Experimental Study on the Effect of Natural Rubber Latex and Plastic Fiber in Concrete

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Abstract In the modern construction industry, there are a lot of materials introduced for enhancing the properties of concrete. Natural Rubber Latex (NRL) is polymer latex obtained from renewable and locally available resources, which can be employed for the effective modification of cement composites thereby encouraging a sustainable construction practice. The Natural Rubber Latex modification significantly improves the plain concrete from porous to an impermeable and denser microstructure by forming a lining of latex film across voids, pores, and micro-cracks. Polyethylene Terephthalate (PET) is a polyester polymer obtained from recyclable bottles. This project work investigates the combined effect of rubber latex and PET fibers in M40 grade concrete. Various tests are conducted on the laboratory cast concrete specimens and their behaviors are observed and documented for 7 days and 28 days testing. The solution offered in the project by using waste plastic is one of the answers to the long-standing menace of waste disposal.

Keywords Polyethylene terephthalate (PET) · Natural rubber latex (NRL) · Polyester polymer

1 Introduction

The common practice in the modern construction industry is to make use of locally available and natural materials from renewable resources to produce high-performance cement composites thereby ensuring an energy-efficient and environmentally responsible construction system. Concrete is one of the most widely used construction materials in the world because of its high compressive strength, long

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service life, and low cost [1]. But concrete has some inherent disadvantages such as low tensile strength, crack resistance, and limited ductility [2].

A discontinuous heterogeneous system exists in concrete even before the application of any external load. When a load is acting on concrete, micro-cracks are developed, and thereby tensile strength decreases. Application of external load leads to the formation of micro-cracks. It has been investigated that short plastic fibers are used to reinforce the concrete, which drastically improves the concrete performance and eliminates the disadvantages of normal concrete such as low tensile strength, low ductility, and low energy absorption capacity.

One of the most important synthetic fibers, namely Polyethylene Terephthalate (PET) is used in industrial production. The present-day worldwide production of PET exceeds 6.7 million tons/year. In India, domestic waste plastics are increasing day by day and it causes reasonable damage to the environment. The main disadvantage of plastic waste is that it is nonbiodegradable and hence it is a big headache to the environment which needs effective disposal. Annually, about 40 million tons of solid waste is produced in India. Every year this is increasing at a rate of 1.5–2%. Plastics constitute 12.3% of the total waste and most of them are produced from discarded water bottles [3]. PET bottles cannot be disposed of by dumping or burning because they produce uncontrolled fire and contaminate the soil properties and vegetation. For overcoming these situations, one of the feasible solutions is using RPET as reinforcing short fibers in structural concrete.

2 Material Characteristics

2.1 Cement

Cement is one of the ingredients of concrete that acts like a binder used for construction that sets, hardens, and adheres to other materials to bind them together. The cement used for the work is Ordinary Portland Cement with its grade as 53 [4]. The properties of cement are given in Table 1.

Table 1 Properties of ordinary Portland cement

S. No.	Properties	Value
1	Specific gravity	3.15
2	Standard consistency (%)	33%
3	Initial setting time (in minutes)	89
4	Final setting time (in minutes)	283
5	Mortar cube compressive strength (MPa)	55

Table 2 Properties of fine aggregate

S. No.	Properties	Test results
1	Water absorption (%)	0.23
2	Specific gravity	2.6
3	Bulk density(kg/l)	1.51

Table 3 Properties of coarse aggregate

S. No.	Properties	Test results
1	Water absorption (%)	0.36
2	Specific gravity	2.8

2.2 *Fine Aggregate*

For the work, river sand is used as the fine aggregate. It should be passed through 4.75 mm [5]. The properties of fine aggregate are given in Table 2.

2.3 *Coarse Aggregate*

Coarse aggregate is the crushed stone that is used for making concrete. 20 mm size of aggregate is used for the work [5]. The properties of fine aggregate are given in Table 3.

