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USE OF PLASTIC AGGREGATES IN CLSM FOR HIGHWAY APPLICATION

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ABSTRACT

The project aims to investigate the potential of using plastic aggregate in place of conventional aggregate as the objective of minimizing the harmful emissions to the atmosphere during the disposal. The rapid industrialization and urbanization in the country leads lot of infrastructure development. This process leads to several problems like shortage of construction materials, increased productivity of wastes and other products. This project deals with the reuse of waste plastic as complete replacement of coarse aggregate in CLSM (controlled low strength materials).Tests were conducted on coarse aggregates, fine aggregates, cement and waste plastics to determine their physical properties. The blocks are casted and tested for 7 days and 28 days strength. With various material ratios, the general characteristics of the CLSM mixture, including flowability characteristics, initial setting time and density were studied. To ascertain the engineering characteristics of controlled low strength material, such as compressive strength, Permeability, Dry shrinkage and Thermal conductivity, a number of combinations produced with binders and aggregates were carefully examined.

Keywords: Controlled Low Strength Material, Permeability, Thermal Conductivity, Dry Shrinkage.

I. INTRODUCTION

Concrete has become one of the oldest and most popular construction materials in the world, mostly due to its low cost, vast availability, durability, and resistance to adverse weather. The global production of concrete is ten times bigger in tonnage than that of steel. As opposed to concrete, other building materials like steel and polymers are more expensive and less common. Concrete is a brittle material that has a high compressive strength, but a low tensile strength. Thus reinforcement of concrete is required of allow it to handle tensile stresses. Such reinforcement is usually done using steel. The next practical and technically feasible solution to the problem of plastic waste is recycling. The strategy produces a second supply chain of raw materials using a number of technologies. According to the waste hierarchy, recycling secondary raw materials is given the top priority after reuse. For multilayered plastics (MLPs), where it is difficult and expensive to separate individual layers, tertiary recycling is preferred. Recycling options are typically divided into primary and secondary recycling. Citizens must perform waste material separation at the source because recycling requires public participation.

Controlled Low Strength Material (CLSM) is a relatively new technology whose use has grown in recent years. CLSM, often referred to as flow able fill, is a highly flowable material typically composed of water, cement, fine aggregates, and fly ash. Other byproduct materials such as foundry sand and bottom ash and chemical admixtures including air-entraining agents, foaming agents, and accelerators also have been used successfully in CLSM. Using CLSM rather than compacted fill has a number of inherent advantages. These advantages include quicker construction and the ability to place material in confined spaces, as well as lower labor and equipment costs (due to the self-leveling characteristics and lack of compaction). CLSM's relatively low strength is advantageous because it enables possible future excavation. Another benefit of CLSM is that it frequently includes waste products like fly ash and foundry sand, which lessens the need for landfill space where these materials might otherwise be dumped. Despite these benefits and advantages over compacted fill, the use of CLSM is not currently as widespread as its potential might predict. One reason is that CLSM is somewhat a hybrid material; that is, it is a cementitious material that behaves more like a compacted fill. As such, much of the information and discussions on its uses and benefits have fallen between the cracks of concrete materials and geotechnical engineering.

II. RESEARCH OBJECTIVES AND SCOPE

The Scope and objectives of use of Plastic Aggregates in CLSM for Highway Application are:

- Attempt towards utilization of waste plastic which is finding problem in disposal.
- Use of waste plastic as coarse aggregate and industrial waste by-products in concrete as CLSM materials.
- Studies on Fresh and Hardened properties of CLSM using the above waste materials.
- Studies on In-service properties of CLSM.

III. MATERIALS AND EXPERIMENTAL METHODS

Materials

Controlled Low Strength Material (CLSM) is a relatively new technology whose use has grown in recent years. CLSM, often referred to as flow able fill, is a highly flowable material typically composed of water, cement, fine aggregates, and fly ash. Other byproduct materials such as foundry sand and bottom ash and chemical admixtures including air-entraining agents, foaming agents, and accelerators also have been used successfully in CLSM.In the present study recycled plastic aggregates are supplied by local waste plastic recycler shop as shown in the figure 1 and they are stored. The physical properties are given in the table 1. The aggregates are obtained from crusher near to kanakapura and their physical properties are examined and their test results are shown in table 2.The pond ash and fly ash are bought from the raichur, table 3 and 4 displays the test results.

