CONCRETE TECHNOLOGY AND SUSTAINABLE DEVELOPMENT

Key Issues from the 1999 Vancouver Symposium on Concrete Technology for Sustainable Development

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INTRODUCTION

With growing population, industrialization, urbanization and globalization it is clear that there will be a corresponding growth in the world=s demand for clean water, clean air, waste disposal, safe and rapid transport of people and goods, residential and industrial buildings, and sources of energy. During the 20th century, Portland cement has emerged as the material of choice for modern infrastructural needs. It is not surprising, therefore, that the concrete industry today is the largest consumer of natural resources, such as water, sand, gravel, and crushed rock(1). The manufacturing of Portland cement, which is the commonly used binder for modern concrete mixtures, also requires large amounts of natural materials. As one of the most energy intensive and polluting industries, the Portland cement industry has come under increased scrutiny from regulatory agencies and the public(1,3). Being the most important player in the infrastructure development and a major consumer of energy and natural resources, the concrete industry needs to be reoriented through the adoption of environmentally friendly and more sustainable technology(3).

The growing infrastructural needs of the world will have to be balanced against the equally important human need of preserving the life-sustaining environment on earth, which is being threatened by the uncontrolled use of natural resources and increasing amounts of pollution. There is a rapidly increasing concern that we can no longer continue to ignore the pollution problems on the one hand and the unrestricted depletion of natural resources on the other hand. *A satisfactory solution is essential because, if unresolved, environmental pollution and depletion of natural resources present a clear threat to our standard of living, and more importantly, to the entire fabric of life support systems on which the planet earth is dependent*(4). This answers the question of why the issue of sustainable development has great importance.

DEFINING SUSTAINABLE DEVELOPMENT

In 1987, the World Commission on Environment and Development defined sustainable development as *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*(7), and later on at the 1992 Earth Summit in Rio de Janeiro as *Economic activity that is in harmony*

1 Copies of the papers presented at the symposium are available upon request at Tel. (604) 921 - 2250.

with the earth=s ecosystem(1).

There are three key objectives for a sustainable future:

∃ *A socially and environmentally innovative, resource efficient economy that delivers quality of life in the developed world;*

∃ *An improvement of economic welfare and quality of life in the developing world;and,*

∃ *A healthy environment with resources used and conserved wisely - world wide(7).*

HIGHLIGHTING THE PROBLEM

The problem we are facing today is that approximately 20% of the world=s population, mostly living in western Europe, North America and Japan, account for almost 80% of the world=s total energy and resource consumption in order to sustain a Ahigh standard of living≅. Meanwhile the remainder of the world, numbering almost 5 billion people, has greatly accelerated the pace of industrialization in pursuit of a Abetter life≅(1,2). It is not hard to imagine the end result of a process that encourages the continuation of high rates of consumption of natural resources and correspondingly high rates of environmental loading by a variety of pollutants. Clearly, the equation does not add up; there is simply not enough energy nor resources for everyone to carry on with Abusiness as usual≅, and if we do, a global environmental disaster will be unavoidable.

The world population just hit the 6 billion mark this year. This is an increase of 3 billion people since 1960 and an increase of 5 billion since the beginning of 1800(13). As the world=s population grows, enormous demand is put on natural resources and the supply of construction materials to build new infrastructure - such as housing, transportation, ports, water supply and sanitation - needed to support daily life. For example, approximately 1.2 billion people live in China, which has the highest rate of construction activity of any country in the world today(9). It is forecasted that the Pearl River Delta region (comprising Hong Kong, Shentzen, Zhuhan and Macau) alone could become the world=s largest Amegacity≅ with over 40 million people(9). These megacities will require an enormous amount of infrastructure and create tremendous pressure on resources and the environment. *The question of who will make the important decisions on what type of future we want, particularly with respect to infrastructure and the environment, remains open. Engineers, as highly respected designers of the infrastructure, are in a unique position to influence these decisions, and by doing so , the course of history*(4).

CONCRETE TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Concrete has become by far the most popular and widely used construction material in the world. Concrete is perceived and identified as the provider of a nation =s infrastructure and indirectly of its economic progress and stability, and indeed, of the quality of life(6). Concrete is easily and readily prepared and fabricated in all sorts of conceivable shapes and structural systems in the realms of infrastructure, habitation, transportation, work and play. Its great simplicity lies in that its constituents are most readily available anywhere in the world.

Unfortunately concrete has two major drawbacks with respect to sustainability:

∃ *The production of Portland cement is an extremely resource and energy intensive process where every tonne of cement requires about 1.5 tonnes of raw materials. In addition, each tonne of cement produced releases approximately one tonne of Carbon Dioxide (CO_2) into the environment. Thus the production of Portland cement is a significant contributor to atmospheric pollution and the Agreen house effect@(2).*

∃ *Concrete deteriorates when exposed to the environment, which significantly influences its service behavior, design life and safety. Cracking of the concrete, inadequate cover and quality of the cover to steel, and the overall quality of the structural concrete are the three major factors that encourage the transport mechanism of aggressive agents, such as chlorides and sulphate into concrete(2).*

Obvious ways of dealing with the above Aflaws≅ are to minimize the amount of concrete used by avoiding over-design as well as to use appropriate and high quality mix designs, correct designs that follow the recommended crack control parameters, stringent construction inspection and adequate concrete curing. In addition, numerous case histories have shown successful substitution of natural aggregate with crushed concrete from demolition. Also, recycled water from ready-mixed concrete plants has been used as a substitute for fresh mixing water for concrete(6).

