



NATIONAL WASTE MANAGEMENT

SUMMIT AND AWARDS 2025

With a special emphasis on Fly Ash &
Gypsum Utilization



**TECHNOLOGIES FOR LARGE-SCALE
ASH UTILISATION**

MR. PRANAY PANDIT

Technologies for Large-Scale Ash Utilisation

ASH Utilization



NTPC – NETRA
06.10.2025



About NETRA



About NETRA:

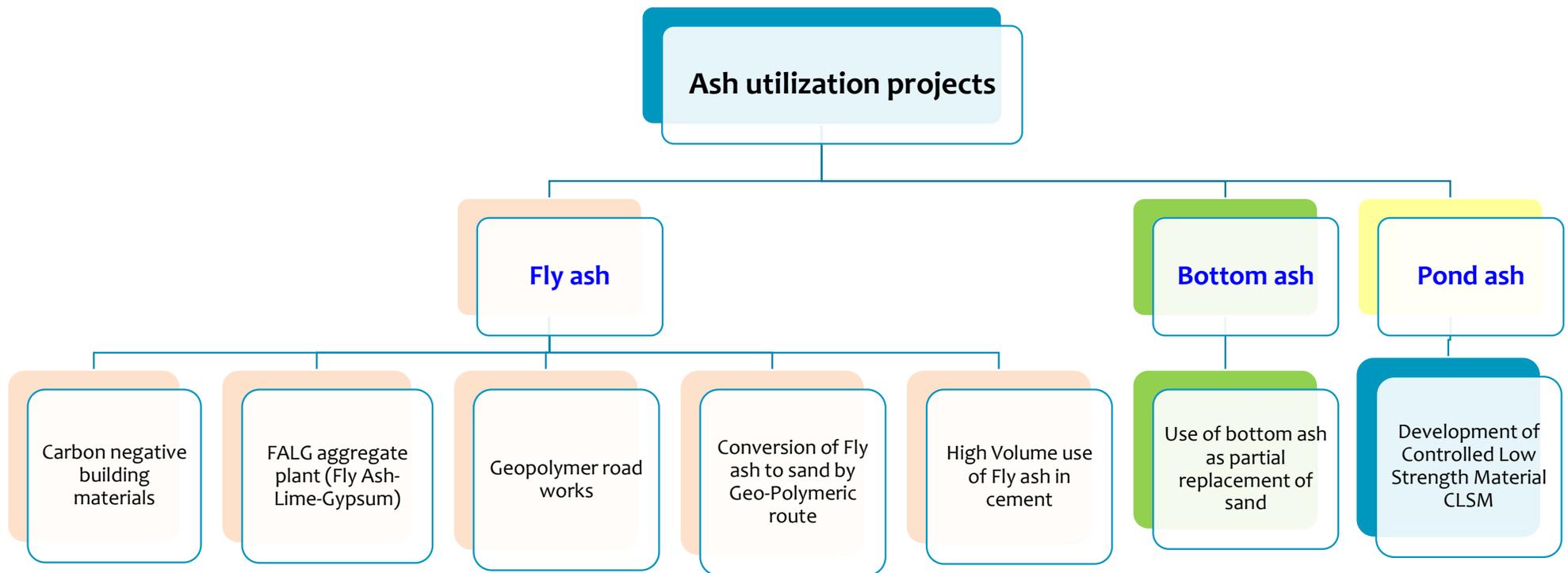
- NETRA (NTPC Energy Technology Research Alliance) is a **'applied research'** based premier R&D institution in the domain of **'Energy'**.
- Primarily, it focuses on **'critical technologies'** important for company, sector and country – with a view to (i) setup **'fully automated 'demonstration plants'** & (ii) plug **'knowledge gaps'** where ever needed.
- It provides wide array of **'on-field'** and **'in-lab'** **advanced scientific services** to power station – both NTPC as well as non-NTPC.
- **It was setup in 2009** – by merging two (2) depts i.e R&D Centre (set up in 1981) & Energy Technology Centre (set up in 2004)



NETRA Main Building



Ash Technologies-Bulk Ash Utilization





Ash Technology Projects

Ongoing Projects:

1. 2 Lakh/day Carbonated Brick Plant at NTPC Ramagundam
2. 30,000 m³/ year FALG Aggregate Plant at NTPC Korba
3. Carbonated Fly Ash Aggregate

Completed Projects:

