RAKNOR READY MIX CONCRETE

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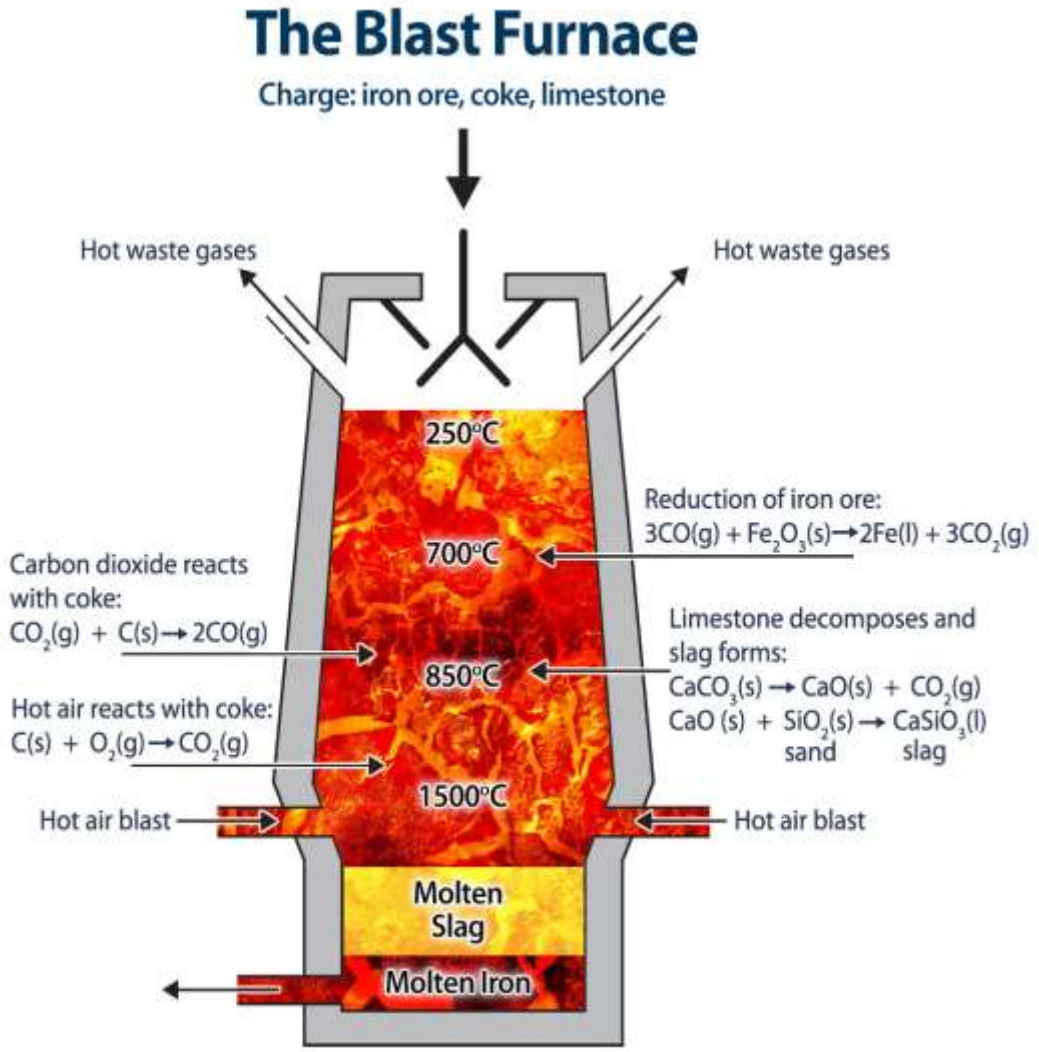
WE PRODUCE DURABLE GREEN AND SUSTAINABLE CONCRETE

What is GGBS ?

(Ground Granulated Blast Furnace slag)

The blast furnace slag is a by product of the iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temp of about 1500°c to 1600°c

The molten slag has a composition of about 30% to 40% SiO_2 and about 40 % CaO, Which is close to the chemical composition of Portland Cement.



Cement Grade VS Concrete Strength

- Use of High Grade of Cement should not be taken for granted to yield high grade (Strength) Concrete, Increase in cement Grade does not increase the quality of Concrete.

- Concrete may possess high strength but may deteriorate sooner than expected, Concrete made should satisfactorily in both strength and durability.

