Importance of Portland Pozzolana Cement (PPC) for Durable Construction
Contents

- Introduction
- Durability of Concrete
- Portland Cement
- Blended Cements
- Portland Pozzolana Cement
- Conclusion
Introduction: Concrete

- Is the largest consumed man made material on the earth
Introduction: Requirements

• Plastic when newly mixed

• Strong and durable, when hardened
Introduction: Strong and Durable Concrete

- The key to achieve strong, durable concrete rests on careful proportioning and mixing of the ingredients.
Introduction: Water

- Why water:
  a. Chemical reaction with cement.
  b. Workability
    - only 1/3 of the water is needed for chemical reaction
    - extra water remains in pores and cavities
    - results in porosity
    - Good for preventing plastic shrinkage cracking and workability
    - Bad for permeability, strength, durability
DURABILITY OF CONCRETE
Durability of Concrete 1: Definition

Durability of concrete is the ability of the material and the structure to maintain its level of reliability and serviceability during its lifetime at normal maintenance cost levels.
Durability of Concrete 2

- Durable concrete performs satisfactorily in working environment during its anticipated exposure conditions during service.
- Materials and mix proportions specified /used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.
- Main characteristics influencing durability is permeability of concrete to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances.
Factors influencing Durability of Concrete

- Environment
- Cover to embedded steel
- Type and quality of constituent materials
- Cement content and water/cement ratio of concrete
- Workmanship: required full compaction and efficient curing
- the shape and size of the member
<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Environment</th>
<th>Exposure Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Mild</td>
<td>Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.</td>
</tr>
<tr>
<td>ii)</td>
<td>Moderate</td>
<td>Concrete surfaces sheltered from severe rain or freezing whilst wet. Concrete exposed to condensation and rain. Concrete continuously under water. Concrete in contact or buried under non-aggressive soil/ground water. Concrete surfaces sheltered from saturated salt air in coastal area.</td>
</tr>
<tr>
<td>iii)</td>
<td>Severe</td>
<td>Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation. Concrete completely immersed in sea water.</td>
</tr>
<tr>
<td>iv)</td>
<td>Very severe</td>
<td>Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete in contact with or buried under aggressive sub-soil/ground water.</td>
</tr>
<tr>
<td>v)</td>
<td>Extreme</td>
<td>Surface of members in tidal zone. Members in direct contact with liquid/solid aggressive chemicals.</td>
</tr>
</tbody>
</table>
Physical Causes of Deterioration of Concrete

SURFACE WEAR
- ABRASION
- EROSION
- CAVITATION

CRACKING
- VOLUME CHANGE DUE TO:
  1. Normal temperature and humidity gradient
  2. Crystalization Pressure of Salts in Pores
- STRUCTURAL LOADING
  1. Overloading and Impact
  2. Cyclic Loading
- EXPOSURE TO TEMP. EXTREMES
  1. Freeze-Thaw
  2. Fire
Deterioration of concrete by chemical reactions

B: Exchange reactions between aggressive fluid and components of hardened cement paste
   I: Removal of Ca^{++} ions as soluble products
   II: Removal of Ca^{++} ions as non-expansive insoluble products
   III: Substitution reactions replacing Ca^{++} in C-S-H

A: Reaction involving hydrolysis and leaching of the components of hardened cement paste
   Increase in porosity and permeability
   - Loss of alkalinity
   - Loss of mass
   - Increase in deterioration processes
   - Loss of strength and rigidity

C: Reaction involving formation of expansive products
   Increase in internal stress
   - Cracking, spalling, popouts
   - Deformation

Detrimental effects of chemical reactions
Durability of concrete 4: Water- the Main Culprit

- Acts as a carrier for deleterious material.
- Leaves vulnerable voids
- Shrinkage problems
- Causes cracks
- Causes segregation, bleeding
Deterioration Mechanism

- Reinforcement Corrosion: 48%
- Chemical Attack: 19%
- Fire Damage: 16%
- Alkali-Silica Reaction: 8%
- Accidental Load: 5%
- Structural Damage: 4%

40% of Construction Budget for Restoration Life Cycle Cost VS Initial Cost
PORTLAND CEMENT
Portland Cement

It is defined as a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulphate as an inter-ground addition (ASTM C150).
Chemical Composition

