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Polypropylene Fiber Reinforced Fly Ash Concrete – A Literature Review

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Abstract: Concrete is a composite material consisting of cement, water and aggregates. Concrete is sufficiently strong in compression but weak in tension. Concrete is widely used as construction material worldwide. It consumes most of the natural aggregates. Due to high speed in development of infrastructure, the natural aggregates are being fall short off. To ensure long life and sustainability of concrete construction materials, it is the need of the hour to preserve the natural aggregates. One such attempt is to utilize the waste products from industry in the manufacture of concrete. The waste products are fly ash, silica fume, rice-husk, polypropylene, marble powder, foundry sand etc. The necessity of utilization of waste materials as a component of concrete composite can be in the form of either replacement of ordinary Portland cement by a waste having similar cementing properties and fine aggregate having similar composition and waste materials can also be added to concrete composites so as to improve the properties of concrete composite. This will help in management of preservation of natural aggregates, saving in energy for production of cement, utilization of waste which is a problem for thermal power plants as well as industries, saving in greenhouse gas emission, economical construction material, green concrete composite and many more factors.

Keywords: *Concrete, Fly ash, polypropylene fibers, workability, compressive strength, flexure strength, split tensile strength, water absorption, freeze-thaw resistance and abrasion resistance*

1. Introduction

Concrete is most widely used man made construction material in the world and is second to water as the most utilized substance on the planet [42]. Concrete has its mould ability in to any required structural form and shape due to its fluid behavior at early ages [30]. Concrete essentially consist of a binder and mineral filler. This is the only construction material which is manufactured at site [45]. The concrete industry uses 12.60 billion tons of raw materials each year and hence, is the largest user of natural resources in the world [8]. The global production of concrete has reached a value of more than one ton of concrete per capita of planet [5]. Concrete made with Portland cement has certain characteristics; it is relatively strong in compression but weak in tension and tends to be brittle [46]. This poor tensile strength of the concrete is overcome by adding steel reinforcement in the tension zone by providing long bars. The brittle nature of concrete can be overcome by the application of discrete fibers. Reinforcement with fibers has been proved an effective and economical way to convert cementitious material in to a tough and ductile product [3]. The conventional concrete has limited ductility, low impact and abrasion resistance and little resistance to cracking. To improve the ductility of concrete composite polypropylene fibers have been added in small proportion to improve its performance. The ductility of concrete composite depends on the ability of the fibers to bridge cracks at high level of strain. It is well demonstrative that the sudden failure of brittle concrete is eliminated with the addition of discrete fibers and gradual release of fracture energy. Fibers inhibit micro crack formation by strengthening the matrix and thereby control brittle failure [38]. Extensive research on fiber reinforced concrete began in 1960 [23]. Fiber reinforcement is predominantly used for crack control and not for structural strengthening [46].

1.1 Fly ash

Fly ash is a finely divided mineral residue resulting from combustion of coal in electric generating plant [11]. Fly ash is removed from the combustion gases by the waste collection system either mechanically or by using electrostatic precipitators before they are discharged to the atmosphere. According to the American Concrete Institute (ACI) committee 116 R, fly ash is defined “The finally divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the particle removal system” (ACI Committee 232, 2004) [2]. The estimated annual worldwide production of fly ash is of the order of 1000 million tons at present and is likely to exceed 2000 million tons by 21st century [45]. The dumping of fly ash in open fields results in ecological and environmental problems. Fly ash is by product and less inexpensive than Portland cement [6]. Fly ash possesses good pozzolanic properties and is commonly used in concrete in replacement ranging from 0 to 30% by mass of total cementitious materials. The use of fly ash to partly replace cementing material in concrete addresses the sustainability issue and its adoption will enable the concrete construction industry to become more sustainable [32]. The earlier studies established that fly ash could be transformed from a waste product to useful by product use in concrete [10]. In recent times the importance and use of fly ash in concrete has grown up so much that it has almost become a common ingredient of concrete [13]. Fly ash can be used as an additive or by replacing a fraction of cement in concrete. The use of fly ash in concrete enhances the long term strength and durability [25]. Use of pozzolan not only decreases environmental pollution but also improves the properties of concrete [17]. These are generally finer than cement and consist of spherical particles of size between 10 to 100 microns. The earliest work on record to indicate the use of fly ash was reported in 1932. The first overall comprehensive work on the use of fly ash in concrete was reported by Davis and his associates of the University of California in 1937 [5]. In India first ever study on fly ash in concrete was carried out in 1955 by CBRI Roorkee [2]. The pozzolanic properties of fly ash were first reported in the 1914 edition of engineering news USA. The era of fly ash concrete originated in USA [45]. The replacement of OPC in contest of BIS 456 is of the order of 35% by mass of cementitious materials [12].

