Effect of Elevated Temperature on Mechanical Properties of Early Age Concrete

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***Abstract* - In its most basic form concrete is mixture of cement, coarse aggregate, fine aggregate and water. The most important content of concrete is cement. Now a days most concrete mixtures contain supplementary cementitious material that make a portion of cementitious component in concrete. These materials are generally a byproduct from various processes or natural materials. Fly ash by product of coal fired at power generation facilities and is the noncombustible particulates removed from flue gases. Characteristics of fly ash can vary significantly depending on the source of the coal being burnt. Sugarcane bagasse ash is a solid waste generated from the sugar manufacturing industry. India is world's biggest cane producers. Bagasse is the fiber residue remaining after extraction of the cane juice from sugarcane. Rise husk is generated during the milling process is most used in fuel in boilers for producing energy through direct combustion. Farming waste is crude material for environment these days. Banana leaf ash obtained locally from burning of dry banana leaves. The leaves were completely burnt under atmospheric condition.**

Concrete material in structures is likely exposed to high temperature during fire. The relative properties of concrete after such an exposure are of great importance in terms of serviceability of building. The properties that affect the performance of concrete are thermal and mechanical properties. The thermal properties that influence temperature rise and distribution in a concrete are thermal conductivity, specific heat, thermal diffusivity and mass loss. The mechanical properties that determines the fire performance of reinforced concrete members are tensile strength, compressive strength and modulus of elasticity. At rise in temperature compressive strength is highly influenced by room temperature.

***Index Terms* - Fly ash, Sugarcane Bagasse ash, Rise husk ash, Banana leaf ash, Temperature, compressive Strength.**

I.INTRODUCTION

Concrete with its reliable properties like easy availability of constituent materials, mouldability i.e. capacity to acquire any desired shape when it is in the fresh state, durability, and better thermal resistance, it is widely used as a major constituent in infrastructure development. Building constructed in wood are the examples of fire damage but building constructed in reinforced concrete are also damage in fire despite its good fire resisting properties. This is because of a change in its mechanical properties due to the change in its physical and chemical composition.

The research of the National Fire Protection Association (NFPA), a leading association in the United States, indicated that the United States fire department responses after every 24 seconds to fire somewhere in the nation. In that, 72% of fire is the structure fires that occurred in homes. Fire incidences in the home structures were increased with 5% from the previous year and in the year 2017 NFPA reported almost the loss of USD 23 billion as a result of the fire. Fire may occur at any time during the entire life span of the structure and it may occur during construction stage also. Most of the fire-damaged structures do not lose its strength completely and that only 9% RCC structures lose their entire strength hence, they can be demolished but, rest of 91% can be repairable. Hence, demolishing the entire structure may not prove to be an economical decision. Thus itis practiced to repair or retrofit the fire damaged structures by using different retrofitting techniques available in the construction field.

II. RESPONSE OF CONCRETE TO FIRE

Reinforced concrete structure deteriorates when exposed to elevated temperature. Loss in properties such as a reduction in bond strength, compressive strength, elastic modulus, tensile strength and ductility of steel, spalling and cracking. Although the concrete structure damaged during fire holds a certain load carrying capacity. Consequently, it is good to repair the structure by using retrofitting techniques rather than demolishing and rebuilding. The rebuilding of the whole structure proves to be an uneconomical option.

Exposure of concrete to elevated temperature during fire leads to thermal expansion of the constituents of concrete, moisture evaporation, and development of pore pressure. Two major effects of fire on structural concrete can be observed:

(1) Loss in strength of the matrix by the degradation of the hydrate structure, cracking

(2) The severity of the spalling of the outermost concrete, physical effects and color change in concrete which depend on the change in temperature.

III. MATERIAL USED

The various material used in preparation of concrete are cement, coarse aggregate, fine aggregate, various supplementary cementitious materials and water.

IV. SUPPLEMENTARY CEMENTITIOUS MATERIAL USED AS PARTIAL REPLACEMENT OF CEMENT

Fly Ash-

ASHCON super fine fly ash is finely divided product resulting from combustion of pulverized coal in power plants. It has almost become a common ingredient in concrete, particularly for making high strength concrete. It contains large amount of silica and alumina.