- Approximate oxide compositions limits of OPC

<table>
<thead>
<tr>
<th>Oxide</th>
<th>% Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>60-67</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>17-25</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>3-8</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>0.5-6</td>
</tr>
<tr>
<td>MgO</td>
<td>0.1-4</td>
</tr>
<tr>
<td>K$_2$O, Na$_2$O</td>
<td>0.4-1.3</td>
</tr>
<tr>
<td>SO$_3$</td>
<td>1.3-3.0</td>
</tr>
</tbody>
</table>
# Cement Compounds

<table>
<thead>
<tr>
<th>Process</th>
<th>Tri-calcium Silicate $C_3S$</th>
<th>Di-calcium Silicate $C_2S$</th>
<th>Tri-calcium Aluminate $C_3A$</th>
<th>Tetra-Calcium Alumino-ferrite $C_4AF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence of formation of products in kiln</td>
<td>Fourth</td>
<td>Third</td>
<td>Second</td>
<td>First</td>
</tr>
<tr>
<td>Rate of reaction of products with water</td>
<td>Moderate</td>
<td>Slow</td>
<td>Fast</td>
<td>Moderate</td>
</tr>
<tr>
<td>Strength attained by reaction product formed</td>
<td>High</td>
<td>Initially low, later high</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Quantum of heat liberated during hydration process</td>
<td>High</td>
<td>Low</td>
<td>Very High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Calcium Hydrates

\[ 2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2 \]

\[ 2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2 \]

\[ 2C_3A + 6H \rightarrow C_3AH_6 \]

\[ C_4AF_6 \rightarrow CaO-Al_2O_3-H_2O \]
Metabolism of Cement (Chemistry)

- **Associative metabolism**
  - Al$_2$O$_3$
  - CaO
  - SiO$_2$
  - Fe$_2$O$_3$

- **Dissociative metabolism**
  - C$_3$A
  - C$_3$S
  - C$_2$S
  - C$_4$AF

- **HEAT**
  - C$_6$(A)(F)S$_2$H$_{32}$
  - C$_4$(A)(F)SH$_{12}$
  - CH
  - C$_3$S$_2$H$_3$
Liberation of Heat during Hydration

Liberation of Heat is linked to chemical activity, this further affects hardening process. Please note the high exothermic activity at start, gypsum cooling and exothermic activity close to final setting.
Cement Hydration Compounds

- $C_3S$ is responsible for early strength of concrete
- $C_2S$ is responsible for later strength of concrete
- C-S-H gel makes up 50-60% of volume of solids in a completely hydrated cement paste. It determines the good properties of concrete
- $Ca(OH)_2$ is soluble in water and gets leached out making concrete porous, particularly in hydraulic structures
Water Requirements for Hydration

- 23% of water is required by weight of cement for chemical reaction with Portland cement compounds (bound water)
- Certain quantity of water is imbibed within gel-pores (gel-water)
- Bound water and Gel water compliment each other well
- 15% of water by weight of cement is required to fill up gel-pores
- Total 38% of water by weight of cement is required for complete chemical reactions and to occupy space within gel-pores
Types of Portland Cements

• Ordinary Portland Cements (OPC)
  – 33 Grade (IS 269)
  – 43 Grade (IS 8112)
  – 53 Grade (IS 12269)

• Special Cements
  – Rapid Hardening Portland Cement (IS 8041)
  – Low Heat Portland Cement (IS 12600)
  – Sulphate Resisting Cement (IS 12330)
  – Super Sulphated Cement (IS 6990)
  – White Cement (IS 8042)

• Blended Cements
  – Portland Slag Cement (IS 455)
  – Portland Pozzolana Cement (IS 1489)
  – Masonry Cement (IS 3466)
  – Earlier additive/blending was not permitted to clinkers except gypsum
BLENDED CEMENTS

A HOLISTIC APPROACH TO ENGINEERING
Permissible Blending Materials
(IS 456 - 2000)

- Fly Ash (Pulverized Fuel Ash) (IS 3812)
- Ground Granulated Blast furnace Slag (GGBS) (IS 12089)
- Natural pozzolana and volcanic ash (IS 3812)
- Silica Fume
- Meta-Kaoline
- Rice Husk Ash

The world wide trend now is to increase the use of pozzolana and cementitious materials in concrete
Methods of Blending

- “Blending” now replaces the term “additive”. Hence, blended cements are those containing minerals as additive to OPC.
- Inter-grinding with cement clinker & gypsum.
  - Suited for factory
  - Blending OPC with powdered minerals.
- Suited at RMC or Cement productions manufacturing centres.
- Blending at on-site mixers
  - Low efficiency
Environment: Disposal of Waste?

