30% and 40%) were substituted by the same volume of plastic aggregates, and another four various amount of plastic fibers (0.5%,1%,1,5%, 2%) were introduced by volume in sand concrete mixes. Three concrete mixtures were made. Literary codes identify each mixture in a precise way:

- **CSC**: reference sand concrete containing 100% of NDS
- **SCn%PP**: Sand concrete with n% of plastic powder.
- **SCn%PF**: Sand concrete with n% of plastic fibers.

n: number

The specimens produced were cured in air at 20°C and 50% RH. After 24 h, they were removed from the molds and placed in water for another 24 h and then open-air stored until the day of testing. Such curing has been chosen according the normal manufacturing of sand concrete in Algeria. This procedure was respected for all compositions and all tests.

2.3. Tests procedures

The workability of concrete was measured in terms of slump according to NF P 18-451. The air content was determined by the aerometer according to NF P 18-353. The flexural strength was measured on 40 · 40 · 160 mm specimens at the ages of 7,28 and 90days by a three-point bending test, using a testing machinewith a maximum load capacity of 30 kN (according to EN 196-1).The half-samples resulting from this test were then submitted to compression test.

3. Results and discussion

The variation of concrete slump with powder plastic particles is shown in Figure 4. The use of plastic waste type LDPE as partial replacement of sand contributes to increase the workability of sand concrete about 40%. This is probably due to the presence of more free water in the mixes containing plastic than in other containing only natural aggregate, since unlike natural aggregate, plastic aggregates do not absorb water during mixing. Choi et al. [11] reported an increase in the slump value of concrete with increasing content of two types of treated PET-bottle aggregate in concrete. The aggregates were spherical in shape. Al-Manaseer et al. [6] determined the slump of concrete mixes made with plastic aggregates. They reported that there was increase in slump when plastic aggregates were incorporated in concrete. The concrete containing 50% plastic aggregates had a slightly higher cone slump than the concrete without plastic aggregates.

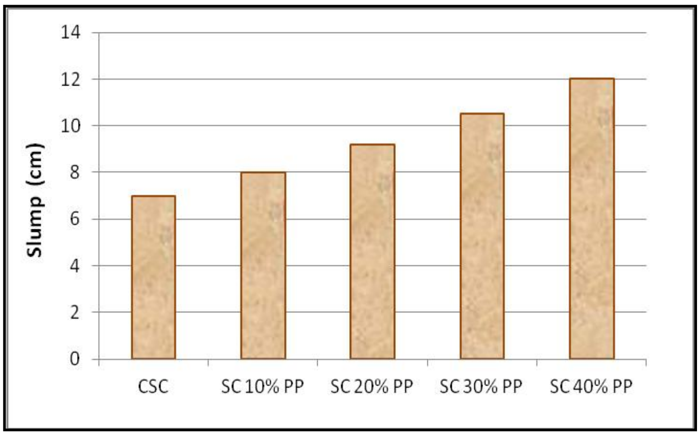


Figure 4: Slump of sand concrete as function of plastic powder content.

Figure 5 shows the the variation of the slump of sand concrete with the percentage of incorporated plastic fiber.The results displayed that the workability of sand concrete decrease up to 60% for40% of plastic fiberscontent. Several papers reported that the introduction of any kind of fibers in the composite, involves a significant reduction in the workability of the concrete [12].

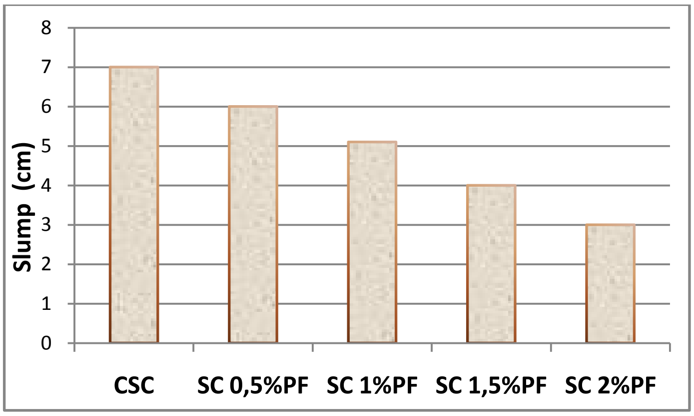


Figure 5: Slump of sand concrete as function of plastic fibers content.

