International Journal For Technological Research In Engineering
Volume 4, Issue 4, December-2016 ISSN (Online): 2347 - 4718

BEHAVIOUR OF FLYASH BLENDED CONCRETE SUBJECTED TO DIFFERENT THERMAL CYCLES

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ABSTRACT: All over the world, the construction activities are taking place on a large scale. Due to this there is a great increase in cost of construction. However, the production of cement increases the emission of CO2 which causes the greenhouse effect and global warming. To reduce the emission of CO2 and consumption of cement the use of some conventional materials has been adopted. These materials may be naturally occurring, industrial wastes or by-products that require relatively less energy to manufacturers. Some of the conventional waste materials like Fly Ash (FA), Rice Husk Ash (RHA), Silica fume, Metakaoline, Ground Granulated Blast Furnace Slag etc. can be used as supplementary materials. The present work focuses on M20 to M50 grades of concrete with partial replacement of cement using Fly ash (FA = 25%). The cubes are casted and tested for compressive strength at the age of 28 days and 56 days. For the same specimens after curing period both ordinary and fly ash concretes cubes were subjected to thermal cycles of 28 and 56 at a temperature of 1000C in an electric oven then they were also tested for compression. From the above studies it is observed that the compressive strength of concrete with partial replacement of cement with fly ash is shows the more strength than the ordinary concrete. The compressive strength of fly ash concrete for thermal cycles of 28 and 56 shows the more strength than the ordinary concrete after exposing to 1000C for 8hrs duration.Thus, the resistance to adverse effect of thermal cycles is more for fly ash concrete when compared to ordinary concrete.

I. INTRODUCTION

1.0 GENERAL:

Now a days the use of concrete in infra- structural activity is on the rise and with cement being the most important but costly component of concrete, effort to lessen the cost by partial replacement of cement with accompanying cementitious materials has gained momentum and is even made as a government regulation. However, the production of concrete is not environmentally friendly. In this scenario, the use of conventional waste materials, such fly ash, Rice husk ash, Ground granulated blast furnace slag, silica fume, sugarcane bagasse ash etc. as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for the sustainable development of the concrete industry. Currently, industrial waste such as Fly Ash (FA) is being used as supplementary cement replacement material. Therefore, a great potential exists to reduce the concrete industry`s contributions to greenhouse gases through reduction in cement consumption.

The various elements of the structure like columns, outer walls and roof of slab were subjected to solar heat throughout the life. The rise in temperature is from sunrise to a maximum of four times the ambient temperature. In many parts of the world and in India, the peak temperature during summer goes beyond 400C and in such conditions the structures will be subjected to 800C and 900C. The humidity also influences the temperature within the exposed elements due to solar heat. Hence all the elements of the structure which are exposed to solar radiation are said to be experience one thermal cycle in a day. Concrete is the extensive material used for making all the structural elements necessitates the study of behaviour of concrete subjected to temperature variations. The present experimental work was carried out on the concrete by partial replacement of cement with fly ash by 25% for all the grades of concrete subjected to thermal cycles of 28 and 56 per 8 hrs duration in a day at a temperature of 1000C in an electric oven. The mix design of M20 to M50 grades of concrete were designed as per the method specified in IS 10262-2009.

II. LITERATURE REVIEW

V.Bindiganavile, K.N.Vishwanath and N.Suresh in 2014 [1]: Conducted an experimental study on the M30 grade of concrete with replacement of fly ash up to 30 percent and cubes of size 100x100x100 mm were subjected to temperature variations up to 3000C for a period of 3 hours after 28 days curing period and the specimens were allowed to cool to room temperature then tested for compression. The results are indicated that M30 grade of concrete at 3000C temperature and at 30% replacement of fly ash gave better resistance to heat exposure. And remaining replacement of fly ash grades was given less resistance to heat exposure. So the compressive strength of concrete cubes is highest at 3000C for M30 grade concrete was observed at 30 % fly ash replacement to ordinary concrete.

Bairagi N.K. and Dubal N.(1996) [2]: Presented the concept of thermal cycles to find out the variation of strengths in the concrete so they casted the cubes and kept in an electric oven for thermal cycles of 30 and 365 at 600C and 900C.the compressive strength was found to decreased by 15.9% after 30 thermal cycles at 600C and 21.2% after 30 thermal cycles at 900C.in the same way the compressive strength was found to decreased by 20% after 365 thermal cycles at 600C and 35% after 365 thermal cycles at 900C.

