Recent Advances in Concrete and Sustainable Materials

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Session Outline

1. Sustainability
2. Sustainable Concrete
3. C & D Waste Management
4. Scientific Utilization of Industry Waste
5. Geopolymers
6. Sustainability : Factors
7. Applications

What is Sustainability?

- **Sustainability** can be defined as the

"Development that **meets the needs** of the present without **compromising the ability of future generations** to meet their own needs,"

(According to the Brundtland Commission Report (1987)).

Problem with Concrete as a Sustainable Material

- **Concrete** is the most widely used **material** and **consumes** a **great amount of resources.**
- **Contemporary Concrete**, typically, contains about
  - ✓ **16–20 percent → Cementitious Materials**
  - ✓ **6–8 percent → Mixing Water**
  - ✓ **60–70 percent → Aggregate** and
  - ✓ **2–3 percent → Admixtures By Mass.**

Why Concrete is not Sustainable ?

- In **Cement Manufacture**, **Limestone** has to be decomposed as

$$\text{Limestone}(CaCO_3)(1000^{\circ}C) \rightarrow CaO + CO_2$$

$$(100) \qquad (56) \qquad (44)$$

- ✓ One ton of cement contains **620kg CaO**, and hence **$CO_2 = 620 \times 44/56 = 487$ kg.**
- ✓ *CO_2 is also* produced from **Fuel Burning** during the cement production.
- ✓ The amount is from **320 kg to about 450 kg** and depends on the **advances of the burning technique.**

Why Concrete is not Sustainable? Cont…

- Requires
  - ✓ **Mining,**
  - ✓ **Processing,**
  - ✓ **Transport of huge quantities of aggregate**,
  - ✓ **Billions of tones** of **raw materials needed** for **cement manufacturing,**
  - ✓ **Utilizes considerable energy,**
  - ✓ **Adversely affects the ecology of virgin lands.**
  - ✓ **A large amount of CO2 is produced.**

Why Concrete is not Sustainable? Cont…

- **Huge consumption of natural resources** has a great **impact on environment**,
  - ✓ if **not well controlled**,
    - Definitely compromise the **ability of future generations** to meet their own needs.

Concerns : Sustainability of Concrete?

- The considerations on **sustainability of concrete** may contain **three aspects:**
  1. **How to Reduce Gas Emissions, especially CO_2 emissions ?**
  2. **How to Reduce Energy Consumption ?**
  3. **How to reduce raw materials consumption from natural resources during production, construction, and application of concrete?**

Sustainable Concrete

Video

Possible Solutions for Sustainability

How To Make Concrete More Sustainable?

- The **three methods** of achieving **sustainability of concrete** are
  - ✓ **Reduce,**
  - ✓ **Reuse, and**
  - ✓ **Recycle.**

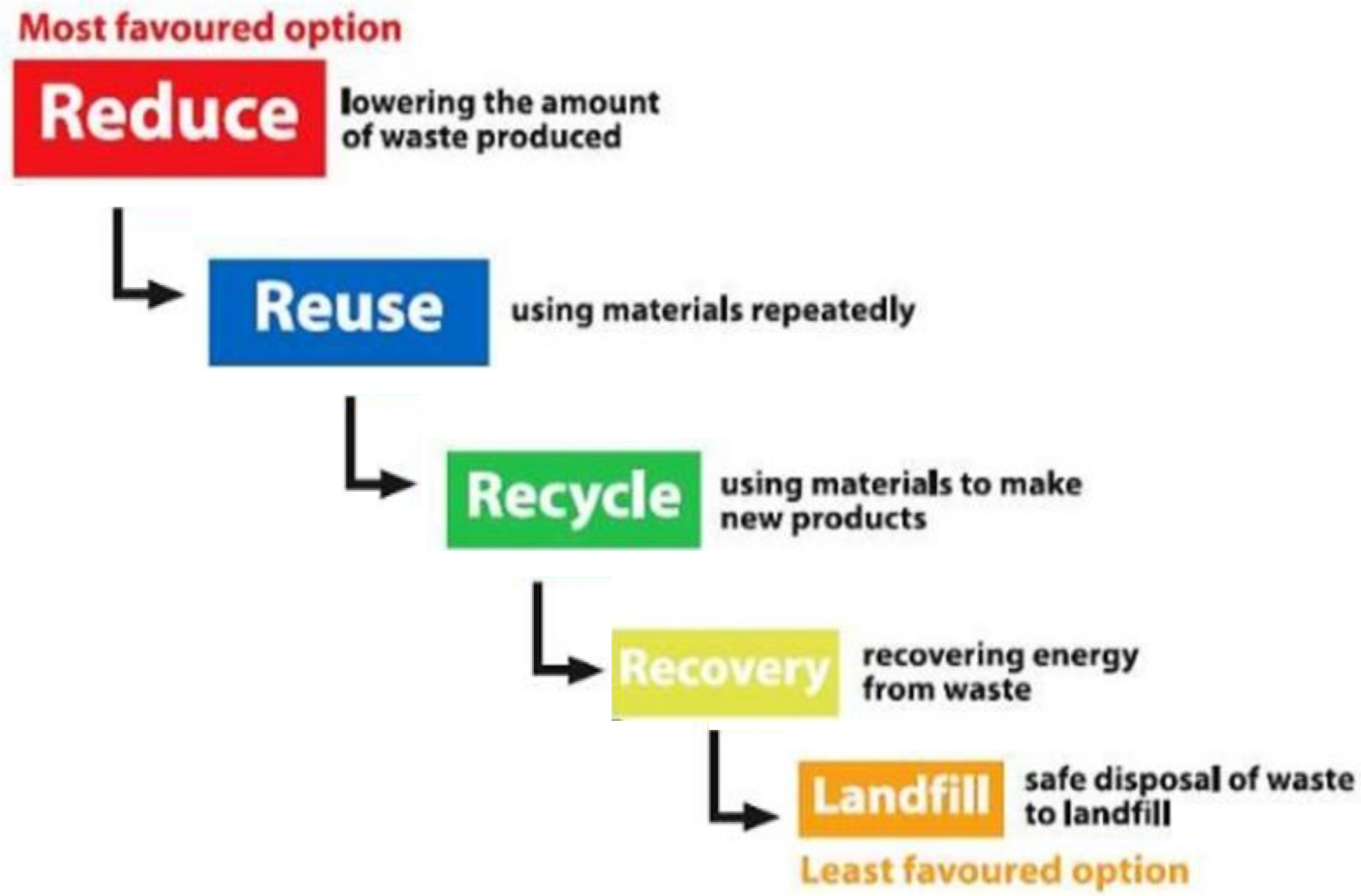
Cont..

- It should be emphasized that as **more and more concrete structures age**, **more and more demolished concrete will be produced.**
  - ✓ If it cannot be **recycled and reused**,
    - The **deposition of the construction waste** will **cause another environmental problem.**

Cont..

- **Aggregates recycled** from demolished concrete are usually more **porous and weak**.
- Hence, it is important to **develop some technique** to **overcome the problem** and ensure the **quality of the concrete** made of **recycled aggregates.**

Hierarchy for C & D Waste Management



C & D Waste Management

C & D Waste Management : Introduction

Construction waste: Unwanted materials generated during construction processes. For example: Demolished concrete fragments, Brick pieces, Wood, Plastic wastes etc.

Reuse: The process of using a material again for same or a different function. For example: Using coarse aggregate obtained from concrete waste, for preparation of fresh concrete.

Recycling: The process of converting waste materials into new ones for reduction of waste of potentially useful materials.

What is C & D Waste?

Renovation
40%

Demolition
50%

New Construction
10%

C & D Waste

- ❖ **"Construction and Demolition Waste"**
  - ✓ **Waste** comprising of **building material debris and rubble** resulting from **construction re-modelling/renovation, repair and demolition** of **any Civil Engineering Structure**

C & D Waste

Whether these structures will have prescribed useful life?

Unsafe construction

Waste is created from non engineered poor quality construction

Poor quality of construction and maintenance

Environment Concern

Necessity of Reusing and Recycling of Construction Waste

- ❖ **Disposal** has also emerged as a **problem in India**.
  - ✓ **India** is presently generating **construction and demolition waste** to the **tune of 23.75 million tons.**
  - ✓ Yet, **no disposal method** is being practiced in **70 percent of the industry** because of the **easy availability of the raw materials.**
- ❖ Due to **unlimited use of aggregates**,
  - ✓ The **extinction of naturally occurring materials** will soon take place. Due to this, the **application of reusing and recycling of waste materials** is favoured.

Why to focus on Concrete

- It is the most commonly used **construction material** (**1 ton for every man on earth**)
- **Aggregates** are
  - ✓ Used in **concrete** for **very specific purposes.**
  - ✓ Typically make up about **60% to 75% of the volume** of a concrete mixture,
  - ✓ **Least expensive of the materials** used in concrete,
  - ✓ The **economic impact is significant.**

Cont…

- Compared to other **comparable building materials**, **concrete is less costly** to **produce and remains extremely affordable.**