1. Geopolymer Road, Pavers & Tetrapods
2. Bottom ash as a partial replacement of Sand in concrete



Set up of 2Lakh/day C-Brick Plant at Ramagundam



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CO₂ emission by sectors

Source: International Energy Agency

Share of global emissions

7.4%

of CO₂ emissions from combustible fuels, 2022

CO₂ emissions from fuel combustion in India

Total, 2022

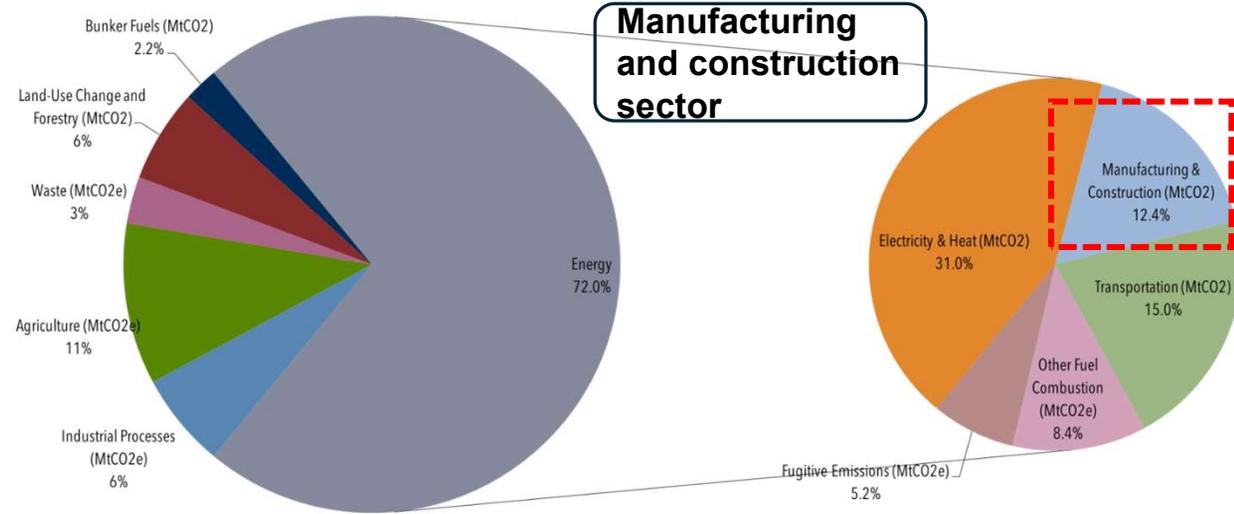
2516.967

Mt CO₂

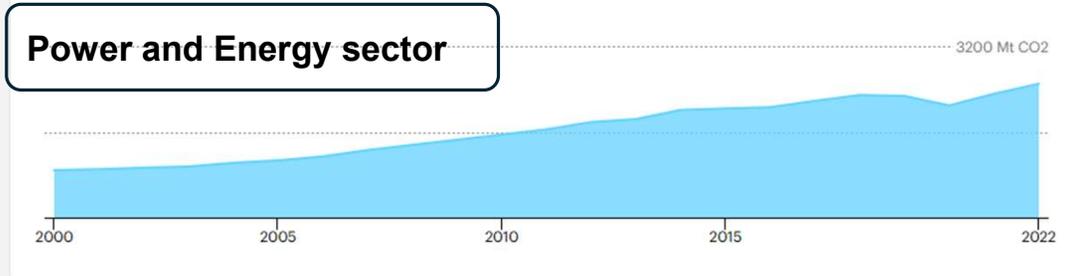
Trend

↑182%

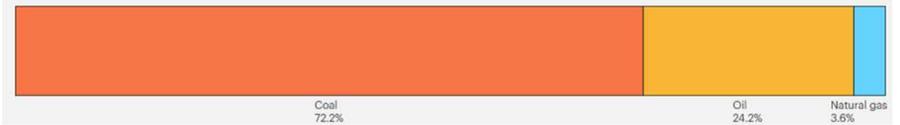
change 2000-2022



CO₂ emissions from fuel combustion, India



CO₂ emissions by fuel, India, 2022

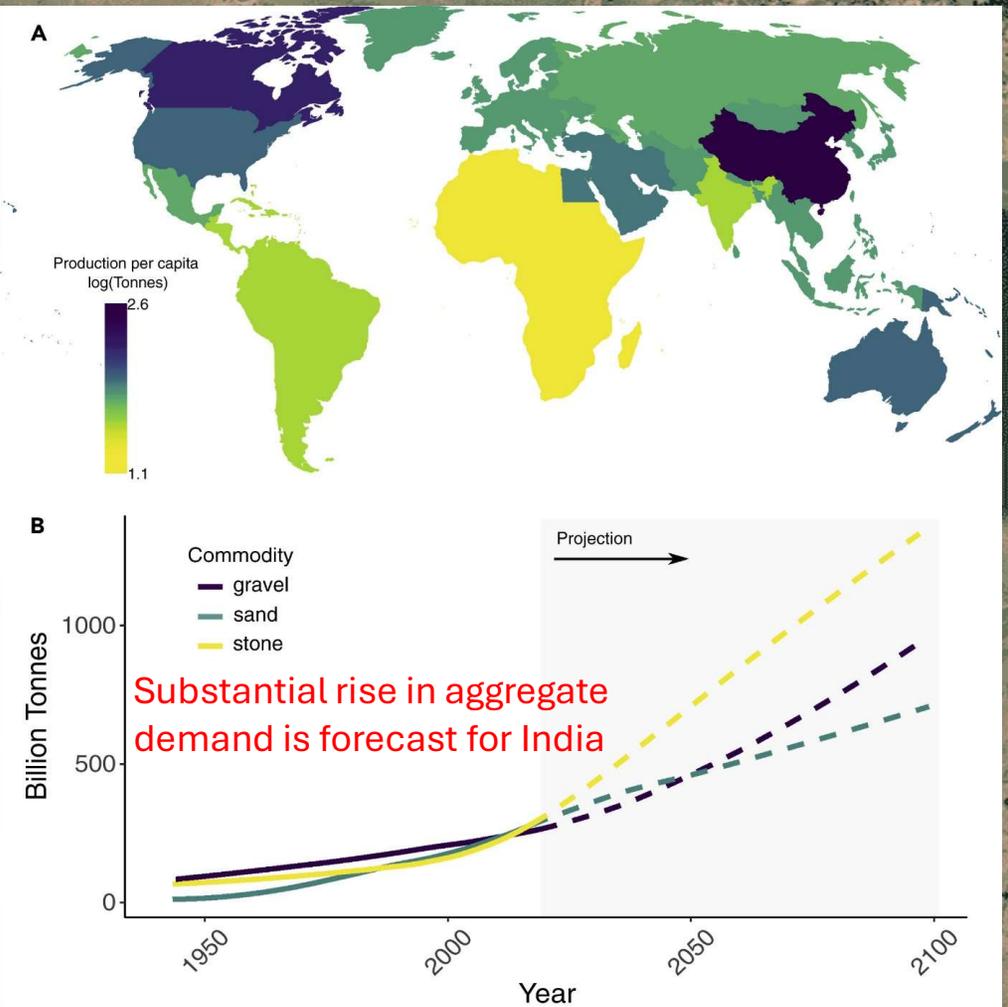


Largest source of CO₂ emissions in India, 2022

Coal

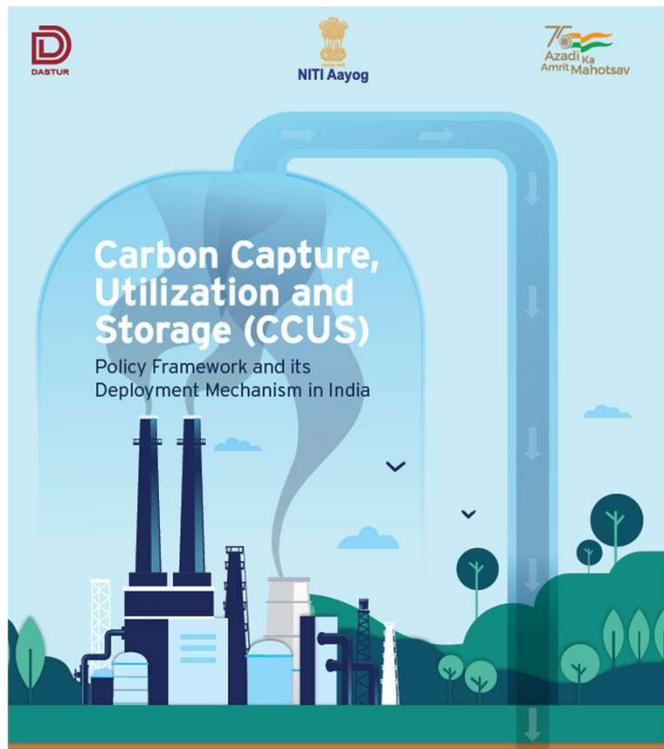
72%

of total CO₂ emissions from fuel combustion



Scarcity of Natural Aggregates

Mineral carbonation in concrete as a national priority measure for reducing net emission



Cement	196	325	Another major CO ₂ emitter, where fossil fuels are difficult to replace. Utilization of CO ₂ in aggregates has synergies with the cement business	Establish CCUS clusters in key identified areas/districts
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Additionally, there are other promising propositions for the utilization of CO₂. The relatively matured CO₂ utilization pathways are:

- (i) **Building material (concrete and aggregates):** A high-level review of the new technologies indicates that utilizing CO₂ for producing building materials (aggregates and concretes) is likely to be the most attractive and feasible option. There is a large market for aggregates and concrete in a developing country like India. CO₂ can be used both during concrete curing and aggregate formation. Since CO₂ is injected in a liquid state

