Sustainable Use of Corn Cob Ash in Metakaolin Based Geopolymer as a Partial Replacement for Metakaolin

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***Abstract*–This paper reports the effect of corn cob ash as well as carbon nano tubes on the compressive strength of metakaolin based geopolymer mortars. Corn cob ash, an agricultural waste product was used as a partial replacement for metakaolin from 0 to 10% at an interval of 2.5%. Carbon nano tubes, produced by Chemical Vapor Deposition (CVD) method was used as an additional material up to 1 % by weight of binder. Alkaline activator to binder ratio was 0.6 for all the mortar mixes. Thermal curing was done on the samples for 24 hours and then these were cured at ambient temperature until the age of testing. The results showed that the metakaolin based geopolymer mortar with corn cob ash and carbon nano tubes had higher compressive strength than the mixes without the usage of corn cob ash and carbon nano tubes. It was also depicted that the optimum compressive strength of metakaolin – corn cob ash based geopolymer was obtained at 0.5% CNTs.**

Keywords: Geopolymer Mortar, Sustainable development, Environment friendly, Compressive strength.

I. Introduction

There has been a drastic change in the world of industrialization. The number of industries is burgeoning day by day which has dramatic effect on the environment and also, the level of carbon dioxide emissions is increasing at a peak rate thereby making it unsuitable for sustainable development. Carbon dioxide has become major rationale for the yielding of green house effect which is mainly due to the cement production as depicted by the green technology research. Thus, it has become obligatory to alleviate the manufacturing of cement by replacing it with other materials, for instance, rice husk ash, corn cob ash, fly ash, bottom ash, ground granulated blast furnace slag etc. which has the similar properties of cement. According to the research work done by various researchers, alkali activated binders (geopolymer) has shown great potential to become an alternative to Ordinary Portland Cement (OPC) as these reduce the effect of green house besides improving the durability performance [1-4].

Geopolymerisation is a chemical response between alumino-silicate oxides with silicates under profoundly alkaline conditions which yields the polymeric Si–O–Al–O bonds representing that any Si–Al materials could become sources of geopolymerisation. Various geopolymer binders, which are rich in alumina and silica such as fly ash, rice husk ash, ground granulated blast furnace slag, metakaolin etc; are used as a source material and potassium or sodium based alkaline solutions are used for the activation of binders in geopolymerization. Metakaolin , an alumino-silicate material was used as a source material in this study. It helps in enhancing the early strength of concrete [5]. The geopolymer mortar made of blended source material is having more strength than the geopolymer mortars which are made of single source material [6-7]. Therefore an attempt has been made to develop high strength geopolymer mortar using corn cob ash and metakaolin.

Corn Cob Ash (CCA), an agricultural waste product leads to the pollution if it is not properly disposed off was used as a partial replacement of metakaolin in geopolymer. The CCA content improves the workability and mechanical characteristics [8]. The use of corn cob ash as a cementitious material is an eco friendly approach and it also contributes towards the sustainable growth of construction industries. Mujedu et al. [9] have investigated the feasibility of using CCA and saw dust ash (SDA) as cement replacement in concrete at various proportions such as 0% to 50% with an interval of 10%. Test results revealed that the compressive strength was 23.99 N/mm^2 at 56 days for 10% combination of CCA and SDA [9]. According to the investigation, it was found that 10% of CCA can be used in cement as it does not compromise the reliability of structures.

For the strengthening purposes of structures, nano materials have been used as these are very advantageous for improving the microstructure and mechanical properties of the matrix. Carbon nanotubes are defined as the allotropes of carbon with cylinderical structure having indistinguishable attributes as single or multiple layers of graphite sheets in nano sizes are viewed as amongst the most significant materials of this century. Because of their noteworthy mechanical properties, carbon nanotubes have been utilized to strengthen the matrix either cement or concrete [10-12]. According to Mohsen et al [13], augmentation in the mixing duration enhanced the dispersion quality and properties of MWCNTs cement matrix. The use of multi walled carbon nano tubes by less than 1% by weight of cement can significantly enhance the mechanical properties of the composites [14-17].

In the present study, by replacing metakaolin with an agricultural waste product (corn cob ash); multi walled carbon nano tubes have been employed in metakaolin based geopolymer mortar.