Figure 1. Plastic aggregate

Table 1. Properties of plastic aggregates

Properties	Results	Specifications
Aggregate Impact value (%)	0	<35%
Specific gravity	2.61	2.5-3
Los Angeles – Abrasion value (%)	0	40-60%
Water absorption (%)	0.49	0.1-2%
Aggregate crushing strength (%)	0	<30%

Table 2. Properties of coarse aggregates

Properties	Results	Specifications
Aggregate Impact value (%)	26.89	<35%
Specific gravity	2.61	2.5-3
Los Angeles – Abrasion value (%)	28.6	40-60%
Water absorption (%)	0.4	0.1-2%
Aggregate crushing strength (%)	24.75	<30%

Table 3. Basic Properties of pond ash

Properties	Results	Specifications
Fineness test	4.5%	3-6%
Specific gravity	2.1	2.03-2.27

Table 4. Basic Properties of fly ash

Properties	Results	Specifications
Fineness test	8.3%	5-35%
Specific gravity	2.26	2.1-3

Experimental Methods

This project looked into the usage of recycled plastic coarse aggregate in CLSM mixture. To assess their properties such as Permeability, Thermal conductivity, Dry shrinkage and Hardening time. The materials are used on the basis of ACI 229 R .The mix is finalized on the two categories, on their strength and flowability. Here we have considered two categories of mixes, Conventional Mix (CM) and Alternate Mix (AM). An attempt on various trial mixes are been carried out to determine optimized mix to consider as CLSM. Further to study the performance of optimized mix in terms of Fresh, Hardened and In-service properties of CLSM. As it can be seen, it is usually a mixture of fly ash, fine aggregate, plastic aggregates, water, and a small amount of Portland cement (29.7–118.6 kg/m^3) and conventional coarse aggregates. According to American Concrete Institute (ACI 229), the upper and lower limits for 28 days unconfined compressive strength of CLSM are limited to 8.3 MPa and 0.3 MPa respectively. Table 5 shows the material proportions of the mix.

Table 5. Mix proportions in cum

MIX	OPC 53	Fly Ash	Pond Ash	M sand	RPCA	CCA	Water
CM	110	70	194.6	83.4	_	417	225
AM	110	70	194.6	83.4	417	_	225

Flowability

CLSM typically needs high flowability with a slump flow value greater than 200 mm to achieve self-flowable characteristics for placement and backfilling. Prepare concrete as per mix design and Pour the freshly mixed concrete into the slump cone mold, the overflowed concrete on the cone is struck off using a trowel. Slowly, lift the slump cone mold vertically up & let the concrete flow. Measure the spread of concrete in Diameter using a centimeter scale horizontally. The arithmetic mean of the four diameters shall be the measurement of flow in millimeters and flow time in sec is recorded.

Wet Density

To figure out the wet density, you are filling up a container with concrete. This container must have a known volume. First, weigh the empty container and record that value $\mathbf{M_a}$. After filling the container concrete then weigh the container and record the value $\mathbf{M_b}$.The unit weight is determined by the formula below. Subtract the weight of the container filled with concrete with the empty weight of the container. Next, divide this weight (kilograms) by the volume of the measuring cube (cubic meter) to obtain the density expressed as Kg/m^3.

$$\mathbf{D = (M_b - Ma) / V}$$

Hardening Time

The time intervals needed for the mortar, which was sieved from the concrete mixture, to reach the specified penetration resistance values measured from the initial contact of cement and water, are known as the initial setting time and the final setting time. The time elapsed after initial contact of cement and water acquires a penetration resistance of 3.5MPa is initial setting time. The time elapsed after initial contact of cement and water acquires a penetration resistance of 27.6MPa is final setting time.

