Factor Ten Emission Reductions: The Key to Sustainable Development and Economic Prosperity for the Cement and Concrete Industry

by R. Horton

Synopsis: Sustainable development in the concrete and cement industry is achievable in the near future. This paper proposes the viability of a factor 10 reduction in the negative environmental effects of current cement/concrete production through the use of cement blends with minimum portland cement and maximum pozzolanic loading. Such cement blends substantially extend the longevity of concrete and avoid the enormous cost of several repair and replacement cycles. The transition to sustainable concrete technology will be driven not by environmental imperative but rather by market forces pursuing economic advantage through more durable concrete. Market driven economics already in place will soon prove that concrete durability is worth a high premium but is available at a bargain. There is enormous leverage in improving concrete quality as a doubling of the price of highest quality cement would add only 2% to overall construction project costs while the extended service life of the structure would offer a many-fold return on the additional investment. In coming years, the consideration of CO_2 emissions regulations and increasingly valuable internationally traded CO_2 credits will assume an economic importance equal to or greater than capital and operating costs among cement producers. Those who do not move to sustainable concrete technologies will run the risk of losing substantial market share or business failure.

Keywords: CO_2 credits; cement; concrete; durability; economics; emmisions; factor 10; pozzolan; rice husk ash (RHA); strength; sustainable development

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INTRODUCTION

At a conference held in Beijing, China in 1996, world experts on the environment and environmental technologies discussed various challenges facing the country and an impressive array of options to address them. After three days of deliberation, the Chinese official in charge of the conference gave his concluding remarks beginning with acknowledgement that a great many good ideas had been presented that should be implemented and, taken together, would make a measurable impact on the environment in China and in the world. Unfortunately, he said, most would not be implemented because they represented cost rather than profit and, in a developing country like China, capital resources would almost always be allocated first to projects with potential to rapidly develop the economy. He told the conference attendees that if they hoped to see their ideas implemented, they must be sold based on economic, rather than environmental benefits. Specifically, he suggested that the only way to sell environmental solutions in China was to be able to say and prove to a potential user, 'I have a secret way to save you money.'

The point made is generally true, not only in China, and embodies a central theme of this paper. To make any industry greener, the case must first be made that the environmentally friendly solution will be more economically profitable. This premise most certainly holds true for the cement/concrete industry. It is entirely within our reach, however, to make vast environmental improvements hand in hand with healthy profits. In fact, this paper outlines a factor 10 improvement in the amount of environmental disturbance created by the production and use of cement (1). Put simply, we have it within our power to arrest environmental degradation due to cement to one-tenth of the current level. The factor ten reduction can and will be achieved. Competitive market forces will drive positive environmental changes because we have the knowledge right now to make concrete formulations based on high-pozzolan content cements that are cleaner, greener, more durable and longer lasting. Not only do such formulations currently exist, they have been tested, proven and advanced over several years in technical papers by researchers in concrete technology, namely, Mehta, Malhotra and others (2, 3).

The futurist Buckminster Fuller theorized that it took 25 years for a systemic change to be integrated into common use (4). Even when the idea is recognized by experts, a period of time is required to overcome the inertia of the marketplace and to make the necessary investments and marketing and operational changes. We have reached such a threshold. For more than two decades those on the cutting edge of concrete technology have touted the rich benefits of pozzolanic cement additives. The drawbacks of pozzolans have been largely overcome and the lines of resistance to their use are now crumbling. The transition to these more durable, environmentally sustainable concretes is underway. It will be made profitably by market leaders while those committed to conventional or environmentally insensitive practices will be left behind.

THE CHALLENGE

Before going further, it is important to take stock of our present situation and forecasts for the future. Current projections estimate world population increasing from today's six billion to nine billion by 2050 and to eleven billion by the end of the century. Providing basic requirements for a population nearly double that of today will intensely magnify pressure for food, water, land, resources, energy, goods and services. As humans struggle to survive, so too the life support system will struggle to endure.

