SUSTAINABILITY OF CONCRETE USING FLYASH AND METAKAOLIN TO SAVE CO_2 EMISSION

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ABSTRACT. Concrete is apparently the most widely used construction material throughout the world. The present challenge before concrete industry is to produce high strength and high performance concrete by adding supplementary materials. The effect of increase in cement use ultimately results in increase in CO_2 level in atmosphere. To reduce down such adverse effects on atmosphere, supplementary materials can be used. One such commonly used supplementary material is fly ash. The current status of fly ash production in India is around 185 million tonne per year, out of this part replacement of cement in concrete utilization is 0.75 million tons. The use of fly ash enhances durability of concrete and life at effective cost and minimizes demand of landfill spaces for dumping problem of such waste materials. Another supplementary material which can be used as part replacement of cement in concrete for producing high performance concrete is metakaolin. In this paper the combined effect of fly ash and metakaolin on the concrete mixture was investigated for making concrete more sustainable

Keywords: Concrete, CO_2, Fly ash, Sustainability.

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INTRODUCTION

Concrete is apparently the most vastly used construction material in the globe. The supplement of material admixture with various amount of cement has desperately grown along with blooming of construction industry, because of considerably cost, sustainable environment and to protect green energy.In the past few decades all the climatic condition against to sustainability so here need of future generation to stop to drastic change as early as possible with using natural resources. From the news obtained by Times of India, gives hint that earth can sustain life for 1.8 billion years and after that impossible to live on blue planet. The facts given by same news agency in edition of Aug 30, 2016 on climatic change directly said that plant will become less thirsty as carbon dioxide in the atmosphere rises. According to data published by NASA, the 2015 is the warmest year on the record. Figure 1 shows last 100 years global land ocean temperature index and latest measurement in between 0.800 – 0.900.

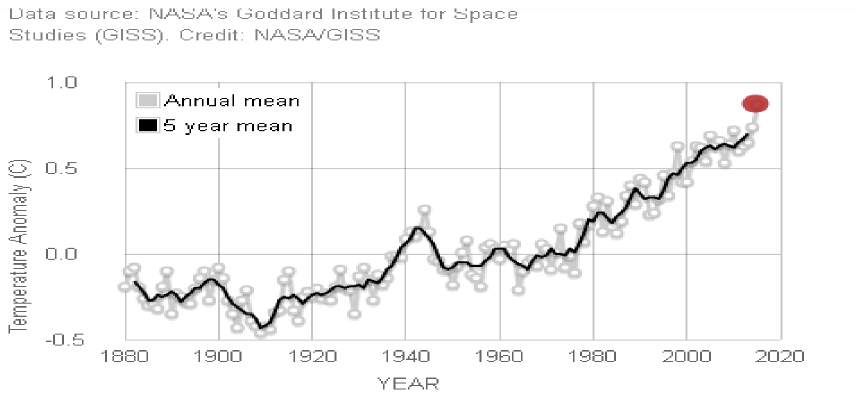

Figure 1 Global land- ocean temperature Index

Time series global surface temperature differences rectify in figure 2 and 3 for the year 1915, 2015 respectively.

