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STRUCTURAL MODELLING AND ANALYSIS OF CONCRETE CANOE HULL

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INTRODUCTION

The design of a ship usually goes through three stages; concept, preliminary and contract design. The fact that computer-aided design is being used on ships also claims that computers are only a tool to help with design. Therefore, the designer of the ship is responsible for resolving the problems with reasonable and sometimes creative design formulas and critically examining the consequences. Even if some standard sub-tasks are almost automatically performed by computers, ship design is done by people using computers. But despite the advances in technology, computer-aided ship design will continue throughout the history of human beings as a responsibility of people. The ship design process serves to provide a complete product description, suitable for all subsequent performance and safety assessments, and for planning of inputs and delivery to ship production. To this end, the design process should produce a complete product model that defines the ship's characteristics for all subsequent assessments as required. For this reason, computer programs are indispensable helpers for ship designers (Nowacki, 2010).

Team **Atharva** had to take some key decision as it was the first time making 2-meter concrete canoe. Team did extensive research on various parameters that govern the stability and speed of the hull. The focus was having stability not compromised whilst making sure adequate speed is achieved by streamlining the shape of the hull.

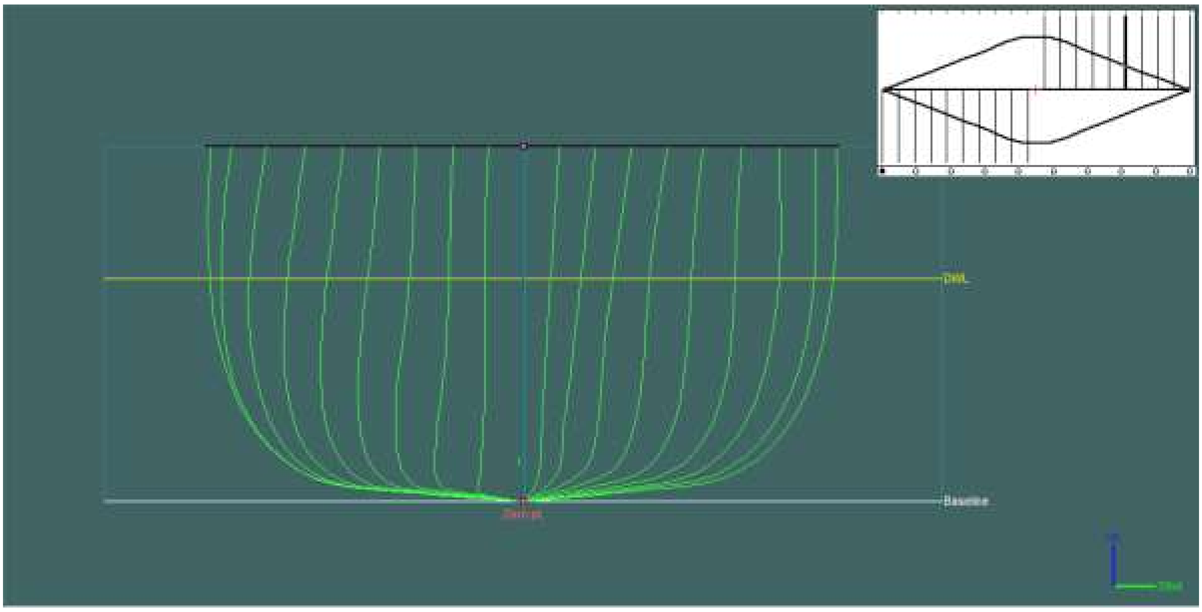

Figure 1: Cross-section of Hull

The length and beam of the canoe were decided by taking into consideration the rules of the competition. The length of the boat is restricted to 2 meters. Maximum beam should not exceed 0.8 meter while the maximum allowable depth was 0.4 meter. (Aaruush, 2019)

HULL DESIGN

For designing the canoe's hull-form, MAXSURF©, a naval architecture software by Bentley® for fast, accurate design and analysis of all types of marine vessels was used for designing, hydrostatic and resistance prediction (figure 1). The mentioned software helped us optimise our model and calculate the required displacement providing flexibility with standalone window for each process of hull design.

The shape of canoe was decided to be symmetrical and flat bottom. A flat-bottomed canoe can capsize easily if highly windy but provides initial stability which is essential. For comparison Flat bottom and round bottom were considered. The former gave lower Vertical centre of gravity while the latter offered lower resistance. The decision was made on basis of giving the canoe higher stability and reducing the surface area, thus decreasing the overall weight of canoe.