II. Materials and Methods

A. Material and Sample Preparation

Metakaolin procured from the Kaolin Techniques Private Limited, Gujarat was used as the source material. Its chemical composition is given in Table 1. The source material was partially replaced by Corn cob ash (CCA). The CCA was obtained after the grinding of dried corn cobs. The grounded corn cobs were burnt until these turned into ashes. Then ash was grounded and passed through 75 micron IS sieve. The chemical properties of CCA are given in Table 2. Multi walled carbon nano tubes (MWCNTs) were used as an additive material up to 1% by chemical vapor deposition method. These were obtained from Platonic Nanotech Private Limited, Jharkhand and there dimensions are 5 to 15 nm diameter and 10 to 15 microns length, respectively.

Mix proportions of the geopolymer mortar mixes for 12 molar concentration of Sodium hydroxide are given in Table 3. MWCNTs were first dispersed in polycarboxylate based superplasticizer (5% by weight of binder) and water using ultrasonic water bath for about 1 hour. For homogeneous mixing, the binders (Metakaolin and CCA) were first mixed before mixing with water and alkaline activator solution, using alkaline activator to binder ratio and water to solids ratio as 0.6. River sand, sand to cement ratio of 3, was added and then mixed. After that, the mixes were poured into oiled moulds (70.6 × 70.6 × 70.6 mm^3) for compressive strength, compacted, surfaced-smooth and then placed in oven for 24 hours thermal curing. After the thermal curing, the specimens were then removed from the moulds and cured at ambient temperature until testing.

Table 1: Chemical Composition of Metakaolin

Sr. No.	Chemical Composition (%)	Values
1.	SiO_2	52 ±1%
2.	Al_2O_3	42 ±1%
3.	TiO_2	0.5 Max.
4.	Fe_2O_3	< 1.3%
5.	CaO	< 0.5%
6.	MgO	< 0.5%
7.	Na_2O, K_2O	0.5 – 2.5%
8.	Loss on ignition	0.8 - 1.2

Table 2: Chemical Properties of Corn Cob Ash

Sr. No.	Chemical Composition (%)	Values (%)
1.	Carbon	0.43
2.	Oxygen	55.02
3.	Sodium	0.01
4.	Magnesium	4.37
5.	Aluminum	0.51
6.	Silicon	16.13
7.	Potassium	20.20
8.	Calcium	0.87
9.	Phosphorus	2.24
10.	Iron	0.23

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Table 3: Mix Proportion of Metakaolin Based Geopolymer Mortar Mixes

Mix	MK (g)	CCA (g)	MWCNT (g)	AAS (g)	SH (g)	SS (g)	FA (g)	W (g)
S1	1800	0	0	1080	308.6	771.4	5400	647.06
S2	1755	45	0	1080	308.6	771.4	5400	647.06
S3	1710	90	0	1080	308.6	771.4	5400	647.06
S4	1665	135	0	1080	308.6	771.4	5400	647.06
S5	1620	180	0	1080	308.6	771.4	5400	647.06
S6	1800	0	9	1080	308.6	771.4	5400	647.06
S7	1755	45	9	1080	308.6	771.4	5400	647.06
S8	1710	90	9	1080	308.6	771.4	5400	647.06
S9	1665	135	9	1080	308.6	771.4	5400	647.06
S10	1620	180	9	1080	308.6	771.4	5400	647.06
S11	1800	0	18	1080	308.6	771.4	5400	647.06
S12	1755	45	18	1080	308.6	771.4	5400	647.06
S13	1710	90	18	1080	308.6	771.4	5400	647.06
S14	1665	135	18	1080	308.6	771.4	5400	647.06
S15	1620	180	18	1080	308.6	771.4	5400	647.06

MK= Metakaolin, CCA= Corn cob ash; MWCNT = multi walled carbon nano tubes; AAS = Alkaline Activator Solution; SH = Sodium Hydroxide; SS = Sodium Silicate; FA = Fine Aggregates; W = Water

III. Results & Discussion

Table 4 elucidates the compressive strength results of metakaolin based geopolymer mortar incorporating MWCNTs along with the replacement levels of metakaolin with CCA. It was found out that the compressive strength of geopolymer increased with the increase in CCA and MWCNTs content up to the concentration of 5% and 0.50% as depicted from Fig.1 to Fig. 3. It was also depicted that the compressive strength increased with the increase in curing period (that is, for 3, 7 and 28 days). Though, the dispersion of MWCNTs played a significant role in upgrading the properties of the matrix. In this manner, uniform dispersion of MWCNTs achieves the better strengthening of matrix and improves the mechanical properties of the nano composites [18 - 20]. Besides, the incorporation of CNTs fines pore size distribution and reduces the porosity (or nanoporosity) of composites by filling the pores between the hydration products. Consequently, the composites become considerably more compacted [21 - 23]. The overall trend shows that the addition of small amounts of MWCNTs produce better results. This behavior may be regarded to the effective dispersion of MWCNTs at lower percentage addition [24].