1.1.1 Technical benefits

The use of fly ash in concrete as a construction material results in following technical benefits [45]:

- Reduced bleeding and segregation
- Improved finished ability and flow properties
- Increase cohesiveness leading to excellent pump ability
- Reduced heat of hydration
- Increase resistant to cracking
- Increase durability
- Increase resistance to chemical attack

1.1.2 Chemical composition of fly ash

The important chemical compositions of fly ash are as under [45]:

Oxides	Mass Percentage	
	Low Lime fly ash (F)	High Lime fly ash (C)
SiO_2	50	40
Ai_2O_3	28	18
Fe_2O_3	3	8
CaO	3	20
MgO	1	4
SO_3	1	2
Others	8	8

1.2 Polypropylene fiber

Polypropylene is a versatile and widely used polymer, Polypropylene fiber resins are a general class of thermo plastics produced from polypropylene gas. It is petroleum by product [6]. Polypropylene additions in cement concrete have shown significant improvement in the strength, durability of cement matrix and acts as fill materials for the pores in concrete [40]. Polypropylene fibers are new generation chemical fibers. They are manufactured on large scale and have fourth largest volume in production after polyesters, polyamides and acrylics [24]. About 4 million tonnes of polypropylene fibers are produced in the world in a year [19].

Polypropylene fibers were first suggested for use in 1965 as an admixture in concrete for construction of blast resistant buildings meant for the US Corps of Engineers [19].

Polypropylene fiber is used in the construction industry as a secondary reinforcement which arrests cracks, increases resistance to impact/abrasion and greatly improves the quality of construction [14].

These fibers are manufactured using conventional melt spinning [24]. The commonly used fibers are steel, glass, polymeric, carbon, asbestos and natural fibers. The polymeric fibers such as polypropylene, polyethylene, polyester and acrylic fibers are becoming popular these days [30].

Polypropylene fibers were formerly known as Stealth. These are micro reinforcement fibers and are 100% virgin homopolymer polypropylene graded monofilament fibers. The raw material of polypropylene is derived from monomeric C_3H_6 which is purely a hydrocarbon.

In ordinary concrete, where vibration is necessary, the best and most acceptable method for preventing cracks formation caused by paste contract is by using fibers. The use of polypropylene fibers has increased tremendously in construction of structures because addition of fibers in concrete improves the toughness, flexure strength, tensile strength and impact strength as well as failure mode of concrete [34]. Polypropylene fiber are used for secondary temperature shrinkage reinforcement, overlays and pavements, slabs, flooring systems, precast pile shells and shotcrete for tunnel linings, canals and reservoirs [18].

For effective performance, the recommended dosage rate of polypropylene fibers is 0.9 kg/m^3 [19]. Polypropylene fiber is a synthetic fiber with low density, fine diameter and low modulus of elasticity. It has special characteristics such as high strength, ductility, and durability, so, it can be widely utilized in concrete products [23].

Without any fiber in concrete, micro cracks develop due to plastic shrinkage, drying shrinkage and due to change in volume of concrete by any reason. These micro cracks cause elastic deformation of concrete [37].

Concrete composite with fibers, packs the occurrences of cracks in matrix and support the matrix itself so that the next crack must occur anywhere else. It prevents the propagation of cracks. Failure develops as a gradual of concrete like plastic yielding.

