Assessment of mechanical properties and workability for pure HDPE granules reinforced concrete

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Abstract - *In this analysis, an effort is made to assess the performance and sustainability of concrete with adding pure milky white HDPE granules. The mechanical characteristics were explored experimentally in this investigation. five high density Polyethylene (HDPE) granules weight fractions (1%, 2%, 3%, 4%, 5%), concrete grade M25 were used to investigate their effects on the fissure tensile properties and compression characteristics, and flexural strength, modulus of elasticity, as well as the ductility, workability and toughness of the concrete. For combination HDPE granules reinforced concrete, an unique failure mechanism was identified and a new behavior categorization was developed. In comparison to plain concrete, the combination of HDPE granules reinforced concrete demonstrated superior flexural strength, beginning post-cracking strength, and magnificent energy absorption and decreasing the effect of harmful chemicals. pure high density Polyethylene (HDPE) granules seems to be more durable than some other types of fibers because it does not rust with time, like steel fibers do. Compressive strength improved from 27.84 N/mm2 to 34.94 N/mm2 in this study, while flexural strength grew from 15 N/mm2 to 16.66 N/mm2 and tensile strength improved from 3.45 N/mm2 to 7.6 N/mm2 and the small change in new concrete's workability with the increasing percentage of HDPE.*

Key Words: —"Fiber reinforced concrete", "High density Polyethylene granules", "glass fiber reinforced concrete", "workability", "Compressive strength", "Tensile strength", "Flexural strength"

1. INTRODUCTION

The advancement of the structural engineering field has resulted in a growing need for engineering materials with high "tensile, compressive, and flexural strengths, as well as good durability and combat" to environmental influences. Concrete is a mixture type material which is assemble of sand, aggregates, cement and fluid and that hardens over a period of time. Concrete is the lion's share and most frequently utilized edifice material in the whole planet. The advancement of contemporary civil structural engineering construction has created a great need for the modification of concrete characteristics and the production of new kind of concretes. Mixing fibers to concrete is an effective way to improve concrete characteristics [1]. The idea of concrete reinforced using fibers to increase its tensile qualities is not new. Since ancient times, fibers have been utilised to reinforce concrete. The insertion of HDPE fibers to concrete upgrade its tensile strength, ductility, and fracture resistance [4-5]. The fibers inside the concrete operate as a fracture arrester, improving almost all mechanical characteristics, impact resistance, and brittleness.

Polyethylene qualities differ from species to species, owing mostly to molecular structure and density. Polyethylene is widely utilised as a fundamental raw material in the chemical process industries, mostly for the production of films, containers, pipelines, monofilaments, wires and cables, everyday requirements, and so on. It's also utilised as a high-frequency insulator for TV and radar, among other things. Polyethylene are present in different structure such as LDPE, HDPE, and LLDPE [2].

In this paper, HDPE granules are used to upgrading the almost all properties of concrete, and here the HDPE granules are milky white in colour, which is shown in fig.1 High density Polyethylene reinforcement concrete is a different variety of concrete which is made by the addition of high density Polyethylene granules. polymer reinforcement concrete is extensively used in structures, Because concrete is a brittle kind of material with poor tensile and flexural strength, reinforcement such as high density Polyethylene polymer, steel, or other kinds increase these mechanical qualities as well as ductility and strength.

High density Polyethylene reinforcement concrete may be utilized for new kind of construction as well as renovation of old concrete. HDPE as polymer additives to concrete [3]. Polymer concrete's adhesive qualities enable for the repair of both polymer and traditional cement-based concretes. High density Polyethylene Polymer concrete can be utilized in swimming pools and sewer construction and drainage channels and electrolytic cells and other type of structures that contain acids and alkalis or corrosive chemicals due to its corrosion resistance and acids resistance and low permeability.

Because of its capacity to tolerate poisonous and corrosive sewage gases and harmful bacteria often found in sewage systems, it is particularly suitable to the building and restoration of manholes. High density Polyethylene reinforcement concrete, unlike traditional concrete buildings, does not require coating and welding of PVCprotected layers. and Because of its smooth surface, it may also be used as an asphalt pavement bonded wearing course, for increased durability and strength on a concrete foundation, and in skate parks.

2. MATERIALS AND METHODOLOGIES

A. Materials

A material or mixture of substances that makes up an item is referred to as a material. Materials can be either pure and impure in nature. The constituent materials, such as reinforcing fibers, cement, sand, and aggregates, can have a significant impact on the mechanical properties of HDPC. These constituent materials are discussed in this section.

