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Low Carbon High Performance Concrete – Sustainability Approach

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ABSTRACT:

Industrial by products such as Blast furnace slag, flyash, silica fume & engineering materials metakolin have conventionally been used for concrete as supplementary cementitious materials primarily from the aspect of the effective utilization of industrial waste. Considering natural resources conservation and prevention of global warming, new tailor made material which does not generate extra CO^2 *emission should be urgently established in concrete-related industries. Concrete is an environmental friendly material and the overall impact on the environment per ton of concrete is limited. Concrete accounts for large percentages of both resources input and* CO_2 *emission. This paper profiles various high grade of concrete M80, M90 and M100& analysis of* CO_2 *emulsion and implement reduction of* CO_2 *load on environment by employing the best cementitious substitutions. Relation between cubical and cylindrical concrete mould for 28days compressive strength were also developed.*

Index Terms— *High performance concrete, Low carbon concrete,* CO_2 *emulsion, tailor made materials. Relation curve for cubical vs cylindrical concrete mould.*

I. INTRODUCTION

Concrete is by far the most important, most versatile, and most widely used building material worldwide. It is an engineered material, which means that we can design mixes to satisfy almost any set of reasonable performance specifications. Portland cement is and will remain a major construction material of choice in civil engineering construction. Unfortunately, cement manufacturing released approximately 1 ton of CO_2 into the atmosphere during the production of 1 tonne of cement. Thus partial replacement of Portland cement in mortar/concrete by mineral by-product such as flyash, slag, silica fume & engineering material like metakolin etc. can significantly reduce CO_2 emission. Cement manufacturing is a source of greenhouse gas emissions, accounting for approximately 7% to 8% of CO_2 globally. [2,3,4,7]The cement industry has made significant progress in reducing CO_2 emissions through improvements in process and efficiency, but further improvements are limited because CO_2 production is inherent to the basic process of calculating limestone. [8, 11, 17]

A. Steps to decrease CO_2

Following are the steps to decrease the total amount of CO_2 product by the global cement industry would be [5, 9, 26]

1) Decrease the proportion of cement in Concrete.

2) Decrease the proportion of calcined materials in cement.

3) Decrease the number of buildings using cement. Rammed earth where soil is compressed within a formwork to create a concrete like mass.

4) Longer – term decrease in living standard for humans and a global decrease in per-capita cement consumption.

B. Present study

In this study considering the first step proportion of cement is replace by 40%, 45%, 50% by combine percentage of flyash& various mineral admixture like silica fume, UFGGBS, Metakolin for making concrete of Grade M80, M90, M100, and analyzing the carbon emulsion and relation between cubical vs cylindrical concrete cube for the mix

II. MATERIAL STUDY

There IS 456: 2000 permits usage of FA, SF, MK, GGBS, and Rice Husk Ash (RHA) as mineral admixtures. The advantage of mineral admixtures in concrete is in two ways: To replace cement to a certain percentage, and to impart strength in the form of secondary hydration. How much cement replacement can be done depends on the type and characteristics of pozzolana selected. Because of these advantages mineral admixtures are being used in concrete at construction sites and in ready mixed concrete. [1, 12, 13, 16]

To use these materials in concrete, IS specifies required properties in the respective codes. IS 3812, IS 15338 and IS 7668 (under circulation) are meant for FA, SF and MK respectively. There is no IS code for specifications of GGBS and RHS to use in concrete. However, they can be used in concrete as per IS 456:2000 if they are satisfying the desired required properties of concrete. Most of these materials except GGBS are siliceous in nature and fine to microfine (from 300 m^2/kg to 700 m^2/kg) in nature. No doubt, addition of these materials enhances mechanical properties of concrete. Recent studies indicate although these materials help to enhance strength and reduce permeability to some extent still considerable micro pores are left over and the interfacial zone between aggregate and paste may not be fully intact. [25,28] Further pozzolana may affect some properties like workability, water requirement, cohesiveness, flow ability etc. which need to be taken care of tailor made Microfine materials play a significant positive role to improve in these cases particularly particle packing in concrete.[12,14,15]

