International Conference on
Advances in Construction Materials and Structures (ACMS-2018)
IIT Roorkee, Roorkee, Uttarakhand, India, March 7-8, 2018

SUPPLEMENTARY CEMENTITIOUS MATERIAL FROM RECYCLED CLC AND AAC BLOCK DUST

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ABSTRACT

The prospect of reusing demolished cellular lightweight concrete (CLC) and autoclaved aerated concrete (AAC) block dust as partial replacement of ordinary Portland cement in cement mortar is studied. The microstructural analysis confirms that CLC and AAC block dust have specific pozzolanic properties. The experimental result revealed that up to 20% replacement of CLC or AAC block dust does not reduce the strength of the mortar significantly. Further replacement of CLC or AAC leads to delayed hydration of the mix and porous microstructure which results in the lower compressive strength of mortar. Such use of waste CLC and AAC dust can reduce the environment pollution without compromising the strength significantly.

Key Words: *AAC, CLC, recycled material, cement mortar, compressive strength*

INTRODUCTION

Construction demand is increasing with the continuous industrial development and growth in urbanization. In India, the rate of construction has rapidly increased since last two decades. Ordinary Portland cement (OPC) is a chief construction material for the construction industry, which is a substantial contributor of the Carbon dioxide (CO_2) emissions with other harmful products like sulfur dioxide (SO_3) and nitrogen oxides (NO_2) which contribute to the environmental damage. Approximately one ton of CO_2 with other greenhouse gases is released into the atmosphere for every ton of cement manufacture. (Lodeiro et al., 2009). In the present scenario, the need to find a supplementary cementing material for the improvement of environmental effects is of great significance.

Nowadays, construction waste resulting from the demolition of old structures is generated in huge amounts. Generation of construction waste per annum is reported as 145 million tonnes worldwide (Revathi et al. 2013). A huge amount of space is required for land-filling this much-produced waste. Therefore, to reduce the quantity of open area required for land-filling and to preserve the environmental resource conservation, recycling of construction waste is vital (Revathi et al. 2013, Torgal et al. 2013). It has been broadly reported that recycling decreases pollution, consumption of energy, greenhouse effect, global warming, along with cost (Khalaf and Venny 2004; Torgal and Said 2011; Ameri and Behnood 2012; Vázquez 2013; Behnood et al. 2015; Pepe 2015 and Behnood et al. 2015). The use of recycled waste materials in concrete or mortar production provides a reasonable solution for problems related to waste management. Many previous studies are carried out to investigate possible replacement materials for Portland cement. Some alternatives materials have already been used as a replacement of OPC such as bagasse ash, ceramic materials, fly ash, zeolite, silica fume, limestone and siliceous stone powder etc. in previous literature (Payá et al., 2002; Ganesan et al. 2007; Yılmaz et al. 2007; Naceri and Hamina, 2009; Achtemichuk et al. 2009; Lavat et al., 2009; Frías et al., 2011; Oliveira et al., 2012; Vardhan et al., 2015; Shehab et al., 2016; Bentz et al., 2017; Singh et al., 2017) etc.

Several new eco-friendly substitutes of clay bricks such as Cellular Lightweight Concrete (CLC) and Autoclaved Aerated Concrete (AAC) block which is manufactured using 60-65% of fly ash have gained a lot of traction in the Indian market (IBABM-2021, 2017). Most of the modern constructions use CLC and AAC blocks as infill masonry owing to their several beneficial attributes. At this stage replacement of cement by demolished CLC and AAC block dust can be a promising method for both reducing CO_2 emission in the cement industry and minimizing the waste of used CLC and AAC blocks in the concrete and cement industry. Therefore, the main objective of the present study is identified as to explore the prospect of utilizing the demolished CLC and AAC dust as an alternative material for partial replacement of OPC.

