Reinforcing concrete with recycled plastic wastes

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Reinforcing concrete with recycled plastic wastes

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Abstract. Solid waste is one of the many factors that negatively affect the environment. The plastic is an important type of solid waste with a strong environmental impact, all types of plastic used in daily life becoming, sooner or later, waste. Therefore, increasing consumption of various types of plastic products is one of the most important challenges in environmental protection. From different perspectives, waste reuse is important because it helps to recycle in the production process, reduces environmental pollution, and helps sustain and conserve non–renewable natural resources. On another hand, many constructions require precise techniques and technologies that can utilize a number of new materials. Also, the lightweight building material industry is considered useful in promoting reused materials. In this context, the use of simple concrete and reinforced concrete is somewhat restricted by specific phenomena such as: cracking, fire resistance, shrinkage, shock resistance, wear resistance, durability, etc. For this reason, an improvement in the performance of the concrete can be obtained by adding in their mass of reinforcements dispersed in the form of fibres from different materials. The dispersed reinforced concrete results in the inclusion of a variable amount of discontinuous fibres in the concrete mass. These fibres can be of different types and sizes and have different properties. This type of reinforcements has become a major research subject in recent years. Therefore, using plastic waste in the materials industry is an environmental solution to minimize the proportion of landfills used in waste incineration. Reusing plastics as concrete additives could also redirect old water and soda bottles, the bulk of which would otherwise end up in a landfill. Research has focused on the impact of adding plastic material to fresh and hardened concrete. This study aims to investigate the use of polyethylene terephthalate (PET) wastes in concrete.

1. Introduction

Nowadays, thanks to the modern lifestyle, advances in industry and technology have led to a significant increase in the quantity and types of waste [1–4]. The problem of year–on–year accumulation of waste is a problem found all over the world. Waste is a major environmental problem when thrown into landfills, quarries, rivers or oceans [1–7].

In recent decades, PETs have become the most toxic waste that pollutes the environment [1–4]. They are found everywhere, at the top of the mountain, in the forest, on the watercourses, in recreational areas or in the outskirts of the neighbourhoods. It is a problem that many states are also facing (Figure 1). According to most research studies [1–13], plastic containers are the highest pollutant of European waters, accounting for 14% of all plastic waste in Europe's rivers [1–4]. The collection and recycling of this waste has become a priority of environmental policies. Plastic packaging is usually also made of plastic packaging, which resumes its toxic circuit in nature. But what about discarded, uncollected and unused? Plastic, mostly PET container, occupies about 12% of the volume of landfills, which is why the incineration of waste has become increasingly attractive for energy recovery, but with negative effects on the atmosphere due to the resulting combustion gases [1–4]. Selective plastic collection discourages waste incineration, reducing the profitability of incineration and directly benefits air quality. Finding new ways to recycle PET remains a challenge [1–25].

Figure 1. Terephthalate polyethylene wastes

The recovery of waste is difficult because of its variety, as well as its unknown properties over time. The construction materials industry is an area of interest for the use of waste, and researchers have tried to produce new building materials that incorporate waste [1–25]. The new generation of building materials is developing rapidly. For environmental reasons it is recommended to use waste extensively, although some waste may be too risky to use [1–25].

This research aims to contribute to the depollution of the environment by designing a new ecological and innovative concrete that incorporates as much recycled waste as possible from the PET waste category [16–18]. Research aims to use waste stocks, for which the current recycling possibilities are limited. Thus, PET waste can be processed in the first phase by sorting, grinding, chopping technologies, after which it will be used as reinforcements in the new concrete. Terephthalate polyethylene is a lightweight, corrosion–resistant and recyclable plastic. It can be turned into synthetic fibres or foil. This category includes colourless or coloured PET vials for water, beer, alcoholic beverages, juices, vegetable oil, and other plastic containers [16–18].

2. Methods & Materials

To continue to be competitive, concrete has improved a number of properties, resulting in new types of concrete, such as: high–strength concrete, high–performance concrete, dispersed fibre concrete, reactive powder concrete, polymeric concrete, heavy concrete, apparent concrete, etc. [4,16–18]

Concrete is made from natural aggregates, cement and water, compounds that make it a cheap and easy material to produce anywhere. Typically, ordinary concrete contains about 12% cement, 8% water and 80% aggregates (Figure 2, Table 1) [4,16–18]. The new concretes use different types of additions in the composition (Figure 3). A wide range of materials, waste or other materials can be introduced into regular concrete, which can either improve its properties or are used for consumption because their storage affects the environment. These may include: rubber waste, expanded polystyrene waste, steel slag waste, wood waste, and other waste [4,16–18].