Displacement and freeboard: our mix design has a density of 1200 kg/m^3. Meeting the criteria of making the canoe float, we decided to have 120 kgs as our displacement with 42 kg of canoe and 80 kg of paddler. Assuming a wall thickness of 20 mm, team decided to reduce the depth of canoe for Vertical Centre of Gravity to be at brim level. Thus, a depth of 0.35 was finalised.

A speed to length ratio of 1.20 was decided with prismatic coefficient of 0.57. It was also essential for us to keep length to beam ratio above 2 and reduce prismatic coefficient indicating a finer hull which added to the straight-line speed. This value of cp ensured that neither too much water was to be pushed (increase in drag) nor let it sink in its own waves. The model helped keep the metacentric height above its minimum and ensured streamlining of the canoe. Thus, after several iterations a length of 1.80 and beam of .63 was finalised.

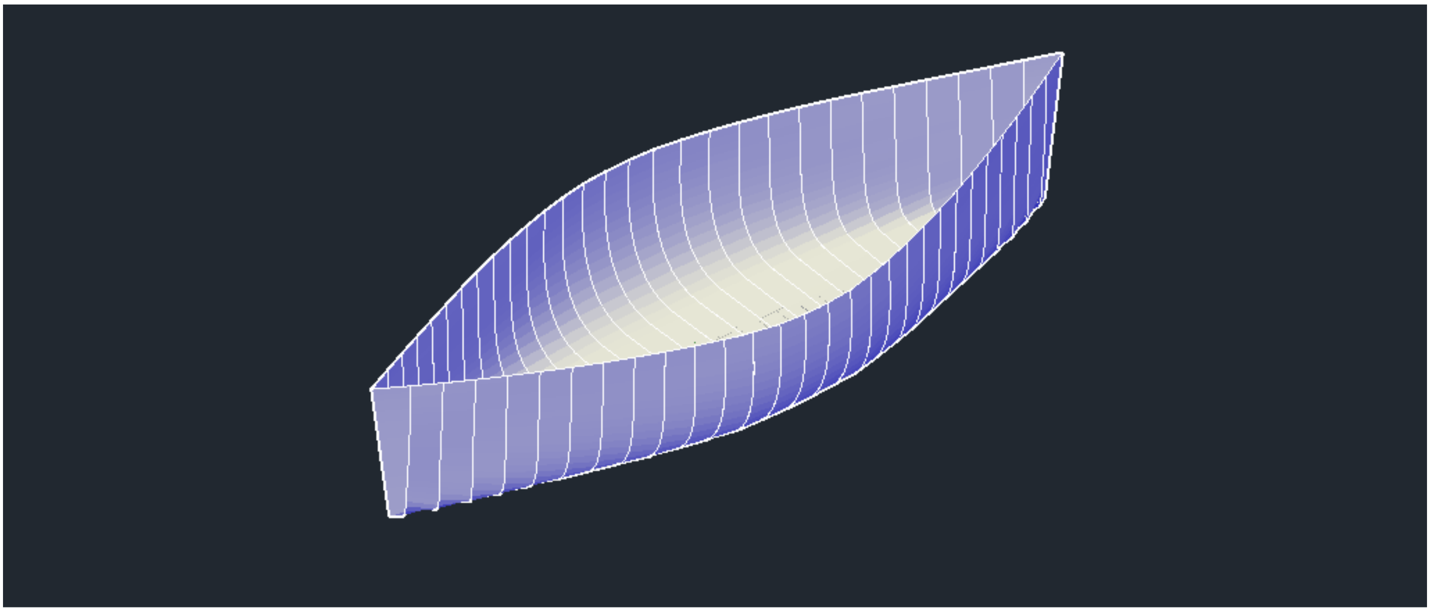

Figure 2: Rendered view of Hull

TABLE 1: HULL SPECIFICATIONS	
NAME	**ATHARVA DIMENSIONS**
LENGTH	1.80 m
MAXIMUM WIDTH	0.63 m
MAXIMUM DEPTH	0.35 m
WALL THICKNESS	0.02 m
WEIGHT	42 kgs

The hull was given bow and stern angle of 5 degree for streamlining and reduce manoeuvrability as the race follows a straight path and no curves to be encountered. The ends are kept v-shaped for it to cut through water and increase speed; resistance was analysed from speeds ranging from 1 to 3 knots.

