Executive Summary 1.0

Like an animal in the wild, The Clemson University Concrete Canoe Team (3CT), in conjunction with the Clemson student chapter of ASCE, has evolved into a competative force and has emerged from the jungle with this year's entry, ***Instinct***, in the ASCE/MBT National Concrete Canoe Competition. ***Instinct*** is the result of the vision, hard work, and dedication of Clemson University students.

Instinct's
Design Characteristics:

Weight:	**45.4 kg (100 lbs)**
Length:	**6.4 m (21 ft)**
Beam (at Gunwale):	**73.66 cm (29 in.)**
Beam (at Waterline):	**66.0 cm (26.00 in)**
Thickness:	**11.1 mm (7/16 in)**
Color:	**Black with white and orange decals**

3CT's 2000 entry, ***Instinct***, incorporates a sleek hull combining both straight-line speed and maneuverability, while providing an ergonomic vessel for paddlers. The concrete mixture is lightweight and flexible incorporating lightweight aggregates and fibers. The reinforcement design incorporates lightweight and durable polypropylene mesh combined with a new, high strength material called Tensylon™, which was pre-tensioned in the gunwales. 3CT has also utilized innovative management tools and techniques to improve team organization and communication.

Introduction 2.0

In the picturesque foothills of western South Carolina lies the small town of Clemson, home of Clemson University. Founded in 1889, Clemson University is a fully accredited, co-educational, land grant university dedicated to the professional and personal development of approximately 13,000 undergraduate and 4,000 graduate students through teaching, research, and service.

Of the 17,000 Clemson students, 275 undergraduate and 60 graduate students are enrolled in the department of civil engineering. In this department, 21 faculty prepare the students for the real world by providing them with the knowledge and problem solving skills necessary to lead successful careers and lives.

The Clemson University student chapter of ASCE is the 11th largest chapter in the nation consisting of 90 members. For the past 17 years, the chapter has participated in the Carolinas' Conference, consisting of nine colleges and universities from North Carolina, South Carolina, and Georgia. 3CT, backed by the ASCE student chapter, has experienced great success at this regional conference posting eight consecutive concrete canoe titles since 1993. This year's regional title leads 3CT back to the National Concrete Canoe Competition, where they have traveled the United States and found success at each of these competitions placing 6th, 5th, 4th, 5th, 11th, 3rd, and 1st, respectively.

This year 3CT has a crew of 15 undergraduates, 5 graduate students, and a faculty advisor. Over half of the team, including all of the team leaders, were involved with last years project, *The Sequel*, and have returned for this year's project, ***Instinct***. Their experience and dedication, along with the enthusiasm of the new team members has made ***Instinct*** a reality.

Hull Design 3.0

The concrete canoe competition challenges teams to use their instincts to design canoes that must not only be fast in a straight-line, but must also have the maneuverability to quickly navigate the slalom course and 180 degree buoy turns. These two characteristics are not commonly combined in canoe design, so it was up to 3CT's hull design team to complete an extensive investigation and design a canoe that would prevail in a jungle of competitors. This task was divided into three major phases: 1.) Gather information, 2.) Design of canoe hull using a genetic optimization computer program and AutoCAD, and 3.)

Evaluation of a full-scale prototype.

The first step taken by the 3CT hull design team was to gather input from last year's paddlers and determine which hull characteristics needed to be considered while designing ***Instinct***. The main targets set forth by the team were to maintain the fast straight-line speed of *The Sequel* while enhancing the maneuverability and paddling ergonomics. Speed and maneuverability were deemed important due to the demands of the different races. Paddling ergonomics are very important to the paddlers during the races and impact the efficiency of paddling technique. Last year's canoe, *The Sequel,* was a wide canoe having a beam of 0.84 m (33 in). This proved to be too wide for the middle paddlers to paddle efficiently during the four-person race, so the beam had to be reduced to accommodate all paddlers.

Once the main hull design characteristics for ***Instinct*** were identified an extensive literary and Internet search was conducted to learn as much about naval architecture and canoe design as possible. This search led to the finding that the most important emphasis in canoe design is residual resistance, a component of total drag. Residual resistance is mainly composed of resistance caused by the waves made by the canoe, and the fewer, or smaller, the waves are, the faster the canoe will be. This finding made minimizing wave-making resistance of the canoe the most important goal of 3CT while designing ***Instinct's*** hull. The main factors considered in accomplishing this goal included canoe length and beam.

Phase 2 involved the use of a computer program called GODZILLA to optimize the hull shape below the waterline. GODZILLA is a hull design program that was developed to design canoes, kayaks, and rowing shells, so it was perfect to design this year's canoe. Research was first conducted to discover how GODZILLA works. This provided the team with the knowledge of what all of the input and output data means, which prevented 3CT from accepting results that may not be true, or even realistic. This program allowed the hull design team to enter and vary all of the design parameters of the canoe to determine the optimum shape for the competition that provided the ergonomics needed for efficient paddling.