Industry adoption of carbon sequestration technology



0.05 – 1.5% CO₂ storage by wt. of cement

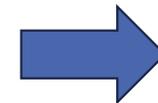


3- 5% CO₂ storage by wt. of concrete blocks

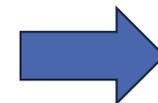
C-Brick: Compliance with Codes & Standard



Parameter	Red Clay Brick	Fly Ash Brick	C-Brick
Code	BIS 1077	BIS 16720	Code NA
Strength	> 7.5 MPa	>7.5 MPa	>9.5 MPa
Drying Shrinkage	NA	<0.05%	<0.05%
Moisture	<20%	<20%	<20%
Environment Impact	High CO ₂ emission, soil depletion	Eco-friendly, reduces waste	Carbon Credits
Thermal Insulation	Moderate	Better	Better
Aesthetic Appeal	Best (traditional red colour)	Gray	Gray



Mandatory
Codal
Compliance

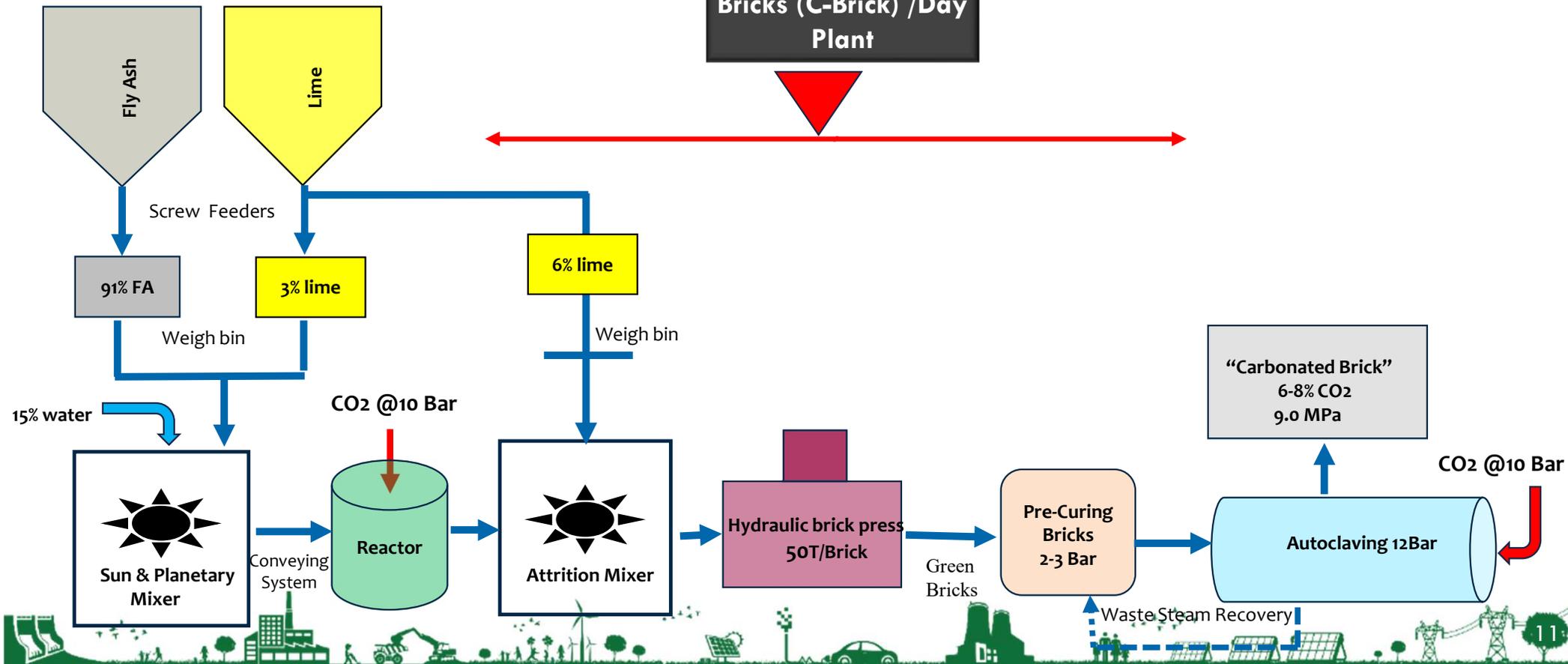


Non Codal

Key takeaway: 'C-Brick' fulfils all Codal provisions

Process Description: C Brick Plant

200,000 Carbonated Bricks (C-Brick) /Day Plant



Results and Validation



Mix		Avg. CO2	Compressive Strength of Brick (Mpa)
3L+5L	Surface1	7.52	9.7
	Surface2		
	Centre1	6.47	
	Centre2		
3L+6L	Surface1	8.30	10.2
	Surface2		
	Centre1	6.03	
	Centre2		
5L+5L	Surface1	8.83	10.4
	Surface2		
	Centre1	6.61	
	Centre2		

