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A Comparative Study Of Amalgamation Of Various PET Fibres In Concrete And Their Influence On Mechanical Properties: A Review

Showkat Maqbool Bhat[1]

[1]*Dept. of civil Engineering, SOET, BGSB University-Rajouri(J&K),India.*

Abstract: *The concrete is the most significant material which is almost used in every form of civil engineering construction. The efficiency of the concrete at the construction level is mainly enhanced by some of its properties such as good compressive strength, durability, specific gravity etc. but at same time as every material or system possess some limitations so does concrete which namely comprise of brittleness, low tensile strength, low impact strength, heavy weight etc.Since it possess greater number of advantages, therefore it become mandatory to add a suitable material which in turn can enhance its mechanical properties. Management and disposal of waste at proper designated places is one of the major challenges, as a result of which there is considerable implications on the environment, and economy and social issues.Thus waste utilization in civil engineering construction is considered as appropriate and attractive alternative for disposal and shielding environmental degradation. The paper provides a comprehensive summary of experimental approaches used by various authors to add PET shredders as replacement of coarse aggregate, fine aggregate and also are used as fibers in concrete in order to enhance the mechanical properties of concrete which not only are eco-friendly but at the same time approach is techno-economical for the commercial use.*

***Keywords*:** *PET, coarse aggregate, concrete, environmental degradation, mechanical properties.*

I. INTRODUCTION

PET is one of the extensively used plastics in the world, as per the estimates India produces 500000 tons of PET waste every year. Due to the increased use of PET bottles the amount of waste is going to grow by leaps and bonds. The capacity for recycling in India is around 145,000 TPA, so such quantity of waste needs a large landfill to dump. Now a day the recycling rate of PET bottles is very less than the cost of virgin PET production for common use. This gap is drastically increasing and constraining to find a solution of the problem.

These advantages have forced civil engineers to add something to concrete so that the mechanical properties can be enhanced. Till date so many materials have been utilized to overcome the limitations of concrete such as steel, glass and plastic fibers which have shown satisfactory laboratory results to improve the durability aspects of concrete. The use of industrial by-products such as flyash, silica fume, blast furnace slag, glass culets etc. are used in the concrete to modify the properties of concrete and for the safe disposal of these products.

The word plastic means a substance that has plasticity; accordingly anything that is formed in a soft state and used in a solid state can be called a plastic. Plastics can be divided in two types. Thermoplastic: This type of plastic can be melted for recycling in the plastic industry such plastics are polyethylene, polypropylene, polymoid, polytetrafluorethene, polyetheleneterephthalete and polyoxymethylene. Second type of plastic is thermosetting plastic. This plastic cannot be melted by heat; such plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin etc

It has many advantageous properties such as good compressive strength, durability, specific gravity etc. due to which it is most frequently used in construction material throughout the world. It is characterized with some bitter properties such as brittleness, low tensile strength, low impact strength, heavy weight etc. These advantages have forced civil engineers to add something to concrete so that the mechanical properties can be enhanced. The use of industrial by-products such as flyash, silica fume, blast furnace slag, glass culets etc. are used in the concrete to modify the properties of concrete and for the safe disposal of these products. The fiber inclusion in cement base matrix acts as an unwanted micro crack arrester. The prevention of prorogation of cracks under load can result in improvement of static and dynamic properties of cement based matrix. The serviceability of fiber reinforced cement concrete is also enhanced due to restricting entry of water and other contaminants through micro cracks which causes corrosion to steel reinforcement. Waste is the one of the main challenges to dispose and manage. It has become one of the major environmental, economic and social issues. Recycling is the most promising waste management process for disposal of waste materials. The waste utilization in civil engineering construction has become an attractive alternative for disposal and the Polyethylene (PET) bottles are available without any cost as these are waste products and can be economically shredded. The fibers of these shredded bottles are added to the normal concrete for making it as an alternative material for construction, dispose off the non-biodegradable waste with eco-friendly process and then making it techno-economical for the commercial use.