Demolished Concrete

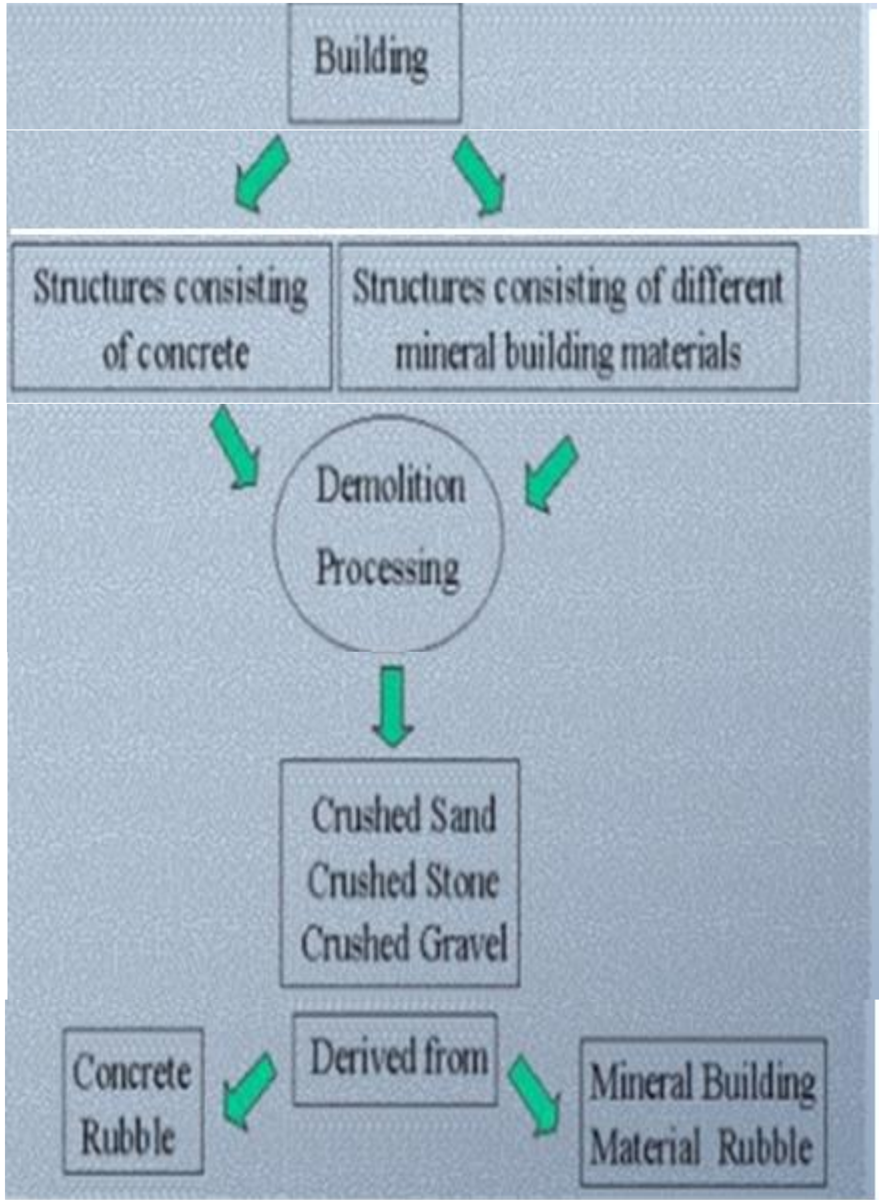
- Sometimes, the **concrete material** has to be **demolished** during **ongoing or old construction.**
  - ✓ The **concrete waste** obtained from these **processes** is called **Demolished Concrete**.
- It is a very common **type of waste** generated during **Pile foundations, Precasting** etc.

What does C & D Waste Consists

- Concrete
- Brick
- Timber
- Sanitary ware
- Glass
- Steel
- plastics

Process of Reusing Demolished Concrete

- **Collections of Construction Scraps** from the site
- **Classify them** according to their properties
- Send them to the **Separation and Treatment Plant**
- **Differentiating the Components** i.e. the **Aggregates, Treating them, and finally reusing them** for **constructing Fresh Concrete**



What to do?

- ❖ **Store at Source**
  - ✓ **Appropriate storage Space.**
- ❖ **Segregate**
- ❖ **Then**

Process of Recycling the Demolished Concrete

- There are many **processes for recycling**. However, the **common procedure adopted** is:
  - ✓ **Collection of Waste from the Site.**
  - ✓ **Transporting to the Recycle unit.**
  - ✓ **Initial crushing and Sieving.**
  - ✓ **Final crushing and Grinding.**
  - ✓ **Forwarding it to the Constructing unit.**

Mechanical Sorting Process

- ❖ **Bar Screening**
- ❖ **Magnetic Separation**
- ❖ **Air Classifier**

Alternative of Natural Sand Recycled Sand

Properties and Experimental Verification

❖ Particle Size Distribution

- ✓ **Sieve Analysis** is done after **crushing and sieving** as per **IS Code 2386** to **separate out coarse** and **fine aggregate.**
- ✓ **Recycled aggregate** meets all the **standard requirements of natural aggregate**

❖ Specific Gravity & Water Absorption

- ✓ **Sp. Gravity** (saturated surface dry condition) of **recycled concrete aggregate(RCA)** was found from **2.35 to 2.58** which is slightly lower than **natural aggregate.**

Sorting Process of Construction & Demolished Waste

Chemical Mineralogical Appraisal

Mechanical Sorting

Observation

- **Water Absorption** ranges **3.05% to 7.40%** which is **slightly natural aggregate.**
- **Modulus of Elasticity**
  - ✓ **RCA** has lower than **NCA** up to 15% only.
  - ✓ It can be increased if **hardened cement paste** adhere to **aggregate are removed well.**

Observation

- **Compressive Strength**
  - ✓ The **average compressive strengths**
    - **cube cast are determined** as per **IS 516** using **RCA** and
    - **Natural aggregate at age 1, 3, 7, 14, 28, 56 and 90 days.**
  - ✓ **Reduction in strength of RCA** as compared to **NCA:**
    - **2-14 % = M-20**

Crushing and Impact Values

- As per **IS 2386**, the **crushing & impact values** for **concrete, wearing surfaces** should **not exceed 45% and 50%** respectively.
- **RCA** should satisfy the **BIS specifications.**

Challenges in Indian Context

- For **Recycled Concrete** to be used in **greater quantities** in a **country like India**, there are **certain aspects** that need to be taken care of **initially.**
- The **setting up of a proper institutional mechanism** for taking care of all the steps, such as **collection of the construction and Demolition Waste, Transportation,** and **Disposal is of Key Importance.**
- **Outsourcing** of such functions to **private enterprise** is an idea that the **concerned authorities** could give a thought to in this day and age of **open economies.**

Steps to be Taken

- Set up of the **necessary processing infrastructure**.
- **Necessary infrastructure** should also be available for **testing the quality of recycled aggregates.**
- **Project developers** need to be **educated on on-site waste management plans.**
- **Concerned authorities** need to plan an **awareness campaign**, using the **electronic and online media** to promote the **virtues of recycled aggregates.**
- **Removing misconceptions** about **recycled aggregates** as being of **inferior quality among the public.**

Private Construction

- The **Indian real estate market size** is expected to reach **US $180 billion by 2020.**
- Thus **C & D waste** both from **new construction and Demolition** (Re-development) is **going to be generated.**

Advantages: Recycled Concrete/ Aggregates

- The advantages of using **recycled concrete/ aggregates** are:
  - ✓ **Conserve diminishing natural aggregate resources**
  - ✓ **Use of construction wastes**
  - ✓ **Protection of environment**
  - ✓ **Economical**
  - ✓ **Create additional business opportunities**
  - ✓ **Avoids excess Landfilling**

Disadvantages: Recycled Concrete/ Aggregates

- **Inexperience with recycled aggregate products** due to **lack of exposure** still remain a **surmountable barrier** to the **recycled concrete market.**
- **Water pollution** can also happen during **recycling process.**
- It is still **not feasible in all sites** and requires **heavy machinery and equipment's.**

Reuse

Reuse

❖ **"De-construction"** means a **planned selective demolition** in which

- ✓ **Salvage,**
- ✓ **Re-use and**
- ✓ **Recycling of the Demolished Structure is Maximized**

Recycling

CPCB Guidelines 2017

- The **guidelines** recommends **pollution mitigation measures** in operation of **C dump sites / processing facilities.**
- Mainly for **bulk generators in cities / towns**


GUIDELINES ON

ENVIRONMENTAL MANAGEMENT OF CONSTRUCTION & DEMOLITION (C & D) WASTES

(Prepared in compliance of Rule 10 sub-rule 1(a) of C & D Waste Management Rules, 2016)

Illegal dumping causes loss of potential to reuse / recycle of C&D wastes

MARCH 2017

cpcb

CENTRAL POLLUTION CONTROL BOARD

(Ministry of Environment, Forests & Climate Change)

Recyclable-Concrete

Video

Scientific Utilization of More Industry Waste

Scientific Utilization of More Industry Waste

- One way to make **concrete sustainable** is to
  - ✓ **Utilize industry waste** or
  - ✓ **By-products to replace** the **raw materials for making concrete**, such as **cement and aggregates**.
    - The **industry by-products** utilized to **replace cement** are usually called **Supplementary Cementitious Materials (SCMs).**
    - Currently, **Blast Furnace Slag, Fly Ash, Limestone Powders, And Silica Fume** are the most commonly used SCMs.

Recycling in Concrete Industry

- **Concrete industry also recycles**
  - ✓ The waste products of the electric and steel industries as substitutes for virgin raw materials of concrete industries, thereby reducing the environmental impact of both.
- **Moreover, these SCMs**
  - ✓ contain reactive silica that can react with CH in concrete to form secondary C–S–H and to improve concrete properties. Due to the incorporation of SCMs into concrete, the structure of concrete at the nanometre and micrometre levels becomes more complex.

Why Not OPC?

- It is the most **consumed commodity** in the world **after water.**
- It is also the **most energy intensive material**
- **Cement production** leads to **high carbon-dioxide emission.**
  - ✓ **1 ton of CO_2** is produced for **every 1 ton of cement.**
  - ✓ It is produced by **calcination of limestone** and **burning of fossil fuels**

Alternatives for Sand amd OPC

Fine Aggregate s are:

Manufactured Sand For Concrete

Recycled Glass Aggregate

Blast Furnace Slag (BFS)

Fly Ash

Recycled Waste Glass an Aggregate for Concrete

Low Energy and Low CO_2 Emission Binders

- One system along this line is **alkaline-activated cementitious materials,** in which **geopolymer** and **alkaline activated slag** are **two good examples.**

- A **new high belite cement** was developed recently in **China (Sui et al., 2009).**

  - ✓ This type of **belite-based Portland cement** (**High Belite Cement, HBC**) contains **45–60% C2S, 20–30% C3S, 3–7% C3A, and 10–15% C4AF.**

Comparison of Energy Consumption

- **Comparison of energy consumption** and **CO_2 emission for C2S and C3S Formation**

Mineral	Formation Enthalpy kJ/kg	Température oC	CaO%	CO_2 Emission Coefficient
C3S	1848	1450	73.7	0.578
C2S	1336	1300	65.1	0.511

Why Geopolymer Concrete?

