GREEN BUILDING: IMPACTS OF FLY ASH ON SUSTAINABLE DEVELOPMENT

Erin Wright
Department of Civil Engineering, College of Engineering, University of Arkansas

BACKGROUND

Concrete is the most widely used building material in the world. It is composed of aggregate, water, and cement. In most cases, the cement used is Portland cement; however, the cement production has a significant effect on the amount of carbon dioxide emitted into the atmosphere by the construction industry. In order to reduce these harmful emissions, a portion of the cement can be replaced by fly ash. Fly ash is a cementicious waste material formed during the combustion of coal. Fly ash is generally substituted for a maximum of 15-25% of Portland cement in the United States.

PROJECT OVERVIEW

Before analyzing the environmental impacts of fly ash substitution, its merit as a structural material was considered. Impacts on workability, curing time, strength, and freeze-thaw resistance were compared to determine if there were any significant, negative effects stemming from the use of fly ash as cement. The method of determining the sustainability of fly ash concrete began by extrapolating carbon emissions from Portland cement use to 2013 and assessing differences in the amount of embodied carbon from standard concrete mixes to those using varying percentages of fly ash. This data allows a total global savings of carbon emissions to be determined. Also, based on senior-level Foundation Design Project, the emissions saving can be compared for a standard-size residential building to put findings in comprehendible terms.

RESULTS

If high quality fly ash is used in a concrete mix design, it will increase the workability of the concrete due to its unique spherical structure. The curing time of fly ash concrete is higher than that of typical concrete and its early strength is noticeably lower. However, when properly cured (which is especially important in colder climates) fly ash concrete has a higher ultimate strength.

RESULTS

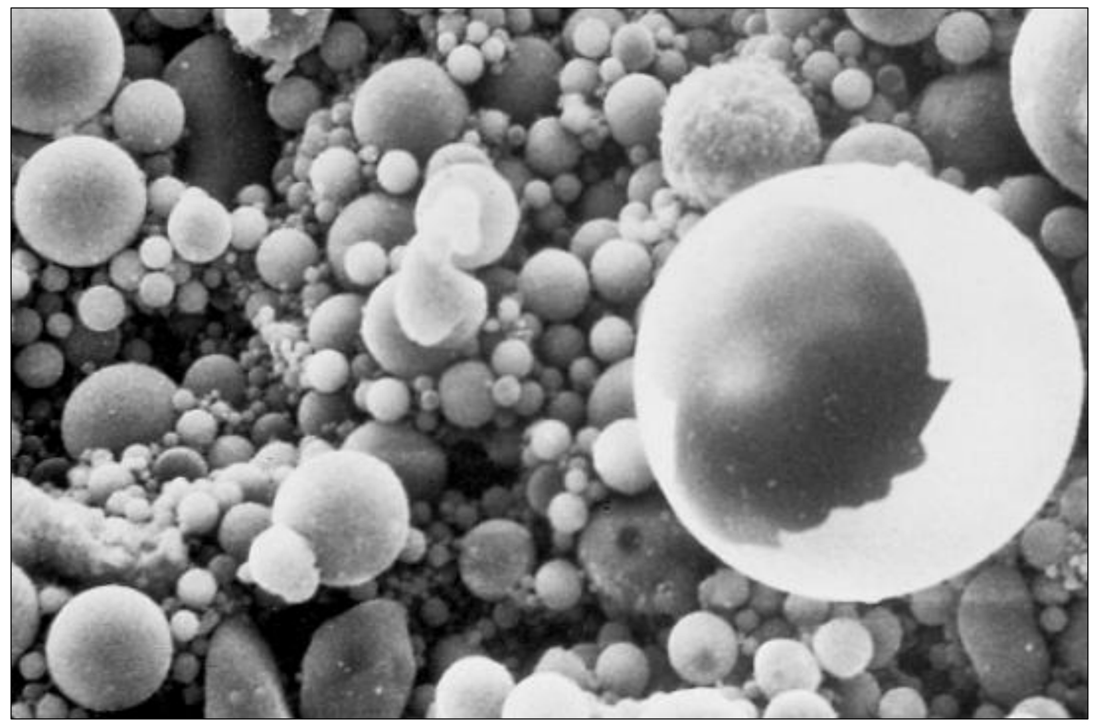

Figure 1. Micrograph of spherical fly ash particles (Thomas)

The figure above illustrates the unique spherical shape of fly ash particles. Coal combustion leaves a residue of molten mineral droplets that harden to form the spherical particles. This shape is the reason behind the increased workability and high late strength of fly ash concrete. Portland cement, however, has a jagged, angular microstructure and therefore has different structural properties.

Figure 2 below represents the growth of cement production globally from 1970-1995, which illustrates the immense growth of the industry and therefore global carbon dioxide output.