Fiber reinforcement when used in the form of short discrete fibers, they act effectively as rigid inclusion in the concrete matrix and may be used in the form of three-dimensionally randomly distributed fibers throughout the structural member, have added advantages of the fiber to shear resistance and crack control can be further utilized [28]. The most frequent used reinforcement's synthetic fibers in the last decades were included organic fibers (Acrylic, polyvinyl alcohol, polyolefin, polyethylene and polypropylene) and inorganic fibers (alkali resistant glass and carbon) [3]. By using polypropylene fibers in paver blocks, it increases compressive strength of paver blocks, reduces the maintenance cost and improves the life span of the paver blocks [14].

The density of concrete composite decreases by addition of polypropylene fibers whereas the mechanical strength increases. The most important fiber parameters which affect the mechanical behavior of the composites are geometry, distribution, orientation and volumetric properties of fibers in the matrix.

1.2.1 Advantages of polypropylene fiber

The following are important advantages:

- Polypropylene fibers are Non-Magnetic
- Polypropylene fibers are rust free
- Polypropylene fibers are safe and easy to use
- Polypropylene fibers are alkali resistance
- Polypropylene fibers are cheap
- Polypropylene fibers are abundantly available and are of consistent quality
- Polypropylene fibers are compatible with concrete chemical admixtures
- Polypropylene fibers can be handled with ease
- Polypropylene fibers are chemically inert and hence any chemical that will not attack the concrete constituents will not have effects on fiber also. When more aggressive chemicals come in contact the concrete will always deteriorate first before fibers
- Polypropylene fiber has hydrophobic surface not being wet by cement paste which helps to present balling effect by chopped fibers
- The water demand of polypropylene fiber in concrete is nil
- No need of minimum amount of concrete cover
- Presence of fibers reduce the settlement and bleeding of concrete. Polypropylene fiber improves resistance to abrasions, freeze and thaw resistance and impact resistance
- Polypropylene fiber is fire resistance material

2. Literature Review

The term fiber reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine and coarse aggregates and discontinuous discrete fibers [1].

Many researchers have investigated the effect of various types of fibers on the mechanical and durability properties of concrete, which are presented as under:

2.1 Properties of Fresh Concrete

With addition of fibers, the entrapped air voids increase and hence the increased air content reduces the workability causing difficulty in compaction of mixes.

S. N. Sachdeva, et al [33], conducted experimental study on high volume fly ash concrete for paver blocks of grades M30, M35, M40 and M50 with maximum nominal size of aggregate 12.5mm crushed and zero slump. It was concluded that with addition of fly ash the water to cementitious material ratio reduces for all mixes for same level of workability.

J. J. Raju and J. John, [32], studied the strength of high volume fly ash concrete with fibers (Recron 3S) and concluded that the slump and compaction factor values decreases with fiber addition. The fly ash based concrete performs well at later stage than at early age.

J. P. Mehul and S. M. Kulkarni, [22], found in their research that workability of concrete decreases with increase in polypropylene fibers in terms of volume fraction.

M. Parsad, et al, [30], compared polypropylene fiber reinforced silica fume concrete with plain cement concrete and reported that the slump decreases with increase in polypropylene fiber content.

S. Thirumurgan and A. Sivakumar, [40], reported that the workability of concrete with polypropylene fibers and fly ash decreases but it can be overcome by adding of High Range Water Reducing Admixtures.

R. Kolli, [18], studied the fresh properties of polypropylene fiber (PPF) reinforced concrete by adding PPF ranging from 0%, 0.5%, 1%, 1.5% and 2%. It was concluded that the reduction in slump with increase in fiber content, especially beyond 1.5% dosage.

C. Marthong and T. P. Aggrawal, [20], studied the effect of concrete properties when OPC of varying grades partially replaced by fly ash in variation of 10%, 20%, 30% and 40%. The researchers concluded that the use of fly ash improves the workability of concrete and workability increases with the decrease in the grade of cement.