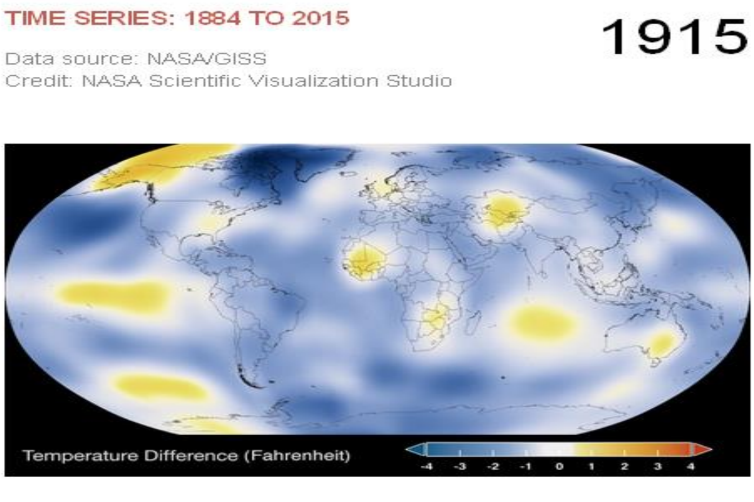

Figure 2 Global Surface temperatures in Year 1915

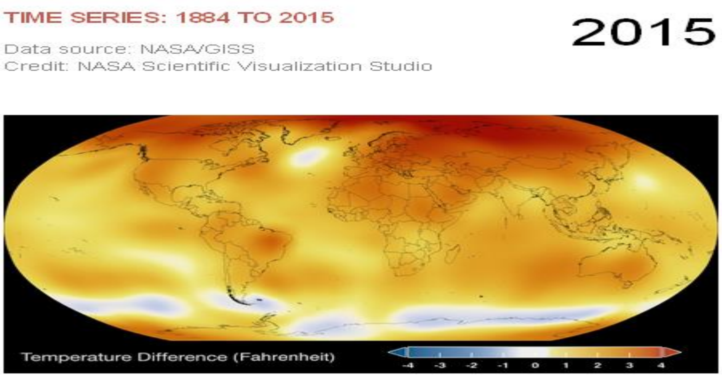

Figure 3 Global Surface temperatures in Year 2015

In this two figure easily notice area cooler than average i.e. dark blue indication in the year 1915 and In 2015, dark red indication shows area warmer than averages. Both source of images from Global climate change vital signs of the planet. There are both natural and manmade sources of CO_2 emission. Here focused on activity like cement production, burning of fossil fuel.

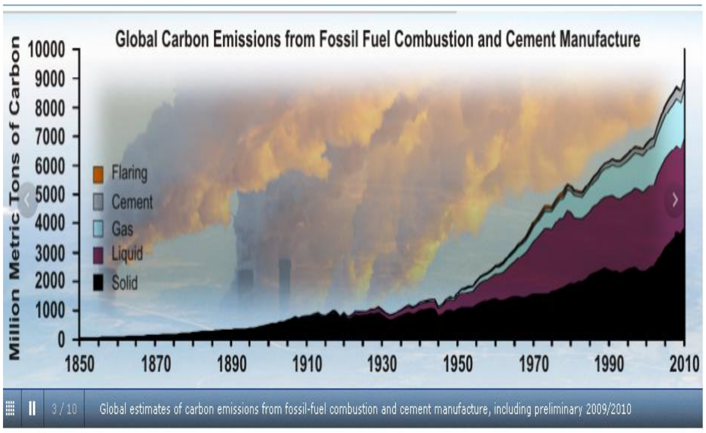

Figure 4 Global carbon emissions from fossil fuel combustion and cement manufacture

The Carbon dioxide information analysis center (CDIAC), observing ecosystem level and exchange of CO_2 and plot graphs which indicates the rising phenomena in the global carbon emission from fossil fuel combustion and cement manufacture as shown in figure no 4.

As current growth of production definitely conclude that supplementary materials will plays effective role after by year 2070 because limestone continuously used without appraisal of world recourses in cement manufacturing.In India at the current status, fly ash production has shown about 12% to 13 % of the whole world consumption. Now the present challenge for concrete industry is to produce high strength and durable supporting material. The use of fly ash enhances durability of concrete and life at effective cost. The impact of Concrete production should have minimum risk on the environment. The challenges may be overcome by following ways effectively.

(i) By minimizing the quantity of cement content in concrete mix, as one tone of cement saved will save an equal amount of CO_2 to be discharged in to atmosphere. India produces

280 million metric tonne of cement annually. Even ten percent saving will reduce 10 million tons CO_2 to be discharged to atmosphere, (ii) By reducing the use of natural fine and coarse aggregates which source of supply are limited and are producing very rapidly and (iii) By focusing ultimate possible alternative materials like fly ash in concrete as it will minimize demand of landfill spaces for dump problem of such waste materials.

Therefore challenging reasons, from few years ago, to grow the practice of partially replacing cement with waste by products which possessing pozzolanic properties. The calcined clay is one available source for a pozzolana. From the thousands of years pozzolans used in the form of calcined kaolinite clay with lime have been used to produce cementitious materials. The objective of this Study is to report supplementary material which can be used as part replacement ofcement in concrete.