The team analyzed 74 different canoes having varying lengths, beams, and draughts. In order to compare the different hulls to each other a canoe load of 345 kg (760 lbs) (4-person race) and the design speed of 4 m/s (13 ft/s) were held constant along with the water condition parameters. The best canoe length for this competition has proven to be about 6.4 m (21 ft) from more than 4 years of competition experience. Longer canoes are too long to be maneuverable and get too heavy to be competitive, while shorter canoes can get cramped during the 4-person race and do not possess the speed to be competitive. The beam of the canoe showed to be the main variable in the design of ***Instinct***. Theory states that the narrower the canoe is, the faster it will be. This was reflected in the results obtained from GODZILLA (Figure 3.1), which has been checked experimentally for all types of designs.

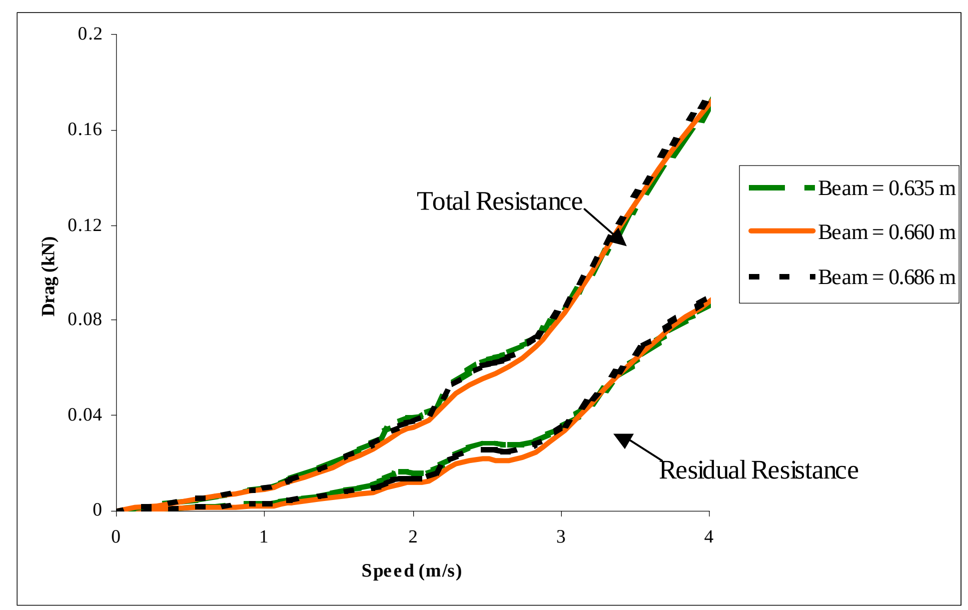
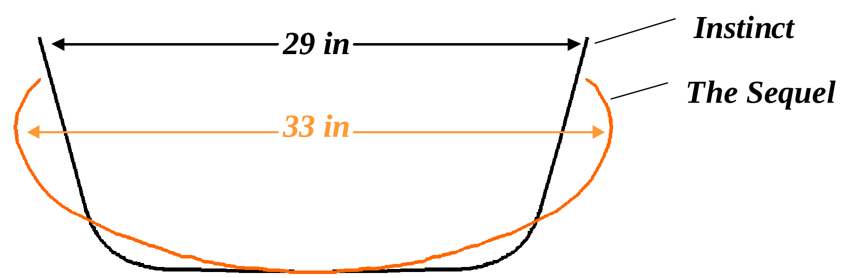


Figure 3.1: GODZILLA output of resistance of 6.4 m canoes having different beams at a draught of 0.14 m

Figure 3.2: Comparison of *Instinct's* shape to 3CT's 1999 canoe



The optimum beam of 0.66 m (26 in) at the 0.14 m (5.5 in) waterline was determined to provide the minimal drag, desired ergonomics, and adequate stability by the design team and paddlers. This was a significant improvement over *The Sequel* (Figure 3.2).

Once the design below the waterline was completed in GODZILLA, the data was entered into AutoCAD, where the design was completed above the waterline and the rocker was added for maneuverability. Cross-sectional data points were entered into AutoCAD and each cross section was slightly adjusted to incorporate a 6.35 cm (2.5 in) rocker into the bow and a 3.81 cm (1.5 in) rocker into the stern. This rocker was determined from paddling experience. Last year's canoe had rocker of 3.81 cm (1.5 in) in both the bow and stern, but it was decided that some additional rocker could be added to ***Instinct's*** bow for enhanced maneuverability, without sacrificing a noticeable amount of speed or tracking ability. The design was completed in AutoCAD with the completion of the gunwale shape. Each cross section was then plotted and used as templates for form construction.

