ULTRA HIGH PERFORMANCE CONCRETE FOR CONSTRUCTION OF ROADS AND BUILDING

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Abstract

Since a large amount of construction materials is required for the construction of roads and building , there should be a target of efforts to find use for byproducts like fly ash, slag, silica fume etc (also known as mineral admixtures as these are obtained from mines) in the construction of roads and structures. All these mineral admixtures are being utilized in making ultra high performance concrete of very strength. The main reason of opting for such materials is saving in huge cost, using potential energy hide in these material, solve their disposal problem, accomplishment of good fertile soil, make environment clean and green due to GHG reduction in air, saving in natural/virgin material, light weight structure, less dead load on foundation sub-soil, faster in construction, less transportation cost is minimum use of imported diesel/petrol etc. The paper deals with such innovative material and their latest Indian codes.

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1. INTRODUCTION

The major byproduct available in India is fly ash obtained from. Coal based thermal power stations which have been set up in large numbers to meet the increasing electrical energy demand. These plants cause environment pollution due to burning of powdered coal in the chimneys.
Lighter fraction goes up the chimney and is caught by electrostatic precipitator (ESP). This is known as fly ash. The other fraction containing coarser material collected at the bottom of the furnace is called bottom ash. About 80 percent of the total ash produced is fly ash. In the wet disposal system, which is being followed by most of the power stations in our country, both fly ash and bottom ash are mixed with water and pumped into artificial lagoons. This combined ash is known as pond ash.

Rules and regulations with regard to environmental pollution are now-a-days becoming very stringent and also the Ministry of Environment has also made the use of fly ash mandatory in Civil Engineering construction works especially embankment if it is available within 100km. Further, CPWD and IRC (IRC: 112 and IRC:SP:70) have also recently issued circular that Fly ash can be used in all RCC and pre-stressed concrete structures. Therefore, environmental pollution has been an inescapable part of the industrial revolution. Now-a-days it is started to be collected from exhaust gases by electrostatic precipitator or bag filters. Fly ash is one of the most economical mineral admixtures used as cement replacement upto 35% by weight of cementitious material (IS: 1489) .
These mineral admixtures improve character of plastic concrete and improve workability, pumpability, reduce bleeding and easier finishing. Alkali silica problem has been long recognized in the field evaluations of concrete failures and has been traced to reactive silica present in aggregates and found in many areas of the world. The silica component of mineral admixtures consumes available alkalis present in cement and reduces the level of the expansion to be non-destructive to concrete quality. It has been observed that flexural strength of High Performance Concrete (HPC) is better than concrete made with only Portland cement.

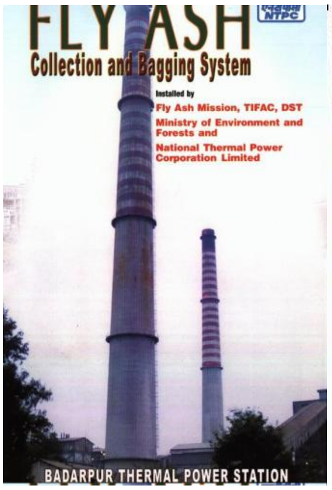
In India as per statistics, approximately 140 million tonnes of fly ash are produced per year and of which only about 30-50 million tonnes is used. In case of silica fume, these are the ultra-fine spheres of amorphous pure silicon di oxide (byproduct from ferro -silicon industries) which fill the gaps between the cement grains, refining the voids in the fresh concrete. The particles act like ball bearings and, while making the concrete much more cohesive, actually give more mobility to the mix by allowing the concrete to flow more easily when energy is applied to it. Segregation and bleeding are reduced or eliminated. This enables surface finishes to be achieved earlier than with a normal concrete.

Production of silica fume in India is very rare. The organizations which are using HPC in India, are importing silica fume basically from Norway. IIT Chennai is working very hard on reactive metal fibres. To make the concrete more ductile and durable, fibres (Both neutral and reactive metal fibres) are also normally added to make Ultra HPC (especially for high strength and long term performance). IIT Delhi is working of concrete of grade about M 500 equivalent to steel. HOLCIM is using M200 in tall building in Mumbai.

