In Pursuit of A National Concrete Canoe Title

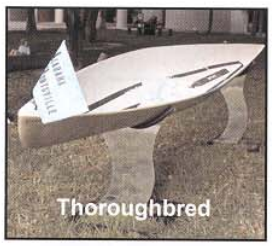
by ***John A. Gilbert, Ph.D.*** [1]

The 17th Annual American Society of Civil Engineers/Master Builders, Inc. National Concrete Canoe Competition (NCCC) will be held in Washington, DC, on June 17-20, 2004. The American Society of Civil Engineers (ASCE) Headquarters, in conjunction with Washington area ASCE organizations, hosts the event. The competition is scheduled to coincide with the National Building Museum's exhibition opening of **Liquid Stone: Architecture in Concrete** and teams competing in the event are expected to showcase some of the most exciting and revolutionary concepts being studied in the area of reinforced concrete design.

In the more than 35 years since concrete canoe racing began, the efforts of students combining engineering excellence and hydrodynamic design to construct water-worthy canoes has culminated into an advanced form of concrete construction. But the general public and most practitioners don't realize how significant the advancements being made really are. Not to mention that concrete canoes are among the most flexible and resilient reinforced concrete structures on Earth.

Competitive boats feature amazingly thin composite sections (typically 6-8 mm thick) that are so light that they are neutrally buoyant (lighter than water), thereby allowing the canoes to float without the need for the flotation cavities typically found in their heavier aluminum and Kevlar counterparts.

As illustrated in the accompanying photograph taken of the University of Alabama in Huntsville's (UAH's) "Thoroughbred," concrete canoes often feature complex inlays and/or artistic graphic designs. During the final product judging, the boats are displayed side by side like pieces of fine art with teams anxiously awaiting the critical eyes of a demanding and inquisitive judging panel. Scoring is based equally in four different areas: a design report submitted prior to the competition, an on-site oral presentation, the final product judging, and a series of races.


Thoroughbred

The top hull speeds of approximately 4.3 m/s are not too shabby considering that each boat must be designed to allow five different teams with as many as four paddlers to negotiate slalom, distance, and sprint courses. During the competition, the canoes are subjected to massive service loads and the hulls must be designed to withstand reverse loadings that create complex torsion and bending modes. Nonetheless, many of the winning entries remain unscathed following the races with teams defying the judges to identify even a single crack.

By thinking "out-of-the-box," the teams building these unique crafts are pressing the envelope of reinforced concrete design well beyond the limits imposed by the textbooks that they utilize in the classroom. The fact of the matter is that many of the assumptions used to study conventional reinforced concrete structures simply do not hold and conventional techniques cannot be applied to accurately determine the stress distribution and dynamic performance of concrete canoes. Some of the underlying design concepts are very complex and somewhat radical.

Take, for example, the entry currently being designed and built by five-time national champion, UAH, to qualify for the competition. "*ConQuest*" is a strategically tuned absolutely resilient (STAR) structure that is designed to perform as a mechanical energy storage device. As the paddlers initiate their strokes, the boat is driven to controlled resonance... something that dynamics professionals shy away from... so that as much elastic strain energy as possible is stored in the deformed hull. During recovery, this potential energy is converted into work as a forward propulsive component, allowing the boat to surge forward between strokes and swim.

Envisioning the concept was radical enough. But accomplishing this feat from a structural standpoint and quantifying their boat's dynamic performance were no easy tasks for UAH.

Their structural design relies on the large difference in stiffness between the constituents in a composite section to drive the internal stress from a flexible cementitious matrix to three layers of relatively stiff reinforcement. The team places materials symmetrically to form an adaptive section optimized to resist stress reversals, and orients fiber layers differently to tune the modal response.

They developed a modified transform section theory to quantify the structural behavior of their multi-layered section based on a composite modulus obtained by pulling a tension specimen reinforced with only a single layer of mesh. The composite is modeled by assuming that concrete, having a known elastic modulus, is placed around homogeneous layers having the same thickness and stiffness as the composite sample.

Team UAH demonstrated that composite laminate plate theory could be applied for dynamic analysis of reinforced composite plates and they have used finite element models to predict the modal response of "*ConQuest*." Their computer simulations show the boat's movement mimics that of aquatic creatures.

The team was startled to find that nature incorporates amazingly similar compliant composite sections into many fish and mammals. The orientation of the layers in a shark's skin, for example, prompted them to investigate the impact of changing the orientation of fibers in the different layers of reinforcement. The team found that they could increase the torsional rigidity (GJ) and lower the flexural rigidity (EI) of their composite section to create a better balance between the mode shapes that occur while racing. This makes it easier for the boat to swim.

During their quest to become the 2004 National Concrete Canoe champion, Team UAH plans to continue to *innovate* and meticulously document the technology underlying their efforts, *educate* civil engineering students, educators, practitioners, and the general public about the discoveries that they have made, *disseminate* that information via a thorough design report, magnificent oral presentation and marvelous product, and *captivate* their audiences with team spirit and power-packed deliveries unmatched in the history of the competition.

According to ASCE, there are two hundred and fifty nine student chapters and clubs. Ninety-two of these have competed at the national level and the possibilities offered by the technological advancements made by the participants are endless.

There is a really good chance that the materials being developed by UAH, for example, will replace standard aerospace composites. Researchers working there have already received Congressional funding to support such efforts and have high hopes of using their concrete to support telescopes in space, for rocket fuselages, to build a lunar colony — or for low-cost emergency shelters on Earth.

The Department of Defense is also underwriting the UAH effort and Team UAH plans to use the U.S. Army's state-of-the-art, Remote Readiness Asset Prognostic and Diagnostic System (RRAPDS), currently being developed by the Army to monitor missile readiness, to quantify the dynamic performance of "*ConQuest*."

Details can be found on the web by typing the string "Team UAH" into your browser, or, by logging onto concretecanoe.org.

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