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Cementitious Material from Recycled CLC and AAC Block Dust

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Abstract
In the present scenario where the constructions are increasing, the need to find a supplementaryCementing material for the improvement of strength and which has less environmental effects isofgreatsignificance.
The main objective of the research work is to investigate the possibility of utilizing cellularlightweight concrete and autoclave aerated concrete block dust as partial replacement of cement.The basic properties like consistency, specific gravity was determined and compare with ordinaryPortland cement. SEM, EDX and XRD analysis is also performed for chemical composition andcrystallography of utilizing cellular lightweight concrete and autoclave aerated concrete blockdust. The result of the study shows that up to 20% replacement of cellular lightweight concreteblock dust gives more strength that normal mortar cube. However, large levels of replacement lead to delayed hydration of the mix and porous microstructure and consequently lower compressivestrength of cube. From the XRD analysis of cube sample shows that 20% replacement of cellularlightweightconcreteblockdusthasmorecalcitecomponent than0% replacementofmortarcube.
***Keywords**: chemical composition, compressive strength, consistency, crystallography, specificgravity*

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I. Introduction

Most engineering constructions are not eco-friendly. Construction industry uses Portland cement,whichisaheavycontributoroftheCO2emissionsandenvironmentaldamage.InIndia,amountofconstructionhasrapidlyincreasedsincelasttwodecades.ItiswellknownfactthatCO_2emissionscontribute about 65% of global warming and it is predictable to increase by 100% by 2020. Thecement industry contributes around 2.8 billion tons of the greenhouse gas emissions annually, orabout 7% of the total man-made greenhouse gas emissions to the earth's atmosphere.The cementindustry produces many other environmentally harmful products like sulfur dioxide (SO_3) andnitrogen oxides (NO_X) which contribute to the global warming factors. The contamination raisedfrom cement production pushed the concrete community to find many alternatives to decrease theCO_2 emission. One of those solutions is replacement of cement by Autoclave Aerated Concrete(AAC)andCellularLightweightConcrete(CLC)blockdust.

CELLULARLIGHTWEIGHTCONCRETE
WhatisCLCBlock?
Cellular Light Weight Concrete (CLC) is also known as a Foam Concrete. Cellular Light WeightConcrete (CLC) is a very light in weight that is produced like normal concrete under ambientconditions.CLCBlocksareacement-bondedmaterialmadebyblendingslurryofcement.Stable,pre-formedfoammanufacturedonsiteisinjectedintothisslurrytoformfoamconcrete.

AUTOCLAVEDAERATEDCONCRETE
WhatisAACBlock?
Autoclaved Aerated Concrete is a high quality building material manufactured from quartz sand,cement,aluminumcompound,lime,andwaterseveralnaturalchemicalreactionstakeplaceduringthemanufacturingprocessthataccountforAAC'shighstrength,light-weightandthermalproperties.

II. OBJECTIVES

Based on a detailed literature review, the major objective of the present research work is identifiedas the investigation of properties of cement mortar cube using by AAC and CLC dust and itspossibleenhancement.Followingarethesub-objectivesto achieve themajorgoal.

I. TostudybasicpropertiesofAACand CLCdust(passingthrough ISsieve90µ).

II. Tofindoutthe%usefeasibleforconstructionasacementitiousmaterialwithAAC,CLCblocks.

III. Tofindoutthecompressivestrength ofmortar cubeusingcertainreplacementofcementbyCLCandAACdustandcomparewith normalmortarcube.
IV. Tostudythe causeofdecreasecompressivestrength.

Applications

AAC is well suited for urban areas with high rise buildings and those with high temperaturevariations. Due to its lower density, high rise buildings constructed using AAC require less steeland concrete for structural members. The requirement of mortar for laying of AAC blocks isreduced due to the lower number of joints. Similarly, the material required for rendering is alsolower due to the dimensional accuracy of AAC. The increased thermal efficiency of AAC makesit suitable for use in areas with extreme temperatures, as it eliminates the need for separatematerialsfor constructionandinsulation,leading to fasterconstructionandcostsavings.

