Research Article

New Mortar Mixes with Chemically Depolymerized Waste PET Aggregates

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Nanoparticles are used in innovative mortars in order to improve their engineering properties. In this paper, recycled PET (polyethylene terephthalate) nanoparticles were used as a substitute for sand in mortars. PET aggregates were obtained cutting water bottles wastes into many small sized pieces and the plastic fibres were treated through chemical depolymerization process. Mortars with different percentages of PET were tested to determine their physical and mechanical (flexural and compressive strength) properties. Specific attention is given to the heat-transfer capacity of the cement pastes investigated. The results of the mechanical tests showed a reduction of the flexural and compressive strength values when the amount of PET nanoparticles increase. The thermal conductivity tests showed that chemically depolymerized PET nanoparticles derived from plastic wastes reduced the heat conduction capacity of the mortar. Therefore, the innovative mortars here tested can be considered for thermal insulation applications in the construction field with the advantage of recycling waste PET.

1. Introduction

Polyethylene terephthalate or PET is defined as a polyester resin which results from the combination of terephthalic acid and ethylene glycol or dimethyl terephthalate and ethylene glycol [1]. Furthermore, it accounts for around (18%) of all polymers, which are produced worldwide; over 60% of its production can be used for synthetic fibres and bottles, which form approximately 30% of global PET demand [2]. It is generally used for various applications such as bottles, mouldings, fibres, and sheets due to its excellent tensile and impact strength, clarity, chemical resistance, thermal stability, and process ability. It is commonly agreed that PET, which differs from natural polymers, is a nondegradable polymer in the natural environment and becomes a pollutant when it is discarded after use. Therefore, it has been noticed that recycling the discarded PET polymer is one of the most important approaches to protect the environment and reduce the consumption of resources at the same time [3].

Nowadays, in fact, the recycling rate of PET bottles is much lower than the sales of virgin PET production for common uses. This gap is dramatically increasing, pushing towards finding a solution to this problem and a higher recycle of PET. As a consequence, the reuse of waste PET bottles is stirring particular interest. With the aim to reduce the waste and take profit from this material in the last two decades, many authors investigated the uses of PET in concrete. This field has been investigated in several different ways, focusing on different possible utilization of this material [4].

In recent decades, with the aim of giving the conglomerate a better behavior in terms of mechanical characteristics, it was attempted to add in its mixture fibres and aggregates of various types [5, 6]. A possible application is to utilize waste PET fibres as reinforcement for concrete to

improve its tensile strength [7–12]. Concrete, as it is known, is a material with good compressive strength but low tensile strength. This reduced tensile strength is partly due to the presence of micro- and macrocracks caused by shrinkage of the concrete. These cracks, moreover, represent a factor in the aggression of steel bars in reinforced concrete elements provoking a fast oxidation of the bars and the degradation of the structure accompanied by a reduction of its tensile strength.

Some preliminary studies on the utilization of fibres obtained from PET bottles to improve the mechanical behaviour of concrete can be found in Silva et al. [13]. The good results of this experimental study pushed the research towards the utilization of this kind of fibres. However, what makes PET so important, among the plastics used as reinforcement for concrete, is its recyclability together with the great abundance of postconsumer waste in the form of bottles. The presence of fibres improves the tensile behaviour of concrete thanks to the sewing effect that they have on the cracks [14]. Their action, in fact, is more effective in the postcracking phase, preventing and reducing the propagation of cracks. Concretes with a higher ductility and a reduced shrinkage cracking are obtained. Ductility is evidenced by a large deformation associated with the fibre elongation at break.

From the point of view of recycling waste to be added in concrete the use of waste PET bottles in concretes is not as common as scrap rubbers since slitting, shredding, and retreating processes are relatively more complex and costly [15].

Mechanical recycling is a current industrial technique for the recovery of waste polymers, but another available pathway for recycling of polymers consists in the chemical processing. This type of recycling has a high potential for heterogeneous and contaminated plastic waste material if the separation is neither economical nor completely technically feasible [16, 17]. Chemical recycling routes can be roughly divided into thermochemical and catalytic conversion processes. Chemical recycling of PET can completely depolymerize it into its monomers terephthalic acid, dimethyl terephthalate, bis(hydroxylethylene) terephthalate, and ethylene glycol (EG). The depolymerization is the reverse reaction of the polymer formation route. There are different depolymerization routes such as methanolysis, glycolysis, hydrolysis, ammonolysis, aminolysis, and hydrogenation, depending on the chemical agent used for the PET chain scission. Glycolysis is the simplest and oldest method of PET depolymerization, converting the polymers into smaller molecules, which can be subsequently seen as sustainable through a closed system glycolysis process.

