Feasibility study of concrete by using polyethylene terephthalate fiber in enhancing the mechanical properties of concrete

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Abstract: In these project Polyethylene terephthalate fiber (PET) fibers are use to improve the mechanical property of concrete and minimize the environmental pollution of earth. PET is use to prepare container for water, cold drinks, food etc. which is single used and it thrown in to the sea, dump on free land and burning. It cause many serious effect on animals, sea animals, destroy land fertility and other health related issues. The PET material are used to improve mechanical property of concrete like compressive strength, dry and wet density and static and dynamic elastic modulus. Thus fibers are available in natural and artificial material. Now a days, artificial fibers are widely used in India. The types of fibers are plastic fibers, glass fibers, steel fibers etc. In India according to solid waste management data is 15,350 tons daily and 1,84,120 tons annually generate, but only 9,350 tons daily and 1,12,120 tons annually collected. So the uncollected data is that about 6000 tons daily and 72,000 tons annually uncollected, in such a way that it causes many problems to the atmosphere so that it becomes environmentally harmful. For developing country concrete is most important material. It is extensively used in construction industry. Concrete have many advantages like long service life, durability, chemical attack resistance etc. Thus concrete has some many disadvantage like low tensile strength, flexural strength and cracks. To overcome these disadvantage add some supplements in concrete to improve its strength. The fiber are one of them. It reduces environmental problem it becomes eco-friendly. In case of compressive strength test, wet density test and direct method of UPV result are obtain as concrete carry higher applied load also it give high compressive strength, high wet and dry density of concrete and quality of concrete is good when adding 0.4% of shape - 01 PET fiber in concrete.

Keywords: Polyethylene Terephthalate Fiber (PET), Artificial Fiber, UPV, Wet density, Eco-Friendly.

1. Introduction

PET fiber are use to improve minimize the environmental pollution of earth and concrete of property which is mechanical. For developing country concrete is most important material. It is extensively use in concrete industry. It has many advantages like long service life, durability etc [1]. Thus it has some many disadvantages like low tensile strength, flexural strength and cracks. To overcome these disadvantage add some supplements in concrete to improve its strength [2]. The fiber are one of them. It reduces environmental problem and construction with higher results. PET fiber is use to prepare container water, cold drinks, food etc. PET material have many properties like impact strength, chemical resistance etc. PET material are use to improve mechanical property of concrete like compressive strength [3]. Fibers are available in natural and artificial material. The use of PET fiber waste there advantage are to improve properties of materials which is in construction and the advantage of PET fiber
waste is polluted the environment. Now a days plastics are use in the world thus the replace the other material like glass, wood, steel etc [4]. So this project is beneficial for our environment. Thus the plastic is one of those material which take a more time to decompose.

In India plastic becomes more broadly use material but there growth is regularly and it causes many major issues in India. Thus the plastic is one of the material that take much time to decompose. So that the maximum 1000 year is required to decompose into the landfill. So that some plastic bottles are required minimum 450 year to decompose or more [1]. Most of the time municipal solid waste corporation burnt plastic solid waste is 12%. So, in case of burning the plastic solid waste it release toxic gases like dioxin, furnace, mercury etc. Into the atmosphere [5]. In India according to solid waste management data is 15,350 tons daily and 1,84,120 tons annually generate, but only 9,350 tons daily and 1,12,120 tons annually collected. So the uncollected data is that about 6000 tons daily and 72,000 tons annually uncollected, in such a way that it causes many problems to the atmosphere so that it becomes environmentally harmful. In case of compressive strength test, wet density test and direct method of UPV result are obtain as concrete carry higher applied load also it gives high compressive strength, high wet and dry density of concrete and quality of concrete is good when adding 0.4% of shape - 01 PET fiber in concrete.