Of course, to imply that humans aspire simply to survive is misleading. What most human beings, in fact, aspire to is not survival but rather aspiration for a better life. Moving toward the prosperity such as that enjoyed by many citizens of developed countries -- home ownership, luxury automobiles, expansive entertainment and media, access to excellent health care, travel, the freedom of wealth -- this is the stuff of the human dream. With the profusion of worldwide information, even the poorest villager in the most remote settlement is aware of the stark contrast of lifestyle available to him or her compared to citizens of more prosperous countries. Unfortunately, accelerating waste-producing consumption is the rule in both developed and developing nations.

In a world increasingly influenced by free markets and more democratic political systems, rising expectations in the developing world must be addressed by government actions that produce visible and tangible improvement quickly, else those populations will support the rise of other leaders promising faster growth. In short, the developing world must and will develop.

In this relentless upward push, the environment will be stressed for resources to make it happen. Even at current levels of human activity, virtually every expert observer agrees on the long-term lack of sustainability inherent in our present use of energy and resources, and the attendant degradation of air, water, soil and climate. Already we are depleting, without adequately restoring, the natural resources such as fish, forests, arable land, fresh water and clean oxygen-rich air at a rate and in ways that will diminish the quality of all life, including that of the most affluent human beings. In virtually all of the major cities of the world, air available to both the most and least fortunate is equally lacking in oxygen and contaminated with particulate and toxic gases. Increased occurrence of extreme weather events, such as super tornadoes, floods, typhoons and hurricanes, which most experts link to global climate change, devastate rich and poor alike.

Worldwide, environmental degradation is well recognized and, particularly in richer nations, governmental regulations as well as voluntary measures are increasingly enacted to minimize the negative environmental impact of our lifestyles. Unfortunately, many such programs are poorly conceived and have minimum effect. An exception has been the recycling of aluminum in the U.S. Even with the success of this recycling program, however, American consumers and industry still throw away enough to rebuild the country's entire commercial airfleet every three months (5). While everyone wants a clean environment for themselves and their families, those who have not first met basic needs cannot be expected to take the time and effort to be environmentally responsible unless that responsibility carries with it a near term economic reward. In less developed countries, environmental policy must be shown to make money if it is to succeed.

Herein lies the challenge: the reconciliation of societal aspirations with the planet's ability to support them. Meeting this challenge is at the heart of the concept of sustainable development. This central goal of sustainable development is one of the supreme imperatives of our time. It requires significant advances in basic knowledge, in the social capacity and technologies to implement what we know and in the political will to aggressively support sustainable development wherever and whenever possible.

However, even if intentions are the best, laws are passed and the population is educated, history has taught us that environmental-friendly enterprises will not be sustained just because they have long-term planetary benefit. Sustainable development, if it has any hope of realization, will be achieved only if those who must support it will also realize current economic gain for their efforts.

Proceeding from this premise, let us examine the situation in the cement and concrete industry. Concrete is the most widely used building material in the world using more than 1.4 billion tonnes of cement in 1999. The production of portland cement is one of the most energy-intensive and polluting of any industrial processes. Eight percent of all CO_2 released into the atmosphere due to human activity is directly associated with portland cement production (6). Suffice to say that our industry is not yet a poster candidate for sustainable development, but the situation is changing.

WINDS OF CHANGE

The production, distribution and application of cement and concrete is so decentralized and varied that it is difficult to say much that is generally true about participants in the industry except we all want to make more money. While many view the cement and concrete industries as mature and inflexible, powerful winds of change affecting the fundamental economics of our businesses are gathering strength. Those who pay attention to which way these winds are blowing can prosper; those who do not will certainly lose market share, if they survive at all.

Like the rest of the world, managers within the cement and concrete industry will embrace the changes necessary for sustainable development only to the extent that compelling and immediate economic forces drive their actions. Many of these market forces are now in place. At the core of the new realities of the marketplace are two principal economic drivers: 1) a market demand for more durable concrete, and 2) environmental costs and benefits that are beginning to figure as importantly, if not more so, to our bottom line as capital and operating costs.