The plastic waste material can often be heterogeneous and contaminated so as to make the mechanical production of PET aggregates difficult. Furthermore, the separation process is not economical and in many cases not entirely technically feasible. Consequently, the chemical recycling process has a high potential in PET-waste recycling. In the chemical process, the PET bottles do not need to be purified as instead provided for the mechanical one. Chemical recycling by glycolysis is a suitable tool and this should reduce the cost of the recycled pet base. The polimeric mortar applications thus helps to reduce costs and provides long-term disposal of PET waste, an important consideration in recycling applications.

In this paper, the authors have studied the possibility to adopt a chemical approach to depolymerize PET (DPET) in order to use it in the cement paste as a substitute for, or in addition to, sand. In particular, the effect of additive degraded PET on the properties of cement paste has been analysed. Consequently, the effect on the mechanical and thermal properties of modified paste has been studied, finding an improvement especially in terms of heat-transfer; finally, the optimum percentage of plastic waste (PET) by comparing the conventional and modified material has been determined.

2. Substitution of Aggregates

In the last decade, more attention has been paid, to the use of aggregates made from PET bottles as a partial replacement of the aggregate in the concrete mix. Choi et al. [18] published an in-depth research on the subject that analysed the substitution of fine aggregate with PET bottles lightweight aggregate. The tests, carried out on concrete specimens prepared with varying percentages of aggregate replacement (0%, 25%, 50%, and 75% by volume of inert), regarded numerous properties of the concrete such as the density, the failure, the workability, the compressive and tensile strengths, and the modulus of elasticity, thereby creating an almost complete framework on this subject. The results showed first a decrease of the specific weight of concrete as the content of PET increases. The influence of the substitution of aggregates on the workability of concrete was also studied; it was found to grow with the fraction of inert replaced, also thanks to the spherical shape of the aggregate in PET. With regard to the compressive and tensile strengths, instead, a reduction was pointed out in correspondence of the increased proportion of the replaced aggregate.

Further studies were carried out on this topic in the following years. Among these, it is worth citing the results obtained in 2007 by Marzouk [19], who showed that the partial or complete substitution of sand with PET in concrete composites does not affect either the compressive nor the tensile strengths of concrete if the level of substitution is below 50% of the volume. PET aggregates, however, should not have an equivalent diameter lower than 5 mm, as it does not significantly influence the compressive and tensile strength of the concrete. These results represent a significant incentive to the innovative use of PET, since they confirmed the undeniable economic benefits regarding the possibility of using waste material readily available and the environmental aspects, which involve the possibility to reduce the waste.

The same results are found in [20] where 5% by weight of siliceous sand was substituted with PET in the concrete mix. WPET aggregates were manufactured from waste PET bottles and, through a grinding process, these granules pass from a thickness of 1–1.5 mm to the size of 0.1–5 mm. Irrelevant differences were detected in the compressive and

tensile strengths in case of mixes containing Waste PET (WPET) at low w/c ratio (0.45). The differences became slightly more significant by increasing the w/c ratio (up to 0.55) because the interface between WPET and the hydrated cement Portland presented a higher porosity. In this case, it was detected that small percentages of fine aggregates (PET) do not affect the water absorption. As a result of this study, when WPET is used as a partial substitute for fine aggregates in a reference concrete, there is an increase in the toughness and ductility, the same values of workability, and a shrinkage influenced by the higher ductility but still acceptable for the structural elements.

In other research studies, instead, (i.e., Hannawi et al. [21]) a decrease in compressive strength is observed with the use of PET (particle size ≤ 10 mm) and polycarbonate (particle size ≤ 5 mm) waste aggregates as replacement in volume of sand. Probably it can be attributed to the poor bond between the matrix and plastic aggregates, but the specimens tested were able to carry a load for a few minutes after failure without full disintegration, showing also a higher ductility. This trend seems to be more obvious as the percentage of plastic aggregates increases. Otherwise, the flexural strength values remain almost unchanged when the sand volume substituted with aggregates varies in a range of about 0–20%. Additionally, a significant improvement of the postpeak flexural behaviour is observed. The calculated flexural toughness factors increase significantly by increasing the volume fraction of PET and polycarbonate aggregates because also the energy absorbing capacity increases, a fundamental characteristic in case of dynamic or impact forces (in fact there is a decrease of the elastic modulus). In addition, the good sewing effect of PET and polycarbonate fibres has been experimentally demonstrated in the postcracking phase of concrete when included in the concrete mix as aggregates.