III. METHODOLOGY

Followingstepbystepmethodologyisadoptedtoachievetheabovementionedobjectives

I. Literaturereview (studiesinRCAconcrete,studiesonmechanicalpropertiesofCLCandAACblock,and studiesonmortarcubeusingdifferentcementitiousmaterials)
II. Collect demolishedCLCandAACblockandmakingfinedustwhichwaspassingthrough90µI.S.sieve.
III. FindthebasicpropertiesofOrdinaryPortlandCementandCLCandAACblockdust.
IV. Find the chemical composition and crystallography of CLC and AAC block dust throughSEM,EDXandXRDanalysisandmakeadecisionwhetherithascementitiouspropertiesornot.
V. Prepare a cement mortar cube and replacement of cement by CLC and AAC block dustabout0%to30%.
VI. Findthe7daysand28 days'compressivestrengthofmortarcube
VII. StudytheX-raydiffractionofthesamplesusedforcompressivestrengthtoobtain.

IV. Literature Review

GENERAL

Literature review for the present study is carried out broadly in the direction of concrete made ofrecycled materials for sustainability. The present study uses of Recycled CLC and AAC concreteblock dust as a partial replacement of cement. For the presentation purpose, the literature reviewis divided in three segments such as (i) studies in RCA concrete, (ii) studies on mechanicalproperties of CLC and AAC block (iii) studies on mortar cube using different cementitiousmaterials.

Studiesin RCA Concrete

Crushed concrete that results from the demolition of old structures is generated nowadays in largequantities. The current annual rate of generation of construction waste is 145 million tonnesworldwide [Revathi *et al.* 2013]. The area required for land-filling this amount of waste isenormous. Therefore, recycling of construction waste is vital, both to reduce the amount of openland neededfor land-filling and topreserve the environment through resource conservation[Revathi *et al.* 2013, Pacheco-Torgal*et al.* 2013]. It has been widely reported that recyclingreduces energy consumption, pollution, global warming, greenhouse gas emission as well as cost[Khalaf and Venny 2004; Pacheco-Torgal and Said 2011; Ameri and Behnood 2012; Vázquez2013; Behnood*et al.* 2015; Pepe 2015 and Behnood*et al.* 2015]. This in turn is beneficial andeffectiveforenvironmentalpreservation.

Various researchers have examined about the physical and mechanical properties of the RCA andits influence when natural aggregate is replaced partially or fully by RCA to make concrete. It hasbeen found that the mechanical strength of the RCA concrete is lower than that of conventionalconcrete. This is due to the highly porous nature of the RCA compared to natural aggregates andtheamountofreplacementagainstthenaturalaggregate[Rahal2007,BritoandSaikia2013].

Barbudo*et al.* (2013) studied the influence of the water reducing admixture on the mechanicalperformance of the recycled concrete. This study shows that use of plasticizers may improve theproperties of recycled concrete. Rahal (2007) investigated the mechanical properties of recycledaggregateconcreteincomparisonwithnaturalaggregateconcrete.

Tabsh and Abdelfatah (2009) studied the behaviour of recycled aggregate and their mechanicalproperties. It is reported that the strength of recycled concrete can be 10–25% lower than that ofnatural aggregate concrete. It is reported that though the recycled aggregate is inferior to naturalaggregate,theirproperties canbeconsideredtobe withinthe acceptablelimits.

Bairagi*et al.* (1990) proposed a method of mix design for recycled aggregate concrete from theavailable

conventional methods. It has been suggested that the cement required was about 10%moreinviewoftheinferiorqualityaggregate.
It has been reported that concrete made with 100% recycled aggregates is weaker than concretemadewithnaturalaggregatesatthesamewatertocementratio(*w*/*c*)andsamecementtype.
Manypublishedliterature[Amnon,2003;TabshandAbdelfatah,2009;Elhakam*etal*.2012and McNeiland Kang, 2013] reported that RCA concrete with no NCA reduces the compressive strength by amaximum of 25% in comparison with NCA concrete. A similar trend was observed in the case oftensilesplittingstrengthandflexuralstrength[Silva*etal*.2015].

