



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 5, May 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com

A Sustainable Approach Using Waste Plastic Coarse Aggregate as Controlled Low Strength Materials

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ABSTRACT: Controlled low strength material (CLSM) has different uses of materials that have gained considerable traction in various engineering applications. This paper presents the development and applications of CLSM by utilizing waste plastic coarse aggregate, fly ash, ordinary portland cement, M sand, Pond ash and water. The strength of CLSM is less than 8.3 MPa, As a result, CLSM is not suitable for supporting buildings, bridges, or other structures. Instead, it is primarily used as a replacement for backfilling, compacted backfill, trench filling and other applications. Here the waste plastics which are available in different forms are utilized as replacement to conventional coarse aggregates. Production of recycle plastic coarse aggregate and characterization of the same along with other ingredients are been carried out. Studies on CLSM using Recycle Plastic Coarse Aggregate (RPCA) and industrial by products including fly ash replacement to filler and binder and their influences on fresh and hardened properties. The outcomes of the research explore possible solutions for utilizing waste plastic and industrial by-products to prevent their disposal in landfills which is creating lot of impact on the environment. The scope of this research aims towards reduction on impact of environment pollution due to plastic waste. To development of eco-friendly construction materials and to utilization of waste materials for construction applications.

KEYWORDS: Controlled Low Strength Material (CLSM), waste plastic coarse aggregate, fresh and in-service properties.

I. INTRODUCTION

India is overall the construction sector is the biggest it uses a wide variety of materials and produces a lot of garbage when a project is completed. Environmental contamination is an issue that the entire globe is now confronting. The biggest threat to wildlife is plastic. Aquatic life and animals are also severely harmed by plastic. As far as we know, plastic cannot be entirely destroyed. Thus, we may lessen the threat that plastic poses to the environment by reusing discarded plastic in our daily lives. Waste plastic can serve as a useful substitute for natural landfill materials. The environment by using plastic garbage. The concrete will be environmentally friendly.

1.1 CONCRETE

Concrete its as long durability, and ability to sustain extreme weather environments. Concrete is a mixture of binder, water, aggregates and admixtures. In concrete, the composition typically includes 41% coarse aggregate, 26% fine aggregate, 22% water, and 11% binder. The global consumption of concrete is approximately 30 billion tonnes each year. The production of cement exceeds 2.8 billion tonnes, and the global usage of the aggregate is estimated to be 16.5 billion tonnes.

1.2 PLASTIC

Plastic is a wide range of synthetic or semi-synthetic materials that use polymers as the main ingredient in their composition[60]. Plastics can be separated into two types. The first is thermoplastic, can be melted down and reused. Their plasticity makes it possible for plastics to be moulded and pressed into solid objects of various shapes. It as lightweight, durable and flexible.

1.3 STATISTICS OF PLASTIC WASTE GENERATED

The global production of plastic has reached 400 million tonnes in the year 2021. The future trends in plastic indicate that annual production is estimated to exceed 1.1 billion tonnes by the year 2050. Globally, around 7 billion tonnes of

plastic waste are generated, but less than 10 percent of it has been recycled. India generates 3.5 to 3.6 million tonnes plastic waste per year.

In India, approximately 3.4 million tonnes of plastic waste are produced each year. Unfortunately, only 50 to 60 percent of the plastic waste is recycled.

1.4 IMPACT OF PLASTIC ON THE ENVIRONMENT

- Groundwater and soil pollution.
- Pollution in oceans which affects aquatic life and eco-system.
- Dangerous for human life.
- Environmental pollution.
- Wildlife harm.

1.5 CONTROLLED LOW STRENGTH MATERIAL (CLSM)

Controlled low-strength material CLSM is defined by American Concrete Institute ACI Committee 229 as a self-compacted cementitious material that is generally utilized as backfill as an alternative to compacted fill. In addition to these terms, CLSM is also known by the names K-Krete, flowable fill, unshrinkable fill, controlled density fill, flowable mortar, and plastic soil-cement. According to ACI, CLSM is defined as having a maximum compressive strength of up to 8.3 MPa. Currently, 2.0 MPa or fewer compressive strengths are needed for the majority of CLSM applications. In order to enable CLSM excavation in the future, a lower strength requirement is required. Long-term compressive strengths of 0.35–0.70 MPa are very low when compared to concrete[12].