Recently, a study similar to [21] has been developed in [22] where PET has been obtained from waste bottles subjected to a grinding process to obtain PET particles used as fine aggregates in the concrete. In this case, lower percentages of PET than in [21] have been utilized as a substitute for sand (5%, 10%, and 15%) but the results indicate a lower density. For these percentages of PET, a lower workability has been detected, together with a lower modulus of elasticity and splitting tensile strength with respect to a conventional concrete. The compressive and flexural strengths show an ascending trend at the initial stages; however, they tend to decrease in the second stage. Finally, to investigate the structure of the concrete containing PET particles, ultrasonic pulse tests have been performed and a porous structure has been observed. As demonstrated by experimental results in a further study, the mechanical properties of the concrete depend on the PET particle size and its concentration [23]. Lower sizes and concentrations of PET particles create less space in the concrete, and, consequently, the compressive strength and the compression strain increase, while Young's modulus decreases when the size of PET particles used is increased. This means that deformations tend to be higher, but the maximum stresses reduce in magnitude.

In order to use the recycled PET nanoparticles in addition to or a substitute for fine aggregates (i.e., sand) in the cement paste, the chemically polymerization process of PET can be a valuable tool to reuse the PET wastes. PET is considered as a polyester with functional ester groups that are cleaved by reagents, like acids, bases or water (hydrolysis), alcohols (alcoholysis), amines (aminolysis), ammonia (ammonolysis), and glycols (glycolysis). Previous studies have shown that it is possible to use plastic waste in concretes, mortars, or bituminous conglomerates as a binder with the aim to remove the PET waste by means of mixing it directly into the mixtures [24, 25]. Most of the studies carried out for the depolymerization of PET have discussed the role of various types of glycols and metal acetates to be used as catalyst in the process [26–28].

The main depolymerization processes that have reached commercial maturity up to now are glycolysis. Specifically, the glycolysis reaction is the molecular degradation of PET polymer by glycol, in the presence of trans-esterification catalysts, basically by using ethylene glycol as solvent. The ester linkages of PET polymer are broken and replaced by hydroxyls terminals to give bis (2-hydroxyethyl terephthalate) (BHET), which is the raw material for producing PET, according to the following reaction scheme [29]:

$$PET_n + (n-1)EG \rightleftarrows nBHET \qquad (1)$$
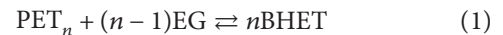
Glycolysis of PET is the most frequent process by using metal acetates (Zn, Co, Pb, and Mn) as catalysts [30].

Studies on the kinetics of PET glycolysis have revealed that glycolysis without using a catalyst seems to be very slow and a complete depolymerization of PET to BHET cannot be achieved. In addition, it yields an end-product which has a significant number of other oligomers in addition to the BHET monomer. These results face difficulty in recovering the BHET monomer when it is the aimed product. The current interest in the depolymerization of PET by glycolysis to recover bis-hydroxyethyl terephthalate (BHET) monomer has led to studies of glycolysis catalysts. Therefore, the efforts of recent research is directed towards duplicating the rate and BHET monomer yielded through the development of highly efficient catalysts and other techniques, in addition to optimizing the reaction conditions (such as time, temperature, PET/catalyst ratio, and PET/EG ratio) [31, 32]. It has been concluded that zinc acetate is the most suitable glycolysis catalyst of the four metal acetates (lead, zinc, cobalt, and manganese) under a pressure of 1 atm [33].

In the present paper, the influence of using processed PET waste particles as a part of fine aggregates on the mechanical and physical properties of cementitious paste is investigated. In particular, the amount to be substituted is determined as weight percentage of the sand. In the following, the process of PET particles production is described and illustrated.

3. Materials and Test Methods

3.1. Materials and Samples Preparation. In this study, the depolymerized PET obtained by chemical degradation of plastic water bottles is added as a modifier of cement paste to

evaluate the recycled effect on mechanical behaviour. Ordinary Portland cement type CEM I-52.5R was used throughout the current experimental campaign of preparation of the specimens. The chemical composition of the cement employed is presented in Table 1.