Table 4: Compressive Strength Results of Metakaolin Based Geopolymer Mortar

Mix	Multi walled carbon nanotubes (%)	Corn Cob Ash (%)	Compressive strength (N/mm²)		
			3 days	7 days	28 days
S1	0	0	39.37	44.72	50.01
S2		2.5	40.21	45.56	51.48
S3		5	41.72	46.3	53.52
S4		7.5	41.06	47.01	52.92
S5		10	40.65	44.41	50.49
S6	0.5	0	49.42	55.81	63.34
S7		2.5	51.13	58.28	66.33
S8		5	53.32	60.05	68.46
S9		7.5	52.23	58.39	66.81
S10		10	51.8	57.14	65.03
S11	1	0	44.08	49.14	56.7
S12		2.5	44.94	50.39	57.37
S13		5	46.84	51.52	58.77
S14		7.5	44.8	50.11	57.46
S15		10	43.05	49.73	56.59

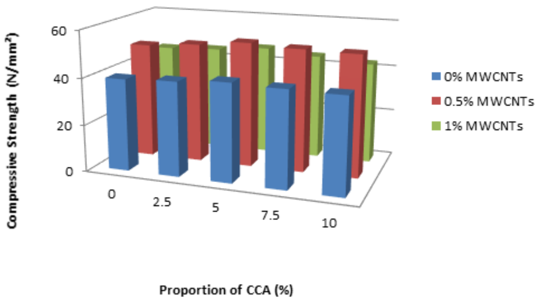

Fig. 1: Effect of CCA on the Compressive Strength of Geopolymer Mortar at Different Concentrations of MWCNTs for 3 Days of Curing

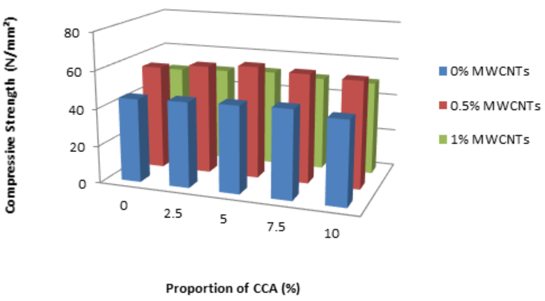

Fig. 2: Effect of CCA on the Compressive Strength of Geopolymer Mortar at Different Concentrations of MWCNTs for 7 Days of Curing

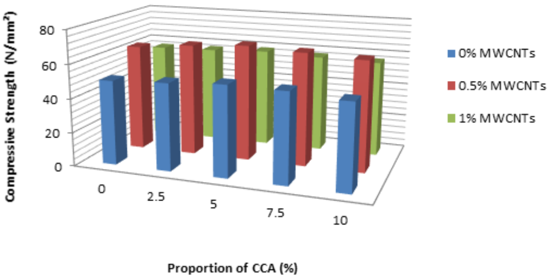

Fig. 3: Effect of CCA on the Compressive Strength of Geopolymer Mortar at Different Concentrations of MWCNTs for 28 Days of Curing

IV. Conclusion

From this study, following conclusions are drawn:

1. The test results highlight the potential of CCA as an effective pozzolan which could enhance the sustainability and economic aspect of geopolymer.
2. The compressive strength is affected by the replacement levels of CCA with metakaolin and also with the incorporation of MWCNTs.
3. Small incorporation of MWCNTs in the matrix increased the properties of the matrix as these are uniformly or homogeneously distributed while large quantity of MWCNTs results into the reduction in strength as MWCNTs are poorly distributed.
4. The significant increase in the compressive strength of geopolymer was observed when 5% CCA was replaced with metakaolin and with the incorporation of 0.50% of MWCNTs. But beyond 5% CCA and 0.5% MWCNTs, there was reduction in compressive strength of geopolymer. This can be due to the fact that there is agglomeration and bundles of MWCNTs which hinders the affect of geopolymerization.
5. The maximum compressive strength was observed for the mix S8 using 12M of NaOH solution and 5% replacement of CCA with metakaolin along with incorporation of 0.50% MWCNTs.

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