



**FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA**

**DUALITY OF CEMENT- BASED STRUCTURES:
MITIGATING GLOBAL WARMING
AND BUILDING COLLAPSE**

By

JOSEPH OBOFONI ODIGURE

*M.Sc. (Hons), DEA., Ph.D, MNSE
Professor of Chemical Engineering
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INAUGURAL LECTURE SERIES 13

5TH MARCH, 2009



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This book is dedicated my wife Mrs. Helen E. Odigure and children; Hilda, John, Josephine and Joseph and most especially, to Almighty God for His unfailing love.

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Ladies and Gentlemen**

I also want to acknowledge the presence of our God, the ALMIGHTY Father in this gathering.

INTRODUCTION

The concept of this work and my sojourn in academy is a product of the contrast in my University education and my working environment; a contrast between a robust academic abundance and poverty. The Nigerian education is presently driven by theory. This presentation is structured in triple helix; chemical analyses developing reaction mechanism/models predictable outcomes. The global relevance of this work stems from the developed models.

There were 2.35 billion tons of cement used in 2007 and demand is increasing at 130 million tons per year worldwide. 1.4 billion tons of cement is produced and used in China in 2007¹. It is estimated that Nigeria local

installed capacity should be in the region of 6 or 7 million metric tonnes at the moment. The total national demand for cement is put at about 15 million metric tonnes while production is in the neighborhood of 6.2 million metric tonnes and 8 million metric tonnes are imported in bulk and re-bagged in Nigeria.

CO₂ emissions are 27 billion tons per year worldwide². The entire US production of CO₂ is now 6 billion tons. Current cement production process technology releases about 5 billion tons of CO₂/year. The growing atmospheric carbon dioxide concentration will reach 550 ppm by the end of the century if left unchecked. The Kyoto agreement calls for reduction of CO₂ emissions by industrial nations to 5% below 1990 levels between 2008 and 2012.

Cement-based products constitute the largest surface area man-made structure apart from naturally occurring sea and forest land. The World trade center used 955,000 tons of cement and 200,000 tons of steel and had 10 million square feet of space. The world commercial building business is a trillion dollar industry making billions of square feet each year³. Shanghai had 3000 buildings over 24 meters (12 stories) high by 2000 meters and a hundred of which are over 100 meters high⁴. New 5-7 MW and larger wind turbines are over 120 meters tall and require hundreds of tons of cement for each construction. There are also demands for hundreds of new airports. 10.8 million tons of cement used for the Three Gorges Dam.

C e m e n t c o s t s b e t w e e n \$ 9 0 - 1 5 0 / t o n ^{3 , 4} .

The various ways to reduce CO₂ emissions include developing revolutionary emission free energy production processes, sequestration by artificial carbonate rocks, forestation of desert land etc. Various goals for avoiding climate change suggest reducing those emissions by 7 billion tons/year or more aggressively to half the current level. Calera, a Vinod Khosla funded company, is starting up a pilot plant for a new type of cement and process that would remove 1 ton of CO₂ from the air to make 1 ton of cement. The plan is to have 100 plants producing up to 1 billion tons of the new cement by 2015.

This technology has the potential to accelerate cement production by 10-40 billion tons/year instead of 4 billion tons per year (under normal growth) by 2020. It would be a major form of productive carbon sequestering^{3,5,6}.

Robert Niven, founder of Halifax-based Carbon Sense Solutions⁷, says that his company's process would actually allow precast concrete to store carbon dioxide. The company takes advantage of a natural process; carbon dioxide is already reabsorbed in concrete products over hundreds of years from natural chemical reactions. Freshly mixed concrete is exposed to a stream of carbon-dioxide-rich flue gas, rapidly speeding up the reactions between the gas and the calcium-containing minerals in cement (which represents about 10 to 15 percent of the concrete's volume). The technology also virtually eliminates the need for heat or steam, saving energy and emissions^{1,7,8}.

Work is expected to begin on a pilot plant in the province of Nova Scotia this summer, with preliminary results expected by the end of the year. If it works and is widely adopted, it has the potential to sequester 20 percent of all cement-industry carbon-dioxide emissions⁷.

The idea of concrete carbonation has been around for decades but has never been economical as a way to strengthen or improve the finished product. In the late 1990s, researchers showed how carbon dioxide could be turned into a supercritical fluid and injected into concrete to make it stronger, but the required high pressures made the process too energy intensive. Carbon Sense Solutions claims to achieve the same goal but under atmospheric pressure and without the need for special curing chambers

It is well documented that all concrete absorbs carbon dioxide over time if left to cure naturally--but only up to a point. The gas usually penetrates the first one or two millimeters of the concrete's surface before forming a hard crust that blocks any further absorption. Naik says that something as simple as using less sand in a concrete mix can increase the porosity of the finished product and allow more ambient carbon dioxide to be absorbed into the concrete. It's simpler than Carbon Sense Solutions' accelerated curing

process and can be applied to a much larger market⁸.

Other groups are working at utilizing the emissions from the cement-making process itself. Researchers at MIT are seeking new ingredients in cement that are less energy intensive, while companies such as Montreal's CO₂ Solution have an enzymatic approach that captures carbon-dioxide emissions from cement-factory flue stacks, converts the greenhouse gas into limestone, and feeds it back into the cement-making process. Calera, backed by venture capitalist Vinod Khosla, even claims that it can remove a ton of carbon dioxide from the environment for every ton of cement it produces.

Cement-based structures are hardly ever built under ideal conditions, so, for variety of reasons, defect may occur as the concrete is being cast or after some time⁹. The factors that initiate corrosion of cement-based structure could be physical or chemical in nature^{10,11}. Reactions occurring internally in cemented systems may have significant adverse effect on concrete structure¹⁰⁻¹⁵. The compressive strength of cement-based structures is expected to increase steadily with age. However, this statement may not be true for many structures, especially those serving in aggressive environments. In some areas, most cement-based structures were found to develop micro-cracks within a few years after construction despite the fact that acceptable standard were observed¹¹. Various researchers have proved that long exposure of cement-based structures to aggressive medium containing acids, salt and alkalis immensely enhance their physicochemical and mechanical properties deterioration¹⁰⁻¹⁶.

Reactions occurring internally, such as alkali aggregate reaction give cause for concern, because this type of deterioration does occur in non-aggressive environment¹⁵. The potential for reaction is conditioned by chemical and mineralogical nature of the concrete system components; cement-aggregate - water composition, as well as prevailing environmental condition - temperature, humidity, etc. Results of various researchers have shown that the weak point in hardened cement microstructure remains the presence in it

of soluble and reactive $\text{Ca}(\text{OH})_2$ ¹⁰.

The basic origin of the chemical energy potential involved in alkali-aggregate reaction is associated with the thermodynamically unstable nature of the reaction products involving the siliceous aggregate materials and the alkaline mineral hydrates from the cement¹⁷. This to a large extent defines the cement-based structures matrix rheology and morphology. For structures exposed to seasonal wetting or flooding by water their chemical deterioration will depend on the extent of solubility of the mineral hydrates and possible migration through the various hardened matrix. Such migration of the soluble salts or hydrates will be enhanced by contact of such structure to a wet earth base/foundation. This determines the stability of the cement based structure it development of microcrack or even collapse. Presented in Figures 1- 6 are common pictures of cement-based structure failures.



Figure 1: Poor adhesion at paint cement mortar interphase



Figure 2: Cracking of sandcrete wall



Figure 3: Cracked wall