MATERIALS

In the experimental study, OPC of grade 43 was used, which complied with the requirements of Indian Standard IS: 8112 (2013). Fine aggregate used in present study is natural river sand of specific gravity 2.68, a fineness modulus of 2.2 and water absorption of 0.8% (by weight), respectively. The grading of sand is found to be of Zone-IV in accordance with Indian Standard IS: 383 (1970). The particle size distribution curve of the sand is presented in Fig. 1.

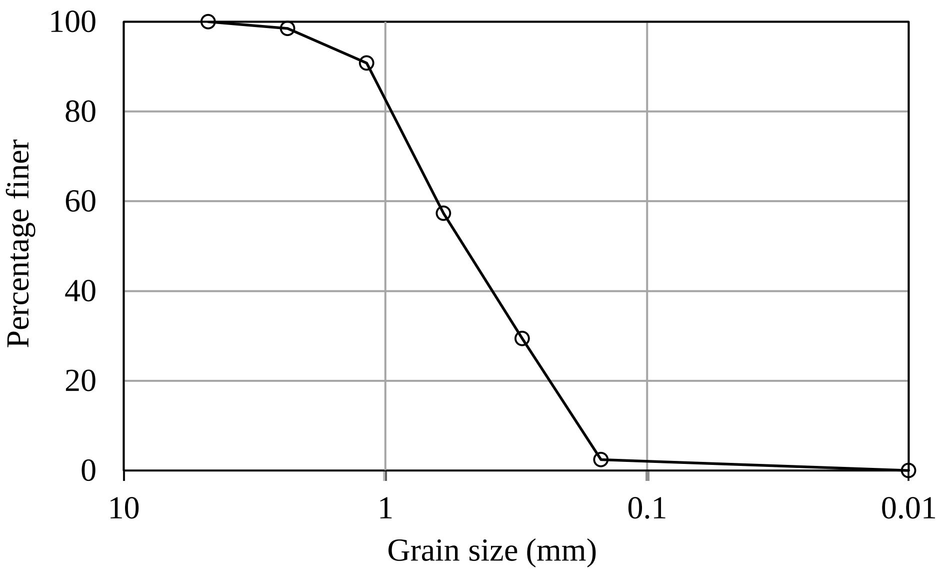

Figure 1 Particle size distribution curve of sand

The CLC and AAC dust material investigated in this study were obtained from waste CLC and AAC blocks, which were crushed in the laboratory and sieved through a 90µ I.S. sieve. Physical properties of CLC and AAC block dust are tested in the laboratory as per Indian Standard IS: 4031 Part 4 (1988) and presented in Table 1. The results for OPC is also presented in this table for reference.

Table 1 Physical properties of OPC, CLC and AAC block dust

Properties	AAC dust	CLC dust	OPC
Specific gravity	2.10	2.18	3.15
Consistency	45	53	31

Field Emission Scanning Electron Microscope (FESEM), Energy Dispersive X-ray Analysis (EDX) and X-Ray Diffraction (XRD) analysis were carried out to find the chemical composition and crystallography of CLC and AAC block and make a decision whether it has cementitious properties or not. FESEM images for CLC and AAC block dust are presented at a magnification of 100,000 in Fig. 2 and Fig. 3.