P. A. Patel, et al, [28], reported that the workability of concrete reduces with higher polypropylene fiber content.

O. Gencel et al, [09], studied the workability properties using mono-filament polypropylene fibers in self-compacting concrete with fly ash and reported that, an addition of fibers in general causes loss of flow and workability, but in this study have good flow and workability.

I. Patel and C. D. Modhera [27], studied fiber reinforced concrete containing high volume fly ash of grades M25, M30, M35 and M40 concrete with different percentages of F type fly ash 50%, 55% and 60% in addition to 12mm triangular shaped polypropylene fiber @ 0.25% by mass of cementitious material. It was reported that the compaction factor remained between 0.85 and 0.94 for different mixes, which was suitable.

2.2 Properties of hardened concrete

2.2.1 Compressive strength

Compressive strength of concrete is one of the most important properties of concrete. It is a qualitative measure of concrete. Failure of concrete under compression is a mixture of crushing and shear failure. The compressive strength varies as a function of both cement paste and fibers. Higher binder ratio gives higher compressive strength.

O. Gencel et al, [09], reported that compressive strength was increased by PP Fiber inclusion.

J. J. Raju and J. John, [32], studied the strength properties of high volume fly ash concrete with fibers at 0.1%, 0.2% and 0.3% of cement and with 60 % fly ash replacement with cement. It was found that fiber addition had increased compressive strength by 12.5% over control mix.

V. K. Singh and D. Kumar, [37], studied the fiber content variation from 0.1%, 0.3%, 0.5% and 0.7 % by weight of concrete with 75% glass fiber and 25 % polypropylene fiber. The results showed that compressive strength of concrete increased with addition of fibers in M25 grade. For better results 0.5% addition of fibers was optimum.

S. N. Sachdeva, et al, [33], studied high volume fly ash concrete for paver blocks for M30, M35, M40 and M50 grade size with maximum nominal size of aggregate 12.5mm with zero slump. It was concluded that 90 days cube compressive strength increased up to 30% of fly ash after that its value falls.

V. K. Singh, [37], studied the effect of polypropylene fibers with different percentages of 0% to 0.7% addition of polypropylene fiber in Portland cement for M25 grade of concrete and it was found that the addition of 0.35% fiber showed better results of compressive strength.

A. P. Sathe, [34], experimented on polypropylene fiber reinforced concrete with artificial sand. The various types of fiber used in investigation were glass, carbon, steel, asbestos, polyester and polypropylene. The results showed that the crushed sand may be used as a substitute to natural sand. The addition of polypropylene fiber in the range of 0.1% to 1.5% improved compressive strength of concrete by about 8% - 16%.

B. K. Narenda, [25], studied the compressive strength on design mixes M30, M40 and M50 for cement replacement levels of 20%, 35% and 50% for different periods of curing. It was concluded that as curing period was advanced the strength of Fly Ash Concrete (FAC) and Normal Concrete (NC) increased. The addition of Fly ash was found to reduce the compressive strength in comparison to NC at early ages. There was marked increase of compressive strength between 28 days and 56 days and a slight increase thereafter up to 91 days.

A. Sivakumar, et al, [38], studied the influence of fiber addition in concrete mix by adding both steel and polypropylene fibers, Addition of steel fiber dosage was done at 1% to 2% volume fraction (vf) and inclusion of polypropylene fiber dosage at 0.1% to 0.3%. It was concluded that maximum increase in compressive strength was observed at 1% volume fraction of glued steel fibers and 0.1% of polypropylene fibers.

J. P. Mehul and S. M. Kulkarni, [22], used fibrillated polypropylene fiber in percentages of 0.5%, 1% and 1.5% in high strength concrete with super plasticizer. It was observed that the compressive strength of concrete increased with addition of fibers.

K. Murahari and R. M. Rao, [24], studied the effect of polypropylene fibers in fly ash concrete using fiber volume fraction of 0.15%, 0.20%, 0.25% and 0.30% with class C fly ash. It was concluded that the compressive strength increased gradually from 0.15% to 0.30% fiber content.