Supplementary Cementitious Materials

- Pulverized Fuel Ash
- Ground Granulated Blast Furnace Slag
- Silica Fume
- Rice husk Ash
- Natural pozzolana and volcanic ash *
- Meta-kaolin *

* not a waste product
Conclusion 1

BLENDING CEMENT is a better alternative to Ordinary Portland Cement as:

It gives better performance of concrete in terms of:

- STRENGTH,
- DURABILITY,
- FINISHING.....; &
- ADDRESSES THE SOCIETAL OBLIGATIONS

- Minimum cement $300 \text{ kg/m}^3$ includes OPC + blended materials.

- Maximum $450 \text{ kg/m}^3$ Quantity of OPC not to exceed this limit.

- Blending material can be added to any quantity.

- Soil & Sub-soil water quality with respect to $\text{SO}_3$ & $\text{Cl}_2$, allows use of blended cements in most cases.
PORTLAND POZZOLANA CEMENT
CLINKER (65%-80%)
POZZOLANA (15%-35%)
GYPSUM (3-5%)

GRINDING MILL

PORTLAND POZZOLANA CEMENT
Pozzolana

Essentially a siliceous or siliceous & aluminous material.

- Natural form
  - clay & shale,
  - volcanic tuffs,
  - diatomaceous earth

- Artificial form
  - Fly ash
  - Rice husk
Fly Ash

Fly ash is a pozzolana, which is defined as fine material, which in itself is not cementitious but reacts with lime in the presence of water, under ambient conditions and forms hydrated mineralogy akin to that of OPC.
Pozzolana - Fly ash

Fly ash: Commonly used in cement industry should have
• High lime reactivity
• Low carbon content
• High fineness
Fly ash is an engineering material and not a waste...

* BIS CODE- IS:3812-1981
* Grade - I- (CaO+Al$_2$O$_3$+Fe$_2$O$_3$) > 70%
  - Low CaO- from Bituminous coal
* Grade-II- (CaO+Al$_2$O$_3$+Fe$_2$O$_3$) > 50%
  - High CaO-from lignite coal
Fly ash origin

(1) Plants remove carbon dioxide from the air. 
(2) When the plants died, they were buried in the earth. 
(3) After millions of years, their remains turned into coal and oil. 
(4) People mine the earth for coal and oil, which are called “fossil fuels.” 
(5) When people burn fossil fuels, they send carbon dioxide and other greenhouse gases into the air.

Fly ash is a by product from the combustion of fossil fuels.
Importance of Fly Ash in Durable Concrete

- Fly ash generation in developed countries is less as electricity generation is by use of natural gas / nuclear / other means. In India good quality of fly ash is abundantly available, which if used with cement as a partial supplement, produces durable concrete.

- At present it is estimated that about 36% of the electricity generated worldwide is Thermal while in India it is about 75%.
Importance of Fly Ash In Durable Concrete

- For making higher grade concrete, Silica Fumes and Fly ash being used (products are results of combustion of coal)
- Fly Ash based cement not only safeguards against environment hazards but also improve quality of concrete structures in terms of durability
- Japan utilizes 94% of its fly ash for concrete compared to 10-15% in India. (growth seen in utilization over the past few years)
Importance of Fly Ash in Durable Concrete

- CO₂ emission can be minimized by using Fly Ash in cement concrete.

**Some Facts**
- Replacing 15% cement worldwide by SCM (Supplementary Cement Material (i.e. Fly Ash) will reduce CO₂ emission by 227 million tonnes.
- Replacing 50% of cement worldwide by SCM will reduce CO₂ by 750 million tonnes.
- This is equal to removing 25% of all automobiles in the world.
Fly ash as Value Added Material for Concrete

- Good quality fly ash has mineralogical composition mainly consisting of Silica, Alumina, Iron Oxide and lime.