The bulk densitiesof the various mixes are shown in Figures 6 and7. According to the results presented in Figure6, the use of plastic powder as partial replacement of sand contributes to reduce (10%) the bulk density of sand concrete. This is probably due to the lower density of the plastic particles compared with the dune sand. This result is confirmed by da Silva et al. [13] and Iucolano et al. [14]. Indeed, the results obtained by Al-Manaseer et al. [6] showed that density of concrete was reduced by 13% for sand concrete containing 50% of plastic waste as aggregate.

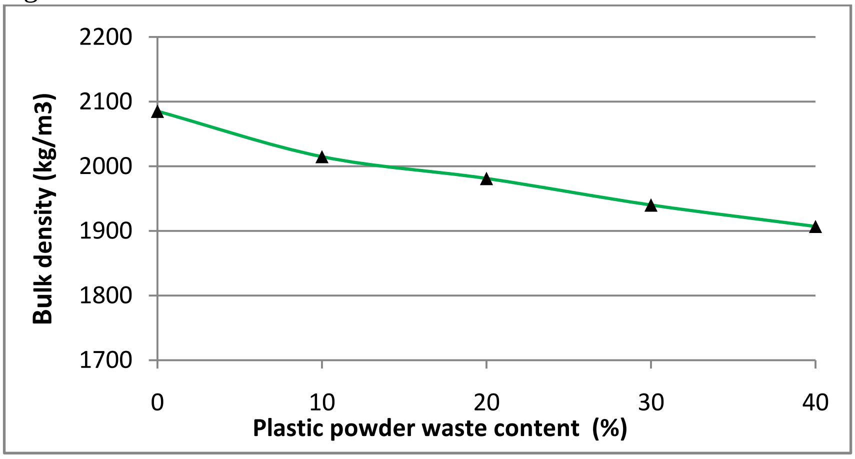


Figure 6: Evolution of bulk density of sand concrete as function of plastic powder wastes content.

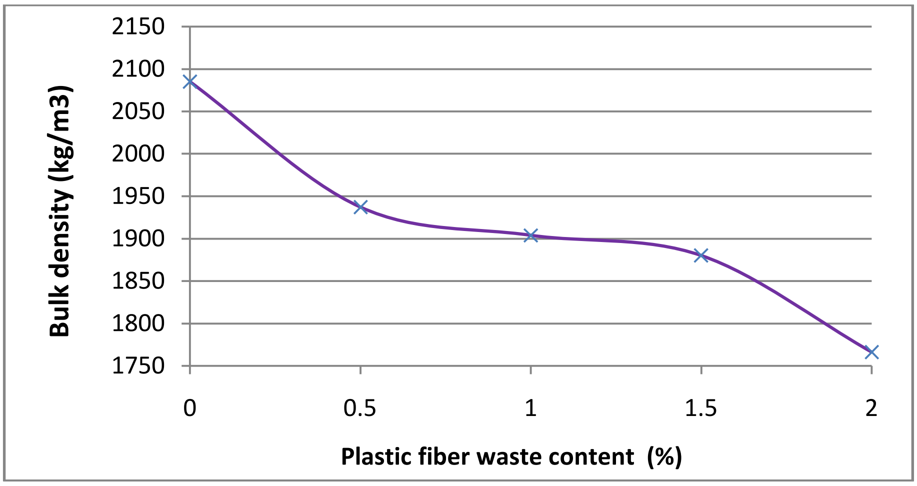


Figure 7: Evolution of bulk density of sand concrete as function of plastic fibers wastes content.

The result presented in figure 7 show a decrease (15%) of the density of sand concrete when the plastic fibers content increases. These results agree with those of Pereora et al.[15]for concrete with recycled PET fibers.