A plot of resistance vs. speed was made for 1 to 3 knots based on our speed to length ratio of 1.2. It was noticed that till the speed of 2.65 knots resistance was increasing in linear fashion suggesting less resistance in initial stage.

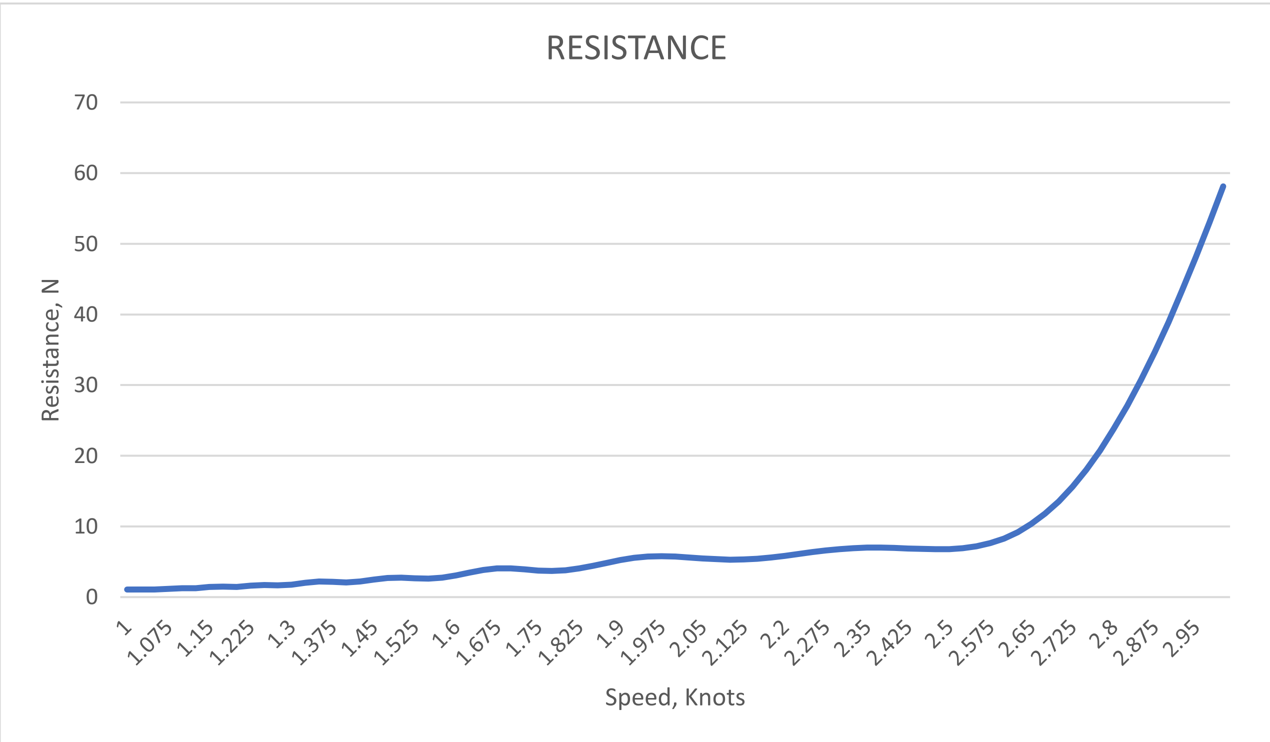

Figure 3: Resistance vs Speed

HULL ANALYSIS

Simple analysis method was used for calculating shear and bending moment. The method treats the canoe as a beam with uniform distributed loading with self-weight of canoe and buoyancy force. The paddler was considered as a point load acting at the centre of this beam.