B. K. Kashiyani, et al., [16], studied the addition of polypropylene fiber in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that addition of 0.4% fiber mixed in concrete paver block had the maximum compressive strength up to 40%.

R. Kolli, [18], studied the strength properties of polypropylene fiber reinforced concrete by adding Polypropylene Fiber (PPF) ranging from 0%, 0.5%, 1%, 1.5% and 2%. It was concluded that the maximum increase in compressive strength was 34% as compared to mix without fibers at optimum dosage of fibers as 1.5%.

S. Thirumurgan and A. Sivakumar, [40], analyzed the influence of crimped polypropylene fiber in cementtitious matrix, the addition of crimped polypropylene fibers of 0.1% and 0.3% with water cement ratio 0.3 with fly ash 25% and 50% with HRWR admixture. It was concluded that polypropylene fiber of 0.3% by volume fraction showed higher compressive strength with HRWR admixtures.

J. Chamundeswari, et al, [06], studied the polypropylene fiber reinforced concrete using fly ash class C in ratios 50%, 55% and 60% with replacement of cement and Polypropylene fiber in dosage of 0.9% for M35 grade. It was concluded that 50% replacement of fly ash gave good strength and at dosage more than 50%, it showed decrease in strength. At extended curing period, fly ash started to react and gain more strength. It could be treated as an eco-friendly concrete.

P. A. Patel, et al, [28], reported that the compressive strength increases with increasing fiber content and addition of 1.5% of polypropylene fiber by volume of concrete has beneficial effect of strength enhancement.

T. Uygunglo, et al., [41], studied the influence of fly ash content @ 0%, 10%, 20%, 30% and 40% and replacement of crushed sand stone aggregate with @ 0%, 10%, 20%, 30% and 40% concrete waste and marble waste in prefabricated concrete interlocking blocks and concluded that compressive strength decreases as the fly ash replacement ratio increased.

Y. Shrivastava and K. Bajaj, [36], studied the performance of high volume fly ash concrete in pavement design and found that compressive strength increases with increase in replacement of cement up to 35%.

C. Marthong and T. P. Aggrawal, [21], studied the variation of fly ash dosage of 10%, 20%, 30% and 40% in replacement of Ordinary Portland Cement (OPC) of 33, 43 and 53 grades. It was concluded that compressive strength of concrete increases with grade of cement. Fly ash concrete is more durable as compared to OPC concrete and fly ash up to 40% replacement increase with grade of cement.

I. Patel and C. D. Modhera, [27], studied fiber reinforced concrete containing high volume fly ash of grades M25, M30, M35 and M40 with different percentages of F type fly ash 50%, 55% and 60% in addition to 12mm triangular shaped polypropylene fiber @ 0.25% by mass of cementitious material. It was concluded that 55% cement replacement shows optimum gain of compressive strength for all grades of plain and fiber reinforced HVFA.

C. Marthong, [21], investigated the size effect phenomenon for concrete with 20% fly ash on partial replacement of cement. The result showed that the gain in long term strength was maximum for small specimen and it decreased as the specimen size increased. This was an indication for existence of size effect. The size effect on fly ash concrete was observed to be more at early age as compared to later age.

V. M. Sounthararajan, et al., [39], investigated the replacement level of fly ash at 25% and 50% with addition of polypropylene fiber from 0% to 0.3%. It was concluded that addition of 0.1% volume fraction (vf) of polypropylene fibers has increased compressive strength up to 7.92% and 23.33% at 7 days and 28 days respectively.

M. V. K. Rao, et al, [31], studied the behavior of polypropylene fiber reinforced concrete deep beams with PP fiber (recron 3S) content (0%, 0.5% and 1%) with 20% fly ash as cement replacement and reported a marginal increase in compressive strength as the fiber content increases.

R. A. Mtasher, et al., [23], carried out strength prediction of polypropylene fiber reinforced Concrete. The results showed that the compressive strength increased with the inclusion of polypropylene fiber in the amount of 0.4% and 1.5%.

