

Sen Du

Creating Concrete with High-Volume Coal Fly Ash

By Yue Huang



Sen Du, a Ph.D. student from the Department of Civil and Environmental Engineering on the WSU Pullman campus, won first place for the Outstanding Graduate Student award, granted by [the International Association of Chinese Infrastructure Professionals](#). The Association is a U.S. registered non-profit professional organization with its members working or studying in the fields of Civil Infrastructure and Systems and related areas.

This was Sen's first time winning this award. "It greatly inspires me to complete my dissertation defense this spring and continue researching and working in the academic field," said Sen with gratitude.

Sen joined the WSU Transportation Engineering Ph.D. program in 2017, right after finishing a two-year exchange program at WSU. Now, he is pursuing a dual Ph.D. with Harbin Institute of Technology, China and WSU, mentored by Dr. Xianming Shi.

Sen's research focused on improving concrete. Specifically, he added coal fly ash, a coal combustion product driven out of coal-fired boilers, into concrete to greatly replace cement, a traditional and significant component of concrete. His goal is to maintain the strength while improving the durability of the concrete, such as its resistance to freeze-thaw cycles.

"The reason to replace cement is that it is not environmentally friendly, because producing it consumes a lot of energy and releases a large amount of carbon dioxide," said Sen. "Using fly ash to replace cement in concrete should be a good solution."

This solution, in fact, was not new in the civil engineering area, yet there was no consensus on how much fly ash could be added without compromising the durability of concrete. Whereas the transportation industry has routinely used 20 percent of fly ash for cement replacement in concrete, Sen added 60 percent of fly ash, together with a small amount of nano-materials such as nano-silica.

"Researchers care about the amount of fly ash added because it is commonly believed that the more fly ash added, the lower the early-age strength of the concrete will be," explained Sen. "However, both the strength and durability of our concrete are well maintained, even with such a large amount of fly ash inside of it."

Sen attributed the success in producing this high-volume fly ash concrete to how he added the nano-silica. Instead of simply mixing it and other materials together, Sen employed a targeted approach: He

targeted the nano-silica around the interface between the paste and coarse aggregate to improve the strength and durability of this specific area, the commonly believed weakest part of the concrete.

Sen also considered the implementation of his concrete. He believes this new concrete has as good or even better mechanical properties and durability performances as the traditional one, and it features lower cost and environmental impacts over its life cycle because fly ash is a waste industrial material. These advantages could result in a good potential of applying the concrete in real-world settings.

However, Sen noticed that the concrete had its limitations. “The biggest one derives from the variability in properties of the fly ash,” said Sen.

In Sen’s experiment, the fly ash was from a coal-fired power plant in Oregon State, but if it came from another place where the quality of the coal and the technique of using the coal were different from those in this power plant, the properties of the fly ash might be quite different. In this situation, additional research was needed to ensure the resulting concrete could achieve reasonable quality, strength, and durability.

The limitations stimulated Sen to continue his explorations in this area. “Curiosity about the unknown is what always drives me to learn and research, and implementation is what researchers always need to take into account,” said Sen.