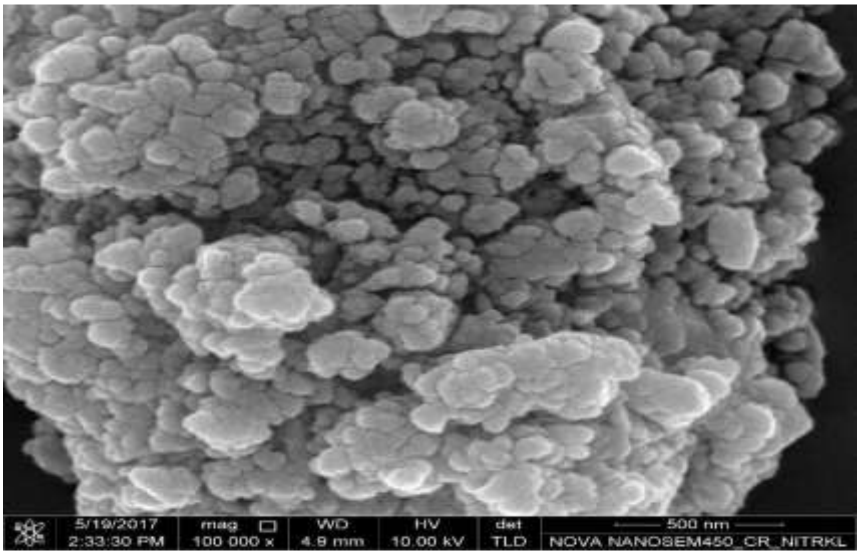

Figure 2 FESEM of CLC block dust

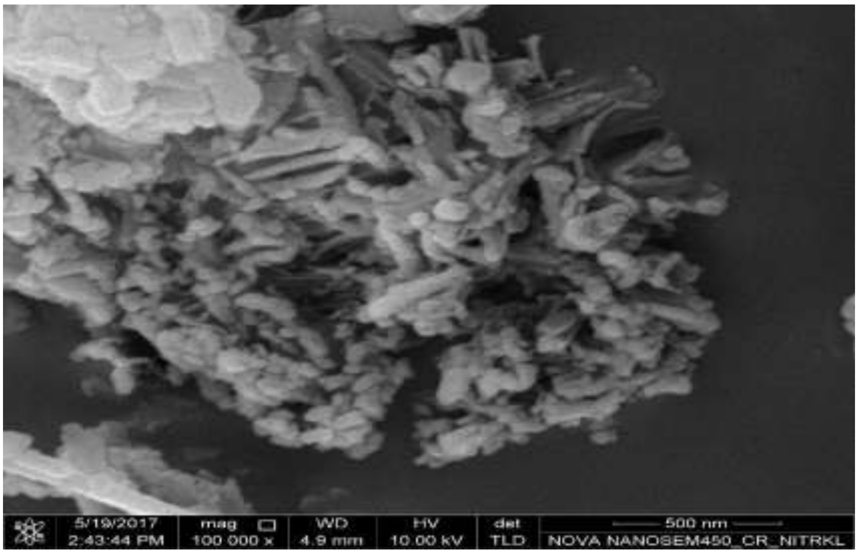

Figure 3 FESEM of AAC block dust

EDX results for CLC and AAC block dust are shown in Fig. 4 and Fig. 5 respectively. From the EDX result, it can be seen that that calcium (Ca), silicon (Si), alumina (Al), and iron (Fe) are the chief composition of CLC and AAC block dust, which is very similar to the cement composition. The EDX result shows that demolished CLC and AAC block dust can be used as cementitious materials.

