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RESEARCH ARTICLE

ENVIRONMENTAL CONCRETE - GEOPOLYMER OF CONSTRUCTION

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ABSTRACT

The cement industry is the India's second highest payer of Central Excise and Major contributor to GDP. With infrastructure development growing and the housing sector booming, the demand for cement is also bound to increase. However, the cement industry is extremely energy intensive. After aluminium and steel, the manufacturing of Portland cement is the most energy intensive process as it consumes 4GJ per tonne of energy. After thermal power plants and the iron and steel sector, the Indian cement industry is the third largest user of coal in the country. In 2003-04, 11,400 million kWh of power was consumed by the Indian cement industry. The cement industry comprises 130 large cement plants and more than 300 mini cement plants. The industry's capacity at the beginning of the year 2008-09 was about 198 million tones. The cement demand in India is expected to grow at 10% annually in the medium term buoyed by housing, infrastructure and corporate capital expenditures. Considering an expected production and consumption growth of 9 to 10 percent, the demand-supply position of the cement industry is expected to improve from 2008-09 onwards.

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INTRODUCTION

Coal-based thermal power installations in India contribute about 65% of the total installed capacity for electricity generation. In order to meet the growing energy demand of the country, coal-based thermal power generation is expected to play a dominant role in the future as well, since coal reserves in India are expected to last for more than 100 years. The ash content of coal used by thermal power plants in India varies between 25 and 45%. However, coal with an ash content of around 40% is predominantly used in India for thermal power generation. As a consequence, a huge amount of fly ash (FA) is generated in thermal power plants, causing several disposal-related problems. In spite of initiatives taken by the government, several non-governmental organizations and research and development organizations, the total utilization of FA is only about 50%. India produces 130 million tonne of FA annually which is expected to reach 175 million tonne by 2012. Disposal of FA is a growing problem as only 15% of FA is currently used for high value addition applications like concrete and building blocks, the remainder being used for land filling. Globally, less than 25% of the total annual FA produced in the world is utilized.

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In the USA and China, huge quantities of FA are produced (comparable to that in India) and its reported utilization levels were about 32% and 40%, respectively, during 1995. FA has been successfully used as a mineral admixture component of Portland pozzolan blended cement for nearly 60 years. There is effective utilization of FA in making cement concretes as it extends technical advantages as well as controls the environmental pollution. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. GGBS is a glassy, granular, non metallic material consisting essentially of silicates and aluminates of calcium and other bases. Slag when ground to less than 45 micron from coarser, popcorn like friable structure, will have a specific surface of about 400 to 600 m2/kg (Blaine). GGBS has almost the same particle size as cement. GGBS, often blended with Portland cement as low cost filler, enhances concrete workability, density, durability and resistance to alkali-silica reaction. Alternative but promising gainful utility of FA and GGBS in construction industry that has emerged in recent years is in the form of Geopolymer cement concretes' (GPCCs), which by appropriate process technology utilize all classes and grades of FA and GGBS; therefore there is a great potential for reducing stockpiles of these waste materials.

Importance of Geopolymer Cement Concretes

Producing one tonne of cement requires about 2 tonnes of raw materials (shale and limestone) and releases 0.87 tonne (H" 1 tonne) of CO2, about 3 kg of Nitrogen Oxide (NOx), an air contaminant that contributes to ground level smog and 0.4 kg of PM10 (particulate matter of size 10 µm), an air borne particulate matter that is harmful to the respiratory tract when inhaled. The global release of CO2 from all sources is estimated at 23 billion tonnes a year and the Portland cement production accounts for about 7% of total CO2 emissions. The cement industry has been making significant progress in reducing CO2 emissions through improvements in process technology and enhancements in process efficiency, but further improvements are limited because CO2 production is inherent to the basic process of calcinations of limestone. Mining of limestone has impact on land-use patterns, local water regimes and ambient air quality and thus remains as one of the principal reasons for the high environmental impact of the industry. Dust emissions during cement manufacturing have long been accepted as one of the main issues facing the industry. The industry handles millions of tonnes of dry material. Even if 0.1 percent of this is lost to the atmosphere, it can cause havoc environmentally. Fugitive emissions are therefore a huge problem, compounded by the fact that there is neither an economic incentive nor regulatory pressure to prevent emissions. The cement industry does not fit the contemporary picture of a sustainable industry because it uses raw materials and energy that are non-renewable; extracts its raw materials by mining and manufactures a product that cannot be recycled. Through waste management, by utilizing the waste by-products from thermal power plants, fertiliser units and steel factories, energy used in the production can be considerably reduced.This cuts energy bills, raw material costs as well as green house gas emissions. In the process, it can turn abundantly available wastes, such as fly ash and slag into valuable products, such as geopolymer concretes. 'Geopolymer cement concretes' (GPCC) are Inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementing the conventional concretes. GPCC have high strength, with good resistance to chloride penetration, acid attack, etc. These are commonly formed by alkali activation of industrial aluminosilicate waste materials such as FA and GGBS, and have a very small Greenhouse footprint when compared to traditional concretes.