- Good quality fly ash consists of:
  - $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ - 75-80%
  - Silicon dioxide in Amorphous phase - 20% (min.)
  - Very fine particles of Silica of uniform consistency, mostly in spherical shape
  - Fineness nearly 3500 - 4000 blains ($\text{cm}^2 / \text{g}$)
  - Lime Reactivity > 5 MPa
  - Carbon Content < 2%
OPC and Fly ash - Synergy Effect: Fly ash is complimentary to OPC

<table>
<thead>
<tr>
<th>Compound</th>
<th>OPC (%)</th>
<th>Flyash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>22</td>
<td>57</td>
</tr>
<tr>
<td>CaO</td>
<td>64</td>
<td>3</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>MgO</td>
<td>1.00</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Both show synergy in Chemical Composition
Reaction Mechanism

Reduction in Leaching

- Leaching in concrete reduces. Excess Ca(OH)$_2$ is consumed by HRS
- Increase in durability and strength over a period of time
CSH Gel (Graphic display)
7: The pore filling of Portland cement concrete

9: The pore filling of fly ash cement concrete
Pozzolanic Reaction: Benefits

• Continued hydration
  – Higher long term strength
  – Reduced heat of hydration
  – Improved resistance to chemical attack

• Reduced Water demand (7.5-9.4%)
  – Reduced bleeding
  – Reduction in shrinkage and creep
  – Lower permeability

• Improved Cohesion
  – Less segregation
  – Less difficulties in concrete placement
Pozzolana- Benefits

• Presence of very fine pozzolana results into following:
  – Cohesive & workable concrete
  – Superior finish
  – Less evaporation of water
## Chemistry of Fly ash

<table>
<thead>
<tr>
<th>Sno</th>
<th>Test</th>
<th>Unit</th>
<th>IS 3812</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$</td>
<td>%</td>
<td>70 min</td>
</tr>
<tr>
<td>2</td>
<td>$\text{SiO}_2$</td>
<td>%</td>
<td>20 min</td>
</tr>
<tr>
<td>3</td>
<td>Reactive silica</td>
<td>%</td>
<td>20 min</td>
</tr>
<tr>
<td>4</td>
<td>$\text{MgO}$</td>
<td>%</td>
<td>3 max</td>
</tr>
<tr>
<td>5</td>
<td>$\text{SO}_3$</td>
<td>%</td>
<td>3 Max</td>
</tr>
<tr>
<td>6</td>
<td>$\text{Na}_2\text{O}$</td>
<td>%</td>
<td>1.5 max</td>
</tr>
<tr>
<td>7</td>
<td>Total Chlorides</td>
<td>%</td>
<td>0.05 Max</td>
</tr>
</tbody>
</table>

Saurashtra Cement Limited

11/9/2012
<table>
<thead>
<tr>
<th>Sno</th>
<th>Physical Test</th>
<th>Unit</th>
<th>IS 3812</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fineness (Blaines Permeability test)</td>
<td>m²/kg</td>
<td>320</td>
</tr>
<tr>
<td>2</td>
<td>Residue on screen 45 microns</td>
<td>%</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>Loss on Ignition (Max)</td>
<td>%</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Water requirement</td>
<td>%</td>
<td>115</td>
</tr>
<tr>
<td>5</td>
<td>Lime Reactivity</td>
<td>N/cm²</td>
<td>4.5</td>
</tr>
<tr>
<td>6</td>
<td>Moisture content (Max)</td>
<td>%</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Soundness (Autoclave)</td>
<td></td>
<td>0.80%</td>
</tr>
<tr>
<td>8</td>
<td>28 day comp st - plain mortar cement</td>
<td>N/mm²</td>
<td>80%</td>
</tr>
</tbody>
</table>
Good Quality Flyash (HRS)

Ordinary Flyash
Electron micrographs of a Typical Fly Ash

Spherical and Glassy particles

A Plerosphere
Figure 4.1 showing SEM images of normal fly ash (A) General overview of fly ash particles under scanning electron microscope. (B) Spherical particles with irregular particle at the center. (C) Small irregular fly ash particle. (D) Highly crystalline impurities and surface salts on fly ash particle. (E) Smooth particle without any impurities on its surface. (F) Fly ash particle with spots of impurities in the form of alkalis.

SEM images of normal fly ash

(A) General overview of fly ash particles under scanning electron microscope.
(B) Spherical particles with irregular particle at the center.
(C) Small irregular fly ash particle.
(D) Highly crystalline impurities and surface salts on fly ash particle.
(E) Smooth particle without any impurities on its surface.
(F) Fly ash particle with spots of impurities in the form of alkalis.
Mechanisms by which Fly ash (HRS) Improves Properties of Concrete

- Dispersion of cement particles
  - Availability of larger surface area for hydration.
  - Reduction in amount of trapped water between cement particles

- Particle Packing effect
  - Reduction in voids - HRS is more efficient void filler than OPC
  - Reduced water requirement to achieve a given consistency

- Ball Bearing effect
  - Spherical shape reduces inter-particle friction.
  - Facilitates mobility of mix and improves its rheology
Dispersion of Cement Particles

Presence of electronic charges, on Portland cement particle surface, tend to form flocks that trap large volumes of water.