- **Reduces the demand of OPC** which leads **CO_2 emission.**
- **Utilise waste materials** from industries such as **fly ash, silica-fume, GGBS.**
- **Protect water bodies** from **contamination due to fly ash disposal**.
- **Conserve acres of land** that would have been used for **coal combustion products disposal.**
- Produce a more **durable infrastructure.**

Geopolymer Concrete A Sustainable Material

- **Geopolymer concrete** is an innovative, **eco-friendly construction material.**
- It is used as **replacement of cement concrete.**
- In **geopolymer concrete cement** is not used as a **binding material.**
- **Fly ash, silica-fume, or GGBS**, along with **alkali solution are used as binders.**

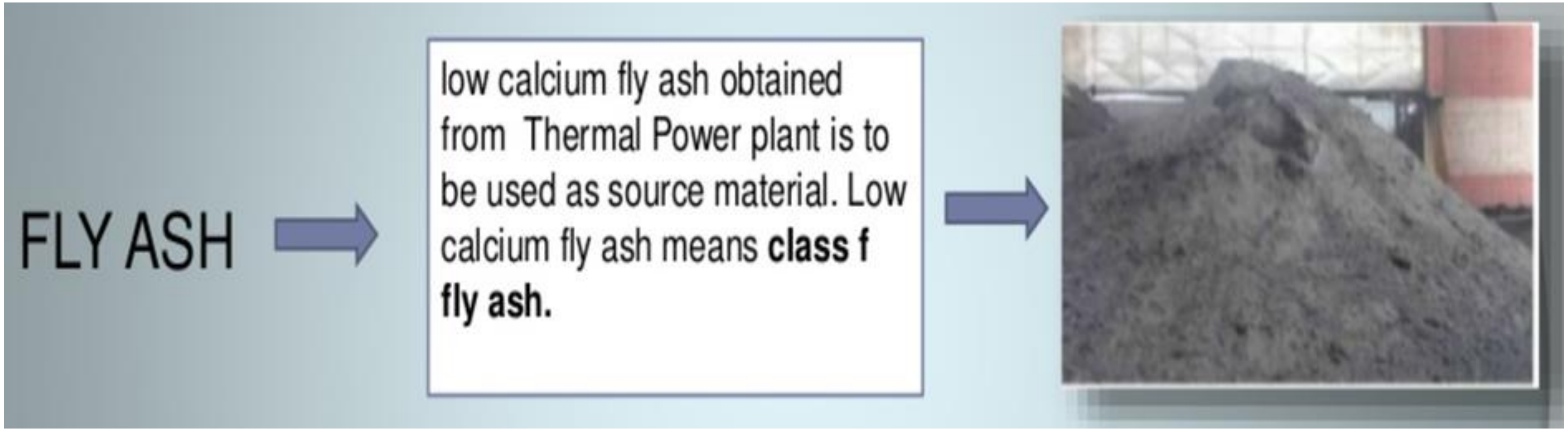
What is the Geopolymer Concrete?

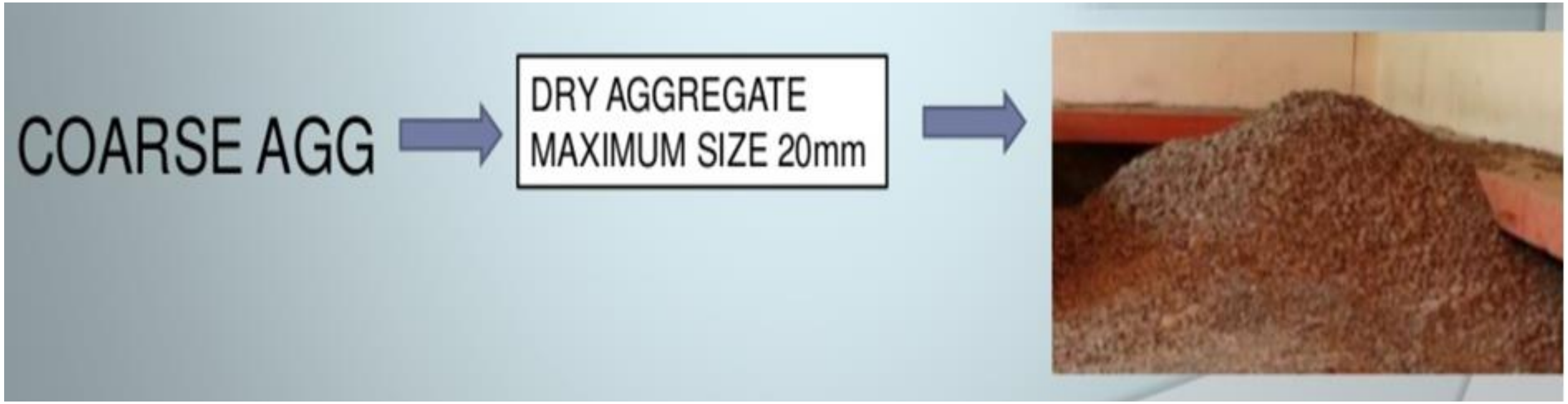
- An **innovative material** that is characterized by **long chains networks** of **inorganic molecules**—is a potential alternative to **conventional port land cement concrete.**

Constituents

- **Coarse Aggregate**
- **Fine Aggregate** → Sand or bottom ash can be used
- **Admixture** → Superplasticizers (naphthalene based or naphthalene sulphonate based)
- **Alkaline Activators**
  - ✓ Alkaline activation is a process of mixing powdery aluminosilicate with an alkaline activator .
  - ✓ It produce a paste which sets and hardens within short duration

Material Used For Making Geopolymer Concrete





Material Used in GPC

FINE AGG.

The locally available fine aggregate, confining to Zone II. Initially the aggregate chosen is sieved through 2.36mm and the passing material is chosen for the test.

SODIUM HYDROXIDE &
SODIUM SILICATE

Desirable Properties of Aggregate Used in Concrete

PHYSICAL PROPERTIES	COARSE AGGREGATE		FINE AGGREGATE
	CA 1	CA 2	FA (SAND)
TYPE	CRUSHED	CRUSHED	SAND
MAXIMUM SIZE	20mm	12.5mm	4.75mm
SPECIFIC GRAVITY	2.65	2.65	2.5

GGBS(Ground, Granulated Blast Furnace Slag)

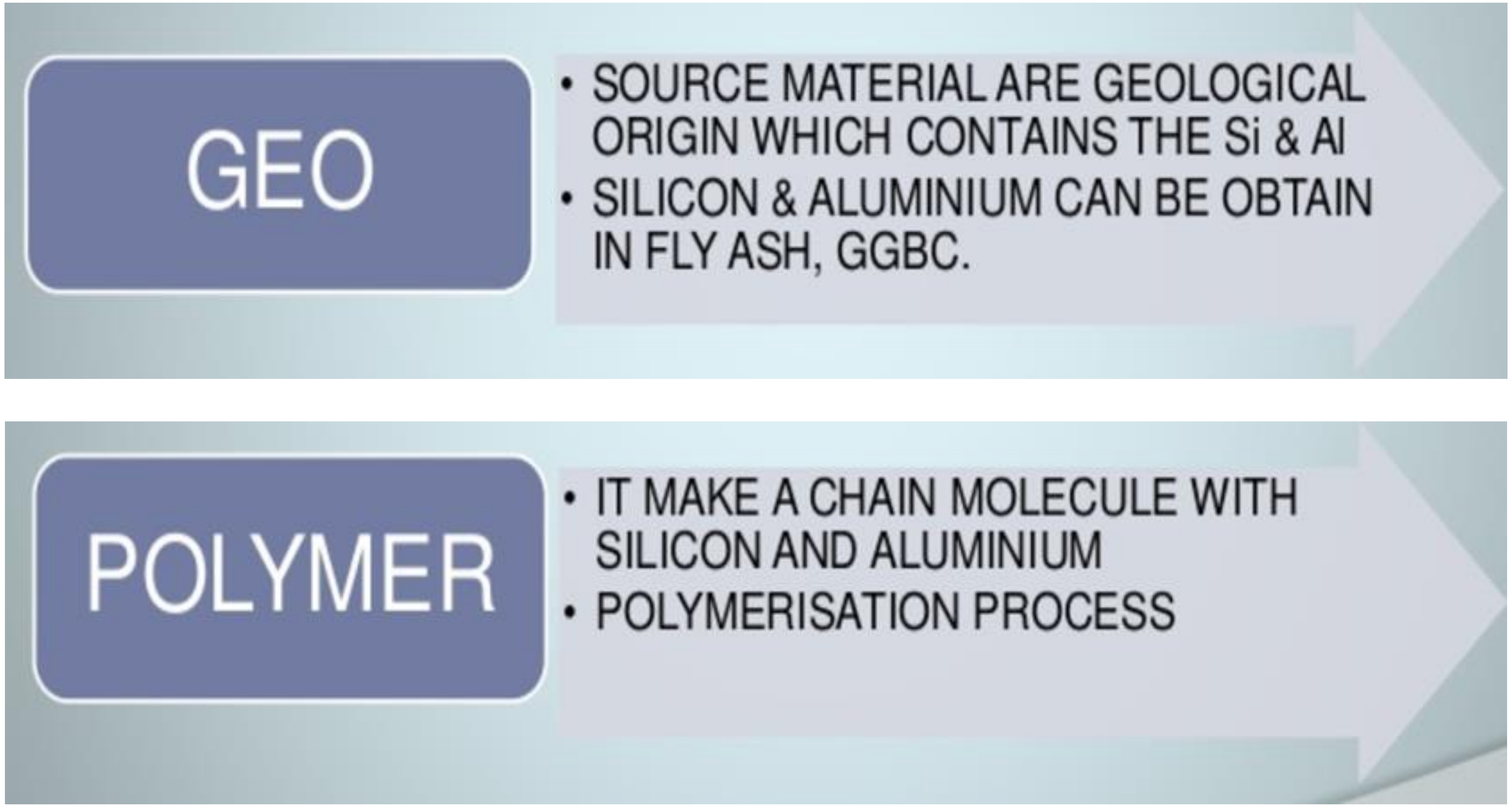
- A **Mineral Admixture** of **silicates and aluminates of Ca** and other bases
- Same main **chemical constituents as OPC** but in different proportions
- Improves **compressive strength of GPC**

Table : Chemical Composition of GGBS

CEMICAL CONSTITUTION	CEMENT(%)	GGBS(%)
Calcium oxide	65	40
Silicon dioxide	20	35
Aluminium oxide	5	10
Magnesium oxide	2	8

Geopolymer Concrete

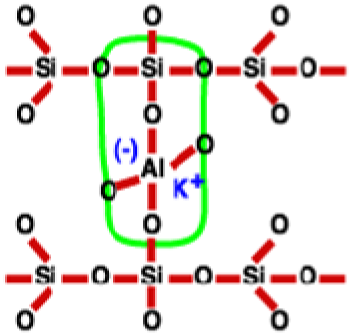
Why it is Called "Geopolymer" Concrete?

