Construction and Building Materials 161 (2018) 254–266

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Impact strength, permeability and chemical resistance of concrete reinforced with metalized plastic waste fibers

Ankur C. Bhogayata [a,*], Narendra K. Arora [b]

[a] Department of Civil engineering, Faculty of Engineering, Marwadi Education Foundation's Group of Institutions, Rajkot 360003, Gujarat, India
[b] L.E. College, Morbi, Gujarat, India

HIGHLIGHTS

- Innovative usage of metalized plastic waste for plain concrete reinforcement as macro fibers.
- Use of metalized plastic waste unfit for recycling creating management and disposal issues.
- Evaluation of concrete containing metallized fibers subjected to impact loads.
- Evaluation of modified concrete for chemical and permeability resistance.
- Assessment of concrete to get the optimum length and dosage of metalized plastic fiber in concrete.

ARTICLE INFO

Article history:
Received 2 July 2017
Received in revised form 23 November 2017
Accepted 25 November 2017

Keywords:
Metalized plastic waste
Concrete
Impact strength
Permeability
Acid resistance
Sulfate resistance
Chloride penetration
Corrosion
Water sorptivity

ABSTRACT

This paper represents the results of experimental investigations of impact strength and durability properties of concrete reinforced with post-consumer metalized plastic waste (MPW) generated from the discarded food packaging plastics. The addition of MPW into the conventional concrete can extend a dual benefit of reduced hazards on the environment and improved mechanical and durability properties of concrete. The MPW films were shredded into the macro fibers of varying lengths of 5 mm, 10 mm, and 20 mm and mixed into the concrete by volume fractions from 0% to 2%. The test results showed excellent improvement of the impact resistance by concrete containing MPW fibers of 20 mm length compared to the conventional concrete. The resistance against acid and sulfate attack, chloride penetration, corrosion of concrete, water, and air permeability, and the resistance to the water sorptivity were improved due to the addition of 5 mm length short MPW fibers. For all test conditions, the maximum improvement was observed with the addition of 1% volume fraction of MPW fibers mixed into the conventional concrete.

1. Introduction

The development of fiber-reinforced concrete with post-consumer plastic wastes is one of the emerging research areas in the field of preparing sustainable construction materials. The post consumer plastic wastes have been extensively utilized in concrete to overcome the shortfalls of limited tensile strength, poor crack resistance, brittleness and varying permeability to water and gases. Researchers have investigated the fresh and hardened properties of concrete reinforced with a variety of plastic wastes namely polyethylene terephthalate (PET) bottles, polypropylene (PP) and polyethylene (PE) bags. On the other hand, the metalized plastic used by food packaging industry has not been extensively utilized as reinforcing the material into the plain conventional concrete which in fact is a large source of littering of plastic waste. Moreover, PET, PP and PE based plastic wastes are recyclable and can be reused to an extent, while the metalized plastic waste (MPW) are largely unfit for recycling and cannot be directly reused [1]. The modern food habits are demanding more packaged foods and thereby a constant growth of MPW is observed [2]. It may be interesting to carry out explicit research on utilization of MPW in concrete as a reinforcing material in preparing a sustainable concrete and to mitigate the environmental hazards due to the uncollected MPW causing the littering of waste plastics into the surroundings.

Concrete is susceptible to having the microcracks and lack of effective protection against the water and gas permeability. Consecutively, due to the poor cracking and permeability resistance,

* Corresponding author.
E-mail addresses: ankur.bhogayata@marwadieducation.edu.in (A.C. Bhogayata), narendrakarora@gmail.com (N.K. Arora).

https://doi.org/10.1016/j.conbuildmat.2017.11.135
0950-0618/

the plain concrete has to suffer by chemical attacks and mediocre impact resistance. The usage of macro plastic waste fibers may be one of the solutions to such shortfalls in an environmentally friendly manner.

The addition of macro plastic fibers obtained from the leading plastic wastes namely PET, PE, and PP have shown the potential of reducing the cracking and improved impact and durability performance of the conventional concrete.

The literature shows the excellent feasibility of recycled PET, PP, and PE macro fibers into the concrete. The addition of recycled PET fibers has demonstrated improved tensile strength, cracking resistance [3,4], and flexure strength up to an extent [5], improved deformation and ductility in the post- cracked state [6]. An overview on usage of recycled PET, and PVC macro fibers in concrete revealed that addition of recycled PET macro fibers improves the toughness and allows 4 times larger deflection of plain concrete prior to the final failure. Properties of concrete like thermal conductivity, reduced chloride penetration, erosion-abrasion due to water have been noticed due to the addition of PET fibers [7]. The impact resistance and mechanical properties are remarkably improved due to the presence of PET fibers as noticed by many researchers [8–11]. Literature shows capability of recycled fibers in chemical resistance in marine environments [12], water permeability resistance [13]. Extensive reviews are available on the use of recycled plastics in concrete in varying forms namely recycled aggregates and fibers [14,15,16]. It is observed that the presence of PE fibers reduces water permeability and cracks developed due to the drying shrinkage at the lower dosage of fibers [17]. Recycled high-density polyethylene (HDPE) fibers improved the flexural toughness up to 30–40% at the dosage of 0.75–1.25% by volume of concrete. Additionally, it improved water permeability up to 42% and remarkably reduced the cracks due to the drying shrinkage up to 50% at the dosage up to 1.25% by volume [18].