The compressive and flexural strength are presented in Figures 8 to 11 at age of 28 days in accordance with EN 1015-11. From Figures 8 and 9,it clearly appears that compressive and flexural strengths of sand concrete increases of about 30% with 20% of plastic powder content. This increase is agreement with the results of Rahmani et al. [16]. This is a desirable result that a concrete with more ductile behaviour can be obtained using waste PET particles. Contrarily, others papers [17, 18] reported that the use of plastic aggregate as partial substitution of natural aggregate in concrete and/or mortars can affect negatively the mechanical performances.
From Figure 10 it appears that compressive strength of sand concrete increases up to 25% with 1.5% of plastic fibers content. In same way, in Figure 11 it can be clearly observed that flexural strength of sand concrete increases up to 40% with 1% of plastic fibers content. Pereora et al. [15] have reported that 1.5% of PET fibers increase the flexural strength of mortar about 30% at 28 days. In same way Ochi et al. [19] reported approximately the same results and describe methods for manufacturing reinforcing fibers from recycled PET

bottles, and evaluate their beneficial effects in terms of ductility, bending and compressive strengths of concrete specimens.

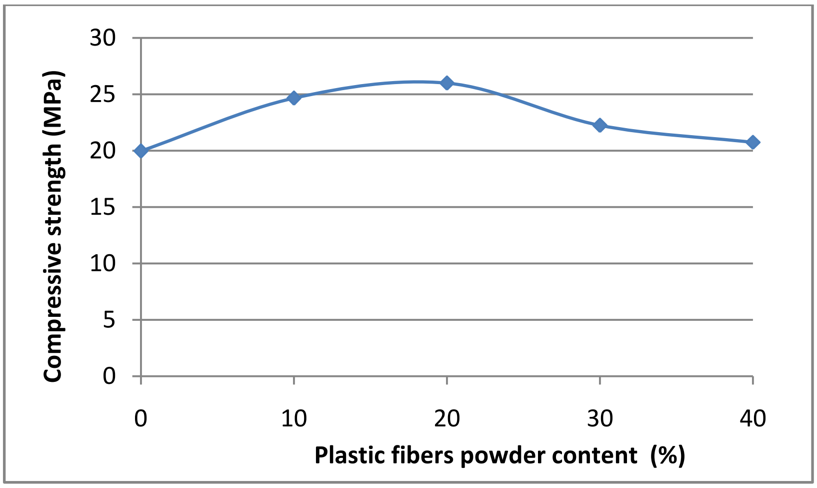


Figure 8: Compressive strength of sand concrete as function of plastic powder content at 28days.

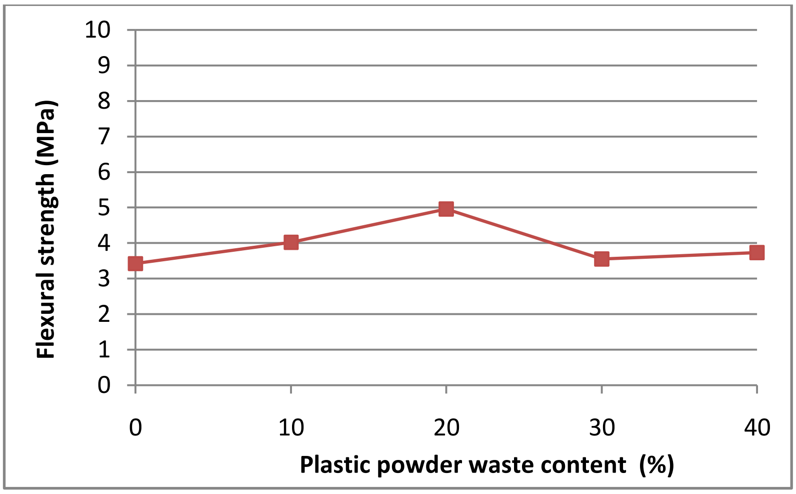


Figure 9: Flexural strength of sand concrete as function of plastic powder content at 28days.