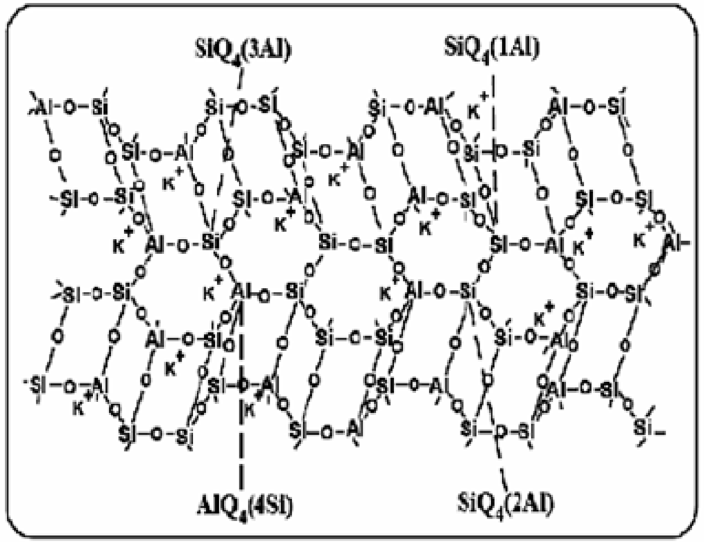


Geopolymers

Geopolymers

- **Geopolymers** are **cementitious materials** that do not require the presence of OPC to harden or gain strength.
- **Geopolymers** are formed by a **3d network of Si & Al mineral molecules** linked through **covalent bonds with oxygen molecules**.
- A **positive ion** must be provided to **allow aluminium** to become tetravalent.





Geopolymers

- The source of **Si & Al for geopolymers** can be **any mineral (e.g. metakaolin) or by-product (e.g. fly ash)**
- The **positive ion** is usually provided by a **hydroxide solution of Na or K**, etc.
- **Water glass** provides the **monomers** from which the **polymeric chains grow.**
- In most cases a slightly **elevated temperature** is required to kick start the **geo-polymerization reaction**

Geopolymerization

- **Geopolymeric reaction** occurs can be divided into **three steps:**

1. **Dissolution of species** - Si and Al dissolve in the alkaline media providing monomers.
2. **Transportation/Initial gelation-** Orientation of the precursors takes place.
3. **Condensation/setting-** Hydrolyzed aluminate and silicate species policondensate and harden

Types of Geopolymer

- **Slag based geopolymer**
- Slag is a mixture of **metal oxides and silicon dioxide**
- A **transparent by-product material** formed in the **processing of melting iron ore.**
- **OPC replacement** with slag improve workability and **reduce lifecycle costs**
- It also increase its **compressive strength**
- **Examples : Corex Slag, Steel Slag, Iron Blast Furnace Slag**

Mixing

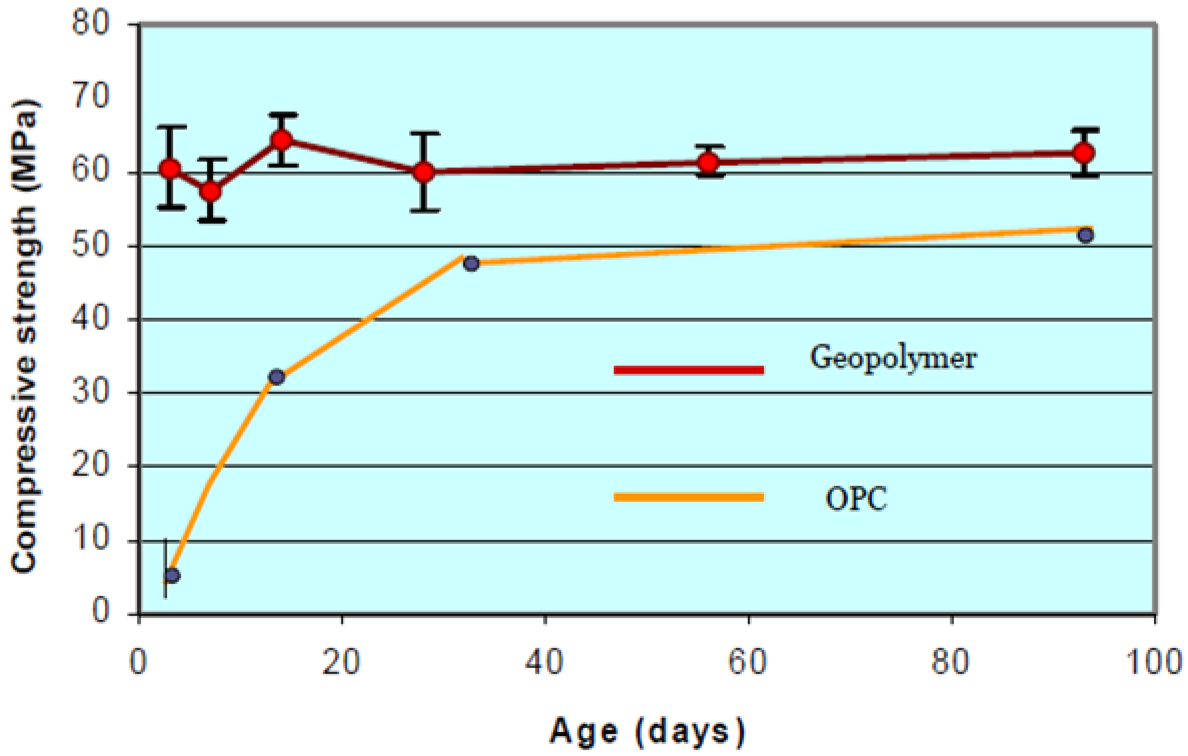
Geopolymer paste can be mixed with the same aggregates used for Portland cement, for its use as mortar or concrete.

ACTIVATOR SOLUTION + FLY ASH + FINE & COARSE AGGREGATES

Tests on Geopolymer Concrete

Properties

Typical compressive strength curve of Geopolymer vs. Portland cement. Observe the high early strength of geopolymer (up to 12,000 psi after 3 day of curing).

