Cementitious Material from Recycled CLC and AAC Block Dust

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Cementitious Material from Recycled CLC and AAC Block Dust

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By

Pranab Halder

(Roll Number: 215CE2028)

Based on research carried out
Under the supervision of

Prof. Pradip Sarkar
and
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Supervisor's Certificate

This is to certify that the work presented in this dissertation entitled *Studies on Cementitious Material from Recycled CLC and AAC Block Dust* by *Pranab Halder*, Roll Number: 215CE2028, is a record of original research carried out by him under our supervision and guidance in partial fulfilment of the requirements of the degree of *Master of Technology* in *Structural Engineering*. Neither this dissertation nor any part of it has been submitted for any degree or diploma to any institute or university in India or abroad.

Robin Davis P.
Assistant Professor

Pradip Sarkar
Associate Professor

DEDICATED TO

MY FAMILY & FRIENDS

Declaration of Originality

I, Pranab Halder, Roll Number: 215CE2028 hereby declare that this dissertation entitled *Studies on Cementitious Material from Recycled CLC and AAC Block Dust* represents my original work carried out as a M-Tech student of NIT Rourkela and, to the best of my knowledge, it contains no material previously published or written by another person, nor any material presented for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the section “Bibliography”.

I am fully aware that in case of my non-compliance detected in the future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

May, 2017

NIT Rourkela Pranab Halder

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As I am about to submit this dissertation for the award of M-Tech degree, I must acknowledge that this has been the most venturesome odyssey of whole of my personal, professional and academic life till date. In the process many hurdles and challenges of monstrous proportion came crashing upon me which nearly derailed my journey. However, my unflinching faith in Almighty somehow saw me through those difficult times and safely guided me to my destination.

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Abstract

In the present scenario where the constructions are increasing, the need to find a supplementary Cementing material for the improvement of strength and which has less environmental effects is of great significance.

The main objective of the research work is to investigate the possibility of utilizing cellular lightweight concrete and autoclave aerated concrete block dust as partial replacement of cement. The basic properties like consistency, specific gravity was determined and compare with ordinary Portland cement. SEM, EDX and XRD analysis is also performed for chemical composition and crystallography of utilizing cellular lightweight concrete and autoclave aerated concrete block dust. The result of the study shows that up to 20% replacement of cellular lightweight concrete block 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 compressive strength of cube. From the XRD analysis of cube sample shows that 20% replacement of cellular lightweight concrete block dust has more calcite component than 0% replacement of mortar cube.

Keywords: chemical composition, compressive strength, consistency, crystallography, specific gravity

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Chapter 1

Introduction

Most engineering constructions are not eco-friendly. Construction industry uses Portland cement, which is a heavy contributor of the CO_2 emissions and environmental damage. In India, amount of construction has rapidly increased since last two decades. It is well known fact that CO_2 emissions contribute about 65% of global warming and it is predictable to increase by 100% by 2020. The cement industry contributes around 2.8 billion tons of the greenhouse gas emissions annually, or about 7% of the total man-made greenhouse gas emissions to the earth's atmosphere. The cement industry produces many other environmentally harmful products like sulfur dioxide (SO_3) and nitrogen oxides (NO_x) which contribute to the global warming factors. The contamination raised from cement production pushed the concrete community to find many alternatives to decrease the CO_2 emission. One of those solutions is replacement of cement by Autoclave Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC) block dust.

1.1 CELLULAR LIGHTWEIGHT CONCRETE

1.1.1 What is CLC Block?

Cellular Light Weight Concrete (CLC) is also known as a Foam Concrete. Cellular Light Weight Concrete (CLC) is a very light in weight that is produced like normal concrete under ambient conditions. CLC Blocks are a cement-bonded material made by blending slurry of cement. Stable, pre-formed foam manufactured on site is injected into this slurry to form foam concrete. Fresh foam concrete looks like a milk- shake and the volume of slurry in the foam dictates the cast density of the foam concrete. Fig. 1.1 presents typical CLC blocks.

Fig: 1.1- Cellular Lightweight Concrete (CLC) block

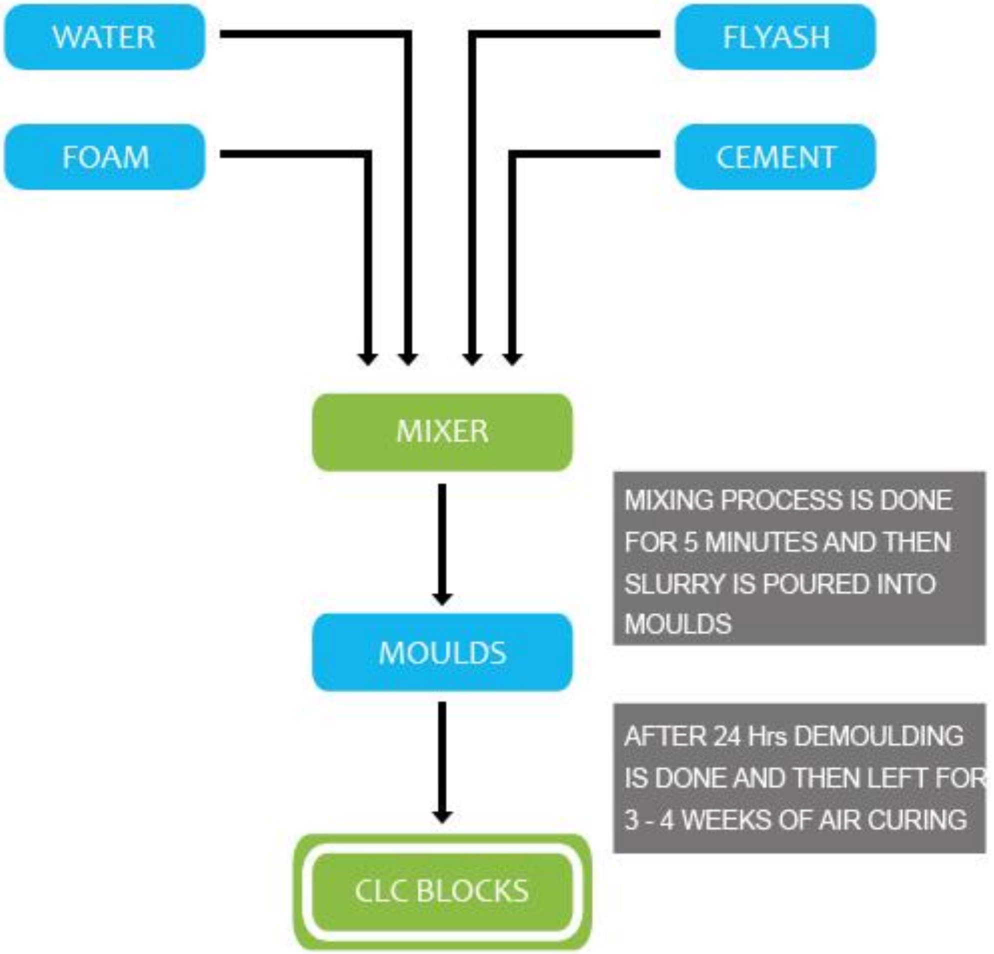
1.1.2 Advantages of CLC Block

- **Light in Weight:** It very lightweight with density ranging from 300 to 1800 kg/m^3. Which was three times less weight than fly ash or clay brocks.
- **Eco friendly:** It is Environment-friendly. Foam concrete is made by eco-friendly material as fly ash and other industrial waste material are used in part of manufacturing blocks to protect the environment. The production process of Foam concrete or its use does not release any harmful effluents to water, ground or air. Due to its low weight is ideal for making partitions. The use of Foam concrete for this purpose will reduce the need for plywood partitions. This consequently will result in reduction in deforestation and will benefit environment.

