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A Sustainable Environmental Study on Corn Cob Ash Subjected To Elevated Temperature

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Abstract

Rapid increase in greenhouse gas induces mischievous impact on environment. In this study, carbon dioxide emission can be reduced to some extent by replacing some amount of cement with corn cob ash. The performance of concrete at high temperature was also studied. This paper investigates the effect of elevated temperature on strength property of ordinary concretes of grade M25, containing Corn Cob Ash (CCA) at various replacement levels of cement. The cube samples were subjected to high temperature of 150 ^{0}C, 300 ^{0}C, 450 ^{0}C and 600 ^{0}C for 2 hour duration in a muffle furnace. The samples were tested for compressive strength after air cooling to the room temperature. It can be seen that at normal temperature, compressive strength of the concrete decreases as the CCA content increases. The compressive strength of concrete increased significantly for all the mixes including control mix when the temperature was raised to 300 ^{0}C. The recommended maximum replacement content of cement with CCA and elevated temperature was 10% and 300 ^{0}C respectively.

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Keywords

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Introduction

Carbon dioxide gas (CO_2) available in earth's atmosphere is about 0.04 %. In change in amount of CO_2 creates adverse effect on environment. CO_2 emission occurs due to combustion of fossil fuels, cement production and deforestation which causes global warming. The cement production contributes large amount of global CO_2 emission generated from calcinations of lime stone and combustion of fuels in a kiln. In order to control carbon dioxide emission, it is necessary to minimize the production and use of cement to some extent by partial replacing it with other environment friendly material. The agricultural waste used as a partial replacement of cement is one of the best solution to minimize water, land and air pollution. The waste agriculture products which possess pozzolanic properties have been studied were rice husk ash[1], saw dust ash[2] and corn cob ash[3]. Corn is one of the most important crop in India after wheat and rice. Worldwide production of corn is about 1070 million metric tons in 2016-17. United States of America was the largest producer of corn

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in 2016-17 and contributes about 36 % of the total production of corn in the world. India is at 7th place in the production of corn. India produces about 26 million metric ton of corn for the year 2016-17.

Corncob is a waste product obtained during production of corns, with approximately about 170-190 kg corn cob generated for every 1000 kg of corn produced[4]. For the purpose of removal of heavy metal from waste water[5] corn cob has also been used and its ash is used as ingredient to ordinary Portland cement concrete[6]. Corn cob ash (CCA) is obtained by burning of corn cob waste. CCA has about 70 % of combined content of SiO_2 and CaO. Investigators and researchers have various opinion on the properties of concrete in account of effect of temperature in the range of 100-300 ^{0}C[7-9] and the compressive strength of concrete above 300 ^{0}C goes on decreasing. The serious deterioration has found at 600 °C, at this stage concrete loses almost half of its original strength[10-11]. Concrete containing CCA is used in structures under normal temperature conditions. Properties of CCA concrete under ambient temperature conditions have received considerable research attention. However, the behaviour of CCA concrete at elevated temperature has not sufficiently been covered. Compressive strength of CCA concrete under elevated temperatures needs to be studied. The present study investigates the effect of elevated temperature on the compressive strength of CCA concrete.

Materials Used

Ordinary Portland Cement (OPC)

Ordinary Portland cement 43 grade was conforming to BIS: 8112[12] was used. The physical properties of ordinary Portland cement are given in Table 1.

Table 1: Properties of OPC 43 grade cement

Characteristics	Experimentally Values Obtained	Values specified by BIS 8112
Standard consistency	31%	-
Specific Gravity	3.15	-
Initial Setting time (min)	152	not less than 30
Final Setting time (min)	249	not more than 600
Compressive Strength		
3 days	23.60 MPa	23 MPa
7 days	34.84 MPa	33 MPa
28 days	46.55 MPa	43 MPa

Coarse and Fine Aggregates

The coarse aggregate used was crushed stone having nominal size of 20 mm. Locally available river sand having nominal size of 4.75 mm was used. The sand was conforming to grading zone II as per BIS: 383[13]. Table 2 shows the physical properties of coarse and fine aggregates.

Table 2: Physical properties of coarse and fine aggregates

Property	Fine aggregate	Coarse aggregate
Specific Gravity	2.74	2.68
Fineness modulus	2.73	6.62
Water absorption %	0.5	1

Corn Cob Ash (CCA)

To prepare CCA, first corn cobs were broken down into small pieces which helps in enhancement of combustibility and reduction in carbon content that affects the pozzolanic properties. CCA was produced by burning of pieces of corn cob in furnace at about 700 ^{0}C up to 5 hours. The chemical composition of CCA is shown in Table 3.