In the first phase, PET water bottles were cut into many small sized pieces. Such plastic particles with diameter equal to 2 mm were employed in the PET depolymerization process through the glycolysis reaction. The $C_2H_6O_2$ Ethylene Glycol (EG) solvent and the catalyst consists of TiO_2 zinc-dioxide particles were added to allow the reaction activation. In the mixture, the EG : PET molar ratio was equal to 4 : 1 with 0.5% catalyst based on the weight of PET. In PET chemical recycling phase, the mixture was heat-treated at 190oC for five hours until the mixture came in the resin state [34]. Heat treatment was involved in the complete condensation in close system through the use of glass condenser using water as a cooler (Figure 1(a)). The unreacted (EG) solution was separated in the form of depolymerized polyethylene terephthalate (DPET) as shown in Figure 1(b). After a liquid separation, the solid component was ground and reduced to fine powder with diameter 30 nm.

In the second phase, different cement pastes were produced depending on the manufacturing of the specimens. The cement mixtures were obtained to replace a part of sand with DPET particles. The nanoparticles were mixed with cement in a dry condition, and the dry mixtures were sieved several times for a proper dispersion of the nanoparticles. The materials were mixed in a planetary mixer according to the UNI-EN 196 recommendations [35]. The water-cement ratio (W/C) used was set to 0.45.

Seven cement pastes were prepared using normalized sand (according to UNI-EN 196-1-2006 [35]) and unnormalized sand with particle size from values of 0.5 to 2 mm. The samples of the DPET mixtures were prepared to measure the additional effect of DPET to the mixture and to using six different amounts added to the content of cement (Table 2).

Three samples (40 mm × 40 mm × 160mm) were prepared for each proportion to determine the unit weight, flow, mechanical characteristic (compressive and flexural strength), and thermic properties.

3.2. Test Methods

3.2.1. Thermal Conductivity.
The thermal conductivity and the specific heat capacity were measured using the multifunctional commercial device, ISOMET 2104. Such instrument is equipped with various types of optional probes, for example, needle probes for porous, fibrous, or soft materials, and surface probes for hard materials. The measurement of the thermal properties of the material is based on the analysis of temperature response to heat flow impulses. The surface of sample to test is put in direct thermal contact with the heat flow induced by a resistor. The thermal data in this research were acquired measuring the moisture content constantly (Figure 2).

3.2.2. Flexural Strength.
For each investigated mortar described in Table 2, three specimens were casted according to EN 196-1 [34]. All 40 × 40 × 160 mm prismatic specimens

Table 1: Chemical composition of cement.

Oxides	Content (%)
SiO_2	20.3
Al_2O_3	4.4
Fe_2O_3	2.6
CaO	62.5
MgO	2.5
SO_3	2.1
LOI	1.0

(Figure 3) were stored at 20 C (90% RH). As suggested by EN 196-1 https://www.sciencedirect.com/science/article/pii/S0950061816317111?casa_token=4vjs3FIZOn4AAAAA:n0EoE21cF3wBGXgIc5w5w8sQIA0bzi7Dmdq5Rp6utBk7l0KLPJeqPbKAUf28HaiFEoEZh337fg [35], three point bending tests were carried out after 28 days to assess the flexural strength. The external load P was applied through an Instrom L.T.D. loading machine, having a loading capacity of 50 kN. Tests were performed by driving the displacement of the loading cell, whose stroke moved at a velocity of 0.5 mm/min. Both the applied load P and the midspan deflection δ of the beam were recorded during the tests, until the complete failure of the specimen (Figure 4).

The flexural strength was determined by the following according to [35]:

$$R_f = \frac{1.5 * P * l}{b^3}, \quad (2)$$

where R_f is the flexural strength (N/mm^2); P is the load applied to the middle of the prism at the first crack, in Newtons; b is the side of the square section of the prism, in millimetres; l is the distance between the supports, in millimetres.

3.2.3. Compressive Strength.
Compressive strength tests of the cement paste samples were carried out at 28 days after casting. The cubic specimens were obtained by the prismatic samples after being tested for bending. The flat surfaces of the cubic specimens were polished and smoothed in order to eliminate the unevenness. Three samples were tested for each paste. The load was applied perpendicularly and continuously on the specimen by using a hydraulic testing compression machine with a maximum load of 150 kN. The compressive strength was determined according to [35] (Figure 5).

The compressive strength of the specimen was calculated by dividing the maximum load carried by the specimen during the test by the average cross-sectional area of the specimen as shown in the following in accordance with [35]:

$$R_c = \frac{F_c}{A}, \quad (3)$$

where R_c is the compressive strength, in N/mm^2; F_c is the maximum load at fracture in Newtons; A is the area of the prism face in millimetres (40 × 40).