Metin Husem (2006) [3]: investigated that the variation compressive and flexural strengths of ordinary concrete and high performance concrete was determined. In the case of ordinary concrete the specimens were casted for M30 grade and in the case of high performance concrete M70 grade with alternative of cement with silica fume by 10%. In both of the grades of the prisms of size 40mmx40mmx160mm were maintained. The casted the specimens were exposing them at a temperature of 2000C, 6000C, 8000C, 10000C for 1 hour duration. And finally the results indicate that the strength of high performance of concrete will give the better strength as compared to the ordinary concrete and the type of cooling will also be affects the compressive strength and flexural strengths.

Nimlyat.S and Datok.E. (2013) [4]: investigated the compressive strength and flexural strength of M40 grade concrete when the ordinary Portland cement was replaced by saw dust ash by 10% and subjected to elevated temperatures of 2000C, 4000C, 6000C and 8000C after completion of the heated specimens were cooled to room temperature and then tested for compression. The loss of compressive strength for 10% saw dust replaced was found to decrease by 23.04% for different temperatures, but in the case of ordinary Portland cement was decreased by 29.11% for different temperatures. At 8000C temperature the cubes were completely failed by flexure.

Neelam Pathak and Rafat Siddique (2012) [5]: Presented the properties of self compacting concrete such as compressive strength, splitting tensile strength. When open to the elements to prominent temperatures. And similarly the same self compacted concrete was replaced by class F fly ash varied from 30% to 50%. In this they compared the control mix concrete to the fly ash blended concrete after completion of the thermal effects. After completion of the curing period of 28 days, the specimens like cubes and cylinders were subjected to heat exposure at different temperatures of 200C, 1000C, 2000C and 3000C. From the test results they were found that the compressive strength was slightly increased at a within the temperature range of 2000C to 3000C when compared to 200C to 2000C but there is little reduction in tensile strength of concrete was found at 200 to 3000C.

Potha Raju.M, Srinivasa Rao.K, P.S.N. Raju [6]: investigated that the behaviour of compressive strength of high strength concrete of grade M60 made with Portland pozzolona cement concrete cube specimens were open to the elements to various temperatures of 500C to 9500C at intervals of 500C for different periods of 1,2 and 3 hours. After exposing the specimens to eminent temperatures, and they were tested for their compressive strength in heat condition. From the results they are observed that increase in compressive strength gradually takes place between the temperature ranges of 1000C to 2500C.lncrease in compressive strength is nominal within the temperature range of 250°C to 350°C.The concrete retains its original strength up to a temperature of 400°C for all durations of exposure. The rate of decline in compressive strength is gradual in the range of 400°C to 700°C and then faster in the 800°C to 950°C.

Rambabu.K, Srinivasa Rao.V and Srinivasa Rao.K (2014) [7]:Conducted tests on M30 and M60 grade slag cement concrete cubes for compressive strength subjected to temperature varied from 1000C to 5000C. in this the specimens were casted for the different curing periods like 7,28,56 and 91days. After completion of curing period the M30 and M60 grades slag cement concrete cubes were subjected to heating of period 1hour for different temperatures varied from 1000C to 5000C.finally they were observed that the compressive strength of concrete cubes were increased up to 3000C for both M30 and M60 grade slag cement. But, after 3000C to 5000C temperature the compressive strength of concrete cubes were found to reduced and compared to M60 grade slag cement concrete gave better strength than the M30 grade concrete.

Srinivasa Rao, Potha Raju, and Raju (2007) [8]: Conducted tests on compressive strength for M60 grade high strength concrete made by both ordinary Portland cement and Portland pozzolona cement. After cubes were removed from curing tank they were subjected to different temperatures like from 500C to 2500C, there is at an interval of 500C temperature for all the specimens, and the concrete specimens were exposed to heating periods of 1 hour, 2 hours and 3hours. The heating period rate of specimens was followed from the code of ISO-834. Finally they concluded that concrete made by the Portland pozzolona cement was gave more strength than the concrete made from the ordinary Portland cement.

