POLICY BRIEF

National Center for Sustainable Transportation

Alkali-Activated Materials are Promising Alternatives for Reducing Roadway Emissions

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Issue

Road infrastructure construction and maintenance is enormously expensive. The capital investment in the United States is on the order of $100 billion/year. Beyond the monetary costs, both asphalt and Portland cement concrete production require intensive consumption of natural resources and produce carbon dioxide (CO_2) emissions and water pollution. Cement production accounts for around 8% of human-made CO_2 emissions worldwide. Global concrete demand is expected to grow as countries like China dramatically increase road infrastructure investments alongside continued urban development.

These planned substantial investments emphasize the need for alternative materials that can reduce economic and environmental costs. Alkali-activated materials are one such alternative. These inorganic binders can be produced with fewer CO_2 emissions than asphalt and concrete binders while offering comparable mechanical properties. Alkali-activated materials also develop strength more rapidly, facilitating rapid construction and large-scale repair and maintenance operations. These materials are produced by the activation of an alumino-silicate source (mainly by-products of other industrial processes such as industrial slags from iron production or fly ash from coal combustion) with an alkaline solution. If made from by-products of other industrial processes, alkali-activated materials could potentially be produced at lower cost than asphalt or Portland cement.

Existing studies suggest that alkali-activated materials would produce fewer CO_2 emissions than conventional cement. However, work to date has not considered availability of the precursors needed to produce alkali-activated materials. Limited availability of raw materials could result in significant additional emissions from transporting materials long distances to market. Researchers at the Georgia Institute of Technology analyzed published life cycle assessment literature to understand whether alkali-activated materials can achieve the same mechanical performance as Portland cement with lower CO_2 emissions, considering the local availability of raw materials.

Key Research Findings

Alkali-activated materials display a lower CO_2 intensity when compared to Portland cement binders. The researchers analyzed three categories of materials: alkali-activated binders, Portland cement binders, and cementitious binders with both Portland cement and supplementary cementitious materials. In all of the analyzed literature, alkali-activated materials displayed lower embedded CO_2 when compared to the materials currently used (Figure 1).

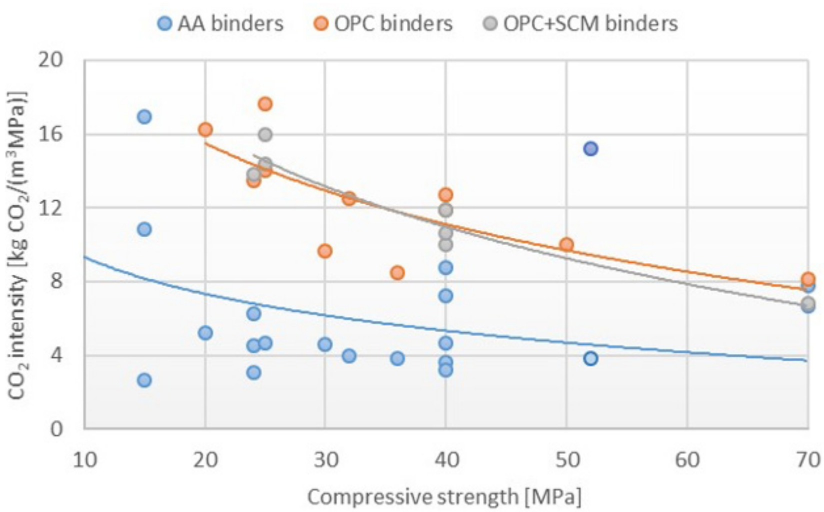

Figure 1. Comparison of CO_2 intensity among alkali-activated materials (AA binders, blue) Portland cement (OPC, orange) and Portland cement + supplementary cementitious material binders (OPC + SCM, grey).

Alkali-activated materials provide the required mechanical properties for pavement applications. Data from existing literature show that alkali-activated binders may provide the required strength for pavement applications with considerably fewer CO_2 emissions than traditional technology, though future work is needed to ensure that durability indicators such as permeability and wear resistance are also considered.