CO_2 EMISSION FORM CEMENT CONCRETE

Every concrete part consumes cement and per mix of cement concrete depends on the manufacturer of cement industry. The concrete industry main source of carbon dioxide emission its value around 5% of worldwide man made emission. 900kg of CO2 release in air for fabrication of every ton of cement. It is estimated that 1% replacement of cement with fly ash represents reduction in energy consumption up to 0.7%. The main obstacles to more use of fly ash and slag may be risk of construction with new technology which has not long run field testing. Cement production also growing 2.5% annually, and may be reaches in between 4.0-4.4 billion tons by 2050. The world annual production of Cement has 4100Mt out of that 6.7% contributes by Indian cement industries. Therefore, the entire community associate with cement industry focused on alternative material to cement in partial way or by obtained sustainable concrete.

REFORMING WITH SUSTAINABILITY

By applying number of possible things, minimization of adverse effect of cement should be done. To create sustainable environment in concrete field some techniques may use as: (i) To find out materials like fly ash, slag, silica flume as supplementary material. : (ii) Utilization of recycled material, (iii) Focused on durable concrete, (iv)Lower the water to binder ratio, (v)Use of carbon negative cement material and (vi) Use of Renewable energy source in cement manufacturing process.

UTILITY OF FLY ASH AND SLAG

Fly ash is obtained from combustion of coal at thermal power plant which content high calcium oxide content and reactive silica. In practice prove that fly ash can substitute 15% to 35% cement. Fly ash increase workability and in design mix reduces water required. Slag improves resistivity to chemical attack and inhibits rebar corrosion. Slag cement can improve strength and environmentally friendly.

REVIEW OF LITERATURE

Metakaoline gives cementitious structural property which enhances mechanical properties in concrete H. Toutanjii et al. [1] observed that the greater the amount of fly ash, the lower the resistance to freeze and the difference in durability performance between the mix containing 20% fly ash and 30% fly ash is small but it's significant. Naik and Ramme [2] examined the fly ash can be used upto 40 % for high strength. Sawant and Ghugal [3] also suggested that metakaoline includes calcium carbonate contents which help to create reaction with alumina and has been used as binding material. Patil et al.[4] reported that addition of 15% amount of metakaolin has considerably reduce workability but when it is used in below 15% of replacement shows 20% higher strength than regular concrete.

Varma and Ramrao [5] investigated the improvement in concrete with potential of meatakaolin for higher grade M70 and detect split tensile strength enhancement maximum at 15% replacement of cement with metakaolin. Manikandan et al. [6] showed that the range between10% to 15% has been found as a more effective amount of replacement for compressive strength. Aieswarya S et al. [7] determined the setting time which reduces while metakaolin used as superplastisizer and for control mix it has gives effective result in strength with durability concern.

Marinos et al.[8] experimentally found out chloride permeability for period of hydration 28, 90, 180 days results gives idea for reduces chloride permeability by 10% substitution of metakaolin but increases compressive strength. Ahmad et al. suggested fully exploit fly ash suitable for higher compressive strength. Blended cement with metakaolin helps where durable concrete needed in influence of salt attack have been studied by Abbas et al. [9]. Patil et al. [10] has indicated that workability and strength of concrete can be improved by addition of metakaolin as a partial replacement. Nova John [11] has been reported variation observed in values of split tensile strength for all mixes and clearly mentions that after more than 20% content of metakaolin decreases split tensile strength also obtained maximum flexural strength for 15% replacement. Explosure of addition of HRM has more effective than replacement of HRM in concrete as per compressive strength assessment and improve resistance against sulfate attack demonstrated by Maroliya [12]. Mahajan L S [13] stated with innovations in construction field, there are barrier to adoption. Papadakis [14] investigated effect of low calcium fly ash on number of parameters likes' strength, porosity, heat evolution, Calcium hydroxide content. Fly ash replacement done upto 30% and specimen mix was prepared with 0.5 water cement ratio however, the present study discussed briefly given of ways to improve sustainability.

MATERIALS AND METHOD

For the all the mixtures cement used was normal 53 grades OPC confirming to BIS 12269:1987 [15]. This cement is the mostly used in the construction industry across India. Maximum size of Coarse aggregates is 20 mm used for this study which taken from Jalgaon district, Maharashtra. For fine aggregate natural sand of river bed is used which confirming to grading Zone –II of table 4 of IS 383 were procured from Maharashtra. Fly Ash is obtained from Thermal power plant, Eklahre, Nasik in Maharashtra. Drinking water is used for casting and currying of the concrete blocks. The calcined clay in the form of Metakaolin (MK) as a pozzolanic used as a supplementary to cement replacement to prepare concrete.