First, let us look at the economics of durability and why the market embraces it now and will increasingly do so in the future. More and more, the cement and concrete market is dominated by governmental agencies that participate in regulating and/or financing applications of these products. In the United States, 45% of direct cement purchases are for public works. In more controlled economies, such as China, the percentage is much higher. Historically, while regulations and standards existed as local guidelines, frequently they were either poorly conceived and/or not strictly enforced. Into the present, inconsistent products and application techniques lead to many structural failures that are both costly and embarrassing. Even good quality products applied as prescribed have a poor history of durability, causing government agencies, as the ultimate consumers, to themselves become sophisticated and intolerant of poor cement and concrete performance.

Examine, for example, a 1997 National Research Council study in the U.S. that stated its objectives "were to look beyond near-term developments in concrete technology to identify R&D opportunities in innovative, nonconventional materials and processes that have the potential to accelerate the construction process, improve the durability of highway pavement and bridges, and enhance the serviceability and longevity of new construction under adverse conditions. Meeting even one of these three objectives could save billions of dollars in construction and maintenance costs. The U.S. Department of Transportation estimates that the cost of maintaining 1993 highway conditions is

$49.7 billion per year and the cost of improving them is $65.1 billion per year. For bridges, the cost to maintain 1994 conditions is estimated at $5.1 billion per year and the cost of improving them at $8.9 billion per year." (7)

For multibillion-dollar reasons like these, a trend toward more stringent durability requirements is well underway. Caltrans (the transportation authority for the State of California) now requires at least 25% fly ash by mass of the cementing materials in concrete products to avert durability problems stemming from alkali-reactive aggregates. The Port Authority of New York and New Jersey has specified a 1000 coulombs charge in the standard ASTM test for rapid chloride penetration (ASTM C1202) to control the permeability of concrete. These are but two of many examples across the United States. The world today increasingly demands specific steps be taken by the concrete construction industry to improve the longevity of its products.

Simple economics is the reason that the trend toward durability requirements will continue. The cost of concrete in most projects is no more than 4% of total project cost. Cement cost is roughly half this amount. If a more reliable or long-lasting structure or road can be ensured by even a doubling of the cost of cement, insurance of durability and quality can be had for a 2% increase in the project cost. To illustrate, take for example a 30-year project at a cost of $10 million. If the useful life of this project is extended by ten years, giving it a 40-year life, its productive use is extended by one-third, thus saving a building cost of $3.33 million. If the cement cost in this project were 100% more, or $400,000 instead of $200,000, the savings from using a longer lasting formulation would produce a seventeen-fold return.

With savings this compelling, and as projects are increasingly subjected to computer-driven cost modeling, the institutions that set the rules and pay the bills will increasingly insist on maximum durability for many projects, regardless of the price of cement. Economics will drive this decision. Today, the formulations, standards and understanding of what constitutes value in concrete are available instantly and at no cost via email to any interested party.

And there are some very interested parties. The enormous financial strain on the construction budgets of many governmental agencies has reached crisis proportion due to the premature maintenance costs and alarming failure rates of buildings and infrastructure. For this reason alone, the argument for requiring and using the highest-quality, longest lasting cements available is irresistible for all but the most temporary structures. High performance cement is a multi-billion dollar opportunity for our industry and an economic bargain for our customers.

Whereas portland cement and its various types have been the standard for the construction industry for 150 years, new blended cements priced on a performance basis will dominate in the 21st century. This domination will take hold as the market becomes increasingly educated and willing to pay for performance. Top performance will require far more careful attention to mixing, sizing, water content, aggregates and curing methods than are now commonly practiced by many in the ready-mixed concrete industry. Those who adapt to a higher standard of performance will flourish as products are increasingly customized and priced based on a specific application. The use of blended cements and precasting of concrete will also increase as many advantages of controlling formulation conditions are better understood.