4. Results and Discussion

4.1. Flow Value.
To evaluate the fluidity of the cement pastes, a slump test was conducted on the cementitious mix prepared at the laboratory by using the slump cone or Abrams

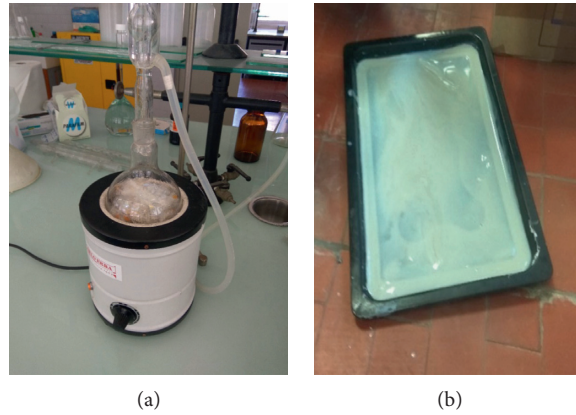(a)   (b)

FIGURE 1: (a) Close system of chemical recycling step; (b) depolymerization of polyethylene terephthalate (DPET) after a liquid separation.

TABLE 2: Mixture typologies with the sand type used and the weight replacement of sand by DPET.

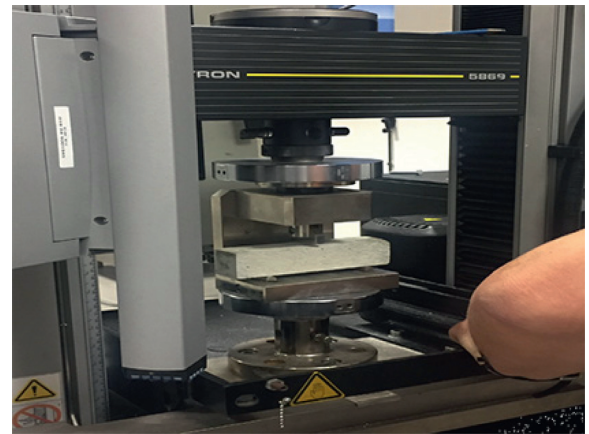| Cement paste	Sand type	Sand (g)	DPET (g)	Sand (%)	DPET (%)	Specific weight ρ (kg/m^3)
1	Normalized	500	—	100	—	2100
2	Normalized	350	150	70	30	1950
3	Unnormalized	500	—	100	—	1960
4	Unnormalized	400	100	80	20	1812
5	Unnormalized	300	200	60	40	1636
6	Unnormalized	200	300	40	60	1494
7	Unnormalized	100	400	20	80	1451

FIGURE 2: Conductivity test device.

FIGURE 4: Flexural test on prismatic sample.

FIGURE 3: DPET-prismatic samples tested to flexural load.

cone, which was filled with the prepared mortar mix in three stages. The slump was thus determined by measuring the distance from the top of the subsided cement paste to the level of the top of the slump cone and was recorded in terms of millimetres. In Figure 6, the flow value of each cement paste normalized to the flow value of the conventional cement mixture (Paste 1 in Table 1) is represented. The results obtained from the slump test show that the mixture 3 and 4 were more fluid than mixture 1. The flow values decrease continuously for the DPET percentage greater than 20% (paste 4-5-6-7 in Table 1).
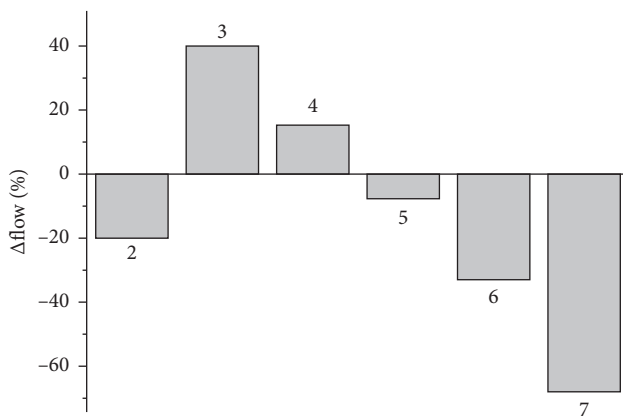
FIGURE 5: Compressive test on cubic sample.

FIGURE 6: Flow values normalized to flow value of cement paste 1.