- Beyond a certain Period all grades shows same strength, Only advantage of use of higher grade cement is faster rate of gain in strength in initial period.

Chemical Composition of OPC,GGBS & PFA (% by Weight)

Oxides	OPC	GGBS	PFA
SiO_2	21	32	50
CaO	64	37	2
Al_2O_3	6	19	27
MgO	2	8	2
Fe_2O_3	4	1	8
Others	4	5	10

Mechanism of Cement Hydration

OPC 42.5/52.5

+

Water

C-S-H + $Ca(OH)_2$

OPC 42.5/52.5

+

Water

C-S-H + $Ca(OH)_2$

+

Fly ash or GGBS

C – S – H

Additional C-S-H gel shall make the concrete non permeable and give strength benefits in later ages

Mechanism of Cement Hydration

- **Chemical Reaction During Hydration**

- When Water is added to Cement, the following series of reaction occur :
- The Tricalcium Aluminate reacts with the gypsum in the presence of water to produce ettringite and heat
- Tricalcium Aluminate + Gypsum + Water = Ettringite and Heat
- $C_3A + 3CSH_2 + 2\ 6H = C_6AS_3H_{32}$ DH = 207 cal/g …… (i)
- Ettringite consist of Long crystal that are only stable in a solution with gypsum. The compound does not contribute to the strength of the cement glue.

- The Tri calcium Silicate (Alite) is hydrated to Produce Calcium Silicate Hydrate, Lime and Heat
- Tricalcium Silicate + water = Calcium Silicate Hydrate + Lime + Heat
- $2C_3s + 6H = C_3S_2H_3 + 3CH$, DH = 120 cal/g …… (ii)

- Thus CSH has a short Networked fiber Structure which Contributes greatly to the Initial strength of the Cement glue.

Mechanism of Cement Hydration

- Once all the Gypsum is used up as per Reaction (i) the ettringite becomes unstable and reacts with any remaining tri calcium aluminate to form monosulfate aluminate hydrate crystals:

- Tricalcium Aluminate + ettringite +water = Monosulphate aluminate hydrate
- $2C_3A + 3\ C_6AS_3H_{32} + 22H = 3\ C_4ASH_{18}$
- The Monosulphate crystals are only stable in a sulphate deficient solution. In the Presence of Sulphate, the crystal resort back into ettringite, whose crystals are two and a half times the size of the monosulphate. It is this increase in size that causes cracking when cement is subjected to cement attack.

- The Di calcium silicate (belite) also hydrates to form Calcium Silicate hydrates and heat.
- $C_2S + 4H = C_3S_2H_3 + CH$ DH = 62 cal/g
- Like in reaction (ii) the Calcium silicate hydrates contribute to the strength of the cement paste. This reaction generate less heat and proceeds at slower rate, meaning that the contribution of C_2S to the strength of cement paste will be slow initially. This compound is however responsible for the long term strength of Portland cement concrete.

Mechanism of Cement Hydration

- The Ferrite (Tetra Calcium aluminum ferrite) undergoes two progressive reaction with the Gypsum.
- In the first of the Reactions, The ettringite reacts with the gypsum and water to form ettringite, Lime and Alumina hydroxides i.e.
- Ferrite + Gypsum + water = ettringite + Ferric aluminum hydroxide + Lime
- $C_4AF + 3\ CSH_2 + 3H = C_6(A,F)S_3H_{32} + (A,F)H_3 + CH$

- The ferrite further reacts with the ettringites formed above to produce garnets i.e.
- Ferrite + ettringite +Lime + water = Garnets
- $C_4AF + C_6(A,F)S_3H_{32} + 2CH + 23H = 3C_4(A,F)SH_{18} + (A,F)H_3$

