ABSTRACT

Manufacturing of Portland cement is an energy intensive process and releases very large amount of green house gases into the atmosphere, which affect the earth’s ecosystem. Efforts are being carried out to conserve energy by means of promoting the use of industrial wastes or by-products, such as Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Silica Fume (SF), Rice Husk Ash (RHA) etc., which contain amorphous silica in its chemical composition, as mineral admixture for partial replacement of cement.

In India, the thermal power plants produce more than 100 million tonnes of FA every year. Apart from this, large quantity of RHA is also generated from the agricultural sector. These by-products develop serious environmental problems if not utilized properly. The partial replacement of cement by these by-products reduces the production cost of concrete and also addition of FA / RHA with cement has beneficial effect on workability, heat of hydration and permeability of concrete. The addition of admixtures not only improves the impermeability, but also acts as scavengers for penetration of chloride ions, which prevents corrosion of embedded rebar in the concrete. However, reduction of the compressive strength of concrete, flexural strength of concrete at the early ages and increasing carbonation of concrete are found to be major drawbacks in the FA based blended concrete. The early age strength development and setting time of concrete are important parameters for quick removal of formworks. Addition of second super fine mineral
admixture like SF etc, improves the compressive strength and flexural strength of concrete at the early ages and reduces the carbonation of concrete because of pore filling and fast pozzolanic reaction.

The study consists of two phases of investigations. In the first phase, optimum replacement level of FA / RHA for preparing binary blended concrete was determined based on the compressive strength. Initially M 20, M 30 and M 40 grade control concrete specimens were prepared with w-c ratio of 0.55, 0.50 and 0.45 respectively. Addition of FA / RHA was varied from 5% to 25% and the optimum replacement level of FA and RHA is found to be 20% and 18% respectively for M 20, M 30 and M 40 grade of concrete based on the compressive strength of the binary blended concrete.

In the present study, ternary blended concrete was prepared by adding a super fine mineral admixture such as SF as partial replacement of cement for all concrete grades (M 20, M 30 and M 40 grades) blended with either 20 % FA or 18 % RHA. The various replacement levels of SF such as 4%, 8% and 12% were used to determine the fresh and hardened properties of concrete such as air content, setting time, compressive strength, splitting tensile strength, bond strength, elastic modulus and durability properties of concrete such as permeation, corrosion of rebar, chemical attack and carbonation.

The addition of the SF as second mineral admixture reduces the slump value of the ternary blended concrete mainly due to increasing water demand of super fine nature of SF particles. The addition of upto 8% SF reduces both initial and final setting time of M 20, M 30 and M 40 grade concrete. The slower pozzolanic reaction of FA / RHA causes the strength
reduction of binary blended concrete at early ages. Addition of SF improved the compressive strength of the concrete at the early age and it is noted that the compressive strength of 7 days cured 8% SF based ternary blended concrete was slightly higher than control concrete. The splitting tensile strength results of FA / RHA based binary blended concrete is found to be lower than the control concrete, whereas addition of 8% SF improved splitting tensile strength of the ternary blended concrete. Based on the experimental results, the relationship between the compressive strength and splitting tensile strength of ternary blended concrete was developed. The addition of SF upto 8% improved the bond strength of the blended concrete also. The relationship between the compressive strength and elastic modulus of ternary blended concrete was also developed.

The addition of mineral admixtures modifies the micro-structural arrangement of concrete. The saturated water absorption of 8% SF based ternary blended concrete is marginally lower than that of 4% and 12% replacement level of SF based M 20, M 30 and M 40 grade concrete. The effective porosity of 28 days cured FA and RHA based binary blended concrete is found to be 20% and 18% lesser than control concrete respectively. The addition of 4%, 8% and 12% SF drastically reduces the porosity of the concrete. The maximum reduction of porosity (upto 30% of control concrete) was observed when 8% SF was added. Based on the sorptivity studies, it is noticed that addition of 8% SF reduces the permeability of ternary blended concrete to half than that of binary blended concrete.
The 8% and 12% SF based ternary blended concrete specimens have not shown any active corrosion state when exposed in salt solution for 48 cycles (336 days). 8% replacement of SF shows the lowest rate of corrosion for all grades of ternary blended concrete. The addition of SF prolonged cracking time of ternary blended concrete due to the improvement of the micro structural properties of concrete. Based on RCPT test, it is found that the addition of 8% SF reduced the chloride ion penetration approximately 80% for FA and 70% for RHA ternary blended concrete compared to control concrete.

Based on chloride permeability studies, it is found that only very little amount of free chloride ions present in the ternary blended concrete compared to control concrete. From the experimental results, it is observed that the depth of chloride ion penetration of control concrete specimen is three times higher than the binary blended concrete and also four times higher than the ternary blended concrete. The FA and SF or RHA and SF based ternary blended mortar had only 6% - 8 % expansion compared to control mortar. The ternary blended concrete had more sulphate resistance than the control concrete

Based on the various mechanical and durability properties studies, the following combinations are found to be the best mix proportion for ternary blended concrete:

1. 72% cement + 20% FA + 8% SF
2. 74% cement + 18% RHA + 8% SF