Bulk Fly Ash Utilization - R&D Initiatives of NTPC

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Abstract

There is a growing need for disposing of fly ash with the ever increasing demand for coal as an energy source. Fly ash generation was 196 MT in 2017-18 and with the present momentum of the capacity addition is likely to increase around 241 MT by 2022. *Current levels of efforts of ash utilization have resulted in achieving just 67.13% by 2017-18 and India is nowhere near its target of utilizing 100% of fly ash generated by the coal based power plants and the balance ash is getting dumped as solid waste in ash ponds.*

A lot of R&D efforts have been put forward to achieve the target of mandatory 100% utilization of fly ash by power utilities over a stipulated time span, as stipulated in Ministry of Environment & Forests Gazette Notification, Government of India of 3rd November, 2009. These efforts include setting up of Sintered fly ash Light Weight Coarse Aggregates manufacturing plant for technology demonstration at NTPC Sipat of capacity 50,000 m3/Annum, Construction of Fly ash based Geo-Polymer concrete road as per IRC specifications, Use of Bottom Ash as Replacement of Fine Aggregate in Cement Concrete, Process development for conversion of fly ash to fine aggregate (Sand) & Casting of fly ash based spun/Hume pipes.

An attempt has been made, here, in this paper to highlight these R&D technologies which can lead to bulk fly ash utilization and prove to be beneficial from both financial & technological point of view not only to NTPC but to entire power sector and nation as a whole.

Key words – Light Weight Aggregate, Road, Geo-polymer, Tetrapods, Hume pipes, bottom Ash

INTRODUCTION

There is a growing need for disposing of fly ash with the ever increasing demand for coal as an energy source. Fly ash generation was 196 MT in 2017-18 and with the present momentum of the capacity addition is likely to increase around 241 MT by 2022 .Presently, NTPC generates around 61 million tons of coal ash annually from its coal based thermal power plants with an ash utilization of 63.71 % in 2018-19. A lot of R& D efforts have been put forward to achieve the target of mandatory 100% utilization of fly ash by power utilities. These efforts include setting up of Sintered fly ash Light Weight Coarse Aggregates manufacturing plant for technology demonstration at NTPC Sipat of capacity 50,000 m3/Annum, Construction of Fly ash based Geo-Polymer concrete road as per IRC specifications, Use of Bottom Ash as Replacement of Fine Aggregate in Cement Concrete, Process development for conversion of fly ash to fine aggregate (Sand) & casting of fly ash based Spun/ Hume pipes etc.

1. FLY ASH BASED GEOPOLYMER ROAD

NETRA has developed technological processes for utilisation of fly ash generated from coal-based power stations by development of Geopolymer pavement quality concrete road construction technology. Fly ash based Geo-polymer concrete road of M40 strength has been constructed successfully at NTPC-Dadri as per IRC specifications first time in the country.

Technology involved:

The road has two layers of Geo-polymer concrete, DLC (Dry lean concrete) and PQC (Pavement quality concrete) layer. The M-10 strength DLC is 150 mm thick, M40 strength PQC is 280 mm thick. PQC is separated from DLC by 125-micron thick polythene separation sheet. The main ingredients utilised in road construction are Fly ash (waste of power plant), Slag (waste of steel plant), caustic soda and sodium silicate apart from admixtures without any utilisation of cement. Around 0.3 T of fly ash is consumed per cum of concrete road laid. This comes out to be consumption of 1035 MT of fly ash/Km of road built. The pavement mix comprises fly ash-ground granulated blast furnace slag powder mixes, coarse aggregate, fine aggregate, activator, polypropylene/polyester fiber or alike, chemical admixture, superplasticizer & water. In the process, fly ash retained on less than 34% on a 45 µm sieve is intermixed with ground granulated blast furnace slag in a ball mill to obtain a homogeneous powder mix, preparing the activating solution consisting of sodium hydroxide and sodium silicate in a ratio of 1:2.5, mixing the activating solution containing superplasticizer with dry concrete ingredient consisting of powder mix, fine and coarse aggregates in a weigh batching mixer and added chemical admixtures at the final stage of mixing. The pave mix so obtained is laid in 280 mm thick slab over dry lean geopolymer concrete sub-base. The performance highlights of this Geo-polymer concrete road are:

a. **NO CEMENT** - Developed Fly ash based green concrete road without cement with M 40 strength

