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The Need of Ternary Blended Concrete

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ABSTRACT *Extensive research work for decades also is in progress throughout the globe in concrete technology in finding alternative materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability aspects. Amongst the many alternative materials tried as partial cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash, etc., now termed as complimentary cementitious materials (CCM) are quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials.The use of appropriately proportioned ternary blended allows the effect of one SCM to compensate for the inherent shortening of another.*

Introduction
It is important to discuss the cement chemistry and the changes in the mix design and the construction practices required to keep pace with the modern society and its fast needs.

Trends and developments in the last few decades:
After the Post world war scenario (1940s) there was immense pressure to quickly rebuild the nations!!!! This led to development of high strength cements. How? this was done by increasing the content of C3S at the cost of C2S from 1:2 to 2:1 and increasing the fineness of cement from 180 to300 m2/kg and further to 400 m2/kg. This brought a transition in portland cement scenario globally. There was increase in 7-day compressive strength, by almost more than 100% and transition in portland cement in Indian scenario of Indian cements was 33 Grade (1951) with compressive strength of 3 day, 7 days and 28 days as 16, 23 and 33MPa respectively then 43 grade cement (1976) with compressive strength of 3 day, 7 days and 28 days as 23, 33 and 43MPa respectively and finally 53 Grade (1987) with compressive strength of 3 day, 7 days and 28 days as 27, 37 and 53MPa respectively(1).

2.2 Problems associated with high early strength cement.
There was high early rate of strength gain of concrete for formwork removal means major strength-potential was tapped at the early stage of hydration, resulting in concrete of low extensibility (high elastic modulus, low creep and low tensile strength) leading to a rigid concrete. Thus, it was high early strength cement rather than high strength cement. Since the content of C3S was more so more surplus lime was generated due to hydration of cement this surplus lime made concrete vulnerable to sulphate attack, carbonation effect and acid attack causing premature distress in concrete due to cracking. Even the heat of hydration was much more released due to more C3S content leading to micro cracking.

Looking to the problems above the changes in mix design and construction practices were as follows:

The cement content was reduced. In order to meet the high speed of construction ready-mixed concrete was developed, high workability was essential to meet the needs of pumping concrete; for which w/c was increased in the absence of chemical admixtures. The combined effect was the porous concrete. Thus again changes were done in mix design and construction practices, the cement content was increased, and w/c decreased with advent of admixtures. This led to high strength cement in high quantities resulting in other associated problems like cracking and chemical attacks of concrete. The fundamental rule of material science that there exists a close connection between cracking and durability was disrespected.

2.3 Impact of high strength cement on structures.
It was very upsetting in 1970-80 that structures built after post WW II with high strength cements yielded to premature distress, while those built earlier with low strength cements proved to be in sound health. Why the relation between strength and durability was impaired, was a mind boggling question. It was realized that long term performance of structural concrete was proven better with low strength cements than with high strength cements.

The secret behind the sound health of millennia old structures was unraveled and investigations furthered in this direction leading the issues of durability of OPC as:

(a) Surplus lime, which is due to high C3S, associated with high fineness more lime is released in early days, leading either to leaching (more porosity) or to chemical attacks.
(b) High heat of hydration, which is due to fine grinding of cement more heat is released in early days of hydration, resulting in micro cracking and thermal shrinkage cracks.
(c) Transition Zone, which is due to existence of oriented crystals of Ca(OH)2 and resultant micro cracking, this forms the permeable and weakest link of concrete. Compressive stresses during thermal expansion and tensile stresses due to thermal shrinkage, both under restraint, also weaken the transition zone. Introspection on the sound health of millennia old structures found that these structures were free from side effects such as, lime complaint, heat of hydration, internal cracking and leaching, weak transition zone, corrosion of rebar's.

Thus the challenges before concrete industry on durability count to address the phenomenaassociated with early distress of concrete were, lime leaching, micro-cracks, permeability, carbonation, chemical attack, ingress of gases and moisture, Corrosion, depassivation and chloride induction.

2.4 The issues of durability in high strength cement and the role of CCM
Enlarging the scope of material science to complementary cementious materials (CCM) viz., fly ash, slag, silica fume, rice husk ash and Metakaolin in the use of concrete, this led

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to the concept of blended cements and blended concretes. Thus impact during early hydration was reduction in generation of surplus Ca(OH)2, control of heat of hydration and mitigation of continuous bleed channels.

So, reorienting the mix design for improved performance of concrete with thrust on

(a) Controlling OPC content but increasing the total cementitious material,
(b) Controlling water content, using chemical admixture, for improved workability, for offsetting slow hydration with CCM.

Thus the impermability the first defence was achieved.