Table 3: Chemical composition of CCA

Chemical Components	Value
SiO_2	64.56 %
CaO	12.0 %
Fe_2O_3	5.12 %
Al_2O_3	9.42 %
MgO	3.01 %

Methods

Concrete Mixes and Mix Proportions

Control mix C1 was designed as per BIS: 10262[14] for M25 grade of concrete. Then four mixes were casted at various replacement levels of OPC (0%, 5 %, 10 %, 15 % & 20 %) with CCA and are designated as C2, C3, C4 and C5. The water/cement (w/c) ratio in all the mixes was kept at 0.45. Mix proportions of concrete mixes are given in Table-4.

Table 4: Mix proportions of concrete mixes

Mixes	CCA %	CCA (kg/m^3)	W/C Ratio	Water (l/m^3)	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)
M1	0%	0	0.45	191.58	425.73	1100.22	719.16
M2	5%	21.2	0.45	191.58	404.53	1100.22	719.16
M3	10%	42.57	0.45	191.58	383.16	1100.22	719.16
M4	15%	63.86	0.45	191.58	361.87	1100.22	719.16
M5	20%	85.14	0.45	191.58	340.59	1100.22	719.16

Preparation of Test Cubes

All the specimens were casted in accordance with BIS: 516[15]. After casting, the cubes were wrapped in plastic sheets and kept at room temperature for 24 hours. The cubes were removed from the moulds after 24 hours of casting and submerged into water for curing till the time of the test.

Compressive Strength of CCA Concrete at Elevated Temperature

The cubes were heated in a muffle furnace at 150 ^{0}C, 300 ^{0}C, 450 ^{0}C, and 600 ^{0}C for 2 hours after 28 days curing. The cubes were allowed to cool at room temperature naturally. The compressive strength was performed on cubes of size 100 mm X 100 mm X 100 as per BIS: 516[18]. Loading rate of 2.5 kN/s was applied for compressive strength test.

Results and Discussions

The test results of compressive strength of CCA concrete subjected to different elevated temperature is given in Table 5. The effect of elevated temperature of CCA concrete on compressive strength is shown in Figure 1. It was observed that the compressive strength of all mixes increases up to elevated temperature of 300 ^{0}C. Beyond the temperature of 300 ^{o}C, the compressive strength decreases significantly for all mixes. The compressive strength of mixes M1, M2, M3, M4 and M5 at elevated temperature of 1500C was increased by 3.01%, 1.20 %, 3.29 %, 2.55 % and 1.19 % respectively, as compared to normal temperature.

Table 5: Average Compressive strength of CCA concrete at elevated temperature

Mix	28 days Compressive strength at room temperature (MPa)	Compressive strength at elevated temperature (MPa)			
		150 ^{0}C	300 ^{0}C	450 ^{0}C	600 ^{0}C
M1	36.43	37.53	41.43	32.33	12.4
M2	32.47	32.86	36.75	29.00	11.12
M3	27.33	28.23	31.76	22.73	10.06
M4	23.07	23.66	25.63	20.56	10.5
M5	20.15	20.39	23.03	16.68	9.13

