Environmentally Friendly Concrete

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Recent years have seen many new advances in cementitious materials. Supplementary cementing mineral admixtures (SCMs), if used to their full potential, give rise to concrete properties that are considered to be well beyond the range normally attributed to hydraulic cement concrete.

It is coming to be recognized that suitability of concrete for different purposes and properties is often better attained by the use of variable proportions of SCMs than by the use of different types of cement. With increasing use and recognition of the importance of mineral admixtures (pozzolans), many industrial by-products formerly lost as waste are accepted widely as important constituents of hydraulic cement concrete.

All by-product SCMs – notably flyash (pfa, pulverized fuel ash), condensed silica fume (csf), and ground, granulated blast furnace (ggbf) slag – when of proper quality (chemical composition, physical state, fineness, and type/grade), and when used correctly and in an adequate amount, can improve portland cement concrete in both fresh and hardened stages. They replace a portion of the cement, the most expensive and energy intensive component of concrete, and in this way are indispensable for reducing both energy and the carbon dioxide generated in the production of cement.

Environmental Considerations

The production of 1 tonne of cement roughly generates 0.55 tonnes of chemical C02; the combustion of carbon fuel yields an additional 0.40 tonnes of carbon dioxide.

To explicate: 1 T of cement = 1 T of carbon dioxide.

One plausible reading of scientific data is that the build up of C02 may lead to a warming of the Earth in our lifetime, and the carbon dioxide greenhouse effect may result in climatic changes and complex problems. We in the concrete industry have a morally compelling and ethical responsibility here. If the concrete industry acts responsibly with a keen realization of the contributions it can make to cope with the technical, social and ecological developments, concrete as a construction material will always have an important role in the future.

Huge NYCDEP construction projects are underway and more are planned, not only for new construction but also for retrofit, repair and rehabilitation/improvement of existing structures. Due to the massive size of needed structural elements, it is usually steel that competes with concrete.

The choice of steel versus concrete as a dominant construction material is increasingly and clearly in favor of concrete based on economic, environmental and service considerations, engineering properties, and energy savings. Concrete is an environmentally-preferred construction material.

Ecological Profile of Concrete

From ecological considerations, there is manifestly no better home or permanent resting place than concrete for millions of tonnes of pozzolanic and cementitious by-products.

Stockpiles of these industrial by-products on land can cause air pollution. Dumping them into streams releases toxic metals that are normally present in small amounts. Even low value applications such as landfill, subgrades and highway shoulders can be ultimately hazardous to human health because toxic metals will find their way into ground water.

On the other hand, incorporation of flyash and slag as components of blended portland cements or as mineral admixtures in concrete present a relatively inexpensive way of proper disposal of the toxic elements present. Also, there is considerable interest in recycling demolished concrete as an aggregate and using flyash and metallurgical slag for making aggregates.

Besides the technical and economic advantages of replacing a part of the hydraulic cement in concrete with fly ash or ggbf slag, these mineral admixtures offer an easy way of conserving the raw materials and energy sources used in making cement.

Conservation of material resources is, after all, ecological. The energy to produce flyash or slag comes free, almost costing nothing to concrete. For instance, replacing 30% of portland cement in concrete with flyash or slag will reduce the energy content of the cementing material by almost the same amount. Flyash or slag may be used to replace even larger amounts of cement in concrete to achieve various objectives.

It is mainly from the stand point of resource and energy conservation that the USEPA has issued firm guidelines prohibiting specifications that discriminate against the use of flyash in construction projects funded by the federal government.

Development of High Volume Slag and Flyash Concrete Systems at DEP

The Material Assurance Division of DEP's Bureau of Environmental Engineering is presently engaged in laboratory investigations that would optimize SCMs, extending their use to new frontiers in the efforts to make DEP concrete more durable, energy efficient and ecologically beneficial through savings on portland cement used.

At present, DEP water pollution control and combined sewer overflow (CSO) projects require 15-20% flyash substituted for total cementitious content. Investigations currently in progress are aimed at developing structural concretes incorporating high volumes of low calcium (ASTM C 618 Class F), flyash and (ASTM C 989 Grade 120) ggbf slag.

Typically the cement content in these concretes is kept low and the proportion of flyash or slag to the total cementitious materials ranges from 30 to 80%. The water content is kept low and a high degree of workability is obtained by using a mid-range water reducer (ASTM C 494, Type A) or a high range water reducer (ASTM C 494, Type F).

We have already carried out several investigations on high volume slag concretes. The results of the first series of tests have been extremely successful and the level of expertise/confidence of the DEP engineers who utilize SCMs at the construction sites has been going up as investigations continue.

Changes to the NYC Building Code

The economic and ecological costs would be too high if we continue using irrelevant and inflexible standards based on 28 day (f ' c and f c r) strength of concrete. Excessive reliance on such criteria impedes rather than helps construction progress and may on occasion be counterproductive to durability. Moreover, meeting a strength requirement does not necessarily assure that a conventional concrete will be durable in a specific environment. These requirements are not truly applicable to concrete that incorporates SCMs. Here, strength development is predominantly a long term process.

The CIB's proposed revisions to the NYC Building Code incorporate the use of ecologically friendly SCMs like flyash or slag which have a relatively slow rate of heat liberation (due to pozzolanic reaction, which is slow) and consequent slow rate of strength development.

At later ages, concrete using SCMs meets or exceeds normally specified engineering properties. High volume flyash and high volume slag concrete technology are revolutionizing concrete. We cannot depend on available specifications and codes for long service life of structures made with conventional concrete.

The Honorable Joel A. Miele, Sr., P.E., Commissioner of the NYC Department of Environmental Protection reviewed an early draft of the manuscript and made some helpful comments which were incorporated in the preparation of the final draft.

As reported by *Compressed Air Magazine,* December 1949...
The process for making cement for construction purposes was originated by Vicat in 1820, but concrete placed in forms was first used by Francois Coignet in 1847 in putting up a building. In the next year Lambot constructed a boat of reinforced concrete. In 1949, Monier built flower boxes and Coignet constructed the first floor of a buildiing out of reinforced concrete...French engineers used the material for some years, and then the practice gradually became world-wide.