Phase 3 involved the construction of a full-scale Kevlar prototype of the canoe that gave the paddlers the opportunity to test the design on the water and compare it to previous canoes. The prototype was evaluated for one month prior to placement of Instinct. This time allowed the paddlers to make suggestions for improvements of the design that could be made before placement. The only change that was made was an increase in overall depth from 28.9 cm (11 in) to 32.4 cm (12.75 in). This change allows for sufficient freeboard in the four-person race while paddling in rough conditions.

This phase also proved that ***Instinct*** is a more competitive canoe than *The Sequel*. ***Instinct's*** design is as fast as *The Sequel* in a straight-line, but the real difference was noticed in its maneuverability. 3CT Paddlers have recorded times through the seven buoy slalom course that were ten seconds faster with ***Instinct*** than with *The Sequel*. This is a remarkable improvement and will enable 3CT to be very competitive in all of the races.

Instinct's hull was designed utilizing years of competition experience, knowledge gained in the classroom, and a canoe design computer program. The evaluation of a full-scale prototype enabled the team to confirm the theory behind the design. A hull length of 6.4 m (21 ft) and beam of 0.66 m (26 in) at a draught of 0.14 m (5.5 in) minimizes the residual resistance of the canoe, which will enable 3CT to compete to be "king of the jungle."

concrete Mix Design 4.0

Every year 3CT is faced with the challenge of designing a concrete mix that will endure the rigors of racing, have a unit weight light enough to be competitive in the races, as well as survive the stresses of transportation. This year 3CT set forth on this expedition with clear goals for the concrete research. These goals were based on experience and data obtained from the past two 3CT adventures. The goal was set to make this year's mix a simple mix, for accuracy and ease of batching. The target values of the concrete mix were then estab-

Compressive Strength:
4.13-4.26 Mpa (600-700 psi)
Unit Weight:
640.7-720.8 kg/m^3 (40-45 lb/ft^3) Unit Weight
Composite Flexural Strength:
6.89 Mpa (1000 psi)
Low Modulus E for a less brittle concrete

lished.

Testing first explored individual aggregate strength to weight ratios. This year 3CT chose to test a variety of glass bubbles. By using different types of the same material a more homogeneous mixture of aggregate in the concrete would be created. Four different types of glass bubbles were selected based on their individual compressive strength to weight ratio. 3CT wanted to have a broad range of choices to select the best possible blend for the concrete mix. All four types of bubbles were tested as the sole aggregate in a control mix. By only varying the type of bubbles used, a direct comparison of the aggregate's respective strengths could be seen. Testing the individual aggregates was done by testing 50.8 mm (2 in.) cubes in compression on a Universal Testing Machine (UTM) following ASTM C192 procedures. For all individual aggregates tested, six samples were used to assure an accurate statistical sample size.

Table 4.1: Trial Mixes in Kg/m^3(lb/yd^3)

		Control Mix	Final Design Mix	Patching Mix
Binding Materials:				
	Type III Portland Cement	899(1516)	555(936)	674(1137)
	Latex 337	---	138(232)	---
	Latex 338	---	---	210(355)
Admixtures:				
	Retarder	---	2.8(4.7)	---
Aggregates:				
	K1 Glass Bubbles	89(150)	66(111)	80(135)
	A20 Glass Bubbles	---	21(35)	26(43)
	D32 Glass Bubbles	---	35(59)	---
	H50 Glass Bubbles	---	30(50)	---
Other:				
	HPF	---	2.8(4.7)	---
	Carbon Fiber	---	4.2(7.2)	---
	Water	558(940)	293(493)	344(579)
Engineering Properties:				
	Dry Unit Weight, Kg/M^3(PCF)	992(61.9)	708(44.2)	780(48.7)
	Compressive Strength, MPa(PSI)	7.7(1120)	6.7(976)	7.1(1026)
	Water/Cement Ratio	0.62	0.52	0.51

Another segment of the individual component testing was exploring the use of fibers in the concrete mix to add flexural strength. 3CT had previously used carbon fiber in past mixes with great success. This year, in addition to carbon fibers, 3CT also explored the use of Tensylon™ fibers and high performance fibers (HPF) in the mix design. Both of these products are brand new to the market, so there was a great deal of interest in how they would perform in the concrete mix. Testing the fibers for the mix was conducted by casting beams that measured 25.4 mm (1 in.) by 50.8 mm (2 in.) by 279.4 mm (11 in.) with a control mix (Table 4.1). The beams were tested in center point bending on a UTM following ASTM C293. It was discovered that while carbon fibers had a larger initial strength, the HPF fibers had a higher ultimate strength. The design decided to use a combination of both carbon fibers and HPF fiber to achieve the optimum performance in flexural strength.