b. **NO WATER CURING -** Construction of fly ash based GPC road without water curing.
c. **Bulk utilisation of Fly Ash**
d. **Negligible CO2 emission** in comparison to high CO2 emission in cement production
e. **High early compressive strength -** Strength is achieved in 7 days in comparison to 28 days for normal Concrete road.
f. **Negligible shrinkage** – No cracks observed in GPC road
g. **Low permeability -** Monolithic
h. **Good durability** in aggressive environment compared to conventional concrete road. Concrete durability test such as drying shrinkage, Alkali-Silica reaction, exposure in acid environment, exposure in sulphate environment has been conducted & found satisfactory.
i. **Low thermal conductivity**
j. IRC accreditation – IRC has accredited 'Geopolymer concrete' for road construction developed by M/s NETRA – NTPC Ltd. On dt 05.01.2018.

Double lane 100 m X 7.5 m Geo-Polymer road at Dadri

Ramagundam 1.36 Km x 8.5 m

k. Recently, 1.36 Km double lane stretch at Ramagundam has been constructed. Geopolymer roads are next proposed to be constructed at Rihand, Kahalgaon and Talcher Kaniha.

2. USE OF BOTTOM ASH AS A PARTIAL REPLACEMENT OF FINE AGGREGATE

NTPC had undertaken a study on "Use of Bottom Ash as replacement of fine aggregate in cement concrete". Study was carried out on bottom ash collected from two sources i.e. NTPC Korba and NTPC Vindhyachal. Study was carried out on two water cement (w/c: 0.40 & 0.65) ratios and two fractions of each source of bottom ash i.e. "As such fraction" and "fraction between 4.75 mm and 75µ" to evaluate their influence on engineering properties of concrete when part of the fine aggregate is replaced with Bottom Ash.

Concrete mixes were cast at two water-cement ratios i.e. 0.4 & 0.65. A total of 60 number of concrete mix trials were made using OPC and bottom ash of both the fractions i.e. “as such” and “fraction between 4.75 mm and 75µm” using both the sources of Korba and Vindhyachal. Out of the total mixes, 4 control mixes, 16 with 25% replacement of bottom ash, 16 with 50% bottom ash, 16 with 75% bottom ash and 8 with 100% bottom ash were planned. With 25% and 50% replacement, all the trials were successful in terms of desired workability. With 75% replacement, only 8 out of 16 trials were successful, however, in another 8 trials desired workability could not be achieved even at higher percentage of admixture dosage. With 100% replacement, none of the 8 trials were workable even at higher percentage of admixture dosage. While evaluating fresh concrete properties in terms of workability, it was found that with increased percentage of bottom ash the water demand and admixture dosage increases.

Concrete mixes were evaluated for fresh and hardened properties and durability tests were also carried out on selected mixes. For validation of results obtained with OPC, few trials were also carried out using PPC with 25% and 50% replacement of fine aggregate with bottom ash. The study recommended “that 50% replacement of crushed/natural sand with as such fraction of Bottom ash is technically feasible in the desired mixes of concrete for RCC work. It may be noted that with the addition of Bottom ash as a replacement of fine aggregate increases the water demand of concrete for same level of workability. Therefore, these mixes shall only be designed with an increased dosage chemical admixture, depending upon the quality & quantity of bottom ash”.

Further trials on bottom ash samples of 10 more projects of NTPC are being analysed for establishing (i) general specifications of Bottom Ash for its use as partial replacement of sand in concrete & (ii) establishing guidelines for mix design of concrete incorporating bottom ash as partial replacement of sand. Upon validation data will be submitted to BIS for codification. Since the demand for sand is huge, even with this 50 % replacement, the total bottom ash generated at NTPC stations can be utilized with increase in total ash utilization from present 53.45% to

73.45%. This study was conducted in collaboration with NCCBM, Ballabhgarh.

3. Fly ash based tetrapods

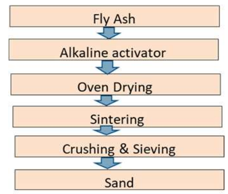
Tetrapod's of M30 grade (height 2 feet and armed length 1 feet) of weight around 90 Kg have been developed through geo-polymeric binder using sea sand and sea water instead of conventional cement concrete at NTPC Simhadri. The developed tetrapod's have potential application at coastal sites and can be used as breakwater from the effects of both weather and longshore drift. The technology involved is based upon geo-polymerization reaction and heat curing.