Figure 2. Solid factions of the concrete recipe

Table 1. The mixing concrete

MIXING CONCRETE	Cement	Sand	Aggregate
General purpose concrete	1	2	3
Foundation concrete	1	2.5	3.5
Paving concrete	1	1.5	2.5

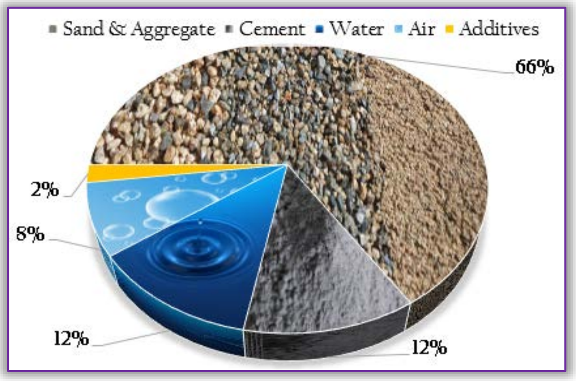

Figure 3. Typically concrete mixture

Some of the usual concretes have been studied through the incorporation into the composition of the various materials, depending on the desired purpose. Thus, if a number of materials, in particular waste, are intended to be consumed for environmental purposes, the concrete obtained can be used in a narrower field, depending on the resulting physical and mechanical characteristics. If, however, the aim is to improve the properties of concrete by using various additions, then concretes with an extended area of use can be obtained. The use of concrete additions has developed not only from economic and ecological requirements, but also because they improve the properties of concrete.

In studies carried out to date, the additions used to obtain different types of concrete fall into two categories:

— various fillers (thermal ash, ultrafine silica, ashes)
— various fibres (glass fibres, metal fibres, cellulose fibres and wood chips, silica fibre, carbon fibres, aramid fibres, polypropylene fibres, polyester fibres, polyethylene fibres)

In concrete with fillers, they play an important role because they fill the very fine gaps in the matrix, thus creating a more homogeneous and compact structure [16–18]. Fibres are most often used in cement concretes, both ordinary and high–performance, their role being to improve the properties of concrete.

Figure 4. Typically fibers used in fibre–reinforced concretes

The contribution of dispersed fibre reinforcement (Figure 5) to the improvement of the mechanical properties of concretes depends on several factors, such as the shape, size and volume of the fibres. Depending on the specifications of the project can be produced concretes with different types of fibres in a wide range of strength classes.

Figure 5. Fibre–reinforced concrete

Macro polymer fibres are synthetic fibres successfully used to replace steel fibres, welded wire nets and, in part, conventional reinforcement bars in a wide variety of applications. These fibres have been developed with the aim of improving both bending, abrasion and impact resistance, as well as decreasing the risk of cracks, reducing their opening and altering their colour. Following the advancement of research and development in the field, it has been proven that macro polypropylene fibres, although initially developed as an alternative to steel fibres in some applications bring benefits in a wide range of applications. The size of the fibre shall be chosen according to the maximum size of the aggregate and the type of fibre shall be determined according to the loads. Some types of fibres also help to reduce cracking in plastic contraction, with a beneficial effect on the durability of the built element.

If the use of steel fibres or macro synthetic fibres is intended to improve mechanical characteristics, synthetic/polymeric micro fibres can significantly reduce shrinkage cracking. Main applications: pedestrian paths, prefabricated tiles, borders, sidewalks etc. (Figure 6).

Figure 6. Typically applications of the fibre–reinforced concretes

3. Results

In recent years, concrete researchers have investigated and successfully utilized low–volume fractions of various types of synthetic fibres as a supplement to the traditional approach of reinforcing the cement composites. Therefore, different types of synthetic fibres are often used in concrete. Our previous results presented in [4,16–18] indicate promising possibilities of using recycled polyethylene terephthalate (PET) polymer fibres in concrete products (Figure 7). At the same time, such applications would contribute to solving the problem of waste polyethylene terephthalate (PET) disposal.

Figure 7. Several reinforcing possibilities with recycled polyethylene terephthalate (PET) (strips, chips, mesh woven and rope strand) [16–18]

The experimental results presented in [4,16–18] indicated that the dosage and form of the reinforcements are the two most influential parameters in the concrete reinforcing process. For a given volume fraction of recycled polyethylene terephthalate (12 grams), changing the fibre form (width, length, thickness) we experimented several reinforcing possibilities, large presented in [4,16–18]. Also, decreasing the fibre profile or equivalently increasing the number of fibres in the concrete mix significantly improves the compressive strength.