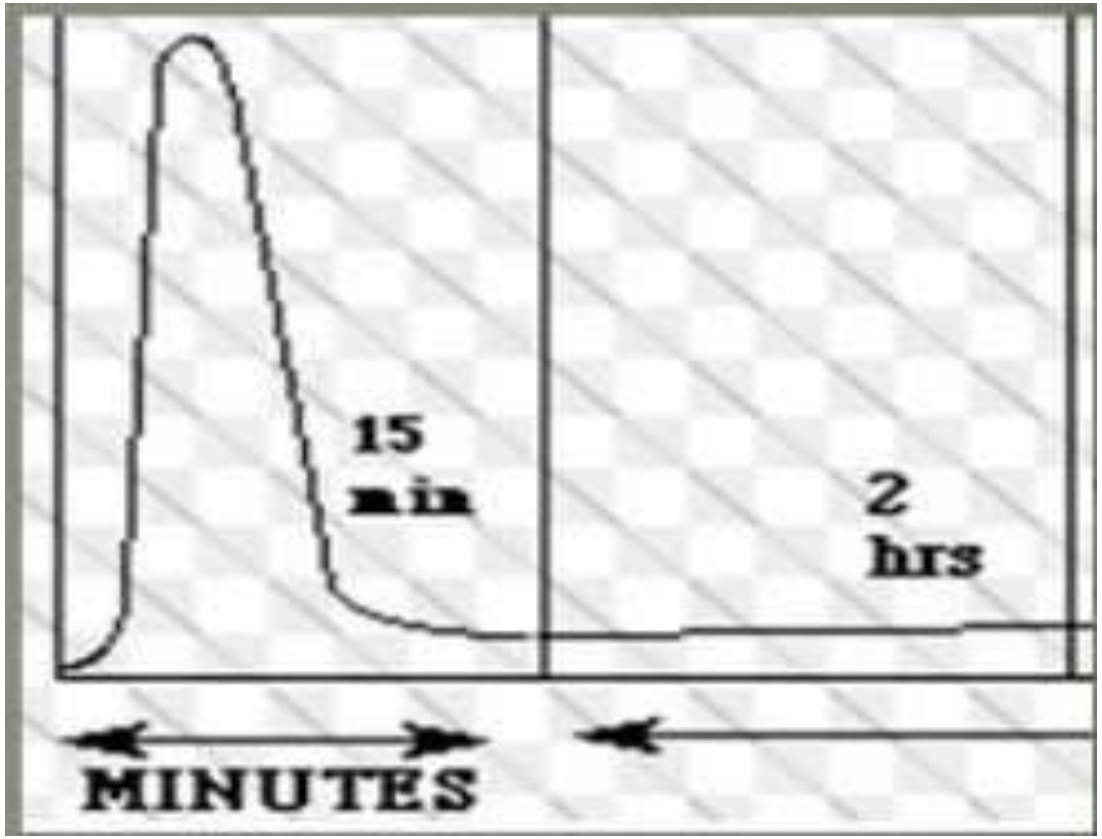
- The Garnets only take up space and do not in any way contribute to the strength of the cement paste.

- (C stands for CaO , S stands for SiO2, A stands for Al2O3, F stands for Fe2O3, H stands for H2O, DH stands for Heat)

Benefits of GGBS in Concrete

Heat of Hydration

- Cement hydration generates heat. Heat Dissipates from the concrete Slowly. The thicker the section the longer it will take the interior to cool. This can result in Large temperature differentials between the concrete surface and its interior.
- The concrete is then subject to high thermal stresses which can result in cracking and loss of structural integrity

