Not Cast in Concrete

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Have you heard the idioms, “set in stone” or “cast in concrete”? Growing up, I learned that they meant something that is firmly secured, permanent, and not subject to change. “These class rules are set in stone,” my second grade teacher would announce. It makes sense, right? When concrete is set, it becomes solid and can’t be modified. However, the recent innovation of flexible concrete undermines these adages. And yes, I said flexible. It is concrete reinforced with fibers designed to give stiff conventional concrete elastic characteristics. Research from scientists around the world supports the unlimited potential for flexible concrete and its application.

Over the past two millennia, concrete has had a major role in the creation of the urban world. A mixture of gravel, limestone, sand, water, and chemical additives, concrete has been the basic building block for many roads, bridges, and buildings. However, as useful and as standard concrete is, it has its drawbacks. The concrete global industry contributes 5% of the carbon dioxide emitted into the atmosphere. [1] Conventional concrete is brittle, prone to damage, and requires constant maintenance to work efficiently.[2] Over the typical lifetime of a conventional concrete structure, maintenance can cost as much or more than construction.

One of the new flexible concretes that might prove effective to infrastructure would be engineered cementitious composites (ECC). This mixture is a high-performance fiber reinforced concrete that has proven more durable and long-lasting than standard concrete in harsh environments. This mixture contains most of the same elements as standard concrete, however, its formula calls for the replacement of coarse gravel with steel or carbon fiber. Thanks to this change, the concrete becomes less brittle and more bendable.[3] Preliminary tests indicated that concrete made with this formula would be lighter-weight, more resistant to cracking, and longer lasting than existing formulas. According to the data compiled in the tests reported below, this concrete may even exceed initial expectations.[4]

The first test assessed the strain capability handled by both ECC and concrete. After careful experimentation, ECC emerged with a final strain capacity of 3% to 5%; 300 times that of conventional concrete. The next test measured mean crack widths under pressure. ECC performed exceptionally in this test as well as with the mean crack width remaining at 60 μm while displaying the same permeability under stress as non-stressed standard concrete. The final and most damaging test involved the environmental phenomenon which is most often linked to concrete failure, the freeze-thaw cycle. Li and Lepech tested prisms of ECC vs. concrete to determine their overall elasticity and durability. In this experiment, ECC and conventional concrete were supposed to be tested continuously for 14 weeks with about 22 cycles each week. However, the conventional concrete lasted only for 5 weeks, while the ECC endured the cycles for the entire 14 weeks.

Other studies conducted at a group of French Universities by Bouhaya, Roy, and Feraille-Fresnet, have investigated the use of another kind of flexible concrete, ultra high performance concrete (UHPC) and wood in bridge design by assessing these materials' durability and environmental impact. The UHPC consisted of steel fibers and silica fumes, which is a byproduct of the silica industry. These materials were used as substitutes for cement and aggregates to provide flexural strength without the harsh carbon footprint. The bridge was reinforced using wood beams instead of rebar because while alive, the wood removed an amount of carbon dioxide equivalent to that produced in the fabrication of UHPC.[5]

An environment analysis was carried out using a life cycle assessment (LCA). The assessment tracked the amount of renewable and nonrenewable energy consumed and the tons of carbon dioxide emitted during the bridge's projected 100 year life span. The analysis consisted of five phases: fabrication, transportation, construction, maintenance, and demolition.

In fabrication, 2078.3 GJ of energy was used and -24.8 tons of CO_2 released. Why is CO_2 production negative in fabrication? Well, the tree being used for the beams had utilized CO_2 from the atmosphere over its lifetime. In return the carbon dioxide released during fabrication was overlapped by the original carbon absorption. Meanwhile in the transportation phase, 25.9 GJ of energy was consumed and 2.62 tons of CO_2 were released. In the construction phase, 61.1 GJ of energy was consumed with a release of 5.37 tons of CO_2. Moreover during maintenance periods, the aged beams were replaced with new ones and downcycled for other uses. These activities used 585.3 GJ of energy and effect the "product ion" of -10.9 tons of carbon dioxide. And lastly, for the end-of-life phase, breaking up the bridge took 79.5 GJ of energy and released 9.7 tons of CO_2. The overall result of the study was that of 2830 GJ of energy and a carbon footprint of -17.93 tons. Standard concrete on the other hand releases 302 tons of carbon dioxide during its life span. And according to Lounis and Diagle's study, the UHPC Wood structure emits 106% fewer quantity of gases into the atmosphere than a conventional concrete bridge.[7] Hence the utilization of flexible concrete has and will have a great global impact due to its durability as well as its environmental success.[6]

Only about a couple years ago, a suspension bridge in Minneapolis plunged 108 feet into the waters of the Mississippi River. With it, the bridge took down 111 cars, injured 145 people, and killed a total of 13.[7] The cause of collapse was determined to be cracked, aged, and weakened concrete. Seeing as flexible concrete is less brittle than standard concrete, its use may have prevented this accident, and can still prevent others in the future.

Furthermore besides the structural advantages outlined above, flexible concrete can be utilized at a lower cost than conventional concrete. Even though the initial cost of regular concrete is $100 per m^3, fiber-reinforced concrete $200 per m^3, and ECC $250 per m^3 - the overall cost after the cycle is $750,000 for concrete, $520,000 for fiber-reinforced, and $490,000 for ECC. [8]

An estimated one-third of the United States roadways are in poor or mediocre condition.[2] This issue has been acknowledged by President Barack Obama in a recent policy statement, "…an infusion of federal money, $60 billion over the [next] 10 years, to provide financing to transportation infrastructure projects across the nation….will be directed to invest in our nation's most challenging transportation infrastructure needs."[9] Investing in traditional concrete would only temporarily improve the state of the U.S. transportation system. After only a few years, the roads would be in the need of repair due to cracks from weathering and layering more concrete to stabilize foundations. Conversely, new infrastructure built from flexible concretes would cost less, be more environmentally friendly, and last longer.

In conclusion, based on the evidence presented above, it is apparent that fiber-reinforced concrete would be a safer, practical replacement for the concrete currently used in construction. Scientists believe that ECC and UHPC will provide a strong foundation and stable structure for buildings, bridges, and roads while remaining friendly to construction budgets.[10] Considering the current economic crisis, every precious infrastructure dollar needs to be invested wisely; starting with flexible concrete.

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