The use of these materials in partial replacement of cement in concrete have numerous benefits: reduced greenhouse gas emissions environmentally-friendly concrete with excellent long-term strength and durability characteristics reduced energy consumption and lessened pressure on natural resources.[21, 24, 27]

A. FLYASH

Fly ash one such material obtained by combustion of coal. It is finely divided residue and transported by fuel gas. India is a resourceful country for fly ash generation with an annual output of over 110 million tons, but utilization is still below 20% in spite of quantum jump in last three to four years. Availability of consistent quality fly ash across the country and awareness of positive effects of using fly ash in concrete are pre- requisite for change of perception of fly ash from 'A waste material' to 'A resource material'. Now a day's due to strict control on quality of coal and adopting electrostatic precipitators, fly ash of consistent quality is separated and stocked, and it is gaining popularity as a good pozzolonic material for partial replacement of cement in concrete. [6, 10, 14, 19]. Physical Properties mentioned in Table no 1. Distinctive chemical composition mentioned in Table no 2.Distinctive Particle Size Distribution of cementitious materials mentioned in Chart 1.

B. SILICA FUME

Silica fume, also known as Micro Silica, is a fine-grain, thin, and much-surface area silica. Silica fume consists of fine vitreous particles with a surface area on the order of 215,280 ft^2/lb. (20,000 m^2/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement particle. Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys.[20, 22] Physical Properties mentioned in Table no 1. Distinctive chemical composition mentioned in Table no 2. Distinctive Particle Size Distribution of cementitious materials mentioned in Chart 1.

C. METAKOLIN

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of Metakaolin is smaller than cement particles, but not as fine as silica fume. High Reactive Metakaolin (HRM) is a quality enhancing pozzolana. HRM is manufactured from natural kaolin, which is available in abundance in the country. [18, 24] It is produced by calcinations of natural kaolin at a temperature of 650ºC to 700ºC through either dry process or wet process. Physical Properties mentioned in Table no 1. Distinctive chemical composition mentioned in Table no 2. Distinctive Particle Size Distribution of cementitious materials mentioned in Chart 1.

D. UFGGBS

Fly Ground Granulated Blast furnace slag (GGBS) is a byproduct for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolonic material.[25, 27, 28]However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolonic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using UFGGBS as partial replacement of cement in concrete in India is scanty. [23, 29, 30, 31] Physical Properties mentioned in Table no 1. Distinctive chemical composition mentioned in Table no 2. Distinctive Particle Size Distribution of cementitious materials mentioned in Chart 1.

Physical analysis	**OPC**	**Flyash**	**SilicaFume**	**UFGGBS**	**Meta -kolin**
Surface area cm^2/gm.	4000	2600	16900	11500	10500
Physical analysis	OPC	Flyash	Silica Fume	UFGGBS	Meta -kolin
Surface area cm2/gm.	4000	2600	16900	11500	10500
Specific Gravity	3.15	2.2	2.23	2.45	2.6
% Passing 45 µm sieve	93	95	98	100	100

Table no -1: Distinctive Physical properties

Chemical Analysis	**OPC**	**Fly ash**	**Silica Fume**	**UFGGBS**	**Metakolin**
CaO %	61.43	1.64	0.65	32.3	0.68
Al_2O_3 %	5.35	25.43	0.15	19.2	29.79
Fe_2O_3 %	3.35	7.55	0.85	1.9	1.32
SO_3 %	2.59	0.33	0	0.6	-
MgO %	2.59	1.8	2.54	8.6	0.35
SiO_2 %	20.77	57.25	90.4	34.5	62.68