Basics of Geopolymers

The term 'geopolymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium- silicate-hydrates (CSHs) for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors to attain structural strength. Two main constituents of geopolymers are: source materials and alkaline liquids. The source materials on alumino-silicate should be rich in silicon (Si) and aluminium (Al). They could be by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. Geopolymers are also unique in comparison to other aluminosilicate materials (e.g. aluminosilicate gels, glasses, and zeolites). The concentration of solids in geopolymerisation is higher than in aluminosilicate gel or zeolite synthesis.

Composition of Geopolymer Cement Concrete Mixes

Following materials are generally used to produce GPCCs:

- Fly ash,
- GGBS,
- Fine aggregates and
- Coarse aggregates
- Catalytic liquid system (CLS): It is an alkaline activator solution (AAS) for GPCC. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of AAS is to activate the geopolymeric source materials (containing Si and Al) such as fly ash and GGBS.

Formulating the GPCC Mixes

Unlike conventional cement concretes, GPCCs are a new class of materials and hence, conventional mix design approaches are applicable. The formulation of the GPCC mixtures requires systematic numerous investigations on the materials available. Preparation of GPCC Mixes. The mixing of ingredients of GPCCs can be carried out in mixers used for conventional cement concretes – such as pan mixer, drum mixer, etc.

Mechanical Properties

Compressive Strength: With proper formulation of mix ingredients, 24 hour compressive strengths of 25 to 35 MPa can be easily achieved without any need for any special curing. Such mixes can be considered as self curing. However, GPCC mixes with 28 day strengths up to about 60-70 MPa have been developed at SERC.

Modulus of Elasticity The Young's modulus or modulus of elasticity (ME), Ec of GPCC is taken as tangent modulus measured at the stress level equal to 40 percent of the average compressive strength of concrete cylinders. The MEs of GPCCs are marginally lower than that of conventional cement concretes (CCs), at similar strength levels.

Stress Strain Curves The stress-strain relationship depends upon the ingredients of GPCCs and the curing period.

Rate of Development of Strength This is generally faster in GPCCs, as compared to CCs.

Reinforced GPCC Beams

Load carrying capacity of GPCC beams, are up to about 20% more of CC beams at similar concrete strength levels. Cracking of concrete occurs whenever the tensile strength of the concrete is exceeded. The cracking in reinforced concrete is attributable to various causes such as flexural tensile stresses, diagonal tension, lateral tensile strains, etc. The cracking moment increases as the compressive strength increases in both GPCC and CC beams. Reinforced concrete structures are generally analyzed by the conventional elastic theory (Clause 22.1 of IS 456:2000) which is equivalent to assuming a linear moment-curvature relationship for flexural members. However, in actual behaviour of beams, non-linear moment curvature relationship is considered. The moment-curvature relation can be idealized to consist of three straight lines with different slopes. The slopes of these line changes as the behaviour of the beam is changed due to increasing load. Thus each straight line indicates different phases of beam history. The moment-curvature relations of GPCCs and CCs are essentially similar. The service load is generally considered as the load corresponding to a deflection of span/350 or maximum crack width of 0.2 mm, whichever is less. The deflections at service loads for the GPCC and CC beams are found to be almost same. Thus, at service loads, the behaviour of the GPCC and CC beams are similar. Ductility factor of the beams is considered as the ratio of deflection at ultimate moment (äU) to the deflection at yield moment (äY). The ductility factor decreases as the tensile reinforcement increased. The ductility factor of GPCC beams could be marginally less than CC beams indicating higher stiffness of GPCC beams. The crack patterns observed for GPCC beams are similar to the CC beams.