Plastic shredders are gaining widespread recognition in the manufacturing industry as their advantages produce the desired results at an economical cost. Plastic shredders are found to be versatile as they can come with dual hex shafts, easy reconfigured knife designs and easily installed bed screens for the desired output. There are many forms and sizes of plastic shredders; hand-fed small plastic shredders for small operations to totally engineered plastic shredders for the complete works of shredding. There are customized plastic shredders which can be ordered for specific shredding needs depending on the application. Heavier plastic shredders systems can handle plastic components all the way to a few hundred pounds.

II. LITERATURE REVIEW

The various researchers have used the experimental and analytical approaches to add or replace ingredients of concrete by using PET fibers and from the research it has been established that various mechanical properties such as compressive strength, tensile strength, and flexural strength, etc are influenced to a reasonable extend. The following summary of various authors, clearly provide the effectiveness with which the properties are enhanced or degraded.

Research group led by Nibudey R.N has utilized 0-3 % shredded PET fibers by weight of cement in M20, and M30 grades of concrete with size 25mm*1mm and an aspect ratio of 35 and 50 . It was concluded from the study that dry density was reduced in PFRC which is beneficial in reducing dead weight of concrete. For experimental observations author has made use of cubical and cylindrical samples to ascertain effectiveness on compressive strength , it was further established that strength remain intact without forming any definite pattern, which in turn revealed that the samples with PET fibers have shown ductile behavior, which is an added advantage to enhance the life of concrete using shredded PET fibers. While as the samples without PET fibers broke abruptly into the pieces and the behavior was contrary to the ductility.

Dora Foti and his group used 0.26% PET to weight of concrete with a size of 32mm*5mm, after the experimental analysis it was found that by the use of PET fibers concrete attained ductility, reduced the shrinkage cracks of concrete and acquired the alkali resistance, it further enhanced the compressive strength of concrete to a considerable amount. The addition of PET fiber in concrete reduced the propagation of water into the concrete and also reduced the sorptivity, which is a tendency of material to absorb and transmit water by the phenomenon of capillarity. There was a little improvement in the compressive strength of PFRC, the percentage of improvement was observed from 0 to 1% volume fraction of PET, it was further analyzed that sorptivity of PFRC is decreased at 1% fiber volume fraction and increased at higher volume fraction in different grades of concrete viz.M20 and M30 when aspect ratio was between 35 and 50.

T. SenthilVadivel et.al In their research authors used 1, 2, and 3% of PET fibers which were added to the concrete and found a clear impact on its mechanical properities, it was established that after the comparison between conventional concrete and PFRC, PFRC produced better results.It was clearly revealed that after every percentage increase in PET fiber, compressive strength was increased. From the experimental results it was also observed that 3% addition of fiber provide 12.5% increase in compressive strength when compared with conventional concrete.The experimental results also revealed that there was an increase of 9% in tensile strength and 8.12% in flexure strength when the strength of PFRC with 3% fibers was compared with conventional concrete. It was further analyzed that PET fibers acted as crack arresters, hence prevented shrinkage cracks, this property increased with the increase in the addition of quantity of PET fibers. The experimental observations revealed that there was a definite enhancement in mechanical properties of concrete when it was amalgamated with PET fibers.

Md. JahidulIslam,……et@ author investigated the study by replacing the course and fine aggregates (by volume) with the PET . The study was carried forward by producing PFA concrete (PFC),50% of sand (by volume) was replaced by PFA and in PCA concrete (PCC) 50% of the brick chips (by volume) where replaced with (PCA) at the same time for the experimental investigations different water cement ratio Viz. 0.42, 0.48 and 0.5 where used. The relationship between workability and replacement of course and fine aggregate showed a considerable increased in workability with the replacement of course aggregate by PCA and keeping the same water cement ratio when compared with NAC. The result was contrary in view of lower slump values which mean lower workability was obtained for PFC. In both PCC and PFC the compressive strength showed a variation with varied water cement ratios. With this replacement a lower density was achieved for PCC and PFC as compared to NAC.

Ms K. Ramadevi……et@ author elucidated the experimental and research work to replacement of PET fibers in the concrete with the ratio of 1%, 2%, 4%, 6% as fine aggregate and were compared with the normal concrete. The experimental investigation revealed that the concrete mixed with PET fibers reduced the weight of concrete. Inclusion of plastic fibers effectively made concrete light based on unit weight. It was further observed that the compressive strength, split tensile and flexural strength increased when 2% of fine aggregates were replaced with the PET fibers and it subsequently decreased for 4% and 6% replacements of fine aggregate and as consequence the 2% replacement yielded good results.