2.5 Pozzolanic chemistry:
The basic requirement to improve the durability of concrete was to use Pozzolanic materials such as fly ash, slag, silica fume, rice husk ash and Metakaolin.

Then the reaction is expressed as:

OPC + H ⇨ Hydrated Mineralogy +CH (hydrated lime)

Pozzolan + H + CH ⇨ Hydrated Secondary mineralogy

The above equations indicate that the hydration chemistry in blended cements/ concretes is a two-stage mechanism, - - Principal + Interest Thus always more in quantity and stronger.This is how 'pozzolan concretes' become stronger in performance resulting in durable concretes.

2.6 Advantages of ternary blends:
Incorporating a single SCM to improve a concrete rheology or a specific durability property, however, may have associated limitations with its use (depending on the SCM), such as low early age strength, extended curing periods, increased admixture use, increased plastic shrinkage cracking, and freeze/thaw scaling in the presence of deicer salts. In some instances, using a single SCM to address one durability concern may result in reduced performance due to another. Example of material incompatibility is the incorporation of silica fume (SF) at levels greater than 10% by mass of cement. Such replacement levels are necessary to prevent ASR expansion but typically lead to problems with the workability of the fresh concrete as well as difficulties adequately dispersing the SF. A viable solution is to use a high-performance ternary blend concrete that uses moderate levels (15 to 35%) of blast-furnace slag or FA in combination with SF at lower than typical levels (< 7% by mass)(2)

The use of appropriately proportioned ternary blends allows the effects of one SCM to compensate for the inherent shortcomings of another. Such concretes have been found to exhibit excellent fresh and mechanical properties. For example, the addition of an ultra-fine pozzolan, such as SF, to a mixture containing blast-furnace slag can prevent excessive bleeding problems. In a ternary combination of cement, fly ash and silica fume system a synergistic rheological effect was observed in which the FA content offset the increased water demand typically associated with SF use. This was also observed during the construction of the ScotiaPlazaTower in Toronto, Canada. Ternary blended concrete with SF and either slag or FA required reduced dosages of high-range water-reducing admixtures to obtain satisfactory workability. It was found that a blend of 25% ground granulated blast-furnace slag and 3.8% SF required a lower water-cement ratio (w/c) for a given slump than a 100% PC mixture, without the need for a high-range water-reducing admixture. The new Canadian Standards Association (CAN/CSAA23.2 2000) concrete standard provides advice on the use of ternary blends to mitigate deleterious expansion due to ASR.

Ternary mixtures can be designed for: high strength, low permeability, corrosion resistance,sulfate resistance, ASR resistance, elimination of thermal cracking. Ternary mixtures can be used and have been used in virtually any concrete application, general construction (residential, commercial, industrial, Paving), high performance concrete, precast concrete, masonry units, mass concreting and shotcrete. Some of the high profile structures made by ternary blended concrete are Euro tunnel, BandraWorli sea link, Akashi Kaikyobridge in Japan which is the longest suspension bridge of the world with

suspension span of 1992 meters.

On the home front in India, blended cements are gaining attention only for the last few years. The inclusion of complementary cementitious materials or Pozzolana such as fly ash, slag, silica fume and rice husk ash, on durability criteria in the revision of IS 456-2000 is a testimony to this fact. Cement can be replaced by pozzolanic material by upto35%.

The incorporation of these above CCM makes the concrete achieve the following objectives of sustainability, disposal of waste material from other industries and rendering the environment cleaner, reducing the raw materials and energy requirement in cement manufacturing, reducing the consumption of cement in concrete and making concrete durable and thus increasing the service life of construction, And Much More Than That…Satisfies Social Obligation

Every million ton of CCM that supplements OPC

- Reduces depleting limestone (conserves 1.5 million ton of limestone)
- Reduction of industrial waste
- Reduced CO2emission (reduces1 million ton of CO2)
- Enhancing ecological balance (conserves 0.25 million tons of coal, and 80 million units of power) Thus by using ternary or tertiary blends sound concrete practices are achieved as:
- reducing the porosity of concrete,
- densifying the concrete by absorption of the surplus lime to form secondary hydrated mineralogy,
- minimizing the interconnectivity of pores,
- reduction in heat of hydration and thermal cracks,
- pore refinement and grain refinement,
- improved impermeability to resist ingress of moisture and gases.

Conclusion
The ternary blends also over comes the disadvantage of low early age strength, extended curing periods, increased admixture use, increased plastic shrinkage cracking due to single pozzolana. The use of appropriately proportioned ternary blends allows the effects of one SCM to compensate for the inherent shortcomings of another Thus ternary blended cements render multifaceted benefits both technically and economically, and as a renewable resource use of fly ash and slag contribute for environmental welfare and ecological protection. Thus by use of fly ash, slag, silica fume and metakaolin the health of the structures and human ecology both is enhanced.

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