- **Sound Insulation:** Foam concrete are excellent for Sound insulation which keeps the house warm in winter and cool in summer which cause saving energy/electricity for heating and cooling. It is possible to achieve even higher values depending upon the thickness of block.
- **Thermal Insulation:** Thermal insulations as a 100mm thick CLC wall, the equivalent thickness of dense concrete wall would have to be more than ten times heavier and 5 times thicker.
- **Lower Water Absorption:** The water absorption of cellular lightweight concrete block has relatively lower than any other concrete block. This compares much better than concrete 50% and ordinary brick, which has water absorption of around 50% to 80%. For this lower water absorption property of these material will help to reduce the cracks in the walls.
- **Fire Protection:** Cellular lightweight concrete blocks offers grater fire protection during occurring fire hazard. With a just 100mm thickness of wall with density of 1000 kg/m^3, offers fire endurance for heat transmission for 4 hours without releasing any toxic fumes during the fire. Fire rating of cellular concrete is far superior to that of dense concrete or brickwork.
- **Easy to Handling:** Foam concrete blocks are easy and quick to install, which causes construction costs minimizes. They require no minimal maintenance, which reduces long-term costs. Foam concrete blocks are saving in cement, sand, water, labor, energy & time.

1.1.3 Manufacturing of CLC Block

Cellular lightweight concrete blocks typically consists of a cement slurry and fly ash or sand and water, although some Foam concrete plant recommend pure cement and water with the foaming agent for very lightweight mixes. This slurry is further mixed with a synthetic aerated foam in a concrete mixing plant. The foam is created using a foaming agent, mixed with water and air from a generator. The foaming agent used must be able to produce air bubbles with a high level of stability, resistant to the physical and chemical processes of mixing, placing and hardening.



MIXING PROCESS IS DONE FOR 5 MINUTES AND THEN SLURRY IS POURED INTO MOULDS

AFTER 24 Hrs DEMOULDING IS DONE AND THEN LEFT FOR 3 - 4 WEEKS OF AIR CURING

Fig: 1.2- Flowchart of CLC block production

(https://www.iyantra.com/CLC/product-clc-lcp.php)

Foamed concrete mixture may be poured or pumped into molds, or directly into structural elements. The foam enables the slurry to flow freely due to the thixotropic behavior of the foam bubbles, allowing it to be easily poured into the chosen form or mould. The viscous material requires up to 24 hours to solidify (or as little as two hours if steam cured with temperatures up to 70 °C to accelerate the process, depending on variables including ambient temperature and humidity. Once solidified, the formed produce may be released from its mould. Fig. 1.2 presents flow-chart for manufacturing process of CLC blocks.

1.1.4 Applications

Foamed concrete can be produced with dry densities of 400-1600 kg/m³, with 7-day strengths of approximately 1-10 MPa. Foam concrete is fire resistant, and its thermal and acoustical insulation properties make it ideal for a wide range of purposes, from insulating floors and roofs, to void filling. It is also particularly useful for trench reinstatement. Few of the applications of foam concrete are:

- Precast concrete blocks
- Precast wall panels / elements
- cast-in-place walls / Cast-in-situ
- Insulating compensation laying
- Insulation floor screeds
- Insulation roof screeds
- Sunken portion filling
- Trench reinstatement

- Sub-base in highways
- Filling of hollow blocks
- Prefabricated insulation boards.

1.2 AUTOCLAVED AERATED CONCRETE

1.2.1 What is AAC Block?

Autoclaved Aerated Concrete is a high quality building material manufactured from quartz sand, cement, aluminum compound, lime, and water several natural chemical reactions take place during the manufacturing process that account for AAC's high strength, light-weight and thermal properties. Fig. 1.3 shows photographs of typical AAC blocks.

Fig: 1.3- Autoclaved Aerated Concrete (AAC) block

AAC (Autoclaved Aerated Concrete) lightweight blocks (bricks) can be used as external (exterior) wall, internal (interior) wall, partition wall to well replace tradition bricks and precast concrete. The new building material has been used in various kinds of buildings, such as public facilities, industrial constructions, civil housing, hospitals, hotels, schools, stores, supermarkets etc.

1.2.2 Advantages of AAC Block

It offers several significant advantages over other cement construction materials, one of the most important being its lower environmental impact.

- Improved thermal efficiency reduces the heating and cooling load in buildings.
- superior fire resistance due to Porous structure.
- Workability allows accurate cutting, which minimizes the generation of solid waste during use.
- Light weight saves cost & energy in transportation, labor expenses, and increases chances of survival during seismic activity.
- **Environmentally friendly:** When used, it helps to reduce at least 30% of environmental waste as opposed to going with traditional concrete. There is a decrease of 50% of greenhouse gas emissions. When possible, using autoclaved aerated concrete is a better choice for the environment.
- **Fire resistant:** Just like with regular concrete, ACC is fire resistant. This material is completely inorganic and not combustible.
- **Great ventilation:** This material is very airy and allows for the diffusion of water. This will reduce the humidity within the building. ACC will absorb moisture and release humidity; this helps to prevent condensation and other problems that are related to mildew.

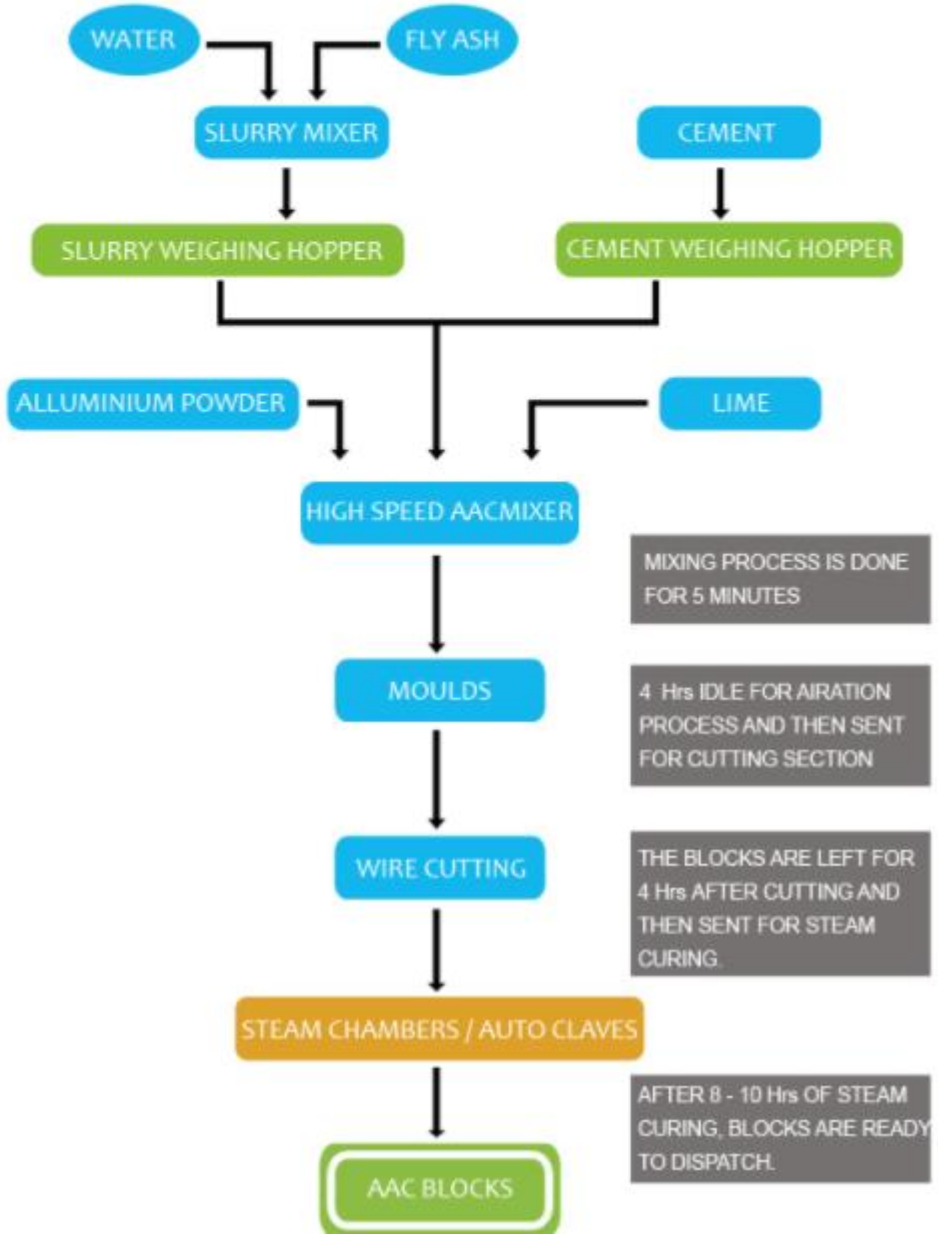
- **Non-toxic:** There are no toxic gases or other toxic substances in autoclaved aerated concrete. It does not attract rodents or other pests nor can it be damaged by such.
- **Lightweight:** Concrete blocks that are made out of ACC weigh about one-fifth of typical concrete. They are also produced in sizes that are easy to handle for quick construction.
- **Quick assembly:** Since it is a lightweight material and easy to work with, the assembly is much quicker and smoother.