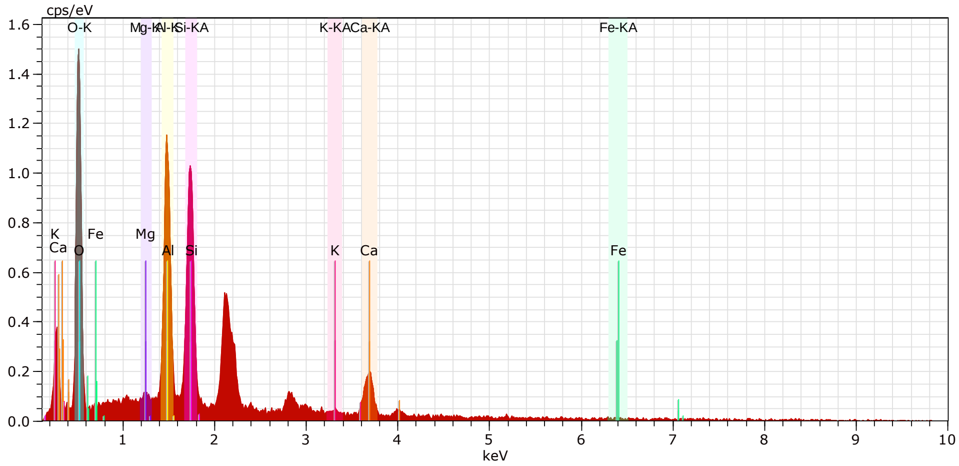

Figure 4 EDX plot of CLC block dust

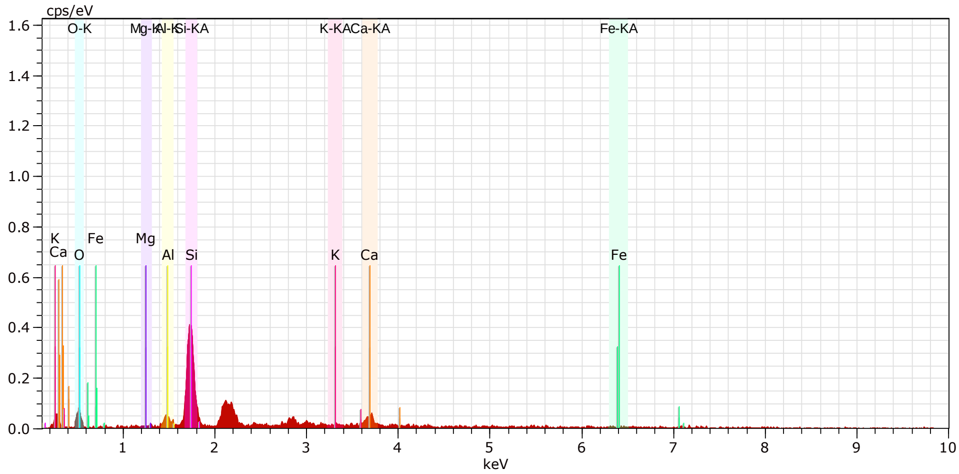

Figure 5 EDX plot of AAC block dust

Fig. 6 and Fig.7 presents the XRD analysis results for CLC and AAC block dust respectively. From the XRD analysis data, it is observed that the chief 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) while in case of 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).