4.2. Thermal Conductivity. The results obtained from the thermal conductivity tests are reported in Table 3 and are represented in Figure 7(a). The thermal conductivity is substantially indicated as the attitude of a heat-transmitted material. The data relating to the conducted tests show that the experimental values regarding this characteristic decrease with the progressive increase of DPET amount in the cementitious paste.

In Table 3, the thermal diffusivity values of all tested specimens are reported. Such characteristic describes the propagation of the thermal field where the regime of the boundary conditions is not stationary and the capacity of the material to adapting to the changes in temperature imposed from the outside. Similarly to the thermal conductivity, the thermal diffusivity decreases when the DPET percentage increases in the mixture. This trend is not observed for sample 6, which can be still counted among the measurement errors due to the smaller surface of the test sensor.

It is clear from the results represented in Figure 7(b) that the more DPET is added to the mixture, the more the diffusivity is lowered, and therefore the thermal inertia increases.

The minimum thermal conductivity value was 0.35 W/m K, observed at 80% aggregates replacement. From this result, it was concluded that waste PET aggregates replacement with conventional aggregate in the mixture showed better insulation properties (i.e., lower thermal coefficient). The low unit weight and high thermal conductivity values of DPET mortars make it possible to assess the use of such materials in construction applications.

In fact, the thermal conductivity values of produced mortars decreased with increasing weight fractions of depolymerized plastic, and their thermal conductivities were lower than the ordinary mortar by about 31–62%. Such reduction is in agreement with the experimental results in another preliminary research conducted on mortars with milled PET waste until reaching particles size similar to sand [36, 37]. In [37], the percentual improvement of thermal property has increased up to 57% in mortars with sand replacement by PET obtained by milling. As noted in the presented experimental results, the cement mortar containing a large part of polymeric material replacing sand preserves the high thermal performances of milled PET mortar with the added advantage of using nondepurated plastic waste. For this reason, it can prove to be a highly recommended material that can offer advantages in terms of thermal insulation.

4.3. Mechanical Strength. The flexural and compressive strengths of the different mixtures are collected in Table 4.

Specifically, Table 4 shows the variations in the flexural strength of the different mixtures as a function of the percentage of sand replaced by the same weight of plastic. Comparing with the control mixture, no significant changes are observed for mixtures containing up to 40% of DPET aggregates. However, a decrease of 46% and 51% for mixtures with, respectively, 60% and 80% of DPET content is observed. In Figure 8, the flexural strengths of the DPET mixture with respect to the specific weights are represented.

The experimental results show a decrease in compressive strength when the plastic content increases both the normalized and unnormalized sand mixtures. The drop in compressive strength seems not to be proportional to the weight fraction of sand replaced by plastic aggregates. In fact, a decrease of 20% for the mixture with 30% of DEPT aggregates and normalized sand (cement paste 2 in Table 4) is observed. For mixtures with, respectively, 20%, 40%, 60%, and 80% of DPET aggregates and un normalized sand (cement paste 4, 5, 6, and 7 in Table 4) a decrease equal to 25%, 47%, 60%, and 66% of compressive strength, respectively, is observed. The drop in compressive strengths due to the addition of plastic aggregates is closely related to the decrease of the specific weight of the DPET mixture (Figure 9).

TABLE 3: Thermal conductivity and thermal diffusivity values of the seven mixtures investigated.

| Cement paste	Sand type	Sand (%)	DPET (%)	Specific weight ρ (kg/m^3)	Thermal conductivity (W/mK)	Thermal diffusivity (m^2/s) x 10^{-8}
1	Normalized	100	—	2100	2.02 ± 0.05	1.10 ± 0.08
2	Normalized	70	30	1950	1.45 ± 0.10	0.892 ± 0.05
3	Unnormalized	100	—	1960	0.99 ± 0.06	0.608 ± 0.1
4	Unnormalized	80	20	1812	0.627 ± 0.02	0.426 ± 0.03
5	Unnormalized	60	40	1636	0.57 ± 0.02	0.38 ± 0.05
6	Unnormalized	40	60	1494	0.42 ± 0.09	0.518 ± 0.06
7	Unnormalized	20	80	1451	0.35 ± 0.01	0.35 ± 0.02

(a)