After the individual testing was complete, the next segment of the adventure began. The resulting data was analyzed, and testing was started on different blends of glass bubbles and cement. The blending was done by using an equal volume of cement, with a series of slightly changing bubble combinations. Each blend was tested for compressive strength using 50.8 mm (2 in.) cubes in a UTM with a sample size of six cubes. By making slight changes to the volume of different bubbles used, a trend was developed to find the best blend for the concrete mix

The final phase of the mix design was to maximize the flexural strength of the mix. This was done by two means. Both latex and fibers were added to the mix at this stage. The optimum fiber combination was determined in individual component testing. The latex was not added until this stage due the variance caused by the different blends. After the top two blends were established latex testing was started. This testing was done using both beams for flexural strength and cubes for compressive strength. The beams showed how much the latex improved the flexural strength, while the cubes showed the loss in compressive strength. The top combination was then selected, and the previously tested fibers were added (Table 4.1).

The mix design team also faced the challenge of discovering a patching mix to be used for detailed finishing of the canoe. The patching layers would be very thin, so bond strength was an important factor to examine in this phase. Several different mixes were tried in a bond strength test with our final mix for the canoe. Bond testing was done by testing 50.8 mm (2 in.) cubes in compression on a Universal Testing Machine (UTM) following a modified ASTM C1042 procedure. Each of the cubes was made half of the boat mix and half of the patch mix. Because bond strength was the major factor and a relatively small amount of this mix would be used, weight was not as much of a factor when considering the patch mix.

The final concrete mix design also took workability into consideration. As testing progressed, the workability of the mix was evaluated. The mix consistency goal was that of peanut butter. This would facilitate the ease of placement, and the total construability of the boat.

After taking all considerations and test results into account 3CT has developed a concrete mix that will meet and exceed our needs for ***Instinct*** to outwit the predators in a jungle of competition.

Reinforcement Design 5.0

3CT's main objective when taming the reinforcement animal of the project was to optimize the use of the polypropylene mesh used for reinforcement in last year's canoe. The design team wanted to develop a scheme that incorporated less polypropylene material in order to facilitate construction and provide the strength necessary for ***Instinct*** to endure the stresses encountered during construction, racing, and transport throughout the concrete canoe season.

The first step in the reinforcement research was to observe and analyze the type and location of cracks that occurred in last year's entry, *The Sequel*. After careful examination, it was concluded that cracks occurred only in the middle of the canoe at the tops of the gunwales. No failures were noticed elsewhere in the canoe. This led 3CT's reinforcement team to conclude that more emphasis needed to be placed on preventing cracks in the gunwales. Based on these findings the design team moved forward in developing a reinforcement scheme for ***Instinct***.

Polypropylene was considered as a final reinforcement material based on its physical properties as well as preliminary research conducted on different materials. The polypropylene material has a low specific gravity (SG = 0.905), is workable, and 100% alkali resistant. Research indicated that materials such as fiberglass and Kevlar® degrade and lose strength over time in concrete due to alkali attack. Thus, both materials were eliminated from consideration for this year's reinforcement design. 3CT also considered a new polyethylene material called Tensylon™. This material was eliminated because it could not be obtained as a woven mesh and attempts by 3CT to weave a mesh proved unsuccessful. This research, along with the polypropylene's physical properties led the design team to select polypropylene as the primary reinforcing material.

Tensile testing was performed, in accordance with ASTM D5034, on two different polypropylene meshes, Viper and Boa (Table 5.1). This test was performed in the warp (longitudinal) and the cross (transverse) direction of the fabric to determine the strength of the fabric in all directions (Table 5.1). These values were used by the design team to determine the direction that the reinforcement would need to be placed to ensure the higher tensile strength strands would be placed in the direction of the highest tension in the canoe.

The two different polypropylene meshes were then tested in a

Engineering Properties	Reinforcement: Viper	Reinforcement: Boa
Weight, g/m^2 (oz/yd^2)	68 (2)	107 (3)
Tensile Strength, N (lbf)		
Warp Direction	295 (65)	360 (80)
Cross Direction	275 (60)	310 (70)
Modulus of Rupture*, MPa (psi)	2.0 (290)	2.2 (325)
Workability	9	9

* Test plate consisting of 1 Layer of reinforcement in a control concrete mix

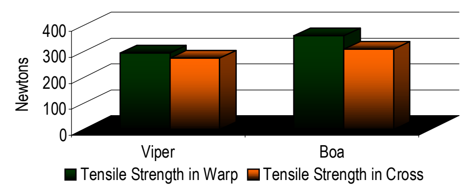


Table 5.1: Reinforcement Properties

thin-shell concrete composite. The composites were tested after preparing 7.60cm x 30.48cm x 0.95cm (3in. x 12in. x 0.38in.) plates with varying reinforcement configurations. The plates were then tested in flexure by center-point loading per ASTM C293 (Table 5.1) to develop the final reinforcement scheme. The final design consisted of a four layer scheme incorporating two layers of the Viper mesh sandwiched between two layers of the Boa mesh. When combined with the final concrete design a composite flexural strength of 6.03 MPa (875 psi) was achieved.