In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. About 43% is

recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

Sugarcane Bagasse ash –

Bagasse is the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a biofuel for the production of heat, energy, and electricity, and in the manufacture of pulp and building materials. Sugarcane bagasse ash is a byproduct of sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. The disposal of this material is already causing environmental problems around the sugar factories. On the other hand, the boost in construction activities in the country created shortage in most of concrete making materials especially cement, resulting in an increase in price.

Rise husk ash –

Rice husk ash is used in concrete construction as an alternative of cement. The rice paddy milling industries give the by-product rice husk. Due to the increasing rate of environmental pollution and the consideration of sustainability factor have made the idea of utilizing rice husk. Rise husk ash is that is obtained by burning the rice husk until it gets reduced. The rice husk for research was obtained locally. These husk then deliberated until fine ash is being produced. These ash were sieved by the 90 micron where further impurities are being minimized.

Banana leaf ash –

Banana leaf ash is an agricultural waste that as potential to replace one of the construction material which is cement. Because it contains a pozzolanic reaction that usually occurs in Portland cement. This ash as a potential to improve the performance of the concrete. The leaves available in this process are dried for period of 30 days (minimum), after which the dried banana leaves are combusted in a control environment and residual ash of the leaves with stemis collected. The residue remained after the burning is collected and known as Banana Leaves Ash.

V. CONCRETE MIX PROPORTIONS FOR M25GREADE

Mix Design of Concrete

Series	W/C	Mixture Proportion (kg/m^3)			
		Cement	Fine Aggregate	Coarse Aggregate	Water
1	0.47	419	677	1117	197

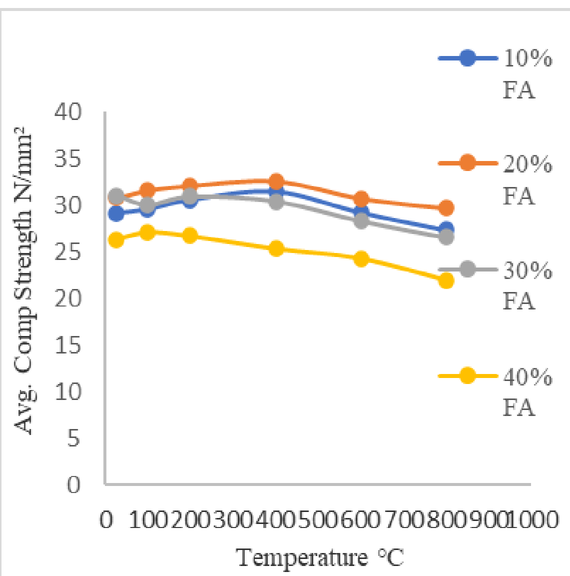
Therefore Cement : Fine Aggregate : Coarse Aggregate
= 1 : 1.61 : 2.66

VI. METHODOLOGY

The utilization of various supplementary cementitious materials like fly ash, sugarcane bagasse ash, rice husk ash and banana leaf ash at temperature 0℃,100℃,200℃, 400℃,600℃ and 800℃ for replacement ratio 10 %,20 % ,30%&40% by with cement concrete of a grade M25.The composition is done for compressive strength after various temperatures.

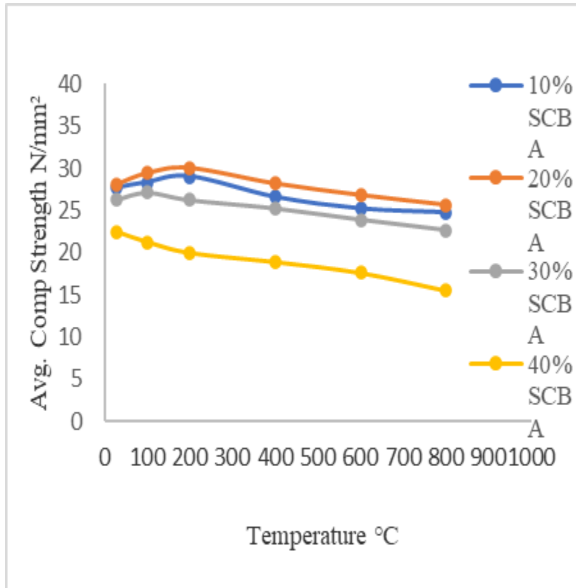
VII. TEST RESULT OF COMPRESSIVE STRENGTH