Sireesha.G, Kanta Rao.M and Kanta Rao.P (2013) [9]: studied those strength properties of concrete when cement is partially replaced with sugar cane bagasse ash. In this study they prepared M25 grade of concrete with replacement of cement by sugarcane bagasse (0-40%) for cubes, cylinders and prisms are casted for curing period of 28 days and then they are tested for compression, split tension and flexure. And similarly with the same grade of concrete with replacement of sugar cane bagasse (0-40%)specimens of cubes, cylinders and prisms were casted and afterwards specimens were exposing up to 8500C in muffle furnace for about 8 hours duration up to 28 days. The results indicate that the heated specimens were gave more strength than as compared to the without heating specimens.

Srinivasa Rao.P, Sravana.P, and M.V. Seshagiri Rao (2006) [10]: Conducted tests on concrete for compression, tension and dynamic modulus. In this they are used M20 and M30 grades of concrete replaced with 25% fly ash replacement, after completion of the curing period of 28 days the specimens were from oven and kept in electric oven for thermal cycles of 7, 14, 21 and 28 at 500C and 1000C temperature. The compressive strength of fly ash blended concrete was found to increase by 11 and 12% after 28 thermal cycles at 500C and 1000C in similar way spit tensile strength, dynamic modulus of elasticity of fly ash blended concrete was found to increase by 5 to 10% after 28 thermal cycles at 500C and 1000C

Srinivasa Rao .P and Mouli Chandra (2011) [11]: Conducted tests on M40 and M50 grades of both ordinary concrete and glass fibre concrete for compression. In this they used the concept of thermal cycles. The concrete specimens of size 100mmx100mmx100mm cubes were kept for thermal cycles of 28, 56, 90 and 180 at 1000C temperature in an electric oven. From the test results we observed that compressive strength of glass fibre concrete was found to decrease by 17 to 28% in glass fibre concrete mixes when compared to the zero thermal cycles of ordinary concrete.

Sravana.P, Srinivasa Rao.P (2006) [12]: Conducted tests on concrete cubes for compression M20 toM50 grades of concrete. Here they replaced cement with high volume fly ash in all grades of concrete. After the curing period of specimens were exposed to thermal cycles of 7, 28, 45 and 90 at temperatures of 500C and 1000C. From the test results they observed the compressive strength of ordinary concrete was found to decrease by 4 to 19 % for thermal cycles of 7,28,45,90 at 500C & 7 to 24% for thermal cycles of 7,28,45,90 at 1000C. The compressive strength of high volume fly ash blended concrete (both addition of fly ash+ replacement) was found to increase by 3 to 5 % for thermal cycles of 7,28,45,90 at 500C & 1000C temperature.

III. SCOPE OF INVESTIGATION

3.1 GENERAL

The scope of present research is to study and evaluate “the effect of thermal cycles on compressive strength of M20 to M50 grades of ordinary concrete and fly ash concretes”. Cubes of standard size 100mmx100mmx100mm (length x width x depth) were cast tested for 28 days and 56 days compressive strength. After completion of the normal curing period of 28 days and 56 days the specimens were tested for compression and then the specimens were kept in the electric oven for thermal cycles of 28 days and 56 days at a temperature of 100^0C for about 8 hours daily and also specimens were tested for compression. In this chapter the methods that are adopted and tests that are conducted are explained briefly. The method adopted to obtain the design mixes for M20 to M50 grades of concrete are done according to IS: 10262-2009. For fresh concrete the slump cone test, compaction factor test and vee-bee time has been conducted and for hardened concrete the tests like compressive strength for cubes of size 100mm x 100mm x 100mm has been conducted.

3.2 OBJECTIVES

The work reported in this study, Fly ash obtained from the Fly ash used was brought from NTPC, Visakhapatnam is used as a cement replacement material in concrete mix. The final focus of this work is to ascertain the performance of concrete mix containing fly ash and compare with plain concrete mix. This is expected to provide:-

To partially replace cement content with fly ash in concrete as it directly influences economy in construction.

To evaluate the workability characteristics in terms of slump, compaction factor and vee-bee time on addition of fly ash only (25%).

To design and proportion the concrete mix for M20 to M50 grades concrete, as per the recommendation of IS: 10262:2009

To find the Volume proportions of the concrete mixes by partially replacing Cement by fly ash.