2.4 *Natural Rubber Latex*

The Natural Rubber Latex is obtained from the tree, namely called Para rubber [6]. The term latex means a polymer with water-based liquid. Rubber trees are largely cultivated in South America in the initial stages and later it spread to Kew garden, UK, Sri Lanka, Indonesia, Singapore, and reached India. People of Kerala started growing Rubber trees first in India. Natural Rubber Latex is formed by a simple monomer combined through a reaction which is known as polymerization. Natural Rubber Latex is added as a polymer admixture to the concrete. Inclusion of Natural Rubber Latex improves the binding properties and adhesion with aggregates. This provides superior compressive strength to the concrete. In addition, they provide good adhesion to other materials as well as resistance to physical damages such as abrasion, erosion, impact, and chemical attack. The coagulation of Natural Rubber Latex can lead to compositional instability, which is here avoided by adding ammonia-tetramethylthiuram disulfide/zinc oxide.

2.5 Polyethylene Terephthalate (PET) Fiber

PET fiber of length 35 mm and breadth 1 mm is used for the work. PET fibers into the concrete gives high tensile strength but reduces the workability because PET fibers have a very weak bond with cement paste [7].

2.6 Admixture

To enhance the workability, a superplasticizer Mapefluid R440 which conforms to IS: 9103:1999 is used in this work. As per Indian standards, the dosage of superplasticizer should not exceed 2% by weight of cement. After trials, the optimal dosage of superplasticizer was found to be 0.5 to produce a slump of 75 mm.

2.7 Water

Potable water is used for mixing and curing of specimens.

3 Experimental Work

3.1 Specimen Preparation

The concrete specimens are cast for M40 grade by adding Natural Rubber Latex of 0.5, 1, 1.5% of the weight of cement and PET fiber of 0.1, 0.2, 0.3% of the total weight of concrete. Concrete cubes specimens of size 150 mm $\times$ 150 mm $\times$ 150 mm are cast for finding compressive strength. Beams of size 100 mm $\times$ 100 mm $\times$ 500 mm are cast to determine the flexural strength. The cylindrical specimens having a diameter of 150 mm and a height of 300 mm are cast to determine the split tensile strength. Mixer machine is used for concrete mixing. Table vibrator and needle vibrator are used for compacting the concrete mixture. All the concrete specimens are cured for a period of 7 days and 28 days before the test. The results are compared with normal concrete for finding the best combination.

3.2 Mix Ratio for M40 Grade Concrete

See Table 4.

Table 4 Mix ratio for M40 grade concrete as per the mix design result obtained

Cement	Fine aggregate	Coarse aggregate	Water
1	2.07	3.9	0.4

4 Results and Discussions

4.1 Compressive Strength of Concrete

Compressive strength of concrete is computed for varying the percentage of Natural Rubber Latex and PET fiber of 7 and 28 days. From the test results, it is observed that there is a variation in compressive strength when it is compared with normal concrete. Compressive strength of normal concrete and concrete with varying percentages of Natural Rubber Latex and PET fiber are shown in Tables 5, 6, 7, 8.

Table 5 Compressive strength of normal concrete

Days	7	28
Compressive strength(N/mm^2)	29.6	40

Table 6 Compressive strength of concrete with 0.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Compressive strength (N/mm^2)	
Rubber latex (%)	PET fiber(%)	7 days	28 days
0.5	0.1	14.66	33.7
	0.2	37.48	52.2
	0.3	16.88	47.25

Table 7 Compressive strength of concrete with 1% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Compressive strength (N/mm^2)	
Rubber latex (%)	PET fiber(%)	7 days	28 days
1	0.1	40.44	48.148
	0.2	34.9	39.4
	0.3	27.7	50.81

Table 8 Compressive strength of concrete with 1.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Compressive strength (N/mm^2)	
Rubber latex (%)	PET fiber (%)	7 days	28 days
1.5	0.1	35.85	48
	0.2	40	52.29
	0.3	36	46.81

From the above table, it is clear that the maximum compressive strength for 7 days curing period is obtained at 0.5% of Natural Rubber Latex and 0.2% of PET fiber. For 28 days curing period, the maximum compressive strength is obtained at the 0.5% of Natural Rubber Latex and 0.2% of PET fiber which is greater than the compressive strength of normal concrete.