1. Cement

According to IS code: 269-2015 [10] In this study, General Purpose ordinary Portland cement was employed as the binder and A chemical interaction between the dry materials and water causes to set and become sticky or work as a binder. Table lists the physical characteristics and chemical characteristics of this binder.

Table -2: Properties of cement

Chemical & physical properties of cement	
CaO	68.98%
SiO_2	20.54%
Al_2O_3	5.12%
Fe_2O_3	3.26%
MgO	1.14%
Na_2O	0.26%
SO_3	3.04%
K_2O	0.78%
Ignition loss	1.32
Specific surface area (m2 /kg)	3640
Specific Gravity	3.14
Consistency (%)	28.3
compressive strength (MPa)	54
Setting time (min)	101 at initial stage
	158 at final stage

2. HDPE

Here we use high density polyethylene (HDPE) which is granules in shape and milky white in colour seen in figure.1. HDPE is arrange by heating of pure ethene in hydrocarbon solvent at 333-343K under 6-7 atm pressure in the addition of a catalyst and here we use triethylaluminium and titanium tetrachloride as a catalyst (ziegler natta catalyst).the chemical reaction is given below and all the mechanical property of HDPE is given in table.3

$$[n\ CH_2 = CH_2 \xrightarrow[\text{Ziegler Natta catalyst}]{333-343K,6-7\ atm} -(-\ CH_2 - CH_2-)_n -]$$

Ethene Polythene

(HDPE)

High density polymer Properties		
Young's modulus	1000	Mpa
Shear modulus	750	Mpa
Tensile strength	43	Mpa
Density	0.995	g/cc
Resistivity	5.00E+17	$Ohm*mm^2/m$
Elongation	2230	%
Compressive strength	23	Mpa
Fatigue	19	Mpa
Thermal conductivity	0.49	W/m*k
Maximum service temprature	120	°C
Minimum service temprature	-200	°C
Bending strength	32.5	Mpa
Water absorption	0.01	%

3. Aggregate

According to IS code: 383-1970 [7], the fine aggregate passing from 4.75mm IS sieve which is arranged and resulting from natural disintegration of rock and deposited by streams and agencies of glacial. And coarse aggregate are those aggregate which is hold on 4.75mm IS sieve which is arranged and resulting from crushing of gravel or hard stone. the mechanical and physical property of fine and corse aggregate seen in table.1.

Table -1: Physical properties of coarse and fine aggregates

Specifications	C.A	F.A
Specific gravity	2.44	2.84
Unit weight (kg/m3)	1450	1600
Fineness modulus	7.67	2.74
Absorption (%)	2.78	1.19
Moisture content (%)	2.8	1.5

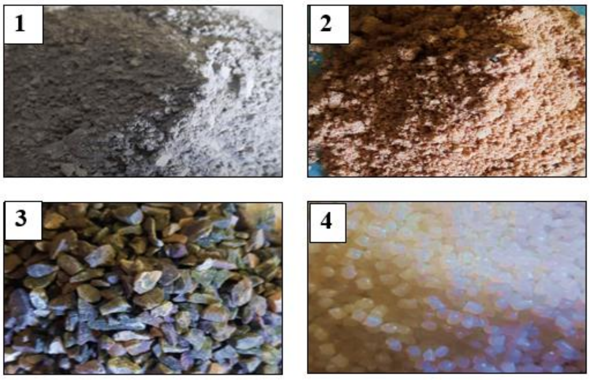

Figure 1: Materials (1. Cement, 2. Fine aggregate, 3. Coarse aggregate, 4. HDPE granules)

B. Methodologies

In this study, the approach and procedures employed were based on the indian standard codes. [6] IS code :456-2000 [1] IS code :516-1959 [16] IS code :5816-1999 as well as IS code: 10262-2019 [17] fig.2 shows the full methodology of this study and the following work procedure was devised and implemented:

- Arrangement of raw material such as standard Portland cement, sand, and coarse aggregate, HDPE granuels and water.
- Preparation of concrete with mixing under the guidance of IS:10262-2019
- Specimens were cast in different shape and size with the help of indian standard codes.
- Testing all the Specimens for obtaining mechanical properties under the guidance of indian standard codes.
- Analyses of various outcomes in order to measure the quality of concrete.

Identify applicable funding agency here. If none, delete this text box.

Figure.2: Research Methodology

1. Concrete mix specifications

The concrete was mixed according to a 1:1:2 weight ratio of standard Portland cement, sand, and coarse aggregate. Without the use of water-reducing admixtures, the W/C-ratio of 0.48 was maintained throughout the mix.