The design team felt very comfortable with this scheme in preventing cracks from occurring in the hull, however there was still some concern about cracks forming in the tops of the gunwales. 3CT then began to focus their efforts to incorporating the before mentioned Tensylon™ with the polypropylene scheme in a pre-tensioning application in the gunwales.

The first step in this phase of the research was to determine the tensile properties of the Tensylon™ per strand compared with other materials such as carbon fiber and steel. Tensile testing was performed per strand in accordance with ASTM D2256 and a strength/weight ratio was determined for each material (Table 5.2). The design team was pleased with these results as the Tensylon™ performed much better than the carbon fiber and had a greater strength/weight ratio than the steel. Based on these results, 3CT wanted to test the Tensylon™ strands in a pre-tensioned application in a thin-shell concrete composite.

The concrete was cast in a 7.60cm x 30.48cm x 0.95cm (3in. x 12in. x 0.38in.) form with three strands of Tensylon™ placed lengthwise 1 in. on center. After placing the first lift of concrete onto the form, the tendons were tightened to the desired tension by using a combination of springs and turnbuckles. The tension applied to the Tensylon™ tendons was measured by the extension of the springs. Each spring used was calibrated with a certain weight and the extension was measured with calipers and recorded. This ensured that the correct amount of tension was applied to each tendon. The tendons were then covered with the final lift of concrete, allowed to cure, and tested in accordance with ASTM C293.

The design team tested tensions ranging from 0.45 kg (1 lb) to 40.8 kg (90 lbs) in order to determine the optimum tension of the Tensylon™ tendons. Designers were looking for any trends or tensions at which the pre-tensioning had a detrimental effect on the flexural strength of the concrete. 3CT also analyzed the ease of full scale pre-tensioning at each tension. The design team observed that tensioning tendons at 18.1 kg (40 lbs) or greater was difficult due to the tie-offs slipping and the tendon losing its tension. After all the plates were tested and analyzed, 9.1 kg (20 lbs) was chosen as the optimum

Table 5.2: Strand Property Comparisons

Material	Weight g/m (oz/yd)	Breaking Strength kgf (lbf)	Strength/Weight Ratio (x106)	Workability
Tensylon™	0.6 (0.02)	83.4 (184)	13.9	8.5
Carbon Fiber	2.7 (0.09)	41.5 (91.5)	1.5	6.5
Steel	9.0 (0.29)	241.2 (532)	2.7	3.5

tension based on strength and ease of construction.

The final step was to combine the pre-tensioned Tensylon™ tendons with the polypropylene scheme that was developed. When combined with the polypropylene scheme in a concrete composite, the flexural strength increased from 6.03 MPa (875 psi) to 7.08 MPa (1027 psi). Based on these results, the design team felt that the addition of pre-tensioned Tensylon™ tendons could eliminate cracking

Construction 6.0

Every year 3CT dedicates more than 2,000 hours to construct a concrete canoe. This year's team was dedicated to planning and developing construction techniques to minimize the overall construction time while producing the best product in 3CT's history.

The first task for the construction team was to construct a mold for canoe placement. Based on past experiences, this year's team decided to use a male form over a female form. A male form allows the harder-to-finish interior of the canoe to be formed and not shaped. The use of a male form also allows for easier form removal and better control of concrete placement.

Figure 6.1: The sequential order that the form was constructed

This year's team opted to use wood as the construction material for the form based on its durability and ability to form truer lines and curves. However, constructing a wooden male form offered new challenges to 3CT's construction team. Past Clemson teams have constructed male forms using foam and female forms using wood, but never a wooden male form. Therefore, it was very important that proper planning and detailed plans were developed before construction began.

The mold consisted of 20-cross-sectional templates plotted from the hull design software package. These plotted cross-sections were traced onto plywood sheets, cut, and sanded to the specified shape. Once completed, each cross-section was mounted onto a strongback made of wood and steel at 30.5 cm (12 in.) intervals along the length (Figure 6.1). The strongback included dado cuts which forced the cross-sections to fit into the strongback at the exact spacing. White pine wooden stringers were then bent onto the cross-sections and screwed into place (Figure 6.1). Once the stringers were attached, door skin plywood was glued on the sides and top of the form directly onto the surface of the stringers (Figure 6.1). The chines were constructed with thin strips of white pine placed side by side around the curve. The entire form was then sanded, sealed with epoxy, and the ribs were routed into the form at designated locations. The final step was to cover the form with a 0.4 mil plastic, which acted as a release agent.