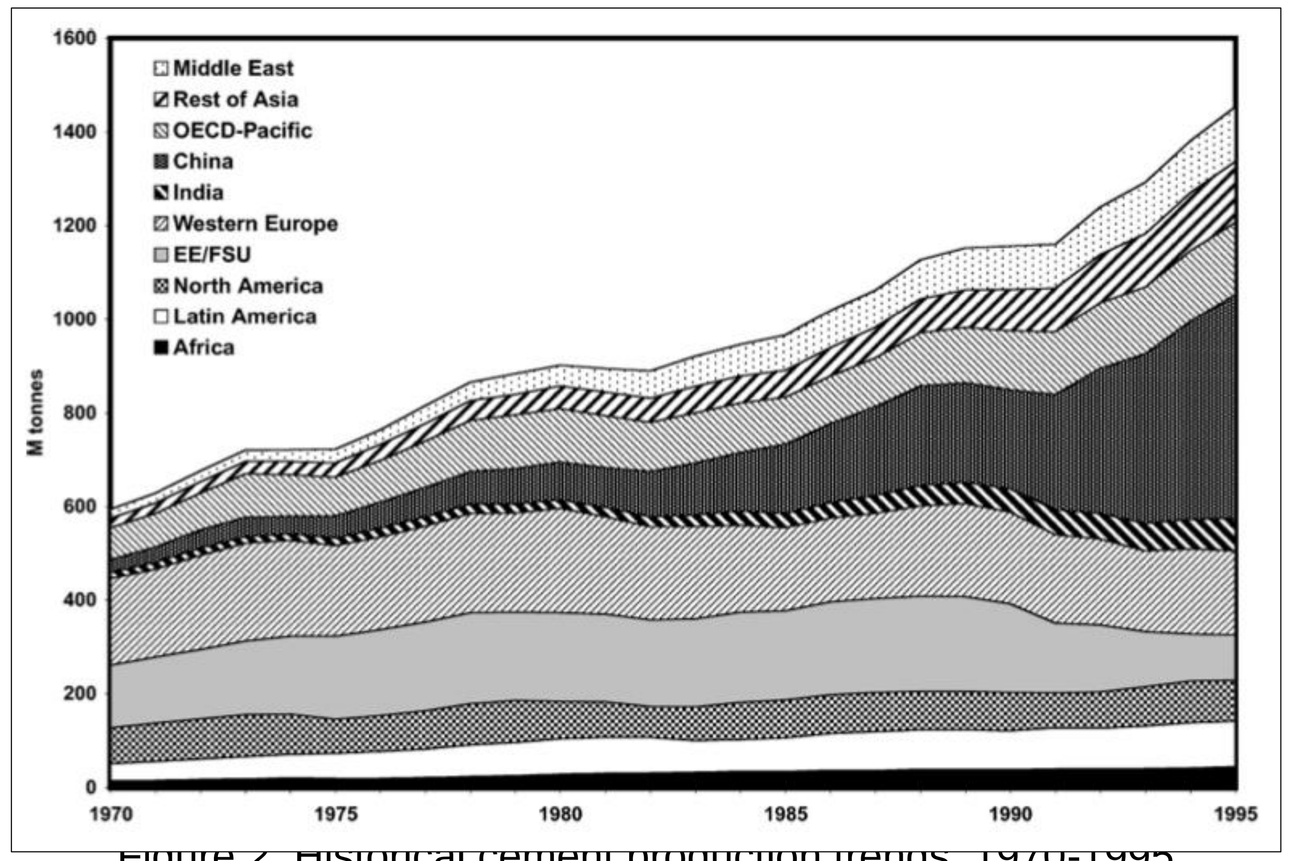

Figure 2. Historical cement production trends, 1970-1995 (Worrell, et al.)

As the world population increases and developing countries grow, the use of concrete for new structures also grows. Every attempt should be made to reduce any negative impacts to the environment as this growth cannot be sustained infinitely.

CONCLUSIONS

When the data below was originally gathered, less than 10% of fly ash produced every year was used rather than sent to a landfill. Since that time, the US and its manufacturing have grown which in turn increases fly ash production, but usage has increased as well.