2.2.2 Split tensile strength

Split tensile strength can be determined either by direct methods, or indirect methods. The direct method has difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and in application of uni-axial tensile load which is free from eccentricity to the specimen.

The splitting test is the well-known indirect test, in which compressive line load is applied along the opposite generators with the cylinder axis being horizontal between the compression plates.

J. J. Raju and J. John, [32], studied the strength properties of high volume fly ash concrete with fibers at 0.1%, 0.2% and 0.3% of cement and with 60% fly ash replacement with cement. It was found that fiber addition had more split tensile strength.

A. P. Sathe, [34], experimented on polypropylene fiber reinforced concrete with artificial sand. The crushed sand was used as a substitute to natural sand. The result showed that the addition of polypropylene fiber in the range of 0.1% to 1.5% improved split tensile strength of concrete about 5% - 23%.

K. Murahari and R. M. Rao p, [24], investigated the strength properties of polypropylene fiber @ 0.15%, 0.20%, 0.25% and 0.30% with C class fly ash in the ratio of 30%, 40% and 50%. It was found that split tensile strength of concrete increased gradually by addition of PP fiber from 0.15% to 0.30%.

B. K. Kashiyani, et al., [14], studied the addition of polypropylene fiber in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that addition of 0.4% fiber mixed in concrete paver block had the maximum split tensile strength.

R. Kolli, [18], studied the strength properties of polypropylene fiber reinforced concrete by adding polypropylene fiber ranging from 0%, .5%, 1% and 2%. It was concluded that the maximum increase in split tensile strength was 40% as compared to mix without fibers. The optimum dosage was found to be 0.1%.

T. Uygunglo, et al., [41], studied the influence of fly ash content and replacement of crushed sand stone aggregate with concrete waste and marble waste in pre-fabricated concrete interlocking blocks and concluded that split tensile strength at 28 days have shown satisfactory results.

O. Gencel, et al., [09], conducted the split tensile strength test using fibers up to 0.9 kg/m^3. It was found that the split tensile strength increased with increasing fiber content. Fibers tend to bridge the micro cracks and hamper the propagation of cracks.

V. M. Sounthararajan, et al., [39], investigated the replacement level of fly ash at 25% and 50% with addition of polypropylene fiber from 0% to 0.3%. It was concluded that the split tensile strength improved with addition of 0.1% of polypropylene fibers. However with the higher dosage of polypropylene fibers showed a slight reduction in the split tensile strength.

2.2.3 Flexural strength

Flexural strength is one of the most important properties of concrete for assessing its suitability for concrete pavements. An accurate measurement of flexural strength of concrete helps in minimizing the cracking problem and reduces the risk of failure of concrete due to bending.

J. J. Raju and J. John, [32], studied the high volume fly ash concrete with fibers at 0.1%, 0.2% and 0.3% of cement and with 60% fly ash replacement with cement. It was found that fiber addition @ 0.1%, 0.2% and 0.3% had increased flexural strength.

M. V. K. Rao, et al, [31], studied polypropylene fiber fly ash concrete using polypropylene fiber content (0%, 0.5% and 1%) and 20% of fly ash in the beams for flexure and reported that ultimate flexure strength found increased from 0.5% to 1%.

V. K. Singh and D. Kumar, [37], studied the effect of fiber content varying from 0.1%, 0.3%, 0.5% and 0.7 % by weight of concrete. At every percentage of fiber content, 75% glass fiber and 25 % polypropylene fiber in M25 grade of concrete. The results showed that flexural strength of concrete increased with addition of fibers. For better results 0.5% addition of fibers was optimum.

S. N. Sachdeva, et al., [33], evaluated high volume fly ash concrete for M30, M35, M40 and M50 grade using 12.5mm maximum nominal size of aggregate and zero slump. It was concluded that 90 days cube flexural strength increased up to 30% fly ash level after that its value falls.

V. K. Singh and D. Kumar, [37], studied the effect of polypropylene fiber in different percentage 0% to 0.7% addition of polypropylene fiber in Portland cement concrete and it was found that addition of fibers marginally improve the flexural strength in M25 grade concrete. The addition of 0.25% of fiber showed better results.

