EXPERIMENTAL STUDY ON PARTIALLY REPLACED CONCRETE WITH AUTOMOBILE INDUSTRIES WASTES

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Abstract. In recent days, the major threat to our environment is waste management. As a contribution to save our environment many research works are happening to utilize waste in their manufacturing process to reduce waste as well as reducing the cost involved in the process. Waste utilization will partially help us to protect our environment. In this paper, for manufacturing concrete with partially replaced fine aggregate is experimented. The objective is to reuse the locally available polypropylene fibre generated as waste by automobile industries. The adhesion between polypropylene fibre and cement matrix is considered as an important factor. To give proper matrix between the fibre and cement, shredded polypropylene fibre is used as partially replaced fine aggregate. The replacement percentages used are 20\%, 40\% and 60\%. The specimens were prepared with water cement ratio 0.5 and tested after 7 days and 24 days of curing period. The influences of polypropylene fibre in concrete in fresh and hardened state are compared with conventional concrete properties. The results obtained shows increase in the strength and workability property for 20\% replacement of polypropylene fibre as fine aggregate in concrete. Hence the disposal of polypropylene waste from automobile industry can effectively be used in shredded form as partial replacement of fine aggregate in concrete.

Keywords: Polypropylene fibre, Automobile waste, Fresh and Hardened state

1. INTRODUCTION

A large amount of waste as plastic, nylon, rubber are produced by the manufacturing industries like automobile parts, household goods, construction projects, industrial wastes etc. In that the automobile waste plastics are non-biodegradable and needs to be recycled. Recent studies have shown that several waste materials can be profitably used to manufacture low cost structural and non-structural components in construction industry. Concrete have a high compressive strength but low tensile strength. To overcome the disadvantages like strain softening the waste fibre can be used. The performance of cement composite depends on the fibre properties, surface texture of fibre, type of fibre, cross section of fibre and the matrix and fibre/matrix interface properties. The adhesion property between the fibre and the cement matrix is an important aspect governs the performance of cement composite. Polypropylene fibre have been used in cement composite to control cracking due to shrinkage, to improve the
toughness of the materials, to improve impact resistance, and to increase the energy absorption capacity of the material. The polypropylene fibre improves mix cohesion, pump ability over long distance, freeze-thaw resistance, impact resistance, increase resistance to plastic shrinkage during curing. The polypropylene fibre obtained from automobile waste is shredded into irregular shapes by means of shredder. The manufacturing process of polypropylene fibre from automobile waste to shredded form is shown in fig 1.1.

Automobilewaste(PPfibre)  Crushedautomobileparts

Final product of shredded fiber  shredding of automobile parts

Fig 1.1 Shredded Polypropylene waste from source

2. LITERATURE SURVEY

Ammar [1] et al, suggested that the mechanical characteristic of no-fine concrete with or without polypropylene fibre are investigated. The results show that the addition of polypropylene fibre in no-fine concrete can improve the mechanical properties, especially the tensile and compressive strength by 19% and 17% respectively compared with the concrete without fibres, and a slight effect on the density. The author concluded that polypropylene fibre actually help to inhibit the formation of crack due to both plastic shrinkage and dry shrinkage. The polypropylene fibre help to maximize the intrinsic strength of concrete and also improve mix cohesion to reduce the bleeding of water.
T.Abadjieva [2] et al, no fine concrete is the form of lightweight porous concrete, the advantage of this type of concrete are lower density, low cost due to less cement content, low thermal conductivity, low drying shrinkage, no segregation and capillary movement of water. The concrete mixes made without fine aggregate and single sized coarse aggregates fraction 13.5 -19mm. The author concluded that the strength of no fine concrete is lower than the normal weight concrete, but sufficient enough for structural use. The suggested mixture could be used for cast in-situ walls in low rise, low cost housing, drainage layers and paving after more extensive research.

Anne Laning [3], synthetic fibres are most commonly added to concrete. It reduces the cracks formed due to early plastic shrinkage and increases the resistance to impact, abrasion and toughness. The fibres can also be added to precast concrete to improve resistance. It is added to pumped concrete to improve cohesiveness. Fibres are added to shotcrete to reduce rebound and material waste. The author concluded that replacing the wire mesh as secondary reinforcement it inhibits the early shrinkage cracking.