“Dispersion of Cement Particles” - Fine HRS particles get adsorbed on the oppositely charged surface of the cement particles and prevent them from flocculation.
- HRS improves density of mix by filling voids.
- Water has lowest density, out of all constituents
- Replacement of water by HRS densifies mix
- Create lubricating action when concrete is in plastic stage
- Spherical shape & smooth surface of HRS helps reduce inter-particle friction.
- HRS particles plasticize cement paste and improve flow-ability and rheology

Reduction in inter-affinity between OPC particles due to Ball Bearing Effect provided by HRS
## Specifications v/s Test Results

<table>
<thead>
<tr>
<th>Particulars</th>
<th>IS12269 OPC 53 Grade</th>
<th>IS:1489 PPC</th>
<th>PPC available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness (m²/kg)</td>
<td>225</td>
<td>300</td>
<td>353</td>
</tr>
<tr>
<td>IST minimum (minutes)</td>
<td>30</td>
<td>30</td>
<td>190</td>
</tr>
<tr>
<td>FST maximum (minutes)</td>
<td>600</td>
<td>600</td>
<td>270</td>
</tr>
<tr>
<td>3 day Comp. Strength MPa</td>
<td>27</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>7 day Comp. Strength MPa</td>
<td>37</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>28 day Comp. Strength MPa</td>
<td>53</td>
<td>33</td>
<td>61</td>
</tr>
</tbody>
</table>
Benefits of PPC in Concrete

Fresh Concrete

- Reduces water demand
- Increases workability
- Improves rheology of mix
- Enhances water retention
- Increases cohesiveness & pump-ability
- Reduces internal bleeding and segregation
- Reduces plastic shrinkage
- Better slump retention
- Reduces danger to honeycombing
- Better surface finish
Effect of Addition of Fly Ash

Hardened Concrete
- Converts Ca(OH)$_2$ to C-S-H Gel
- Contributes to long term strength
- Enhanced uniformity and homogeneity
- Reduces permeability of concrete
- Reduced volume changes
- Enhanced cover quality
- Increases durability
Advantage 1: Long Term Strength Gain

Increase in strength at 180 days is 36% higher than at 28 days.
Advantage 2: Hardened concrete

- Steady strength gain & enhanced long term strength
- Improved transition zone
- Low porosity and discontinuous pores system, better impermeability
- Resistance against chemical attacks
- Reduced carbonation
Advantage 3: Medium Resistance to Sulphates

- Low $C_3A$ in PPC makes it moderate sulphate resisting cement
- IS 456:2000 specifies $C_3A$ between 5-8% to resist chloride and sulphate attack
Scope of PPC in Construction Industry

• Availability of superior blended cements
• High level of sulphate & chloride found in sub-soil and ground water in the coastal belt of Gujarat
• Increasing air pollution - carbonation
• Extreme weather condition
• Recognition of its benefits through codal provisions
• Rising expectations from concrete- High Performance Concrete
Fly ash in concrete: Sites in India

- Gujarat State Highway Projects
- Sardar Sarovar Narmada Nigam Dam Project & Other Dam Projects
- Fly-overs & Bridges
- Bandra-Worli Sea Link Project
- Delhi Metro Rail Project
- Rajasthan Atomic Power Project
- Kaiga Atomic Power Station
Application of PPC

• Dams
  – For high volume concreting work
  – Increase durability
  – Resistance to thermal cracking

• Power
  o Concrete in foundations, floors and roofs
  o improved workability
Application of PPC

• Harsh environments & Marine applications
  – Tunnel-Linings
  – Treatment plants and sewage works
  – Docks, Jetties

• Concrete Roads
Many marine structures in the Netherlands have been built with blended cements.
Good Practices: Concrete using PPC

- Ample water
- Do not let it dry
- Dry concrete = dead concrete, all reactions stop
- Can not revitalize concrete after it dries
- Keep temperature at a moderate level
- Concrete with PPC requires continuous and consistently good quality curing
Good Practices: Stripping of Formwork