Sr. No.	Temperature	Avg. Compressive Strength of Fly ash Concrete(N/mm²)			
		10%	20%	30%	40%
1.	Room Temperature	29.15	30.76	31.05	26.37
2.	100℃	29.58	31.59	30.02	27.12
3.	200℃	30.55	32.12	30.91	26.71
4.	400℃	31.41	32.62	30.41	25.35
5.	600℃	29.19	30.74	28.29	24.29
6.	800℃	27.32	29.67	26.53	21.96



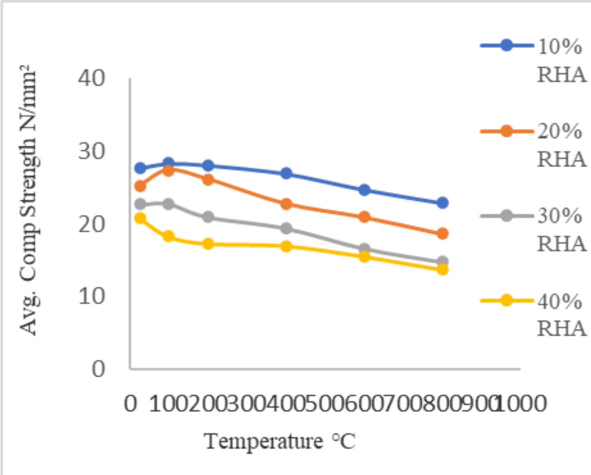
1. Average compressive strength fly ash concrete

Sr. No.	Temperature	Avg. Compressive Strength of Sugarcane bagasse ash Concrete (N/mm²)			
		10%	20%	30%	40%
1.	Room Temperature	27.28	28.07	26.30	22.45
2.	100℃	28.31	29.42	27.17	21.25
3.	200℃	29.01	30.03	26.28	19.96
4.	400℃	26.57	28.19	25.48	18.9
5.	600℃	25.19	26.83	23.92	17.83
6.	800℃	24.74	25.68	22.67	15.55



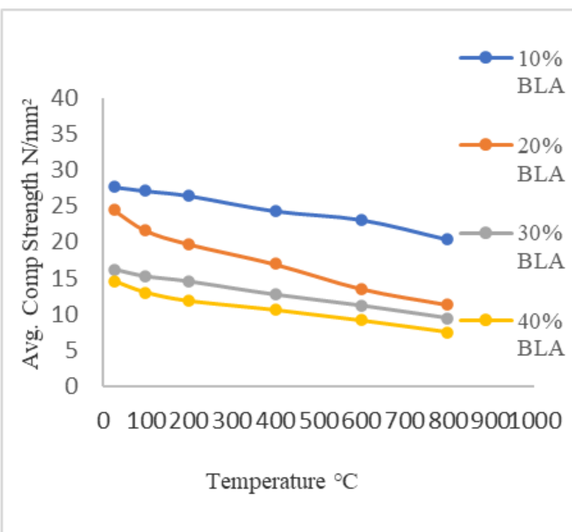
2. Average compressive strength Sugarcane bagasse ash concrete

Sr. No.	Temperature	Avg. Compressive Strength of Rice hush ash Concrete (N/mm²)			
		10%	20%	30%	40%
1.	Room Temperature	27.69	25.27	22.68	20.75
2.	100℃	28.30	27.37	22.80	18.28
3.	200℃	28.07	26.16	20.97	17.30
4.	400℃	26.91	22.79	19.42	16.98
5.	600℃	24.71	20.92	16.62	15.54
6.	800℃	22.86	18.64	14.76	13.73



3 Average compressive strength Rise husk ash concrete

Sr. No.	Temperature	Avg. Compressive Strength of Banana Leaf Ash Concrete (N/mm^2)			
		10%	20%	30%	40%
1.	Room Temperature	27.7	24.47	16.19	14.60
2.	100°C	27.16	21.64	15.23	13.02
3.	200°C	26.47	19.75	14.52	11.84
4.	400°C	24.33	16.96	12.70	10.57
5.	600°C	23.10	13.54	11.19	9.12
6.	800°C	20.33	11.33	9.45	7.51



4. Average compressive strength Banana leaf ash concrete

VII.RESULT AND DISCUSSION

This research concludes that the study of the effect of supplementary cementitious material such as fly ash, sugarcane bagasse ash, rise husk ash and banana leaf ash on the properties of concrete for nominal mix of M25 grade of concrete are as follows.