1.2.3 Manufacturing of AAC Block

Unlike most other concrete applications, AAC is produced using no aggregate larger than sand. Quartz sand, calcined gypsum, lime (mineral) and/or cement and water are used as a binding agent. Aluminum powder is used at a rate of 0.05%–0.08% by volume (depending on the pre-specified density). In some countries, like India and China, fly ash generated from coal fire power plants and having 50-65% silica content is used as an aggregate.

When AAC is mixed and cast in forms, several chemical reactions take place that give AAC its light weight (20% of the weight of concrete) and thermal properties. Aluminum powder reacts with calcium hydroxide and water to form hydrogen. The hydrogen gas foams and doubles the volume of the raw mix creating gas bubbles up to 3mm (⅛ inch) in diameter. At the end of the foaming process, the hydrogen escapes into the atmosphere and is replaced by air.

When the forms are removed from the material, it is solid but still soft. It is then cut into either blocks or panels, and placed in an autoclave chamber for 12 hours. During this steam pressure hardening process, when the temperature reaches 190° Celsius (374° Fahrenheit) and the pressure reaches 8 to 12 bar, quartz sand reacts with calcium hydroxide to form calcium silicate hydrate, which gives AAC its high strength and other unique properties.



MIXING PROCESS IS DONE FOR 5 MINUTES

4 Hrs IDLE FOR AIRATION PROCESS AND THEN SENT FOR CUTTING SECTION

THE BLOCKS ARE LEFT FOR 4 Hrs AFTER CUTTING AND THEN SENT FOR STEAM CURING.

AFTER 8 - 10 Hrs OF STEAM CURING, BLOCKS ARE READY TO DISPATCH.

Fig: 1.4- Flowchart of AAC block production

(https://iyantra.com/AAC/app.php)

Because of the relatively low temperature used AAC blocks are not considered fired brick but a lightweight concrete masonry unit. After the autoclaving process, the material is ready for immediate use on the construction site. Depending on its density, up to 80% of the volume of an

AAC block is air. AAC's low density also accounts for its low structural compression strength. It can carry loads of up to 8 MPa, approximately 50% of the compressive strength of regular concrete. Fig. 1.4 presents flow-chart for manufacturing of AAC blocks.

1.2.4 Applications

AAC is well suited for urban areas with high rise buildings and those with high temperature variations. Due to its lower density, high rise buildings constructed using AAC require less steel and concrete for structural members. The requirement of mortar for laying of AAC blocks is reduced due to the lower number of joints. Similarly, the material required for rendering is also lower due to the dimensional accuracy of AAC. The increased thermal efficiency of AAC makes it suitable for use in areas with extreme temperatures, as it eliminates the need for separate materials for construction and insulation, leading to faster construction and cost savings.

1.3 OBJECTIVES

Based on a detailed literature review, the major objective of the present research work is identified as the investigation of properties of cement mortar cube using by AAC and CLC dust and its possible enhancement. Following are the sub-objectives to achieve the major goal.

I. To study basic properties of AAC and CLC dust (passing through IS sieve 90µ).
II. To find out the % use feasible for construction as a cementitious material with AAC, CLC blocks.
III. To find out the compressive strength of mortar cube using certain replacement of cement by CLC and AAC dust and compare with normal mortar cube.
IV. To study the cause of decrease compressive strength.

1.4 METHODOLOGY

Following step by step methodology is adopted to achieve the above mentioned objectives

I. Literature review (studies in RCA concrete, studies on mechanical properties of CLC and AAC block, and studies on mortar cube using different cementitious materials)
II. Collect demolished CLC and AAC block and making fine dust which was passing through 90µ I.S. sieve.
III. Find the basic properties of Ordinary Portland Cement and CLC and AAC block dust.
IV. Find the chemical composition and crystallography of CLC and AAC block dust through SEM, EDX and XRD analysis and make a decision whether it has cementitious properties or not.
V. Prepare a cement mortar cube and replacement of cement by CLC and AAC block dust about 0% to 30%.
VI. Find the 7 days and 28 days' compressive strength of mortar cube
VII. Study the X-ray diffraction of the samples used for compressive strength to obtain compound.

1.5 ORGANISATION OF THE THESIS

This introductory chapter presents the background, objectives, scopes and the methodology of the present study.

Chapter 1 Brief introduction of CLC and AAC blocks

Chapter 2 presents the literature review of the present study

Chapter 3 deals with the experimental works and the respective results obtained and discussion

Chapter 4 presents the summary and conclusion of the present study

Chapter 2

Literature Review

2.1 GENERAL

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

2.1.1 Studies in RCA Concrete

Crushed concrete that results from the demolition of old structures is generated nowadays in large quantities. The current annual rate of generation of construction waste is 145 million tonnes worldwide [Revathi *et al.* 2013]. The area required for land-filling this amount of waste is enormous. Therefore, recycling of construction waste is vital, both to reduce the amount of open land needed for land-filling and to preserve the environment through resource conservation [Revathi *et al.* 2013, Pacheco-Torgal *et al*. 2013]. It has been widely reported that recycling reduces 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; Vázquez 2013; Behnood *et al.* 2015; Pepe 2015 and Behnood *et al.* 2015]. This in turn is beneficial and effective for environmental preservation.

Various researchers have examined about the physical and mechanical properties of the RCA and its influence when natural aggregate is replaced partially or fully by RCA to make concrete. It has been found that the mechanical strength of the RCA concrete is lower than that of conventional concrete. This is due to the highly porous nature of the RCA compared to natural aggregates and the amount of replacement against the natural aggregate [Rahal 2007, Brito and Saikia 2013].

Barbudo *et al.* (2013) studied the influence of the water reducing admixture on the mechanical performance of the recycled concrete. This study shows that use of plasticizers may improve the properties of recycled concrete. Rahal (2007) investigated the mechanical properties of recycled aggregate concrete in comparison with natural aggregate concrete.

Tabsh and Abdelfatah (2009) studied the behaviour of recycled aggregate and their mechanical properties. It is reported that the strength of recycled concrete can be 10–25% lower than that of natural aggregate concrete. It is reported that though the recycled aggregate is inferior to natural aggregate, their properties can be considered to be within the acceptable limits.

Bairagi *et al.* (1990) proposed a method of mix design for recycled aggregate concrete from the available conventional methods. It has been suggested that the cement required was about 10% more in view of the inferior quality aggregate.

It has been reported that concrete made with 100% recycled aggregates is weaker than concrete made with natural aggregates at the same water to cement ratio (*w*/*c*) and same cement type. Many published literature [Amnon, 2003; Tabsh and Abdelfatah, 2009; Elhakam *et al.* 2012 and McNeil and Kang, 2013] reported that RCA concrete with no NCA reduces the compressive strength by a maximum of 25% in comparison with NCA concrete. A similar trend was observed in the case of tensile splitting strength and flexural strength [Silva *et al*. 2015].

2.1.2 Studies on Mechanical Properties of CLC and AAC Block

Autoclaved Aerated Concrete is lightweight and has a highly porous structure (approximately 80% of the volume of the hardened material is made up of pores, 50% being air pores and 30% being micro pores). It also has lower thermal conductivity, higher heat resistance and lower shrinkage than traditional concrete, and is easier and faster to use in construction and building processes [Alduaij *et al*. 1999; Kearsley *et al*. 2001]

Thongtha et *al.* (2014) by identifying the superior attributes of AAC using waste sugar sediment in the concrete composite. Greater compressive strength, slower heat transfers and lower thermal conductivity of the improved Autoclaved Aerated Concrete (AAC-SL-30-7.5) are significant and important findings in regard to the physical, mechanical and thermal properties of the improved Autoclaved Aerated Concrete when compared to traditional concrete indicate that traditional concrete has greater compressive strength.

Cai et *al.* (2016) studied increasing of substitution mass ratio of iron tailing has negative effect on the compressive strength of AAC, and the finer of iron tailing can effectively enhance strength of AAC products.