Process Finalized

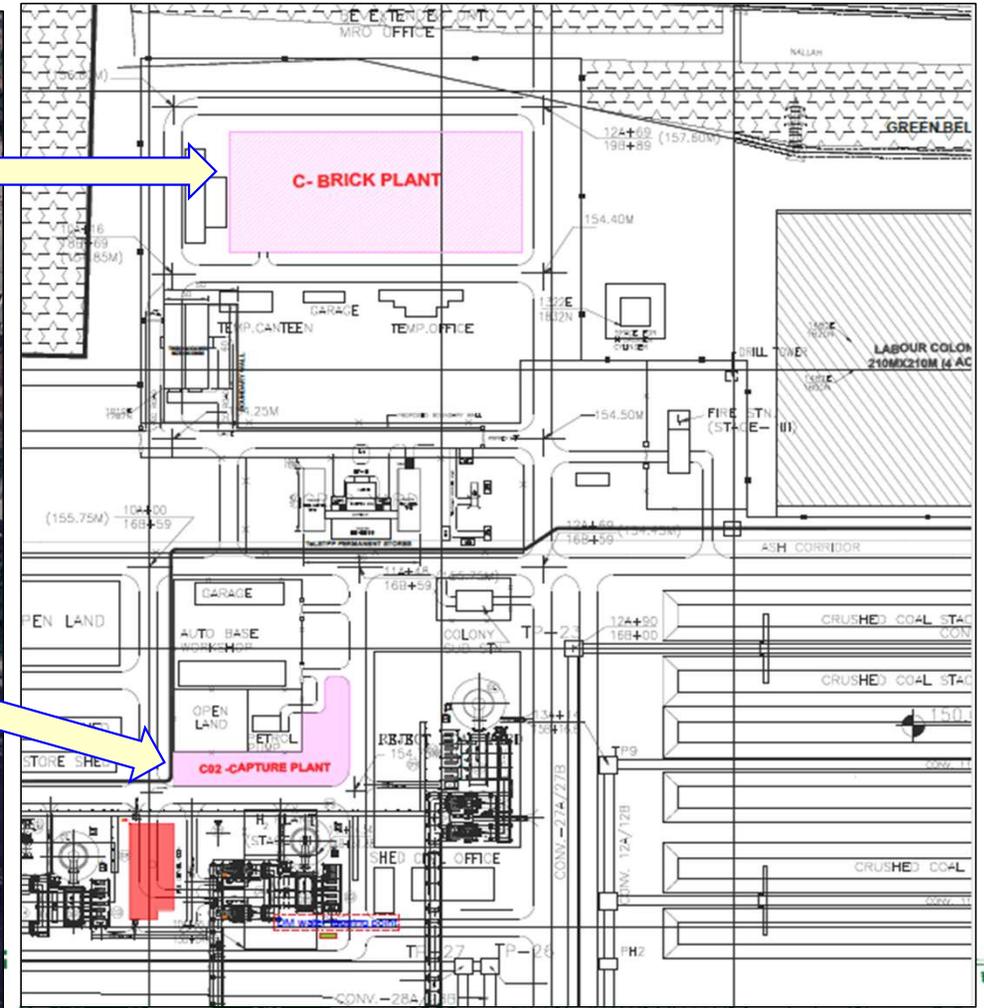
Building Block-1

- 50TPD CO2 Separation from Flue Gas
- Compression & Storage of CO2

Building Block-2

- Addition of Fly Ash +3% Lime
- Addition of CO2 at 6 Bar in Carbonation Mixer
- Addition of 6% Lime in Attrition Mixer
- Hydraulic Brick Pressing (50T/Brick)
- Steam Curing of Brick
- CO2 Curing of Brick

Location – Unit 4 Ramagundam



Utilities for Setting up of C-Brick Plant



S.No	Facility	CO2 Capture Plant	C-Brick Plant	Total
1	Land	Plant: 0.25 Acre	Plant: 1 Acre, Stockyard: ~4 Acre	5.25 Acre
2	Steam	~ 3.5 TPH	~ 3 TPH	~ 6.5 TPH
3	Service Water	~ 10 TPH	~ 3 TPH	~ 13 TPH
4	Power	~ 400 kW	~ 600 kW	~ 1000 kW
5	DM Water	~ 0.5 TPH	Nil	~ 0.5 TPH



Material Requirement



S.No	Material	Quantity
1	Fly Ash	637 MT
2	Lime	68MT
3	Flue Gas	15000 Nm3/hr
4	CO2	50 TPD

NTPC Limited
(A Government of India Enterprise)
Contract Services, EOC Noida

INVITATION FOR BIDS (IFB)

FOR

Carbonated Fly Ash Brick (C-Brick) Plant of 2 Lakh per Day Capacity at NTPC Ramagundam

(Domestic Competitive Bidding)

GEPNIC Tender Ref. No: 2025_NTPC_98848_1

Date: 24.07.2025

Bidding Document No: CS-3100-702-9

1.0 NTPC invites on-line bids at Government e-procurement portal of NIC (GePNIC) at website-<https://eprocurrentpc.nic.in/> on **Single Stage Two Envelope Basis** (i.e. **Envelope-I: Techno-Commercial Bid and Envelope-II: Price Bid**) from eligible Bidders for aforesaid package, as per the scope of work briefly mentioned hereinafter.

2.0 **Brief Scope of Work**

Design, Engineering, Fabrication, Packing, Forwarding, Supply, Transportation and handling, duties, Freight, Insurance Unloading, Storage, Construction, Erection, Testing, Commissioning, PG Test of "Carbonated Fly Ash Brick (C-Brick) Plant of 2 Lakh per day capacity" at NTPC Ramagundam.

O&M and Supply of Hydrated Lime for 12 months for 'Carbonated Fly Ash Brick (C-Brick) Plant of 2 Lakh per day capacity' at NTPC Ramagundam.

3.0 NTPC intends to finance the aforesaid Package through Domestic/Own Resources.

4.0 Detailed specification, scope of work and terms & conditions are given in the Bidding Documents, which are available at the GePNIC (e-tender) portal at <https://eprocurrentpc.nic.in/>. The Bidding Schedule* for the Tender is as under:

Financial Projection: 2 Lakhs/day Plant



Cost Parameter	Quantity	Unit
Capital Cost	1,50,00,00,000	INR
Life of Plant	10	Years
Dep Cost/ Brick	2.27	INR
Utilities Cost/Brick	0.38	INR
O&M Cost/Brick	1.76	INR
Total Price/Brick	4.41	INR





Ash
Technology
Projects

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2. Development of Carbon Negative Building Materials
3. 100 m³/day FALG Aggregate at NTPC Korba

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2. Bottom ash as a partial replacement of Sand in concrete

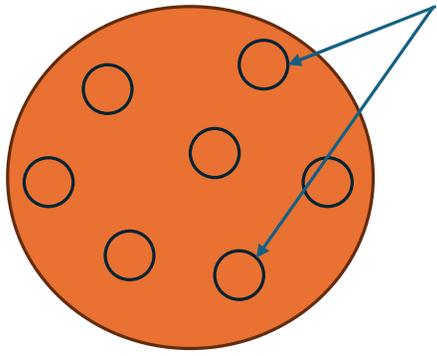


Objectives



- Preparation and characterization of sintered fly ash-based aggregates as per Indian Standard, IS 383
- Effect of thermochemical activation and lime impregnation on the pores of the synthesized aggregates on carbon uptake from **flue gas** and engineering properties (water absorption, pore size distribution, reactivity, etc.)
- Aggregate gradation for replacing 30 - 50% of coarse aggregates in different grades of concrete
- Assessing the engineering properties, including strength, elastic modulus, shrinkage, and durability of concrete mixes containing the treated aggregates. M15 and M30 grade mixes will be developed.

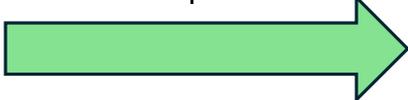




- Macro pores in sintered fly ash aggregates
- Degradation in mechanical performance
 - Not suitable for CO₂ utilization & adsorption

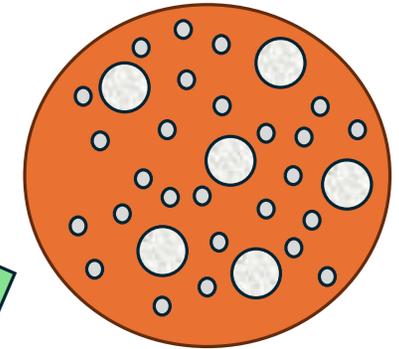
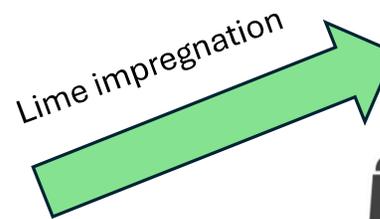
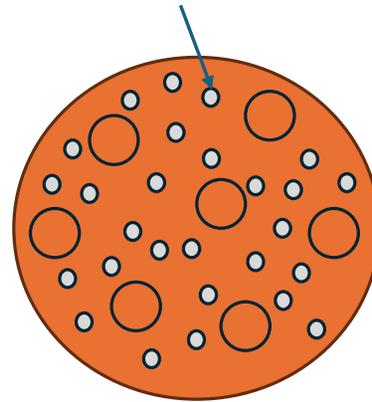