2. Methodology

2.1. Design effective shape of fiber

2.1.1. Specification of first shape fiber
Length = 40mm, Width = 10mm, Thickness = 0.25mm, Numbers of holes = 4, Distance of hole = 10mm c/c, Position of hole = Full hole in centre line, Net area = (total area – hole area) = (400mm² – 78.54mm²) = 321.46mm², Aspect ratio = L/B = 40mm/10mm = 4

![Figure 1. First shape of PET fiber](image)

2.1.2. Specification of second shape fiber
Length = 40mm, Width = 10mm, Thickness = 0.25mm, Numbers of holes = 7 no, Distance of holes = 5mm c/c, Position of holes = half of hole back to back condition, Aspect ratio = L/B = 40mm/10mm = 4, Net area = (total area – holes area) = (400mm² – 68.72mm²) = 331.28mm²

![Figure 2. Second shape of PET fiber](image)

2.1.3. Specification of third shape fiber
Length = 40mm, Width = 10mm, Thickness = 0.25mm, Rectangle = 3 no. (10mm x 8mm), Position of rectangle = back to back, Aspect ratio = L/B = 40mm/10mm = 4, Net area = (total area – hole area) = (400mm² – 240mm²) = 160mm²

![Figure 3. Third shape of PET fiber](image)
2.2. Recycle PET fibers

The selected PET bottles were tested for confirmation and the test results are as follows:

![Figure 4. Shape-01 PET fiber](image)

![Figure 5. Shape-02 PET fiber](image)

![Figure 6. Shape-03 PET fiber](image)

2.3. Concrete mix design

Concrete mix of grade M20 has been designed based on Indian standard recommended guidelines IS: 10262-2009. In that we have used the proportion of M20 grade of concrete is 1:1.5:3. In short concrete mix design is Cement: Aggregate. Concrete mix proportion is used to provide a required strength of grade of concrete [1]. The characteristics of compressive strength of concrete of M20 grade are as follows.

As per IS: 456:2000

- Types of cement = OPC (Ordinary Portland Cement)
- Sp. gr. of cement = 3.15
- Cement density = 1440 kg/m³
- Weight of 1 bag of cement = 50kg
- Density of sand = 1600 kg/m³
- Maximum size of aggregate = 20mm
- Density of coarse aggregate = 1560 kg/m³
- Sp. gr. of fine aggregate = 2.64
- Sp. gr. of coarse aggregate = 2.84
- Volume of dry concrete value = 1.57
- Volume of concrete = 1m³

2.4. Casting Schedule

2.4.1. Conventional concrete

The conventional concrete structures are most commonly used in construction. Conventional concrete is a composite material made of concrete and with or without steel reinforcement. It is obtained by mixing cement, sand, aggregates, and water [1].

2.4.2. PET fiber concrete

PET fibers are used to improve mechanical properties of concrete [8]. According to IS 456:2000, for the calculation of compressive strength of concrete have to cast a cube of size 150 x 150 x 150mm. It is a standard cubic mould available to cast concrete, after the casting curing test are required at days like 7 days and 28 days [1].
2.5. Compressive strength

Compressive strength of concrete is the most important of all properties. For this test cement, sand and aggregate ratio for M20 grade of concrete is taken as 1:1.5:3. The compressive strength is find with the standard cube size 150 x 150 x 150mm. Maximum compressive strength is obtained at 28 days of concrete curing, generally it gives 99% results at 28 days. It is performed on CTM (Compressive Testing Machine) and gives results in N/mm$^2$ [4].