The mix proportion was chosen for this study. Concrete mixture for control mix and with different proportions of metakaoline as 5%,10%, 15% replacement for cement were considered and fly ash with different proportions as 10% , 20% , 30% replacement for cement were considered. While casting the specimen for water cement ratio 0.5 it was found that 100mm slump for this proportion, fig 5 shows slump. When w/c ratio is taken as 0.5 the slump is 100 mm.

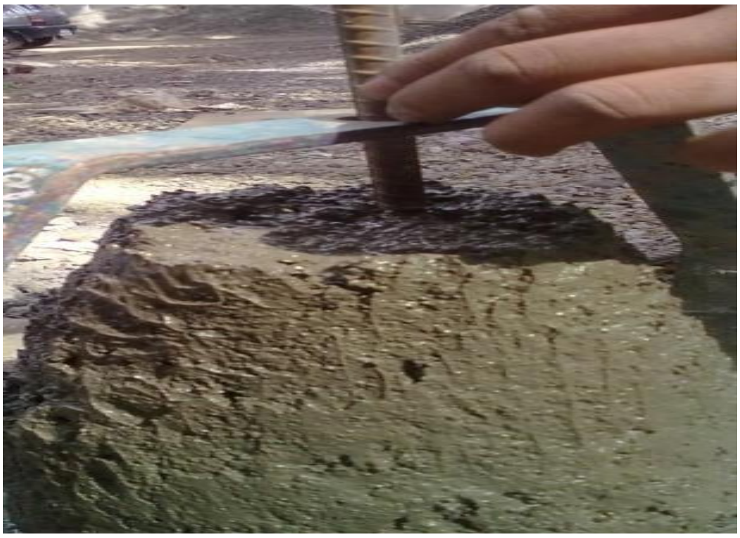

Figure 5   Slump test

One sets of cube, cylinder and beam was prepared and trial mix design are selected with water cement ratio 0.5 and for that w/c ratio specimen are casted and tested for 7 days and 28 days. The mix design is selected for w/c ratio 0.5 for controlled concrete and 3 cubes, 3 cylinders and 3 beams specimen are casted as shown in fig 6 and tested for 7days and 28 days.

Figure 6 Specimen casting, identification and testing

The fineness modulus of coarse aggregate and fine aggregate are determined. The tests like specific gravity, water absorption of coarse aggregates, natural sand, Metakaolin and fly ash performed in laboratory. The mix design proportion evaluated for control mix as shown in table 1.

Table 1   Mix design proportions (control mix)

WATER (lit.)	CEMENT	FINE AGGREGATES (Kg)	COARSE AGGREGATES (Kg)
197.16	394.32	591.89	1229.82
0.5	1	1.5	3.11

For mixing the concrete a half bag mixture is used. First coarse aggregates of 20 mm placed in the mixture then sand is placed then cement and then they are mixed together in dry state then water is added and mixed until the homogeneous mixture were obtained. Each batch is mixed around 3 to 5 minutes and then the mixture is placed in a metallic try and immediately the slump is checked before the concrete is placed in different mould. Cube of size 150 × 150 × 150 mm were used. The cube were cleaned thoroughly a waste cloth and then properly oiled is applied along its faces. Concrete was then filled in mould in three layers, while filling the mould concrete is compacted using tamping road of 600 mm having a cross sectional area of 25 mm2.

Cylindrical mould of size in diameter 150 mm and height 300 mm were used. The oil was enforced along the inner surface of the mould for easy removal of cylinder from the mould. Well mixture of Concrete was poured throughout its length and compacted well by using tamping road as well as vibrating table.

Beam mould of size 100 mm × 100 mm × 500 mm was used. The oil was applied along throughout the inner surface of the mould so it helps to removal of beam from mould. Concrete was poured throughout its length and compacted well by using tamping road as well as vibrating table. After casting of all cubes, cylindrical and beam specimen are kept for curing in curing tank as shown in fig 7. The drinking water is used for throughout curing process. While curing this specimen’s water from the curing tank is changed at the end of every week.