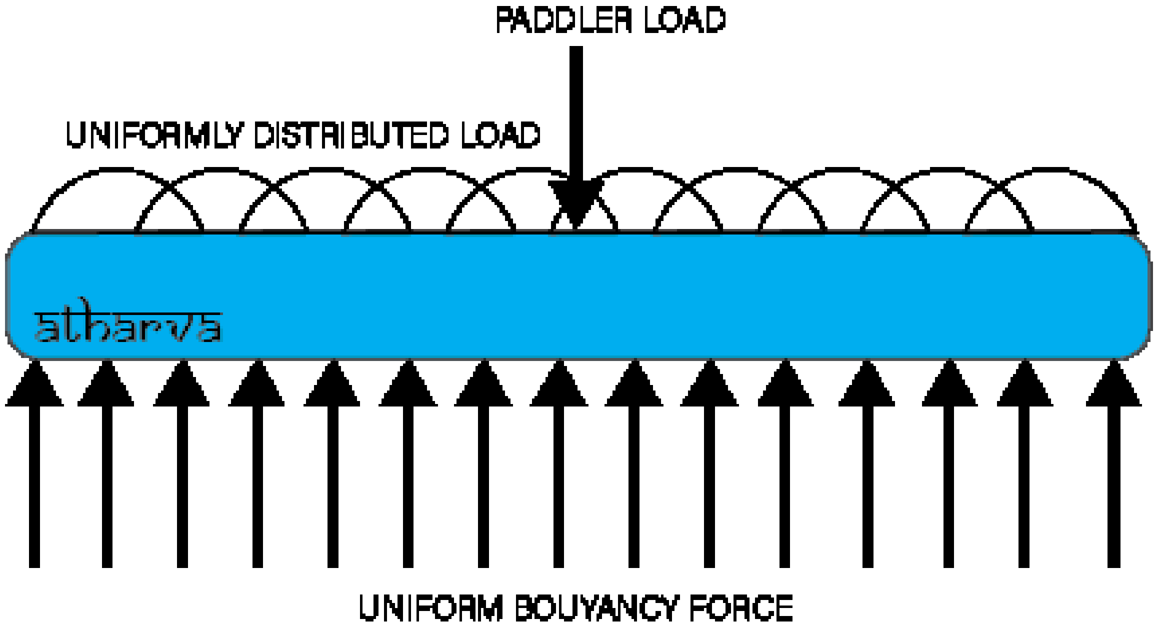

Figure 4: Load distribution

Since the competition involved only one male paddler rowing the boat, his position determined the maximum stress generated within the canoe. A program in MATLAB® was developed to calculate bending moment and shear force along the length of the beam.

The moment was calculated at 20 stations spanning over 1.80 m length. The maximum bending moment was found to be 176.6 N-m at paddler's position.

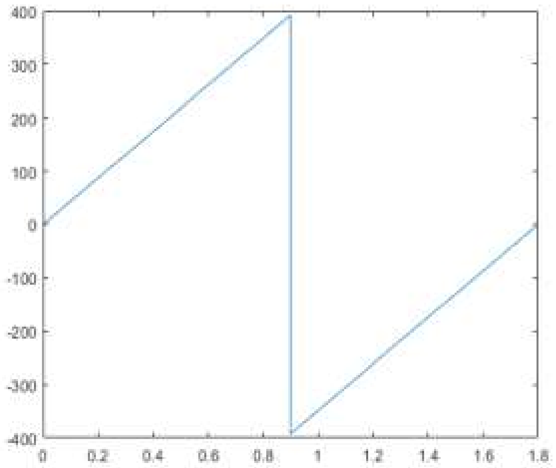

Figure 6: Shear force Diagram

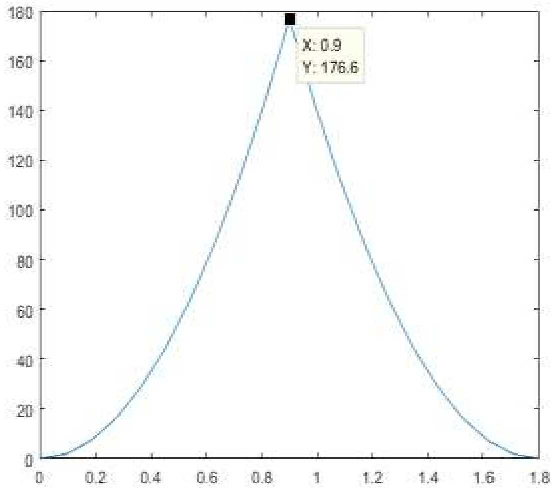

Figure 5: Bending moment Diagram

Alternatively, Rhinoceros® (*Robert McNeel & Associates*) was used to verify results obtained for hydrostatics in MAXSURF®. Moment of Inertia was then calculated in Rhinoceros® of maximum moment acting cross section area along transverse direction.