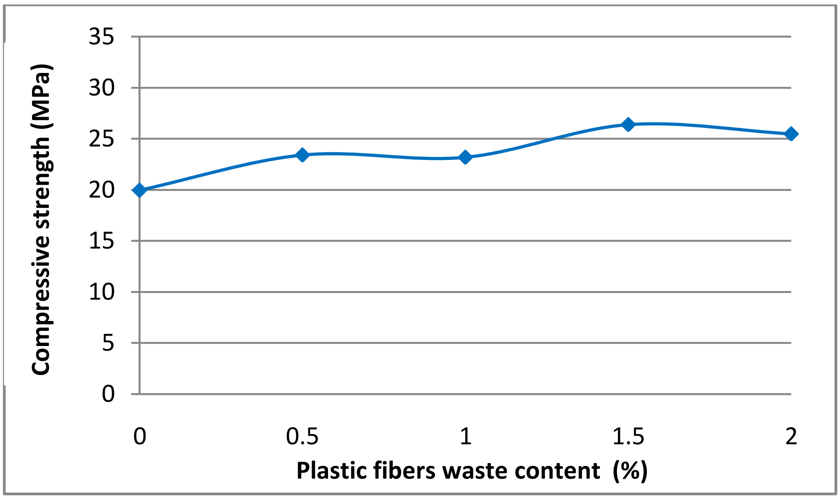


Figure 10: Compressive strength of sand concrete as function of plastic fibers content at 28 days.

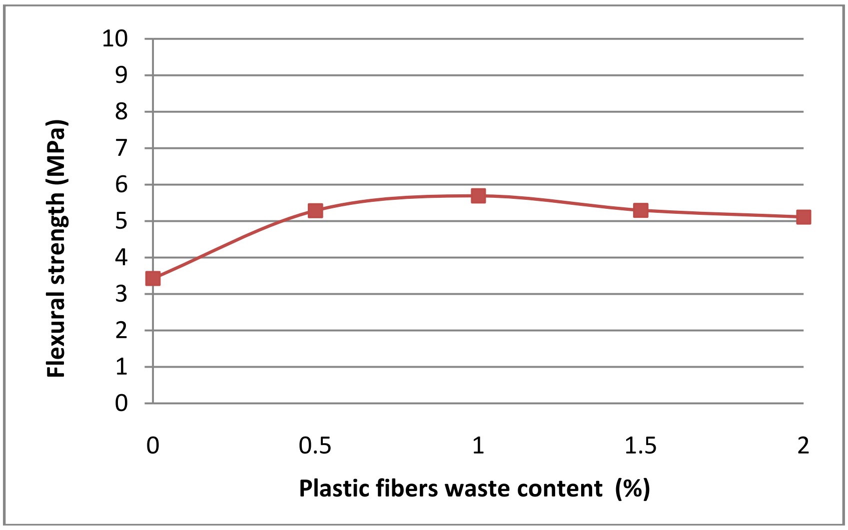


Figure 11: Flexural strength of sand concrete as function of plastic fibers content at 28 days.

Conclusion

The present study is aimed at the use of two type of plastic waste (PET and LDPE) as fibers and aggregates in sand concrete. The conclusions are summarized as follows.

1. The use of plastic (PET and LDPE) waste induces a decrease about 10-15% of density of sand concrete.
2. The workability of sand concrete increases about 40% with plastic powder, however it decreases about 60% with plastic fibers.
3. Mechanical performances of sand concrete seem to be positively influenced by the type of plastic waste added.
4. The increase in compressive strength at 28 days of age was about 30 and 25 % when 20% of plastic powder or 1.5% of plastic fibers are respectively, added.
5. The increase in flexural strength at 28 days of age was about 30 and 25 % when 40% of plastic powder or 1% of plastic fibers are respectively, added.

For an optimal utilization of this type of concrete, the level of substitution should be limited to 20% and 1.5% for plastic powder (LDPP) and plastic fibers (LPE) respectively.

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