Figure 7   Curing tank with specimen

RESULTS

For controlled concrete the compressive strength was found to be 17 N/mm^2 for 7 days and 25 N/mm^2 for 28 days and % wise replacement the compressive strength were shown in the table 2. Concrete cubes of size 150 mm × 150 mm × 150 mm were cast with and without Fly ash And Metakaoline. All the results were shows slightly improvement in mechanical property. The maximum load at failure reading was taken and the average compressive strength is calculated.

Table 2 Strength assessment of mix combinations for compressive, split and flexural strength

MIX	SPECIMEN NO	MK0 +FA0 +C100	MK05 +FA10 +C85	MK10 +FA20 +C70	MK15 +FA30 +C55
Compressive Strength N/mm^2 (7 Days)	1	17.441	18.740	16.560	13.950
	2	15.700	18.741	18.312	15.263
	3	16.130	15.901	18.310	14.825
	Average	14.423	17.794	17.723	14.679
Compressive Strength N/mm^2 (28 Days)	1	25.557	22.740	26.841	20.280
	2	24.232	24.230	27.800	20.220
	3	24.010	22.188	27.092	22.531
	Average	24.599	23.052	27.244	21.010
Split Strength N/mm^2 (7 Days)	1	2.42	2.63	2.51	2.21
	2	3.12	2.77	2.50	2.36
	3	2.36	2.78	2.36	2.19
	Average	2.63	2.73	2.45	2.25
Split Strength N/mm^2 (28 Days)	1	3.10	2.67	2.86	2.41
	2	3.22	2.97	2.87	2.78
	3	2.78	2.99	2.99	2.25
	Average	3.03	2.88	2.91	2.48
Flexural Strength N/mm^2 (7 Days)	1	1.96	1.89	1.57	1.70
	2	1.72	2.17	1.96	1.79
	3	1.77	2.20	1.57	1.81
	Average	1.81	2.08	1.70	1.76
Flexural Strength N/mm^2 (28 Days)	1	2.98	2.34	1.98	1.93
	2	1.98	2.65	2.36	2.02
	3	1.72	2.64	1.97	2.04
	Average	2.22	2.54	2.10	1.99

The combination of MK10+FA20+C70 gives noticeable results of compressive strength. The addition of fly ash resulted a modest increase in strength. The over addition of fly ash exhibited a suddenly reduction in compressive strength , so less than 30% Fly ash shows better result. For split tensile test specimens of size 150 mm in diameter and length of 300 mm was casted and tested under the manual CTM of capacity 300 ton. The specimen is kept under CTM at the center with play wood at top and bottom and load is applied with plus rate 1.3 KN/seconds. Ultimate loading is noted and shown in the table 2. The spilt tensile strength is calculated according to IS - 5816-1970 and IS 516 – 1959 code. Variation easily noticed in split test between 10 to 20%. The beam specimen of size 100 mm × 100 mm × 500 mm is tested for single point load at the midpoint under the UTM of capacity 100 ton. The flexural strength is calculated as per IS 456 – 2000 and IS 516 – 1959.

CONCLUDING REMARKS

In this experimental study easily evaluated the feasibility of utilizing of fly ash and metakaoline for cement replacement in concrete with minimum 28 days compressive strength 20 N/mm2 for slump as 100 mm ± 10 mm. From experimental works it is seen that combination of for 20% fly and 10% metakaoline is most effective for improving compressive strength. The split tensile strength also gives better effect for the combination of same replacement.

The flexural strength for (5% metakaoline and 10% fly ash) was increased up to 13% for 28 days. Conclusions have been drawn that MK10+FA20+C70 (10% metakaoline and 20% fly ash) is the possible best combination instead of cement in concrete. The combination of fly ash and metakaoline with cement utilization shows a greater improvement of mechanical properties of concrete as in compressive strength increases 15-16% and simultaneously we saves 30% cement utilization which traditional mix practices.

It is conclude that in construction industries fly ash and metakaoline used to minimize of CO_2 emission footprint. 1 ton usage of fly ash earns one carbon credit which helps reclamation financial benefit. As with innovations in construction field, there are barrier to adoption, however, the present study discussed briefly given of ways to improve sustainability.

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