Thermo-chemical activation process

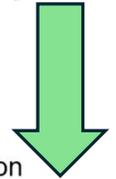


Process parameters to be optimized

Introduction of micro-pores and mesopores that are more active in CO₂ capture



CO₂ sequestration



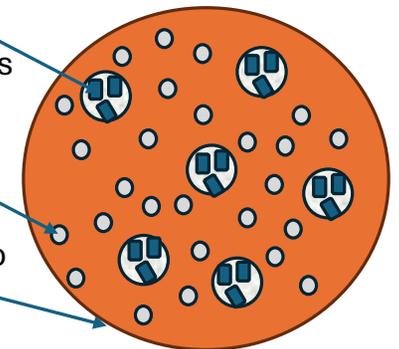
Process parameters to be optimized

Minimize macro-porosity and maximize micro-porosity (< 5 nm) → Better strength and bonding

Pore densification by calcium carbonate crystals

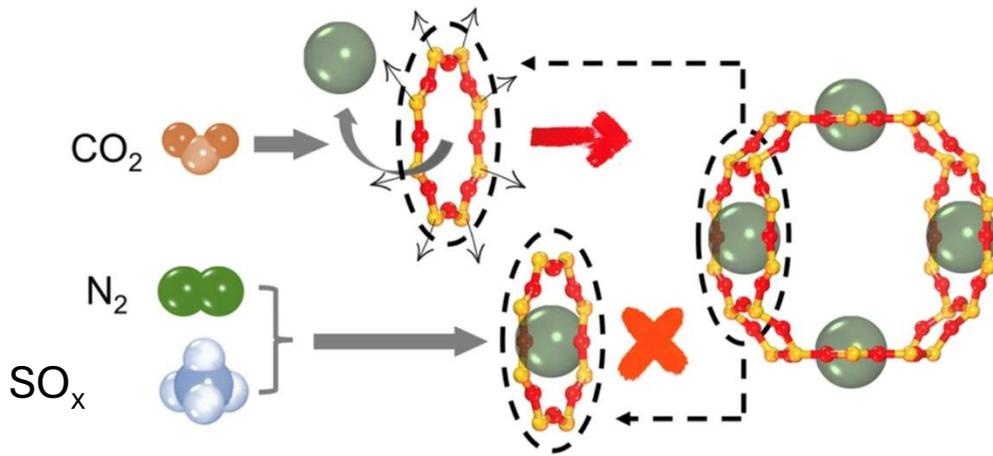
CO₂ adsorbed in pores

Surface reactivity due to CO₂ activation

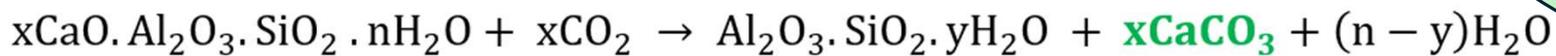
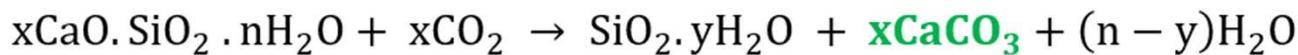
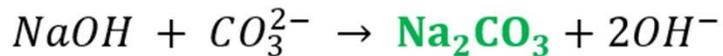
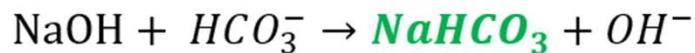
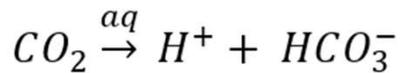


Selective CO₂ adsorption and mineralization by optimizing composition and pore size

CO₂ separation by Gating Effect

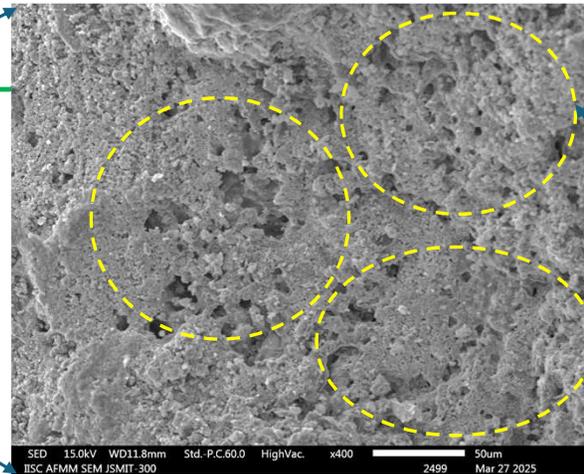


Gas	Kinetic diameter (nm)
CO ₂	0.33
N ₂	0.36



NaHCO₃, Na₂CO₃,
CaCO₃
are the mineral
carbonates that are
stable under ambient
conditions and
sequestered
permanently in the
aggregates

Morphology of core and shell

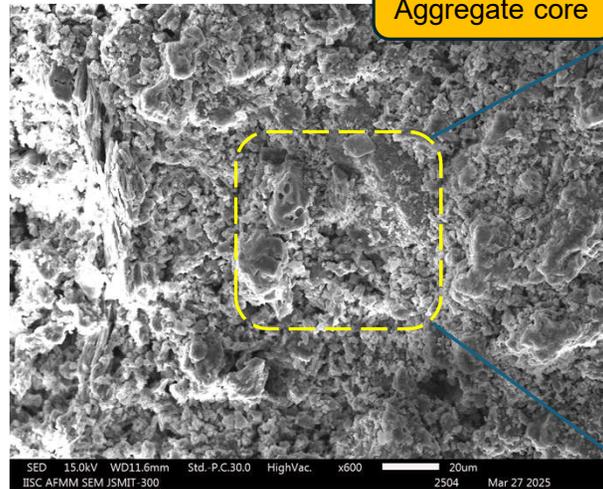


Porous Aggregate shell

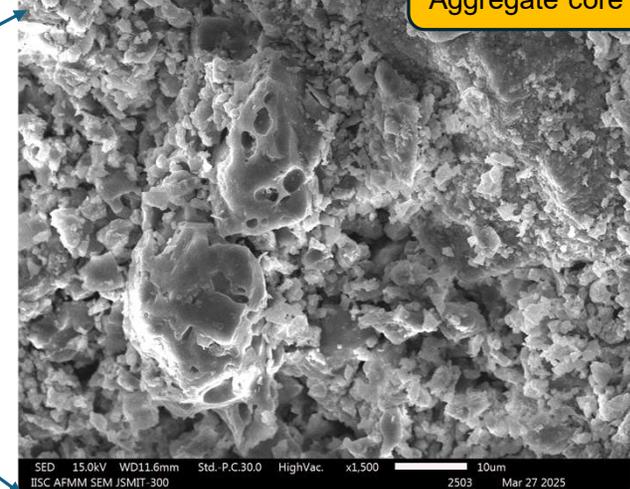
- 1. Micro-pores and macro-pores during sintering
- 2. Provide pathways for CO₂ diffusion