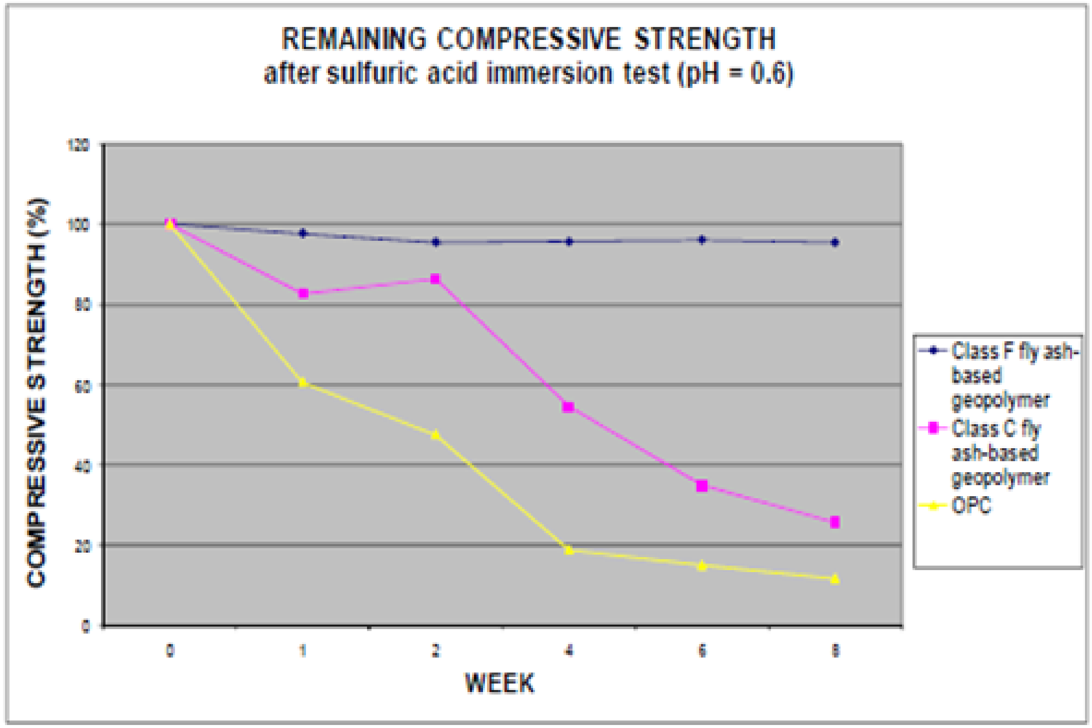


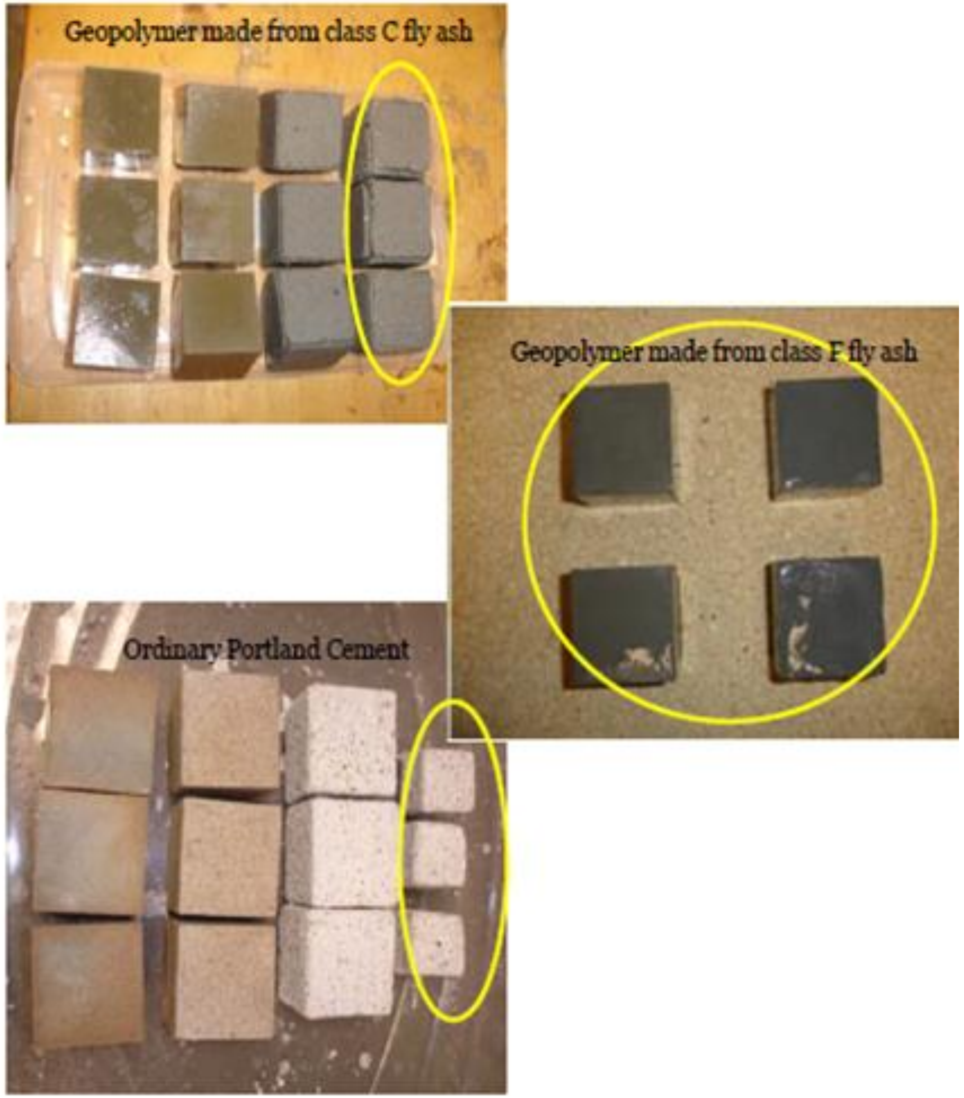
COMPRESSIVE STRENGTH

Properties

CHEMICAL RESISTANCE

Geopolymer's corrosion resistance to the attack of sulfuric acids is significantly greater than that of Portland cement. It is practically inert to sulfate salts attack.





Test On GPC

- **CREEP TEST**
  - ✓ **Three 150x300 mm** cylinders prepared
  - ✓ **Placed on creep testing frame** with hydraulic loading system
  - ✓ Before **loading 7th day compressive strength** determined
  - ✓ Load corresponding to **40% of mean compressive strength** applied
  - ✓ **Strain values measured and recorded**
  - ✓ Test conducted at **23°C and relative humidity 40-60%**

Test On GPC

- **Creep of GPC** smaller than that of **OPC smaller creep** due to **block polymerisation concept**
- Presence of **micro-aggregates** increase **creep resisting function**
- **In GPC** in **OPC creep caused** by cement paste

Drying Shrinkage Test

- **75x75x285 mm prisms** with gauge studs used
- Specimens kept in a **controlled temperature environment**
- **Temperature at 23°C** and relative **humidity 40-60%**
- **Shrinkage strain measurements** taken on **third day of casting concrete**
- Specimen demoulded and **1st measurement taken**
- **Horizontal length comparator** used for measurement
- **Next measurement** taken on 4th day
- **Further measurements** taken till one year

Compressive Strength

- **Higher Compressive Strength** when **heat activated**
- **Slag addition** improves compressive strength at **ambient temperature curing**

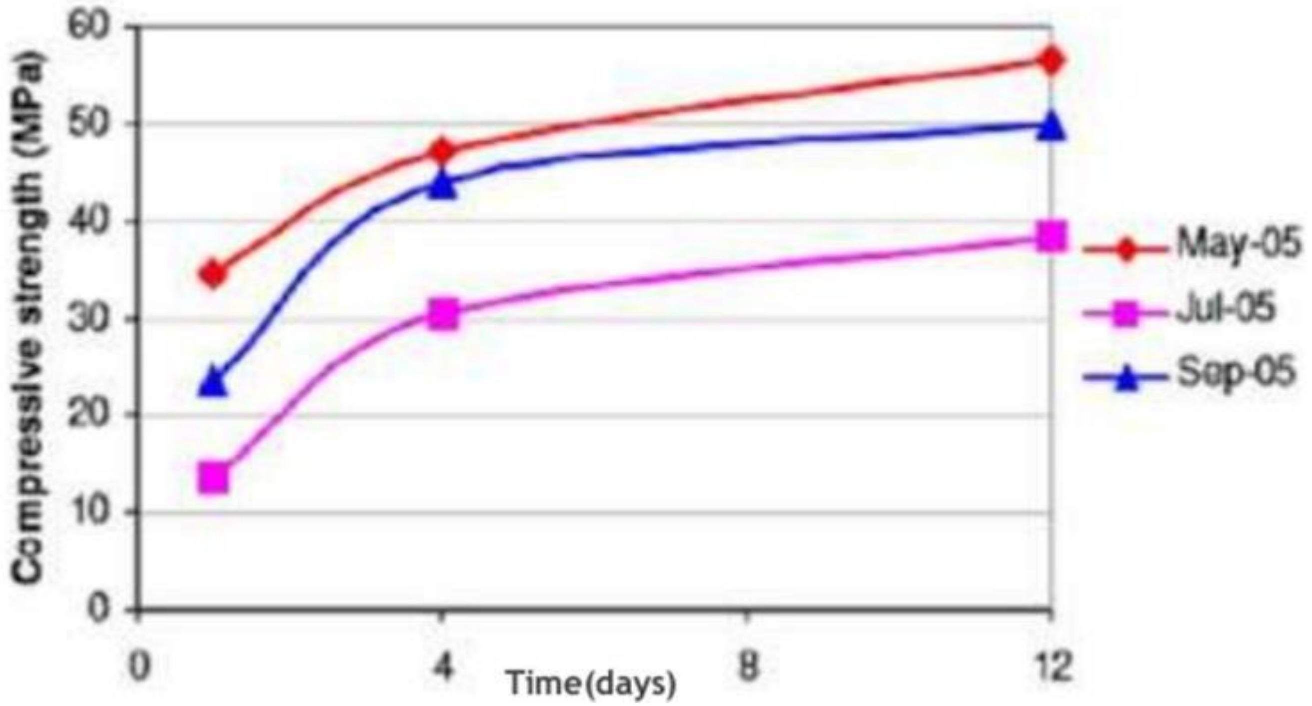


Figure- Compressive Strength Of Geopolymer Concrete In Ambient Condition

Compressive Strength- Cont

- **Compressive strength** of **GPC decreased** with **increasing fly ash content**
- It increased with **higher aggregate content**
- **Higher Strength** at **lower alkali content**
- **Compressive Strength increased** with age
- **Polycondensation** of **silica and alumina contribute** to **high strength**

Modulus Of Elasticity And Poisson's Ratio

- **Modulus of elasticity increased** with **compressive strength in OPC**
- Similar **trend in GPC** but **values lower than OPC**
- **GPC cured at elevated temperature** yields **higher value of E** than **cured at ambient temperature**
- **Poisson's ratio of GPC** similar to that of **OPC** and **increased with compressive strength**