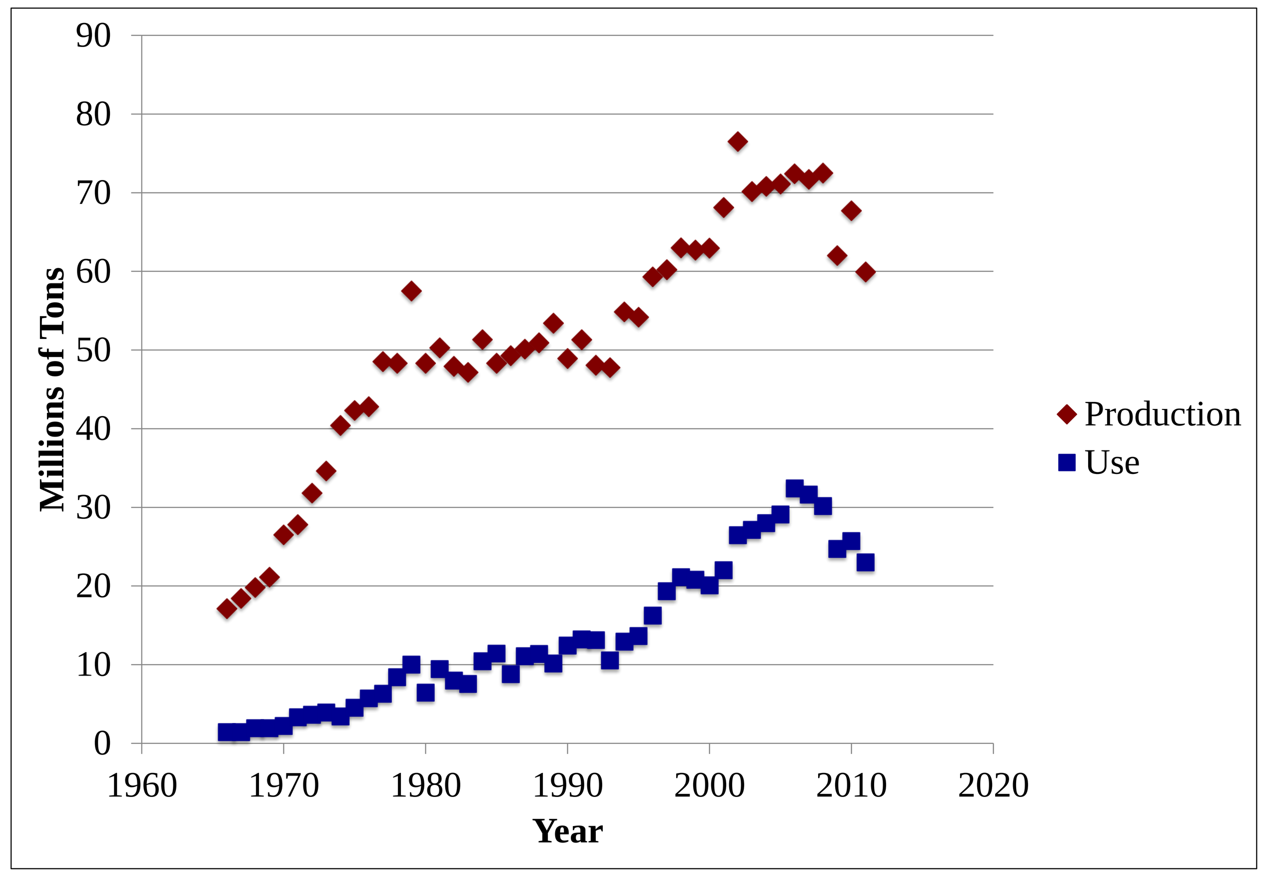

Figure 3. U.S. Production and Use of Fly Ash, 1966-2011 (ACAA)

Portland cement production in the US in 2011 was approximately 83.2 megatons (Worrell et al.). Assuming 25% of that cement could be replaced by fly ash in concrete mix designs, 20.8 Mt of fly ash would be needed. In 2011, 59.9 Mt of fly ash was produced and less than 40% of that amount, or about 23 Mt was used. Some states, such as California, require fly ash to be used in their concrete. However, under the cynical assumption that none of the fly ash used in 2011 was for the purpose of concrete, the difference between the amount of fly ash produced and the amount used would still fulfill a 25% replacement of the total Portland cement produced that year. Therefore, the current resources of the United States allow for the partial replacement of Portland cement to reduce emissions from concrete. Traditional Portland cement concrete has embodied carbon of 0.83 kg CO_2/kg cement. A 25% replacement of fly ash decreases those emissions to 0.62 kg CO_2/kg of total cementicious materials. An estimated 2650 Mt of cement will be produced in 2013. If fly ash concrete was used around the globe, approximately 557 million tons of carbon dioxide would be saved from entering the atmosphere.

SUSTAINABILITY

This project contributes to the sustainability of built systems which due to high carbon emissions have negative impacts on natural systems. By utilizing fly ash in concrete mix designs, the global construction industry can become more sustainable as a whole. Fly ash concrete has lower overall carbon dioxide emissions without compromising but actually enhancing workability, long-term strength, and freeze-thaw resistance of concrete as a construction material.

This project has enriched my experience at the University of Arkansas because it is a perfect example of a simple way to link sustainable concepts to the knowledge I have gained in pursuing a degree in Civil Engineering. Knowledge of green building practices and sustainability is sought after in the field of Civil Engineering and will open many doors when I am navigating the job market. It is my personal belief that sustainable development and sustainable lifestyles are the only way to preserve the standard of living that we are accustomed to for the future.

REFERENCES

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