- 1. Sintered aggregates: Fly ash (FA) + 10% natural excavated clay, activated by 3 mol/L NaOH
- 2. Exposed to 15% CO₂

- 1. Pores on the shell allow CO₂ diffusion and mineralization
- 2. A denser microstructure of the core strengthens the aggregate



Denser Aggregate core



Denser Aggregate core



Ash
Technology
Projects

Ongoing Projects:

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2. 30,000 m³/ year FALG Aggregate Plant at NTPC Korba

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3. Carbonated Fly Ash Aggregate



Fly Ash Aggregate: Technology Comparison



1. Sintering Technology:

- **Product:** (i) Type: Light Weight Aggregate, (ii) Geometry: Rounded
- **Design Mix:** (i) Fly Ash: ~90%, (ii) Bentonite: ~5%, (iii) Coal; ~5%
- **Process:** (i) Type: Continuous, (ii) Steps: Mixing & Palletization, Sintering >1000C
- **Codes & Standards:** BIS 9142 part-1 & 2 (Netra was involved)

2. Cold Binding Technology:

- **Product:** (i) Type: FALG Aggregate, (ii) Geometry: Angular
- **Design Mix:** (i) Fly Ash: ~88%, (ii) Lime: ~12%
- **Process:** (i) Type: Batch (~8 Hrs), (ii) Steps: Mixing & Compaction, Steam Curing (~193 C), Crushing
- **Codes & Standards:** Submitted to BIS

3. Geo-Polymer Technology:

- **Product:** (i) Type: GPC Aggregate, (ii) Geometry: Rounded
- **Design Mix:** (i) Fly Ash: ~60%, (ii) GGBS: ~35%, (iii) Chemicals: ~5% (NaOH, Sodium Silicate)
- **Process:** (i) Type: Batch (~7 Days), (ii) Steps: Mixing & Palletization, Ambient Curing
- **Codes & Standards:** Not Available



FALG 'Angular Shaped Aggregates'



LWA & Geo-Polymer 'Round Shaped'



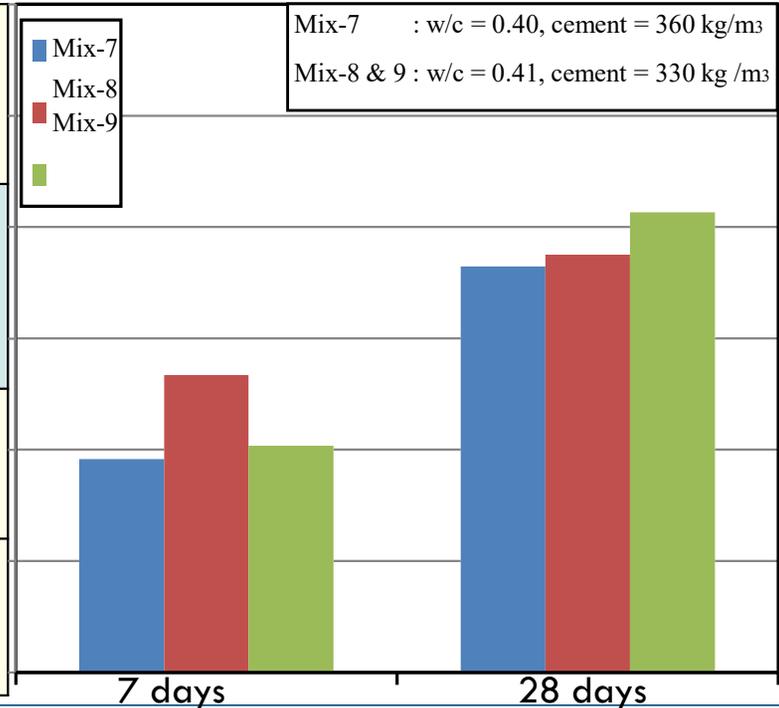
Comparison of Aggregate Properties (FALG vs Natural vs LWA)

Parameters	FALG	Natural for wearing surfaces	Natural for road application	LWA sintered aggregate
Steam Pressure	12 kg/cm ²	-	-	-
Loose Bulk Density (kg/m ³)	≤ 950	-	-	≤ 950
Water absorption**	21.1%	≤ 2%	≤ 2%	≤ 18%
Aggregate Impact value	27.4%	≤ 30%	≤ 30%	≤ 40%
Crushing Value	35.6%	≤ 30%	-	≤ 45%
Los Angeles Abrasion Value *	31.4%	≤ 30%	≤ 40%	≤ 40%
Soundness in Na ₂ SO ₄ #	10.5%	<12%	≤ 12%	≤ 12%

- ✓ **Take Away: FALG aggregates fulfil the codal provisions of LWA****
- ✓ **Report submitted to BIS for incorporation of water absorption.**

Compressive strength with FALG Aggregate: Target M25 grade of concrete

S.N.	Details	Cement	w/c ratio	obtained Density concrete (kg/m ³)	7-day Strength (MPa)		28-day Strength (MPa)		28- day Target Compressive Strength (as per IS 10262:2019)
					Individual Cube Strength	Average Strength	Individual Cube Strength	Average Strength	
Mix 7	FALG aggregate + FALG Sand	360	0.40	1778	24.8	24.58	31.2	33.23	31.6 MPa
					24.4		32.8		
					24.5		35.7		
Mix 8	Fly ash aggregate (Natural condition) + Natural Sand	330	0.41	2015	27.3	28.36	32	33.76	31.6 MPa
					29.5		34.8		
					26.8		34.5		
Mix 9	Natural Aggregate + Natural Sand	330	0.41	2370	24.2	25.17	35.7	35.67	31.6 MPa
					26.0		35.6		
					25.3		35.7		



- ✓ Average bond strength of fly ash aggregate concrete is 11% lower than that of natural aggregate concrete.
- ✓ However, the obtained bond strength of concrete fulfills the design strength for M25 as per IS:456 (2000)

30,000 M3/Yr FALG Coarse Aggregate Plant at Korba





Ash Technology Projects

Ongoing Projects:

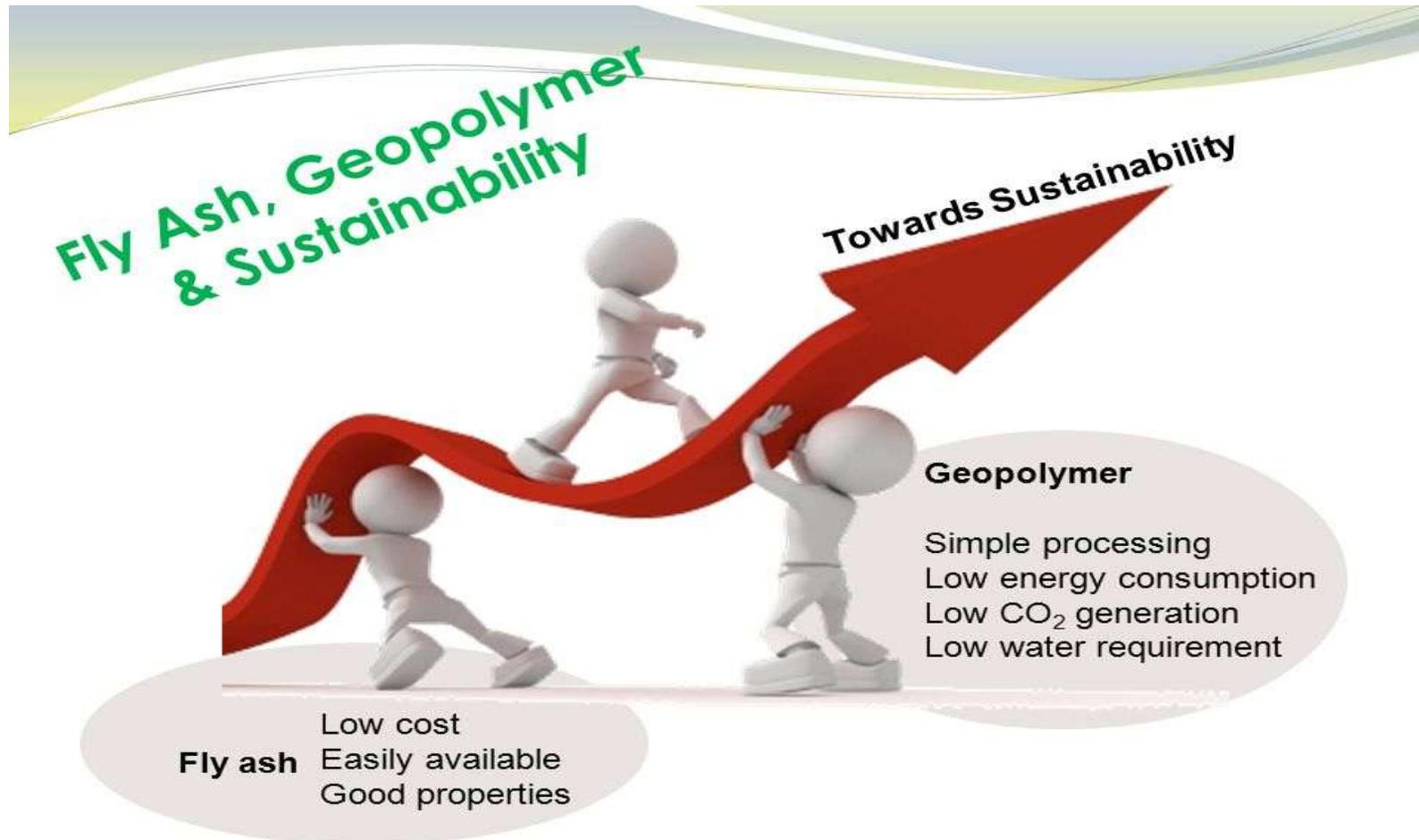
1. 100 m³/day FALG Aggregate at NTPC Korba
2. Development of Carbon Negative Building Materials

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3. Carbonated Fly Ash Aggregate



Geo-polymer concrete road



Geo Polymer Road-Snapshot

Salient Features:

- Grade M20 to M 40
- Cement free
- 50% less Co2 ↑
- 7 days curing time
- Development of retarder(>60 Min)
- IRC accreditation

Ramagundam (1.4 Km) 2019

Rihand (200 M) 2019

Farakka (50M) 2019

Roorkee / Dadri (50/100 M) 2016/2018

NETRA (2.3 Km) 2020

Kahalgaon (2.9 Km) 2021

Sipat (6.7 +
11.0 Km) 2022

Commercialization potential

1. CO2 Footprint
2. Cost
3. Strength and durability
4. Retarder

2022
Bongaigaon (2.8 Km)
Sipat (17.7 Km)
Singraulli (1.0 Km)
BTPS ECO Park -1.0 Km
Barauni -8800 Sqm
Rihand - 5.0 Km

Cost comparison:

Geopolymer Concrete - Rs 8500/m3
DSR rate - Rs 8700/m3

Patent
ganted-03
nos



Geopolymer Road Construction- Technological details

Motivation

- Bulk ash utilization initiative
- Development of technology for geo-polymeric cement free concrete

Implementation Method

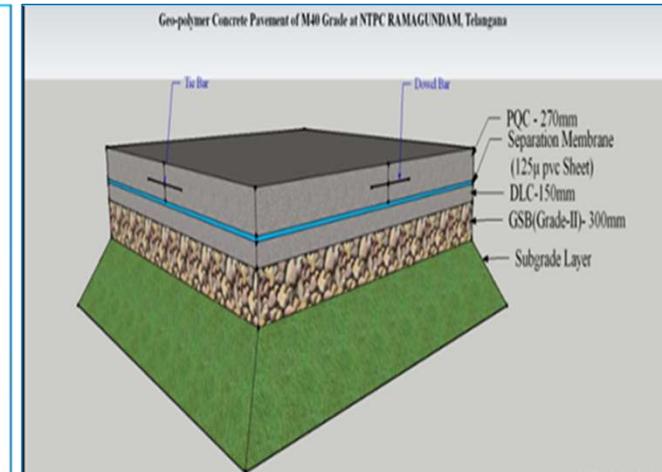
- Development of M10 & M40 geopolymeric ready mix concrete (RMC) using batching plant for first time in India.
- RMC plant capacity 15 cum/hr.
- 100 % cement replacement & 17% Ash utilisation.
- Indian Road Congress (IRC) accredited material i.e. "Geopolymer Concrete"

Challenges:

- Quick setting nature of GPC
- Development of suitable retarder.
- Vendor development in Geo-polymer technology
- Customized design mix requirement

Implementation

- Dadri 100m X 6.5 m (M40)
- Ramagundam: 1.36 km X 8.5 m
- Farakka: 50m X 7.5 m (M 40).
- Rihand – 0.2 Km x 5.5 Mtr.
- NETRA: 2.9 Km x5.0m (M30)



Geopolymer Road Construction- Replication & Scale Up



Dadri, 100 mtr x 6.5 mtr (M 40)



Ramagundam, 1.36 Km x 8.5 mtr



Farakka, 50 mtr x 7.5 mtr (M 40)



NETRA, 2.9 Km x 3.0 mtr

Geo-polymeric concrete Spun / Hume Pipes (first time in India)

Motivation:

- Bulk Ash Utilization
- MOEF guideline for 100% Ash Utilization

Technology:

- Fly ash, Slag, caustic soda and sodium silicate apart along with admixtures without any utilization of cement.

Salient Details:

- Quality standard as per IS 458, NP 3 & 4
- Pipes of Dia 600 mm, 1000 mm and 1200 mm of length 2.5 meter manufactured on 14.10.18
- Can be made of any Size as per IS 458

Benefits:

- Bulk Fly Ash Utilization (Approx. 250 Kg of Fly Ash is utilized for making one pipe of 1000 mm Dia, Concrete Volume 1 M3, Mass-2 MT).
- No use of water except in making the alkaline activator Solution
- Mould can be removed after 6 Hrs.
- Curing within 7 days, while it takes 21 days water curing for the normal concrete pipes
- No use of cement, hence reduced CO2 emission



Geo-Polymeric concrete blocks and tetra-pods –Simhadri & Koldam (90 Kg to 2T)

Motivation:

- Ash utilization technology specific to coastal stations

Technology:

- Fly ash, Slag, caustic soda and sodium silicate apart along with admixtures without any utilization of cement.