1.6 ALTERNATIVES TO FINE AGGREGATE AND COARSE AGGREGATE

Alternatives to Conventional of coarse aggregate:

- Coconut shell
- Tire rubber
- Plastic waste
- Glass waste
- Bamboo chips
- Palm kernel shell.

Alternatives to Conventional of fine aggregate:

- Quarry dust
- Ceramic dust
- Steel powder
- Glass powder
- Coal dust
- Agricultural waste

II. LITERATURE REVIEW

- Brahim Safi, Mohammed Saidi, Djamila Aboutaleb, Madani Maallem “**The use of plastic waste as fine aggregate in the self-compacting mortars**”(2013) Material used waste plastic polyethylene terephthalate (PET) used for bags manufacture as a fine aggregate. Fine aggregate 0%, 10%, 20%, 30% and 50% by weight of the sand Experiments and results therefore, The compressive strength of SCMs may be affected by either a poor bond between the cement paste and the plastic wastes or by the low strength of these plastic wastes. The flexural tensile strength decreases with the increase in plastic waste content[11].

- Ashwini Manjunath B T “**Partial replacement of E-plastic Waste as Coarse-aggregate in Concrete**”(2016) Material used E plastic waste from old computers, TVs, refrigerators, radios. Fine and Coarse aggregate replacement 0%, 10%, 20% and 30%. Experiments and results therefore, Slump test -128, 114, 90, 74 in mm, Compressive strength - 47.18, 44.07, 24.69, 22.18 N/m³. Split tensile strength - 4.9, 4.8, 5.4, 3.8. Flexural strength - 4.35, 4.4, 4.3, 2.5. The use of plastics in the mix lowers the density[23].

- Megha V Gowda, Anusha R, Abhishek Prabhu, Sridev SB, Karthik M “**Studies on Controlled Low Strength Material Using Waste Plastic Coarse Aggregate**”(2023) Material used waste plastic coarse aggregate, fly ash, pond ash, cement, M sand, and water. Experiments and results therefore, Flowability 600mm, Wet density is 2082kg/m³,

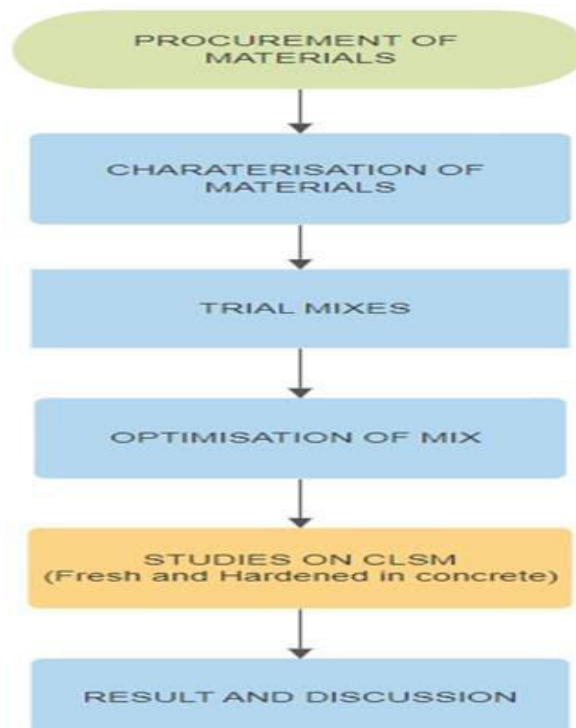
Dry density is 1988kg/m³, Compressive strength is 4.7Mpa. Recycled plastic coarse aggregates strength shows greater impact than coarse aggregates. Plastic waste can be used as a 100% replacement for conventional coarse aggregates in non-structural applications[6].

- Harikrishna Shapariya, Dr. J.R. Pitroda, Prof. Ratansaran Panchal “**Mechanical Properties of Concrete by Using Plastic Waste**”(2021) Material used plastic waste disposal. Fine aggregate replacements are 5%, 10%, 15% and 20%. Experiments and results therefore, slump test - 70, 75, 77, 80. Compressive strength - 28.52, 28.02, 24.62, 23.62. Flexure test - 2.13, 2.01, 1.6, 1.1. This leads to the concrete's unit weight being reduced. Plastics in concrete help to make it ductile, improving its ability [24].
- Parwez Alam, Saurav Yadav, Shivam kumar Jaiswal, Shankar Prakash, Saxena “**A Study on Plastic Waste for Replacement of Coarse Aggregate with Soft and Hard Plastic in Concrete**” (2022). Material used recycled plastic aggregate. Replaced of aggregate as 0% to 25%. The decrease in strength of concrete with increase in plastic waste and he obtained optimum results at 15% of plastic replacement. Plastic waste can act as a partial substitute for coarse aggregate and can also be used in the bituminous road portion to enhance flexibility [27].

