Somero Enterprises

Fort Myers, FL

2/11/2022

EXPLORATORY STUDY ON ESTIMATING CARBON REDUCTION CAPABILITY OF LASER SCREED USAGE

Sustainability in the Concrete Industry

Concrete in one of the oldest and most wildly used building materials within the construction industry. Its application can be seen throughout the built environment in which we work and live; however, there is a global concern among environmentalist with regards to the amount of carbon dioxide (CO_2) emitted during the Portland cement manufacturing process, which is estimated to be 5-8 percent of global CO_2 emissions (*1,2*). Because of this, the concrete industry is continually evolving to mitigate these impacts on our planet. Over the past decade many research efforts have focused on reducing CO_2 emissions associated with the production of Portland cement and the consumption of high-quality limestone, which is a fundamental material used in the Portland cement manufacturing process. Research has shown that blending Portland with industrial by-products, such as fly ash, slag, and silica fume, can reduce the need of Portland in concrete mixtures. Mitigation efforts such as these have certainly had an effect on carbon emissions associated with concrete; however, there is still a need to develop innovative strategies to reduce these concrete based emissions even further.

One particular area in which little to no research has been conducted to minimize concrete CO_2 emissions is the construction techniques used by the concrete industry themselves (*3*). William McDonough, who developed the famous Hannover Principles, pointed out that it's critically important to include innovative construction technologies and methods when creating sustainable structures (*4*). This thoughtful insight suggest that construction methodologies used within industry must continue to evolve to not only meet the demands of an evolving marketplace, but also the environmental stewardship responsibility faced within the construction industry. Ultimately, it is in the hands of concrete industry professionals to develop and implement innovative solutions to meet these stewardship responsibilities and reduce concrete based greenhouse gases emissions.

Mitigating Carbon Impacts Within Concrete Construction

While many research efforts have focused on the development of alternative concrete mix designs to minimize carbon impacts (i.e., reduce Portland cement needed in a mix), limited efforts have focused on developing innovative construction methodologies that aim to reduce the quantity of concrete needed/wasted during concrete placement operations. This approach to concrete sustainability was identified by Mehta (*5*), who proposed a sustainability triangle that focused on three key aspects, which include: 1) consume less concrete for new structures, 2) consume less cement in concrete mixtures, and 3) consume less clinker when manufacturing cement. Mehta indicated that when these key elements are combined, the concrete sustainability triangle would have a net effect of 50% saving in clinker (*5*). Knowing these fundamental concrete sustainability goals, the concrete industry can now focus on how to achieve these goals.

One potential strategy to meet these goals is to begin exploring and adopting new construction technologies that aim to consume and waste less concrete during the concrete placement process. When focusing on horizontal concrete placement operations, this can be achieved by: 1) using automatic machine control technologies during subgrade preparation (e.g. laser guided skid steer), 2) selecting subgrade soils that, when compacted, have minimal pore opening in which concrete may enter (e.g., graded aggregate base) , 3) installing formwork square, level, and plumb per design guidelines using digital survey equipment (e.g. total station), 4) insuring formwork is structurally sound to prevent concrete blowout and formwork undermining (e.g., braced), and 5) finishing concrete mechanical using automatic machine control technologies (e.g., laser guided screed machine). In combination, these construction practices would lessen the demand for concrete within the slab (i.e., filling low areas in the subgrade) and minimize concrete finishing defects along the slab surface (i.e., bird bathing). Practices such as these would certainly be effective ways to improve sustainability of concrete structures within the built environment.

A case study data analysis was conducted to estimate additional concrete consumption when finishing horizontal concrete slab work manually, as oppose to finishing horizontal slab work using a laser guided screed machine. Jobsite data suggest that the use of a laser guided screed can reduce the volume of concrete required by 18 cubic yards over 100,000 square feet when compared to manual screed operations. This reduction can be accreted to a 1/8 inch reduction in leveling error over the surface of the slab, which is often introduced during manual concrete screed operations. This analysis suggest that laser guided screed machines reduce the volume of concrete required, per square foot of horizontal slab placed, by approximately 0.0002 cubic yards. This reduction in concrete ultimately results is a reduction of CO_2 generation of approximately 0.0006 tons (1 YD^3 Concrete Production ≈ 2.9 Tons CO_2 Produced) per square foot of horizontal slab placed using a laser guided screed machine (*7*).

