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RESEARCH ARTICLE

FEASIBILITY STUDY ON THE EFFECT OF PET BOTTLE FIBRES IN CONCRETE.

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Abstract

Plastics and plastic bottles are adjustable for any common use due to its properties like durability, light weight and its ability to be moulded, however it excessive production and use has become a serious man made a threat to the environment. Disposal of plastic wastes have not only degrade degrades land fertility and deteriorates a scenic value of the place but also threatens human health. Moreover, with exponential increment of construction activities taking place around the globe today, many engineers and real estate developers in the construction industries are facing challenges in acquiring raw materials like aggregates due to huge demand of concrete. The extraction of natural aggregates exploits a natural environment and disturbs aquatic life. Therefore, this study was carried out to reduce excessive extraction of natural aggregate and production of plastic waste by using waste PET bottles in concrete. This study have found that, maximum replacement of 1.25% of a natural fine aggregate by weight with shredded PET bottles fulfills the compressive and flexural strength requirement.

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Introduction:-

Plastics are inexpensive, durable and strong material which has potential for diverse applications and its versatility to different user requirements has picked up rapid momentum among human kind. However, temporary use of plastics with its long decomposition period causes huge piling in landfills deteriorating land fertility and the leachate from landfills pollutes surface and ground water disturbing a marine ecosystem.

With the massive growth infrastructure developmental activities, there is a huge increase in demand for construction materials, such as concrete which directly or indirectly causes significant negative impact on the environment. As 60-75% of concrete volume is occupied by natural aggregates (Soloaga et al,2014), higher demand for concrete causes greater exploitation of environment, exposing the land to erosion, silting and disturbance in aquatic life. Thus, by partially replacing a natural aggregate in concrete plastics fibres will not only reduce the disposal of plastic wastes in landfills but also reduce the extraction of natural aggregates without compromising the quality of produce (Soloagaet al, 2014). Therefore, comparative study on compressive strength, split tensile strength and flexural strength between the nominal concrete and concrete with a partial replacement of sand with plastic fibres of 2mm thick and length of 20mm has been carried out.

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Literature Review

Plastics have become part and parcel of today's modern living, where all commodities are either carried in it or packed with it (Gu & Ozbakkaloglu, 2016) due to its varying applications, contributing about 12% of municipal solid waste by weight, in the United States of America in 1996 (Franklin Associates Ltd., 1998; EPA, 2003). Moreover, with industrialization and change in consumption pattern, consumption of plastics has been drastically increased from approximately from 5 million tons in 1950s to 100 million tons in 2001 (Siddique et al, 2008; Jibrae & Peter, 2016)., contributing huge production of plastic related waste which are almost not decompose even after a long period of time in an environment polluting all the natural elements like soil air and water (EPA, 1991; Saikia & Brito, 2012).

Similarly, in Thimphu a capital and largest city in Bhutan with the population of 114551 (NSB, 2018) generates waste about 50 metric tons per day which is equivalent to 174g/capita/day (NEC, 2017). The Plastic waste was found to be 12.73% of the waste generated according to the National Solid Waste Survey conducted by the Ministry of Work and Human Settlement in 2008 (Thimphu Thromde, 2012). Statistical Yearbook of Bhutan 2018 stated that economy of Bhutan is becoming more waste intensive despite a lot of effort done by government and Non-governmental Organizations. Thus, the need of effective waste management has to be looked from the engineering perspectives which would be economically feasible and eco- friendly. On the other hand, with rapid urbanization and infrastructure development, there is a drastic increase in demand on construction materials like sand to produce concrete, tile, brick, glass, ceramics, etc. (Gavriletea, 2017).

Sand is a natural fine aggregate formed by eroding of rock surface during its weathering process (John, 2009; Gavriletea, 2017). For example, France itself consumes approximately 400 million tons of aggregate annually (UNPG, 2006; Jullienet al, 2012) and thus, the United Nations Environment Programme has declared that Sand and gravel has become the second highest raw material in the list, which is consumed on the earth after water and their rate of usage exceeds than their natural renewal rates (UNEP, 2014). Such growth in demand has increased the rate of exploitation, threatening both aquatic and inland ecosystem.