Mohd.Irvwanjaki,……et@ author describes the investigation to formulate the design of concrete mix nomograph for concrete, with PET as fine aggregate. The various physical and mechanical properties where ascertained by using the mix proportions containing 25%, 50% and 75% of PET with water cement ratio of 0.45, 0.55 and 0.05. To be more precise the material which was used for experimental work was waste PET bottles which were processed by plastic granulator machine. The above ingredients achieved low density. PET aggregates compared to fine aggregates of conventional concrete led to the reduction of concrete density. The higher water cement ratio formed pore spaces of water that did not participate in water-binder reaction and hence resulted in small diameter of capillary channels and with the experimental analysis the compressive strength of concrete mixed with 25% replacement ratio of PET aggregate appropriately obtained design strengths mix 25 Mpa. While with the inclusion of PET aggregate the split tensile strength also reduced in similar fashion as compressive strength. From the experimental investigations it clearly revealed that with increasing percentage of PET aggregate in concrete the mechanical properties of concrete such as compressive strength,split tensile and MOE reduced considerably.

SainiVerma,……et@ the author had experimentally used waste crushed PET bottles of suitable size in concrete with partial replacement of fine aggregates as it has potential of dispersing the waste which otherwise has hazardous effects on the eco-system. The analytical observations bring out the comparison of compressive strength of conventional concrete with concrete formed by appropriate substitution of aggregates with PET fibers. Form the experimental results it was established that compressive strength of concrete with the substitution of PET fibers was better in compression to the normal concrete. From the experimental studies it was determined that with the replacement of fine aggregate with PET fibers the compressive strength increased up to 2% replacements which leads to 12% enhancements in compressive strengths and for further increase beyond 2% of PET fibers there is a definite pattern in decrease of compressive strengths. From the environmental aspect and global echo system PET are echo friendly with concrete mix and are non hazardous as they are easily dispersed in concrete mix.

A. Materials Used

Cement: Portland Pozzolana cement (Birla Shakti 43 grade) was used in this study conforming to IS: 1489 – 1991 (Part - I). The physical properties of cement were as follows: Fineness = 388 m2/Kg, Initial Setting Time = 180 minute, Final Setting Time = 260 minute, Soundness = 2.0 mm, 3 days Compressive Strength = 30 N/mm2, 7 days Compressive Strength = 41 N/mm2.

Sand: Natural river sand was used as a fine aggregate. Sand having a specific gravity of 2.23, moisture content of 1.23%, and dry loose bulk density of 1.42 Kg/lit, sand is confirmed to zone – I as per IS: 383-1970 [7].

Coarse aggregates:
For 20 mm aggregates:
i) Specific Gravity = 2.9
ii) DLBD = 1.66 Kg/lit

For 10 mm aggregates:
i) Specific Gravity = 2.21
ii) DLBD = 1.56 Kg/lit\

Water: Potable water was used in concrete mix and for the curing also.

PET Shreds: The PET material has density 1.38 gm/cc. The tensile strength is very good andmelting point greater than 250ºC. The shreds were obtained by manual cutting of mineral water bottles. The fiber width was kept about 2mm and length at 30mm.

Concrete Mix: Based on above test results mix proportion was selected as per IS: 10262-2009.
For M20 Grade of concrete:
i) Cement = 345 Kg
ii) Water = 192 lit
iii) Sand = 889 Kg
iv) 10 mm aggregates = 370 Kg
v) 20 mm aggregates = 688 Kg

For M25 Grade of concrete:
i) Cement = 379 Kg
ii) Water = 192 lit
iii) Sand = 874 Kg
iv) 10 mm aggregates = 364 Kg

v) 20 mm aggregates = 676 Kg

For M30 Grade of concrete:
i) Cement = 379 Kg
ii) Water = 192 lit
iii) Sand = 874 Kg
iv) 10 mm aggregates = 364 Kg
v) 20 mm aggregates = 676 Kg

III. RESULTS AND DISCUSSION

A. Cube Compressive Strength:

The Compressive strength is calculated by testing cube specimen on universal testing machine up to failure, as per IS: 516