<table>
<thead>
<tr>
<th>Type of Formwork</th>
<th>Minimum Period Before Striking Formwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Vertical formwork to columns, walls, beams</td>
<td>16-24 h</td>
</tr>
<tr>
<td>b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)</td>
<td>3 days</td>
</tr>
<tr>
<td>c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)</td>
<td>7 days</td>
</tr>
<tr>
<td>d) Props to slabs:</td>
<td></td>
</tr>
<tr>
<td>1) Spanning up to 4.5 m</td>
<td>7 days</td>
</tr>
<tr>
<td>2) Spanning over 4.5 m</td>
<td>14 days</td>
</tr>
<tr>
<td>e) Props to beams and arches:</td>
<td></td>
</tr>
<tr>
<td>1) Spanning up to 6 m</td>
<td>14 days</td>
</tr>
<tr>
<td>2) Spanning over 6 m</td>
<td>21 days</td>
</tr>
</tbody>
</table>
### Sample Mix Design - PPC blended @ 20% Fly ash: (NPC)

<table>
<thead>
<tr>
<th>Details</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Types of Cement</strong></td>
<td>OPC</td>
<td>PPC</td>
<td>OPC</td>
</tr>
<tr>
<td>Cement Content (kg)</td>
<td>350</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>W/C</td>
<td>0.45</td>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>S/C</td>
<td>2.55</td>
<td>2.54</td>
<td>2.09</td>
</tr>
<tr>
<td>A/C</td>
<td>3.01</td>
<td>2.99</td>
<td>2.67</td>
</tr>
<tr>
<td>Admixture(%)</td>
<td>1.25</td>
<td>1.5</td>
<td>1.25</td>
</tr>
<tr>
<td>Slump (mm) 0 min</td>
<td>210</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>30 min</td>
<td>130</td>
<td>180</td>
<td>200</td>
</tr>
<tr>
<td><strong>Compressive Strength (Mpa)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Days</td>
<td>30.8</td>
<td>26.6</td>
<td>40.9</td>
</tr>
<tr>
<td>28 Days</td>
<td>42.3</td>
<td>43.2</td>
<td>48.3</td>
</tr>
<tr>
<td>56 Days</td>
<td>48.2</td>
<td>52.8</td>
<td>50.6</td>
</tr>
<tr>
<td><strong>Split Tensile (Mpa)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 Days</td>
<td>3.60</td>
<td>3.89</td>
<td>4.13</td>
</tr>
</tbody>
</table>
Conclusion 1

Balanced Chemical Properties of Blended Cements:
Facilitates Durable Construction. Chemically is backed by:

- Low chloride
- Low magnesia
- Low alkali
- Low impurities / insoluble residue
- Optimum $C_3S$
- Moderate $C_3A$
Conclusion 2: ADVANTAGE +

FEATURES: ADDS VALUE TO 53 GRADE ORDINARY PORTLAND CEMENT

A. MAINTAINS OPC 53

- STRENGTH
- SETTING TIME
- SOUNDNESS

B. ADDS ON ADVANTAGES

- DENSER GEL FORMATION
- LOW HEAT OF HYDRATION
- RESISTANCE TO CHEMICAL ATTACKS
- RESISTS INGRESS OF MOISTURE
- MINIMIZES CRACKS
- REDUCES LEACHING
Conclusion 3

**MYTHS**
- SLOW SETTING
- INFERIOR THAN OPC
- NOT POPULAR
- NOT TO BE USED IN RCC
- CHANGE IN CONST.METHODOLOGY

**REALITIES**
- CAN BE REGULATED
- BETTER THAN OPC
- NARROW PERSPECTIVE
- BETTER IN RCC
- NO
Conclusion 4: APPLICATION SPECTRUM for PPC

- HIGH/LOW RISE BLDS
- PILING WORK
- FOUNDATIONS
- HIGHWAYS/ROADS
- INDUSTRIAL STRUCTURES
- DAMS/CANALS
- BUNGLOWS
- PORTS/HARBOURS

ANY STRUCTURE-BIG OR SMALL
Conclusion 5

- Blended Cements enhance Durability: i.e. enhance performance of concrete in aggressive environments
- Good quality Blended Cement is available, which is superior to OPC 53
- Adopting Blended Cements is not a preference but a compulsion
THANK YOU*

* Document prepared with inputs from Prof. Urmil Dave, Nirma University