Fly Ash Utilisation for Value Added Products
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Fly ash and its use in cementitious material in civil engineering

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ABSTRACT

This paper briefly outlines the evolution of ordinary Portland Cement (OPC) and Portland Pozzolana Cement in India and their judicious use in civil engineering constructions .The paper also describes the different classes of fly ash with their varying pozzolanic activities and other properties like strength, corrosion and alkali aggregate reaction while used in concrete.

***Key words** : Fly ash utilisation; Cementitious material; Building materials; Civil work; Pozzalanic activities.*

1.0 INTRODUCTION

It is said that concrete is as old as Roman Empire, but general use of concrete was bare minimum until Joseph Aspidin invented Portland cement in 1824. The presence of Portland cement did not result in much progress for another forty years. Then steel found its application in cement as reinforcement and opened the horizon for expansion and development in the science of concrete. In the 175 years of its history, the ordinary Portland cement (OPC) and the cement concrete have undergone several changes and developments. All these years, OPC controlled the construction activity world over, as an essential building material. More efficient cementitious materials than OPC were recognised long ago and used effectively in hostile environments such as marine environments; such cements are called blended cements. The important constituents of these blended cements are fly ash and blast furnace slag. Use of Blast furnace slag is nearly as old as OPC. It was Emil Large who in 1862 discovered the latent hydraulic properties of the water granulated blast furnace slag. Initially the slag was activated by lime. This development resulted in the first commercial use of slag-lime cement in West Germany as for back as 1865. Later on Portland cement was used as and activator. In 1888, the first blast furnace slag cement works was opened in Germany. Since then the use of slag cement gained momentum and today it is very extensively used in North America and Europe. It is called Portland slag cement (PSC).

Most of the Roman architecture, standing as living testimony for the strength and durability of lime-pozzolana Chemistry, has used pozzolana available from the Volca-

noes. At a much later date, the invention of Portland rock resulted in the development of OPC with improved mineralogy, quick initial setting and attainment of early strength. OPC, then forced pozzolana-lime Chemistry into oblivion. Interestingly, manifestations of distresses in OPC concrete due to lack of durability in harsh environments led to franatic search for alternatives to OPC. The long forgotten pozzolana-lime chemistry has served successfully the purpose. OPC provided lime and fly ash of coal combustion, provided pozzolana. The combination of these two materials is Portland pozzolana cement (OPC) today.

2.0 HISTORY OF PORTLAND CEMENT (PPC) IN INDIA

Production of PPC in India was started and used mainly for augmenting the supply of cement to consumers as a general purpose cement in place of OPC for concrete but not due to recognition of its beneficial properties. In 1957 for the first time, use of fly ash in the manufacture of PPC was planned. In 1967, PPC was made in India for the first time as per IS : 1489. In 1971, about 26,000 tonnes of PPC, utilising fly ash was produced, but in 1972, the production dropped to about 8,000 tonnes due to the absence of consumer awareness and interest and improved availability of OPC. To meet the increasing demand in the country, the production of PPC substantially increased from 1997. In 1980 there was acute scarcity of cement, and the production of PPC peaked to 50% of total cement produced in the country. Restrictions were prevalent in using PPC in important structures such as bridges and high rise buildings due to consumer resistance. The principal reasons for the opposition were slow rate of strength development, resulting in longer curing period and consequent delay in striking the form work, lack of confidence on the quality of pozzolanic materials, and relative changes in certain engineering properties such as modulus of elasticity, and bond strength reduction etc. Several Governmental organisations and groups of engineers debated over the qualities of PPC resulting in its loss of reputation in its Indian market.

Decontrol of cement in 1989, improved demand supply position and the introduction of compulsory quality certification of cement by BIS, have contributed in general for the quality improvement of OPC. PPC was no exception. There are many reasons for the reduced use of PPC. They are — (1) Availability of high strength OPC (2) Lower early strength development (3) Higher initial setting time (4) Inconsistent quality of fly ash, (5) Variations of colour and shade (6) Lack of consumer awareness (7) Absence of long term strength data and engineering properties of concrete made with PPC. While in advanced countries , the PPC produced is more than 50% of total cement Production, in India it is only 15% .

2.1 Portland Pozzolana Cement (PPC)

India has been a steady growth in the production capacity of cement after the de-regulation by the Government. India is the fourth largest cement producing country in the world, next to only China, Germany and U.S.A with a total installed capacity of 96.3 million tonnes.

It is said that Indian cement industry is technologically far superior to the plants in China, USA and Japan. In India OPC is predominantly used for various applications. Many of the Western countries have considerably reduced the use of OPC except for some specialised applications. Indian users are ignorant about the chemistry of cement and concrete and are misguided resulting in the indiscriminate use of OPC. PPC is manufactured by inter grinding Portland cement clinker with pozzolanic material and appropriate quantity of gypsum. Alternatively pre-ground OPC and pozzolana are blended together. In India, mostly former method is used. Pozzolana is contained by fly ash which is used in PPC. Different countries in the world prescribe, pozzolana content varying from 10 to 40 percent for different performance characteristics. In India PPC is manufactured to Indian standard specification 1489; Part-1 (1991) which permits use of fly ash conforming to IS : 3812 Part-1 with pozzolana content in the range of 10-25 percent. Australia, France, UK and USA permit pozzolana content varying from 10-50 percent specifying different performing characteristics. The recommended fineness of grinding for PPC as per Indian Standard is minimum of 3,000 cm^2/gm. As on today, in India about 27% of total cement production comprises the two blended cements, PPC and PSC.