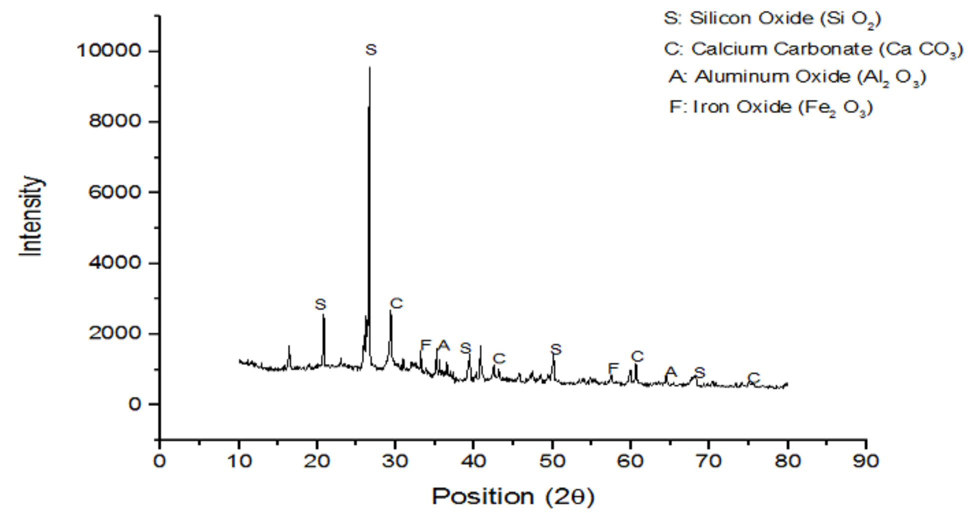

Fig 6 XRD.analysis plot of CLC block dust

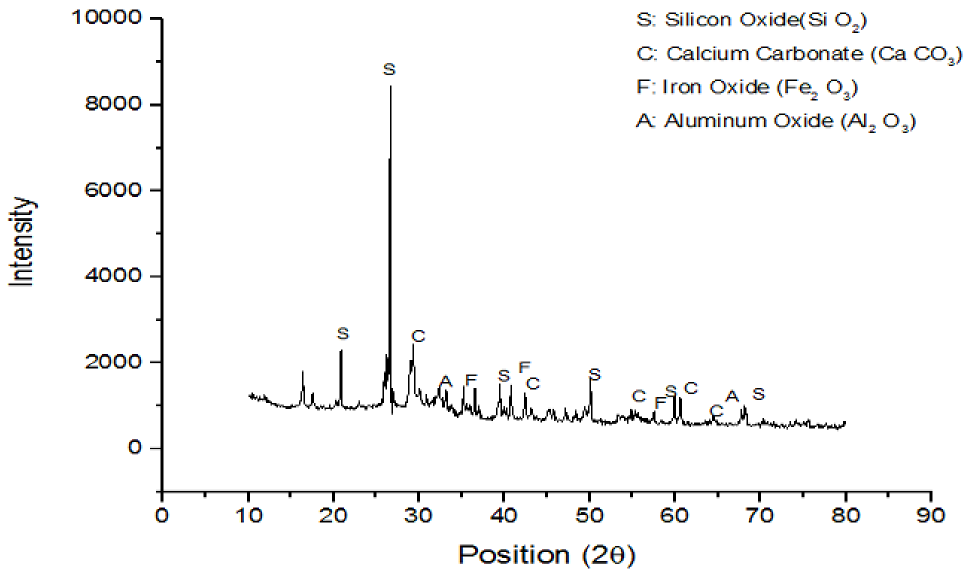

Fig 7 XRD analysis plot of AAC block dust

CEMENT MORTAR USING CLC AND AAC BLOCK DUST

Effect of CLC and AAC block dust in the properties of cement mortar is studied. Seven mortar mixes are prepared using OPC partially replaced with CLC and AAC block dust ranging from 0 to 30%. The mortar cubes are made according to ASTM C-109/C-109M. The size of the specimen moulds is 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. The materials used in the study had a water-to-binder (w/b) ratio of 0.485. The CLC and AAC block dust was used to replace OPC by 0%, 5%, 10%, 15%, 20%, 25%, and 30% of weight. The casted specimens are shown in Fig. 8. The specimens were de-moulded after 24 hours and cured for 7 and 28 days. The cured specimens were used for measuring compressive strength of the mortar block. The cement mortar cubes were tested in a load-controlled universal testing machine to determine the unidirectional compressive strength at 7 days and 28 days as per the procedure outlined in relevant Indian Standard. The compressive strength of hardened mortar cubes are presented in Tables 2 and 3 for CLC and AAC replaced mortar cubes respectively. Fig. 9 presents the variation of compressive strength as a function of the percentage replacement of CLC and AAC block dust.

Fig 8 Prepared specimens

Table 2 Compressive strength of mortar cube with CLC block dust replacement

Specimen	CLC replacement (%)	Compressive strength (MPa)	
		7 days	28 days
CLC-0	0	22.3	27.8
CLC-5	5	17.8	30.0
CLC -10	10	20.1	33.8
CLC -15	15	18.6	31.5
CLC -20	20	18.5	30.6
CLC -25	25	16.5	25.3
CLC -30	30	14.5	**24.9**

Table 3 Compressive strength of mortar cube wit AAC block dust replacement

Specimen	AAC replacement (%)	Compressive strength (MPa)	
		7 days	28 days
AAC -0	0	23.3	29.6
AAC -5	5	20.2	28.3
AAC -10	10	20.5	27.1
AAC -15	15	15.5	26.8
AAC -20	20	14.8	**25.1**
AAC -25	25	14.5	**24.3**
AAC -30	30	13.5	**22.2**