![Figure 7. Cube casting](image)

**Figure 7. Cube casting**

![Figure 8. Compression strength of cube](image)

**Figure 8. Compression strength of cube**

Compressive strength = Applied load / Area of cube = $P / b*d$

Its SI unit is N/mm$^2$

Where, $P$ = Applied load in N  
$b$ = width of specimen in mm  
$d$ = depth of specimen in mm

2.5.1. Compressive strength of conventional concrete

In this test the standard size of mould 150 x 150 x 150mm is taken. The ratio of M20 grade of concrete is 1:1.5:3.

| Sample name | Curing (days) | Compressive strength (N/mm$^2$) | Average compressive strength (N/mm$^2$) |
|-------------|---------------|---------------------------------|----------------------------------------|
| 1           | 7             | 13.02                           | 13.05                                  |
| 2           |               | 13.25                           |                                        |
| 3           |               | 12.90                           |                                        |
| 4           | 28            | 21.05                           | 20.71                                  |
| 5           |               | 20.10                           |                                        |
| 6           |               | 20.98                           |                                        |

*Table 1. Compressive strength of conventional concrete*
2.5.2. Compressive strength of recycled PET fiber concrete

| Days | Shapes | Fiber addition | Compressive Strength (N/mm²) |
|------|--------|----------------|----------------------------|
|      |        | 0.1% | 0.2% | 0.3% | 0.4% |
| 7    | S – 01 | 13.96| 14.97| 15.87| 16.48|
|      | S – 02 | 13.56| 13.77| 14.88| 15.70|
|      | S – 03 | 13.46| 13.33| 14.53| 14.88|
| 28   | S – 01 | 21.92| 22.97| 23.95| 25.02|
|      | S – 02 | 21.86| 22.76| 23.82| 24.66|
|      | S – 03 | 21.70| 22.88| 23.68| 24.57|

**Table 2.** Compressive strength of concrete

![7 days compressive strength](image)

**Figure 9.** 7 days compressive strength

![28 days compressive strength](image)

**Figure 10.** 28 days compressive strength
2.6. Comparison of compressive strength of concrete
The comparison of conventional and PET fiber concrete of shape 1st, 2nd, and 3rd, it gives some interesting and better results with the compressive strength test. It shows that 1st shape of PET fiber is better than the others two shapes and also it gives higher results as compare to the other two shapes of PET fibers. 1st shape of fiber gives high result due to more net area as well as it allows to bear higher stress without fail.

| Days | Shapes | Conventional concrete | Fibers addition |
|------|--------|-----------------------|-----------------|
|      |        | 0%        | 0.1% | 0.2% | 0.3% | 0.4% |
| 7    | S – 01 | 13.05     | 13.96 | 14.97 | 15.87 | 16.48 |
|      | S – 02 | 13.56     | 13.77 | 14.88 | 15.70 |
|      | S – 03 | 13.46     | 13.33 | 14.53 | 14.88 |
| 28   | S – 01 | 20.71     | 21.92 | 22.97 | 23.95 | 25.02 |
|      | S – 02 | 21.86     | 22.76 | 23.82 | 24.66 |
|      | S - 03 | 21.70     | 22.88 | 23.68 | 24.57 |

Table 3. Comparison of concrete

![Comparison of concrete](image)

**Figure 11.** Comparison of concrete

2.7. Wet density of concrete

2.7.1. Wet density of PET fiber concrete
It is calculated as, \( \rho = \frac{W}{V} \)
where,
\( \rho \) = Density of concrete in (Kg/m³)
\( W \) = weight of specimen in (Kg)
\( V \) = volume of specimen in (m³)

| Shapes | Fiber addition |
|--------|----------------|
|        | 0.1% | 0.2% | 0.3% | 0.4% |

Wet density of PET fiber concrete (Kg/m³)
2.7.2. Comparison of wet density of concrete

In that first shape of PET fiber is better and effective than the others two shapes of fiber, due to its high net surface area and smooth surface. Results are obtain in wet density of concrete is that 0.4% of shape – 01 PET fiber it gives higher results as compare to the others two shapes of fibers and conventional concrete.

| Materials       | Fiber addition | Wet density (Kg/m³) |
|-----------------|----------------|---------------------|
| Conventional concrete | 0%             | 2400                |
| Shape - 01      | 0.1%           | 2414                |
|                 | 0.2%           | 2426                |
|                 | 0.3%           | 2438                |
|                 | 0.4%           | 2450                |
| Shape - 02      | 0.1%           | 2411                |
|                 | 0.2%           | 2422                |
|                 | 0.3%           | 2435                |
|                 | 0.4%           | 2447                |
| Shape - 03      | 0.15           | 2408                |
|                 | 0.2%           | 2420                |
|                 | 0.3%           | 2432                |
|                 | 0.4%           | 2444                |