V. Experimental Program

GENERAL

The purpose of present work is to study on the cementitious material like AAC and CLC blockdust which was replaced by cement. For this purpose, mortar cube is casted and tested. Theexperimentalprogramsconsistmaterialstesting,mixproportions,castingandtestingofspecimens.

MATERIALS

Cement

Ordinary Portland cement (RAMCO) 43 grade was used for present study and it is conformed toIS:8112–2013. ItspropertiesareshowninTable:3.1

Table: 3.1 PropertiesofCement

Sl. No.	PhysicalProperties	ExperimentalResults	IS:8112–2013 Requirements
1	Consistency	31	-
2	Specificgravity	3.15	-
3	Initialsetting time	60minutes	<30 minutes
4	Finalsettingtime	500minutes	>600 minutes

CLCandAACBlockDust

DemolishedCLCandAACblockarecollectedandcrushedtheblocktomakefinedustwhichwaspassingthroughIS90µI.S. sieve.XRDtestwasalsodonetoknowtheallthemineralspresentintheCLC and AAC block dust based on crystalline structure of minerals. Properties of CLC and AACblockdustareshowninTable3.2.

Table3.2 BasicpropertiesofCLCandAACblockdust

Physicalproperties	Experimentalresult	
	CLCdust	AACdust
Specificgravity	2.10	2.18
consistency	45	53

Microstructural Studies

In order to understand the chemical composition and crystallography of CLC and AAC block dustmicrostructural studies has been carried out in the present study through Field Emission ScanningElectron Microscope (FESEM) and Energy Dispersive X-ray Analysis (EDX). Figs. 3.1 and 3.2present FESEM images for CLC and AAC block dust respectively at a magnification of 100,000.Figs. 3.3 and 3.4 show the EDX results for CLC and AAC block dust respectively. It is observedfromtheEDXthatcalcium(Ca),silicon(Si),alumina(Al),andiron(Fe)aremajorcomponentsofCLC and AAC block dust. This is very similar to cement in terms of material composition. So, it canbeusedasacementitious materials.

X- RayDiffraction (XRD)Test

XRD analysis is based on constructive interference of monochromatic X-rays and a crystallinesample. The X-rays are generated by a cathode ray tube, filtered to produce monochromaticradiation,collimatedto concentrate,anddirectedtowardthesample.Theinteractionoftheincidentrays with the sample produces constructive interference (and a diffracted ray) when conditionssatisfy Bragg's Law ($n\lambda = 2d \sin \theta$). This law relates the wavelength of electromagnetic radiationtothediffractionangleandthelatticespacinginacrystallinesample.

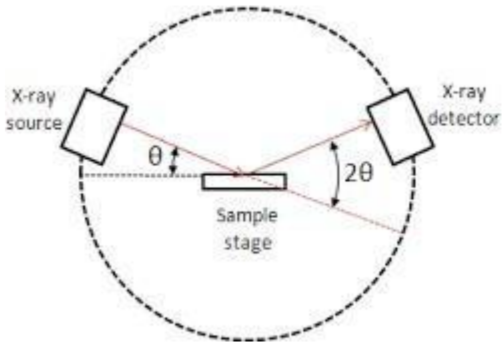

Fig: 3.5-XRDanalysisprinciple

The CLC and AAC block dust sample kept in between X-ray tube and detector, the x-ray passedonthesampleanddiffractedthroughatanangle(2□)asshowninFig.3.5.UsingXperthighscoresoftware,thegraph hastobedrawnandanalysisallthecomponentspresentinthesample.Figs.3.6and3.7 presentstheXRD analysisresultsforCLCand AACblock dustrespectively.

It is observed from the XRD analysis that the main constituents present in CLC block dust areSilicon Oxide (SiO_2), Calcium Carbonate ($CaCO_3$), Aluminum Oxide (Al_2O_3), and Iron Oxide(Fe_2O_3) and Main constituents present in AAC block dust are Silicon Oxide (SiO_2), CalciumCarbonate($CaCO_3$),AluminumOxide(Al_2O_3),IronOxide(Fe_2O_3),andsodiumchloride(NaCl).