The other potential benefits of using fly ash, slag, silica fume and other fibrous materials in cement concrete mixtures are increased life of roads and building, retarded reflection cracking, decreased pollution and increased environmental quality through reduction in waste and preserving our natural sources of materials. Figure 1 shows Chimney of Thermal power plant where powder coal is burnt to produce steam that goes into the power plant for producing electricity, Figure 2 shows the collection of fly ash in bags for commercial use.

2.USE OF FLYASH, SILICA FUME, GRANULATED SLAG AND FIBRES AS ADDITIVES IN CONCRETE MIXES

Durability and long term performance of concrete structures are the two important criteria with respect to the prevailing environmental conditions. Durability cannot be sacrificed to attain high strength. High ultimate strength of concrete is generally accompanied by a low W/C ratio. All types of HPC being used in many applications must provide acceptable frost resistance, repeated heat resistance, sufficient fatigue life and adequate serviceability. The ability of ultra-high performance concrete as compared to conventional concrete is to protect embedded steel from corrosion for a very longer service period. This general conclusion is supported by the good performance observed for offshore concrete platforms in the North Sea, where high performance concrete with compressive strengths of 45 to 70 M Pa has been used. In India today we are making M 200 Grade (2000kg/cm^2 at 28 days) concrete and are in use in the field in Mumbai.



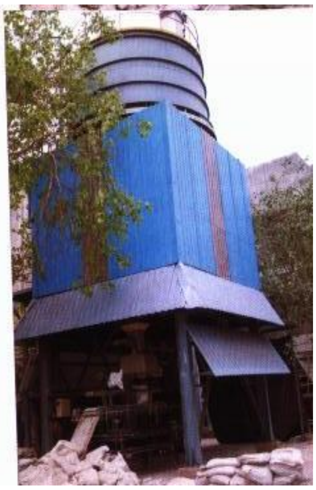


Figure 1: Badarpur Thermal Power Plant* Figure 2: Collection of Dry Fly ash (Bagging System at Badarpur Power Plant)*

** Source: Fly ash Mission , TIFAC, New Delhi*

For these structures, no problems due to corrosion of embedded steel has been reported so far, even after 15 years of the combined exposure to heavy mechanical loading and a severe marine environment. Good quality fine particles of mineral admixtures along with super-plasticizer make the cement concrete durable with improved long term performance because of least permeability and very slow chemical reaction with harmful compounds (chlorides and sulphates) present in the concrete with better abrasion resistance. Because of best abrasion resistance, high performance concrete and ultra high performance concrete has been used in Indian in most of hydro power projects and nuclear reactor structures.

Reasons of using mineral admixtures like Fly ash, and silica fumes are that do not require much processing (grinding or heating etc.) except granulated blast furnace and rice husk ash before their use in the concrete. By using these mineral admixtures, their potential energy in them due to their manufacturing process will be utilized automatically in concrete.

Micro-silica can be used to reduce the heat of hydration – a very important factor in mass concrete constructions. This can be achieved by reducing the cement content and using the micro-silica to boost the strength due to its cementing efficiency. Another way to use a high percentage replacement to another pozzolanic material – such as fly ash and using the reactivity of the micro silica to give early age strength and impermeability, thus allowing the slower materials to work over a much longer period of time. The Scanning Electron Micrograph of silica fume or micro silica is shown in Figure 3.