The availability of different raw materials used to produce alkali-activated materials varies around the world (Figure 2). The three most common raw materials are the naturally occurring clay kaolinite, fly ashes from coal combustion, and ground granulated blast furnace slags (GBSS), a by-product of iron production. Kaolinite is one of the most abundant natural clays worldwide, hence, is widely available. In contrast, fly ashes and GBSS are more readily available in Asia and South Africa than elsewhere and are decreasingly available in the US and Europe. Using the material that is most available nearby can reduce transportation emissions, which account for approximately 10% of the global warming potential of alkali-activated materials.

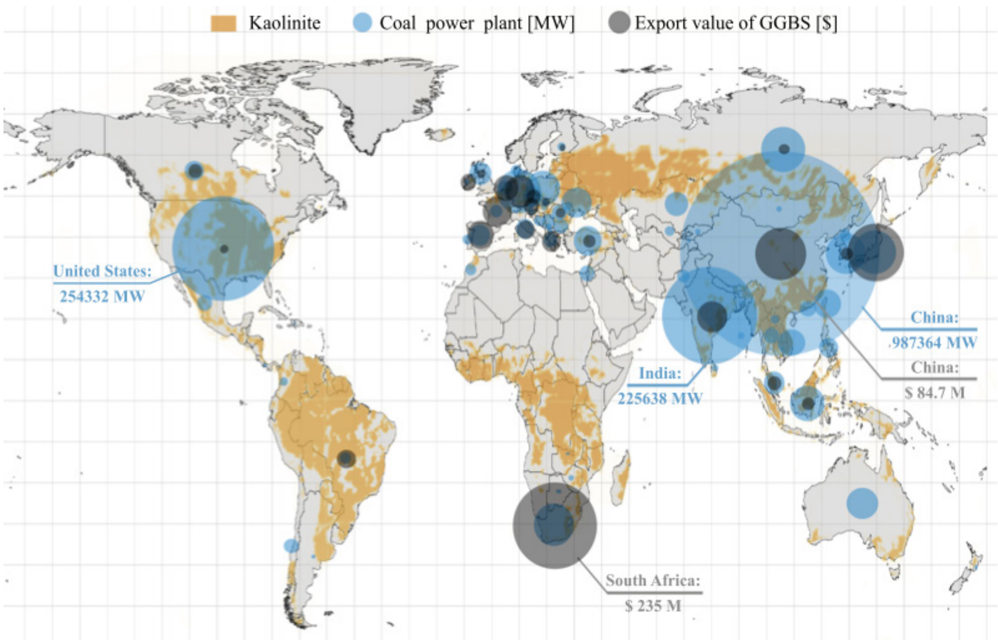

Figure 2. Map and graph displaying the worldwide availability of key raw materials used for alkali-activated material production. Kaolinite clay can be calcinated into metakaolin, fly ashes are a by-product of coal combustion, and ground granulated blast furnace slags are a by-product of iron production.

Policy Implications

This review suggests that there are promising alternative materials to Portland cement and asphalt for pavement applications. However, current construction industry specifications make it difficult to shift from laboratory-scale experiments to actual application. Concrete specifications for pavement application are primarily prescriptive, aiming to indirectly achieve performance by controlling the materials selection. Prescriptive specifications provide limits on the amount of the various mix components (e.g., minimum cementitious materials content, maximum supplementary cementitious material content), as well as their proportions.

Performance-based specifications, on the other hand, directly specify limits on performance without prescribing specific materials or compositions. This type of specification has the main advantage of allowing the use of new materials and approaches to design, which may be more cost-effective or sustainable, while still achieving the same minimums in performance measured for comparable mixes under current specifications. However, a risk for implementation is the potential for increased costs for testing and for delays due to test duration.

More Information

This policy brief is drawn from "Alkali-activated Materials: Environmental Preliminary Assessment for US Roadway Applications," a report from the National Center for Sustainable Transportation, authored by Kimberly E. Kurtis and Francesca Lolli of the Georgia Institute of Technology. The full report can be found on the NCST website at https://ncst.ucdavis.edu/project/life-cycle-assessment-and-life-cycle-cost-analysis-pavements-alkali-activated-materials.

For more information about the findings presented in this brief, please contact Kimberly E. Kurtis at kimberly.kurtis@ce.gatech.edu.

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