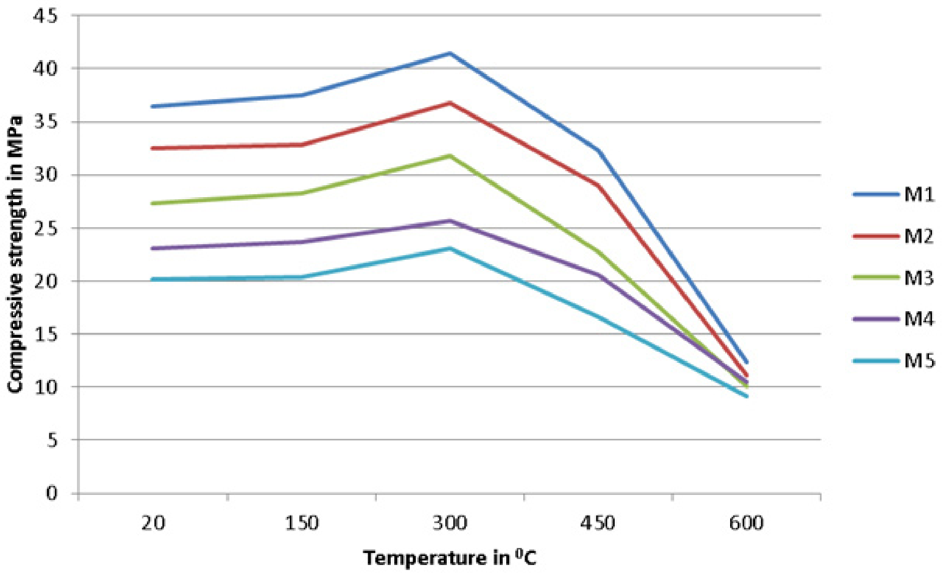

Fig. 1: Compressive strength of CCA concrete at elevated temperature

The increase in compressive strength at elevated temperature of 300 ⁰C with reference to normal temperature for mixes M1, M2, M3, M4 and M5 was 13.72 %, 13.18 %, 16.20 %, 11.09 % and 14.29 % respectively. This may be due to the evaporation of the free moisture content which accelerates the hydration and hence increases the compressive strength till the temperature of 300 ⁰C. The reduction in compressive strength at elevated temperature of 450 ⁰C with reference to normal temperature for mixes M1, M2, M3, M4 and M5 was respectively 11.25 %, 10.68 %, 16.83 %, 10.87 % and 17.22 %. Same trend has been observed at elevated temperature of 600 ⁰C, with percentage reduction (65.96 %, 65.75 %, 63.19 %, 54.48 % and 54.68 %) for different mixes (M1, M2, M3, M4 and M5) respectively. For temperatures higher than 300 ⁰C, the strength of CCA concrete starts decreasing. This decrease is attributed to the fact that chemically-bound water starts to disintegrate and evaporate at this stage.

The coefficient of determination 'R^2' of Mixes M1, M2, M3, M4 and M5 are shown in Figure 2, 3, 4, 5 and 6 respectively. In these equations y is value of compressive strength obtained with respect to temperature 'x'. The comparison between values of R^2 is shown in Table-6.

It is clear from the values obtained from the regression analysis that regression lines of mixes M1 to M5 approximates shows the real data points. The values of R^2 obtained for the mixes M1 to M5 are nearer to the 1 which indicates that the regression line perfectly fits the data.

Table 6: Values of R^2 of the mixes shown in Table 6

Mix	28 days Compressive strength at room temperature (MPa)	Coefficient of determination (R^2)
M1	36.43	0.9912
M2	32.47	0.9902
M3	27.33	0.9709
M4	23.07	0.989
M5	20.15	0.9547