Scaled up version of same with tetrapod's of 2T weight are being developed for NTPC Koldam. Each of the tetrapod will utilize 300 m3 of fly ash. The composition for M30 grade tetrapod's developed at Simhadri is given below.

Serial no.	Components	Weight (gm)	Percentage (%)
1.	Fly Ash	5900	13.96
2.	Sea Sand	13700	32.40
3.	**Coarse Aggregates (20 mm)**	**12050**	**28.50**
4.	**Coarse Aggregates (10 mm)**	**6500**	**15.37**
5.	Sea Water	2360 (ml)	5.58
6.	Additive 1	1180	2.79
7.	Additive 2	590	1.40

4. PROCESS DEVELOPMENT FOR CONVERSION OF FLY ASH TO SAND

Process has been developed for conversion



of fly ash into sand through geo-polymerization of fly ash. The proportion of mixing of Fly ash in NaOH pellets is 12.5:1. Thereafter oven drying at around 100 ºC, sintering, crushing and sieving, Fine aggregates are formed There is approximately 85% conversion efficiency. The 15% wastage can be used as "Murram". The approximate cost of this fly ash based artificial sand is around 4 to 5 times the cost of natural sand.

5. Light Weight Aggregate (LWA)

The concept of the use of fly-ash as construction material emerged as a major route for the recycling of fly-ash and, in the process; a thorough global technology search yielded Sintered Light Weight Aggregates (LWA). The natural aggregate is also facing scarcity in some region of the country; therefore, this is an area where large quantities of fly ash in the form of LWA can be absorbed without causing large market dislocations. To solve fly ash utilization problem and the option of mass application must be emphasized by manufacturing of fly ash based light weight aggregates (LWA) for potential application in structural/plain concrete, concrete products, block and masonry units.

Requirement of Fly Ash for sintered LWA production: Requirement of fly ash for LWA as per manufacturer is fineness Max 35% retention on 45u, Fly ash fusion point < 1300°C and Loss on ignition 9%.

Manufacturing fly ash LWA

Manufacturing fly ash LWA consist of following basic steps:

PELLETIZING:

Pelletizing is the process of agglomeration where fine fly ash particles form aggregate-size pellets.

Pelletizing can be performed by two distinct methods i) Agitation- where fly ash particles are introduced onto an inclined rotating disk along with a wetting agent and an appropriate binder. Balling of the material occurs by the formation of 'seeds' which ultimately grow into pellets of a certain maximum size, usually about 3/8 inches to 5/8 inches in diameter ii) Pressure or extrusion method- where Pelletization is accomplished by using a continuous piston-type press where more or less rectangular or cylindrical pellets are formed which are 3/8 inches to 1/2 inches in size. The extrusion process generally results in a product having a higher density than the spherical pellets produced by agitation.

BONDING: Bonding gives the pellets strength and other properties necessary to meet the criteria for a lightweight aggregate. Bonding of the green pellets can be accomplished in three ways:

i) Cold bonding- In this process lime and/or cement is added to fly ash, along with other substances such as limestone, clay or shale. The mix is then pelletized and allowed to harden. The product from the cold bonding process is thought to possess properties inferior to those of the other two processes due to the lack of firing

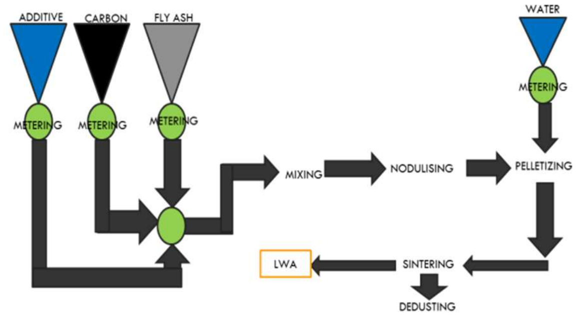
ii) Hydrothermal processing: In the hydrothermal process, bonding is accomplished by adding lime and/or cement to fly ash in order to achieve a chemical reaction that will bond the materials together. After the fly ash and lime have reacted, the mixture pelletized and the pellets are then placed in an autoclave to harden under pressurized saturated steam conditions.

iii) Sintering: During sintering the firing method can be accomplished either in a) Continuous rotary kiln whereby the material is heated in a rotating, almost horizontal kiln to produce the lightweight aggregate product or b) Travelling sintering grate: that transports the material through a sintering oven. In either method, firing is initiated by an outside source of heat (electrical, oil or natural gas) and supported through the sintering process, as much as possible, by the combustible portion of the pellets. The combustible portion is provided by the organic portion of component materials such as the carbon fraction of the fly ash as measured by a loss on ignition test. Additional heat required during the firing process can be supplied by oil, natural gas, fuel or electrical heating that is added to the fly ash prior to pelletizing.