Table 5. Comparison of wet density of concrete
2.8. Ultrasonic Pulse Velocity (UPV) Test
In that we have discuss about UPV (Ultrasonic Pulse Velocity) method, It is also known as NDT (Non Destructive Test). In this test to check quality, strength, and durability of concrete. In that to find good quality of concrete to use direct method. This is an electronic method in which emitter and receiver are connected on opposite surface of concrete [9]. In that time taken by ultrasonic wave to travel through concrete is measured. The pulse velocity is in between 3.75 to 4.40 it means that quality of concrete is good.

2.8.1. Direct method
In this method emitter and receiver transducers are placed on opposite surface of the concrete cube. So that it gives maximum sensitivity and provide a well defined path length. In this method results are obtain as velocity is high then concrete is good [9].
It is calculate by this equation,
\[ V = \frac{L}{T} \]
Where, \( V \) = Velocity of concrete in (Km/sec)
\( L \) = Length or distance of specimen in (mm)
\( T \) = Time in (sec)

![Figure 13. UPV direct method](image)

| Material | Method | Fiber addition | Velocity 7 days (Km/sec) | Velocity 28 days (Km/sec) | Quality |
|----------|--------|----------------|--------------------------|---------------------------|---------|
| Conventional | Direct | 0% | 4.15 | 4.22 | Good |
| Shape – 01 | Direct | 0.1% | 4.03 | 4.09 | Good |
| | | 0.2% | 3.95 | 4.07 | Good |
| | | 0.3% | 3.91 | 4.04 | Good |
| | | 0.4% | 3.83 | 4.10 | Good |
| Shape - 02 | Direct | 0.1% | 4.04 | 4.12 | Good |
| | | 0.2% | 3.90 | 4.06 | Good |
| | | 0.3% | 3.98 | 4.14 | Good |
| | | 0.4% | 3.85 | 4.13 | Good |
| Shape - 03 | Direct | 0.1% | 3.83 | 4.15 | Good |
| | | 0.2% | 3.81 | 4.17 | Good |
| | | 0.3% | 3.87 | 4.07 | Good |
| | | 0.4% | 3.85 | 4.08 | Good |

Table 6. Pulse velocity of concrete
3. Results and conclusion

- PET fiber is a waste material and it causes many serious effects on atmosphere or environment but if we use these waste material as a construction material, so it becomes reduce in serious effects of environmental problems on world by PET fiber bottles and also it helps to improve the concrete properties.
- In that first shape of PET fiber is better and effective than the others two shapes of fiber, due to its high net surface area and smooth surface.
- Results are obtain as in the addition of 0.4% of shape – 01 PET fiber it gives higher results as compare to the others two shapes of PET fiber.
- In the compressive strength test 0.4% of shape – 01 PET fiber it gives higher results as compare to the others two shapes of fiber and conventional concrete at a 7 days and 28 days of curing.
- Results are obtain in wet density of concrete is that 0.4% of shape – 01 PET fiber it gives higher results as compare to the others two shapes of fibers and conventional concrete.
- In the direct method of UPV (Ultrasonic Pulse Velocity) the quality of concrete is good with the addition of 0.4% of shape – 01 PET fiber, and also the quality of shape – 02 fiber addition concrete, shape – 03 fiber addition concrete and conventional concrete is good.

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| Pulse velocity (Km/sec) | Concrete quality |
|------------------------|------------------|
| Above 4.40             | Excellent        |
| 3.75 to 4.40           | Good             |
| 3.00 to 3.75           | Doubtful         |
| Below 3.00             | Poor             |

Table 7. Quality of concrete
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