Using the long polyethylene terephthalate (PET) yarns, they are inserted into a special made–up apparatus (Figure 8) for weaving them in special ropes which will be used as reinforcement in the armed concrete samples. Thus, 18 polyethylene terephthalate (PET) yarns (6 through each clamping element and all 18 attached to the opposite end) passed. The thickness is about 1 cm (Figure 8, Figure 9).

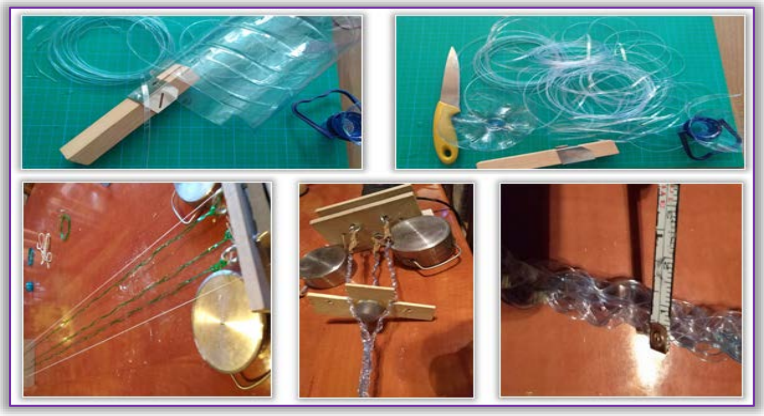

Figure 8. Typically applications of the fibre–reinforced concretes

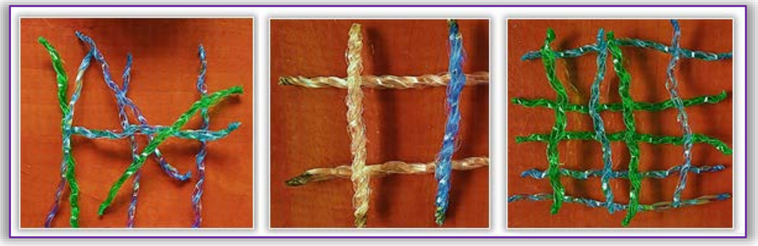

Figure 9. PET rope strands

The concrete used in all samples (3 samples for 1 non–reinforced concrete and 3 samples for 1 reinforced concrete with recycled polyethylene terephthalate), was one and the same, with the same characteristics (class C30/37). In this way, the influence of the reinforcements on the compression characteristics was followed [4,16–18].

Figure 10. Preparing and labelling the unarmed concrete samples

Figure 11. Labelling the reinforced concrete samples of reinforced concrete with recycled polyethylene terephthalate

Non–reinforced concrete (class C30/37) and reinforced concrete with reinforcements from recycled polyethylene terephthalate (PET) waste were made in laboratory conditions, on an exact recipe and in accordance with the requirements (Figure 10, Figure 11).

After the 28 days necessary to achieve the maturation of all the specimens (all cast simultaneously in formworks and matured under the same conditions) and weighing of the concrete samples it is possible to proceed to the accomplishment of the laboratory loads [26–28]. The UTest–Autocon testing equipment was used to determine the compression load. All the experimental values are presented in Figure 12 and Figure 13.