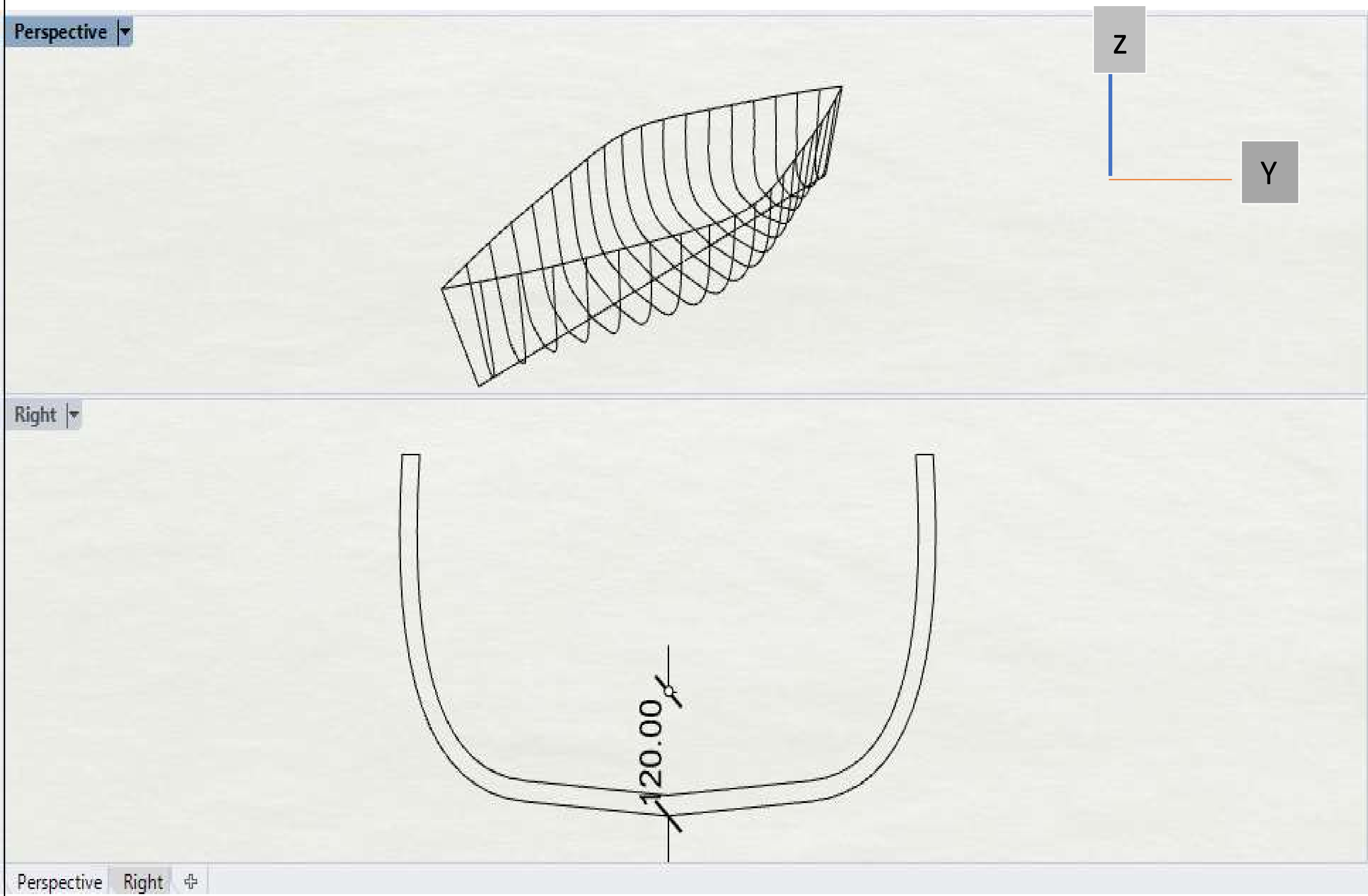

Figure 7: Hydrostatics in Rhinoceros®

TABLE 2: MOMENT OF INERTIA	
Moment of Inertia about X-axis	$1.46560539E + 09\ mm^4$

The maximum stress corresponding to bending moment of 176.5 N-m was found out to be 0.0144 N/mm^2 in tension zone and 0.0276 N/mm^2 in compression zone.