Rudolph and Valor (1954) carried out tests on cellular concrete and suggested that flexure strength of CLC was 1/3 to 1/5 of compressive strength. Panesar (2013) has recently investigated the effect of synthetic and protein foaming agents on cellular concrete properties and he examined that cellular concrete has good potential to be used for lightweight structural applications owing to its evolution of mechanical properties, transport properties and thermal resistance.

2.1.3 Studies on Mortar Cube using Different Cementitious Materials

The cement industry produces many other environmentally harmful products like sulfur dioxide (SO_3) and nitrogen oxides (NOx) which contribute to the global warming factors. The contamination raised from cement production pushed the concrete community to find many alternatives to decrease the CO_2 emission.

Shehab et *al.* (2016) studied on fly ash based geo-polymer concrete and observed that the values of compressive strength, bond strength, splitting tensile strength and flexural strength at 28- days are the highest at 50% cement replacement ratio as compared to mixtures produced from 0%, 25%, 75% and 100% replacement ratio.

Vardhan et *al.* (2015) studied on marble powder. The results of the study indicate that up to 10% of marble powder can be used as replacement of cement with no compromise on the technical characteristics of the resultant mixture. In fact, up to 10% replacement of cement with marble powder helps in improving the workability of the mixture, with the compressive strength of the mixture remaining unaltered.

Alex et *al.* (2016) investigation on rice husk ash as cement replacement on concrete production. They studied that the finer RHA fractions exhibits better Chapelle activity. In case of compressive strength development, the partial replacement of RHA ground samples at 20 wt% could be regarded suitable and for unground RHA 15 wt% might be considered satisfactory. For tensile strength development, 20 wt% replacement was considered to be optimal.

Singh et *al.* (2017) investigation on effect of partial replacement of cement by waste marble slurry. This is good for proper setting of concrete as initial setting time should be sufficiently long for the transportation and placing of cement. Soundness value slightly increases probably because the magnesia content of marble slurry is high as compared to cement.

Bentz et *al.* (2017) studied on Limestone and silica powder replacements for cement. The ability of both limestone and silica powders to accelerate early-age hydration and reduce/maintain initial setting times has been demonstrated.

2.2 SUMMARY

From detailed literature review many previous researchers study the replacement of cement by various type of cementitious materials and try to improve compressive strength of concrete. Many of the past studies on the focus about the recycled aggregate to avoid unnecessary dumped demolished concrete in fertile land. There were very few studies on CLC and AAC block to use replacement of cement.

Chapter 3

Experimental Program

3.1 GENERAL

The purpose of present work is to study on the cementitious material like AAC and CLC block dust which was replaced by cement. For this purpose, mortar cube is casted and tested. The experimental programs consist materials testing, mix proportions, casting and testing of specimens.

3.2 MATERIALS

3.2.1 Cement

Ordinary Portland cement (RAMCO) 43 grade was used for present study and it is conformed to IS: 8112 – 2013. Its properties are shown in Table: 3.1

Table: 3.1 Properties of Cement

Sl. No.	Physical Properties	Experimental Results	IS: 8112 – 2013 Requirements
1	Consistency	31	-
2	Specific gravity	3.15	-
3	Initial setting time	60 minutes	< 30 minutes
4	Final setting time	500 minutes	> 600 minutes

3.2.2 CLC and AAC Block Dust

Demolished CLC and AAC block are collected and crushed the block to make fine dust which was passing through IS 90µ I.S. sieve. XRD test was also done to know the all the minerals present in the CLC and AAC block dust based on crystalline structure of minerals. Properties of CLC and AAC block dust are shown in Table 3.2.

Table 3.2 Basic properties of CLC and AAC block dust

Physical properties	Experimental result	
	CLC dust	AAC dust
Specific gravity	2.10	2.18
consistency	45	53

3.2.2.1 Microstructural Studies

In order to understand the chemical composition and crystallography of CLC and AAC block dust microstructural studies has been carried out in the present study through Field Emission Scanning Electron Microscope (FESEM) and Energy Dispersive X-ray Analysis (EDX). Figs. 3.1 and 3.2 present 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 observed from the EDX that calcium (Ca), silicon (Si), alumina (Al), and iron (Fe) are major components of CLC and AAC block dust. This is very similar to cement in terms of material composition. So, it can be used as a cementitious materials.