Placement of the canoe involved fourteen students placing the concrete by hand. Six students started at the midpoint of the canoe and worked outward while four students on each end worked towards the middle. The first layer of concrete was placed directly on the plastic covered form in a 1.6 mm (0.06 in.) lift. As the layer of concrete was applied, 1.6 mm (0.06 in.) nylon wire spacers were added to control the thickness of the lift. Once the first layer of concrete was applied, the first layer of pre-cut reinforcement was placed on the fresh layer of

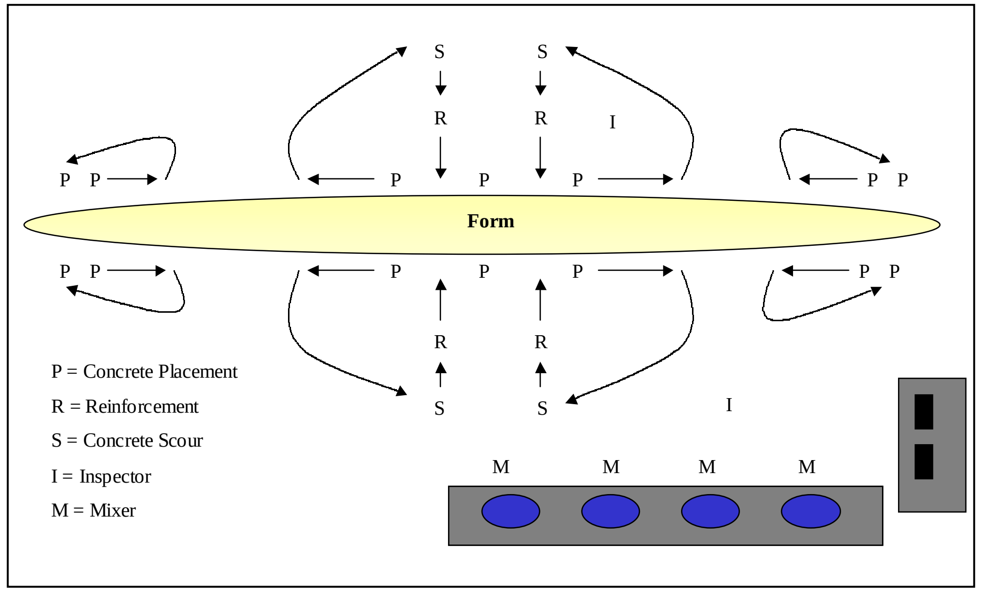


Figure 6.2: The work flow diagram for construction of ***Instinct***

concrete and scoured with a fibrous concrete. After scouring the reinforcement into place, another 1.6 mm (0.06 in.) lift of concrete was added and the process was repeated until all four concrete/reinforcement layers and the final lift of concrete was in place. Figure 6.2 illustrates the placement procedure in the form of a work flow diagram.

The Tensylon™ tendons were added and tensioned in the concrete lift between the second and third layers of polypropylene mesh. Each Tensylon tendon was stretched the entire length of the boat and tied off to an eye bolt at one end and attached to a spring and turnbuckle combination at the other end. Once the tendon was in place, the turnbuckle was adjusted until the spring reached the desired 9.1 kg (20 lbs) of tension, which was measured by the use of calipers. Each spring had been calibrated before placement with a 9.1 kg (20 lbs) weight and the spring extension was measured and recorded for use during placement. Seven tendons were placed along the top 15.2 cm (6 in.) of the gunwales, with the top five tendons spaced 1.27 cm (0.5 in.) and the last two tendons spaced 2.54 cm (1 in.) apart.

During the entire placement process inspectors maintained quality control by monitoring the placement procedure, lift thickness, mix quality, and placement duration. With all the layers of concrete and reinforcement in place, the final layer of concrete was finished smooth to minimize sanding on the canoe exterior. The canoe was then covered with damp plastic and allowed to cure.

The canoe remained covered with plastic and cured in the 21.1 C (70 F) construction facility for three days following placement. After three days, the plastic was removed and the canoe was dry cured in the heated construction facility. Dry curing was chosen due to recommendations of latex manufacturers. This is because the latex in the mix encapsulates water and disperses it over time. Therefore, the only way to allow the water to escape was to dry cure the canoe.