To understand the structural behaviour of the canoe in conjunction with MATLAB®, the final shape obtained from MAXSURF© was imported to SAP2000®. Since the volume underneath the waterline was more or less even throughout due to flat bottomed design, buoyancy and self-weight were distributed uniformly throughout the length of canoe with paddler positioned in the middle. The hull was assigned with our mix design properties as shown in Table 3

TABLE 3: MATERIAL PROPERTIES	
28 DAY CHARACTERISTIC COMPRESSIVE STRENGTH	$10\ MPa$
ELASTIC MODULUS	$4240\ N/mm\hat{}2$
POISSON RATIO	0.18
COEF OF THERMAL EXPANSION	$5.500E-06$
UNIT WEIGHT OF CONCRETE	$1.177E-05\ N/(mm\hat{}2\ )$
TENSILE STRENGTH	$2.2\ MPa$

A rectangular mesh element of size $62mm \times 22mm$ was created with 60 quadrilaterals for each cross section. An iterative process was carried out to determine the hydrostatic pressure applied on the canoe, where the sum of reactions must correspond to weight in Table 5

$Pavg = \ unit\ weight\ of\ water \times\ average\ canoe\ depth.$ (Muzenski and Klett (2010))

$= 998\ kg/m\hat{}3\ \times\ 0.172\ m$

TABLE 4: ITERATIVE SUM OF REACTION	
Hydrostatic Pressure(N/mm^2)	**Sum of Reactions (N)**
.00163	1180
.00180	1262.11
.00170	1191.21
.00174	1219.46

TABLE 5: WEIGHTS ON CANOE	
Self-weight	414.37 N
Weight of Paddler	$784.8\ N$
Self-weight and 1 Paddler	$1200\ N$

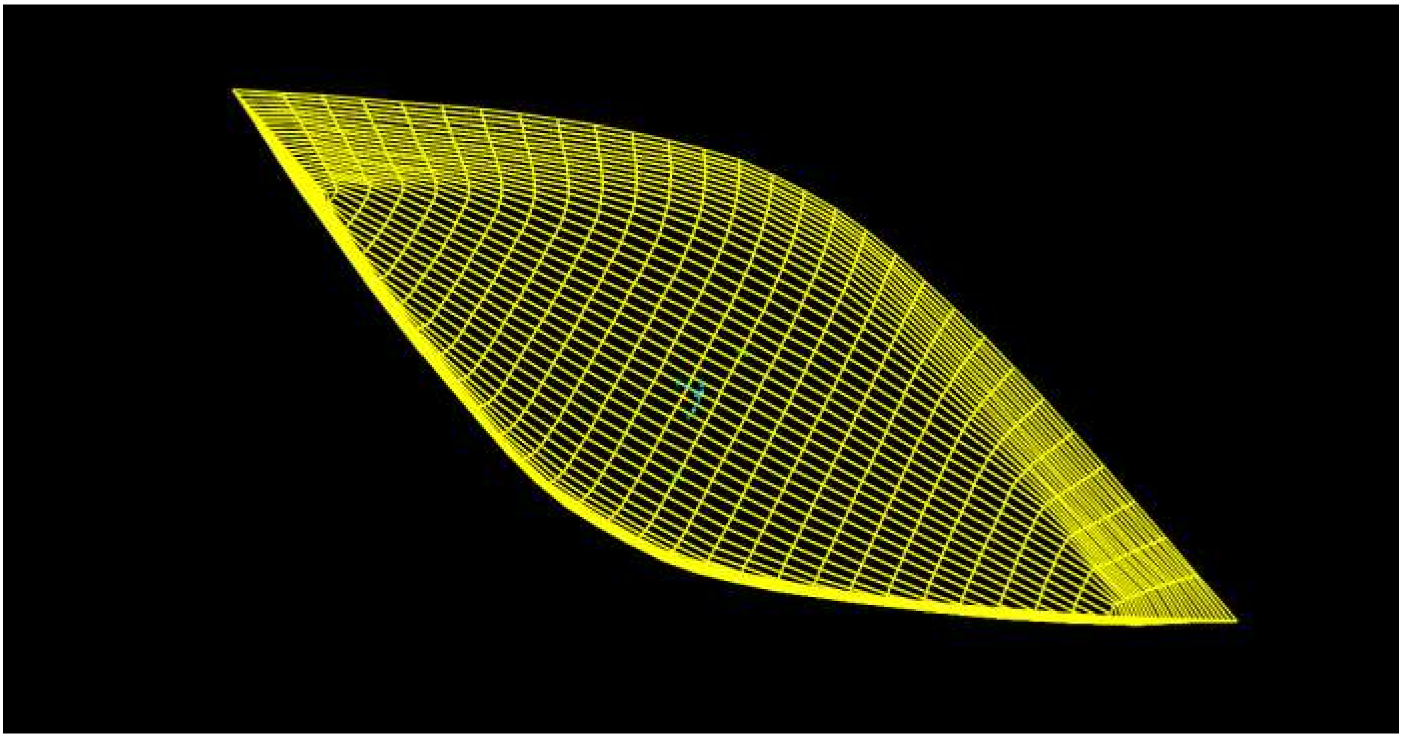

Figure 8: Rectangular mesh in SAP2000

Table 6 shows that largest stress occurred at place where paddler is positioned. It also showcases that top part of the canoe is majorly dominated by compressive stress while the bottom part is in tension as shown in Figure 9. Maximum principal stresses are shown in the numerical model subjected to static loads.