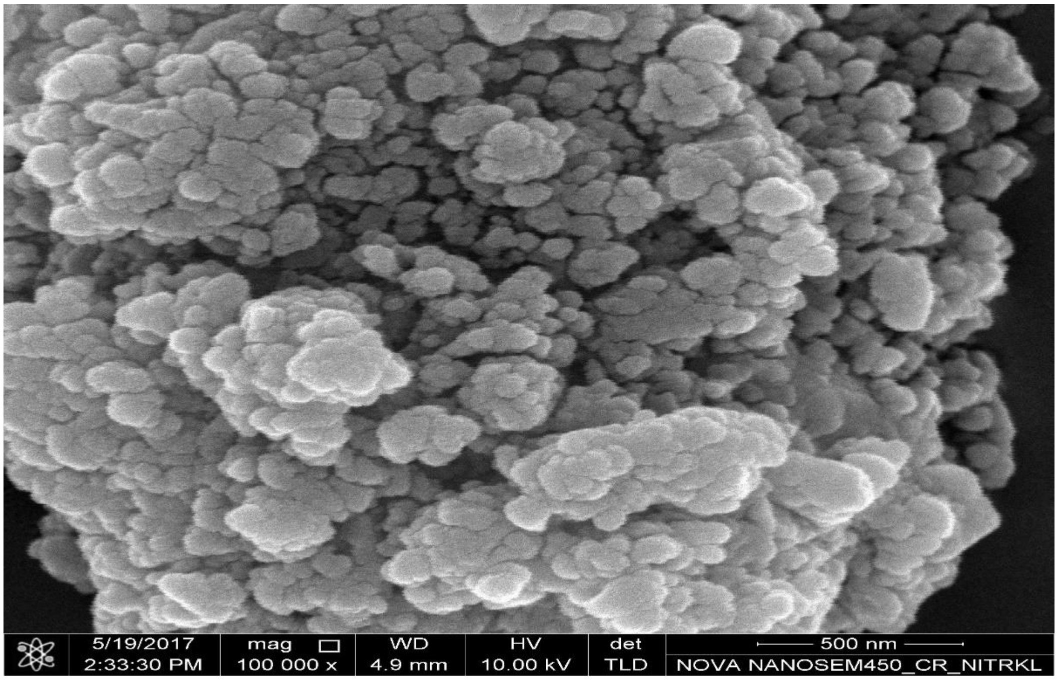


Fig: 3.1- FESEM of CLC block dust

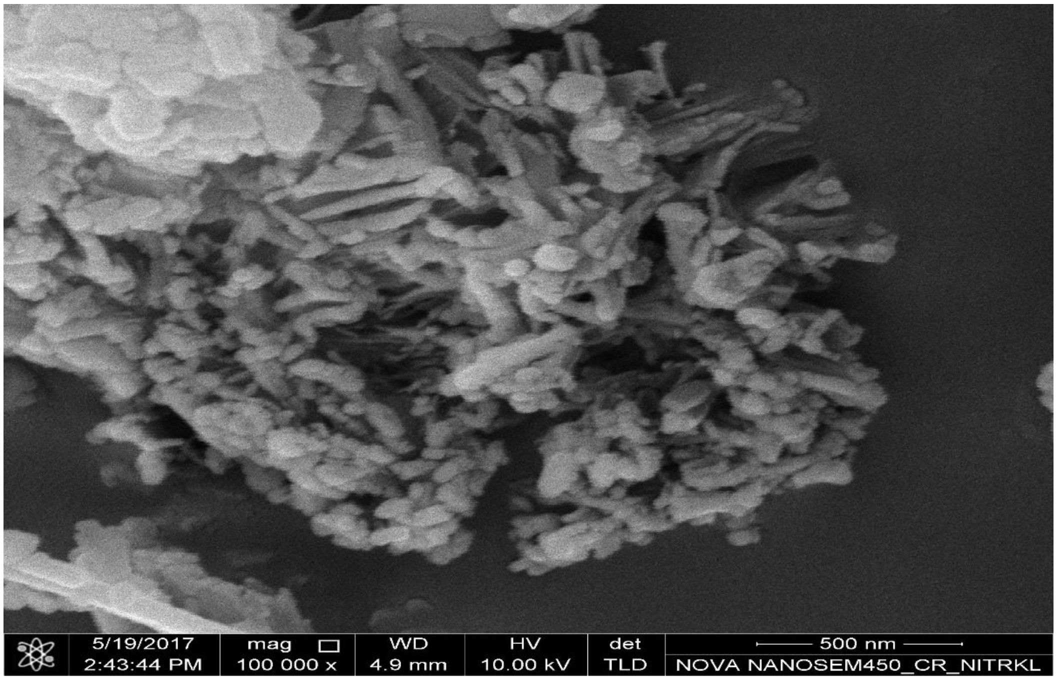


Fig: 3.2- FESEM of AAC block dust

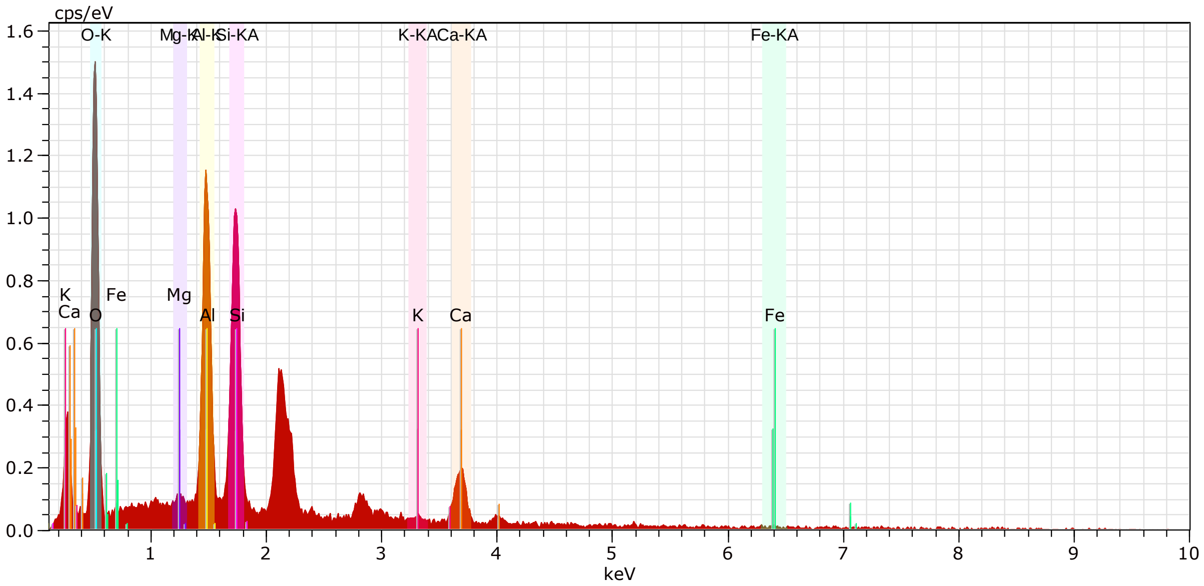


Fig: 3.3- EDX of CLC block dust

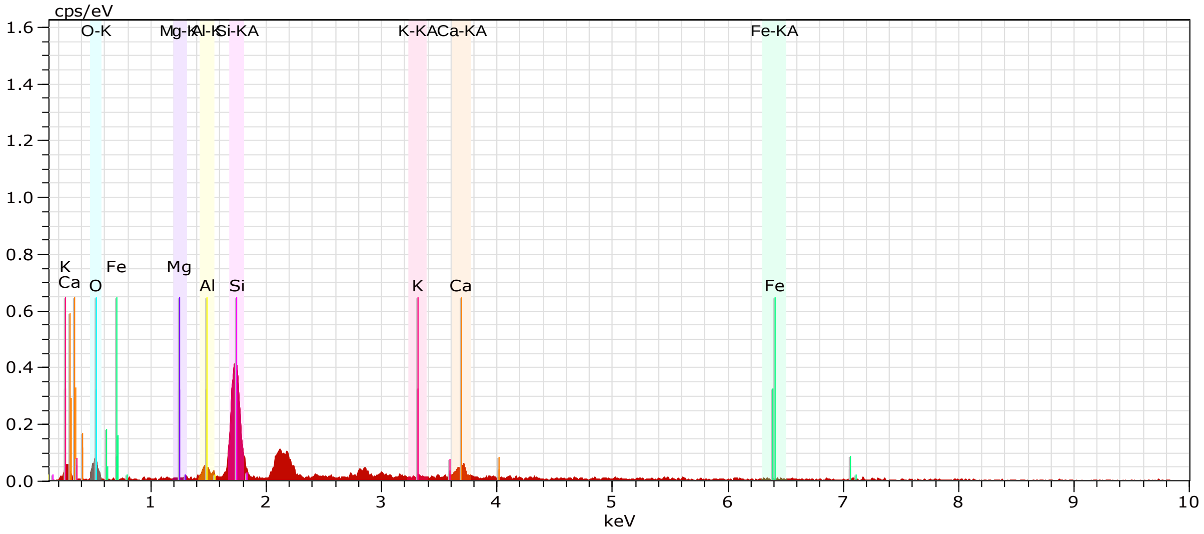


Fig: 3.4 - EDX of AAC block dust

3.2.2.2 X-Ray Diffraction (XRD) Test

XRD analysis is based on constructive interference of monochromatic X-rays and a crystalline sample. The X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy Bragg's Law ($n\lambda = 2d \sin \theta$). This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample.

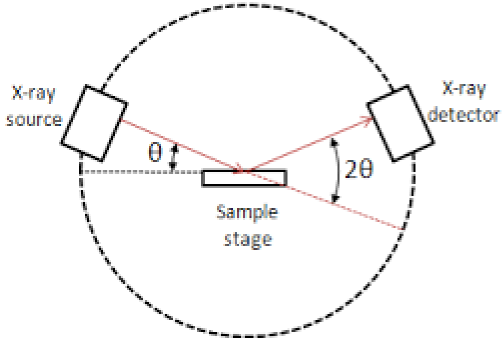


Fig: 3.5 -XRD analysis principle

The CLC and AAC block dust sample kept in between X-ray tube and detector, the x-ray passed on the sample and diffracted through at an angle (2θ) as shown in Fig. 3.5. Using X pert high score software, the graph has to be drawn and analysis all the components present in the sample. Figs. 3.6 and 3.7 presents the XRD analysis results for CLC and AAC block dust respectively.

It is observed from the XRD analysis that the main constituents present in CLC block dust are Silicon 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), Calcium Carbonate ($CaCO_3$), Aluminum Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), and sodium chloride (NaCl).