Finishing ***Instinct*** began seven days after placement by lightly sanding the exterior of the canoe. The exterior was patched with the patching mix, sanded smooth, and then the canoe was removed from the form. Immediately after form removal, the interior was sanded and patched to eliminate imperfections. Once both sides were sanded smooth, each side was sealed with an epoxy water seal, except in the 0.5 m (20 in.) band where the interior was left unsealed and the exterior was sealed with a non-epoxy based sealant. Both sides of the canoe were then primed with an automotive primer and the paint and graphics were applied to get ***Instinct*** to viewing quality.

Project Management 7.0

Managing a project as complex and detailed as designing and constructing a concrete canoe requires organization, detailed planning, and clear communication. ***Instinct's*** management team is composed of two project managers, a principle engineer, and team leaders who managed the ten project teams (Figure 7.1). The integrated management structure encouraged team members to take part in as many teams as possible in order to gain understanding of the overall project. Once the organizational structure was established,

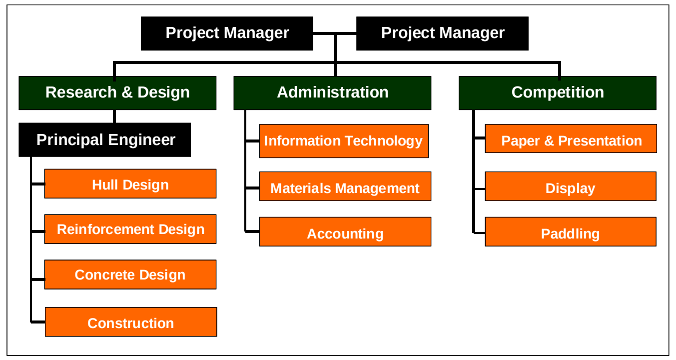


Figure 7.1: 3CT's Organizational Structure

team leaders began meeting in late July to start planning for the 2000 project. Management felt that good, detailed pre-project planning would be one of the keys to producing the best project in 3CT history. The first objective of these early meetings was to establish short term and long term goals for 3CT. Based on classroom knowledge and real world experience, 3CT has learned that projects tend to be more successful when everyone involved with the project works together to achieve one common goal. The objective of these meetings was to make sure everyone in a leadership position agreed with and understood 3CT 2000's goals.

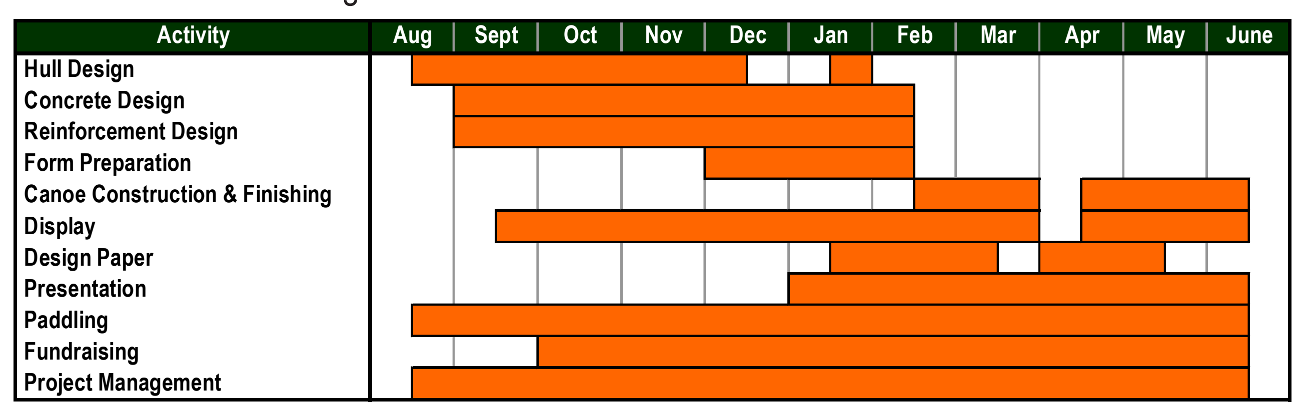
Roles and responsibilities were also assigned to team leaders at these early meetings to eliminate any questions or confusion about who was responsible for particular aspects of the project. Team leaders were then responsible for establishing goals within their respective team which would attribute to achieving the project goals. Once these goals were established, preliminary schedules with milestones were developed for each team and used to map out the overall project schedule (Figure 7.2).

Clear communication was one of the key elements of the project 3CT felt would lead to the success or failure of the project. Regular e-mails were sent and team meetings were held on a biweekly basis throughout the 10 month project. These meetings kept the team informed about what type of work was being performed and any upcoming events. Team leader meetings were held once a week to discuss the performance, progress, and new ideas for each team. The highlights from these meetings were placed on the agenda for upcoming team meetings.