Faisal Fouad Wafa [4], said that the concrete is weak in tension and is brittle in nature. Continuous reinforcement used in concrete helps to increases the strength and ductility only when done with proper workmanship. When crack occurs due to shrinkage, the randomly oriented fibres will arrest the formation of cracks. Fibres also arrest the propagation of cracks. It improves the strength and ductility property of concrete. The expected failure modes of fibre are bond failure between fibre and matrix or material failure. The author concluded that workability problem was not encountered when hooked fibre are used up to 1.5 percent in the concrete mix. The straight fibre produces balling at high fibre content and requires special handling procedure to improve the ductility of concrete. Fibre reinforced concrete controls cracking and deformation under impact load. The results are much greater than plain concrete and increased the impact strength of 25 times.

M.A.Islam [5] et al, has discussed about the effectiveness of using polymer modified concrete (PMC) as a construction material. A detailed literature survey reveals that the concrete property can be varied by varying the nature and concentration of polymer materials. They mentioned about the applications such as protecting the constructed structures from floods, earthquakes, saline water and landslides at embankments. The author concluded that PMC possess remarkable potential due to its features, properties and applications. The material can effectively respond to the needs of current and future construction works. Infrastructure can be repaired by using polymer modified concrete. It will be extremely feasible and with low maintenance requirements.

Kolli. Ramujee [6], the compressive strength and split tensile strength of samples were compared for various proportions of fibre like 0.5%, 1.0%, 1.5% and 2.0%. There was a reduction in slump value was noted by the author with increasing proportion of fibre content. The author concluded that with 1.5% of fibre content produces optimum result when
compared with other sample. The optimum increase in compressive strength was noted as 34% and split tensile strength as 40% when compared with conventional concrete.

Mr. Mehul J. Patel [7] et al, said that the effect of various proportion polypropylene fibre on the properties of high strength concrete was carried out to analyze its effects on compression, tensile, flexural, shear strength and plastic shrinkage cracking. To find the optimum percentage of polypropylene fibre content in the concrete mix, test was carried out for 0.5%, 1%, 1.5% of fibre at different age level of concrete. The author concluded that the polypropylene fibre can be used as partial replacement for cement along with admixtures to increase the strength of concrete. Result showed that the workability of polypropylene fibre replaced concrete is decreasing with increase in polypropylene fibre content.

H.R. Pakravan [8] et al, the fibres plays an important role in improving the cementitious composites fracture toughness. The author discussed about the adhesion between the polymeric fibre and cement matrix. The pull-out behaviour of all tested fibres was almost same for 7 and 14 days curing specimens. But the author found increase in pull-out load of all 28 days curing specimens. Results were proved that N66 fibres can undergo pull-out load.

Saeed Ahmed [9] et al, the author said that the polypropylene fibre is synthetic hydrocarbon polymer so the effect of addition of various proportion of polypropylene fibre in concrete mix gives the notable increase in flexural, tensile and shear strength. The author concluded that the shrinkage cracking is reduced by 83-85% by addition of fibre in the range of 0.35 to 0.50% and the shear capacity is increased when the fibres are added but the effect of addition of polypropylene fibre does not increase the value of compressive strength was found.

M. Sivaraja [10] et al, said that the mechanical strength properties of synthetic fibres with volume fractions (0.5%, 1% and 1.5%) and aspects ratios (30, 60 and 90) were evaluated. Concrete mixed with rural waste fibres improved mechanical strength. Steel, nylon, plastic and coir fibres in mechanical strength enhancement were found more than that of other fibre. The author concluded the optimum volume fraction of fibres was 0.5 -1%. Fibre reinforcing index was most influential parameter and increase in strength of fibrous concrete is proportional to fibre reinforcing index of all proposed models exhibited correct correlation with experimental results.

D. Van Gemert [11] et al, discussed about the materials behaviour, especially in the field of admixtures, and about the curing processes. The author concluded that the polymer has no longer special construction materials that replace classical minerals or organic building materials. As the result polymer is now the vital component in the production of composite and sustainable building materials.

Youjiang Wang [12] et al, discussed about the experimental study conducted. Examined the tensile properties of reinforced concrete with acrylic, nylon and aramid fibres, in the form of random distribution by means of three different tests are compact tension, flexural and split
tensile test. The authors were found that the strength was improved by the inclusion of fibres for reinforcement. The author concluded that the small volume fraction synthetic fibre (2 to 6.5%) added during preparation of a cement matrix have shown significant resistance to failure.