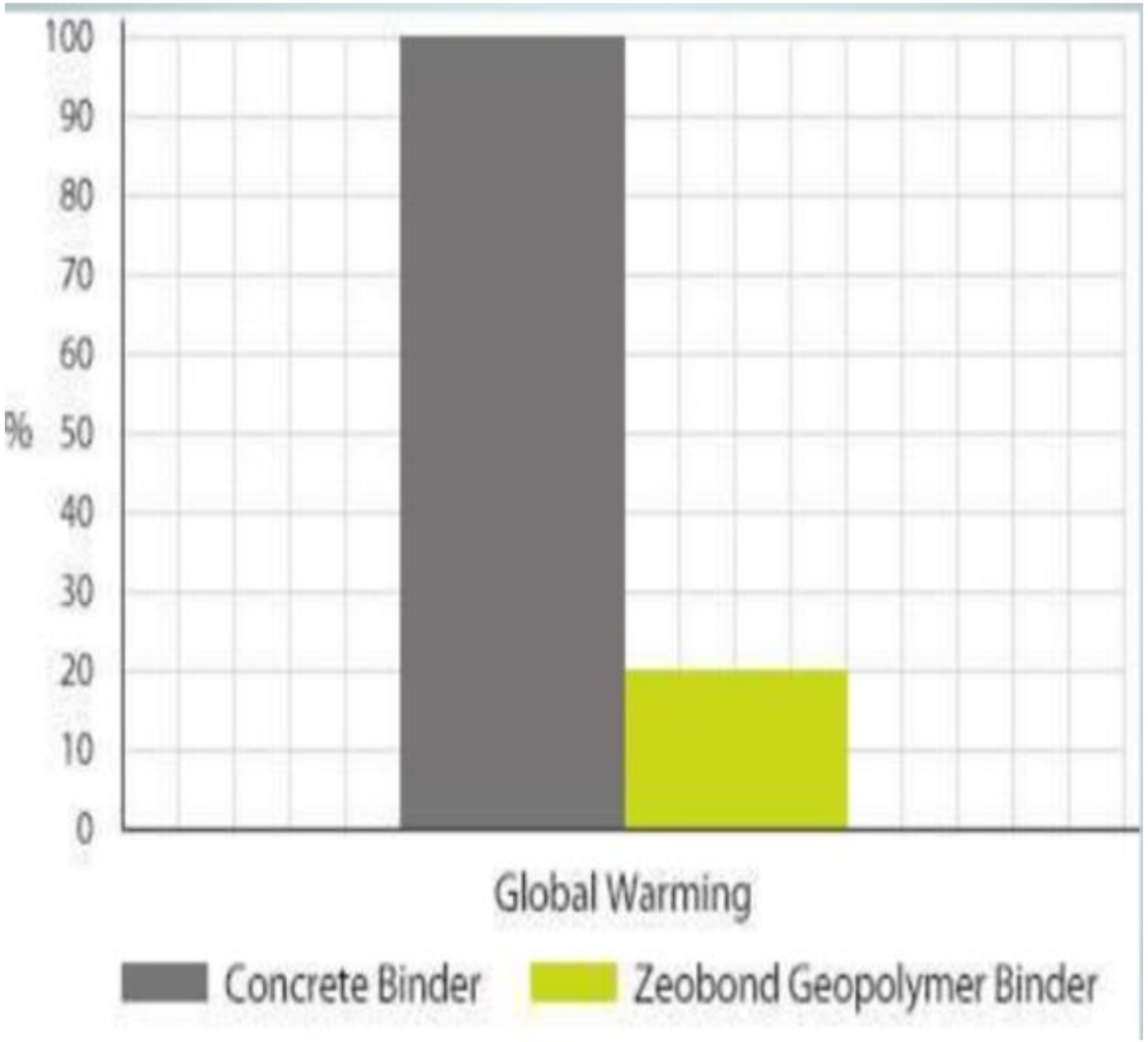
Properties

- **Workability**
  - ✓ Increase in **NaOH and sodium silicate solution** reduce **flow of mortar**
  - ✓ **Superplasticizer or extra water** can be added to **increase workability**
- **Compressive strength**
  - ✓ It depends on **curing time and temperature**
  - ✓ It increase with **fly ash content**
  - ✓ it increase with **fineness of fly ash**

Resistance against Aggressive Environment

- Used in **constructing marine structures**
- In OPC white **layer of crystals formed on acid exposed surface**
- In GPC there is **no gypsum deposition** and **no visible cracks**
- A **soft and powdery layer** formed during **early stages of exposure** which later becomes harder
- Mass loss on exposure to **H2SO4 in GPC was 3%** and in **OPC 20-25%**
- **Higher the alkali content higher the weight loss**
- **GPC showed better resistance**

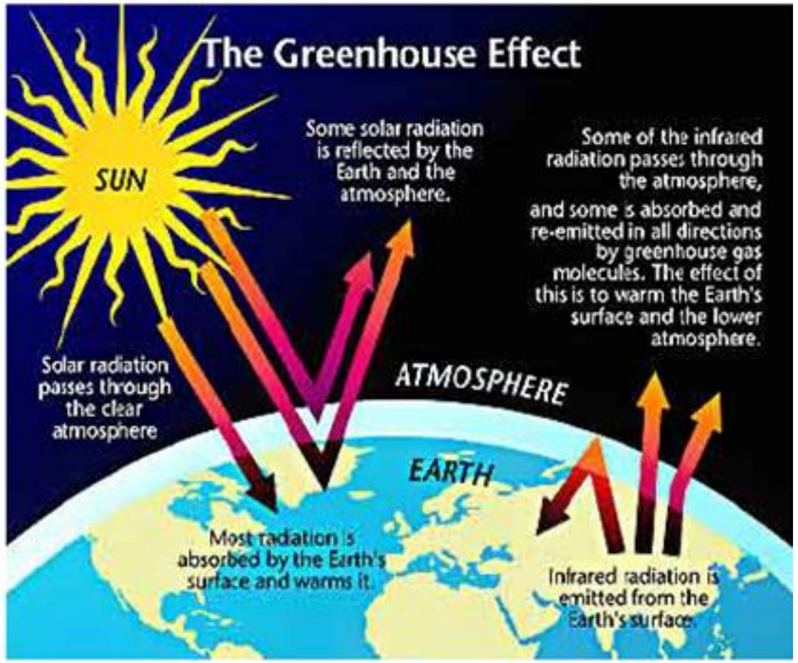
Comparison Between Emission of Carbon Dioxide in OPC and GEO-POLYMER CONCRETE



Sustainability :Issues

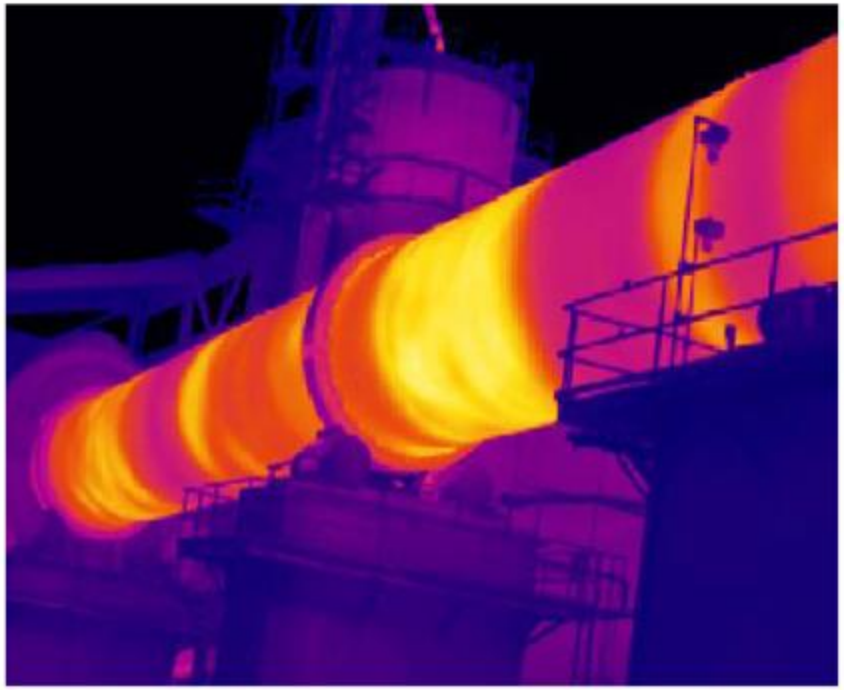
Sustainability : Pollution And Ecological Footpri

- **Actual production of Portland cement** contributes **13.5 billion tons of CO_2** per year. Approximately 5% of the total global emission of CO2 to the atmosphere.
- **Geopolymer** made **out of waste materials** like **fly ash** not only have a smaller footprint but help reduce the footprint of other industries namely, coal-fired power plants.



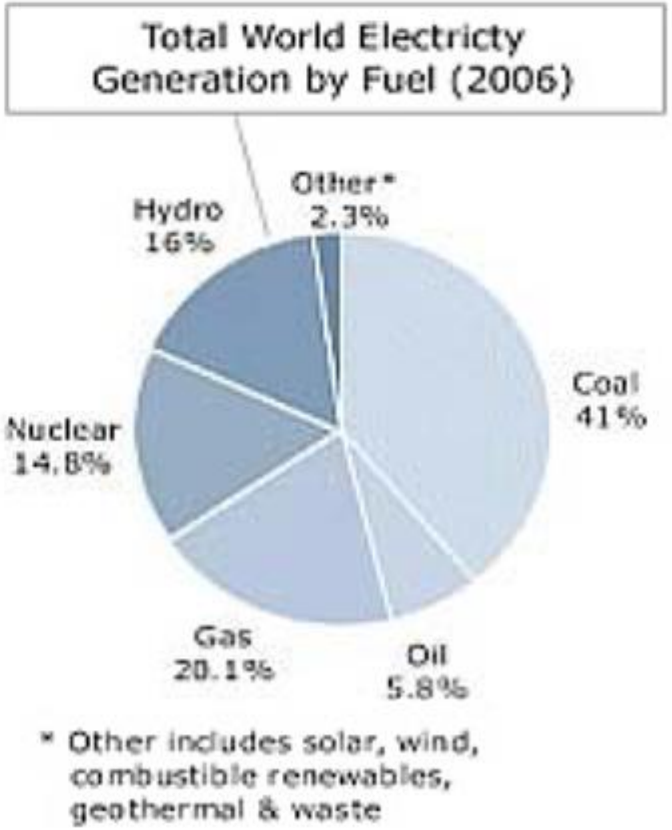
Sustainability : Energy Consumption

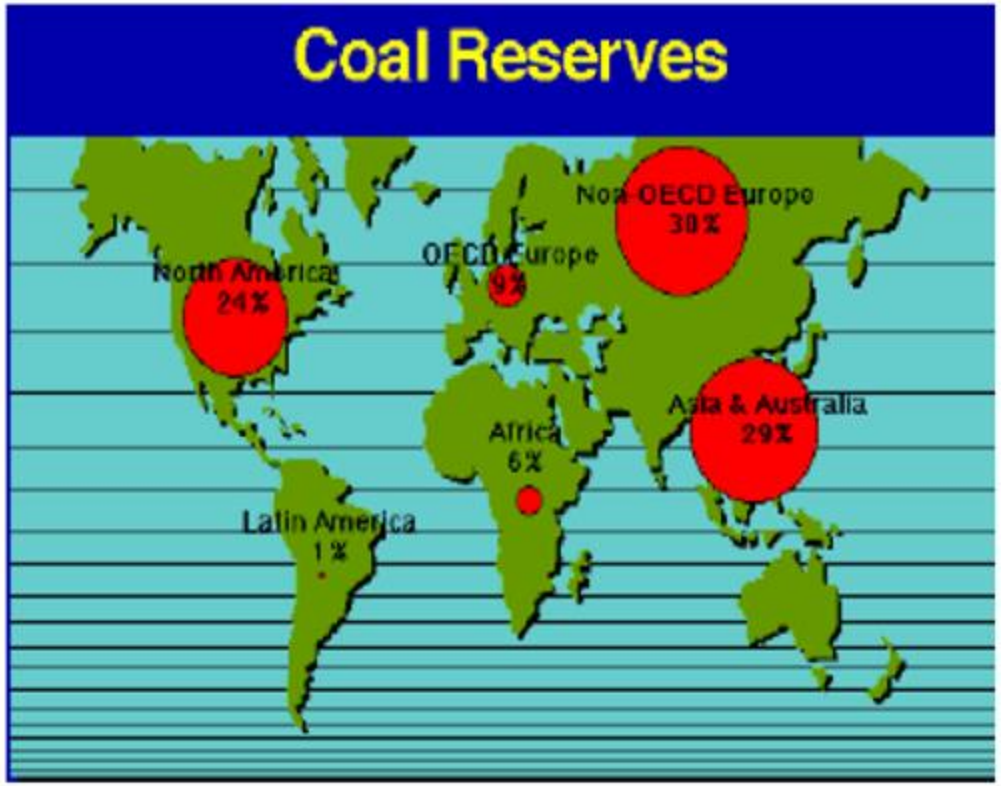
- **Portland Cement Production** requires **heating raw materials over 2550 F**
- **Fly ash based-geopolymers** are a much **less energy consuming alternative.**