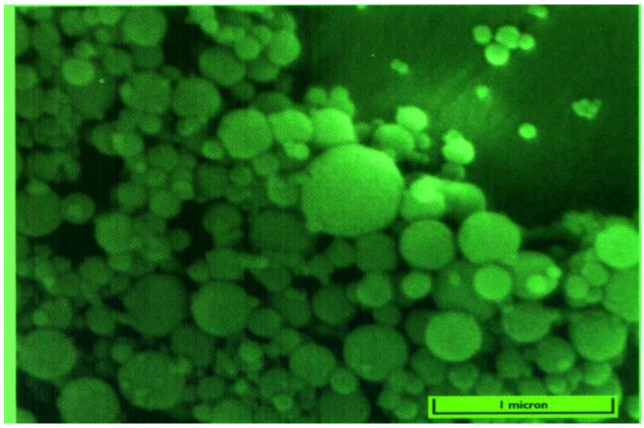


Figure 3: Scanning Electron Micro-graph of Silica Fume

(there may be ten particles of silica fume in one micron size)

Improvement in the performance and preservation of textures of concrete makes their use in the surfacing course of the concrete road pavements.

Under the Xth plan of CRRI projects, efforts were made to use HPC and ultra HPC in the field and also to study the use of polymeric fibres as an additive (about 0.2 % by weight of cement or about 1 kg/cu m of concrete) and/or steel fibres 2-2.5 % to have high performance cement concrete.

Steel fibres of dia 0.5mm to 1mm and length 30 to 40mm have been used in Ultra HPC IRC: SP 46 deals with Steel Fibre Reinforced Concrete (SFRC). These fibres improve the impact strength and inherent flexural strength of HPC being structural fibres.. These fibres (structural) may be used only in some special cases, requiring high impact resistance. Use of these fibres are very much in use in Ultra thin white topping.

Because of many technical benefits of mineral admixture, IS has issued new Code (IS:16415-December 2015) on composite cement specification using OPC 35-65, fly ash 15-35 and GGBFS 20-50% plus some additives like gypsum etc. All OPC cement has also been brought under one code that IS: 269-December 2015 with some revision in Insoluble content.

4. FIELD APPLICATION AND RESULTS

As per American Concrete Pavement Association 1998, the factors differentiating Ultra Thin White-Topping (UTWT) from conventional white-topping include:

- The use of thin PCC surfacings between 50 and 102 mm in case of UTWT.
- The need for extensive surface preparation to promote significant bonding between the PCC overlay and the Hot Mix Asphalt (HMA) pavement.
- The use of short joint spacings (generally between 0.6 and 1.8 m)
- In many cases use of high-strength PCC mixtures to provide early opening times and the inclusion of synthetic fibres (commonly polypropylene and polyolefin) to help control plastic shrinkage cracking and enhance post-cracking behaviour.

Since its (UTWT) inception in 1991, ultra thin white-topping has increased throughout the United States. Most of the sections laid in 1992-1995 rate EXCELLENT according to PAVER System criteria used for performance evaluation.

The same technology has been tried in the campus roads of CRRI in 2003 (Length about 1.5 km) and is performing well both structurally and functionally (within 90% reliability) today also. The durability study on different high performance fibre reinforced concrete (HPFRC) mixes required for construction of concrete pavement was carried out at CRRI. HPFRC or UHPC has been tried for construction of concrete pavement using different types of fibres at CRRI and at Dhaula Kuan under Pass. Figure 4 to 16 shows various uses of these materials in the field, and construction methodology. Table 1 to 2 shows Test Results. There are 12 different specifications adopted in white-topping for campus roads.

Figure 4: Existing Condition of Bituminous road at CRRI Campus

Cracks in the existing bituminous layer were filled with cut back bitumen before laying cement concrete as pre-treatment. But, at present, two innovative methods are being applied for arresting reflection cracking and water proofing. Figure 5 shows for insitu laying of SAMI layer and Figure 6 shows prefabricated bituminous mastic layer without coarse aggregates as crack arresting layer (Stress absorbing membrane).as per IRC:SP:81. Further, modified bitumen emulsion is also in use in in equivalent micro-surfacing.