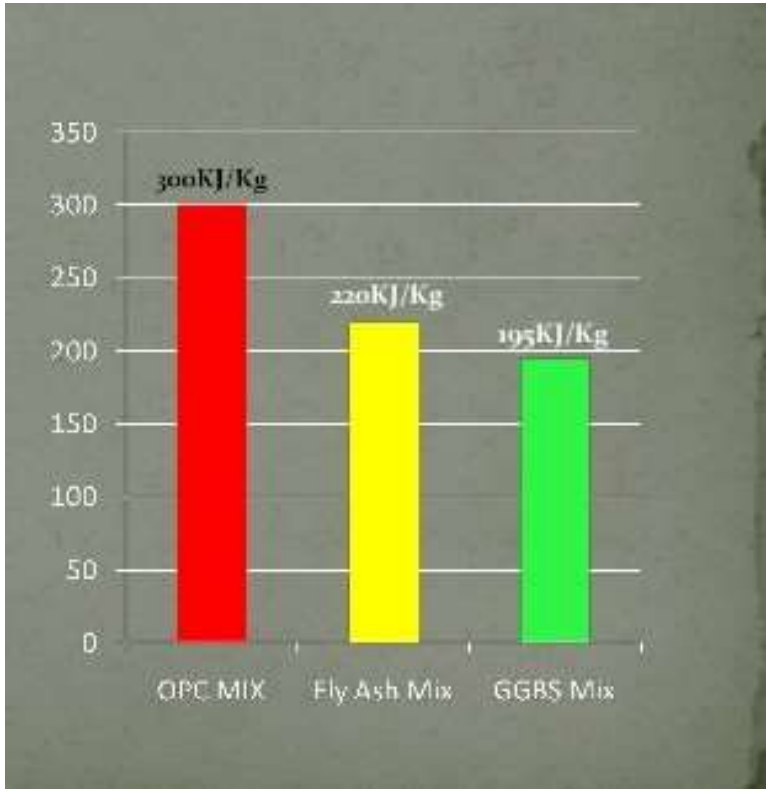


Benefits of GGBS in Concrete

- **Heat of Hydration**

- Gradual Hydration of GGBS with Cement Generates lower heat than Portland Cement. This reduces thermal gradients in the concrete.
- GGBS is used to limit the heat of hydration.

- A reduction in early age temperature rise can reduce the risk of early age thermal cracking.



Water Demand

- **Lower W/C ratio ----------≥ High Compressive Strength**

- Reduced water Cement ratio will contribute to Compressive strength gain.
- GGBS is a glassy material and its smoother surface require less water to adequately cover the particles. Though powder volume increase due to low specific gravity as the percentage of GGBS in the mix increases.

- Any reduction in water may become smaller due to the higher powder volume.

- Rheological behavior between GGBS and Portland cement enable a small reduction water demand of 3-5 % (i.e.5 to10 Liter of water per cu m of Concrete)

Setting Time

- Increased setting time may be advantageous in extending the time for which the concrete remains workable and may reduce the risk of cold joints. This delay is mainly due to the slower initial rate of reaction of GGBS compare to that of OPC.
- The effect is magnified at higher percentage.

Benefits of GGBS in Concrete

- **Appearance**
- GGBS cement also produces a smoother, more defect free surface due to the fineness of GGBS particles.

- GGBS is effective in preventing efflorescence when used at replacement level of 50 to 60%.

Benefits of GGBS in Concrete

- Bleeding
- Bleeding is a form of Segregation where some of the water in the concrete tends to rise to the surface of the freshly placed material. Delamination's are more likely to occur when factors that extend the bleeding time.

- Dusting is developed as of a fine, powdery material that easily rubs of the surface of hardened concrete.

- Fineness of GGBS reduce bleeding than that of Portland cement and therefore reduces the risk delamination's.

Benefits of GGBS in Concrete

Workability

- GGBS particles are less water absorptive than Portland cement particles and thus GGBS concrete is more workable than the Portland cement concrete.
- For equivalent Workability a reduction in water content of up to 10% is possible.

Benefits of GGBS in Concrete & Durability Aspects

Sulphate and Chloride Resistance

Sulphate react with C3A and $Ca(OH)_2$ present in OPC concrete causing the concrete to expand and crack. GGBS is sulphate- resisting, Specifying GGBS at 50-70% content gives optimum protection against sulphate attack.

Steel embedded in concrete is normally protected against corrosion by the alkalinity created inside concrete by hydrated cement. In such conditions, a passive layer forms on the surface of the steel and rusting is inhibited. However, if significant amounts of chloride are able to penetrate the concrete this protection can be destroyed and the embedded steel will rust and corrode. Because of its finer pore structure, GGBS concrete is substantially more resistant to chloride diffusion than Portland cement concrete. For reinforced concrete structures exposed to chlorides, the use of GGBS will give enhanced durability and a longer useful life. This applies in many situations, including highway structures (particularly bridge parapets), car parks subjected to coastal environments. Generally the higher the proportion of GGBS, the greater will be the resistance to chloride penetration. Typically, use of 50% GGBS will give high resistance to chloride and use of 70% GGBS will give very high resistance.

Exposure of Classes and benefits of GGBS for Durability

- **Corrosion induced by Chlorides**

- **Moderately Aggressive (Permanently Submerged)exposure with example**
  - ❖ Surfaces under sea structures which are permanently at least 5 m below low tide level.

- **Aggressive (wet and rarely Dry) exposure with example**

  - ❖ Surfaces Underground in areas with saline groundwater including the capillary rise zone.
  - ❖ Surfaces of structure containing saline water which are in permanent contact with the water.
  - ❖ Surface between high tide level and 5 m below sea level.

- **Severe (Moderate Humidity) exposure with example**

  - ❖ External surfaces which are not affected by condensation, condensation run off, irrigation or leakage and which are more than 3m above ground level of structure which are

  a) In Geographical locations with high saline water table, Salinas or sabkhas. Or
  b) Between 50m and 1km from the sea.