3. EXPERIMENTAL DATA

Polypropylene Fibre: It is hydrophobic. They do not absorb. It has no effect on concrete mixing water requirement. They are available either as fibrillated bundles or monofilaments. To produce fibrillated fibres, manufacturers extrude the polypropylene in sheets that can be stretched and slit. The result is a mesh of interconnected fibre stands and is rectangular in cross section. With fibrillated fibres cement paste penetrates into the network of fibre filaments resulting in better mechanical anchoring to the concrete. The shredded fibres are partially replaced to fine aggregates with volume fraction of 20%, 40% and 60%.

| Fibre      | Specific Gravity | Length in inches | Tensile Strength in psi | Young’s Modulus in ksi |
|------------|------------------|------------------|-------------------------|------------------------|
| Polypropylene | 0.91             | ¼-2½             | 80-110                  | 500-700                |
| Polyethylene | 0.91              | ½-¾              | 40-100                  | 500-700                |
| Polyester  | 1.34              | ¾-2              | 80-170                  | 1450-2500              |
| Nylon      | 1.16              | ¾-2              | 130                     | 750                    |

Table 3.1 Properties of synthetic fibre

Cement: It can be defined as the binding material possesses cohesive and adhesive properties. It makes the cement effective to unite different types of construction materials and form the compacted assembly. Ordinary Portland cement is one of the most widely used types of cement. A mixture composed of properly homogenized limestone and clay. It consists of inorganic oxides; the main one is lime (CaO) with a basic function and silica (SiO2) which is acidic in nature. The cement has the specific gravity of 3.02 and the physical properties are conforming to IS: 12269 – 1987. The cement used was Ordinary Portland cement (53Grade) with a specific gravity of 3.15. Initial and final setting times of the cement were 65 min and 197 min, respectively.

Aggregates: IS 383 & 2386 is the publication deals with specifications for Coarse and Fine aggregates from natural sources for Concrete. These specifications do not specify any limit for fineness modulus to be used in concrete. It divides the sand in four zones i.e. from Zone I to Zone IV. Zone I–Sand being very coarse and Zone 4 sand is very fine. It is generally recommended by code to use sands of zones I to Zone III for Structural concrete works. The fine aggregate shall have not more than 45% passing any sieve and retained on the next consecutive sieve and its fineness modulus will not be less than 2.3 and not more than 3.1.
The River sand was used as fine Aggregate and conforming to Zone III with specific gravity of 2.6, Bulk density of 1680 kg/m³. Coarse Aggregates are Crushed angular granite metal from a local source was used. The Specific gravity was 2.70, Bulk density of 1450 kg/m³ with void percentage 1.5. The physical properties are confirming to IS: 2368-1968.

Water: A concrete mix contains the minimum amount of portable water that has been required for complete hydration of cement. If the concrete is fully compacted it helps to develop the maximum attainable strength at preferable age.

Mix Proportion: The Concrete mix design has been calculated for various proportions and arrived at final mix proportion. It is used for combining the initial materials. After mixing the initial materials, fibres were added. In this the concrete samples were prepared with fibre ratios of 20, 40 and 60% by volume. The ratio of water added to the cement was w/c = 0.50.

| Ingredient        | Quantity in Kg/m³ |
|-------------------|-------------------|
| Water             | 0.745             |
| Cement            | 1.49              |
| Fine aggregate    | 2.02              |
| Coarse aggregate  | 3.74              |
| Water cement ratio| 0.5               |

**Table 3.2 Mix proportion of M20 grade concrete**

Test to be conducted: The properties of conventional concrete and partially replaced fibre concrete are to be determined in fresh and harden concrete. The fresh concrete test’s considered is slump cone test, compaction factor test, flow table test and Vee Bee consistometer test. To determine the hardened concrete properties, cube with 150x150x150mm, beam with 500x100x100mm and cylinders with 150x300mm height are to be casted. Harden concrete test to be performed are compression test, flexure test and split tensile tests cube, beam and cylinder respectively.

4. RESULTS AND DISCUSSION

COMPARISION OF SLUMP VALUES: The workability of concrete mix is mainly determined to find the type of construction, placing condition and the means of compaction required. The properties of fresh concrete, amount and condition of reinforcement, the shape and size of mould are important factor, which control workability. Workability was measured in terms of slump. The slump test results for conventional concrete and with different percentage of polypropylene fibres are given in table 4.1.
| Sample                        | Slump Height in cm | Workability  |
|-------------------------------|--------------------|--------------|
| Conventional concrete        | 25                 | Good         |
| 20% fibre replaced concrete  | 26                 | Very Good    |
| 40% fibre replaced concrete  | 28                 | Very Good    |
| 60% fibre replaced concrete  | 28                 | Very Good    |

**Table 4.1 Comparison of slump cone results**

**Slump Cone Test - Results**

![Slump Cone Test - Results](image)

**Fig 4.1 Comparison of slump cone results**

From the result it is observed that the workability of conventional and polypropylene fibre replaced concrete are good.