In addition to concrete savings, a concrete slab finished using a laser guided screed machine provides a finished surface that does not require costly floor coverings. Three noteworthy sustainable benefits have been identified with the no-floor-covering option in concrete construction. First, a concrete slab without a floor covering has a greater potential to directly contact the atmosphere. This direct exposure facilitates carbonation, which is the absorption of CO_2 back into the cement, thus reducing net CO_2 emissions associated with the concrete slab (*1*). Over the life-cycle of a concrete element, roughly 20 percent of the CO_2 generated during the cement manufacturing process is reabsorbed back into the hardened cement (*6*). Second, uncovered concrete slabs reduce chemical contaminates (e.g., volatile organic compounds) released into the atmosphere because concrete does not off-gas as many floor coverings and adhesives do (*1,6*). The toxic contaminates found in many floor coverings can degrade the indoor environmental air quality of a building and cause occupant discomfort and health issues over time. "Engineering Out" products and materials that are known to have adverse effects on indoor environments is perhaps the easiest way to ensure a healthier indoor environment (*6*). Third, the natural color of finished concrete has a high reflectance value which allows naturel daylight to reflect back into interior spaces, thus reducing artificial lighting requirements (*1*). This has a considerable effect on reducing energy consumption over the life-cycle of a structure, which lessens demand on CO_2 emitting power plants.

Developing Sustainable Construction Practices in the Future

As the construction industry continues to push the cutting edge of concrete sustainability, it's critical to recognize the impacts of concrete mix designs on the environment (i.e., raw material extraction, processing, transportation, consumption, service, deconstruction, and reuse) and resiliency (i.e., designed toughness) requirements of new concrete structure being built. As these factors evolve and take permanent root within industry, concrete construction methodologies must also evolve to meet sustainability demands of society, the economy, and the environment. Early adoption of innovative concrete construction technologies that aim to reduce environmental impacts by minimizing concrete waste and raw material consumption will certainly show commitment to a sustainable future and will provide a marketable advantage when these services become preferred within the sustainable construction community.

The concept of sustainable concrete construction practices (i.e., methodologies used to construct a concrete structure) are vastly unexplored and are often overlooked. To further advance sustainability within the concrete industry, future analyses should focus on identifying the capabilities of state-of-the-art concrete construction practices used when placing and finishing sustainable concrete mixtures containing high percentages of:

- Recycled concrete aggregate (i.e., virgin aggregate replacement);
- Fly ash (i.e., Portland cement replacement); and
- Graywater (i.e., potable water replacement).

Insuring that state-of-the-art concrete construction practices have the capabilities to seamlessly handle sustainable concrete mixtures containing these CO_2 reducing materials will show dedication to the advancement of a sustainable future within the construction industry.

References

1. Hooton, R.D. and J.A. Bickley (2014). "Design for durability: The key to improving concrete sustainability." *Construction and Building Materials*, 67, 422-430. doi: 10.1016/j.conbuildmat.2013.12.016
2. Johnston, D. and S. Gibson (2008). Green from the Ground Up: Sustainable, Healthy, and Energy-Efficient Home Construction. The Taunton Press, Inc., Newton, CT.
3. Naik, T.R. (2008). "Sustainability of Concrete Construction." *ASCE Practice Periodical on Structural Design and Construction*, 13(2). doi:10.1061/(ASCE)1084-0680(2008)13:2(98)

4. McDonough, W.P. (1992). "The Hannover principles: Design for sustainability." *EXPO 2000*, Hannover, Germany, William McDonough & Partners, Charlottesville, Va.
5. Mehta, P.K. (2009). "Global Concrete Industry Sustainability." Concrete International, 45 – 48.
6. Kibert, C.J (2013). Sustainable Construction: Green Building Design and Delivery, 3rd Edition. John Wiley & Sons, Inc., Hoboken, NJ.
7. Case Study Data Provided by Somero Enterprises Inc., Fort Myers, FL, 2022.

Appendix

Determination of CO_2 emissions per yard of concrete production:

$$\left(\frac{1\,YD^3 Concrete}{2\,Ton\ Concrete}\right)\left(\frac{1\,Ton\ Concrete}{0.17\,Ton\ Cement}\right)\left(\frac{1\,Ton\ Cement\ Production}{1\,Ton\ CO_2\ Emmisions}\right) \approx \frac{1\,YD^3 Concrete}{2.9\,Tons\ CO_2}$$