To evaluate the M20 to M50 grades of ordinary concrete and fly ash concretes for the compressive strengths at 28 days and 56 days of normal curing by replacing cement with fly ash in proportion of 0% and 25%.

To evaluate the M20 to M50 grades of ordinary concrete and fly ash concretes for the compressive strengths at 28 days and 56 days thermal cycles at a temperature of 100^0C by replacing cement with fly ash in proportion of 0% and 25%.

3.3 TEST PROGRAMME

To evaluate the strength characteristics in terms of compressive strength a total of 4 mixes were tried with different percentages of fly ash (0% & 25%).In all mixes the same type of aggregate i.e. crushed granite aggregate, fine aggregate, fly ash are used. The relative proportions of cement, coarse aggregate, sand and water are obtained by IS - Code method. M20 to M50 are considered as the reference mixes. (Appendix-I)

The parameters are

- For M20 design mix, the percentage of cement replaced with fly ash is in proportion of 0% and 25%.
- For M30 design mix, the percentage of cement replaced with fly ash is in proportion of 0% and 25%.
- For M40 design mix, the percentage of cement replaced with fly ash is in proportion of 0% and 25%.
- For M50 design mix, the percentage of cement replaced with fly ash is in proportion of 0% and 25%.

A total no. of 96 cubes of size 100mm x 100mm x 100 mm were casted and tested for each percentage of partial replacement of cement. A sample calculation for determination of weight and volumes is presented in Appendix- II. The test programmed consisted of conducting compressive strength test on cubes at 28 days and 56 days of normal curing and 28 days and 56 days thermal cycles at a temperature of 100^0 C.

IV. IV.THEORY

In the present experimental work fly ash has been used as partial replacement of cement as an additional ingredient in concrete mixes. The details of the materials used are given below.

MATERIALS:

CEMENT: The cement used was Ordinary Portland Cement (KCP 53 grade). Thecement procured was tested for physical requirements in accordance with IS: 12269-1987. The details are given in Table3.1

TABLE 4.1 Physical properties of Cement

Properties	Results	Permissible limit as per IS: 12269-19
Fineness	3.0%	Should not be more than 10%
Normal consistency	32%	-
Specific gravity	3.13	-

Setting Time Initial Final	 46 min 242 min	 Should not be less than 30min Should not be more than 600min
Compressive strength of mortar cubes for 3 days 7 days 28 days	 $29.4N/mm^2$ $40.0 N/mm^2$ $56.4 N/mm^2$	 Should not be less than 27 N/mm^2 Should not be less than 37 N/mm^2 Should not be less than 53 N/mm^2
test for expansion		

4.2. FLY ASH:

"Fly ash used was brought from NTPC, Visakhapatnam. Fly ash is one of the residues generated in the combustion of coal. Fly ash, a by-product of the thermal power generation industries, is widely used as a cementitious and pozzolanic ingredient in OPC concrete. Fly ash chemically reacts with the by-product calcium hydroxide released by thechemical reaction between cement and water to form additional cementitious products that improve many desirable properties of concrete. All fly ashes exhibit cementitious properties to varying degrees depending on the chemical and physical properties of both the fly ash and cement. Compared to cement and water, the chemical reaction between fly ash and calcium hydroxide typically is slower resulting in delayed hardening of the concrete. Delayed concrete hardening coupled with the variability of fly ash properties can create significant challenges for the concrete producer and finisher when placing steel-troweled floors."

TABLE 4.2 Physical properties of Fly ash (as per supplier)

Sl. NO.	Properties	Test results
1	Particle shape	Small & spherical
2	Appearance	Dark grey
3	Specific gravity	2.28
4	Bulk density	0.99 g/cc
5	Particle size	6.90 microns
6	Moisture content	3.14
7	Fineness	$320 m^2/kg$
8	Lime reactivity	$4.0 N/mm^2$
9	Compressive strength @28 days	80 % of strength of corresponding plain cement mortar Cubes
10	Soundness by autoclave	0.8%

TABLE.4.3 : Chemical properties of Fly ash (as per supplier)

Sl. NO.	Chemical composition	Chemical composition by % Wt
1	Sulphur dioxide	60
2	Aluminium trioxide	17
3	Iron trioxide	6.5
4	Calcium oxide	5.50
5	Magnesium oxide	2.3
6	Sulphur trioxide	1.00
7	Loss of ignition	4.2
8	Alkalies	0.80

4.3. AGGREGATES:

Aggregates can be classified on the basis of the size as coarse aggregate and fine aggregate.