Different bonding Processes on the basis of manufacturing Temperature is shown below table.

S N	Parameters	Sinter-ing	Hydrothermal	Cold-bonde
1	Temp. (deg. C)	>900	100 < T <250	10 < T 100
2	Micro-structure	Ceramic	Cementatious	
3	Heat treatment	Fired	Auto-claved	Cold bonde

Among the various processes described, the agitation method (palletizing) coupled with the firing (The travelling sintering grate) method for bonding is considered



the best approach for producing a high quality lightweight aggregate. The aggregates manufactured by this process are known as sintered light weight aggregates. This process yields an aggregate with a low unit weight that can be used to produce a good quality structural grade lightweight aggregate concrete. Fortunately, the sintering process is thermally very efficient as it requires only about 4 to 10% carbon in the ash, which is of course highly significant in these days of rising energy prices. The schematic of manufacturing process of sintered light weight aggregates is shown in Fig.

INTERNATIONAL AND INDIAN STANDARDS ON LIGHT WEIGHT AGGREGATE

There are various standards available worldwide as mentioned below.

The potential of fly Ash LWA to produce mix design structural grade concrete was investigated in collaboration with CSIR-SERC. The possibility of development of structural grade concrete using LWA as full replacement for coarse aggregate in concrete was explored. The concrete mixes developed had strengths much more than that required for the particular grade of concrete using LWAs as coarse aggregate. Therefore, Structural concrete can be easily obtained using sintered lightweight aggregate as coarse aggregate. For higher grades further detailed investigation would be required.

Recently, BIS revised IS:9142 part-I for promoting use of LWA in concrete masonry units & released new code IS:9142 part-2 similar to ASTM 330 which would promote the use of fly ash based LWA in structural concrete and more users will be encouraged which would thereby facilitate the installation of manufacturing plants in India.

6. Manufacture of Reinforced Geopolymer Concrete based NP Class Spun Hume Pipe

Utilization of a rapid setting fly ash based Geopolymer concrete mix instead of cement concrete mix, for Hume pipe casting relates to a rapidly setting fly ash based Geopolymer concrete mix with a

SN	Country	Standard Name	Standard Title
1	American standard	ASTM C330 2009	Std. specs for LWA for structural concrete
2		ASTM C331 2009	Std. specs for LWA Concrete Masonry units
3	European Standard	EN 13055-1:2002	Lightweight aggregated for concrete & mortar
4		EN 12620:2008	Aggregated for concrete
5		BS EN206:2014	Concrete specification etc.
6	Chinese standard	GB/T 17431.1-2010	Lightweight aggregate & its test methods- Part-I
7	Japanese Standard	JIS-A5002-2003	Lightweight Aggregates for structure concrete
8	German Standard	DIN 4226-100:2002	Aggregates for mortar and concrete part 100:Recycled aggregate
9	Indian Standard	IS 9142:2018 pt-I IS 9142:2018pt-II	Specs for artificial LWA for 1. concrete masonry units & 2. Structural concrete use

setting time of 6 hours or less utilizing low calcium fly ash (class F), ground granulated blast furnace slag, alkaline activators, aggregates and admixtures without addition of additional water for making Hume pipe.

NETRA has done trial on casting of Hume pipe using Kahalgaon fly ash. In this trial Hume pipes NP class of diameter 600 mm, 1000 mm and 1200 mm were casted.

Conclusions:

NETRA aims to develop all ingredients of concrete viz. aggregate, cement & sand from ash. Various fly ash utilisation projects like manufacture of Geo-polymer cement concrete, Light weight coarse aggregates, Geo-polymeric concrete Tetrapod's, Spun pipes can be considered for large scale technology deployment. Implementation of these technology will be beneficial from both financial & technological point of view not only to NTPC but to entire power sector and nation as a whole.

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