The concrete was made by combining all of the ingredients in the laboratory using a mixing machine at their specified proportions. To make the HDPEGRC mixes in this investigation, hdpe ganules were added in five percentages by weight of cement: 1%, 2%, 3%, 4% and 5%.

For experiment, six groups are divided by the concrete with the different level of 1%, 2%, 3%, 4% and 5% of HDPE respectively, as by weight. See table.4.

Calculation of Quantity of Materials is done according to the laboratory mix.

- Cement volume = (ratio of cement / 4) × 1440 × 1.57 = 565.2 Kg.

- Sand volume = (ratio of sand /4) × 1600 × 1.57 = 628 Kg.
- Coarse aggregate volume = (C.A ratio /4) × 1450 × 1.57 = 1138.3Kg
- W/C ratio = 0.48
- The unit weight of cement = 1440-kg/m^3.
- Fine aggregates have a unit weight = 1600-kg/m^3.
- Here unit weight of coarse aggregates = 1450-kg/m^3.
- We take Unit weight of water = 691-kg/m^3.

Because we all know, when wet concrete is placed during the concreting process, it hardens and hardens after a set period of time. To offset the effect of shrinkage, the educated engineer in the discipline of civil and raising construction have suggested the factor of safety to be set (F.O.S = 1.54 to 1.57)

- For composition dry concrete vol. should be 1.54 to 1.57 times that of the wet concrete volume.

CP0 = control specimen

CP1 = 1% HDPE granules mix with concrete

CP2 = 2% HDPE granules mix with concrete

CP3 = 3% HDPE granules mix with concrete

CP4 = 4% HDPE granules mix with concrete

CP5 = 5% HDPE granules mix with concrete

2. Specimens preparation

In this research paper, All Specimens were cast in concrete grade M25 according to IS code, the ratio of these concrete grade are listed in table.4. In the laboratory for optimal resistance of high density polyethylene granules, the 12 cubes are casted with the perfect measurements of "150 mm * 150 mm * 150 mm" and the 12 cylinder are casted with the measurements of "D = 150 mm * L = 300 mm" to develop compressive quality and tensile quality and flexure prism also cast with the size of "100 * 100 * 500 mm" to perform flexural test. These different shape of specimens was casted for 7 days & 28 days as per normal procedures.

for making specimens "ordinary Portland cement" is utilised as a binder. According to IS 383-1970, river sand passing through an IS sieve of 4.75 mm is utilised for fine-aggregate. The river's sand is devoid of dust particles and filters out unwanted materials and tiny piece particles. The coarse aggregate utilised is a locally available crushed angular gravels with a sieve size of 10 mm. the increasing percentage of HDPE also used for preparation of Specimens with different grade of concrete.

3. Testing methods

For examining the specimens and the behaviour of specimens under the test by a certain method of completion. Several mechanical parameters were investigated for all mixes, including "compressive strength, fissure tensile strength, flexural strength and workability" of concrete.

3.1. Compressive strength test

After specimens had been cured for 7days and 28 days, compression tests were performed in accordance with IS Code 516:1959. Because the HDPE granules, a cube specimen size (150mm × 150mm × 150mm) was used. A cube specimen has been placed as depicted in the experimental setup, Aimil version of compression testing machine was used to apply loading and the vertically load is gradually applied to the cube shape tested piece, and the ultimate load is recorded at the cube's failure, and the compressive strength of the cube is calculated. C.S = P/A is the formula for calculating compressive strength of concrete. Table.5. and Figs.3 illustrate the compressive strength test assembly.

Figure 3: compressive strength test machine.

3.2. Flexural strength test

Flexural testing were carried out with the help of IS Code 516-1959. The flexural strength was calculated using the equation F.S = PL/BD2. The tensile strength of the specimen is estimated indirectly by the flexural test and flexural test findings are provided as a rupture module denoted by MPa. Rectangular shape specimens with perfect dimension (100 mm × 100 mm × 500 mm) and cured for 7days to 28 days, after specimen were dried out and revealed to air. The specimen is placed in the aimil version flexural testing machine for getting data which is indicated in table 6 and Fig. 5. Load was applied at a frequency that causes the maximum stress to rise until it breaks. The fracture displays the width of the middle third of the stress zone.