Figure 5 Insitu laying of SAMI layer

Figure 6 Prefabricated bituminous Mastic layer without coarse aggregates

Figure 7; Form work Ready for Concreting over Existing Bitumen road, (levelling was carridout with lean concrete to adjust the crown in the middle of the road, PQC Thickness 75 mm with 1mX1m joint cutting)

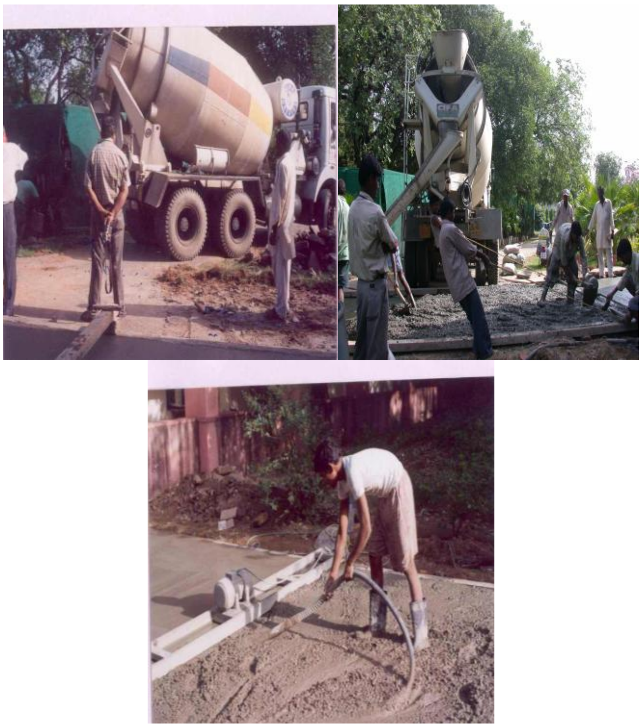


Figure 8 Placing and Laying of Concrete

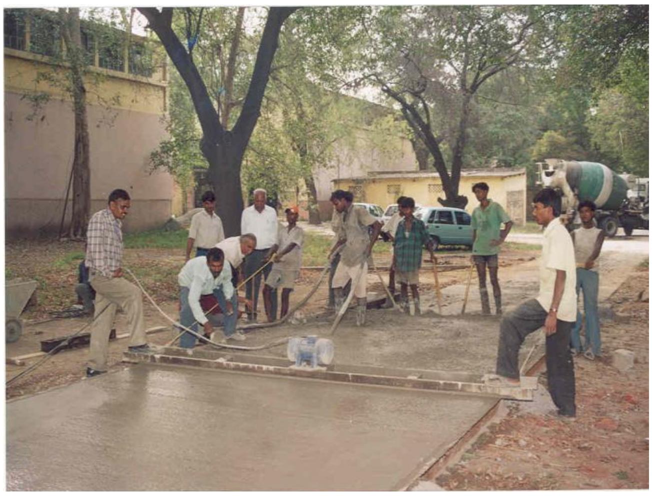


Figure 9 : Compaction with needle and Screed Vibrator

Figure 12: Evaluation (Deflection) of UTWT Using Dial Gauges at CRRI
Curling of UTWT was found maximum 0.2 mm)

Figure 10 Broom Textured Surface (Thickness less than 40 near Director's Office))

Figure 13 Evaluation of UHPFRC Using Instrumentation (FWD and Temerature Sensors)

Figure 11 ; Durability Weathering Chamber at CRRI for Durability test.

Figure 14 : Instrumentation Wires embeded in UHPFRC and Conventional
Pavement in front of the Canteen by Staff of Bridges Div.)

Table 1 : Mix Proportion used in UHPFRC

Materials	Conventional concrete	UHPFRC With FA, SF, Steel Fibre in remaining stretches
Cement	425	350
Water	160	165
Sand	660	670
Coarse Agg.	1215	1140
Additives (SP)	3.5	2.8
W/C	0.38	0.47
Grade	M 35	M-35

Note Ready Mix Concrete was purchased from M/S ACC from Faridabad plant

Salient findings with Instrumentation are given as under with regard to temperature.