Reinforced GPCC Columns

The concrete compressive strength and longitudinal reinforcement ratio influence the load capacity of columns. The load carrying capacity increases with the increase in concrete compressive strength and longitudinal reinforcement ratio. Crack patterns and failure modes of GPCC columns are similar to those of CC columns.

Bond Strength of GPCC with Rebars

The bond strength of GPCCs with rebarsare higher compared to CC. Thus developmental length of steel bars in reinforced GPCC can be kept same, as in the case of reinforced CC. The bond strengths of GPCC and PPCC are significantly more and conservative than the design bond stress recommended in IS: 456-2000. The GPCCs possess satisfactory bond with embedded steel bars so that the conventional design process of reinforced structural components can be applied conservatively to GPCCs also.

Durability Aspects of GPCCS

The GPCC specimens have chloride permeability rating of ‘low’ to ‘very low’ as per ASTM 1202C. GPCCs offer generaly better protection to embedded steel from corrosion as compared to CC. The GPCC are found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids.

Concluding Remarks on GPCCS

From the test data generated at SERC, it can be concluded that GPCCs are good candidates materials of constructions from both strength and durability considerations. Geopolymer concrete shows significant potential to be a material for the future; because it is not only environmentally friendly but also possesses excellent mechanical properties. Practical recommendations on use of geopolymer concrete technology in practical applications such as precast concrete products and waste encapsulation need to be developed in Indian context. Because of lower internal energy (almost 20% to 30 % less) and lower CO_2 emission contents of ingredients of geopolymer based composites compared to those of conventional Portland cement concretes, the new composites can be considered to be more eco-friendly and hence their utility in practical applications needs to be developed and encouraged.

REFERENCES

Brouwers, H.J.H., Radix, H.J. 2005. 'Self-Compacting Concrete: Theoretical and experimental study', Cement and Concrete Research 35., pp 2116 – 2136.

Burak Felekoglu *et al*. 2006. 'Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete', Building and Environment.

Burak Felekoglu, 2007. 'Utilisation of high volume limestone quarry wastes in concrete industry (self compacting concrete case)', Resources Conservation & Recycling, pp 1-22.

Debashis Das, *et al.* 2006. 'Effect of maximum size and volume of course aggregate on the properties of self compacting concrete', *Indian concrete journal.,* March 2006, pp 53-56.

Domone,' P.L. 2006. Self-compacting concrete: An analysis of 11 years of case studies', Cement & Concrete Composites 28, pp 197–208.

Ganesan, N. *et al.* 2006. Durability aspects of Steel Fibre-reinforced SCC', The Indian Concrete Journal, May, pp 31-37

Ho, D.W.S. *et al.* 2002. 'The use of quarry dust for SCC applications', *Cement and Concrete Research* 32, pp 505-511.

JagdishVengala and R.V.Ranganath, 'Mixture proportioning procedures for SCC, Indian Concrete Journal', august 2004, pp 13-21.

Kannan, K. 2007. 'performance of blended cement in Aggressive environment', project report, July, Department of civil engineering, Mepcoschlenk Engineering College.

Kumar, P, 2006. 'Self Compacting Concrete: methods of testing and design', *Journal of the Institution of Engineers* (INDIA) vol 86, February, pp 145-150.

Nan Su *et al* 'A Simple Mix design method for SCC', Cement and Concrete Research 31 (2001), pp 1799-1807.

Okamura. H, Ouchi.M, 2003. 'Self Compacting Concrete', *Journal of Advanced Concrete Technology*, Vol-1, April 2003, pp 5-15.

Prakash, K.B. and Kulkarni, D.K. 2006. 'Effects of addition of more than two chemical admixtures on concrete properties, *Indian Concrete Journal,* pp 17-21.

Shankar, H.Sanni, 2007. 'Effect of Viscosity Modifying Admixtures On Self Compacting Concrete,' CE&CR JULY pp 66-71.

'The European Guidelines for Self-Compacting Concrete,' May 2005.

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