TABLE 6: STRESS RESULTS		
N/mm^2	**Max. Principal stress**	**Min. principal stress**
TENSION	0.294	0.214
COMPRESSION	-0.195	0.267

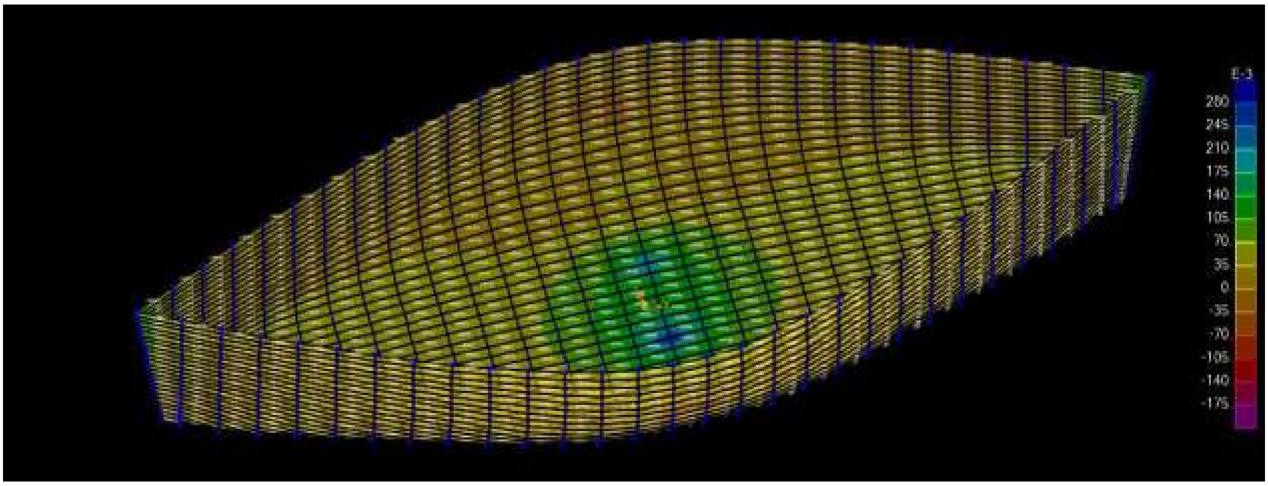