Sustainability

- 480 Million Tons of fly ash produced in 2001
- World wide utilization ranges 20 to 80%

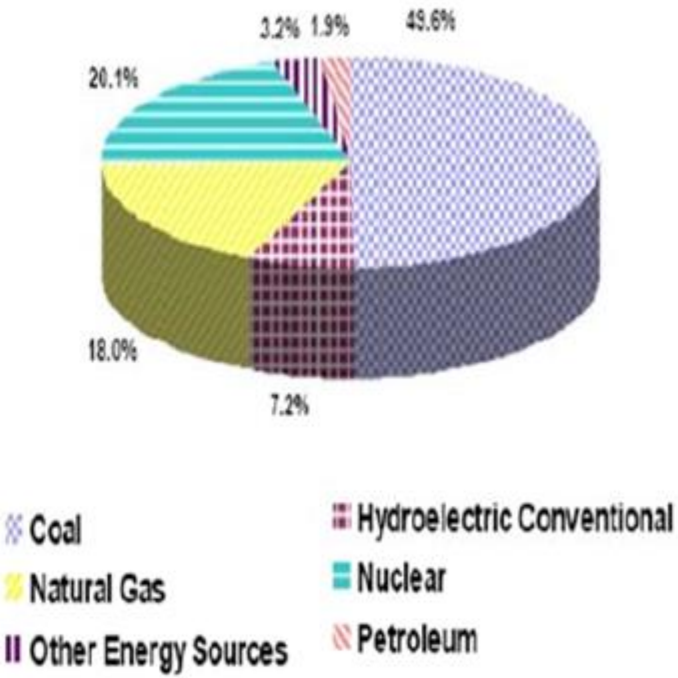




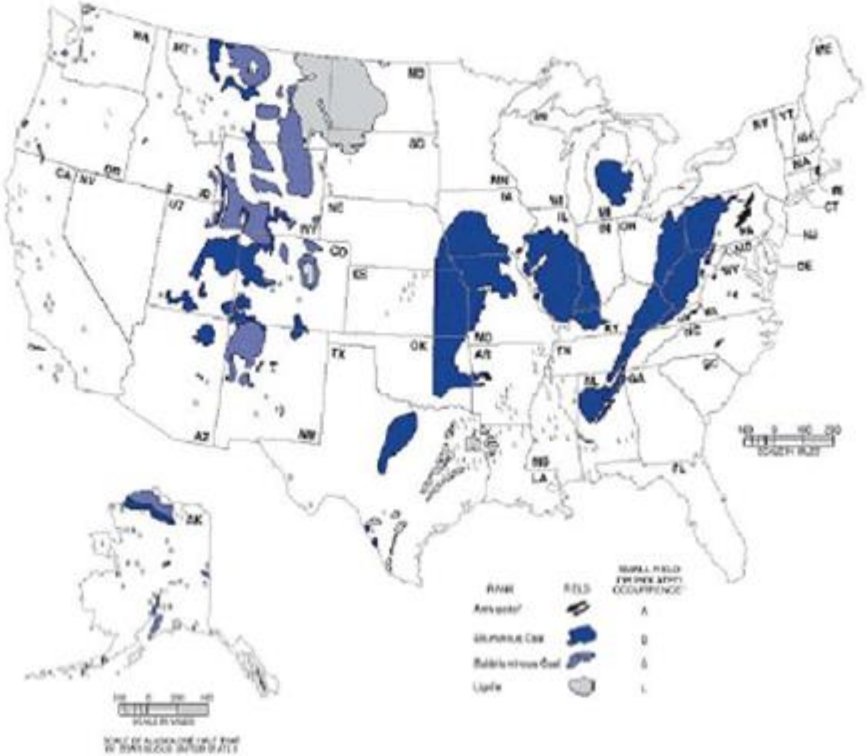
Sustainability

- 72 million tons of fly ash produced in 2008
- Only 30 million tons were used sending around **42 million tons to the landfills**

Energy production sources

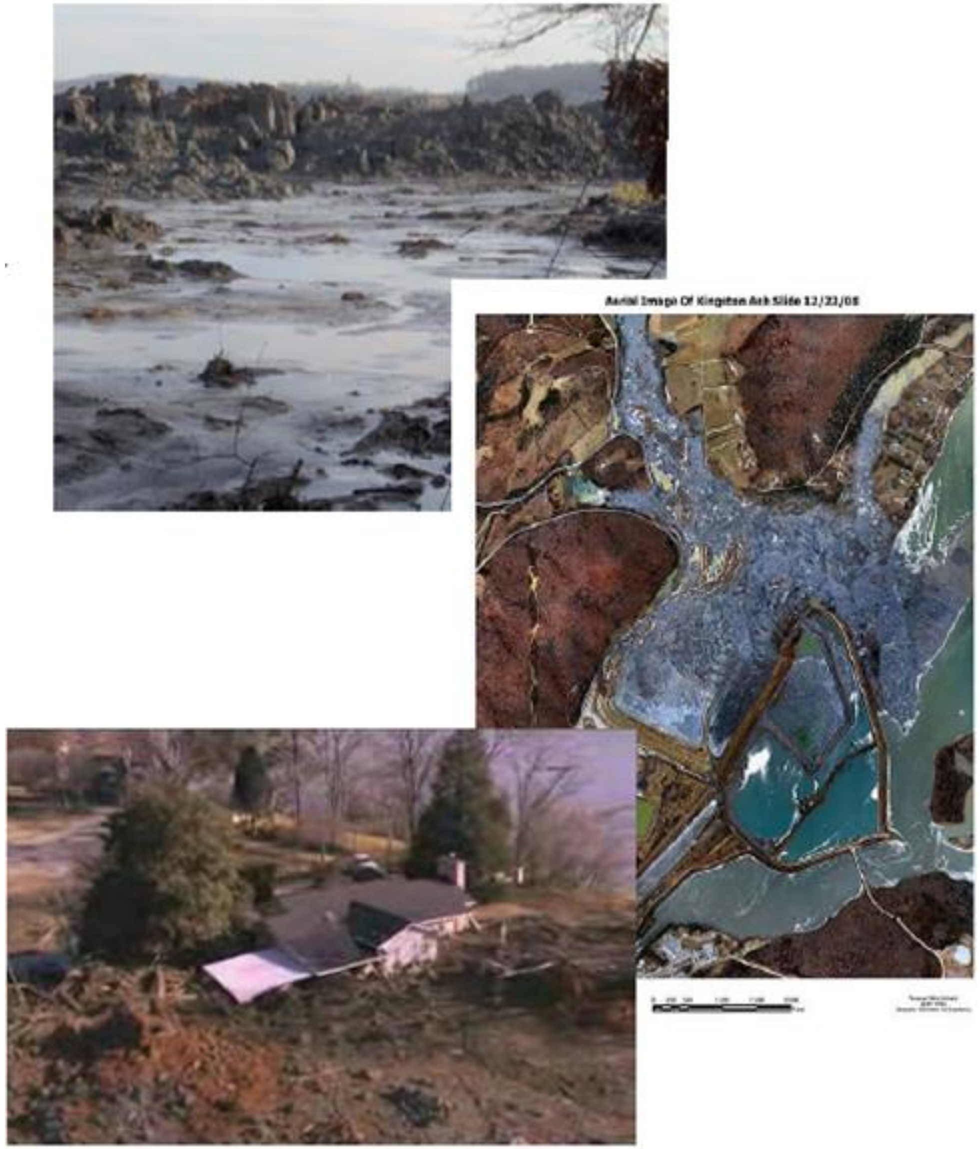


Coal reserves in the U.S.



Sustainability: Potential Risks Of Fly Ash Storage Lagoons

- In **December 2008** a TVA's fly ash storage lagoon ruptured in Kingston, TN
- 1.1 billion gal. of **fly ash slurry** were spilled into the Emory and Clinch Rivers
- **300 acres** of the surrounding land were contaminated
- Estimated clean-up costs: **675 to 975 million**