DETAILSOFMORTARCUBETEST SPECIMENS

For this present research mortar cube are made according to ASTM C-109/C-109M. The size ofthe specimen molds is 2-in × 2-in × 2-in (50mm × 50 mm × 50mm). The proportions of materialsforthestandardmortarshallbeonepartofcementto2.75partsofgradedstandardsandbyweight.Use a water-cement ratio of 0.485 for all Portland cements. The quantities of materials (Table 3.4)tobemixedat onetimeinthebatchofmortarformakingsixtestspecimensshallbeasfollows:

Table:3.4-Quantitiesofmaterials

Materials	Quantities
OrdinaryPortlandCement(gm)	500
Sand(gm)	1375
Water(mL)	242

Then ordinary Portland cement was replaced with various % of CLC and AAC block dust (inweight) like 0%, 5%, 10%, 15%, 20%, 25%, and 30%. Tables 3.5 and 3.6 presents the mixproportionforselectedspecimensofmortarcubesmadeofCLCandAACblockdustrespectively.

Table:3.5-CementreplacementwithCLCblockdust

SpecimenNo.	Ordinary PortlandCement(gm)	CLC blockdust(gm)	Sand(gm)	Water(mL)
C-0	500	0	1375	242
C-1	475	25	1375	242
C-2	450	50	1375	242
C-3	425	75	1375	242
C-4	400	100	1375	242
C-5	375	125	1375	242
C-6	350	150	1375	242

VI. Summarya nd Conclusion

SUMMARY

The objective of this study was to improve the compressive strength of the cement mortar cube byreplacing recycled cellular lightweight concrete block dust with cement. First CLC and AAC blockare crushed and made into fine dust those pass through 90 IS Sieve. A standard mix proportionof cement and sand is considered from ASTM: C 109/C 109M-07. Different mix proportions arethenarrivedbyreplacingcementwithCLCandAACblockdustfrom0-30% byweightofcement.The mortar cubes are prepared and cured in potable water. Compressive strength of the mortarcubes are measured after 7 days and 28 days of curing. Broken sample are collected for furthertestedforthemicrostructureanalysis usingXRD.

CONCLUSION

Based on the experimental investigation on utilization of CLC and AAC block dust in structuralconcreteforsustainableconstructionthefollowingconclusionare drawn:

I. SpecificgravityofCLCandAACblockdustare2.18 and2.10respectivelywhichwas too low compared to the specific gravity of ordinary Portland cement (whichisfoundtobe3.15).

II. TheconsistencyofCLCandAACblockdustarefoundtobe45and53respectivelywhich was more than that of ordinary Portland cement. So it can be concluded thatCLCand AACdustneedmorewaterthancementforcastingmortarcubes.

III. SEM, EDX and XRD analysis results show that CLC block dust contain morecalcite component than AAC block dust and both has cementitious properties.Thereforethesematerialscanbeusedtoreplacecementforconcretemaking.

IV. Compressive strength of mortar cube at 7 day for 5% CLC block dust replacementfound to be lower than normal cement mortar (with 0% replacement) but 10-20%CLC block dust replacement gives compressive strength more than normal cementmortar (with 0% replacement). However, the strength decreases for further increaseof CLC dust replacement. On the other hand AAC block dust replacement does notshow any improvement of compressive strength over the normal cement mortar(with0%replacement).

V. Compressivestrengthofmortarcubeat28dayfor5-20%CLCblockdustreplacementfoundtobehigherthannormalcementmortar(with0%replacement).Compressive strength of mortar cube at 28 day for AAC block dust replacementdoes not show any improvement of compressive strength over the normal cementmortar(with0%replacement).

VI. XRDanalysisofmortarcubesampleconfirmsthat20%CLCblockdustreplacement results more calcite component than normal cement mortar (with 0%replacement).

SoitispossibletoreplacecementwithrecycledCLCblockdusttomakesustainableconstructionwithreducedenvironmentpollution.

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