Due to such pertaining issues, researchers have now ventured in reusing of waste in concrete mix as an environmental friendly (Gu & Ozbakkaloglu, 2016; Siddiqueet al, 2008). These alternatives approach have not only help the society in the reduction of pollution due to waste production and minimization of land and river exploitation, but also able to produce an ecofriendly and economical light weight concrete with plastic aggregates. Jibrael and Peter (2016) have found that an addition of waste plastic bottles in concrete provide better strength than waste plastic bags though both are less compared to nominal mix. The decreasing of strength is due to change in the mode of failure from brittle to more ductile failure. Therefore, this type of concrete can be used for non-structural concrete members like wall fillers and outdoor landscape features.

The reduction in split tensile strength and flexural strength were relatively less compare to the reduction in compressive strength of such specimen. It was found that fibres keep concrete mass bounded together and prevents plastic cracks and dry shrinkage cracks. These fibres also prevent the brittle failure of concrete with enhanced crack control and ductility apart from enhancement of tensile strength and toughness of concrete (Yin et al, 2015). Some micro-cracks were observed during failure instead of a single major crack in such type of concrete that causes gradual failure instead of brittle failure (Ismail & AL-Hashmi, 2008).

Ramadev and Manju (2012) have studies on the effect on the strength of concrete partially replaced the fine aggregate with PET bottle fibres with proportion varying from 5%, 1%, 2%, 4% and 6%. They have concluded that compressive and split tensile strength has increased till 2% replacement and there was a gradual reduction in further replacement. Similarly, flexural strength was also increased with an increasing percentage of PET bottle fibre replacement, however, it remained same for 4% and 6% replacements. Therefore, the authors concluded that 2% replacement to be rational. Based on this finding, the proportion in this study was decided as shown in test procedures.

The addition of plastic aggregates to concrete has lowered compressive strength, tensile strength and flexural strength due to poor and weaker binding between the surface of the plastic particles and the cement paste (Saikia & Brito, 2012) due to its impermeable nature (Siddique et al, 2008). However, this bonding can be enhanced and improved by adding admixture (Ghernouti et al, 2014). Studies have found that, concrete with natural aggregate reduce about 33% of its strength when it is heated up at a temperature of 400 degree Celsius, while concrete with plastic fibres and aggregates shows about 75% reduction in its strength at same the temperature. Therefore, plastic aggregates incorporated concrete are recommended to use for non-structural purposes and require a special fireproof coating if it is used in load bearing structural members (Mathew, 2013).

Materials used and test procedure

While carrying out the laboratory test, following materials are required apart from lab equipment's:

Cement:

Portland Pozzolana cement (PPC) manufactured by Penden Cememt Authority Limited was used to prepare controlled mix.

Fine Aggregate:

Natural sand extracted from Amochu river bank has been used. Sieve analysis was carried out, and the fine aggregate was graded under zone III as per Table 4 of IS 383-1970

Coarse Aggregate:

According to Table 2 and 5 of IS: 383-1970, the chosen coarse aggregate is classified as 20mm size with properties shown in the Table 1.

Table 1:-Properties of coarse aggregate

Specific Gravity	2.98
Water absorption	0.6%

Plastic Fibres:

The shredded PET bottle fibres as shown in Figure 1 with an approximate thickness of 2mm and length 20mm was used for partial replacement of fine aggregate.

Fig 1:-Shredded PET bottle fibers

Preparation of shredded PET bottle fibres

Firstly, PET bottles were collected on a regular interval from college campus like hostels and canteen. They are then rinsed with water to remove foreign particles such as dust, grease and oil. Then these materials are dried in the sun or air. The HDPE bottles are then selected and shredded into small fibres of 2mm thickness and 20 mm length.

Design Mix

The design mix involves the selection of most suitable materials for concrete and determine their relative proportion to produce the most economical concrete with required strength and durability. The mix was designed according to IS: 10262:2009 and the mix proportions are calculated as given in the Table 2 using following formula;

$$f'_{ck}=f_{ck} + 1.65s$$

Where

f'ck = target mean compressive strength at 28 days in N/mm2

fck = characteristic compressive strength at 28 days in N/mm2

s = Standard deviation in N/mm2

The mix was designed for various percentage replacement of the fine aggregate with PET bottle fibre.

