Concrete canoes: the start of things to come

Concrete can be used for much more than just traditional steel-reinforced concrete writes Alan C. Burr (M). He explains how, in the United States, the enthusiasm for canoes made from special concrete could lead to concrete being used in airplanes, submarines, clothing and sneakers as well as having applications in construction.

A dozen brightly-colored, sleek water craft surge through the water in close competition, each paddled by a well-trained team working in harmony and in tense concentration. These craft are not what you might think, for they are not typical canoes but are made of concrete. Reinforced concrete, usually known as a hard and heavy construction material which is strong in compression, is being used for the most unlikely application of building canoes.

In North America there is a thriving concrete canoe contest between American, Canadian and Mexican university teams which devote considerable resources in time, energy, expertise and enthusiasm to the design and construction of these unusual craft. Contrary to what you might expect, the canoes are not overly heavy and cumbersome, but are high-tech and innovative, designed using state-of-the-art computer analysis and built using modern composite reinforcements and admixtures. The concrete canoe contest is inspiring engineering students towards technical research, complex design and construction with a goal of building and paddling the fastest boat. The students’ research shows that the materials used for the canoes also have potential commercial uses in building construction and aerospace.

In the latest national contest in September 2002, sponsored by admixture producer, Degussa, Inc., more than 250 civil engineering students from 25 universities in the United States, Mexico and Canada came to Madison, Wisconsin, for a four-day competition. Contestants paddled their canoes through a series of distance, sprint and slalom events, with the occasional sinking that you would expect in an event like this.

Arguably the most devout enthusiast in the United States is Dr John Gilbert, who teaches mechanical and civil engineering at the University of Alabama in Huntsville. His website: (www.ConcreteCanoe.org), bills itself as ‘the world’s largest and most comprehensive database on concrete canoeing.’ Under his leadership the University of Alabama has won five national concrete canoe championships and 12 Southeast division league titles.

Students working on the concrete canoes, whether in their design, construction or in competition, are learning in depth about the capabilities and material properties of one of the most common construction materials available. They are also learning that concrete is a very versatile material that can be used for much more than just traditional steel-reinforced concrete.

Their research shows that as part of a composite material with the right reinforcement, concrete can be used for very thin and strong shells with high durability and flexural capacities. Gilbert hopes that their research may one day lead to concrete being used in airplanes, submarines, clothing and sneakers, as well as for more durable concrete in long-span bridges and earthquake resilient buildings and structures.

The construction of the canoes uses a range of admixtures and reinforcement materials, to both strengthen and lighten the material. The students have experimented with many materials including tiny glass beads, rice, perlite, silica fume and assorted fillers. The design of the most advanced canoes is made using digital computer modeling and intricate molds. The equivalent material and man-hour costs for designing and building them can equate to over $100,000.

The hulls of the canoes are typically 7–8mm with no more than 50% of that thickness consisting of the reinforcement layer. The rules for the design and construction of the canoes are strict, with precise specifications detailing the requirements for the types and proportions of reinforcement, aggregates, binders and admixtures. The favored reinforcement is glass fibre, graphite or Kevlar matting. The aggregates must contain a minimum of 15% by volume of graded sand and the cementitious binder must contain a minimum of 70% by weight of Portland cement and 20% of Class C fly ash. Types of admixtures used in the binder can include asphalt, resins, polymers and pozzolans such as silica fume, blast furnace slag and fly ash.

At competition events the completed canoes are also subject to rigorous examination to verify their compliance with the specifications. Testing includes a flotation test, aesthetic evaluation, and each canoe must have a strip of the concrete hull exposed for examination by the judges.

Students at the University of Alabama, with assistance from NASA and the US Air Force have been studying the behaviour of Polymer-Enhanced, Graphite Reinforced Cementitious Composite (PEGRCC) materials using finite element and experimental modal analysis. The studies investigate the dynamic behaviour of plates made from
Using the knowledge gained from this research, the University of Alabama designed a new canoe for the 2001 National contest. By adjusting the shape and hull thickness they were able to tune the natural frequency of their canoe such that the forcing function created by the paddlers drove the craft towards resonance. As the hull deformed due to torsional and bending moments caused by the paddling motion, very large stresses and strains developed in the hull. By keeping the hull elastic and structurally resilient, the stored strain energy was able to be recovered. As the crew pulled their paddles from the water, this energy was converted into forward momentum, thereby forcing the boat to surge forward between strokes.

According to Gilbert, this generation of concrete canoe has a speed in excess of a compatible conventional canoe and is only slightly less than the speed achieved in a C2 slalom canoe at the Olympics.

Applications to building and construction
At the University of California, Berkeley, Mark Wan of the UC Berkeley Concrete Canoe Team says that their concrete composite used fiberglass scrim (fabric) for the reinforcement and that the aggregates used are approximately 85% ultra fine synthetics and 15% very fine sand. This composite material is very lightweight and has good crack growth resistance. These characteristics are well-suited for making exterior building claddings and other thin-shelled structures.

At the University of Alabama, Gilbert speculates that STARS (Strategically Tuned Absolutely Resilient Structure(s)), will have widespread applications that will capitalise on the flexibility and strength of the composite structure. Gilbert says that the research team at The University of Alabama has plans to integrate sensors into the material to monitor its structural performance and to embed control elements to adjust the dynamic response of the material in real time.

The researchers are also investigating the self-healing properties of the concrete composite and the ability to make shape changes at will. If successful, Gilbert hopes that the material will be able to be developed to produce mechanical systems capable of storing elastic strain energy that can be recaptured to do work or generate power. Potential applications are the shells of vehicles, building cladding systems and aircraft, including strategic defence systems to contain or absorb energy. The energy absorption properties may also have applications for building seismic systems such as energy dissipation or damping devices.

The concrete canoe contest is a highly competitive event, which is encouraging engineering design and research students to investigate highly technical aspects of the reinforced concrete composite materials used in the canoes’ construction. The research has shown that the concrete composite materials have unique properties of flexibility, strength, durability and energy absorption that can be beneficial to the building construction industry, aerospace and beyond.

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