Table no -2: Distinctive chemical composition

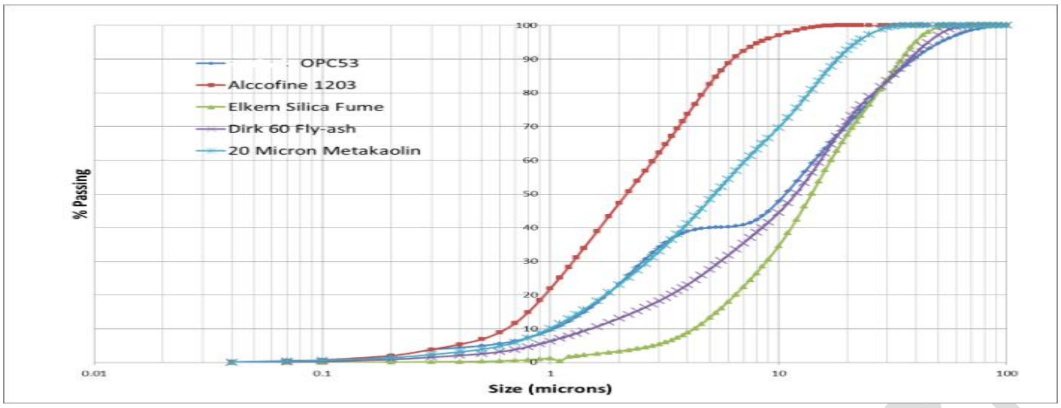

Chart -1: Distinctive Particle Size Distribution of cementitious materials

GRADE	M60	M70	M80
SLUMP		**600 mm after 30min**	
A/C	3.4	3	2.6
W/C	0.27	0.25	0.23
F.A %	43	38	35
CAI %	28	31	32
CAII %	29	31	33

Table no -4: Mix Proportion for difference Grade of Concrete

III. EXPERIMENTAL STUDY

To analysis carbon emulsion for production of concrete, concrete of M80, M90 and M100, is considered with the desired specification of constant slump flow 600mm after 30min. The mix proportion followed and the results obtained are presented in the Tables no 4 and chart 1, 2, 3, 4, 5 & 6 respectively.

A. MATERIALS USED

The Cement : Ordinary Portland cement 53 Grade

Coarse Aggregate: Granite conforming IS: 383-1970 (both 12&20 mm)

Manufactured Aggregate: Crushed sand of Zone II conforming IS: 383-1970

Water: Potable water conforming IS: 456-2000

Mineral Admixtures: Fly ash (FA): Dirk P60 Conforming IS: 3812 part 1

Micro fine Ground Granulated Blast furnace Slag:

Chemical Admixture: Super Plasticizer Glenium B233, BASF

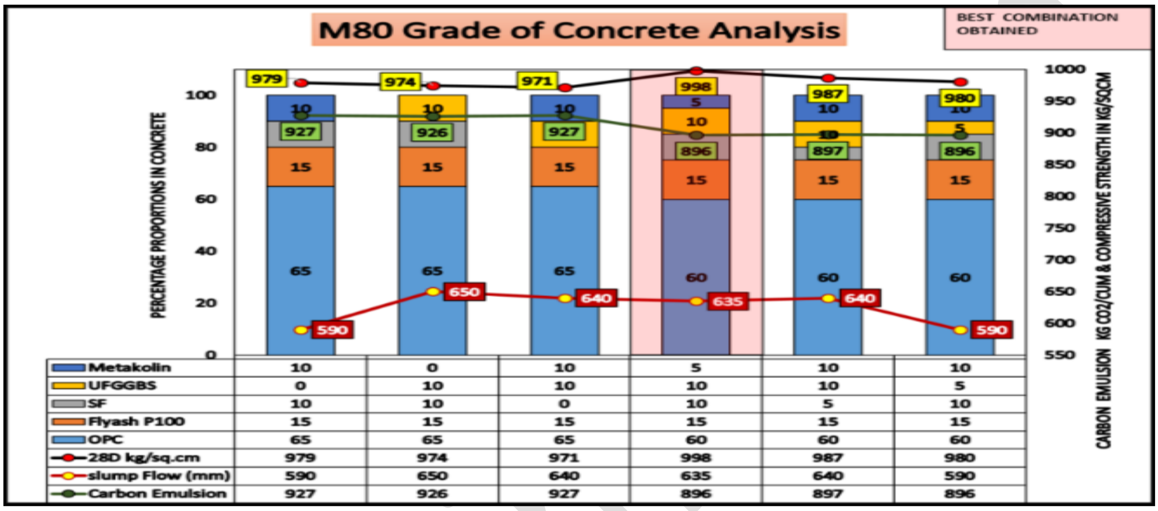

Chart -2: *Analysis results of M80 Grade of Concrete.*

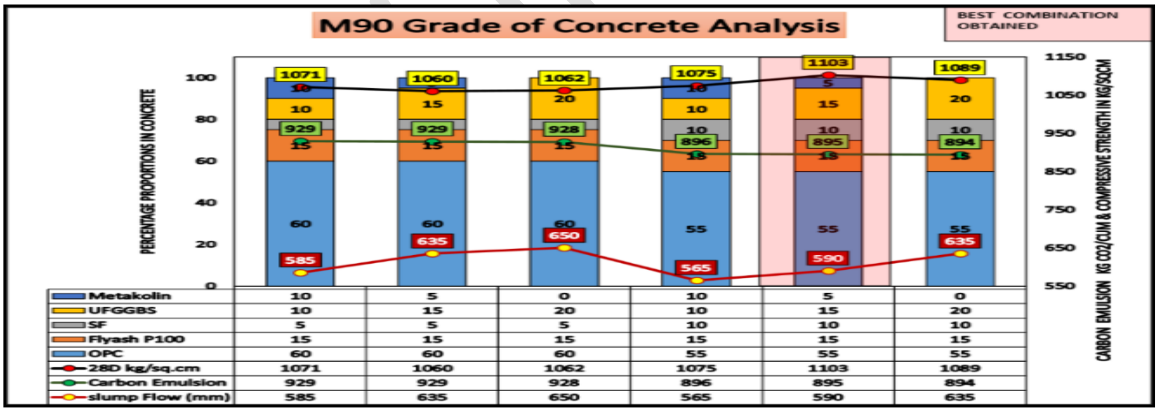

Chart -3: *Analysis results of M90 Grade of Concrete.*

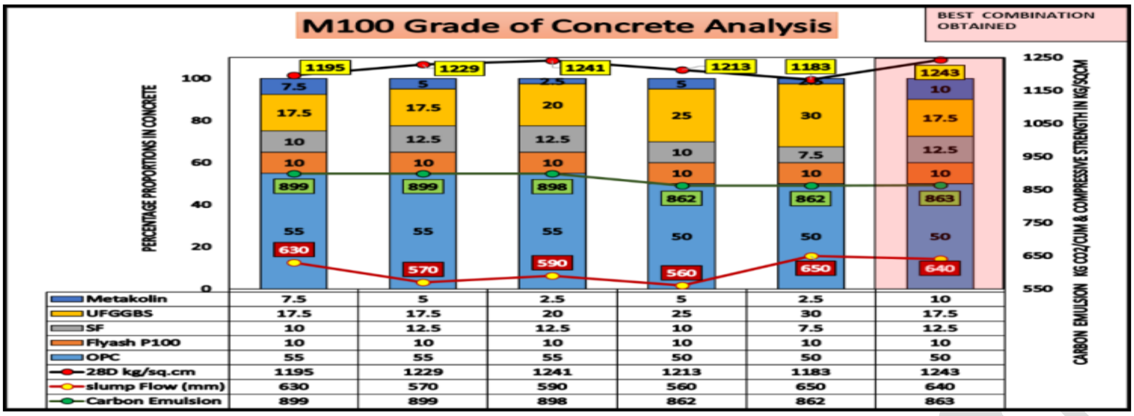

Chart -4: *Analysis results of M100 Grade of Concrete.*

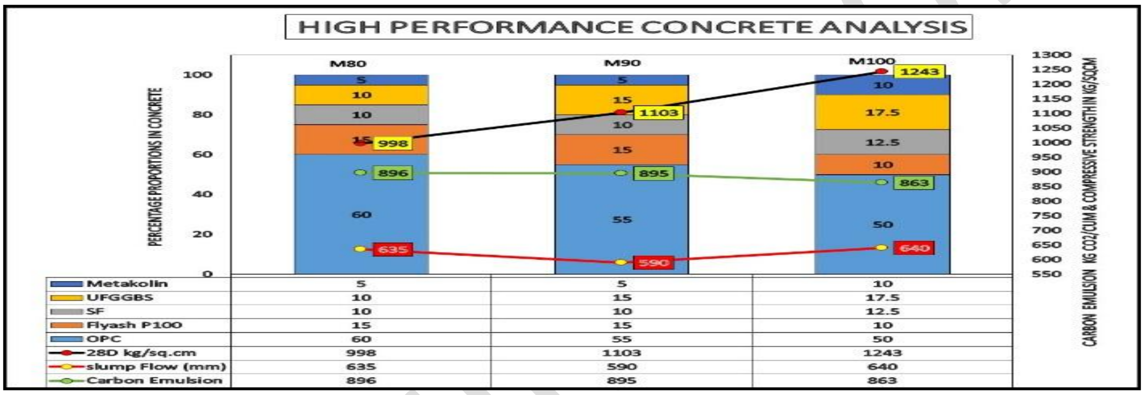

Chart -5: *Analysis results of different Grade of Concrete.*

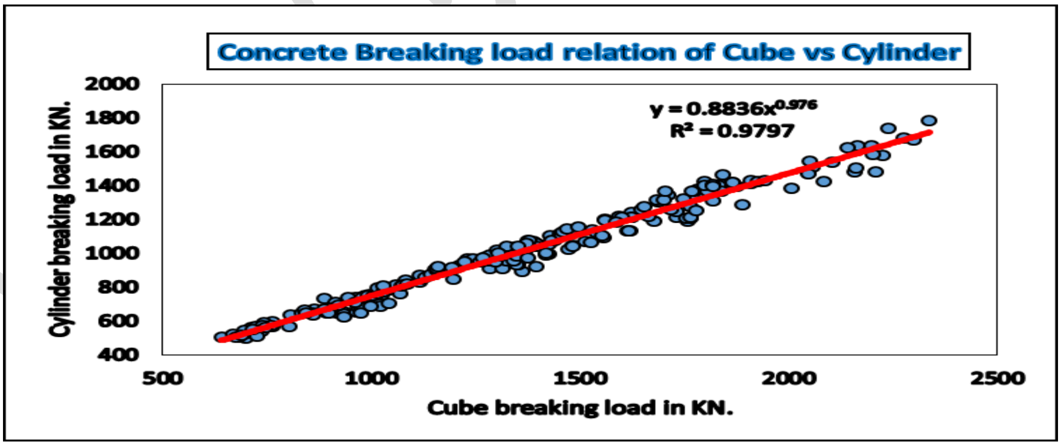

Chart -6: *Relation curve of cubical vs cylindrical concrete mould (28 days compressive strength).*

IV. CONCLUSION

The Experiments with these different grades of concrete i.e. M80, M90, M100, suggest that a subsidiary replacement of cement using different cementitious materials like Fly Ash, Ultrafine Silica Fume, Ground Granulated Blast Furnace Slag and Metakoline resulted in best concrete strength as well as an impactive reduction in carbon emulsion. It is been thus concluded that for various grades out of all combination either of one combination was found to be good in terms of strength with constant carbon emulsion of 875 + 25 kg CO_2/cum and constant slump flow 600mm after 30min. The following are as concluded:

For:

1. M80 – 4th combination: 5% Metakoline,10% UFGGBS, 10% Silica Fume & 15%FlyAsh.
2. M90 – 5th combination: 15% UFGGBS, 10% Silica Fume & 15% Fly Ash
3. M100 – 6th combination: 10% Metakoline, 17.5% UFGGBS, 12.5% Silica Fume & 10% Fly Ash.
4. Power curve shows best fitting curve for relation between cube vs cylindrical concrete mould (28days compressive strength) and have value of $R^2 = 0.9797$ with $y=0.8836x^{0.976}$

Thus in view of environmental impact and demand of high performance concrete above studies have experimented that high performance concrete can be achieved with constant carbon emulsion analysis.

V. FUTURE SCOPE OF WORK

Based on above study further analysis can be done on carbon emulsion with energy consumption and strength factor based on flexural, Split tensile strength.

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