Some people will argue that developing countries in particular will opt to pay less for cement and lower the initial cost of projects. This situation will not persist because of the low incremental cost of higher quality and increased durability of concrete. Self-preservation is well understood by decision makers around the globe. They gain considerable political mileage from a new project or road but little credit for maintenance spending. More durable and longer-lasting projects mean fewer repairs and more money for new projects. Ultimately, officials at the multinational funding agencies will insist on better quality concrete if their funds are to be committed to a given project.

The cement and concrete industry already has extensive knowledge about making better quality concrete, at a price. A great deal can be accomplished toward achieving greater durability by simply teaching concrete buyers that more durable, additive-compatible cements are a bargain even at higher prices. To the extent that the market increasingly shifts to performance-oriented products valued on their strength and durability, prices for superior cements will rise to accommodate incremental cost of achieving superior results. Higher-value, longer-lasting formulations and products will ultimately dominate the market and allow the technology leaders providing them to substantially widen their margins.

Turning our attention to the second major economic driver pushing the transition of our industry toward sustainable development -- the market impact of environmental costs and benefits -- consider first the impact of environmental issues directly on the capital and operating costs associated with our industry. There are many recognized environmental costs already associated with the conventional production and distribution of cement and concrete. Items such as the time and permitting involved in siting a cement kiln are directly affected by the resistance of many localities to have dirty industry locate in their neighborhood. Siting issues can affect proximity to markets and raw materials as well as the ability to install cement production capacity on a timely basis. More than 25 million tonnes of foreign cement was imported into the United States at prices often above local production costs in 2000 due in part to the uncertainties of creating additional kiln capacity. The cost of cement production is also increasing as regulations around the world demand that cleaner, higher cost fuel be used in kilns.

Furthermore, whereas new kilns used to produce portland cement require capital investment of $150 to $175 per annual tonne to site and build, pozzolanic materials, on the other hand, often require little or no plant since they are frequently recycled from other industries. Roughly 400 million tonnes of fly ash are produced annually from coal-fired utility boilers worldwide and several billion more tonnes are stored in ponds and piles. For a fraction of the current cost of producing portland cement, fly ash can be recovered and beneficiated to remove carbon and increase its reactivity.

The two most populous nations on earth, China and India, primarily burn coal to generate electricity. They will likely have the largest growth in cement/concrete demand in this century. They have an enormous economic opportunity to use their abundant fly ash resources effectively, both to avoid the cost of disposal and to extend the value purchased with their construction budgets.

Today in the U.S., the typical cement formulation, if it contains fly ash at all, contains 15% to 20% ash by weight of the total cementitious material. Soon the number will typically be 50% to 60% ash. The line will blur when we speak of 'additives' whether the reference is to pozzolan or portland cement.

Percentage fly ash will escalate because:

- improved technology will allow for higher early strength and consistent reactivity of high percentage pozzolan mixtures;
- fly ash will be widely acknowledged for improving critical performance characteristics, such as workability, impermeability and durability;
- industries emitting high levels of CO_2 will pay a penalty for these emissions; and
- whoever can prove emission reductions will earn CO_2 credits.

CO_2 credits will be a major economic factor that will drive the cement industry toward a factor ten environmental improvement. The Kyoto Accords call for the trading of greenhouse gas (GHG) credits, which, of course, includes CO_2 credits (8). Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), industrialized countries have adopted legally binding emission levels – at 5.2% below 1990 levels on average. These reductions must be made by the first compliance period, 2008-2012.

CO_2 credits will be monetized and traded in much the same manner of the highly successful allowance trading system in the United States to phase out lead in gasoline and cut emissions of SO_2. Cement producers will be taxed on excess emissions. Those using pozzolans in their cements will earn credits to offset these penalties. Within ten years, CO_2 credits and the way they are managed within the cement industry are likely to be as important as the actual cost of portland cement production.

Credits are earned by those who take actions that reduce the amount of CO_2 produced by a given activity. For example, replacement of 25% of portland cement by fly ash in blended cement will reduce the CO_2 required in production by 250 kilograms, or 25%. Therefore a 250-kilogram CO_2 credit would be available for each tonne of blended cement produced with a 25% ash component. On the other hand, companies that produce high levels of CO_2 will be liable to either reduce their emissions to acceptable levels or enter the CO_2 market to buy credits sufficient to reduce their net emissions to regulatory levels.