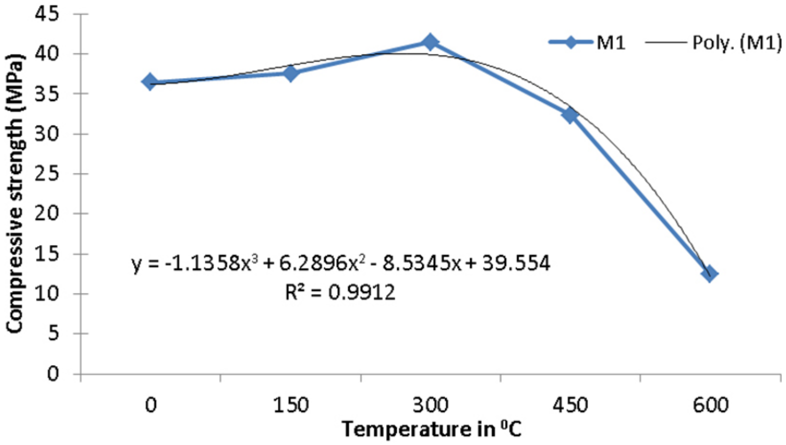

Fig. 2: Coefficient of determination of mix M1

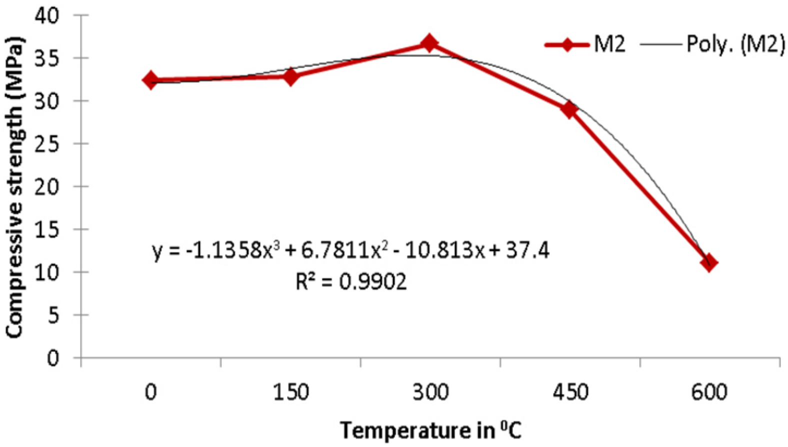

Fig. 3: Coefficient of determination of mix M2

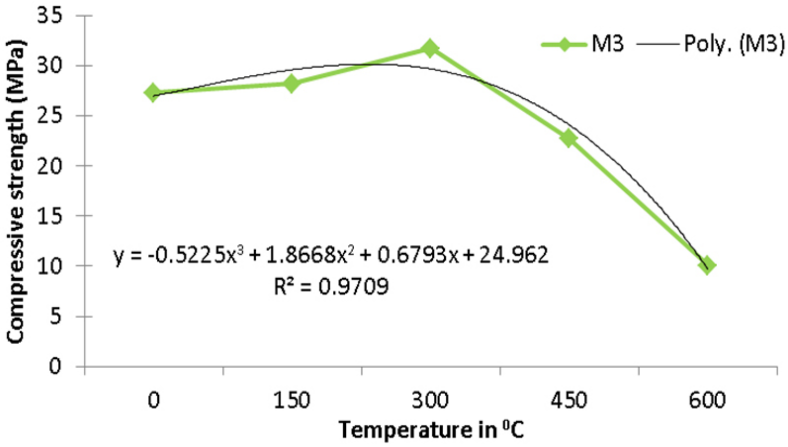

Fig. 4: Coefficient of determination of mix M2

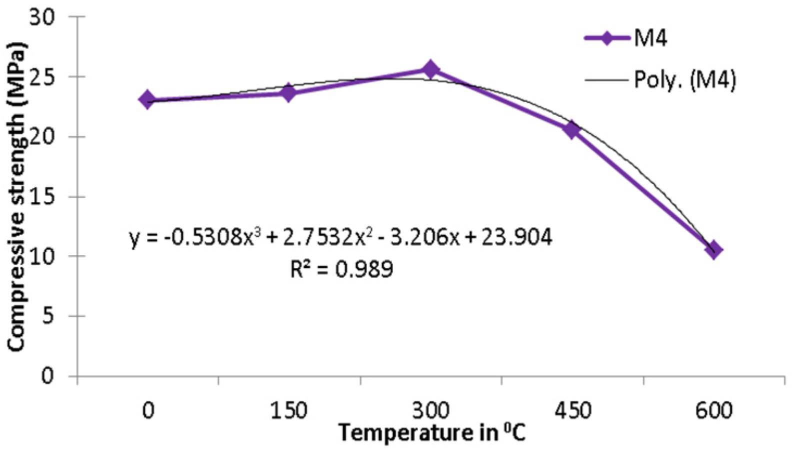

Fig. 5: Coefficient of determination of mix M4

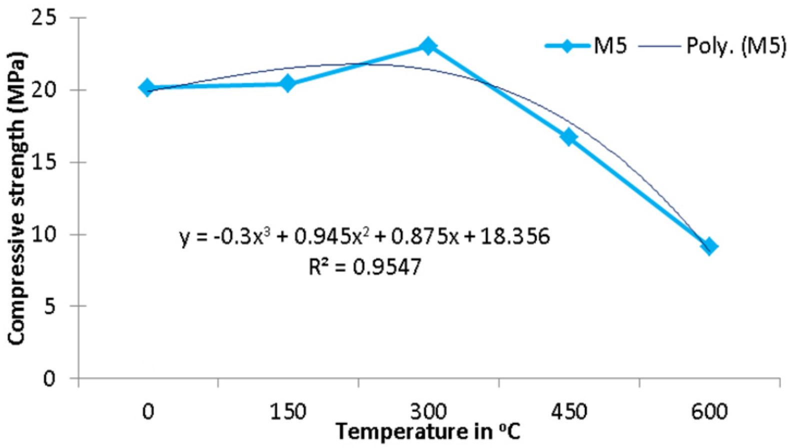

Fig. 6: Coefficient of determination of mix M5

Conclusion

From this study following conclusions are drawn:

- It was noticed that the compressive strength of all mixes increases up to elevated temperature of 300 ^{0}C. Beyond this temperature, compressive strength decreases significantly for all mixes. High rise in compressive strength was noted at 300 ^{o}C w.r.t compressive strength of concrete under normal temperature. The result shows that all reaction providing strength to the concrete gets completed at about temperature of 300 ^{o}C. The compressive strength of normal concrete subjected to temperature of 300 ^{o}C at 28 days curing age was noted 13.72 % higher than that of concrete at normal temperature.
- The optimum content of CCA is recommended as 10 % corresponding to elevated temperature of 300 ^{0}C
- The regression analysis shows that the values of R^2 obtained for the mixes M1 to M5 are nearer to the unity which indicates that the regression line perfectly fits the data.

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