**Comparision of Compaction Factor Values:** Workability of a concrete indicates the full compaction of concrete using a required amount of work. It helps to achieve the desired possible density of fresh concrete with better strength and durable structure. It helps to maintain durability throughout the job. Workability was measured in terms of compaction. The compaction factor test results for conventional concrete and different percentage of polypropylene fibres are given in table 4.2.

| Sample                        | Density of partially compacted concrete | Density of fully compacted concrete | Compaction Factor |
|-------------------------------|----------------------------------------|-----------------------------------|-------------------|
| Conventional Concrete         | 25                                     | 25                                |                   |
| 20% Replaced with Fiber       | 26                                     | 26                                |                   |
| 40% Replaced with Fiber       | 28                                     | 28                                |                   |
| 60% Replaced with Fiber       | 28                                     | 28                                |                   |
Table 4.2 Comparison of compaction factor values

| Fibre Replacement Percentage | Compaction Factor | Workability Reduction |
|-----------------------------|-------------------|-----------------------|
| Conventional Concrete      | 8.44              | 0.81                  |
| 20% fibre replaced concrete | 8.09              | 0.84                  |
| 40% fibre replaced concrete | 8.7               | 0.77                  |
| 60% fibre replaced concrete | 8.9               | 0.67                  |

From the graph it is observed that 20% replaced concrete has a compaction factor of 84% hence it can be used for reinforced concrete structures. The compaction factor for 40% and 60% replaced fibre are 77%, 67% respectively and these can be used for road pavements.

COMPARISION OF VEE-BEE CONSISTOMETER VALUES: In general workability reduces with higher dosage of fibres compared to initial dosage used. Due to increase in addition of fibres, there is increase in amount of entrapped air voids. This is due to presence of fibres and hence it contributes to increases in air content which reduces the workability of concrete. When fibre content replacement percentage is increased, it is noted that difficulty in compaction of the mixes. It may also tend to cause improper finishing problem. The vee-bee consistometer test results for conventional concrete and different percentage of polypropylene fibres as shown in table 4.3.
Table 4.3 Comparison of vee-bee consistometer values

According to the results both 20% and 40% replaced concrete mix gives good workability than conventional concrete. The slump loss occurs when the fine aggregates are replaced by 60% of polypropylene fibre.

**Veebee Consistometer - Results**

COMPARISION OF FLOW TABLE VALUES: It is used to determine consistency of fresh concrete. The concrete will not possess the required strength if the consistency of concrete is not at the desired level. If concrete is too pasty, cavities may form with in the concrete itself. Reinforcement bars may become corroded and the concrete will begin to form cracks. Cavities and cracks reduce the strength of concrete. The flow table test results for
conventional concrete and different percentage of polypropylene fibres are shown in table 4.4.

| Sample                           | Original Diameter in mm | Spread Diameter in mm | Flow % |
|----------------------------------|-------------------------|-----------------------|--------|
| Conventional concrete            | 250                     | 470                   | 88     |
| 20% fibre replaced concrete      | 250                     | 462                   | 85     |
| 40% fibre replaced concrete      | 250                     | 460                   | 84     |
| 60% fibre replaced concrete      | 250                     | 450                   | 80     |

Table 4.4 Comparison of flow table values

FLOW TABLE - RESULTS

Fig4.4 Comparison of flow table values

COMPARISION OF COMPRESSIVE STRENGTH: In general, improvement in strength factor is observed due to fibre addition. It is mainly due to confinement provided by the fibre when added to concrete. The test results are shown in table 4.5.

| Sample                        | Load in KN | Fibre Dosage in kg/m³ | Compressive Strength in N/mm² |
|-------------------------------|------------|------------------------|-------------------------------|
|                               | 7 Days     | 28 Days                | 7 Days                        | 28 Days                       |
| Conventional concrete         | 350        | 460                    | 0.0                           | 15.5                          | 20.4                          |
Table 4.5 Comparison of compressive strength

| Fibre Dosage | Compressive Strength (N/mm²) |
|--------------|------------------------------|
| 20% replaced fibre concrete | 400 | 480 | 0.24 | 17.77 | 21.33 |
| 40% replaced fibre concrete | 360 | 410 | 0.68 | 16.0 | 18.22 |
| 60% replaced fibre concrete | 320 | 340 | 1.14 | 14.3 | 15.1 |

It has been observed that the addition of 20% of polypropylene fibres to the mix increases both 7 days and 28 days compressive strength than conventional concrete. Also it is observed that 60% fibre replaced concrete shows reduction in compression strength.

