Keynote Speech

Climate and Construction: Chained by Carbon – A Perspective

Prof. Narayanan Neithalath

School of Sustainable Engineering and the Built Environment, Arizona State University, Tempe AZ, USA

*Corresponding author: Narayanan.Neithalath@asu.edu
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The enormous amounts of carbon dioxide and other greenhouse gases emitted by various industries have resulted in global climate imbalance. The United Nations report that carbon dioxide levels have pushed passed another record threshold, after rising in 2019 at a rate faster than the average for the last 10 years. Climate impacts are compounding threats to human health, security and economic stability posed by COVID-19. Even with pandemic lockdowns slowing economic activity, atmospheric concentrations of greenhouse gases have continued to rise. It is now well known that, to limit global temperature rise to 1.5 degrees Celsius, global emissions must be reduced by 45% by 2030, from 2010 levels. This can be accomplished only through a collective effort where anthropogenic and natural systems are harmonized. From a perspective of construction, a large industry responsible for the well-being and progress of humanity, many actions can be adopted, some of which are listed here.

Construction is the backbone of a modern civilization. It provides habitat to the growing world population, spaces to carry out all aspects of manufacturing, business and leisure, infrastructure for exploration of energy resources required to sustain the population, infrastructure to protect the population from extreme events, and enables smooth transportation of people and goods through land, sea, or air, to name a few. Construction is a very large component of the global economy, with more than $10 trillion spent on construction-related goods and services annually. With ballooning global population and the need for more housing and infrastructure, this sector is poised for unprecedented growth.

Portland cement concrete is the most prominent construction material all over the world. It offers an inexpensive and simple way to build anything conceived by the humans. After water, concrete is the most widely used substance on earth. Portland cement is the most essential ingredient of concrete. Cement is manufactured by heating limestone to a temperature in excess of 1400^{o}C, to get rid of the CO_2 in limestone. For every ton of cement manufactured, the CO_2 impacts through calcination of limestone and the energy required for the process, results in release of about 0.75 tons of CO_2. With more than 4 billion tons of cement used in the world annually for various construction activities, this results in about 3 billion tons of CO_2 emitted annually. The CO_2 emissions from cement is difficult to eliminate completely because the calcination reaction of limestone is chemically constrained to release approximately 44% of the starting mass of the material as CO_2. Cement industry thus is responsible for 6-8% of the global anthropogenic CO_2 emissions. If the cement industry were a country, it would be the third largest carbon dioxide emitter in the, surpassed only by China and the US. Concrete also consumes large amounts of aggregates, mined from the earth. Concrete also consumes almost a 10th of the world's industrial water use. Some estimates say that our built environment is outgrowing the natural one, with concrete outweighing the combined carbon mass of every tree, bush and shrub on the planet.

Then, is the alternative, searching for another material? Eliminate the use of concrete? For starters, steel, asphalt and plasterboard are more energy intensive than concrete. If one considers timber, the world's forests are already being depleted at an alarming rate even without a surge in extra demand for timber. Above all, there is no material as versatile as concrete, which can be used for low-rise and high-rise buildings, pavements and

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bridges, dams and windmills, offshore platforms and underground foundations, alike. Thus, the focus has to be on making this material more sustainable, at the same time bringing in better tools to reduce the consumption of portland cement. To bring the cement sector in line with the Paris Agreement on climate change, its annual emissions will need to fall by at least 16% by 2030. Strategies to reduce emissions include greater use of renewables in production, improved energy efficiency, more substitutes for clinker and, most important, the widespread adoption of carbon capture and storage technology – though this is expensive and has not yet been deployed in the industry on a commercial scale. Cement manufacturers have been quite successful in using a more effective and sustainable fuel mix for cement production, by reducing the reliance on fossil fuels. More still needs to be done in this sphere, with an emphasis on renewable sources such as wind and solar power. Energy efficiency in cement manufacturing is accomplished through several means such as waste heat recovery and reuse. Clinker substitution is also in vogue, with materials such as fly ash, limestone, and calcined clays accounting for even up to 50% clinker substitution in some cases. From a concrete production viewpoint, this is of immense research interest, since virtually any material with silica or alumina in their chemistry can be used as a cement substitute, provide appropriate chemical reactions and mechanisms are triggered. These are among the most abundant minerals on earth as well. The building industry has to answer to the call of massive levels of cement substitution by discovering and tailoring locally available abundant materials as cement substitutes. Materials like rice husk ash, palm fuel ash etc. are being attempted in various countries based on the availability. The codes and building standards also should evolve to allow higher amounts of cement replacement in concrete, provided enough tests are done and the material is deemed appropriate. When clinker substitution (or cement replacement in concrete) reaches roughly 50% for all concretes in the world, that will ensure attaining more than half of the Paris agreement targets with respect to cement and concrete production and consumption.

Many experts believe that innovative technologies including carbon capture are also needed to meet the climate targets laid out by the Paris agreement. Carbon captured from cement and other construction materials manufacturing can be recycled into curing concrete (through carbonation) to form other construction materials. The idea is that one can form calcite (calcium carbonate) from carbonation of alkali or alkaline earth metals and their silicates. With proper tailoring of materials and control of the dissolution-precipitation reactions, even metallic powders (waste iron powder, or even pure iron powder, which can be obtained abundantly from the earth's crust using energy-and-environmentally efficient processes) can be carbonated for CO_2 sequestration. These materials can serve as construction materials when properly applied. The use of waste materials with some calcium oxide is also amenable to carbonation. Such processes sequester CO_2 permanently in concrete. Carbon capture and storage on deep rocks and in the ocean are also being studied.

Finally, existing structures must be better maintained and conserved to reduce the carbon impacts in construction. Durability of concrete thus becomes an important and viable means of ensuring sustainability in construction. Structural design must also account for sustainability by designing optimized sections. Methods to prevent/delay reinforcing steel corrosion, new methods of structural protection, developing concrete structures that are less crack-prone, preventing cracks from growing wider etc. are relatively easy and high-impact actions that civil and structural engineers can adopt with existing knowledge and technologies. In extreme cases where that is not possible, recycling should be encouraged and practiced.

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