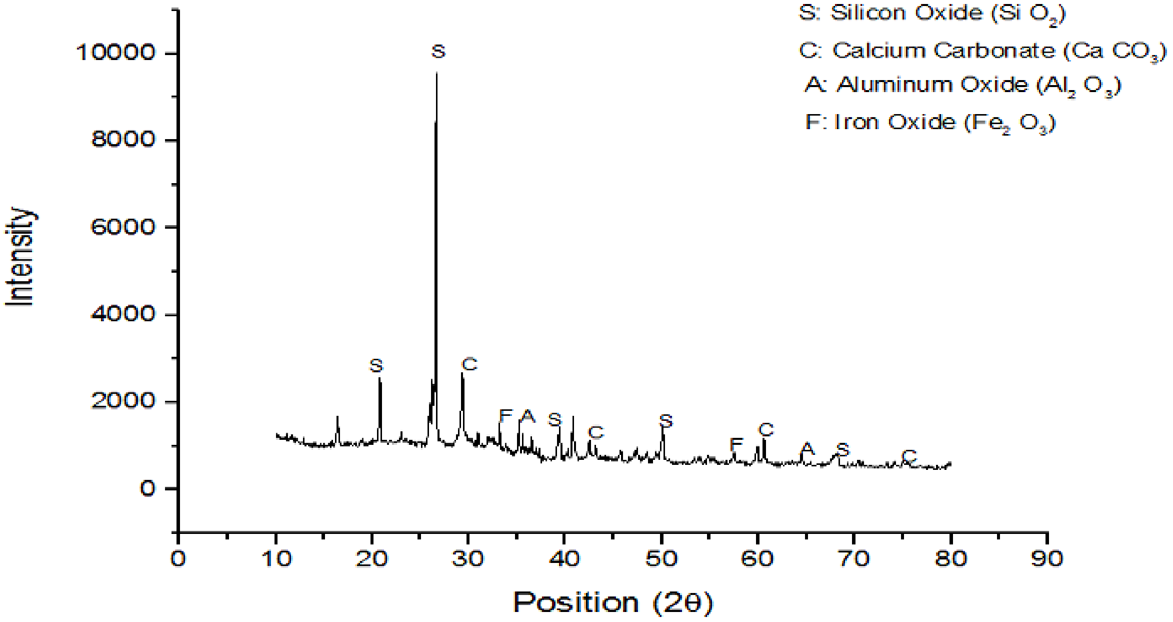


Fig: 3.6- XRD analysis of CLC block dust

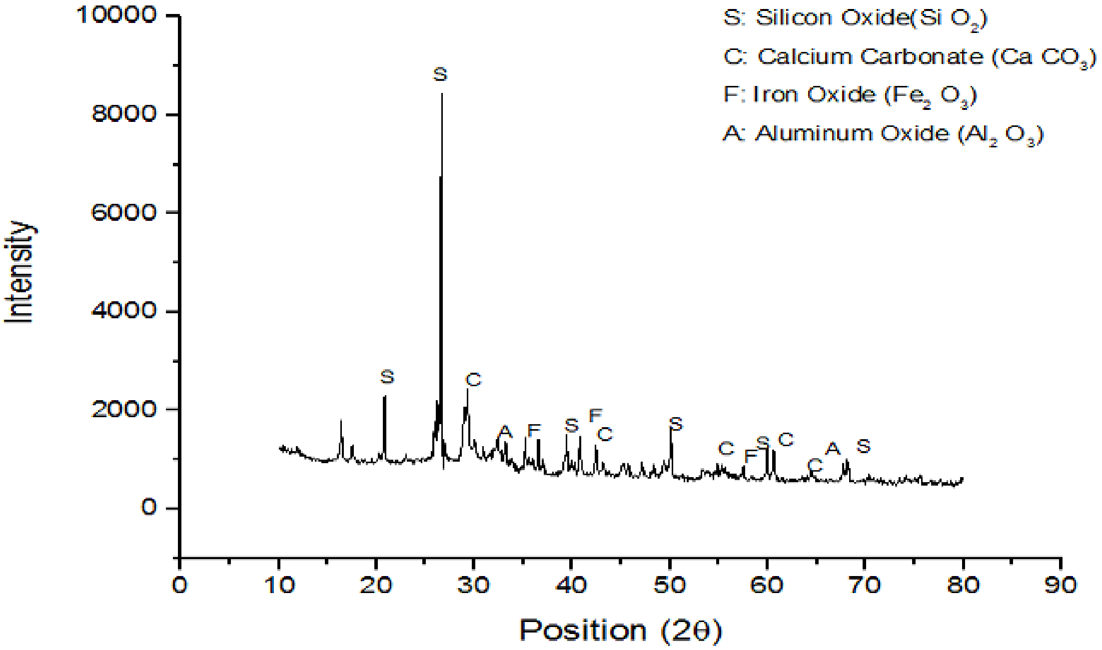


Fig: 3.7- XRD analysis of AAC block dust

These features of CLC and AAC block dust found to be very similar to that of cement. So, CLC and AAC block dusts can be used as a replacement of cement. From XRD analysis it is also found that CLC block dust has more amount of Calcium Carbonate ($CaCO_3$) than AAC block dust which indicates better cementitious properties of CLC block dust.

3.2.3 Fine Aggregate

Fine aggregate which are used in present research work those specific gravity 2.68 and fineness modulus 2.2. The grading zone of sand is (IV) and it is find according IS: 383-1970. The sieve analysis report is given in Table 3.3

Table: 3.3- sieve analysis and grading of fine aggregate

sieve size (mm)	weight retained (gm)	Cumulative retained (gm)	Cumulative % weight retained	% passing	% passing for grading zone (IS:383-1970)
10	0	0	0	100	100
4.75	0	0	0	100	95-100
2.36	15	15	1.5	98.5	95-100
1.18	77	92	9.2	90.8	90-100
0.6	335	427	42.7	57.3	80-100
0.3	279	706	70.6	29.4	15-50
0.15	270	976	97.6	2.4	0-15

3.2.4 Water

The Potable fresh water is used for both mixing of mortar cube and curing of mortar cube specimens.

3.3 DETAILS OF MORTAR CUBE TEST SPECIMENS

For this present research mortar cube are made according to ASTM C-109/C-109M. The size of the specimen molds is 2-in × 2-in × 2-in (50mm × 50 mm × 50mm). The proportions of materials for the standard mortar shall be one part of cement to 2.75 parts of graded standard sand by weight. Use a water-cement ratio of 0.485 for all Portland cements. The quantities of materials (Table 3.4) to be mixed at one time in the batch of mortar for making six test specimens shall be as follows:

Table: 3.4- Quantities of materials

Materials	Quantities
Ordinary Portland Cement (gm)	500
Sand (gm)	1375
Water (mL)	242

Then ordinary Portland cement was replaced with various % of CLC and AAC block dust (in weight) like 0%, 5%, 10%, 15%, 20%, 25%, and 30%. Tables 3.5 and 3.6 presents the mix proportion for selected specimens of mortar cubes made of CLC and AAC block dust respectively.

Table: 3.5- Cement replacement with CLC block dust

Specimen No.	Ordinary Portland Cement (gm)	CLC block dust (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

Table: 3.6- Cement replacement with AAC block dust

Specimen No.	Ordinary Portland Cement (gm)	AAC block dust (gm)	Sand (gm)	Water (ml)
A-0	500	0	1375	242
A-1	475	25	1375	242
A-2	450	50	1375	242
A-3	425	75	1375	242
A-4	400	100	1375	242
A-5	375	125	1375	242
A-6	350	150	1375	242

Mortar cubes are prepared as per following standard methods:

a) Take required amount of Ordinary Portland Cement and sand and mix them dry thoroughly.

b) Add calculated volume of water (0.485P) to the dry mix of cement and sand and mix thoroughly for not more than 4 minutes. (potable water was should be used for the preparation of control specimen)

c) Place the cement mortar in the molds and mount it in the holder of the vibrating machine (Fig. 3.8) and clamp it in proper position.

d) Fill the molds with required amount of cement mortar during vibration and the vibration should be done as per specified speed (12000 cycles per minute) to attain the required compaction.

e) After attaining required compaction, remove the molds from the holder and keep it in a place 24 hours for setting.

f) At the end of 24 hours remove the cube from the molds and immediately submerge in water for attaining the required curing.

Fig: 3.8- vibration machine

3.5 COMPRESSIVE STRENGTH TEST ON CEMENT MORTAR

All the cement mortar cubes are tested in a load controlled universal testing machine and obtain the unidirectional compressive strength at 7 days and 28 days as per the procedure outlined in relevant Indian Standard. Fig. 3.9 presents the hardened mortar cubes before the compressive strength test and Fig. 3.10 present the strain controlled UTM used for the compression test

Fig: 3.9- Mortar cube

Fig: 3.10- Universal testing machine used for the compression strength test

Table: 3.7- compressive strength of mortar cube with CLC block dust replacement

Specimen name	compressive strength (MPa)	
	7 days	28 days
C-0	22.3	27.8
C-1	17.8	30.0
C-2	20.1	33.8
C-3	18.6	31.5
C-4	18.5	30.6
C-5	16.5	25.3
C-6	14.5	24.9

Tables 3.7 and 3.8 present the compressive strength of CLC and AAC mortar cubes respectively after 7 and 28-days of curing. The results for CLC mortar cubes are plotted as shown in Figs. 3.11

and 3.12 at 7 and 28 days respectively. Similarly, Figs. 3.13 and 3.14 presents the compressive strength results of AAC block dust at 7 and 28-days respectively.

