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Effects of Partially Replacing Waste HDPE Plastics as Fine Aggregates on the Mechanical Properties of Self-Consolidating Concrete (SCC)

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Abstract. Artificial fine aggregate synthesized from waste HDPE plastic was incorporated into the concrete mix at 2.5%, 5%, 7.5%, 10%, and 12.5% by weight of the natural fine aggregate. Various tests were performed on both freshly mixed and hardened concrete. Concrete samples, including 150 mm cubes and 100x100x500 mm beams, were cast to evaluate mechanical properties such as compressive strength and flexural strength. The test results indicated that the mix with a 10% replacement of artificial fine aggregate (AFA) improved compressive strength by 6.8% and flexural strength by 4.9% compared to those using natural aggregates. This demonstrates that using plastic-based artificial aggregates enhances concrete properties and supports sustainability.

Keywords: Artificial Aggregate**,** Self compacting Concrete, Mechanical properties, HDPE plastic, Recycle plastic.

1Introduction

The literature review addresses the pressing issue of land filling, exacerbated by the increasing population and limited land availability. A significant part of this waste comprises plastic, notoriousforits slow decomposition rate,taking approximately500 years to break down. To mitigate this issue, recycling plastic instead of disposing of it in landfills is a promising solution. This approach is already applied in various sectors, including construction materials, fuel production fromplastic waste, house hold goods, fabric, and clothing. The focus of this study is on the in corporation of plastic in the construction industry, particularly inconcrete,to enhancesustainabilityandwastemanagement.

Different types of plastics such as Polyethylene Terephthalate (PET), High-Density Polyethylene(HDPE),PolyvinylChloride(PVC),Low-DensityPolyethylene

[1]PleasenotethattheLNCSEditorialassumesthatallauthorshaveusedthewesternnaming convention, with given names preceding surnames. This determines the structure of the

names in the running heads and the authorindex.

(LDPE), Polypropylene (PP), Polystyrene (PS), and Miscellaneous Plastics have beenidentified for potential use in construction. The study investigates the incorporation oftheseplasticsintoconcreteandtheireffectsonitsproperties.

[1] explored the impact of PET plastic waste on the compressive strength of concrete.They found that incorporating PET particles in varying dosages (0%, 5%, 10%, and15%) resulted in reduced compressive strength, with a notable reduction at 15%.However, the 15% PET concrete showed higher resistance under sulfuric acid attack,suggestinga potentialbenefitinspecific conditions.

[2] investigated the use of HDPE waste in concrete, with HDPE content ranging from0-5% of the total mix weight. They observed a decrease in compressive strengthbeyond 0.5% HDPE addition, which could potentially be mitigated by treating theHDPEtoenhanceitsbonding withthe concretematrix.

Further studies by[3]), Beno[45]examined shredded PET bottlewaste as a partialsubstitute for natural aggregates in concrete. These studies consistently found that theincorporation of PET aggregates resulted in lower compressive, flexural, and tensilestrengths compared to conventional concrete. Moreover, the strengths decreased withincreasingPETcontent.

Research on replacing coarse aggregate with polyethylene (PE) in concrete showedareductioninworkabilityby50mmwhensubstitutingPEintherangeof5-15%witha water-to-cement ratio of 0.42. Similar trends were observed in studies utilizingvarious plastic waste materials, including shredded fibers from polythene bags, PETbottlefibers, granulated plasticwaste, and PVCpipes.

A notable gap in the literature is the exploration of using plastic in fine aggregateform rather than as coarse aggregate. This aspect is crucial for sustainability, as itcould reduce the reliance on naturally available aggregates. The present study aims tofill this gap by investigating the use of plastic as fine aggregate in self-compactingconcrete (SCC) instead of conventional concrete. SCC offers enhancedflowabilityand compaction without the need for vibration, presenting an innovative approach toincorporatingplasticwasteinconstructionmaterials.

Inconclusion,whilesignificantresearchhasbeenconductedonincorporatingplastic waste into concrete, primarily focusing on coarse aggregate substitution, thepotential for using plastic as fine aggregate remains underexplored. This study aims toaddress this gap, offering insights into the performance of SCC with plastic fineaggregates.Suchanapproachcouldprovidesubstantialbenefitsintermsofsustainabilityandresourceefficiencyinthe constructionindustry.

2. Experimental Work:

2.1 Materials used:

In this study, Ordinary Portland cement of 43-grade was used, complying with IS(IndianStandards)code8112-1989.Table1providesadetailedaccountofthephysicalpropertiesofallmaterialsinvolved.Riversand fromZoneII,whichmeetsthe requirements of IS: 383–1970 and has a specific gravity of 2.61, was selected asthenaturalfine aggregate (NFA).