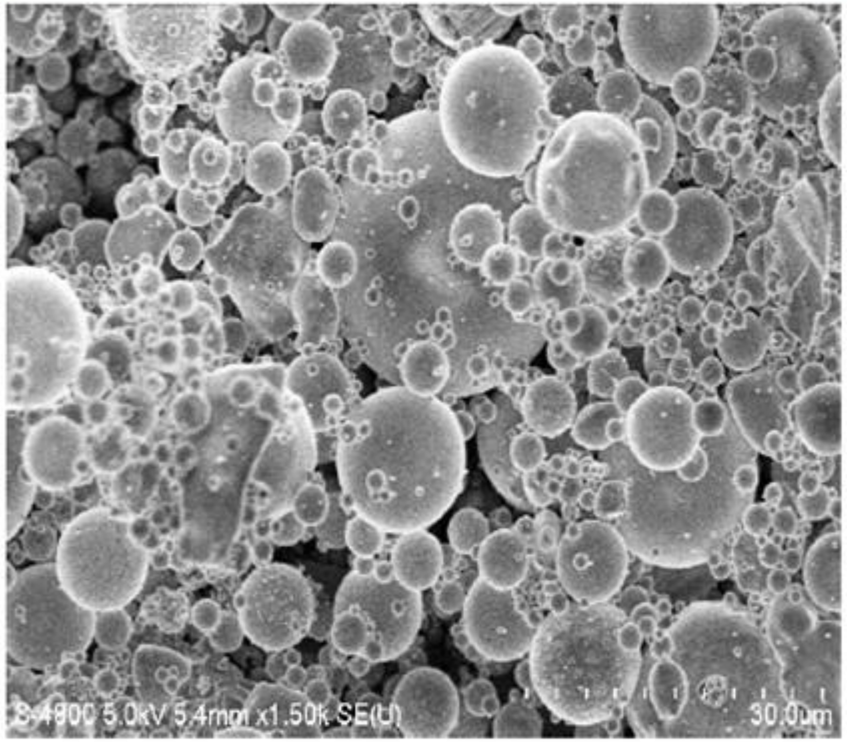


Engineering Fly Ash-based Geopolymer Concrete

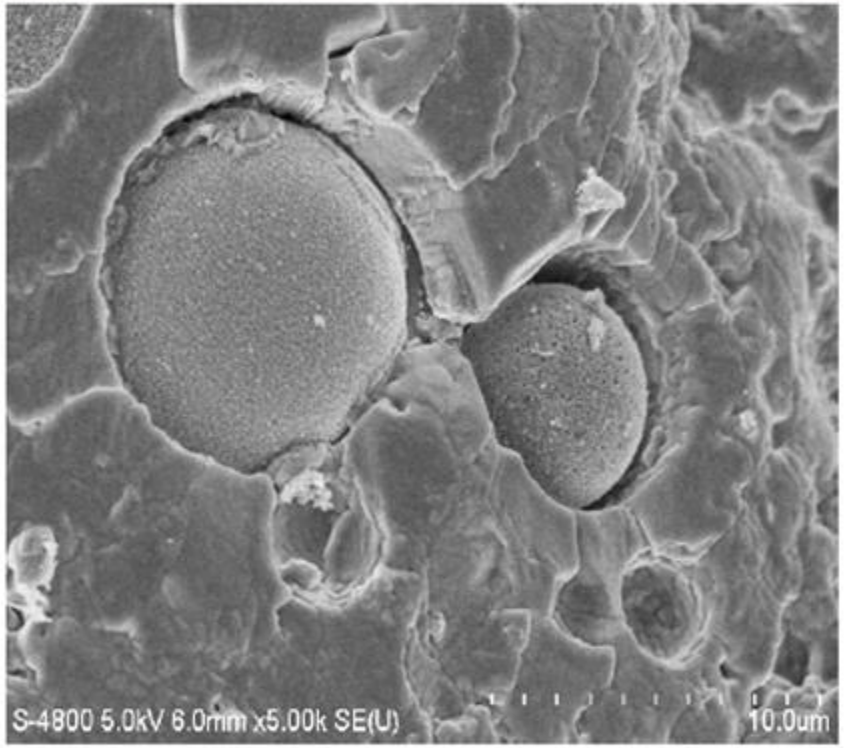
1. **Identify the fly ash characteristics that significantly impact GPC**
   - ✓ Collect fly ash samples
   - ✓ Keep mix design constant
   - ✓ Full mechanical characterization of GPC samples
2. **Evaluate the mechanical behaviour of GPC made from each of the fly ash samples**
   - ✓ Compressive vs. tensile strength
   - ✓ Compressive vs. elastic modulus
   - ✓ Density vs. fly ash fineness
3. **Determine the feasibility of establishing a regression model to predict GPC's mechanical properties using the characteristics fly ash**

Particle Morphology

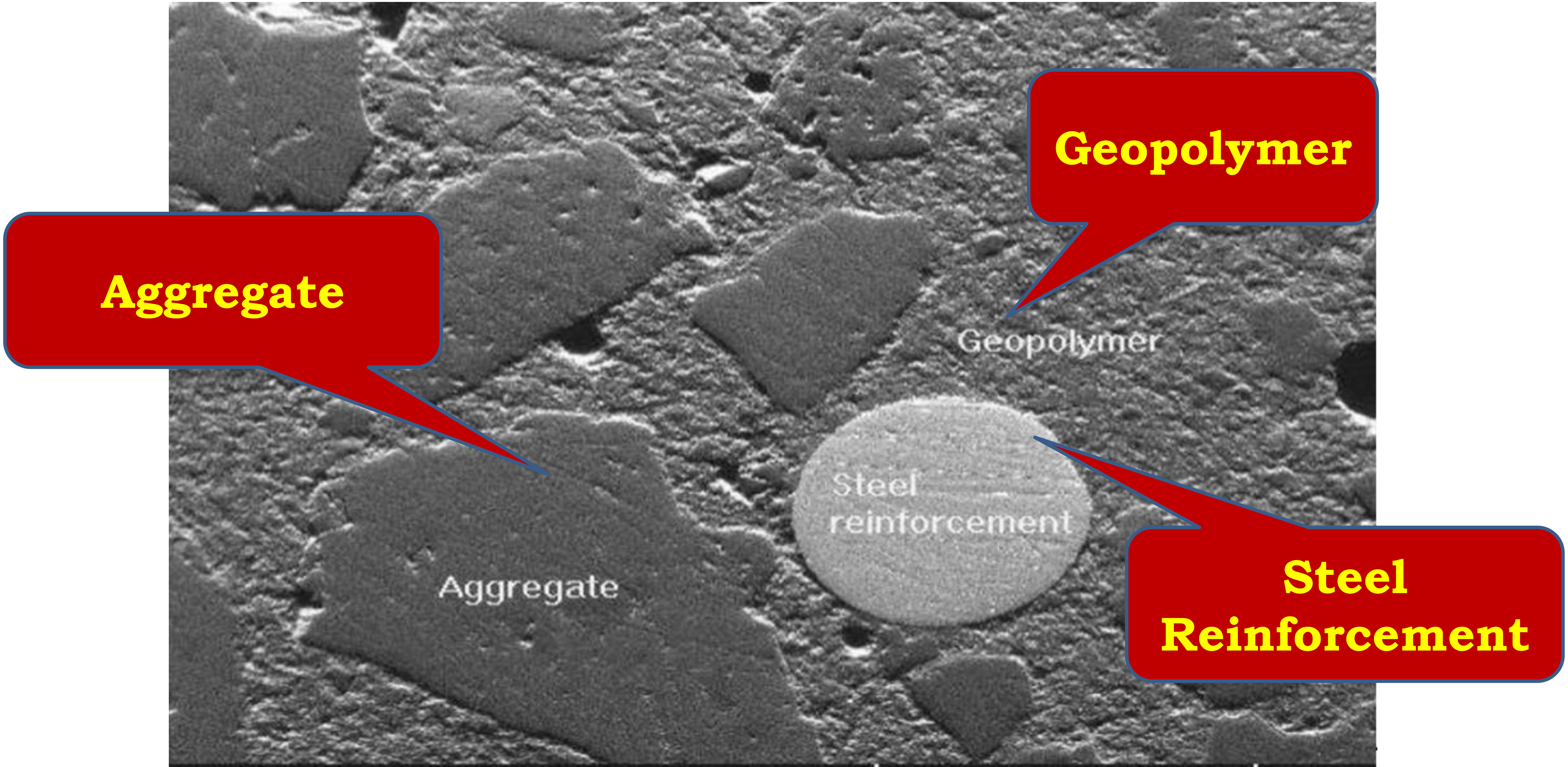
Fly Ash Before Activation



Fly Ash After Activation (Geopolymer)



Boundary between Geopolymer Binder Aggregate and Reinforcement



Behaviour of Geopolymer at Elevated Temperature

- **Behaviour of Geopolymer at Elevated Temperature**
  - ✓ High strength loss during early heating period(up to 200°C)
  - ✓ Beyond 600°C no further strength loss
  - ✓ No visible cracks up to 600 °C
  - ✓ Minor cracks at 800 °C
  - ✓ GPC with more compatability between aggregates and matrix led to less strength loss
- **Bond strength**
  - ✓ Very high
  - ✓ About one third of its compressive strength
  - ✓ Four times than that of OPC

Geopolymer Concrete

Video

APPLICATIONS

Applications: PAVEMENTS

- Light pavements can be cast using GPC
- No bleed water rise to the surface
- Aliphatic alcohol based spray used to provide protection against drying

Figure : Placing of Pavement Using Geopolymer Concrete

Applications: WATER TANKS

- Two water tanks were constructed, one with 32MPa concrete with blended cement and other with GPC
- Autogenous healing occurred in OPC due to calcium hydroxide deposition
- In GPC tank there is little calcium hydroxide
- Nominal leaking in tank healed rapidly due to gel swelling mechanism

Figure : INSITU Water Tanks With Blended Concrete (Left) And Geopolymer Concrete (Right)

Applications: BOAT RAMP

- Approach slab on ground to ramp was made using geopolymer reinforced with FFRP
- Entire constituents remained dormant until activator chemicals were added

Figure : BOAT RAMP CONSTRUCTED WITH BOTH IN-SITE AND PRECAST GEOPOLYMER CONCRETE.

Applications: PRECAST BEAM

- GPC beams formed three suspended floor levels of GCI building
- Beams had arched curved soffit
- Water pipes were placed inside them for temperature controlled hydronic heating of building spaces above and below

Figure : GEOPOLYMER CONCRETE BEAM CRANED TO POSITION

Future..

Future..

Future..

Advantages

- High compressive strength
- High tensile strength
- Low creep
- Low drying shrinkage
- Resistant to heat and cold
- Chemically resistant
- Highly durable
- Fire proof

Disadvantages

- **Difficult to create**
  - ✓ Requires special handling
  - ✓ Chemicals like sodium hydroxide are harmful to humans
  - ✓ High cost of alkaline solution
- **Pre-mix only**
  - ✓ Sold only as pre-mix or pre-caste material
- **Geopolymerisation process is sensitive**
  - ✓ Lacks uniformity

Conclusions

Conclusions

- **Concrete** can be made **Sustainable** by using **Less energy** in **production** and **producing less carbon dioxide** than **normal concrete**
- Usually **Carbon dioxide** is present in the **cement** and **aggregate** and **suitable replacement** can be found.
- **Cheaper, efficient and better** performing **Sustainable materials** are now available

Conclusions : Cont..

- **Geopolymer concrete** is a promising **construction material** due to its **low carbon dioxide emission**
- **High early strength**, **low creep and shrinkage**, **acid resistance, fire resistance** makes it better in usage than OPC
- Wide spread applications in **precast industries** due to
  - ✓ Its **high production** in short duration
  - ✓ **Less breakage** during transportation
- Enhanced research along with acceptance required to make it great advantage to the industry

Conclusions

- It should be emphasized that as ***more and more concrete structures age***, ***more and more demolished concrete*** will be produced.
- If it cannot be **recycled and reused**, the ***deposition of the construction waste*** will ***cause another environmental problem***.

Questions???

Thank You