3.3. Tensile strength test

The tensile properties of a specimen is determined indirectly using separated tensile testing. The cylindrical test piece with a perfect dimension (D=150 mm and L=300 mm) were evaluated after seven and twenty-eight days of curing phase. These measurements were carried out with the aid of a compression quality testing machine with a power rating of 2000 kn. The test specimen is shown below.

Acc. To IS code 5816:1999 The tensile strength cylinder is determined by

$T.S = 2A/\pi L\phi$

- T.S = Fissure Tensile Strength
- A = Failure load in newton
- ϕ = Cylinder Dia.
- L = Length of sample in mm

Tables 7 and Fig.6 shows the tensile valuation which is getting from tensile strength test assembly.

3.4. Slump tests

Slump tests was carried out in accordance with IS code 456:2000 [6] and IS code 1199:1959 [11] to evaluate the workability of new concrete. After a satisfactory mix, the latest concrete was categorized into 3 equal levels in a cone shaped, rodding twenty-five times. The surplus concrete was then removed from the top, and the cone shape was elevated vertically. Slump was defined as the interspace b/w height of the frustum shape frame and the relocated original location of the top level of new concrete (see Fig. 7)

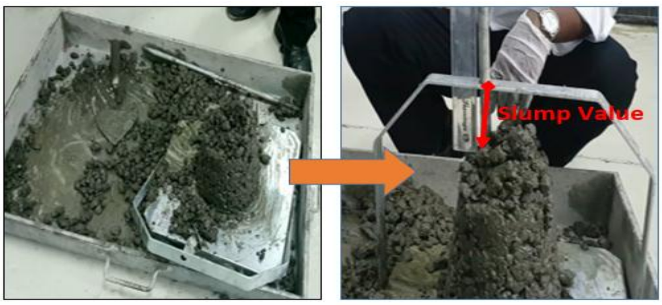

Figure 7: Slump test.

3. DISCUSSION OF THE RESULTS

According to the fig.4. the compressive strength of M25 grade concrete with HDPE granules increased up to 34.94 N/mm2 from 27.84 N/mm2 and after that moderately dropped up to 27.64 N/mm2. The compressive quality test results of individual concrete mix cube test piece having dimension of 150 mm*150 mm*150 mm for preserving interval like 7 days as well as 28 days which is shown in Table 5.

According to the fig.5. the flexural strength of M25 grade concrete with HDPE granules increased up to 16.66 N/mm2 from 15 N/mm2 and after that moderately dropped up to 14.53 N/mm2. The flexural quality test results of different concrete mix rectangular test piece having 100 mm in H × 100 mm in W ×500 mm in L for preserving phase like 7 days as well as 28 days which is shown in Table 6.

According to the fig.6. the fissure tensile strength of modified concrete with the company of HDPE granules increased up to 7.6 N/mm2 from 3.45 N/mm2 and after that severely dropped up to 3.1 N/mm2. The fissure tensile quality test results of variant concrete mix cylindrical test piece having dia. of 150 mm and lengthwise 300 in mm for preserving phase like 7 days as well as 28 days which is shown in Table 7.

According to the chart above, the "compressive, fissure tensile, and flexural strength" of new concrete is increased by up to 3% and after that moderately dropped by 4% and 5%. A fraction or granule's percentage were swap with gravel (1 to 5 percent).

According to the fig.8. the workability of concrete small increase with the increasing up to 2% percentage of HDPE granules and after that decrease slowly which is measured by mm with the help of slump cone test and the data shown in table.8.

Mix label	Cement (kg/m^2)	Fine aggregate (kg/m^2)	coarse aggregate (kg/m^2)	Fiber (kg/m^2)	water (kg/m^2)	W/C ratio
CP0	1440	1600	1450	0	691	0.48
CP1	1440	1600	1450	14.4	691	0.48
CP2	1440	1600	1450	28.8	691	0.48
CP3	1440	1600	1450	43.2	691	0.48
CP4	1440	1600	1450	57.6	691	0.48
CP5	1440	1600	1450	72	691	0.48

Table 4: Materials in composition mixes

S.No.	Samples	Age of concrete	Load(KN)	Compressive strength (N/mm^2)
1	CP0	7-DAYS	412.4	18.33
		28-DAYS	626.4	27.84
2	CP1	7-DAYS	442	19.63
		28-DAYS	649	28.83
3	CP2	7-DAYS	462	20.53
		28-DAYS	689.4	30.64
4	CP3	7-DAYS	495.2	22.01
		28-DAYS	786.1	34.94
5	CP4	7-DAYS	367.4	16.33
		28-DAYS	666	29.6
6	CP5	7-DAYS	342.2	15.21
		28-DAYS	620	27.64