1 Average compressive strength of normal concrete decreasing with increase in temperature. The normal concrete performance up to the temperature 200°C compressive strength of concrete increases but after 400°C compressive strength decreases.

2 The replacement ratio of 10%,20%,30% and 40% of Fly ash with respect to normal concrete at temperature 0°C,100°C,200°C,400°C,600°C and 800°C are

Temperature (°C)	Percentage increase in compressive strength for replacement of fly ash w.r.to Normal concrete			
	10%	20%	30%	40%
Normal temperature	6.30%	12.18%	13.23%	-3.82%
100°C	11.60%	24.86%	18.65%	-7.19%
200°C	12.28%	29.25%	24.65%	7.48%
400°C	12.89%	33.96%	24.88%	4.10%
600°C	12.72%	34.00%	23.32%	5.88%
800°C	12.41%	34.80%	20.53%	2.99%

3. The replacement ratio of 10%,20%,30% and 40% of Sugarcane bagasse ash with respect to normal concrete at temperature 0°C, 100°C, 200°C, 400°C, 600°C and 800°C are

Temperature (°C)	Percentage increase in compressive strength for replacement of sugarcane bagasse ash w.r.to Normal concrete			
	10%	20%	30%	40%
Normal temperature	0.69%	2.37%	-4.80%	-18.12%
100°C	11.89%	16.48%	7.90%	-19.0%
200°C	16.64%	20.74%	5.66%	-19.74%
400°C	9.11%	15.77%	4.64%	-22.38%
600°C	9.80%	16.95%	4.27%	-21.79%
800°C	12.40%	16.67%	2.99%	-29.35%

4. The replacement ratio of 10%,20%,30% and 40% of rice husk ash with respect to normal concrete at temperature 0°C,100°C,200°C,400°C,600°C and 800°C are

Temperature (℃)	Percentage increase in compressive strength for replacement of rice husk ash w.r.to Normal concrete			
	10%	20%	30%	40%
Normal temperature	0.98 %	-7.840%	-17.28%	-24.32%
100℃	11.85 %	8.18%	-9.88%	-27.74%
200℃	12.86 %	5.18%	-15.68%	-30.43%
400℃	10.51 %	-6.40%	-20.24%	-30.26%
600℃	7.71 %	-8.80%	-27.55%	-32.25%
800℃	3.86 %	-15.31%	-32.93%	-37.61%

5. The replacement ratio of 10%,20%,30% and 40% of banana leaf ash with respect to normal concrete at temperature 0℃, 100℃, 200℃, 400℃, 600℃ and 800℃ are

Temperature (℃)	Percentage increase in compressive strength for replacement of banana leaf ash w.r.to Normal concrete			
	10%	20%	30%	40%
Normal temperature	1.02%	-10.75%	-40.95%	-46.75%
100℃	7.35%	-14.46%	-39.80%	-51.46%
200℃	6.43%	-20.58%	-41.61%	-52.39%
400℃	-0.082 %	-30.34%	-47.84%	-56.59%
600℃	-0.69%	-40.97%	-51.22%	-60.24%
800℃	-7.63%	-48.52%	-57.06%	-65.87%

VIII.CONCLUSIONS

1 The 20% replacement of cement with fly ash shows good compressive strength after 28 days of curing in normal condition and up to applied temperatures 800℃

2 The 10% replacement of cement with Sugarcane bagasse ash shows good compressive strength after 28 days of curing in normal condition and up to applied temperatures 600℃

3 The 10% replacement of cement with Rise husk ash shows good compressive strength after 28 days of curing in normal condition and up to applied temperatures 600℃.

4 The replacement of cement with banana leaf ash compressive strength decreases with increase in temperature. Therefore, it is not suitable for replacement of cement.

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