2.1 FINDINGS FROM LITERATURE

In this literature Various alternatives of plastic for conventional coarse aggregate that were considered are E-plastic, PET recycled waste, LDPE recycled waste. These plastic wastes were used in of chips, angular shaped, powdered forms. Partial replacement has been done in various mixes among which plastic aggregate has been replaced upto maximum of 50%. It is observed that the concrete showed lesser density, lesser strength where it can be used non-structural applications. The increase in the use of plastic waste in the concrete mixture reduced the compressive strength. This CLSM can be used as landfill and backfill material as an alternative to the conventional granular material utilizing the industrial waste materials.

III. METHODOLOGY



3.1 CHARACTERISATION OF MATERIALS

Sl.No.	MATERIALS	TESTS	RESULTS OBTAINED	IS CODES	SPECIFICATIONS
		Specific gravity of cement	3.12	IS 8112 - 1989	The range Should be between 3.10 to 3.15
		Normal consistency test	33%	IS 5513-1976 IS 4031-1988 (part4)	24% to 34% depending upon the sample
1.	CEMENT	Setting of cement	Initial setting is 40min Final setting time is 600 min	IS 5513-1976 IS 4031-1988 (part4)	should not be less than 30 minutes & final setting time should not be more than 600 minutes.
		Fineness test by sieve analysis method	8.3%	IS 460-1985 (Part-1) IS 460-1985 (Part-3) IS 3535: 1986 IS 5165: 1969	For ordinary Portland cement the fineness should be <10%
2.	CONVENTIONAL COARSE AGGREGATE	Aggregate crushing strength	20.3%	IS 2386 Part IV IS 383 IRC 15-1970	Crushing value of the coarse aggregate used for the cement concrete pavement at surface should not exceed 30%
		Abrasion test	25.6 %	IS 2386 Part IV IS 383 IRC 15-1970	25 %- 55%
		Impact test	20.9%	IS 2386 Part IV IS 383 IRC 15 – 1970	<10% exceptionally strong 10-20% strong 20-30% satisfactory for road surfacing 35% weak for road surfacing
2.	CONVENTIONAL COARSE AGGREGATE	Flakiness index	1.38%	IS 2386-Part I	It should be less than 15% and normally does not exceed 25%
					For road



		Elongation Index	9.4%	IS 2386 Part I	construction elongation index should be less than 15%
		Specific gravity and water absorption test	Specific gravity =2.61 Water absorption =0.45	IS 2386 (Part3) IRC:47	The Specific gravity of aggregates from 2.5 to 3.0 with an average value of 2.61 Water absorption value ranges from 0.1 to 2.0 %
3.	PLASTIC AGGREGATES	Specific gravity	Specific gravity =0.83	IS 2386(Part3) IRC:47	The Specific gravity of plastic aggregates from 2.5 to 3.0 with an average value of 0.83
		Aggregate crushing strength	0	IS 2386 Part IV	Crushing value of the coarse aggregate used for the cement concrete pavement should not exceed 30%
3.	PLASTIC AGGREGATES	Abrasion test	0	IS 2386 Part IV IS 383 IRC 15 – 1970	The range should be between 40% - 60%
		Impact test	0.05%	IS 2386 Part IV IS 383 IRC 15 – 1970	<10% exceptionally strong 10-20% strong 20-30% satisfactory 35% weak for road surfacing.
		Flakiness Index	7.8%	IS 2386-Part I	used in road construction should be less than 15% and normally does not exceed 25%
					For road