From the above table, it is clear that the maximum compressive strength for 7 days curing period is obtained at 1% of Natural Rubber Latex and 0.1% of PET fiber. However for 28 days curing period, the maximum compressive strength is obtained at 1% of Natural Rubber Latex and 0.3% of PET fiber which is greater than the compressive strength of normal concrete. Here it is found that the compressive strength is decreasing on further addition of PET fiber after 0.1% up to 0.2% and then the sudden increase at 0.3% is maybe due to the balling effect of fiber particles inside the concrete.

From the above table, it is clear that the maximum compressive strength for 7 days curing period is obtained at 1.5% of Natural Rubber Latex and 0.2% of PET fiber. For 28 days curing period, the maximum compressive strength is obtained at the 1.5% of Natural Rubber Latex and 0.2% of PET fiber which is greater than the compressive strength of normal concrete.

4.2 Split Tensile Strength of Concrete

Split tensile strength of concrete is computed for varying percentages of Natural Rubber Latex and PET fiber of 7 and 28 days. From the test results, it is observed that there is a variation in split tensile strength when it is compared with normal concrete. Split tensile strength of normal concrete and concrete with varying percentages of Natural Rubber Latex and PET fiber are shown in Tables 9, 10, 11, 12.

From the above table, it is clear that the maximum split tensile strength for 7 days curing period is obtained at 0.5% of Natural Rubber Latex and 0.2% of PET fiber. However, for 28 days curing period, the maximum split tensile strength is obtained

Table 9 Split tensile strength of normal concrete

Days	7	28
Split tensile strength (N/mm^2)	1.41	2.8

Table 10 Split tensile strength of concrete with 0.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Split tensile strength (N/mm^2)	
Rubber latex (%)	PET fiber (%)	7 day	28 day
0.5	0.1	2.12	3.53
	0.2	2.758	3.11
	0.3	1.83	2.26

Table 11 Split tensile strength of concrete with 1% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Split tensile strength (N/mm^2)	
Rubber latex (%)	PET fiber (%)	7 day	28 day
1	0.1	2.12	2.68
	0.2	2.33	2.68
	0.3	2.2	2.546

Table 12 Split tensile strength of concrete with 1.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Split tensile strength (N/mm^2)	
Rubber latex (%)	PET fiber (%)	7 day	28 day
1.5	0.1	1.76	3.2538
	0.2	1.69	2.82
	0.3	1.8	2.122

at the 0.5% of Natural Rubber Latex and 0.1% of PET fiber which is greater than the split tensile strength of normal concrete.

From the above table, it is clear that the maximum split tensile strength for 7 days curing period is obtained at 1% of Natural Rubber Latex and 0.2% of PET fiber. However, it is found that for 28 days curing period, 1% of Natural Rubber Latex and varying percentages of PET fiber did not achieve the target split tensile strength of normal concrete.

From the above table, it is clear that the maximum split tensile strength for 7 days curing period is obtained at 1.5% of Natural Rubber Latex and 0.3% of PET fiber. But for 28 days curing period, the maximum split tensile strength is obtained at 1.5% of Natural Rubber Latex and 0.1% of PET fiber which is greater than the split tensile strength of normal concrete.

4.3 Flexural Strength of Concrete

Flexural strength of concrete is computed for varying percentages of Natural Rubber Latex and PET fiber of 7 and 28 days. From the test results, it is observed that there is a variation in flexural strength when it is compared with normal concrete. Flexural strength of normal concrete and concrete with varying percentages of Natural Rubber Latex and PET fiber are shown in Table 13, 14, 15, 16.