Fly ash and/or silica fume concrete mixes have been proven to provide excellent strength and increased durability characteristics(2). These materials are ideal companions to Portland cement, and extensive research has now established that superplasticized concrete mixes where the water/cementitious materials ratio is limited to 0.3 or less can have as much as 60% of the cement replaced with fly ash and produce a 55 MPa compressive strength concrete @ 28 days with excellent durability characteristics including significantly less cracking. In addition, fly ash is counteractive to alkali reactions between cement and aggregates, making it possible to use an increased variety of aggregates for the production of a high quality and durable concrete(1). This paper does not go into the details of concrete/fly ash technology , as it can be studied in the over 20 papers presented at the symposium on concrete technology for sustainable development. It should be noted, however, that the use of high performance concrete (HPC) will increase the durability and life span of infrastructure.

Fly ash (coal ash) is a by-product from coal combustion power plants. Of the total 650 million tonnes of coal ash produced today, only about 7% is used by the cement and concrete industries. The rest is being disposed of, mainly in land fills(1).

China, India and Eastern Europe produce over 450 million tonnes of fly ash every year, or approximately 75% of the total world production. At the same time these areas are forecasted to be responsible for nearly 440 million tonnes, or 80% of the total projected increase in world cement consumption by year 2005(1,2). Thus if we can find ways to use all or most of the available coal ash for the production of concrete, we would be able to meet the projected cement demand in 2005 without any increase in the present capacity of cement production.

As indicated earlier:

∃ each tonne of cement replaced by fly ash reduces the CO_2 emissions by approximately one tonne;

∃ an increased variety of aggregates can be used, as fly ash counteracts alkali reactions between cement and aggregates;

∃ fly ash increases the durability of concrete and therefore prolongs the service life of structures;

In addition, coal ash generally contains toxic metals which contribute to land, air and groundwater pollution when disposed of in land fills. However, when incorporated into the hydration process of cement these toxins become immobilized.

Thus if fly ash is fully utilized, more sustainability can be realized in the concrete industry.

RECOMMENDED ACTION

The replacement of cement by fly ash has substantial advantages, not only increased durability and service life of concrete, but also additional ecological benefits. Therefore, every time we specify a concrete mix for a particular design, we should ask ourselves, or the concrete mix design specialist, if more fly ash can be utilized.

In addition, why are we still designing structures with a service life of 25 to 50 years? Several major structures in the Vancouver area are over 50 years old, but are still in use. Why not increase the design service life to 100 years or 150 years? This would mean less use of energy and resources in the long run for the price of a relatively marginal capital cost increase. The owner would spend less money on maintenance and the structure would have a higher value if it was sold. In addition, engineers should promote the study of economics which considers more realistic life cycle analysis and costing methods rather than the presently used cost discounting approaches, market costing and benefit/cost analysis(4,5,8).

There is an inherent resistance amongst developers and engineers to the use of new, innovative technology, higher quality designs, increased design lives etc. However, it is our professional duty as engineers to inform and teach clients, the public and fellow engineers, not just about the current building codes and laws, but also about the long term benefits from using new environmentally-friendly technology and higher quality, durable designs. *Overall, a special responsibility devolves on engineers to develop a world view in problem solving which considers the effects of infrastructure decisions on the earth and on all living things:*

∃ *engineers need to recognize their responsibility for the conservation and preservation of existing resources;*

∃ *they should promote and participate in the implementation of environmentally friendly technology in order to work towards a more sustainable future;and,*

∃ *they must exercise leadership in these areas(4).*

CONCLUSION

To achieve sustainable development in the concrete industry, we need to understand and appreciate what has happened in the world during our lifetime. There have been, particularly during the last four to five decades, enormous social changes, unpredictable upheavals in the world economy, uncompromising social attitudes, unprecedented population growth, world wide urbanization, technological revolutions and unacceptable pollution and damage to our natural environment. Overriding all these factors is globalization, not just with respect to economies, technologies and community lives, but also with respect to climatic changes and weather conditions(2,10,12).

We are all aware of those days when the smog is hanging thick over the Vancouver area due to pollution from cars and industry. We all know about the boat refugees, arriving on the west coast of Vancouver Island, running away from a life in poverty, overpopulation and pollution, in search of Aa better life≅(11). There is tremendous pollution and environmental impact in developing countries, caused by heavy industry, and from which we support our affluent life style. We are all aware of the floods, hurricanes and disastrous weather causing enormous destruction and death in North America and all around the world(12). The problem is there, it is real, it is growing and we need to do something about it.

As we are entering a new millennium, we should pause to look back and reflect on the lessons that can be learned from the past, construct a vision for the future, and lead the industry, particularly the concrete industry, into a new era of sustainable development. To move toward the goal of sustainable development, a balance must be struck between the equally important needs of society, namely infrastructure to support an acceptable standard of living for all people in the world, and the environment(1).

By using cement replacement materials such as fly ash in concrete, designing for durability as well as undertaking life cycle analyses of construction projects, it is possible to direct the construction industry, and particularly the concrete industry down a more sustainable path. As highly regarded professionals, engineers are in a position to be in the driver=s seat of this process. And by doing so, engineers have an opportunity to influence the course of human history beyond the realm of technology.

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