Compressive Strength

In this clause, we have cast cubes for compressive strength, allowed for a one-day setting, and made it for curing by placing it in the water tank. Then after curing for 7 and 28 days.

Applying oil inside the cube frame and thoroughly cleaning the mould pour the concrete. With a trowel, level and smooth the top surface. After two to three days, the concrete cubes are taken out of the moulds. After the allotted curing time, remove the specimen from the water, and wipe off any extra moisture from the surface. Measure the specimen's dimensions to the nearest 0.2mm, and then position it in the machine so that the load is applied to the cube's opposite sides. Place the specimen in the Centre of the machine's base plate. Gently turn the movable part by hand so that it touches the specimen's top surface. Apply the load steadily, without abrupt changes, and at a rate of 140 kg/cm2/min until the specimen breaks. Keep track of the maximum load.

Dry Shrinkage

Prepare the specimens as required in IS 1199 (Part 5).Prepare the gauge stud assembly. At an age of 28 days from moulding, remove the specimens one at a time from the water and wipe the surface dry with a damp cloth. While ensuring that the gauge is correctly seated, rotate the specimen axially until the front face is parallel to the face of the dial gauge and facing the operator. Read the dial gauge and record the reading. Specimen is removed and replaced in the comparator in the same orientation. Continue taking replicate measurements until at least five consecutive determinations have been made, all of which are within 0.001 mm of the average measurement. These readings shall be completed within 2 min of removing the specimen from the water. Record the mean of these five determinations as the initial measurement. The specimen shall then be dried in the oven as described at the specified temperature and humidity for at least 44 h. The length of the specimen shall then be measured as described above at a temperature of 27 ± 2°C. If measurements are made at temperature other than 27°C, they should be reduced by 0.002 percent of the dry length for each 2°C above 27°C. The cycle of drying, cooling and measuring shall be repeated until constant length is attained, that is, when the difference between two consecutive readings separated by a period of drying of at least 44 h, followed by cooling for at least 4 h, is less than 0.01 mm.

Permeability

Specimen is prepared according to IS 1199(part 5).Specimen is tested after 28 days of demoulding. The specimen is fit to apparatus using suitable seal made of rubber or similar material without any leakage. Apply a water pressure of 500± 50 KPa for duration of 72±2h.After apply of water pressure 500± 50 KPa for duration of 72±2h remove the specimen from apparatus. Wipe the face of specimen where water pressure was applied. Immediately split the specimen in the plane perpendicular the face on which the water pressure was applied. The water front shall be compared with acceptable water penetration fronts.

Thermal Conductivity

To evaluate the feasibility of the proposed CLSM mixtures as thermal grouts for geothermal systems, a thermal conductivity test was conducted according to ASTM D 5334. The thermal conductivity of the proposed CLSM was evaluated at the age of 28 days with respect to its use as a backfill material for underground pipes and boreholes.

SEM Analysis

Further studies were carried out on our test specimens to discuss on microstructure and ITZ apart from fresh, hardened and in-service properties wherein, our specimens were subjected to Scanning Electron Microscope (SEM) analysis. Small scale samples were extracted from our test specimens which was casted and was subjected to curing for a duration of 28 days. Further they were subjected to SEM.

IV. RESULTS AND DISCUSSIONS

Flowability

As per ACI: 229 R – 99

- Low flow (<150mm)
- Normal Flow (150-200mm)
- High Flow (>200mm)

The Flow obtained was more than 200mm henceforth we had high flow for both the mixes.