Table 5: Outcomes of compressive strength test

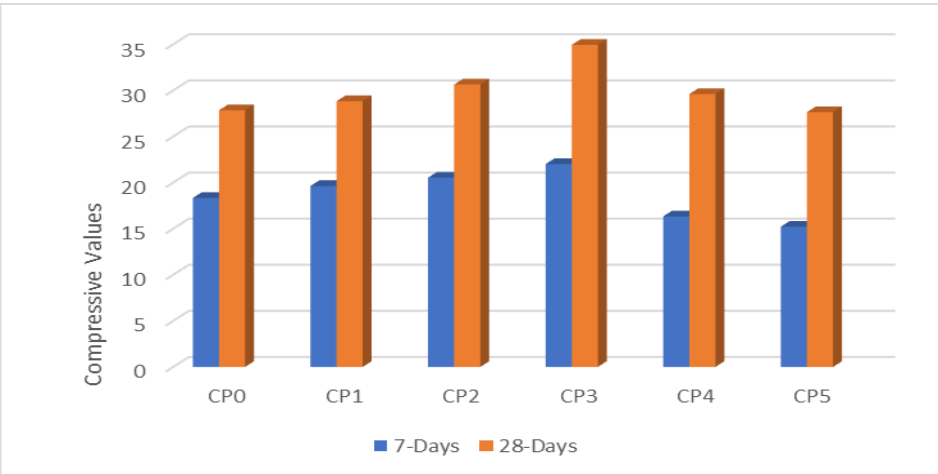

Figure 4: Compressive strength at 7 and 28 days.

S.No.	Samples	Age of concrete	Load(KN)	Flexural strength (N/mm²)
1	CP0	7-DAYS	16	8.12
		28-DAYS	30	15
2	CP1	7-DAYS	17.3	8.67
		28-DAYS	31.5	15.8
3	CP2	7-DAYS	18.2	9.1
		28-DAYS	33.3	16.66
4	CP3	7-DAYS	20	9.85
		28-DAYS	36	18
5	CP4	7-DAYS	18	8.93
		28-DAYS	33	16.32
6	CP5	7-DAYS	15.8	7.93
		28-DAYS	29	14.53

Table 6: Outcomes of Flexural strength test

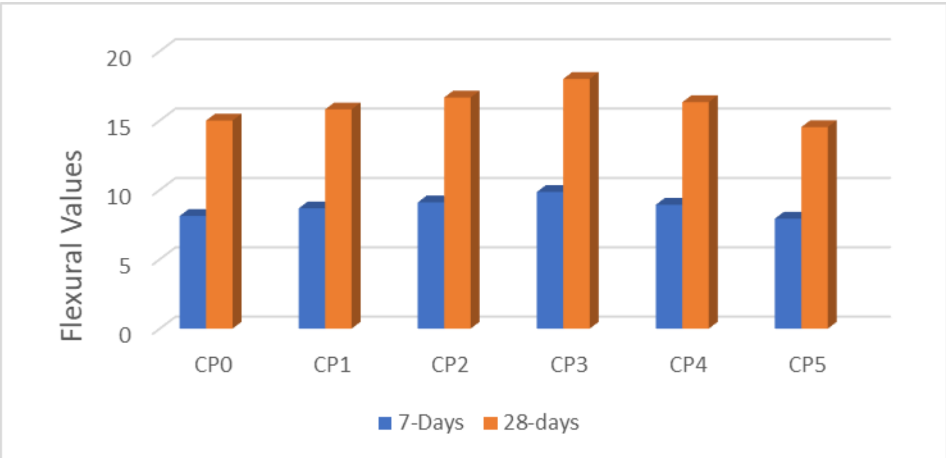

Figure 5: Flexural strength at 7 &28 days

S.No.	Samples	Age of concrete	Load(KN)	Tensile strength (N/mm²)
1	CP0	7-DAYS	156	2.2
		28-DAYS	244	3.45
2	CP1	7-DAYS	178	2.52
		28-DAYS	311	4.4
3	CP2	7-DAYS	201	2.84
		28-DAYS	438	6.2
4	CP3	7-DAYS	206	2.91
		28-DAYS	537	7.6