Demonstration at Simhadri (90 Kg)

- M30 grade geo-polymeric tetra pod developed at Simhadri.
- Replacement of cement and sand in concrete with ash and coastal sand & sea water in concrete mixes.
- Heat curing technology

Demonstration at Koldam (2 T)

- Volume of Tetra Pod – 0.833 M³
- Overall dimension – 1.433 Mtr
- Weight of Tetrapd-2T
- Grade – M 30

Benefits:

- Developed tetra-pod's have potential application at coastal sites and can be used as breakwater from the effects of both weather and long shore drift at NTPC Coastal & hydro station
- Enhanced fly ash utilization

Patent
granted



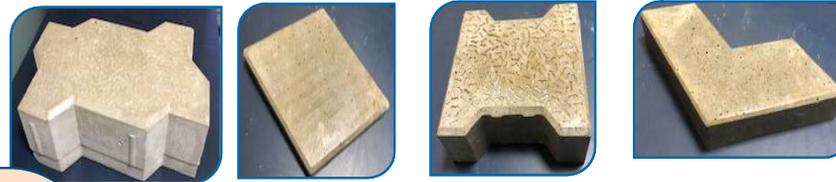
Geo Polymer Paver Blocks

Conventional Paver Blocks:

- Grade M 30
- Use of Cement
- CO₂ emission : 0.9 Kg per kg of cement
- 21 days of curing time
- Cost: Rs. 850 per Sq M for M 30 grade



Geo-polymer concrete pavers developed by NETRA

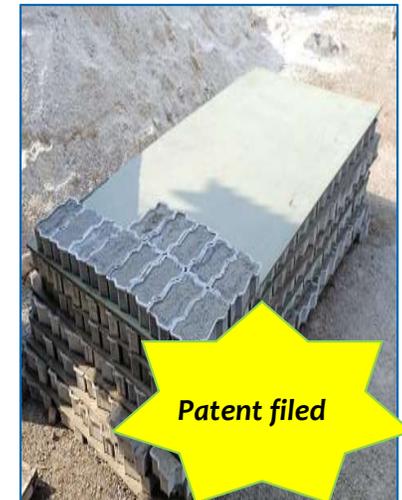


NETRA Paver Blocks:

- Grade M30-M 65
- Cement free
- CO₂ emission : 0.5 Kg per kg of cement
- 7 days of curing time
- Cost: Rs. 865 per Sq M for M 40 grade (awarded)
- DSR price Rs. 860 per Sq M for M30 grade



Revenue Generation



Paver Blocks at NTPC NETRA





Ash Technology Projects

Ongoing Projects:

1. 100 m³/day FALG Aggregate at NTPC Korba
2. Development of Carbon Negative Building Materials

Completed Projects:

1. Geopolymer Road, Pavers & Terapods
2. Bottom ash as a partial replacement of Sand in concrete
3. Carbonated Fly Ash Aggregate



Bottom Ash as partial replacement of Sand in Concrete

Bottom Ash



BA as a replacement of sand used in concrete at NETRA



Natural sand



Implementation

- Identification of physical property of aggregate that represent sand
- Minimum Fineness modulus at what % of BA in the mix
- 10 BA samples, 6 sand type, 10, 20,30, 40, 50% BA-300 samples
- Testing of 300 cubes casted as above
- Establishing value of fineness modulus for M20/30/40 strength
- Providing data to BIS for code amendment
- Internal guidelines issued to all sites, ash group in CC
- Implementation initiated in Khargone/Sipat

Salient Features

- Fineness modulus of Total Composite fine aggregate >1.35
- Upto 50% replacement of Sand by bottom ash for Concrete
- Data submitted to BIS for code amendment IS 10262:2019.

Benefit Post Code amendment

- Total bottom ash utilization
- Reduction in cost of concrete work by Rs 300/m³ of concrete



- Concrete mixes were prepared by replacing 25, 50, 75 and 100 % of natural sand and crushed sand with selected Bottom Ash. Mixes were evaluated for following properties:
- *Fresh concrete properties: slump, air content, wet density, Initial and Final setting time*
 - *Hardened concrete properties: compressive & flexural strength, Modulus of Elasticity & Drying Shrinkage*
 - *Durability properties: Pore structure study, Water permeability, Water absorption test, RCPT, Electrical Resistivity, Air permeability & Accelerated carbonation test*

Based on this study, it was concluded that 50% replacement of crushed/natural sand with “as such” fraction of Bottom Ash is technically feasible in the designed mixes of concrete for RCC work.

Studies for preparation of specifications and guidelines for use of coal based bottom ash as replacement of fine aggregate in concrete

- The recommendations of previous study were based on the bottom ash collected from only two sources i.e. NTPC Korba and NTPC Vindhyachal.
- However, for wide use of bottom ash in construction as fine aggregate it was felt that there is need for specification for conformance criteria in terms of physical and chemical parameters, so that end user can evaluate the bottom ash as per recommended specifications.
- Similarly, guidelines are also required for designing the concrete mixes for part replacement of fine aggregate by bottom ash. *To formulate specifications and guidelines for use of coal based Bottom Ash as part replacement of fine aggregate in concrete, study on 10 sources of bottom ash was conducted.*
- Bottom Ash was collected from 10 Thermal Power Plants- Badarpur, Jhajjar, Solapur, Dadri, Kudgi, Sipat-1, Sipat-2, Unchahar, Mouda & Ramagundam

Specification of Bottom Ash

Physical Properties

Sl. No.	Characteristics	Requirement
1	Material finer than 75 μ , % Max	12
2	Fineness Modulus of Bottom Ash, Min	1
3	Water absorption	2
4	Soundness (Na ₂ SO ₄), % Max	10
5	Soundness (MgSO ₄), % Max	15

Chemical Properties

Sl. No.	Characteristics	Requirement
1	Loss on Ignition, % Max	3
2	SiO ₂ , % Min	50
3	MgO, % Max	3
4	SO ₃ , % Max	2
5	SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃ , % Min	60
6	Acid Soluble Chloride, % Max	0.04
7	Total Chloride, %, Max	0.05
8	Total Alkalies as Na ₂ O equivalent, % Max	1.5

Requirements of composite fine aggregate

Sl. No.	Characteristics	Requirement
1	Minimum Requirement of Fineness Modulus of Composite Fine Aggregate	1.35
2	Max % replacement of fine aggregate by Bottom ash in composite Fine Aggregate while using OPC.	50
3	Max % replacement of fine aggregate by Bottom ash in composite Fine Aggregate while using OPC + fly ash /PPC.	25

Moving towards Eco-friendly Concrete

NTPC -Caring for the Environment

THANK YOU