  This applies to many areas of RAK!

Exposure of Classes and benefits of GGBS for Durability

- **Corrosion induced by Chlorides**

- **Extreme (Cyclic Wet and Dry) exposure with example**

  ❖ External surfaces in geographical locations between 50 m and 1km from the sea or with high saline groundwater, Salinas or Sabkhas which are

  a) Less than 3 m above ground level or within the capillary rise zone.
  b) Affected by condensation, condensation run off, irrigation or leakage

  ❖ Surfaces of water retaining structures where the contained water is saline and which are

  a) Affected by fluctuating water levels, spray or splash or
  b) Or opposite side of the member from the contained water and could be affected by leakage

  ❖ Internal surfaces of water excluding structures such as tunnels and basements where the excluded water is saline

  ❖ Splash zone – External surfaces of structures from high tide level to 50 m inland.

  And this applies to the other areas of RAK!

Benefits of GGBS in Concrete for Durability

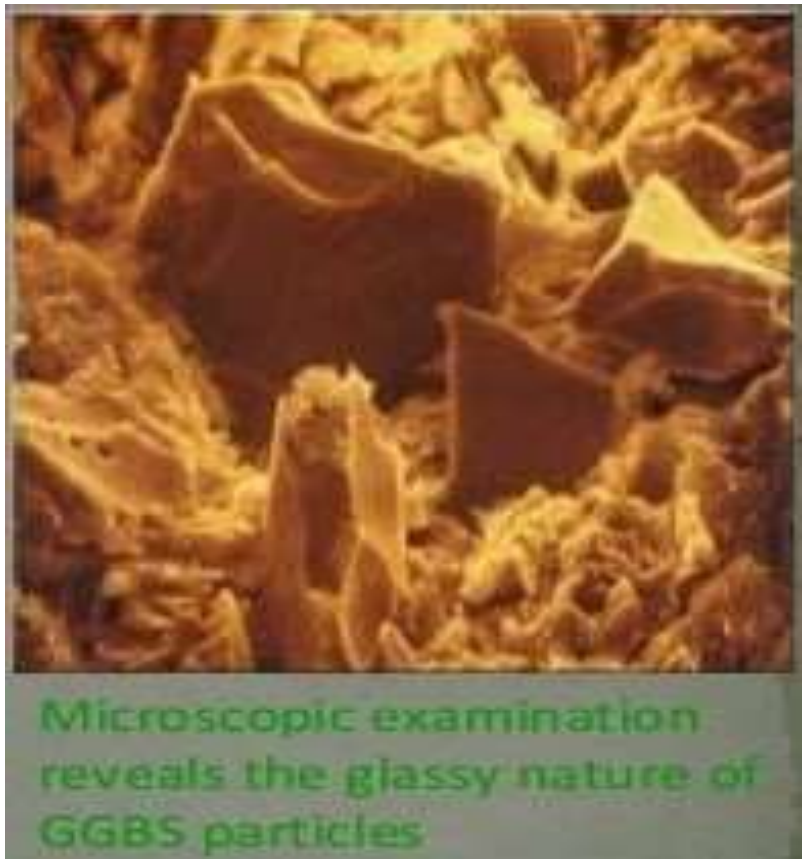
Alkali Silica Reaction :

Alkali Silica reaction is a reaction between the hydroxyl ions in pore water within a concrete and certain forms of silica which occurs as a part of some aggregates. The product of Alkali silica reaction is a gel which imbibes pore fluid and expands.

