2.4 The need of ternary blended concrete

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.

2.4.1 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). (45)

Ternary concrete mixtures include three different cementitious materials. 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 Scotia Plaza Tower 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. (45)

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, Bandra Worli sea link, Akashi Kaikyo bridge 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 (CCM) 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 upto 35%.

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 (10)

Every million ton of CCM that supplements OPC

- Reduces depleting limestone (conserves 1.5 million ton of limestone)
- Reduction of industrial waste
- Reduced CO₂ emission (reduces 1 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: \(^{(45)}\)

- 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.