Table 1 Cube Compressive Strength test results for M25 grade Cubes

Cube No.	% of PET Shreds	Failure Load (N)	Compr Strgth (N/mm2)	Average
1	%	590000	6.22	26.13
2	%	603930	6.84	
3	%	570000	5.33	
4	.25	770000	4.22	33.02
5	.25	699090	1.07	
6	.25	760000	3.78	
7	.50	659990	9.33	29.79
8	.50	681010	0.27	
9	.50	670050	9.78	
10	.75	633000	8.13	28.71
11	.75	637000	8.31	
12	.75	668030	9.69	
13	%	584430	5.97	25.84
14	%	560100	4.89	
15	%	599990	6.66	

B.Results

*Table 1*7th DAY DATA for M20 Concrete

PET %	Avg.Compressive Strength(N/mm^2)	Avg.Flexural Strength	Avg.Split Tensile Strength
0	19.99	2.6	2.08
2	22.66	2.8	2.10
3	24.58	3.10	2.93
4	22.36	2.92	2.20
5	22.32	2.83	2.18

Table 2.28th DAY DATA for M20 Concrete

PET %	Avg.Compressive Strength(N/mm^2)	Avg.Flexural Strength	Avg.Split Tensile Strength
0	31.14	3.65	2.74
2	32.26	3.80	2.83
3	34.21	3.98	3.18
4	31.84	3.67	2.78
5	31.62	3.59	2.70

Table 3.56th DAY DATA for M20 Concrete

PET %	Avg.Compressive Strength(N/mm^2)
0	32.58
2	34.51
3	35.73
4	32.88
5	32.47

*Table 4*7th DAY DATA for M25 Concrete

PET %	Avg.Compressive Strength(N/mm^2)	Avg.Flexural Strength	Avg. Split Tensile Strength
0	24.46	2.9	2.3
2	25.2	3.05	2.5
3	27.5	3.68	2.9
4	24.3	3.15	2.7
5	23.85	3.10	2.7

*Table 5*28th DAY DATA for M25 Concrete

PET %	Avg.Compressive Strength(N/mm^2)	Avg. Flexural Strength	Avg.SplitTensileStrength
0	32.57	3.95	3.3
2	33	4.16	3.35
3	34.8	4.65	3.65
4	32	4.32	3.26
5	30.8	4.19	3.20

Table 6.56th DAY DATA for M25 Concrete

PET %	Avg.Compressive Strength(N/mm^2)
0	33.8
2	34.5
3	36.1
4	34.5
5	33.8

Table 7.7th DAY DATA for M30 Concrete

PET %	Avg. Compressive Strength(N/mm^2)	Avg.Flexural Strength	Avg. Split Tensile Strength
0	28.88	2.49	3.01
2	30.45	3.40	3.06
3	32.01	3.8	3.24
4	29.99	3.29	3.08
5	29.77	3.20	2.99

Table 8.28th DAY DATA for M30 Concrete

PET %	Avg.Compressive Strength(N/mm^2)	Avg.Flexural Strength	Avg. Split Tensile Strength
0	39.11	4.65	3.96
2	40.66	6.08	4.10
3	43.7	6.56	4.26
4	39.33	4.14	4.01
5	39.25	4.12	4.18

Table 9.56th DAY DATA for M30 Concrete

PET %	Avg.Compressive Strength(N/mm^2)
0	42.66
2	43.58
3	46.07
4	43.55
5	43.47

IV.CONCLUSION.

The substitution of concrete with waste PET fiber is effectively used as plastic waste management practices, which not only is echo friendly for growing environmental concerns but also is techno-economical for the commercial objectives. The majority of the authors after a comprehensive experimental analysis have affirmed that up to 2% replacement of appropriate aggregate with PET, the various mechanical properties of concrete such as compressive strength, flexural strengths, & split tensile etc show a definite increasing trend, while if the inclusion of PET aggregates is more than 2% the strength of concrete decreases in a definite pattern relevant to percentage increase of PET. The inclusion of PET fiber up to 3% increases the mechanical properties of concrete to a considerable extent and if the PET fibers used are more than 3%, the majority of the mechanical properties show a decreasing trend to a definite extent.

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