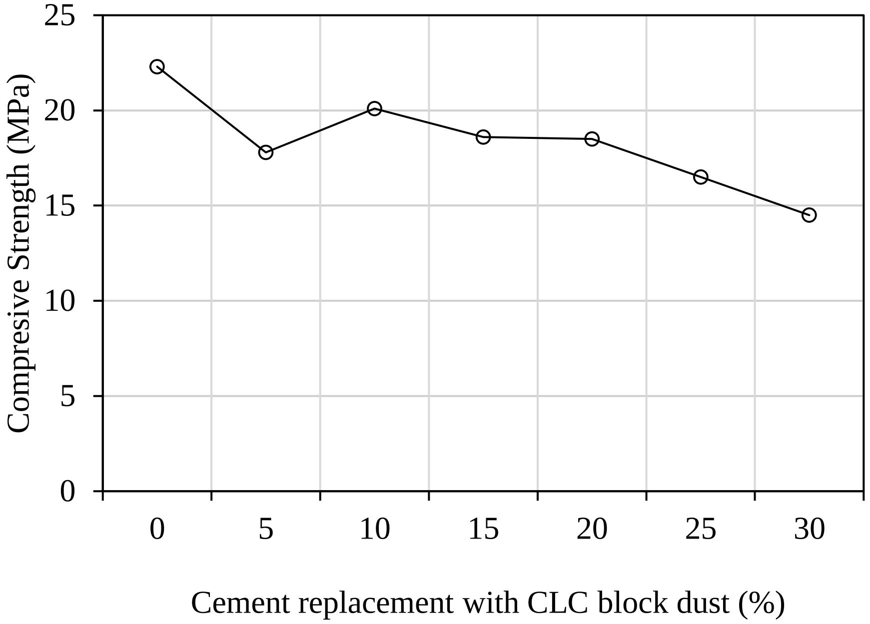


Fig: 3.11- 7days Compressive strength mortar cube with CLC block dust replacement

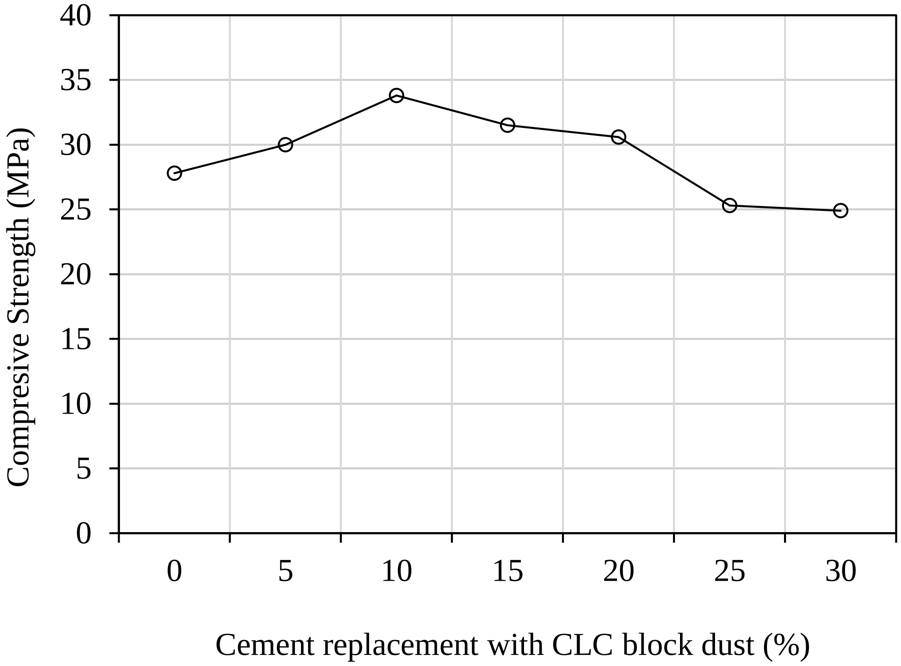


Fig: 3.12- 28 days' Compressive strength mortar cube with CLC block dust replacement

It can be observed from the tables and the figures that as the CLC/AAC replacement increases, compressive strength of mortar cube decreases first and then increases up to a certain percentage of CLC/AAC replacement. Further increase of CLC/AAC replacement reduces the compressive strength.

Table: 3.8- Compressive strength of mortar cube wit AAC block dust replacement

Specimen Name	Compressive Strength (MPa)	
	7 days	28 days
A-0	23.3	29.6
A-1	20.2	28.3
A-2	20.5	27.1
A-3	15.5	26.8
A-4	14.8	25.1
A-5	14.5	24.3
A-6	13.5	22.2

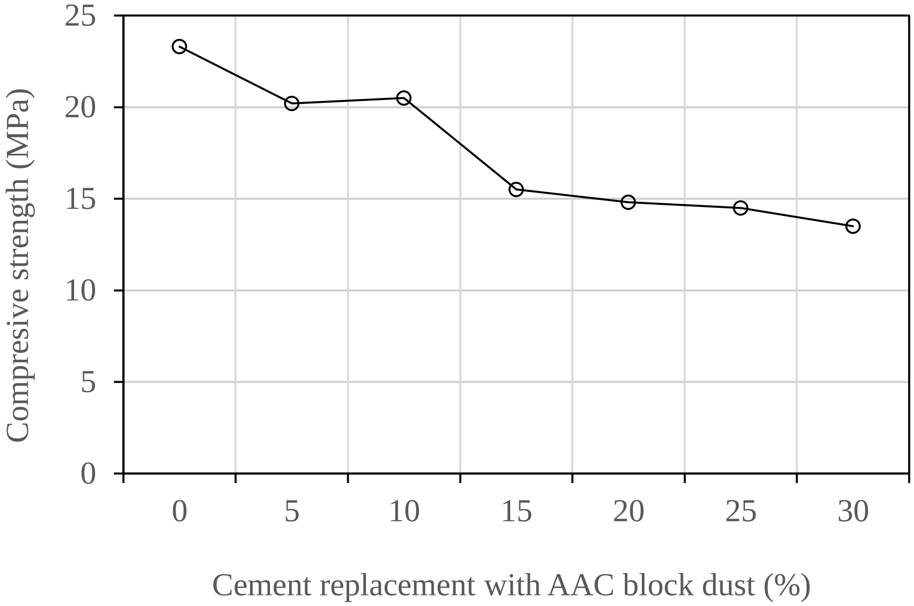


Fig: 3.13- 7 days' Compressive strength mortar cube with AAC block dust replacement

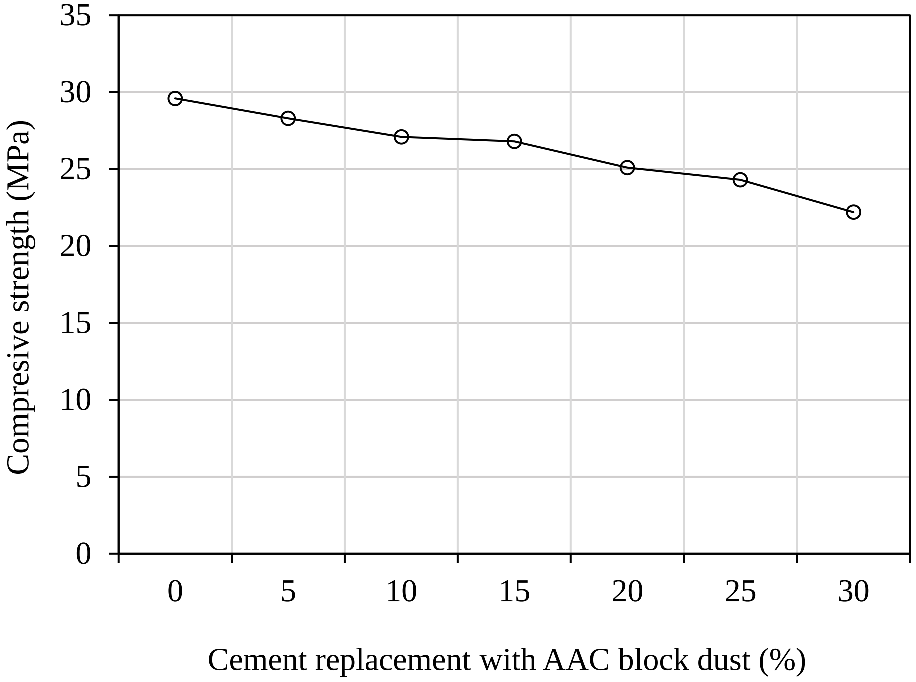


Fig: 3.14- 28 days' Compressive strength mortar cube with AAC block dust replacement

From compressive strength test it is found that mortar cube replaced with CLC block dust has better strength in comparison with AAC block dust. It is also shown from Fig: 3.11 that 5% replacement of CLC block dust gives less strength compare to the 10%, 15%, and 20% replacement at 7 day. However, 28 days compressive strength shows that 5-20% replacement of CLC block dust gives more strength compare to the normal mortar cube (Fig: 3.12). On the other hand replacement of AAC block dust gives lesser strength in comparison with normal cement mortar cubes.