High-Density Polyethylene (HDPE) plastic served as a replacement for the naturalfine aggregate. The HDPE used in the study exhibited tensile strength between 33 and40 MPa, flexural strength ranging from 15 to 55 MPa, and a flash point of 38°C. TheHDPE was processed into fine particles, and those that passed through 4.75mm sieveswereemployedasthe artificialfine aggregate (AFA).

For the coarse aggregate, crushed stone with a particle size of 20mm and a specificgravity of 2.76 was chosen. Given the aim to produce self-compacting concrete (SCC)instead of traditional concrete, a Polycarboxylate Ether (PCE)-based super plasticizerwas used to improve the mix's flow ability and workability while maintaining itsstructuralproperties[6,7].

Table1 Physicalpropertiesofmaterials

Properties	**Cement**	**HDPE**	**FineAggregate (FA)**	**CoarseAggregate (CA)**
Maximumparticlesize(mm)	5micron	4.75	4.75	10
Chemicalresistance	chemicalresistant	Solvents, alkalisAndacids	-	-
Electricalresistivity (ohm-m)	1	1016–1018		
Finenessmodulus	7	3.12	2.48	8.72
Waterabsorption (%)	13	0.32	2.68	0.89
Density	1.44g/cm³	0.90–0.94 g/cm³	2630kg/m³	2442kg/m³
Specificgravity	3.15	0.864	2.61	2.76

2.2.Casting and Mixing

Initially, experiments were conducted to attain M30 grade concrete, incorporatingdiverse quantities of fine aggregate (FA), coarse aggregate (CA), and superplasticizer.Theaimofthesetrialswastodevelopself-compactingconcrete(SCC)thatdemonstratesadequateflow,inaccordancewithEFNARCguidelines.Theseexperimentsweredeemednecessaryduetotheabsenceofastandardizedcodeofferinga designmixfor SCC.

Following numerous trials, a formulation was ultimately settled upon, meeting thecriteria of ample flow and achieving strength of 30 MPa. This formulation is denotedas the controlmix. The proportions for the controlmix are delineatedin Table 2,along with specifics for other formulations considered during the experimental phase.To investigate the influence of HDPE waste plastic as a substitute for fine aggregate(henceforth referred to as artificial aggregate) in concrete, various formulations weredevised with a stepwise increase of 2.5% each, replacing natural fine aggregate. Thesubstitutionspannedfrom0%to10%.Theproportionsforallformulationsareelucidated inTable 2.

Table2 Concrete Mixproportion

SpecimenCode	**Cement(Kg/)**	**AFA %**	**AFA (kg)**	**FA(Kg)**	**CA(Kg)**	**W/C**	**Water(kg)**	**Admixture(Kg)**
Reference	500	0	0	880	880	0.50	225	8
HDPE-2.5	500	2.50	22	858	880	0.50	225	8
HDPE-5	500	5.00	44	836	880	0.50	225	8
HDPE-7.5	500	7.50	66	814	880	0.50	225	8
HDPE-10	500	10.00	88	792	880	0.50	225	8
HDPE-12.5	500	10.00	110	770	880	0.50	225	8

These formulations underwent thorough examination for both fresh and hardenedproperties. Fresh properties were evaluated through slump flow and V box tests, withtheresultspresentedinTable3.Thesetestsoffervaluableinsightsintotheworkability andflow characteristics of concrete formulations containing differingpercentagesofHDPEwasteplasticasasubstitutefornaturalfineaggregate.

Table3 Properties of fresh SCC prepared concrete.

SpecimenCode	**Slumpflow**		**V-funneltimeinSec**	
	Experimental	**Range**	**Experimental**	**Range**
Reference	578	550-600	7.48	<8
HDPE-2.5	582	550-600	7.36	<8
HDPE-5	586	550-600	7.31	<8
HDPE-7.5	594	550-600	7.26	<8
HDPE-10	604	550-600	7.37	<8
HDPE-12.5	604	550-600	7.31	<8

According to the fresh properties results outlined in Table 3, it can be deduced that allformulations fall within the specified range by the EFNARC code, classifying them asself-compacting concrete (SCC) with favourable flow characteristics. Noteworthy isthatwith theincreasein thedosageof artificialfineaggregate(AFA)replacingnaturalfineaggregate(NFA),theslumpflowalsoincreased, reachingitspeakdiameter of 604mm for the formulation with 12.5% replacement. Furthermore, in theV-funneltest,itwasnotedthattheformulationwith12.5%replacementrequiredonly 7.31 seconds emptying the funnel. These observations suggest an enhanced flowcapacity and workability of concrete formulations with higher proportions of HDPEwasteplastic substitutingnaturalfine aggregate.