Table 13 Flexural strength of normal concrete

Days	7	28
Flexural strength (N/mm^2)	3.84	4.56

Table 14 Flexural strength of concrete with 0.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations	Flexural strength (N/mm^2)		
Rubber latex (%)	PET Fiber (%)	7 day	28 day
0.5	0.1	3.4	5.2
	0.2	2.8	5.6
	0.3	3.2	4.88

Table 15 Flexural strength of concrete with 1% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Flexural strength (N/mm^2)	
Rubber latex(%)	PET fiber (%)	7 day	28 day
1	0.1	2.88	5.36
	0.2	3.6	5.92
	0.3	4.4	5.92

Table 16 Flexural strength of concrete with 1.5% of Natural Rubber Latex and varying percentages of PET fiber

Combinations		Flexural strength (N/mm^2)	
Rubber latex (%)	PET fiber (%)	7 days	28 days
1.5	0.1	4	5.28
	0.2	3.76	6.32
	0.3	3.44	5.2

From the above table, it is clear that no combinations were able to achieve the flexural strength of normal concrete in a 7-day curing period. However, it is found that the maximum flexural strength for a 28-day curing period obtained at the combination 0.5% of Natural Rubber Latex and 0.2% of PET fiber and it is a greater value when it is compared with the flexural strength of normal concrete.

From the above table, it is clear that 1% of Natural Rubber Latex and 0.3% PET fiber composes the highest value for flexural strength in a 7-day curing period. It is found that the 1% of Natural Rubber Latex and 0.2% of PET fiber, 1% of Natural Rubber Latex and 0.3% of PET fiber have the highest flexural strength and it is a greater value when it is compared with the flexural strength of normal concrete.

From the above table, it is clear that 1.5% of Natural Rubber Latex and 0.1% of PET fiber are having the maximum flexural strength in a 7-day curing period. However, it is found that the maximum flexural strength for a 28-day curing period is obtained at the combination as 1.5% of Natural Rubber Latex and 0.2% of PET fiber and it is a greater value when it is compared with the flexural strength of normal concrete.

5 Result Analysis

After comparing the test results of varying percentages of Natural Rubber Latex and PET fiber, we can observe that the maximum compressive strength and flexural strength are obtained at the combination of 1.5% of Natural Rubber Latex and 0.2% of PET fiber for 28 days curing period. Maximum split tensile strength is obtained at 0.5% of Natural Rubber Latex and 0.1% of PET fiber for 28 days curing period.

6 Conclusions

After analyzing the obtained results carefully, it is concluded that

- Compressive strength is maximum at 1.5% of Natural Rubber Latex and 0.2% of PET fiber for 28 days curing period and it is obtained as 52.29 N/mm^2.
- Compressive strength is maximum at 1.5% of Natural Rubber Latex and 0.2% of PET fiber for 7 days curing period and it is obtained as 40.44 N/mm^2.
- Split tensile strength is maximum at 0.5% of Natural Rubber Latex and 0.1% of PET fiber for 28 days curing period and it is obtained as 3.53 N/mm^2.
- Split tensile strength is maximum at 0.5% of Natural Rubber Latex and 0.2% of PET fiber for 7 days curing period and it is obtained as 2.758 N/mm^2.
- Flexural strength is maximum at 1.5% of Natural Rubber Latex and 0.2% of PET fiber for 28 days curing period and it is obtained as 6.32 N/mm^2.
- Flexural strength is maximum at 1% of Natural Rubber Latex and 0.3% of PET fiber for 7 days curing period and it is obtained as 4.4 N/mm^2.
- It is proved that the combined effect of Natural Rubber Latex and PET fiber improves the mechanical properties of concrete.
- The effective utilization of PET plastic fiber can create a solution for waste plastic disposal.

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