(b)
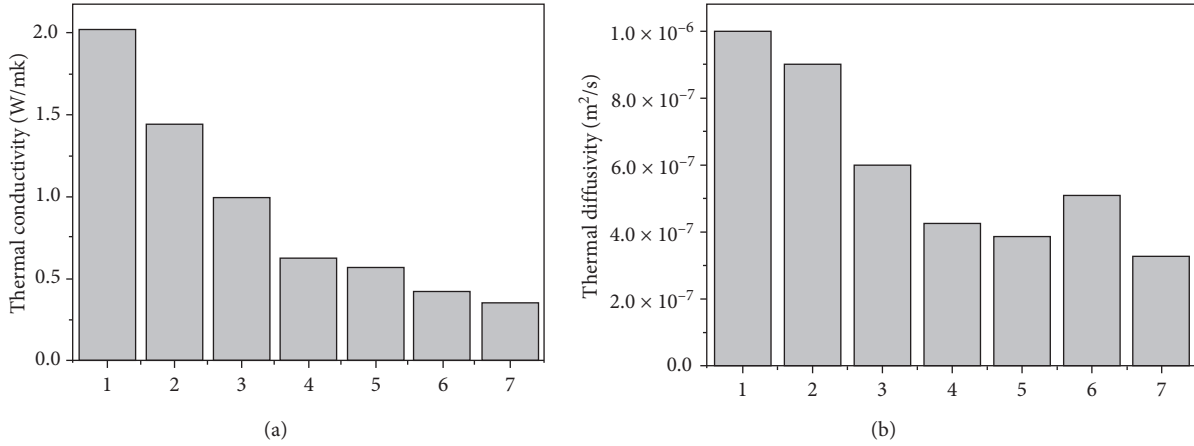
FIGURE 7: (a) Reduction of the thermal conductivity according to each mixture type; (b) reduction of the thermal diffusivity according to each mixture type.

TABLE 4: Results of flexural and compressive strength of cementitious pastes with different weight additions of DPET.

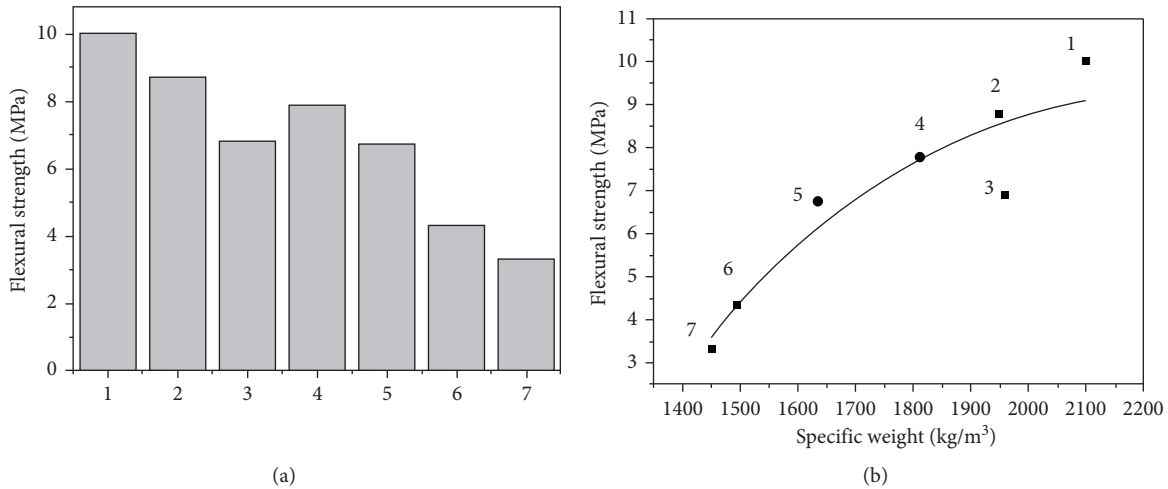| Cement paste	Sand type	DPET (%)	Flexural strength R_f (N/mm^2)	Compressive strength R_c (N/mm^2)
1	Normalized	—	10.02 ± 0.53	51.97 ± 1.32
2	Normalized	30	8.80 ± 0.25	42.06 ± 1.02
3	Unnormalized	—	6.87 ± 0.48	47.91 ± 0.89
4	Unnormalized	20	7.79 ± 0.50	35.82 ± 1.06
5	Unnormalized	40	6.77 ± 0.47	25.60 ± 0.89
6	Unnormalized	60	4.36 ± 0.31	18.78 ± 0.60
7	Unnormalized	80	3.32 ± 0.32	16.27 ± 0.95

(a)

(b)