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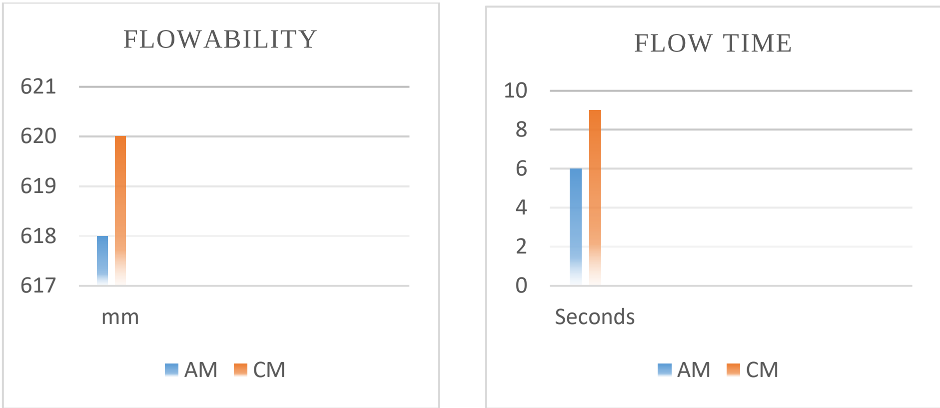

Fig 2. Graph showing Flowability and Flow time of CLSM

Hardening Time

Alternate Mixes shows that the hardening time required is slightly high compared to conventional mixes. As we have used more quantity of pond ash the setting time is more compared to ACI: 229 R – 99 specification.

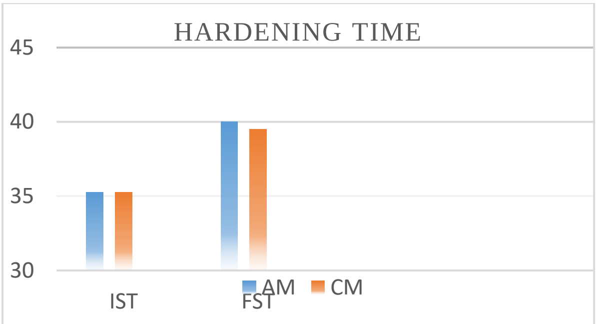

Fig 3. Graph showing Hardening Time of CLSM

Compressive strength

The Maximum Compressive Strength of CLSM should not be more than 8.3 MPa as per ACI: 229 R – 99 specification. Compressive Strength for 28 days obtained was within the specifications for both conventional and alternate mix.

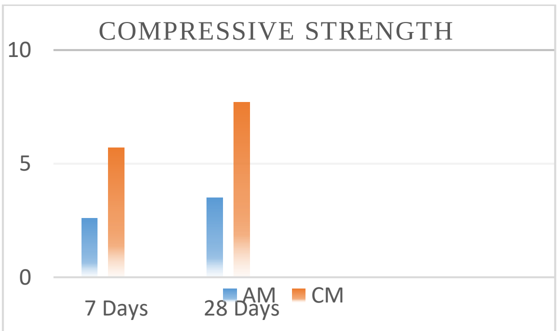

Fig 4. Graph showing Compressive strength of CLSM

Permeability

The permeability of CLSM to both liquids and gases has a significant impact on performance of CLSM in various applications. The permeability of CLSM affects several important properties, including drainage characteristics, durability, and leaching potential. As per ACI: 229 R – 99 typical values ranges from 10^{-4} to 10^{-5} cm/sec.

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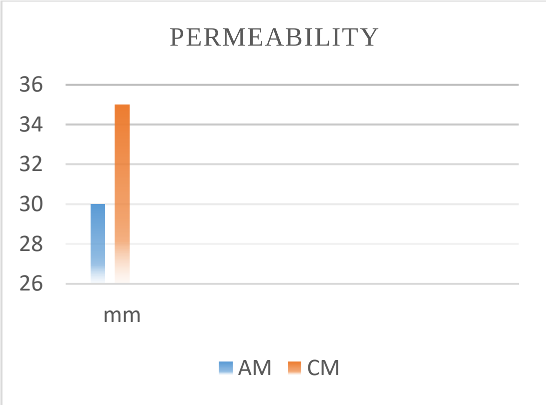


Fig 5. Graph showing Permeability of CLSM

Dry Shrinkage

As per ACI: 229 R – 99 Ultimate Linear Shrinkage varies between 0.02 to 0.05%. Shrinkage obtained for all the mixes were within the specifications, but conventional mix was marginally high.