In order to create a viable market, verification of benefits must be established as well as motivated buyers and sellers. A host of major companies and countries are addressing these issues today. Natsource, a leading broker of energy products, points out that the cost savings in the lead and SO_2 programs in the U.S. have been substantial, amounting to as much as 50% when compared with a control policy in which no trades were allowed. Trading policies have sharpened market awareness and yielded a competitive advantage. They have also spurred development of emission reducing technologies (9).

The likelihood of CO_2 emission reduction regulation poses a significant financial risk to emitters. Emitters must therefore cost-effectively manage their risks in order to protect revenue flow and shareholder value. An emitter might wait to see exactly what reductions are required before purchasing the required credits in the CO_2 market, but projected future prices of greenhouse gas emissions suggest that the cost of compliance at these levels could be crippling to the emitter.

In the current GHG market, banked credits and forward streams of emission reduction credits are trading at attractive prices. Therefore, many emitters are hedging exposure on a forward basis right now. The CO_2 market offers the most cost-effective route to achieving future emissions reduction compliance levels and is driving the market on risk management concerns rather than current compliance issues. In effect, the CO_2 market offers a cost-effective insurance policy that the international market is increasingly pursuing.

From an economic viewpoint, cement companies that do nothing to substantially offset the CO_2 effect from production and use of their products will be forced to add a new cost of production. Today, a one-tonne CO_2 credit is worth between $1.50 and $4.00. Most experts agree that its market value will increase because it offers a feasible economic means to create net environmental gains while operating highly polluting but profitable industries. While it is impossible to say precisely what price credits will command, predictions range from $25-$100 per tonne for credits in the intermediate term.

A useful analog to this situation is found in the coal industry. Historically, coal sold at prices roughly 30% below oil and natural gas on an energy equivalent basis because it was solid, harder to transport and store, dirtier and more costly to burn. Nonetheless, when the price of oil and gas rose, the price of coal rose, like a shadow, a similar percentage amount.

In November 1991, revisions to the Clean Air Act were enacted that called for SO_2 credit trading. Further action has imposed stringent restrictions on NO_X emissions and the trading of their credits. Additional data are also being reviewed relative to heavy metal emissions and these gases are likely to be tightly restricted as well. Because coal, and not oil and gas, emit these gases, the cost of removing them, i.e., the environmental cost of burning coal, has become a real economic penalty. Coal now sells, on an energy equivalent basis, for roughly $1 per million Btu – less than 20% of the current price of equivalent energy in natural gas.

There is no question that, in the near future, the price of cement will also more nearly reflect the environmental costs associated with its production and use. Because cement, like coal, is a relatively environmentally unfriendly commodity, the incremental cost will be substantial. It should also be noted that, like coal, regulations and credits will eventually factor nearly all environmental costs in order to prevent the exporting of pollution to less developed and regulated economies. For example, cement imported from Thailand to the United States will be subject to environmental penalties associated with its production as well as its transportation. In this case, any labor materials or regulatory savings for polluting in Thailand rather than the U.S. will be defeated by higher transportation costs and environmental penalties.

It is a central tenet of sustainable development that, wherever possible, transportation of commodities should be minimized. In this regard, it is interesting to note that roughly 10% of all oil traded worldwide is consumed in its transportation and that more than 25 million tonnes of cement are imported into the U.S. alone. Most international trade in cement will cease to make economic sense when all environmental costs for cement are factored, especially when those costs include incremental penalties associated with extraordinary transportation and its incremental requirement of fossil fuel combustion.

WHAT CAN BE DONE?

Generally, methods available to cement makers to measurably reduce CO_2 emissions involve the replacement of portland cement with fly ash or other pozzolanic material and/or the improvement of cement characteristics enabling less cement to be used for a specific purpose.