4.4.1. COARSE AGGREGATE:

Coarse aggregates are used for making concrete. The aggregate fractions from 80mm to 4.75mm are termed as coarse aggregate. Machine crushed angular granite metal of 20mm passed and 10mm retained has been used. It is free from impurities such as dust, clay particles and organic matter. The coarse aggregate is tested for various properties according to IS 2386-1963.The physical properties and sieve analysis are given in table 4.4 and table 4.5.

TABLE: 4.4: Physical properties of Coarse Aggregate

S.NO	Properties	Test results
1	Specific Gravity	2.81
2	Water Absorption	0.96 %
3	Flakiness Index	14.15 %
4	Elongation Index	21.30 %
5	Crushing value	21.4 %
6	Impact Value	15.8 %
7	Fineness Modulus	7.25

V. EXPERIMENTAL PROGRAMME

In this chapter the methods that are adopted and tests that are conducted are explained briefly. The method adopted to obtain the design mixes for M20 to M50 grades of concrete are done according to IS: 10262-2009. Similarly for all the grades of concrete we replaced the cement with by fly ash is 25%. For fresh concrete the slump cone test, compacting factor and vee-bee time tests have been conducted and for hardened concrete the tests like compressive strength for cubes of size 100mm x 100mm x 100mm has been conducted.

5.1. PREPARATION OF TESTING SPECIMEN:

5.1.1. MIXING:

The required proportions of materials of concrete are taken in dry condition, mixed thoroughly before they were put in the concrete mixer. The wet concrete from the concrete mixer were tested for its workability.

5.1.2. CASTING OF THE SPECIMENS:

The concrete trial specimens of size 100 mmx 100 mmx 100mm cubes were casted and compacted using table vibrator and made the level surface smooth using trowel as per IS 516-1959.

5.1.3. COMPACTION OF CONCRETE:

“Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of placing and mixing of concrete, air is likely to get entrapped in the concrete. If air is not removed fully, the concrete loses strength considerably”.

In order to achieve full compaction and maximum density Table vibrator is used in this experiment.

5.1.4. CURING OF TEST SPECIMENS:

After casting, the moulded specimens are stored in laboratory in room temperature for 24 hours. After these periods the specimens were removed from the moulds and immediately submerged in clean, fresh water curing tank for required period as per IS 516-1959. The specimens are cured for 28 days and 56 days in present experimental work.

VI. SUMMARY AND CONCLUSIONS

6.1 SUMMARY

Results were analysed to derive useful conclusions regarding the workability, strength characteristics of concrete with 25% replacement of cement by Fly ash 25% for M20 toM50 grades of Concrete.

6.2 CONCLUSIONS

1.The concrete trial specimens, irrespective of the grade of without fly ash content a decreasing trend ranging from 10 % to 18 % of compressive strength was observed for 28 thermal cycles.

2. The concrete trial specimens, irrespective of the grade of with fly ash content an increasing trend ranging from 8.63 % to 15 % of compressive strength was observed for 28 thermal cycles.

3.The concrete trial specimens, irrespective of the grade of without fly ash content a decreasing trend ranging from 14 % to 20 % of compressive strength was observed for 56 thermal cycles.

4. The concrete trial specimens, irrespective of the grade of with fly ash content an increasing trend ranging from 5.64 % to 8.5 % of compressive strength was observed for 56 thermal cycles.

5. From the test results an increasing of compressive strength was observed from 28 days to 56 days in case of fly ash blended cement concrete.

6. Based on the experimental investigations fly ash blended cement concretes resists better than ordinary concrete in case of high temperatures.

REFERENCES

[1]. Bindiganavile.V, Vishwanath K.N., and Suresh N , *“Influence of Sustained elevated temperature on flyash concrete”*, The Indian Concrete Journal, January 2014 ,Vol.88, No.1,pp.27-32.

[2]. Bairagi N.K. and Dubal N. *“Effect of thermal cycles on the compressive strength, Modulus of rupture andDynamic Modulus of concrete”*. The Indian concrete Journal, August 1996, Vol.70, No.8, pp.423-426.