FIGURE 8: (a) Flexural strength according to tested mixture type; (b) relationship between the flexural strength and specific weight of the specimens.
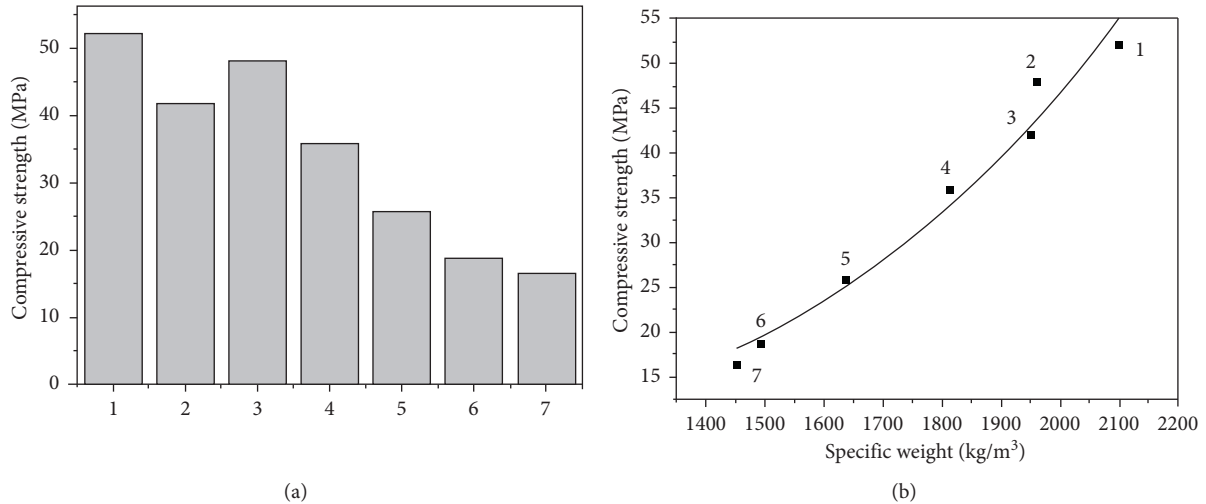
(a)

(b)

FIGURE 9: (a) Compressive strength according to tested mixture type; (b) relationship between the compressive strength and specific weight of the specimens.

The reduction of compressive and tensile strengths in correspondence of the increased proportion of the replaced aggregate results in agreement with the experimental evidence revealed by previous studies carried out on mortars containing milled PET particles [21, 22]. The mechanical behaviour DPET-mortar results were comparable to mortars with the incorporation of ground PET waste. Depolymerization of the PET thus allows obtaining a mortar with similar performance without include the needed steps for the mechanical recycling on (i.e., separation based on shape, density or chemical composition of waste, and washing to removal of impurity).

5. Conclusions

In recent years, the recycling of PET has received a great deal of attention for the heavy amount of plastic material destined to disposal treatment. The presented paper focused on the use of a postconsumer PET-bottles wastes as aggregates in a cement paste in order to evaluate its physical and mechanical characteristics. In the material research field, the postconsumer PET-bottles are mainly recycled into fibres through mechanical process. Nevertheless, mechanical processing can often lead to low-grade material due to the difficulty of obtaining fibres uniform throughout and free from defects. For this reason, the conducted research aimed to explore the possibility of using PET nanoparticles obtained by a chemical process as the depolymerization of plastic pieces through the glycolysis reaction using Ethylene Glycol as a solvent.

Different DPET percentages were added to the cement mixture in replacement of sand. The results of mechanical tests and thermal conductivity tests conducted on mortar mixed with chemically depolymerized PET have been compared with the performance of a traditional paste. The experimental data showed that the use of plastic nanoparticles decreases mechanical performance in terms of flexural and compressive strength of the new mortars. The results showed that a higher percentage of DPET provides a lower heat-transfer capacity to the mortar. For this reason, the chemically DPET- mortars can

be considered a valuable material in the building field for all those cases where a good thermal insulation level is required. Finally, the high advantage obtained from recycling a waste material like PET that is very dangerous for the environment must be underlined.

The present research on PET waste chemically recycle to improve mortar performance can be considered preliminary. It showed interesting properties of DPET mortars such as thermal conductivity; however, further study remains to optimize the chemical process conditions with several reagents and to define the optimal DPET-additive amount. Additionally, this research can also be expanded analysing the microstructure of DPET mortars and evaluating a possible fire resistance difference according to DPET utilization.

Data Availability

The data used to support the findings of the study are included in the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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