3. Results and Discussions

3.1 Compressive Strength Results:

To examine the influence of artificial aggregate on the compressive strength orultimateload-bearingcapacityoftheproducedconcrete,threecubesforeachformulationunderwenttestingusinga compressivetestingmachine(CTM)untilfailure. The outcomes of these tests are documented in Table 3 and visualized inFigures 1 and 2. These results offer valuable insights into the impact of replacingnatural fine aggregate with HDPE waste plastic on the structural performance andload-bearingcapacityofthe concrete.

Table4 Compressivestrengthfor differentages

SpecimenCode	**CompressiveStrength(Mpa) of**			**Increase nstrength 28days(%)**
	3Days	**7Days**	**28Days**	
Reference	15.7	24.7	39.5	-
HDPE-2.5	15.2	23.1	38.7	-2.02
HDPE-5	15.9	26.05	40.3	2.02
HDPE-7.5	16.7	27.3	42.9	8.6
HDPE-10	17.25	29.2	43.5	10.12
HDPE-12.5	16.8	28.9	42.3	7.08

The specimens underwent testing at 3 days, 7 days, and 28 days to observe theimpact of curing on thestrengthwhen fine aggregate (FA) is replaced in concrete.Thefindingsrevealthatwithincreasingcuringtime,thecompressivestrengthenhances irrespective of the dosage of FA replacement. The table also delineates thepercentage increase in compressive strength values for 28 days in comparison to thereferencemix.

Initial observations indicate a decrease in compressive strength by 2.02% for a2.5% dosage. However, subsequently, the strength increases by 2.02% and 8.6% forHDPE 5 and HDPE 7.5 specimens and strength increase by 10.12% for HDPE 10 specimen .As the dosage increase after 10 HDPE the strength tends decline which is 7.08% at HDPE 12.5 specimen which is less thanthat of HDPE 10.

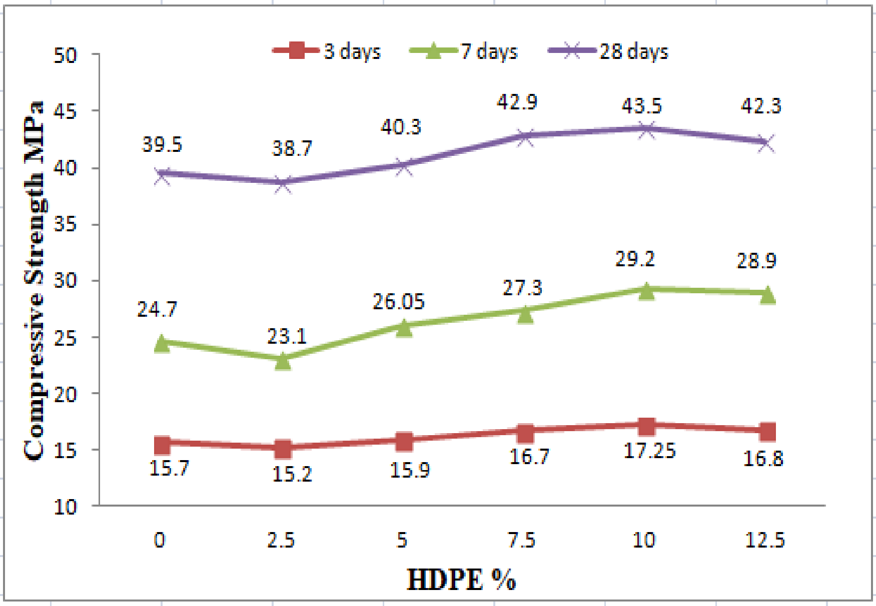

Fig.1 PlotCompressivestrengthfordifferentagesanddosagesofAFA

3.2 Flexural Strength Results:

To evaluate the influence of artificial aggregate on the flexural strength capacity ofthe produced concrete, three beams measuring 75 x 10 x 10 mm were tested underthree-point loading. Each mix was represented by a set of three beams, which werethensubjectedtotestingunderacompressivetestingmachine(CTM)untilfailure.The peak load values were recorded, and the flexural strength was determined usingequation 1 based on these peak loads. The calculated results are summarized in Table5 and depicted in Figures 3 and 4. These findings offer insights into the impact ofreplacing natural fine aggregate with HDPE waste plastic on the flexural strength oftheconcrete.

Table5 Flexuralstrengthfordifferentages.