[3]. IS: 383-1970. Specification for Coarse and Fine Aggregates from natural sources for concrete. Bureau of Indian standards, New Delhi.

[4]. IS 456 -2000 “Code of Practice for Plain and Reinforced Concrete”, Bureau of Indian Standards, NewDelhi.

[5]. IS: 516-1959. Indian Standard Methods of Test for Strength of concrete. Bureau of Indian Standards, New Delhi.

[6]. IS: 650 – 1991 Specification for standard sand for testing of cement.

[7]. IS: 1199-1959. Indian Standard Methods of Sampling and analysis of concrete. Bureau of Indian Standards, New Delhi.

[8]. IS: 2386-1963 Part 1 to VIII. Indian Standard Methods of Test for Aggregate for concrete. Bureau of Indian Standards, New Delhi.

[9]. IS: 3812-2003, Pulverized Fuel Ash specification, part 1 for use as pozzolana in cement, cement mortar and concrete.

[10]. IS: 4031(Part 1):1996 Specification for Methods of physical tests for hydraulic cement: Part 1 Determination of fineness by dry sieving. Bureau of Indian Standards, New Delhi.

[11]. IS: 4031 (Part-IV) – 1988 Specifications for determination of consistency of standard cement paste.

[12]. IS: 4031 (Part-V) - 1988 Specification for initial and final setting time of cement.

[13]. IS: 10262-2009 Recommended Guidelines for concrete Mix. Bureau of Indian Standards, New Delhi.

[14]. IS: 12269-1987. Specification for 53 Grade ordinary Portland cement. Bureau of Indian Standards, New Delhi.

[15]. Metin Husem, *“The effects of high temperature on*

compressive and flexural strengths of ordinary andhigh-performance concrete", Fire Safety Journal 41 (2006) pp.155–163.

[16]. Nimlyat.S and datok.E. *"Performance of Concrete at Elevated Temperatures: Utilizing A Blended*

[17]. *Ordinary Portland cement Saw Dust Ash as Binder",* IOSR Journal of Mechanical and Civil Engineering,Volume 9, Issue 3 (Sep. - Oct. 2013), pp.01-10.

[18]. Neelam Pathak and Rafat Siddique *"Properties of self-compacting-concrete containing fly ash subjectedto elevated temperatures",* Journal of Construction and Building Materials 30, (2012), pp.274–280.

[19]. Potha Raju.M, Srinivasa Rao.K, P.S.N. Raju *"A Study on Variation of Compressive Strength of High Strength Concrete at Elevated Temperatures"* 29th Conference on our world in concrete & structures: 25 - 26August 2004, Singapore.

[20]. Rambabu.K, V.Srinivasa Rao, and K.Srinivasa Rao, *"Performance of M30and M60 grade slag cement concrete subjected to high temperature",* The Indian Concrete Journal, June 2014, Vol.88, Issue6, pp.33-41.

[21]. Srinivasa Rao, Potha Raju, and *Raju "Compressive Strength on heated high-strength concrete",*Magazine of Concrete Research, March 2007,Vol.59,No.2,pp.79-85.

[22]. Sireesha.G, Kanta Rao.M and Kanta Rao.P *"An Experimental Study on Strength Properties of ConcreteWhen Cement Is Partially Replaced With Sugar-Cane Bagasse Ash"* Journal of Mechanical and CivilEngineering Volume 9, Issue 3 (Sep. - Oct. 2013), PP.35-38.

[23]. Srinivasa Rao.P, Sravana.P, and Seshagiri Rao M.V. *"Effect of thermal cycles on the strength propertiesof OPC and fly ash concretes". The Indian Concrete Journal, March* 2006, pp. 49-52.

[24]. Srinivasa Rao P., Mouli Chandra, Seshadri Sekhar T., Pannirselvam N. , P.Sravana and P. Sarika *"Studies on thermal cycles of glass fibre concrete mixes"* 36th Conference on Our World in Concrete &Structures, Singapore, August 14-16, 2011.

[25]. Sravana.P, Srinivasa Rao.P, Seshagiri Rao M. V. "*Effect of thermal cycles on compressive strength ofhigh volume fly ash concrete",* 31st Conference on Our World in Concrete & Structures Singapore, August 16-17, 2006.

[26]. Shetty, M. S., "Concrete technology," Chand S. and Co.Ltd, India (2009)