Table 2:-Materials required as per the mix design

Sl.No	Material	Weight (kg)
1	Cement	413.33
2	Fine aggregate	662.68
3	Coarse aggregate	1309.8

Casting and Curing of samples

Cubes with 150x150x150 mm dimensions, beam with 100x100x500 mm and cylinder with 75 mm diameter and 150 mm height were casted to carry out the comparative analysis of flexural strength, compressive strength and the split tensile strength between the conventional concrete and the plastic fibre incorporated concrete respectively. Nine samples each for a compression test, flexural and a split tensile test were prepared with the water cement ratio of 0.45 for 0.75% ,1% and 1.25% replacement of fine aggregate by PET bottle fibre. Nine control samples were also casted for comparative study of the strength for a curing period of 7, 14 and 28 days. The samples are named as F.75 for 0.75% replacement and F1 and F1.25 for 1% and 1.25% respectively.

Sample Test

Samples were then de-moulded after 24 hours of casting and cured for 7, 14 and 28 days respectively before subjecting to compression, split tensile and flexural test using Universal Testing Machine.

Result and Discussion:-

Compression Test:

Compressive strength of concrete cubes of different curing periods and varying percentage replacement are as shown in graphs of fig. 2, 3 and 4.

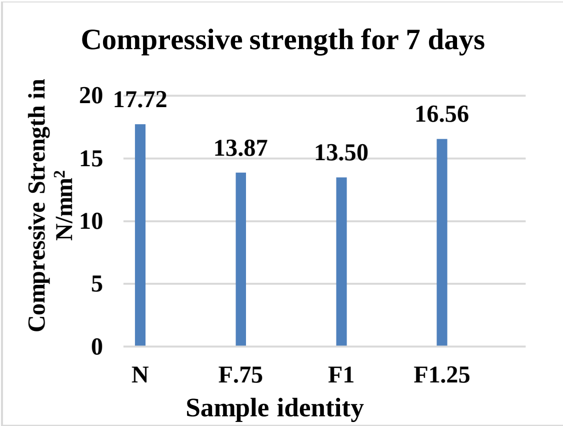

Fig 2:-Compressive strength at 7 days w.r.t. percentage replacement of PET fibre

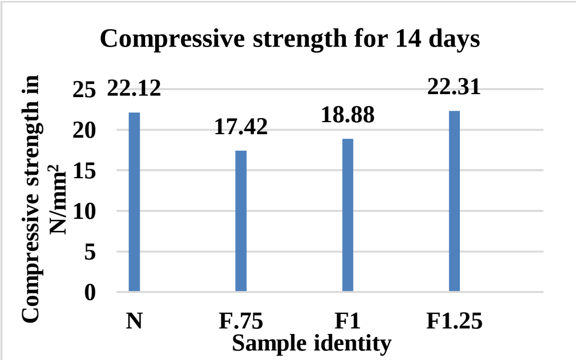

Fig 3:-Compressive strength at 14 days w.r.t. percentage replacement of PET fibre

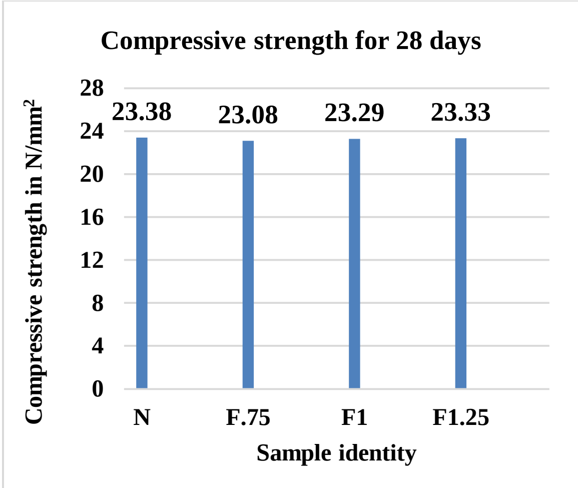

Fig 4:-Compressive strength at 28 days w.r.t. percentage replacement of PET fibre

Compressive strength of concrete is found to increase with an increasing percentage of fibre replacement and is maximum for 1.25% replacement of fine aggregate. The reduction in compressive strength of concrete with 1.25% replacement from that of the controlled sample is negligible.