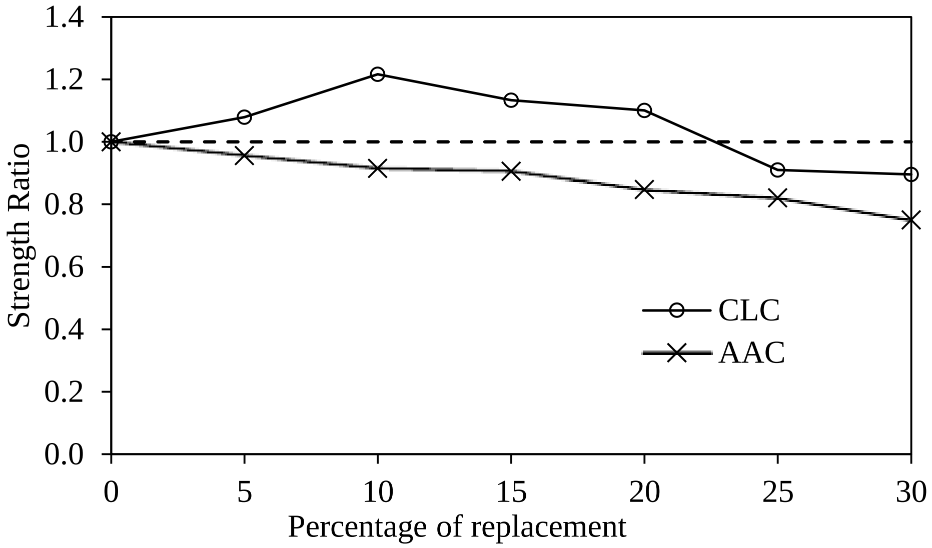

Figure 9 Variation of 28-day compressive strength of replaced samples

It can be observed from the Table 2 and Fig. 9 that the 28-day compressive strength of mortar cube increases with the increase of CLC replacement up to 10%. Further increase of CLC replacement reduces the compressive strength. However, up to 25% of CLC replacement results in 90% or more compressive strength as compared to the control specimen. Similarly, it can be seen from Table 3 and Fig. 9 that the 28-day compressive strength of mortar cube decreases gradually with the increase of AAC replacement. However, this decrease is quite small (less than 10%) up to a replacement of 15%.

The results presented in Tables 2-3 also indicate that the rate of strength gain for the mortar cube is slow during the early ages. The control specimens are found to achieve about 78-80% of the final strength in first seven days whereas the CLC and AAC replaced specimens achieve only about 60% of final strength in first seven days.

XRD analysis has been carried out for control cement mortar cube and that with typical (20%) CLC block dust replacement. The broken mortar cube at 28 days of age was analyzed to compare the changes in microstructure due to the addition of CLC block dust. The X-ray diffraction technique for diffraction angle 2θ ranged between 20° and 80° was used for identification of phases present in the hardened mortar made with or without CLC dust. Figs. 10 and 11 present the XRD plots for control and CLC replaced mortar specimens respectively. These figures show that replacement of CLC block dust yields more calcite compound in comparison with the control specimens. More calcite compound contribute to the higher strength of CLC replaced mortar cube.