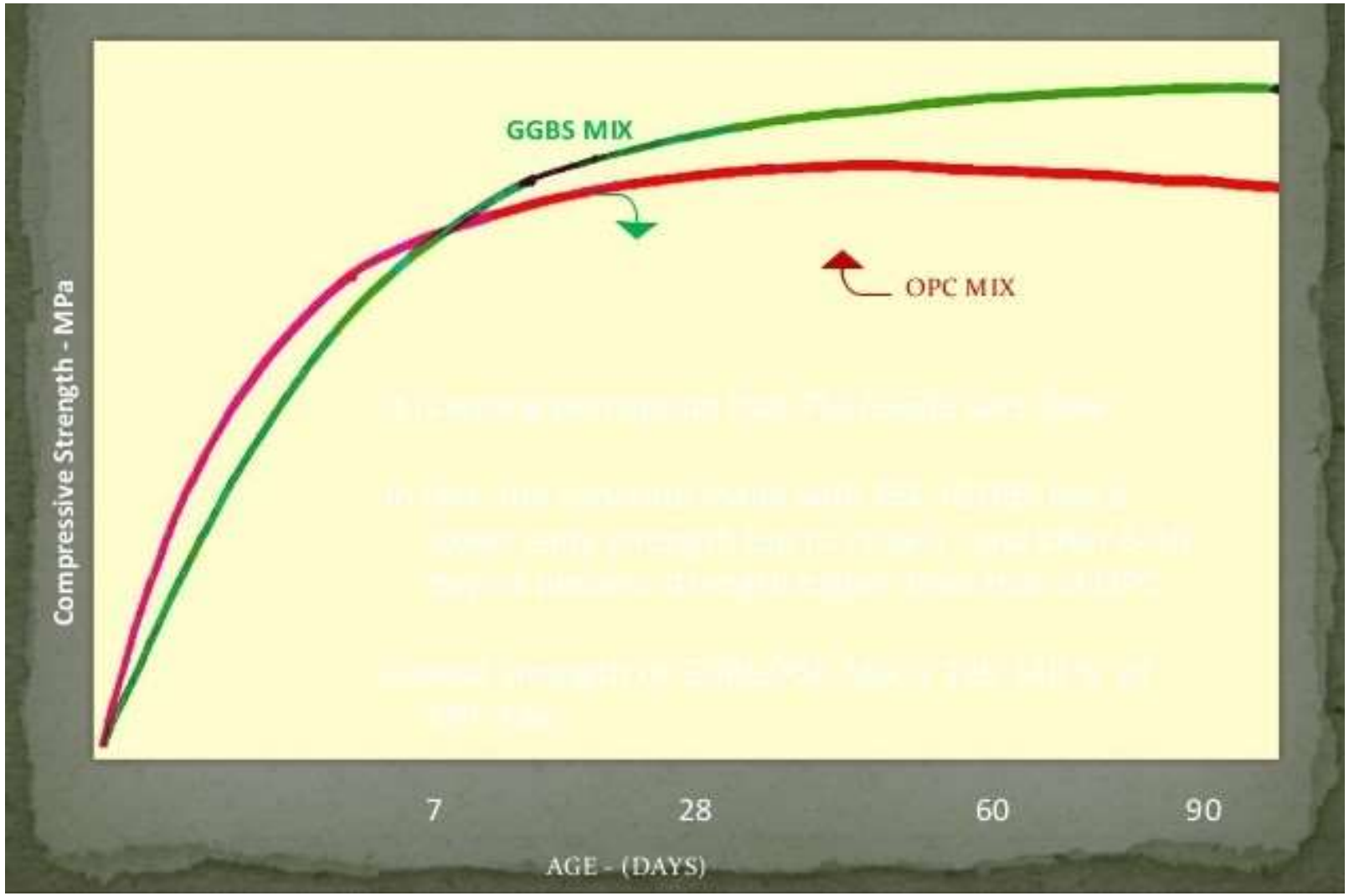
In Some instances this expansion induces internal stress in the concrete of such magnitude that extensive macro cracking of the concrete occurs. GGBS reduce the deleterious effect of AAR due to its low reactive alkali content and its ability to inhibit AAR. The overall lime to silica (Ca/Si) ratio of the hydration products was reduced by inclusion of GGBS. The hydration product of Low Ca/Si ratio can immobilize free alkalis and hence reduce the risk of AAR.

Chemical and Mineralogical Composition of the GGBS (slag)

Parameters	Typical Test Result
SiO_2	34.62 %
AL_2O_3	14.98 %
Fe_2O_3	1.01
CaO	41.50
MgO	5.87
MnO	0.19
LOI	1.25
IR	0.43
Sulphide	0.64
Sulphur	1.09
Glass Content (%)	99.6



Strength Comparison of OPC and GGBS Blend Mix



GGBS Worldwide Presence

- GGBS is used to Make Durable Concrete Structures in Combination with Ordinary Portland Cement and/or other Pozzolanic Materials.
- GGBS has represented high percentage of total production in cement consumption by many countries in recent years.
- Netherlands around 60%, Belgium 32 % ,France 32 % and West Germany 32 %.

- GGBS has been used widely in Europe and now increasingly in the United states and Asia.

- *Thank you*

- **Technical Department – Concrete**