4.	M Sand	Elongation Index	10.9%	IS 2386-Part I	construction elongation index should be less than 15%
		Specific Gravity	2.67	IS 2386-part (1963) IS 383 (1970)	The range should be between 2.65 to 2.67
		Bulk density	1.58 kg/ltr	IS: 2386 (Part 3) 1963	The range should be between 1.200-1.750 kg/ltr
		Sieve Analysis	Zone II	IS 2386-part2(1963) IS 383 (1970)	Grading Zone II 10mm = 100% 4.75mm = 90-100% 2.36mm = 75-100% 1.18mm = 55-90% 600µm = 35-59% 300µm = 8-30% 150µm = 0-10%
5.	Fly Ash	Specific Gravity	2.45	IS:3812 (Part-1) 2003	The range should be between 2.1 to 3.0
		Fineness test	20%	IS:3812 (Part-1) 2003	The range should be between 5-35%
6.	Pond Ash	Specific Gravity	2.13	IS:13757 - 1993	The range should be between 2.03 to 2.27
		Fineness test	4.9%	IS:13757 - 1993	The range should be between 3 - 6%

IV. STUDIES ON CLSM

4.1 Mix Design

Table 4.1 Basic mix design details.

SL NO.	Particular	Details
1	Cube size	150x150x150mm

2	Tests	Flowability, Flow time, Compressive strength, Wet density and Dry density.
3	Materials used	Cement (OPC 53), Fine aggregate (M- Sand), Coarse aggregates, Plastic aggregates, Pond ash, Fly ash and Water.

TABLE 4.2 Mix Proportional of Material (kg/m³):

MIX	OPC 53	Fly Ash	Pond Ash	M Sand	RPCA	CCA	Water
AM1	60	120	194.6	83.4	417	-	225
CM1	60	120	194.6	83.4	-	417	225
AM2	90	90	212.4	65.6	417	-	225
CM2	90	90	212.4	65.6	-	417	225
AM3	120	60	194.6	83.4	417	-	225
CM3	120	60	194.6	83.4	-	417	225

TABLE 4.3 Percentage of Material used in Mix Design:

MIX	OPC 53	Fly Ash	Pond Ash	M Sand	RPCA	CCA	Water
AM1	5.4%	10.9%	17.7%	7.6%	37.9%	-	20.5%
CM1	5.4%	10.9%	17.7%	7.6%	-	37.9%	20.5%
AM2	8.1%	8.1%	19.3%	6.0%	37.9%	-	20.5%
CM2	8.1%	8.1%	19.3%	6.0%	-	37.9%	20.5%
AM3	10.9%	5.4%	17.7%	7.6%	37.9%	-	20.5%
CM3	10.9%	5.4%	17.7%	7.6%	-	37.9%	20.5%

TABLE 4.4 Percentage of Each Materials:

Materials	Binder (180kg/m ³)		Filler (278kg/m ³)		Aggregate (417kg/m ³)		Water (225kg/m ³)
	OPC 53	Fly Ash	Pond Ash	M Sand	RPCA	CCA	Water
AM1	33%	67%	70%	30%	100%	-	100%
CM1	33%	67%	70%	30%	-	100%	100%
AM2	50%	50%	76%	24%	100%	-	100%
CM2	50%	50%	76%	24%	-	100%	100%
AM3	67%	33%	70%	30%	100%	-	100%
CM3	67%	33%	70%	30%	-	100%	100%

4.2 FRESH PROPERTIES OF CLSM

4.2.1 Flowability

TABLE 4.5 Flowability and Flow time of CLSM

SL.no.	MIX	Avg. FLOWABILITY (mm)	Avg. FLOW TIME (sec)
1	AM1	645	10
2	CM1	620	8
3	AM2	610	13
4	CM2	595	12

5	AM3	630	14
6	CM3	605	10

4.2.2 WET DENSITY

TABLE 4.6 Wet Density of CLSM

SL.No.	MIX	Avg. WET DENSITY (kg/m ³)
1	AM1	1643.9
2	CM1	2278.2
3	AM2	1603.9
4	CM2	2228.2
5	AM3	1646.5
6	CM3	2293.2

4.3 HARDENED PROPERTIES

4.3.1 DRY DENSITY

TABLE 4.7 Dry Density of CLSM

SL.no.	MIX	Avg. DRY DENSITY (kg/m ³)
1	AM1	1408.4
2	CM1	2106
3	AM2	1422.9
4	CM2	2181.3
5	AM3	1522
6	CM3	2243.3