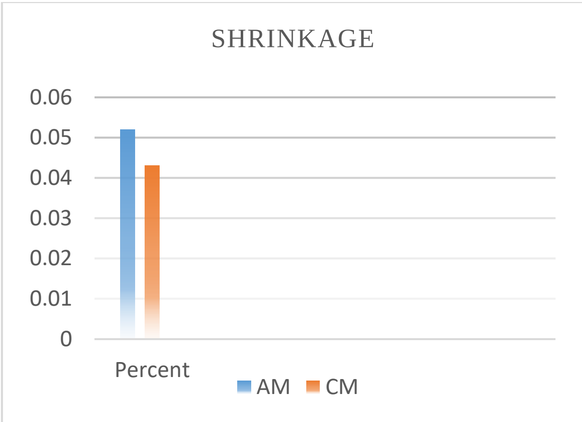
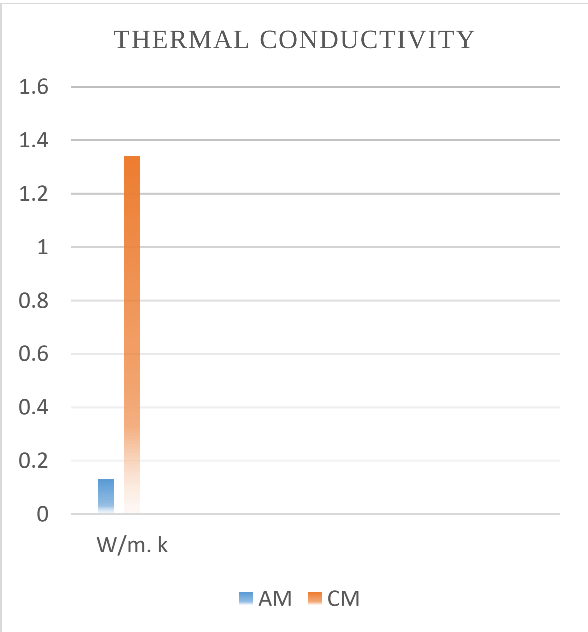


Fig 6. Graph showing Dry Shrinkage of CLSM

Thermal Conductivity

Thermal conductivity varies for different materials at different rate. Alternate Mixes are showing more thermal resistivity and less thermal conductivity compared to conventional mixes.



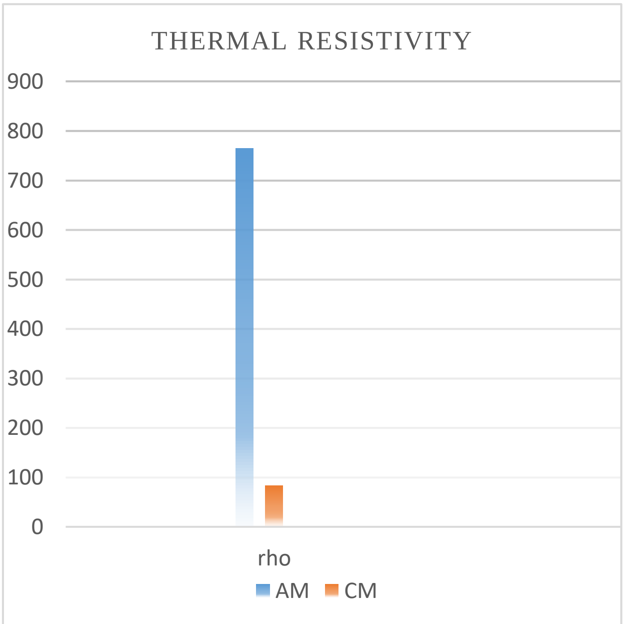


Fig 7. Graph showing Thermal Conductivity and Thermal Resistivity of CLSM

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SEM Analysis

It is observed from the results obtained from SEM images that there was formation of hydrated products which gave an indication of hydration process. At the same time the ITZ between paste and the coarse aggregate found to be weak. Fig 8 and 9 shows the results of SEM Analysis of alternate mix and conventional mix.