SpecimenCode	FlexuralStrength(MPa)	Increase in strength of 28

	3Days	7Days	28Days	days(%)
Reference	1.5	2.63	4.14	0
HDPE-2.5	1.4	2.23	4.08	-1.2
HDPE-5	1.5	2.92	4.19	1.2
HDPE-7.5	1.86	2.41	4.21	1.69
HDPE-10	1.89	2.82	4.25	2.65
HDPE-12	1.75	2.80	4.18	0.96

Similartothecompressivestrengthtesting,thebeamsetsweretestedat3,7,and 28daystoevaluatetheirtensilestrength.Asexpected,replacingnaturalfineaggregate (NFA) with artificial fine aggregate (AFA) did not significantly enhancetensile strength. However, mirroring the patterns seen in compressive strength, anincrease in flexural strength was observed. The increases in strength for the 5%, 7.5%, 10% and 12.5% replacements were 1.2%, 1.69%, 2.65 and 0.96%, respectively. The optimal dosage,once again, seems to be 10%, as it yielded the highest increase in strength. Thesefindings provide important insights into how substituting natural fine aggregate withHDPEwasteplasticaffectsboththetensileandflexuralstrengthoftheconcrete

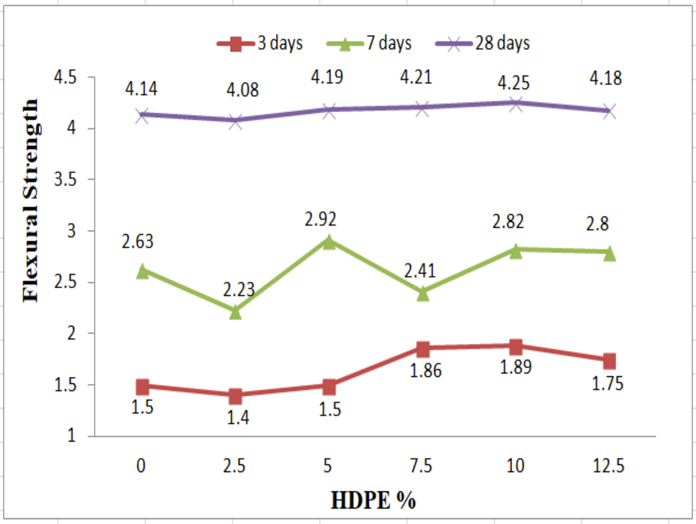

Fig.3 PlotFlexuralstrengthfordifferentagesanddosagesofAFA

4. Conclusions

Based on the findings from this study, the following conclusions are drawn:

1. Thefreshpropertiesofself-compactingconcreteimprovedastheamountofartificialfine aggregate (AFA)increased.
2. The slump flow test showed an increase in flow with higher AFA dosages, reachinga diameter of 604 mm, while the V-box test time decreased to 7.31 seconds at a 12.5%replacement.

3. Compressive strength initially droppedby 2.02% with a 2.5% replacement ofnatural fine aggregate (NFA) by AFA, then increased to 10.12% at a 10% replacementbeforedecliningagain.The optimal replacementlevel is10%.
4. Flexural strength initially decreasedbut achieved a maximum increase of 2.65%witha 10%replacement.
5. In conclusion, sustainable concrete can be produced by substituting natural fineaggregate with waste plastic, leading to environmental benefits and improved freshand hardenedpropertiesoftheconcrete.

References

1. Janfeshan Araghi,H., Nikbin, I. M., RahimiReskati,S., Rahmani, E.&Allahyari,H.Anexperimentalinvestigationontheerosionresistanceofconcrete containing various PET particles percentages against sulfuric acidattack. *Constr. Build. Mater.***77**, 461–471(2015).
2. Naik, T. R., Singh, S. S., Huber, C. O. & Brodersen, B. S. Use of post-consumer waste plastics in cement-based composites. *Cem. Concr. Res.* **26**,1489–1492 (1996).
3. Saikia, N. & de Brito, J. Use of plastic waste as aggregate in cement mortarandconcretepreparation:Areview.*Constr.Build.Mater*.**34**,385–401(2012).
4. Benosman,A.S.*etal.*StudiesonChemicalResistanceofPET-MortarComposites: Microstructureand Phase Composition Changes.*Engineering***05**,359–378(2013).
5. Mathew,P.,Varghese,S.,Paul,T.&Varghese,E.RecycledPlasticsasCoarseAggregatefo rStructuralConcrete.*Int.J.Innov.Res.Sci.Eng.Technol.***2**,(2013).
6. Cholker,A.K.&Tantray,M.A.Strain-sensingcharacteristicsofself-consolidatingconcretewithmicro-carbonfibre. *Aust.J.Civ.Eng.***18**,(2020).
7. Cholker,A.K.&Tantray,M.A.Electricalresistance-basedhealthmonitoring of structural smart concrete. *Mater. Today Proc.* **43**, 3774–3779(2021).