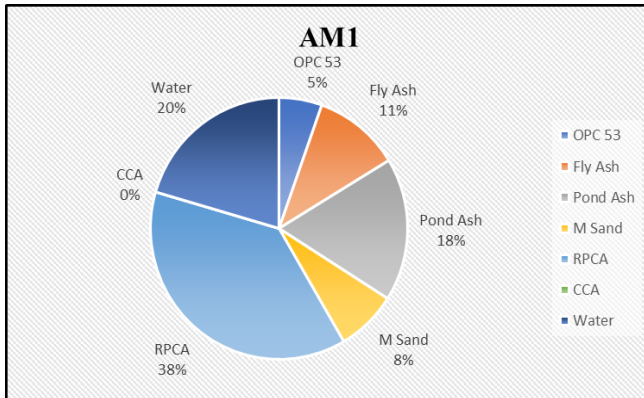
4.3.2 COMPRESSIVE STRENGTH

TABLE 4.8 Compressive strength of CLSM

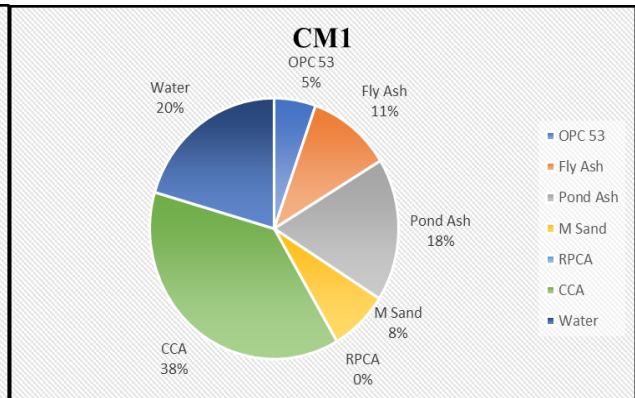
SL.no.	MIX	Compressive strength 7 days (Mpa)	Compressive strength 28 days (Mpa)
1	AM1	3.7	7.9
2	CM1	5.4	7.9
3	AM2	4.6	8.4
4	CM2	5.5	11.9
5	AM3	7.5	13.7
6	CM3	6.8	14.3