5	CP4	7-DAYS	148	2.1
		28-DAYS	255	3.6
6	CP5	7-DAYS	107	1.51
		28-DAYS	219	3.1

Table 7: Outcomes of Tensile strength test

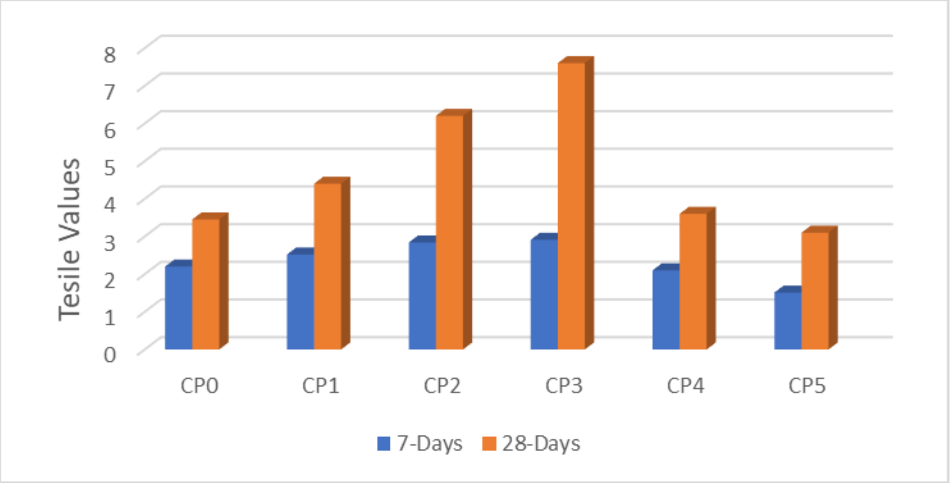

Figure 6: Tensile strength at 7 &28 days

S.No.	Types of concrete	Values of slump (mm)
1	CP0	52 mm
2	CP1	59 mm
3	CP2	57 mm
4	CP3	49 mm
5	CP4	46 mm
6	CP5	42 mm

Table 8: Outcomes of Slump tests

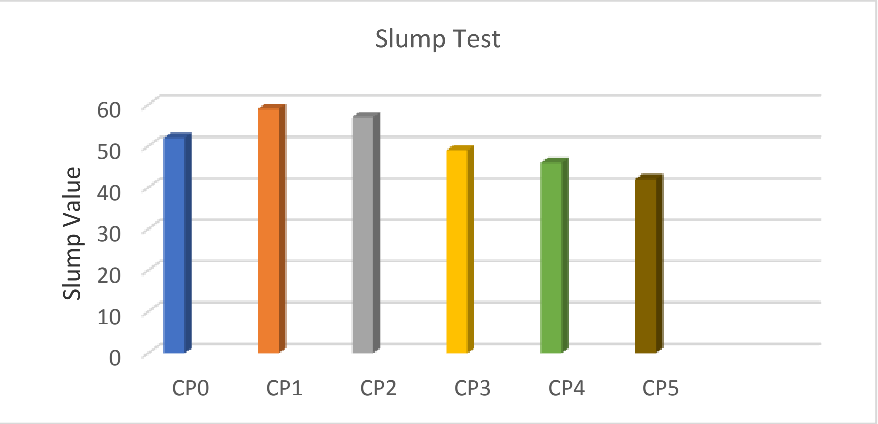

Figure 8: Slump Valuation

4. CONCLUSIONS

The properties of new concrete with calculative partial substitution of coarse aggregate with pure high density polyethylene granules were discovered to be greater enhance as compare to regular concrete which having grade M25 properties.

According to the results, HDPE granules boosts the compressive properties which is good and flexural characteristics and fissure tensile strength which is most important to every standard concrete. the optimal amount is 3%, and the values are growing by 4% and 5%, respectively. It is thought to be economically beneficial to replace some coarse aggregate with HDPE granules, which also improves concrete capacity.

Compressive strength rose by employing HDPE granules, increasing from 27.84 N/mm2 to 34.94 N/mm2 with a ratio of 3% HDPE granules by volume of concrete; however, adding additional granules lowered compressive strength; hence, 3% is the best HDPE granules.

Tensile strength rose from 3.45 N/mm2 (for reference mixes) to 7.6 N/mm2 (for 3% granules) then dropped when additional high density polyethylene granules were added.

Flexural strength rose significantly from 15 N/mm2 to 16.66 N/mm2, and failure of beams under two concentrated loads (third point loading) demonstrates ductile failure when compared to standard concrete, which fails by breaking in two pieces straight.

Workability of concrete rose by employing HDPE granules, increasing from 52 mm to 59 mm with a ratio of 1% granules however, adding additional HDPE granules lowered workability of concrete.

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