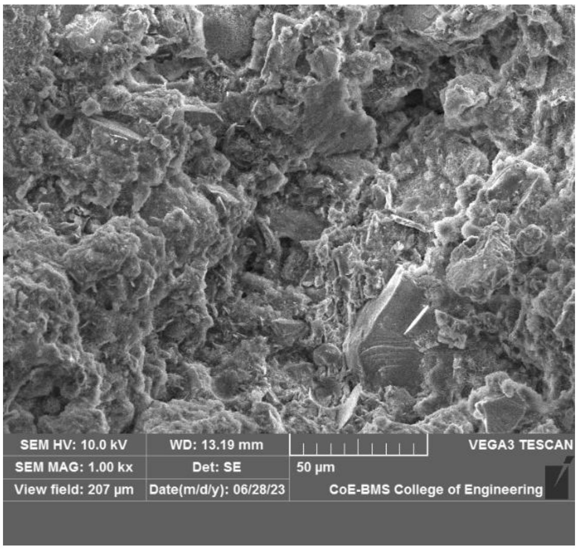

Fig 8. SEM Analysis of Alternate mix

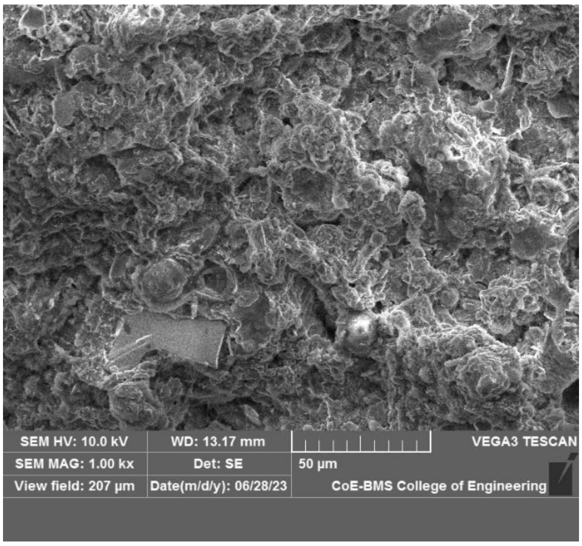

Fig 9. SEM Analysis of conventional mix

V. CONCLUSION

- The crushing, impact and abrasive values showed better results in case of recycled plastic coarse aggregates when compared to conventional coarse aggregates.
- Plastic properties like flowability and bleeding were found to increase with increase in the water content in the mix for various trial mixes. So optimized mix was finalized based on these aspects along with compressive strength which is one of the important criteria to term material as CLSM.
- The different industrial byproducts can be utilized as components in flowable fill production. The type of fine and coarse aggregates used in flowable fill resulted in better performance in terms of both fresh and in-service properties.
- Initial setting time was found in the range of 35.25–39.8 Hours, above the maximum allowable limit as required for general CLSM. It is due to the presence of more quantity of pond ash which was a cause for delay in setting time.
- The flowability in the conventional mixes showed better results than the alternate mix with the flow varying between 3% to 10%.
- The permeability of flowable fills was found to be in the range of 10^{-5} cm/s. The permeability values obtained for higher flowability mixes were slightly higher than that of lower flowability value mixes. The other in-service properties which includes studies on shrinkage, thermal conductivity and resistivity was well within the specifications.
- The formation of hydration products was evidently visible in the SEM analysis wherein the lack of strength might be because of poor ITZ.

VI. FUTURE SCOPE

- Various other industrial by products can be utilized as an alternative to conventional material in production of CLSM.
- ITZ (Interfacial Transition Zone) can be improved to enhance the strength and performance depending on the application of CLSM.
- Studies on Cost economics and embodied energy can be computed to address on sustainability.

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