Split Tensile Test:
Similarly, the results of split tensile strength of concrete are obtained as shown in graphs of Fig.5, 6 and 7.

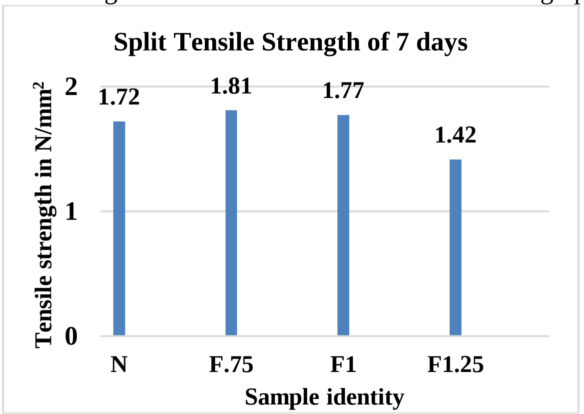

Fig 5:-Split Tensile Strength at 7 days w.r.t. percentage replacement of PET fibre

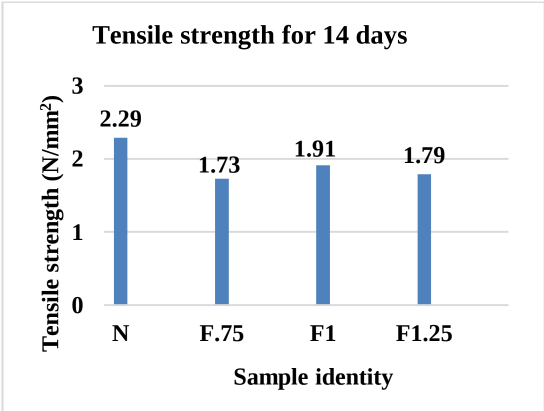

Fig 6:-Split Tensile Strength at 14days w.r.t. percentage replacement of PET fibre

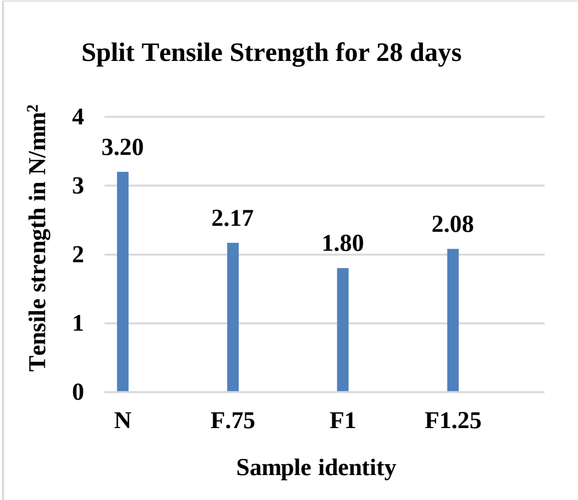

Fig 7:-Split Tensile Strength at 21 days w.r.t. percentage replacement of PET fibre

Split tensile strength was found to be maximum for 0.75% replacement of fine aggregate with PET bottle fibres for 7 and 28 days. However, 1% % replacement dominated for 14 days. A reduction of 32% was observed in split tensile strength of concrete with 0.75% of PET fibre replacement at 28 days.

Flexural strength test

Finally the flexural strength of the prepared concrete specimens are test and obtained the result shown in Fig. 8, 9 and 10.