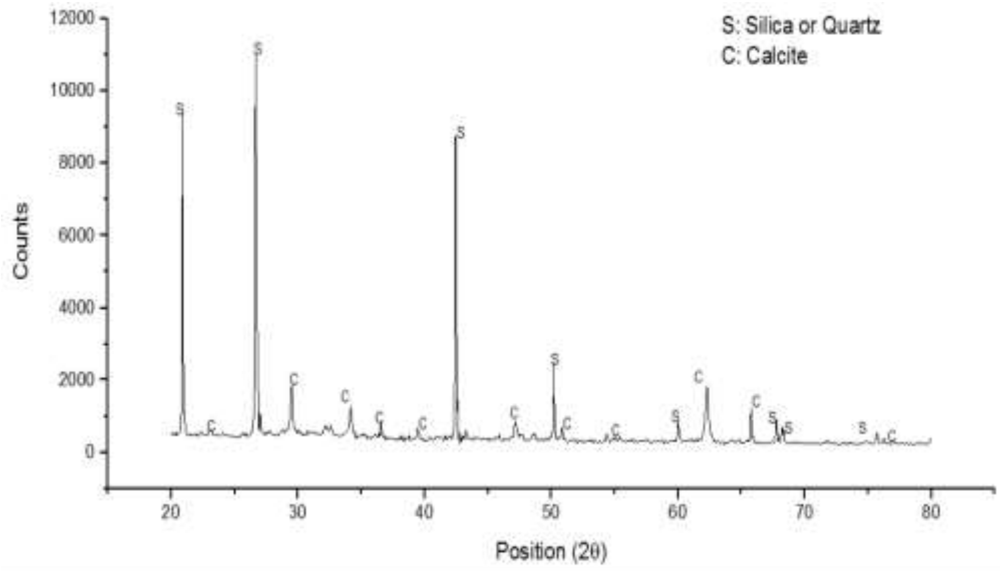

Fig 9 XRD analysis plot of control mortar specimen

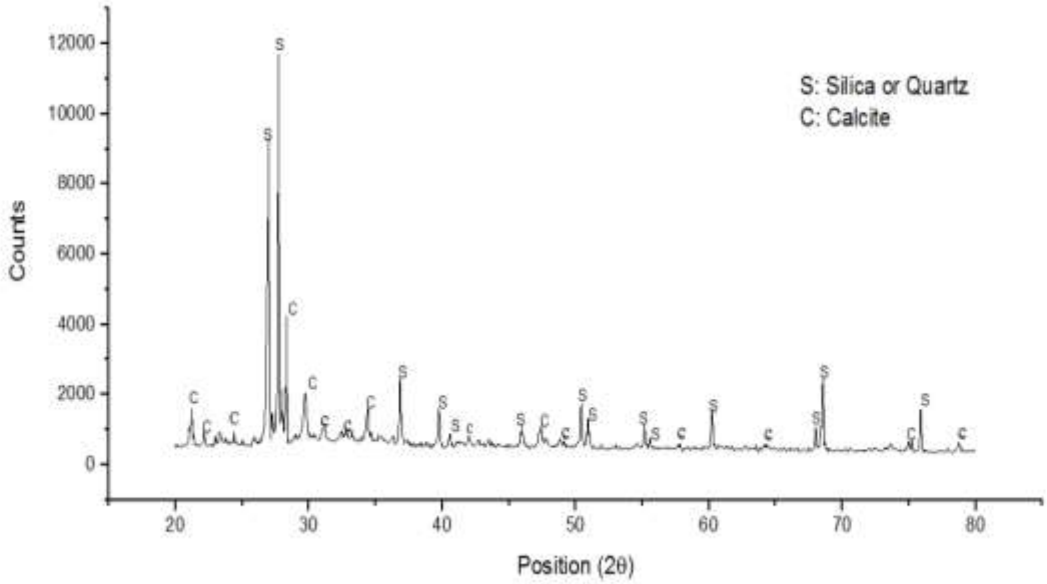

Fig 10 XRD analysis plot of CLC block dust replaced (20%) mortar specimen

CONCLUSIONS

In order to find an alternative application which has a higher economic and environmental values, the cementitious behaviour of demolished CLC and AAC block dust was studied in detail. The results obtained from the experimental investigation are summarized here.

a) The 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). The consistency of CLC and AAC block dust is 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 OPC for casting mortar cubes. Also, CLC and AAC block dust can result in lighter mortar specimens. EDX and XRD analysis results show that CLC block dust contains more calcite component than AAC block dust and both has cementitious properties. Therefore, these materials can be used to replace cement for concrete making.

b) 28-day compressive strength of mortar cube shows that 20% replacement of OPC with CLC block dust and 15% replacement of OPC with AAC block dust can be used without a significant loss (within 10%) of compressive strength. Replacement of CLC block dust can even increase the compressive strength up to a certain limit. This is due to the presence of more calcite component in CLC replaced mortar specimen as confirmed by XRD analysis. Therefore, it can be concluded that recycled CLC and AAC block dust can make sustainable binder material with reduced environmental pollution.

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