Though the ample amount of literature and data is available on the usage of common plastic wastes namely PE, PP and PET in concrete, a limited research work is available to refer to usage of MPW in concrete [19], especially the explicit knowledge on effects of MPW on durability attributes of concrete is a primary research gap and requires attention. Therefore, the present paper focuses on the experimental investigations revealing the effects of the addition of MPW into the concrete by assessing the chemical resistance, impact resistance and permeability in the conventional concrete being a part of an ongoing research program on the usage of MPW fibers in concrete as a fibrous reinforcing material.

In the present study, impact resistance, chemical resistance and permeability of water and oxygen in concrete containing varying length and fractions of MPW fibers have been studied. Concrete in the hardened state was tested under the impact load (drop weight hammer), acid and sulfate attack (weight difference and compressive strength), rapid chloride penetration test (RCPT), accelerated corrosion test (ACC), water sorptivity and oxygen permeability. The test results are compared with the control specimens containing 0% MPW fibers.

1.1. Research significance

The present research is carried out as the answers to the following queries;

- What is a potential of MPW fibers to act as fibrous reinforcement in concrete from the impact and durability perspectives?
- What can be the effective size and dosage of MPW fibers for the impact resistance and durability properties?
- How will the standard response of the concrete be affected due to the presence of the MPW fibers to the chemical and corrosion attack along with the fluid permeability and with what capacity?

The queries have been answered by obtaining and analyzing the experimental test results of the impact loads (drop weight test), oxygen permeability, rapid chloride penetration, water absorption, compressive strength and weight alteration of concrete immersed in acid and sulfate solutions and accelerated corrosion of rebars embedded in concrete containing MPW fibers.

2. Experimental program and tests

2.1. Materials and mix proportions

2.1.1. Concrete mixture

Ordinary Portland Cement (OPC grade 53) manufactured by the Ultratech cement company from Gujarat having a specific gravity of 3.15 g/cm^3 was used. Locally available 20 mm and 10 mm sized aggregates around the Rajkot city area were used as coarse aggregates. Sand from the banks of Aaji River near Rajkot was used as fine aggregates. The specific gravity of coarse and fine aggregates was 2.71 and 2.63 with 0.5% and 0.78% water absorption respectively. The fineness modulus of coarse aggregates was 4.76 and for fine aggregates as 2.99.

2.1.2. Metalized plastic waste (MPW) fibers

Metalized plastic used by food packaging industries was obtained from a plastic packaging industrial unit at the Shapar-Veraval industrial area near Rajkot city. Plastic films made from polypropylene (PP) consisting metallization treatment were shredded into fibers. As shown in Fig. 1, mechanical shredding of metalized films using a manually operated paper cutting tool was carried out in varying lengths of fibers 5 mm, 10 mm, and 20 mm at a constant 1 mm width and designated by Type A, Type B, and Type C fibers respectively. The metalized plastic films were shredded into the desirable length by an ordinary paper cutting machine General and test properties of MPW are listed in Table 1. The fibers were mixed in varying fractions from 0% to 2% by volume of concrete mix resembling the MPW fiber dosage of 0 kg/m^3, 4.5 kg/m^3, 9.2 kg/m^3, 14 kg/m^3, and 18 kg/m^3 respectively. The concrete specimens containing 0% of MPW fibers was considered as the control specimens.

2.2. Concrete mixes

Total 15 concrete batches were prepared at a constant 0.45 water to cement ratio. Details of concrete constituents and the batch-wise fractions of MPW fibers are shown in Tables 2and 3 respectively. A dry mix was prepared with varying fractions of MPW fibers along with the conventional constituents. Water was mixed in a rotating mixer machine according to the standard guidelines for preparing the wet mix. MPW fibers showed excellent adherence to the wetted constituent namely fine and coarse aggregates and thoroughly get mixed in the wet mix.

2.3. Test specimens

Impact load test was carried out on concrete disks of 165 mm $*$ 65 mm in the diameter and thickness respectively. Concrete cubes of 150 mm $*$ 150 mm $*$ 150 mm size were immersed in a normal water, acid and sulfate solutions and subjected to the axial compression. The concrete disks of 100 mm $*$ 40 mm in diameter and thickness respectively were utilized in RCPT, oxygen permeability, and water absorption tests. The concrete cylinders were prepared with 75 mm diameter and 150 mm height containing 16 mm diameter steel rebars embedded in a center of the specimen at the time of the casting.

For each test, three specimens were prepared and tested to obtain the average results for a specific experimental result. Total 195 specimens were prepared including 90 cubes, 180 disks, and 45 cylinders. The concrete cylinders were reformed into concrete disks by a rock cutting machine and all the surfaces were made leveled flat. Before employing the tests, all specimens were conditioned to an oven dried state wherever applicable.

2.4. Test methods

2.4.1. Impact test

As shown in Fig. 2 the drop weight hammer test was employed to obtain impact load resistance on the disk specimens. Recommendations of ACI 544 committee were followed to carry out the tests. A hammer of 4.5 kg weight from 450 mm height was allowed for a free fall on the specimens. The blows were applied manually. An apparatus shown in Fig. 2 was developed at laboratory including a hammer, guiding cylinder, metal ball and base plates with fastening lugs. The load values at first and final crack in disks were recorded. The test results are used to determine the energy absorption capacity of concrete. Therefore, the blow counts were converted into the energy using the recommended equation by ACI 544 committee as shown below,

$$E_{impact} = mgh * N$$