A. P. Sathe, [34], experimented on polypropylene fiber reinforced concrete with artificial sand. The crushed sand was used as a substitute to natural sand. The result showed that the addition of polypropylene fiber in the range of 0.1% to 1.5% improves flexural strength up to 32%.

K. Murahari and R. M. Rao p, [24], investigated the strength properties of polypropylene fiber @ 0.15%, 0.20%, 0.25% and 0.30% with C class fly ash in the ratio of 30%, 40% and 50%. It was found that flexure strength of concrete increases gradually by addition of PP fiber from 0.15% to 0.30%. The maximum gain in strength at early age was observed.

M. Prasad, et al, [30], investigated on Polypropylene fiber reinforced silica fume concrete of M30 grade using silica fume @ 0%, 5%, 10%, 15% and fibers were added @ 0%, 0.2%, 0.4% and 0.6% by volume fraction of concrete. It was reported that the increase in flexural strength was around 40% with use of Polypropylene fibers and silica fume. The optimum dosage of PP was 0.4% and SF 10% for flexural strength.

R. A. Mtasher, et al., [23], studied strength prediction of polypropylene fiber reinforced Concrete. The results showed that the flexural strength increases with the inclusion of polypropylene fiber.

M. T. Selvi and T. S. Thandavamoorthy, [35], reported that the addition of steel and polypropylene fibers to concrete exhibit better performance for flexure strength.

B. K. Kashiyani, et al., [15], studied the addition of polypropylene fiber in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that the flexural strength was increased. The maximum results obtained at polypropylene fiber addition of 0.4% by weight of concrete paver block.

V. M. Sounthararajan, et al., [39], evaluated the composite polypropylene fiber reinforced concrete replacement level of fly ash at 25% and 50% with addition of polypropylene fiber from 0% to 0.3%. It was reported that a maximum strength with the fiber addition at 0.3% volume fraction.

J. Gummadi, et al., [11], studied the effect of particle size and its concentration on the properties of fly ash filled polypropylene composites. The concentration of fly ash varied from 0%, 10%, 20% and 25% by weight in the polypropylene composite. It was found that finest particles showed best flexural strength at all concentration. Fly ash was found to be good filler for polypropylene matrix composites. With fly ash added to polypropylene improves flexural strength. The spherical shaped fly ash gives significant improvement. Fly ash of smaller particle size showed significant improvement in strength of concrete composite as compared to large sized particles.

Y. Shrivastava and K. Bajaj, [36], studied the performance of fly ash and high volume fly ash concrete in pavement design and found that flexural strength increased with increase of fly ash up to 35% replacement in concrete.

I. Patel and C. D. Modhera, [27], studied the fiber reinforced concrete containing high volume fly ash of grades M25, M30, M35 and M40 concrete with different percentages of F type fly ash 50%, 55% and 60%, in addition to polypropylene fiber @ 0.25% by mass of cementitious material. It was concluded that 55% cement replacement showed optimum gain of flexural strength.

A. Karasava, et al., [47], studied the application of 25% fly ash as replacement of fine aggregate for manufacture of concrete paving blocks and concluded that the flexural strength was obtained 6MPa at 7 days age.

O. Gencel, et al., [09], reported that the flexural strength increases with addition of fiber content.

2.3 Durability properties

2.3.1 Water absorption

The water absorption test on concrete cubes of size 100mm x 100mm x 100mm is carried out in accordance with the prescribed specifications ASTM C642, 1993. Three specimens from each mix are tested at 28 days of age and average value is to be calculated.

B. K. Kashiyani, et al., [16], studied the addition of polypropylene fiber in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that addition of 0.4% fiber had reduced water absorption in concrete paver block.

T. Uygunglo, et al., [41], studied the influence of fly ash content and replacement of crushed sand stone aggregate with concrete waste and marble waste in prefabricated concrete interlocking blocks and concluded that water absorption of paving blocks increased on increment in replacement ratio of fly ash.