V. RESULT AND DISCUSSION

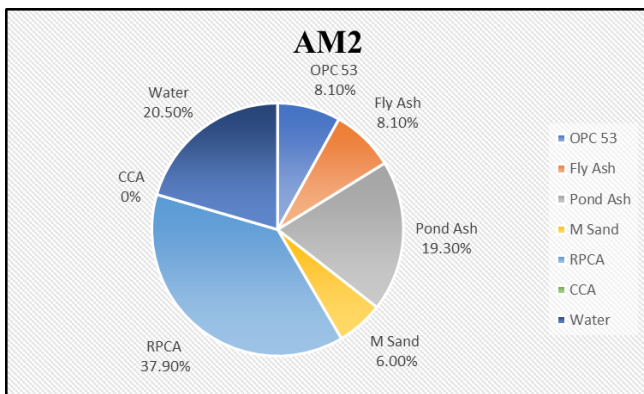
5.1 MATERIAL COMPOSITION



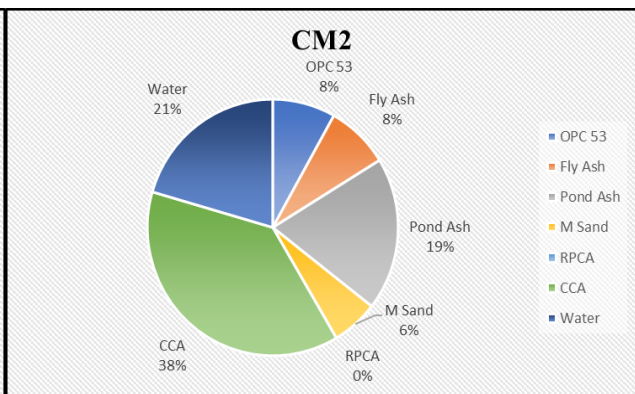
Graph 5.1 Alternative Mix 1



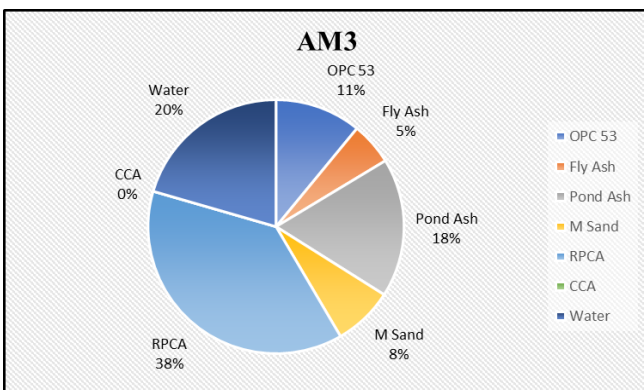
Graph 5.2 Conventional Mix 1



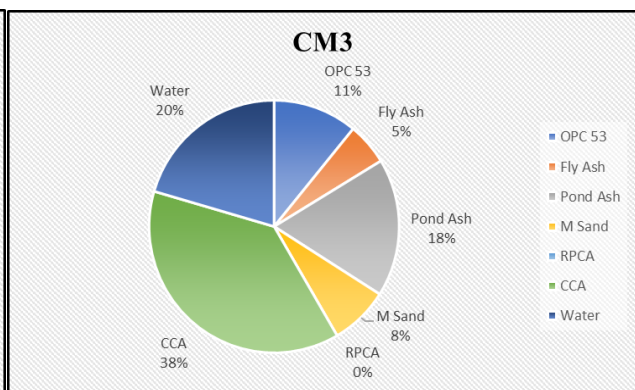
Graph 5.3 Alternative Mix 2



Graph 5.4 Conventional Mix 2

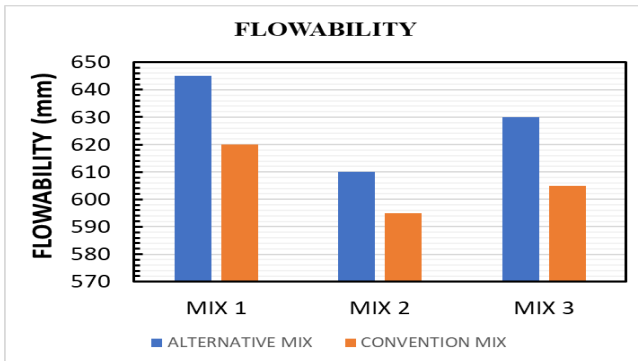


Graph 5.5 Alternative Mix 3

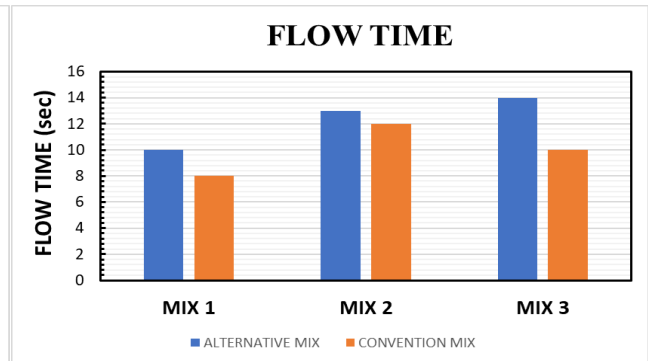


Graph 5.6 Conventional Mix 3

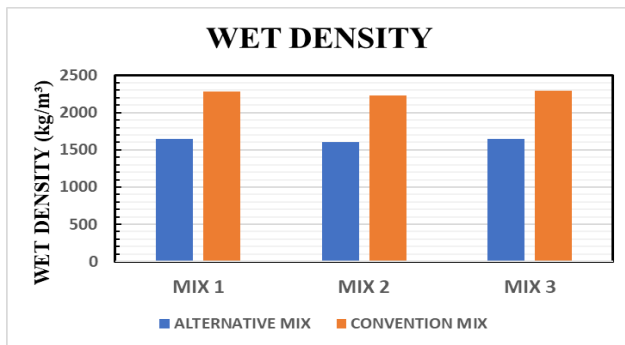
5.2 TEST RESULT



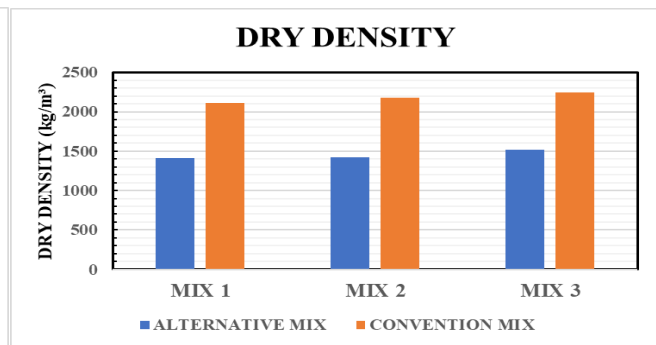
Graph 5.7 Flowability of CLSM



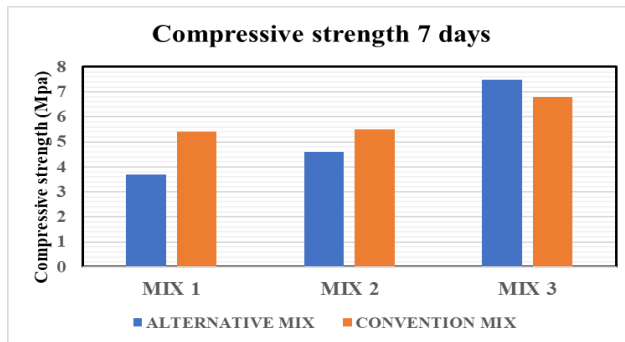
Graph 5.8 Flow time of CLSM



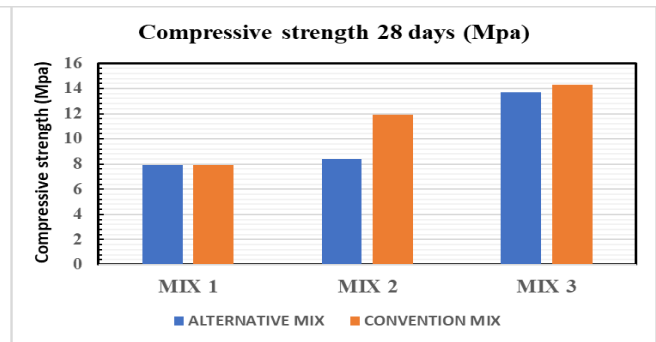
Graph 5.9 Wet Density of CLSM



Graph 5.10 Dry Density of CLSM



Graph 5.11 Compressive Strength of CLSM(7days)



Graph 5.12 Compressive Strength of CLSM(28 days)

5.3 DISCUSSION

There is 6 different mixes are casted Alternate mix (AM1, AM2, AM3) and Conventional mix (CM1, CM2, CM3). In AM1 and CM1 5.4% of OPC53 and 10.9% of fly ash were used as binder, 17.7% of pond ash and 7.6% of M-sand were taken as filler. In AM2 and CM2 8.1% OPC53, 8.1% of pond ash as equal are taken, 19.3% of pond ash and 6% of M-sand. In AM3 and CM3 10.9% OPC53, 5.4% of fly ash, 17.7% of pond ash and 7.6% of M-sand as taken the remaining material were kept constant. 37.9% RPCA and 20.5% water for all mixes. For

Conventional mixes use of CCA of 37.9% and Alternate mix expect that CCA was taken in place of RPCA of 37.9%.