The Internet played a major role in management's communication to team members. Besides the regular 3CT web page, this year's team developed a web page strictly for the team members. This was a controlled access web page that was updated daily and allowed team members to view upcoming work times and events. This web page contained each individual team's goals, schedule, and progress to date so every team member knew what was going on in every facet of the project. Another attribute of the web page was a "Meet the Team" link. This part of the web site contained interesting facts and background information about team members. This allowed for new team members to get to know the older members, which resulted in a much more comfortable and enjoyable working environment.

The most useful aspect of the web page was a database that allowed team leader's to enter the amount of time each team member worked for that week in that team leaders particular aspect of the project. This database allowed all of 3CT to view the amount of time that had been put into the project to date. Team leaders could use the database to evaluate the time and resources being utilized in the

Figure 7.2: Gantt Chart for ***Instinct***



project and allocate resources to areas of the project that are in jeopardy of becoming behind schedule, or already are behind schedule. This aided 3CT in keeping on track with the project schedule (Figure 7.2) established during pre-project planning.

3CT also incorporated a management technique developed from last year's project requiring team leaders to submit weekly progress reports during critical phases of the project. These progress reports contained items such as recently completed work and forecasted work, materials purchased or required, team performance, and any comments for the project managers. These reports allowed 3CT's management to keep track of the project schedule, procure needed materials, and address any concerns within the teams before they had any adverse affects on the project.

The incorporation of several new management tools with the continued uses of existing tools, has allowed the design, construction, and finishing of the highest quality canoe in 3CT's history. A solid organizational structure and detailed pre-project planning helped establish the teams organization and direction for this year's project. Regular e-mails, the team web page, and meetings opened the lines of communication between the team and management, keeping everyone informed on every aspect of the project. These management tools aided 3CT on their expedition to produce the best project in 3CT history.

Cost Assessment 8.0

Instinct's total cost from concept to completion was $209,876. This figure was developed in the Detailed Cost Assessment (Technical Appendices: Detailed Cost Assessment). Of this cost, direct labor accounts for roughly 97% of the total cost. This does leave around $6,000 worth of materials that were consumed throughout the life of the project. This cost is offset by the donation of materials by our sponsors and through fundraising efforts of our own. Table 8.1 shows the specifics of the Cost Assessment.

Cost Summary	
Direct Labor Cost (DL)	**$203,546**
Expenses (E = (MC+DE)*1.1)	**$6,330**
Materials Cost (MC)	$4,555
Project Expenses (DE)	$1,200
Total Project Cost (DL + E):	**$209,876**

The cost assessment methods and labor and material rates used for Instinct were based on Sections III.E and III.F in the 2000 National Concrete Canoe Competition Rules and Regulations. The methods were followed completely, while the cost were only used when supplier information or local market value information were unavailable.

Innovative Features

Each year 3CT looks to build on its past success and push the envelope of Concrete Canoe. In order to keep up with the competition 3CT must look to its team members for unique knowledge or skills that maybe used to stay ahead of the pack. This knowledge or skill may be a tool or technique learned in lecture or it might be in an area the team member possess a special knowledge of thru practical experience. Table 9.1 list some of the innovations 3CT some of the innovations 3CT has used to design, construct, finish, and race ***Instinct.***

Instinct's Innovative Features

Summary

By studying and learning from the successes and failures of previous teams and by using their instincts 3CT has once again created an outstanding product. Instinct takes advantage of cutting edge technology polypropylene reinforcement, lightweight concrete, computer aided hull design and months of hard work and dedication. 3CT looks to prove itself once again academically and athletically at the national level. 3CT looks to lay claim to the title "King of the Jungle".

	Innovative Feature	Feature Role
Hull Design	Computer Design	Computer optimization of the hull below the water line. Allowed a quick through revies of over 70 hulls
	Hull Prototype	Full Scale physical Testing of hull prior to construction. Allowed paddler input on the peposed and final design
Concrete Mixture	Blended Bubbles	Very homogeneous mix. Quality control greatly increased by handling methods
	HPF & Carbon Fiber Blend	Utilized two different fibers to increase flexural strengths before and after initial failure
Reinforcement	Pre-tensioning	Incorporated pre-tensioning in the gunwales to increase flexural strength and prevent cracking
	Tensylon™ Material	New high strength polyethylene material
Construction	Reusable Wooden Form	Replaced reusabel foam form. Creates a sturdier and much truer form for repeated use
	PreBatching Wet & Dry Materials	Allowed for consistent mixes during placement
Project Management	Pre-Project Planning	Detailed planning to establish roles & responsibilities, project goals, objectives, and schedules.
	Team Member Web Page	Allowed team members quick easy access to information about progress, upcoming events, schedules, contact information, etc.