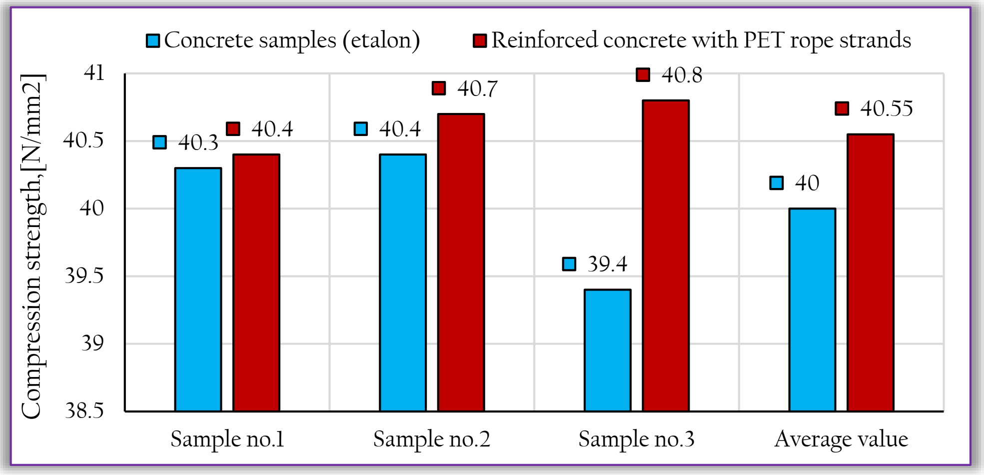

Figure 12. Results on compression strength

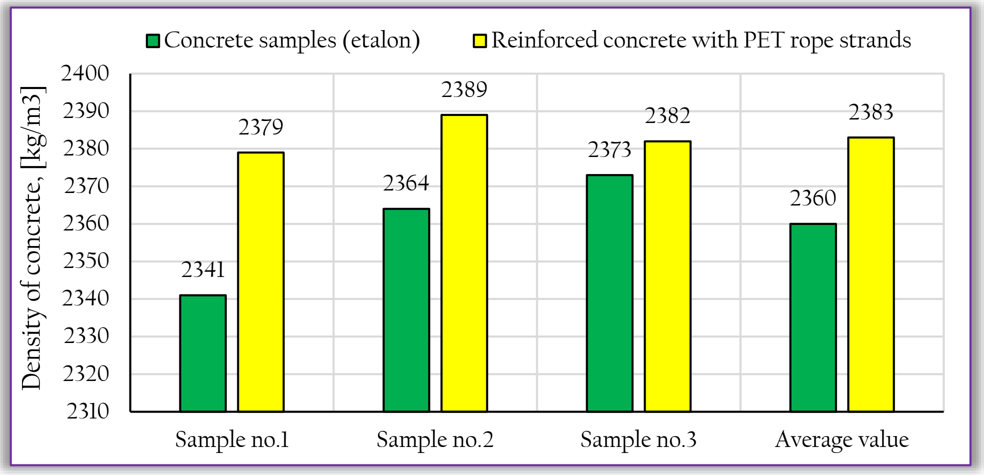

Figure 13. Results on density of concrete

4. Concluding remarks

Fibre–dispersed reinforced concrete cannot completely replace ordinary reinforced concrete. There are, however, areas of use in which fibre–reinforced concrete can be used alternately or in addition to the classic reinforced concrete, offering constructive and economic advantages. It has been found that fibres, of whatever nature, improve the properties of simple concrete.

Concrete dispersed with fibres is defined as the material obtained by mixing cement, aggregates, fibres, additives, mineral additions and water, in the predetermined proportions, whose properties develop by hydrating and strengthening cement and the interaction between fibres and matrix.

Dispersed reinforced concrete results from the mass incorporation of concrete into a variable amount of discontinuous fibres.

The advantage of arming the concrete with PET fibres lies in their ability to disperse throughout the mass of the mixture. The reinforcement is done by simply mixing the fibres in concrete. In this way the fibre achieves a three–dimensional reinforcement unlike the traditional welded steel nets that remain at half of the concrete mass. Thus, PET reinforcement fibres can be used together with the steel nets or represent an alternative to them. It does not require changes in the concrete recipe or handling mode.

Some of the advantages can be stated in this way:

≡ Increased construction durability due to improvement in concrete properties:
— better bending resistance (increase of more than 25%)
— higher impact resistance and compression
— better abrasion and wear resistance
— increased shear resistance
— reducing the appearance of contraction cracks
— increasing long–term sustainability..
≡ Ease of commissioning: can be put into operation by direct casting or by pumping, depending on consistency and access to works
≡ Cost reduction by:
— establishing an optimal concrete recipe in terms of the quantity of fibre required/m^3 , which must be customized for each work, based on a calculation of loads.
— the reduction of the need for further repair, such as that generated by the consequences of incorrect positioning of the reinforcement net.

Most fibre–dispersed reinforced concrete applications are based on the principle of improving the properties and mechanical (resistance) characteristics of the material. However, the role of fibre reinforcement of simple or classically reinforced concretes should be reduced not only to this principle of improving the resistances, but especially to controlling the cracking process and thereby to improving the resistance, energy absorption properties and impact resistance, shock, temperature variations, temperature gradient, fire resistance.

The basic requirements of the fibres, when it is necessary to improve mechanical resistance and delay the cracking process, are: high elongation resistance and appropriate elasticity mode, increased matrix adhesion, chemical stability; furthermore, the fibres should have the quality to bear the efforts for a longer period of time. The properties of the fibres used to disperse concrete are now, for the most part, known. And fibres obtained from PET waste can be a solution.

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