The flowability of AM1 and AM3 was 5% greater than CM1 and CM3, AM2 was greater then 3% CM2. The wet density AM1 was 28% less than CM1 wherever AM2, AM3 are 29% less than CM2, CM3. The dry density was greater by 33%, 35%, 32%in CM1, CM2, CM3 with comparison with AM1, AM2, AM3. The compressive strength

AM1 was equal to the CM1, AM2 was 30% less than CM2 and AM3 was 5% less than CM3. AM1 and AM2 as achieved CLSM strength which is less than 8.3Mpa.

VI. CONCLUSION

In construction industry are facing environmental challenges caused by plastic waste due to the integration of discarded plastic into materials like concrete. There are a few alternative materials in coarse aggregates, which we are selecting as plastic coarse aggregate and replacing coarse aggregate with recycled plastic coarse aggregate in CLSM concrete.

The characteristics of recycled plastic coarse aggregate like aggregate crushing strength, impact and abrasion test show that greater than the conventional coarse aggregate and also the recycled plastic coarse aggregate has low density compare to conventional coarse aggregate.

We have conducted the various trail mixes to compare the recycled plastic coarse aggregate and conventional coarse aggregate by the flowability, flow time, wet density, dry density and compressive strength.

The flowability of the alternate mixes shows that more flowability than the convention mixes about 5% to 8%. The wet density and dry density of the alternate mixes is lesser than convention mix due to low density is about 25% to 30%. In all alternative mixes, compressed strength will decrease for 7 days by 15% to 20% compared to conventional mixes. After 28 days under compression strength, AM1 and AM2 obtained CLSM strengths that were under 8.3MPa.

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