Thickness	Max.Temp (heat of hydration) after 4 to 5 days	Temp. Gradient
30 cm	49 ^{o}C (after 9hr) Conventional	9
25 cm	43 ^{o}C (after 12hr) Conventional	5
7.5 cm	40 ^{o}C (after 9hr) UHPFRC	4

(Pouring Temp. was 34 ^{o}C)

Test results of campus roads are given in Table 2.

5.CONCLUSIONS

White topping may be used as campus roads of tall building. This technology will minimize lane closure times because of use of high strength concrete. Further, closer joint spacing in case of UTWT will make it compatible with flexible pavements.

The controlled cracking due to use of fibres results in improved ductility, energy absorption, resistance to impact, shock and thermal loading of the tall structures. The ability to control the size and amounts of cracks will also lead to improved durability by the use of high performance fibre reinforced concrete.

The basic advantage of using HPFRC is saving in natural materials such as aggregates and manufactured cement, thereby preserving natural sources of aggregates, water and thereby minimizes air pollution and balancing environment with respect to carbon dioxide produced during production of cement. Performance of the campus roads is found to be well suited to the presently moving traffic on the campus roads and aesthetically looking to be satisfactory, because of the satisfactory test results.

Table 2 : Test Results of Campus roads

S.N.	Specification laid	FWD Centre Deflection in micron 4t 5t 10t	Ultrasonic Pulse Velocity m/km	Compressive Strength kg/sqcm at 28 days	IRI in m/km	Skid Resistance Dry Wet	Texture Depth mm
1	Conventional Concrete M 35, 43 Grade Cement (Cement- 425 kg/cu m)	145 190 322 H =30 cm 80 104 189 H= 75 mm -	4434 3775	427 560	5.25 4.85	112 wet 108 wet 102 dry 96 dry	1.07, 1.3

2	Fly ash (5%) admixed Concrete M 35, 43 Grade Cement (Cement- 425 kg/cu m) UTWT, h= 75 mm		4441	447	5.20		1.03
3	Fly ash (20 %) admixed Concrete using 43 Grade Cement (Cement 350 kg/m^3)	163 215 352 137 174 274 150 194 313	2936	450	4.81	102 wet 95 dry	0.943
4	High Volume Fly ash (40%) admixed Concrete using 43 Grade Cement (Cement -350 kg/ m^3)	- - -		415	-	-	-
5	Fibre Reinforced Concrete, M 35, 43 Grade Cement (Cement-425 kg/cu m) (0.2% Polypropylene (Type ! Fib).	134 171 273	-	440	4.15	83 dry 104 Wet	0.97
6	Fibre Reinforced Concrete, M 35, 43 Grade Cement (Cement-425 kg/cu m) (0.2% Polypropylene (Type II, Fib.)	106 135 204	-	561	4.17	88 dry 102 Wet	0.874
7	Fibre Reinforced Concrete, M 35, 43 Grade Cement (Cement-425 kg/cu m) (Polyester Fibre 0.2%)	129 168 273 146 185 396 137 177 334	2940	560	5.24	Dry 82 Wet 97	1.75
8	EXISTING FLEXIBLE PAVEMENT	-	6487	-	8.02	-	1-2

9	Mixed Fibre Reinforced Concrete (steel fibre 1%, 0.1% polyester Cement 425 kg/m^3)	109 142 242	3400	-	-	89 dry 103 wet	1.06
10	High Performance Fibre Reinforced Concrete (1% SF, 0.1 % polyester fibre, Cement 425 kg/m^3) Conventional Joints	169 219 337	3122	-	4.51	98 wet 90 dry	1.07
11	High Performance Fibre Reinforced Concrete (5% SF, 0.2 % polyester+ PP fibre + 15% fly ash, Cement 425 kg/m^3) for UTWT Joints 1 m c/c	-	-	-	4.89	95 wet 85 dry	1.15
12	High Performance Concrete, M 35, 43 Grade, Fly ash 10 % and 0.1% fibre Cement (425kg/cu m),	-		-	5.14	100 wet 88 dry	-
13	Existing Flexible Pavement Existing Rigid Pavement			- -	9.3 on BC 7.32 on CC		-

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