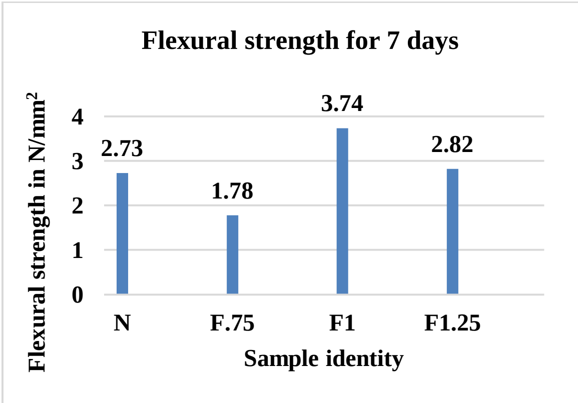

Fig 8:-Flexural Strength at 7 days w.r.t. percentage replacement of PET fibre

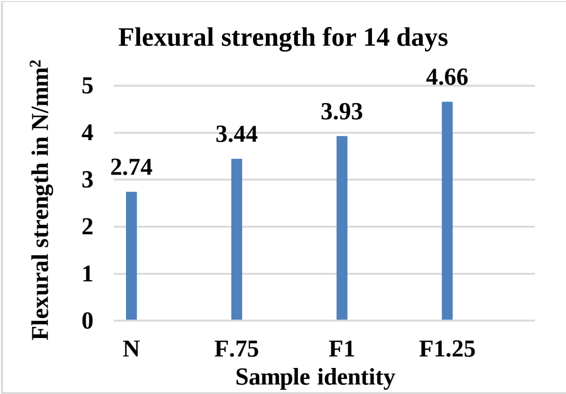

Fig 9:-Flexural Strength at 14 days w.r.t. percentage replacement of PET fibre

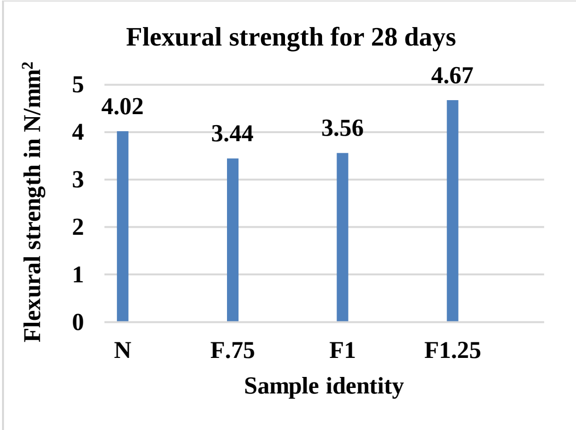

Fig 10:-Flexural Strength at 28 days w.r.t. percentage replacement of PET fibre

Flexural strength of concrete was found to increase with an increasing percentage of fibre replacement and exceeded that of the controlled sample. Therefore, 1.25% replacement was found reasonable for flexural strength of concrete. An increment of 16% was observed in 1.25% replacement at 28 days.

Conclusion:-

Based on the result obtained from the experiments, the following conclusions are advanced. It was found that compressive strength of concrete has increased with increasing percentage till 1.25% of fibre replacement in fine aggregate by weight. The compressive strength of concrete of all curing period decrease drastically when the replacement was more than 1.25%. It was also observed that split tensile strength of concrete has decreased, when fine aggregate is replaced by plastic fibre and reduction of 32% was observed at 28 days with 0.75% replacement. Flexural strength of concrete was found to increase with an increasing percentage of fibre replacement and was found more than that of conventional concrete. Therefore, 1.25% replacement was found reasonable for flexural strength of concrete.

The study concludes that the maximum of 1.25% replacement of fine aggregate by plastic fibre was found to be feasible to produce a workable concrete. However, through literature reviews, such type of concrete is are not recommended in load bearing structural members as plastic tends to melt, decreasing its strength during fire hazards due to immense heat. Thus, such type of concrete is mostly recommended in facades as filler material and construction of outdoor landscape element such as retaining wall, and pavements, etc.

This study also concludes that the partial replacement of natural aggregate by plastic fibres reduces the weight of concrete by almost 1.41% of conventional concrete. Moreover, for a 1 m^3 of this specimen, 4.08 kg of plastics have used to replace the natural fine agreement which is equivalent to 321 water pet bottles of 12.7 g (International Bottled Water Association, 2010). Therefore, such type of technologies could not only generate the light weight concrete, but also reduce the plastics waste generation and environmental exploitation due to high demand of natural aggregates.

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