3.6 XRD SPECTROSCOPY ON MORTAR CUBE

XRD analysis has been carried out for normal cement mortar cube and that with 20% CLC block dust replacement. The broken mortar cube was further analyzed to compare the changes in microstructure due to addition of CLC and AAC block dust at 28 days of age by X-ray diffraction (XRD) analysis. The X-ray diffraction technique was used for identification of phases present in the hardened mortar made with or without CLC and AAC dust as replacement of cement at the age of 28 days. The XRD investigations were performed for diffraction angle 2θ ranged between 20° and 80° in steps of $2\theta = 0.017^\circ$. 20% replacement of CLC block dust found to yield more calcite compound than normal mortar cube.

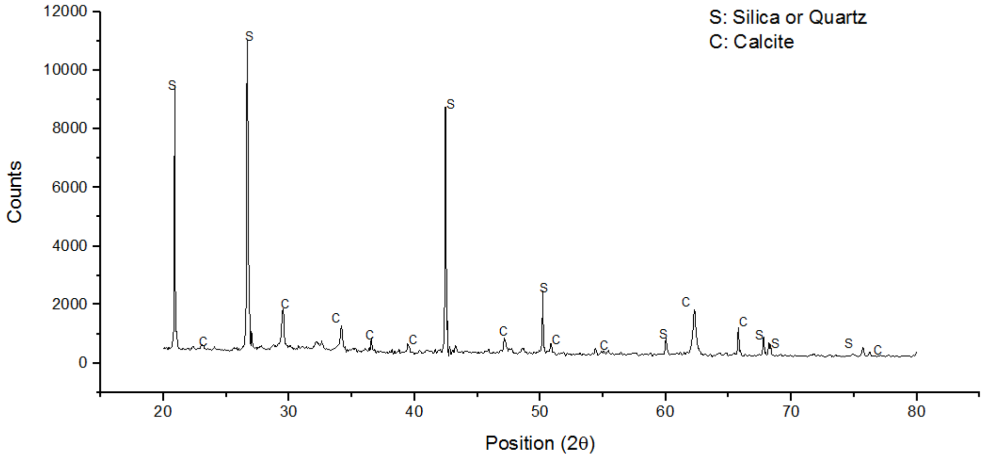


Fig: 3.15 XRD analysis of Normal Mortar cube

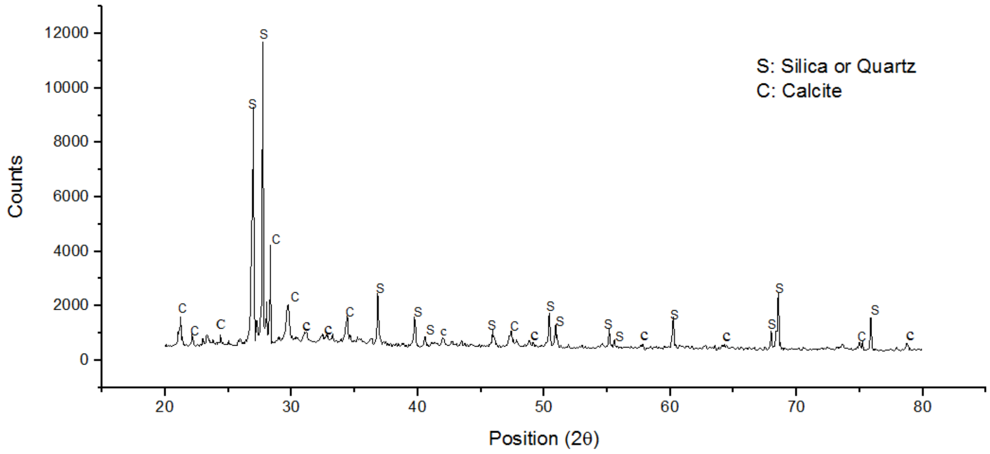


Fig: 3.16 XRD analysis of Mortar cube with 20% replaced with CLC block dust

Chapter 4

Summary and Conclusion

4.1 SUMMARY

The objective of this study was to improve the compressive strength of the cement mortar cube by replacing recycled cellular lightweight concrete block dust with cement. First CLC and AAC block are crushed and made into fine dust those pass through 90 μ IS Sieve. A standard mix proportion of cement and sand is considered from ASTM: C 109/C 109M-07. Different mix proportions are then arrived by replacing cement with CLC and AAC block dust from 0-30% by weight of cement. The mortar cubes are prepared and cured in potable water. Compressive strength of the mortar cubes are measured after 7 days and 28 days of curing. Broken sample are collected for further tested for the microstructure analysis using XRD.

4.2 CONCLUSION

Based on the experimental investigation on utilization of CLC and AAC block dust in structural concrete for sustainable construction the following conclusion are drawn:

I. Specific gravity of CLC and AAC block dust are 2.18 and 2.10 respectively which was too low compared to the specific gravity of ordinary Portland cement (which is found to be 3.15).

II. The consistency of CLC and AAC block dust are found to be 45 and 53 respectively which was more than that of ordinary Portland cement. So it can be concluded that CLC and AAC dust need more water than cement for casting mortar cubes.

III. SEM, EDX and XRD analysis results show that CLC block dust contain more calcite component than AAC block dust and both has cementitious properties. Therefore these materials can be used to replace cement for concrete making.

IV. Compressive strength of mortar cube at 7 day for 5% CLC block dust replacement found to be lower than normal cement mortar (with 0% replacement) but 10-20% CLC block dust replacement gives compressive strength more than normal cement mortar (with 0% replacement). However, the strength decreases for further increase of CLC dust replacement. On the other hand AAC block dust replacement does not show any improvement of compressive strength over the normal cement mortar (with 0% replacement).

V. Compressive strength of mortar cube at 28 day for 5-20% CLC block dust replacement found to be higher than normal cement mortar (with 0% replacement). Compressive strength of mortar cube at 28 day for AAC block dust replacement does not show any improvement of compressive strength over the normal cement mortar (with 0% replacement).

VI. XRD analysis of mortar cube sample confirms that 20% CLC block dust replacement results more calcite component than normal cement mortar (with 0% replacement).

So it is possible to replace cement with recycled CLC block dust to make sustainable construction with reduced environment pollution.

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APPENDIX – A

A.1 TEST FOR STANDARD CONSISTENCY OF CEMENT

Standard consistency test of the cement paste as per IS: 4031 Part 4 -1988.

I. Take 300 gm of cement and put it in the tray.

II. Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. “Gauging time” should not be more than 3 to 5 minutes.

III. Fill the Vicat mould, resting upon a glass plate, with this cement paste.

IV. After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould.

V. Place the whole assembly (i.e. mould + cement paste + glass plate) under the rod bearing plunger.

VI. Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste.

VII. Measure the depth of penetration and record it.

VIII. Prepare trial pastes with varying percentages of water content and follow the steps (ii to vii) as described above, until the depth of penetration is 5 to 7 mm from the bottom. Calculate percentage of water (P) by weight of dry cement required to prepare cement paste of standard consistency by following formula, and express it to the first place of decimal.

$$P = \frac{W}{C} \times 100 \tag{A.1}$$

Where, W = Quantity of water added, C = Quantity of cement used

A.2 TEST FOR SPECIFIC GRAVITY OF CEMENT

Specific gravity of cement was determined to the following procedure:

I. The Flask should be free from the liquid that means it should be fully dry. Weigh the empty flask (W1)

II. Fill the cement on the bottle up to half of the flask (about 50gm) and weigh with its stopper (W2)

III. Add Kerosene to the cement up to the top of the bottle. Mix well to remove the air bubbles in it. Weigh the flask with cement and kerosene (W3)

IV. Empty the flask. Fill the bottle with kerosene up to the top and weigh the flask (W4)

Calculation:

Specific gravity can be estimated using the following equations:

$$S_g = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4) \times 0.79} \tag{A.2}$$

Specific gravity of kerosene is 0.79 g/cc.

Note:

The error value will be acceptable ±0.01.

The practical will be done within 30° C temperature.