Fig 4.5 Comparison of compressive strength

COMPARISION OF SPLITT ENSILE STRENGTH: In general, the split tensile strength test does not give appropriate result about direct tensile strength. The strength is due to mixed stress field and orientation of fibres. The failure pattern of the concrete gives clear idea about the ductility of the material. Failure patterns of split tensile test indicate that a specimen after first cracking does not separate due to failure of the structure. The split tensile strength test results for conventional concrete and different percentage of polypropylene fibres as shown in table 4.6.

| Sample | Load in KN | Fibre Dosage | Split Tensile Strength in N/mm² |
|--------|------------|--------------|---------------------------------|
| Conventional Concrete | 15.5 | | 20.4 |
| 20% Replaced with Fiber | 17.77 | 21.33 |
| 40% Replaced with Fiber | 16 | 18.22 |
| 60% Replaced with Fiber | 14.3 | 15.1 |


|                                | 7 Days | 28 Days | in kg/m³ | 7 Days | 28 Days |
|--------------------------------|--------|--------|----------|--------|--------|
| Conventional concrete          | 80     | 170    | 0.0      | 1.13   | 2.44   |
| 20% replaced fibre concrete    | 150    | 180    | 0.38     | 2.12   | 2.55   |
| 40% replaced fibre concrete    | 100    | 130    | 1.09     | 1.41   | 1.83   |
| 60% replaced fibre concrete    | 90     | 110    | 1.79     | 1.27   | 1.55   |

Table 4.6 Comparison of split tensile strength

From the result, it has been observed that 7 days and 28 days split tensile strength of the concrete with the dosage of 20% fibre replaced concrete is higher than conventional concrete. Further dosage of fibres to the concrete mix reduces the tensile stress of concrete.

COMPARISION OF FLEXURAL STRENGTH: Nominal increase in strength was observed for all the proportions of fibres when compared to normal mixes. The
improvement in flexural strength is recorded due to the improvement in mechanical bonding between the cement paste and fibre. As amount of fibre increases in mix, it extensively helped to reduce the widening of crack more effectively, hence resulted in increase in flexural strength. In order to execute further, to increase the crack opening the applied load need to be increased, this leads to the formation of another crack. The split tensile strength test results for conventional concrete and different percentage of polypropylene fibres as shown in table 4.7.

| Sample                          | Load in KN     | Fibre Dosage in kg/m³ | Flexural Strength in N/mm² |
|---------------------------------|----------------|------------------------|----------------------------|
|                                 | 7 Days | 28 Days |                                 | 7 Days | 28 Days |
| Conventional concrete           | 5.5    | 6.0     | 0.0                        | 2.75   | 3.0     |
| 20% fibre replaced concrete     | 5.9    | 6.5     | 0.35                       | 2.95   | 3.25    |
| 40% fibre replaced concrete     | 5.0    | 4.5     | 1.01                       | 2.5    | 2.25    |
| 60% fibre replaced concrete     | 4.0    | 3.5     | 1.67                       | 2.0    | 1.75    |

Table 4.7 Comparison of flexural strength

![Flexural Strength Test - Results](image)

**Fig 4.7 Comparison of flexural strength**

It has been observed that the addition of polypropylene fibres with 20% dosage to the mix increases the 7 days and 28 days flexural strength of the concrete confinement provided by fibres. Further addition of fibres reduces the strength of the specimen.
5. CONCLUSION

The automobile plastic waste is a threat to the environment when it is disposed; therefore it is used effectively in the concrete mixture as fibre to improve the strength and workability of concrete. The fresh and hardened properties of conventional concrete are compared with the various percentage additions of fibres in concrete. From the test result the following observations are made,

- The workability of conventional and partially replaced polypropylene concrete are good and satisfies the limit
- The addition of polypropylene fibres of about 20% actually increases the 7 days and 28 days compressive strength. When the replacement is 20% the compressive strength is found to increase by 10% than conventional concrete. When the proportion of fibre is increased to 40% the strength decreases by 3% to 6% than conventional concrete.
- The tensile strength gets increased to 5%~10% when fine aggregate is replaced by 20% of fibres. Further addition of fibres gives lower strength than the conventional concrete.
- The flexure strength gets increased to 7%~8% when 20% fibres are replaced the fine aggregates in concrete. After which strength starts reducing with further addition of fibre in concrete. From the results we can conclude that the proportion of fibre added should be limited to maximum of 20%. If the higher percentage is added the negative effect is observed and the strength of concrete degrades. Thus the proper percentage composition of polypropylene fibre used with concrete will improve the strength and workability of concrete.

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