3.0 FLY ASH

Due to increased use of pulverised coal in the electric power generation plants, fly ash is now available in most areas of the U.S.A, Canada, Europe, India, China and many other countries of the world. Approximately 37 million tonnes of fly ash was produced annually by the year 1989-90 in India. About mere three percent of total fly ash production is used in concrete in India.

3.1 Chemical and Mineral Composition of Fly Ash

In general, the fly ash is divided into two distinct categories (1) Low lime fly ash, (2) High lime fly ash. Low lime fly ashes possess truly pozzolanic properties that need an activator to undergo reaction and thus produce cementitious properties. High lime fly ashes possess some cementitious properties, in addition to pozzolanic properties. American standards (ASTM C618) define two classes of fly ash - Class 'F' and Class 'C' based on the CaO content. Class 'C' fly ash is normally produced by burning sub-bituminous coal or lignite having CaO more than 10% while class 'F' fly ash is usually produced by burning anthracite or bituminous coal having CaO less than 10%. Class 'C' fly ash usually has cementitious properties in addition to pozzolana properties, while class 'F' fly ash is rarely cementitious when mixed with water alone. The quantities of silica, iron and potassium oxides are higher in Class 'F' than in Class 'C' where as CaO, MgO, SO_3 and Na_2O quantities are higher in Class 'C' than in Class 'F.

3.2 Physical Properties of Fly Ash

The properties of concrete in green state and hardened state and the rate of strength development of hardened concrete are influenced by the physical properties of the fly

ash such shape, fineness, particle -size distribution, density, and composition of fly ash particles.

3.3 Pozzolanic Activity of Fly Ashes

A pozzolana is defined as a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but which will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. IS : 3812-1981 specifies that for acceptable fly ash, lime reactivity should not be less than 4 MPa. A fly ash with better fineness has greater value of lime reactivity.

There are many types of pozzolana that can be used in the manufacture of PPC. These are diatomaceous earth, opaline charts and shales, tuffs, volcanic ashes, pumicities, materials processed by calcination of soil (burnt clay pozzolana) montmorillonite and also illitic types and artificial materials such as precipitated silica and fly ash. Of these, burnt clay pozzolana and fly ash, a waste material from thermal power plants are mostly used in PPC. IS 3812 (part-1) covers the properties of fly ash suitable for making PPC. The pozzolana constituent shall bot be less than 10% and not more than 25% by mass of portland pozzolana cement. The two constituent of PPC, the OPC clinker and the Pozzolana used, have to be compatible. The PPC manufactured in the country does not show any greater variability than that experienced with OPC.

Portland pozzolana cement (IS 1489) has certain important advantages over the OPC— (1) The hydration process is slower than that of OPC resulting in a lesser rate of heat liberation and slower rate of strength gain, (2) The chemical reaction in PPC consume lime instead of producing lime this has important bearing on the durability of the hydrated cement paste to acidic environment, (3) Studies on pore size distribution of hydrated PPC have shown that the reaction products fill up efficiently large capillary space, contributing to improving the strength and reducing permeability of the concrete matrix. Generating lesser heat of hydration is a boon to massive structures such as concrete dams and massive pours of concrete (pile caps etc.). Availability of least quantity of lime in hydrated paste leads to high durability. Improvement of impermeability is an asset to hydraulic constructions and effectively provides greater resistance to the attack of harsh sea and industrial environments. Thus PPC may be termed a special purpose cement. However in view of many benefits research shows that where OPC is used there PPC can be used tolerating small inconveniences such a larger period of deshuttering, longer and consistent curing and slightly slower rate of strength development.

3.4 Compressive Strength

When OPC is combined with water, C-S-H gel and calcium hydroxide are formed and the C-S-H gel provides strength to the concrete mass. But in PPC the calcium hydroxide reacts with the pozzolana forming secondary C-S-H gel, this enables the strength development for a longer period than for OPC. It is established that OPC strength develop-

ment stops at about 60 days, while in the case of PPC, strength gain proceeds even upto one year. The ultimate strength of PPC is much higher than that of OPC because of additional C-S-H gel formation.

3.5 Corrosion in PPC Concrete

Aggressive agents such as chlorides, fluorides, sulphates etc., in the harsh environment cause corrosion of reinforcement embedded in concrete. Due to more impermeability of PPC concrete, ingress of the aggressive agents is less than with OPC and the corrosion tendency is reduced significantly. Earlier apprehension that incidence of corrosion of steel in concrete with PPC is dispelled now.

3.6 Alkali Aggregate Reaction

If the aggregates used in concrete with OPC are reactive, the aggregate will react with the alkali available from the cement and increase the volume, disrupting the concrete. PPC, with lesser alkali availability in concrete, provides greater resistance against the alkali aggregate reaction.

In India OPC 33 grade is viewed as a general purpose cement. In order to ensure the same, the strength requirement of PPC in terms of 3, 7, and 28 days compressive strength, has been brought at par with that of OPC 33 grade. PPC cements are ground a little finer. 43 and 53 grades of PPC are possible.

4.0 CONCLUSION

Use of blended cements, PPC and PSC have to be encouraged in the country only in the interest of users. Additional advantages are conservation of mineral wealth and energy, fight against pollution, welfare of ecology and lower per capita investment on cement plant.

5.0 BIBLIOGRAPHY

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