2.3.2 Abrasion resistance

The objective of the Abrasion test is to screen out products that might cause excessive wear to the pumps of air tanker bases due to their abrasiveness. The abrasive resistance of concrete is a surface property depends on the quality of surface layer.

B. K. Kashiyani, et al., [15], studied the addition of polypropylene fiber in concrete in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in top and bottom layer of the standard paver block and found that the abrasion resistance of paver blocks improved up to 45%, at 0.3% PPF.

I. Patel and C. D. Modhera, [27], studied fiber reinforced concrete containing high volume fly ash of grades M25, M30, M35 and M40 concrete with different percentages of F type fly ash 50%, 55% and 60% in addition of polypropylene fiber @ 0.25% by mass of cementitious material. It was concluded that inclusion of 0.15% and 0.25%, fiber led to reduction in wear.

2.3.3 Freeze-Thaw resistance

Freeze-Thaw resistance was evaluated on the basis of total amount of scaling residue (mass loss) of the samples as per table:

Freeze Resistance	Amount of Scaling residue after cycles (kg/m^2)
Very Good	<0.1
Good	<0.5
Acceptable	<1.0
Unacceptable	>1.0

T. Uygunglo, et al., [41], studied the influence of fly ash content and replacement of crushed sand stone aggregate with concrete waste and marble waste in blocks and concluded that freeze-thaw durability of blocks decreased with increase in fly ash ratio. Fly ash replacements of 40% fulfill the required strength of freeze thaw resistance.

G. Nader, et al, [10], evaluated the prediction of freezing and thawing durability of concrete paving blocks. Mass loss correlated with cement content. Test result indicated that minimum cementitious content of 395kg/m^3 corresponding water absorption capacity of 3.8% can provide an acceptable level of strength and frost durability for concrete paving blocks. Block samples of higher cement content withstood a greater number of freezing and thawing cycles.

A. J. Clark, [07], studied concrete paving block specimens and concluded that specimen of cement content below 380kg/m^3 suffered considerable surface damage. It was reported that 380kg/m^3 was the absolute minimum level of cement content that could be permitted to obtain a reasonable level of durability.

2.4 Conclusions

From above literature survey the following conclusions could be drawn:

1) The incorporation of fly ash in concrete reduces the compressive strength at early ages but there is a drastic increase in compressive strength at later stages.

2) The spherical shape of fly ash improves the workability of fresh concrete.
3) The small particle size of fly ash works as filler of voids in concrete and produces dense and durable concrete.
4) Using fly ash in concrete is the best solution to rising and high cost of cement.
5) Use of fly ash in mass concrete reduces the temperature and hence chances of thermal cracking.
6) Use of fly ash is ecofriendly in concrete.
7) As the curing period advances the strength of fly ash concrete increases.
8) Freeze thaw resistance of fly ash concrete paver blocks decreases.
9) Workability of concrete decreases with increase in polypropylene fiber volume fraction.
10) In self-compacting concrete with fly ash addition of polypropylene does not affect the workability and segregation problem.
11) Compressive strength increases with increase in polypropylene fiber volume fraction.
12) Compressive strength gains maximum strength at early age in fly ash concrete with addition of polypropylene fibers.
13) The split tensile strength gains more strength at early age of 28 days as compared to 56 days.
14) The split tensile strength increases with increase in fiber contents.
15) Increase in polypropylene fibers in concrete bridges the micro cracks and also hamper the propagation of cracks.
16) The flexural strength increases with increase in fiber contents up to 0.3% and gained more strength at 28 days as compared to 56 days.
17) The addition of steel and polypropylene fiber exhibits better performance with regard to strength and durability.
18) The addition of polypropylene fiber improves the fracture parameters of concrete composite containing 15% fly ash and 6% silica fume such as fracture toughness, fracture energy, effective crack length.
19) Density of paver blocks decreases with increase of fly ash replacement ratio.
20) Fly ash increases resistance of paver blocks to Alkali Silica Reaction.
21) Inclusion of fiber increases impact load capacity beyond first crack development.

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