Figure 9: Maximum principal stresses

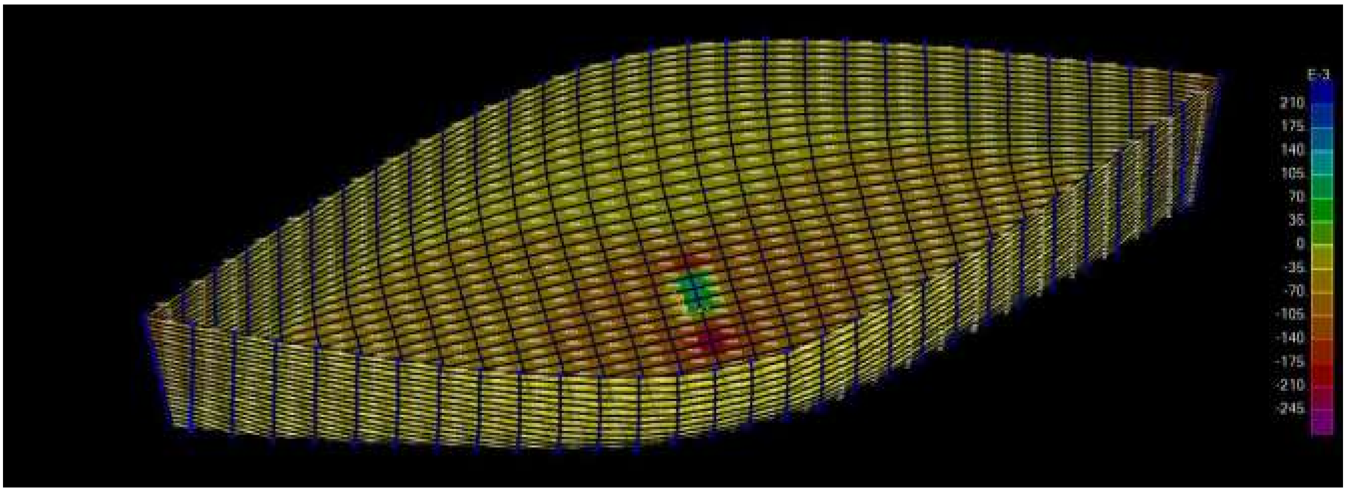

Figure 10: Minimum principal stresses

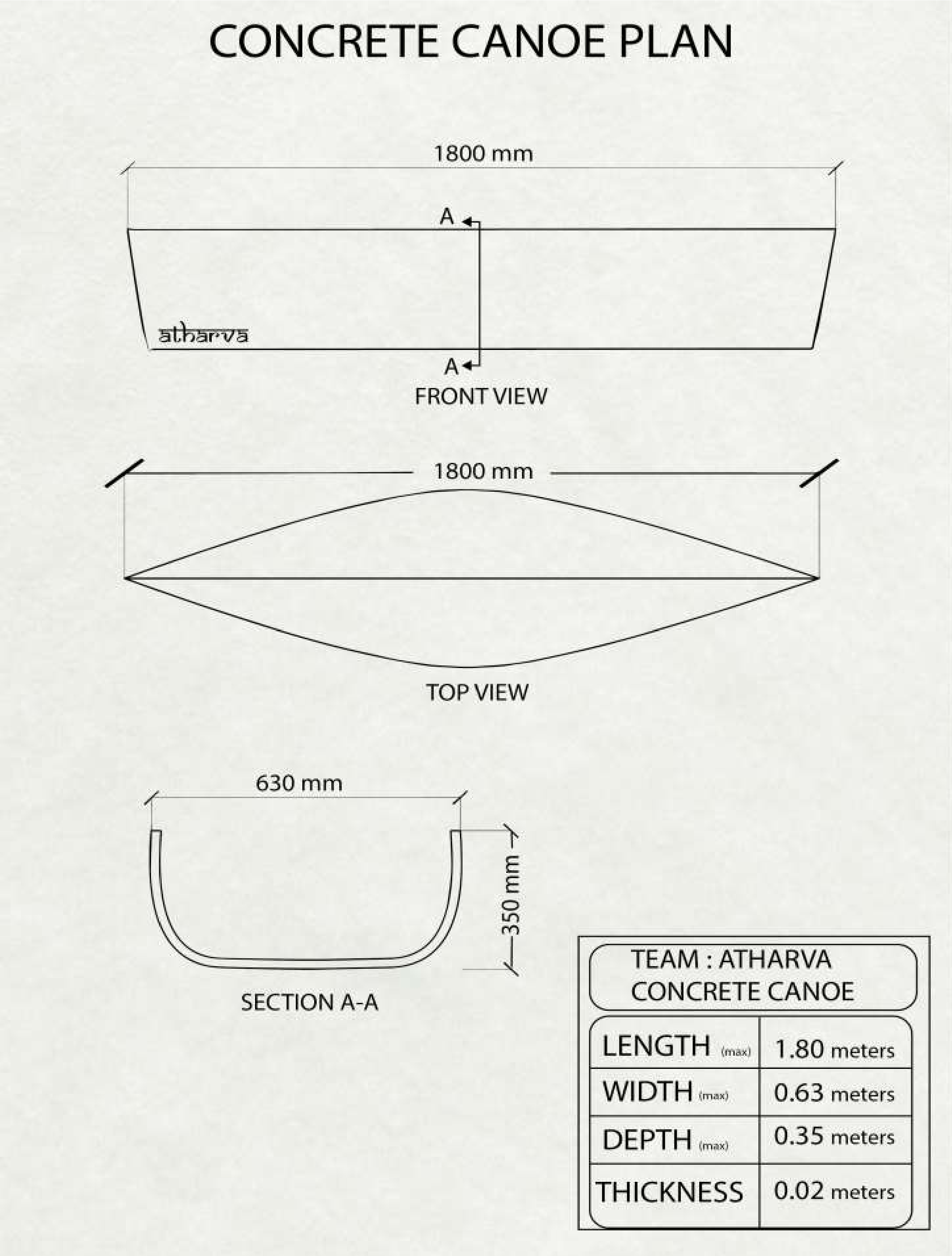

Figure 11: Concrete canoe plan