COMPLIANCE CERTIFICATE

I, Colin McDermott, captain of the 2006 University of Michigan Concrete Canoe Team, hereby certify that our team's entry into the ASCE/MBT National Concrete Canoe Competition has been completely built within the current academic year and complies with the rules and regulations of the 2006 National Competition. We also certify that the six participants representing the University of Michigan are qualified student members and National Student Members of ASCE as specified within the 2006 National Competition Rules and Regulations.

Captain

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Associate Professor Sherif El-Tawil
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Canoe Specifications

Name: **MCCTSX-06**
Maximum Length: 216in
Maximum Width: 28.5in
Maximum Depth: 16in
Average Thickness: 0.75in
Weight: 190 lb

Concrete

Unit Weight: 53.7 lb/ft^3 (860 kg/m^3)
Compressive Strength (estimated 28 day): 670 psi (4.62 MPa)
Composite Flexural Strength: 1000 psi (6.89 MPa)

Eligible Participants

Christina Choi
pending

Katie Harding
461510

Lori Kindschy
425729

Ryan Rudy
pending

Nate Sosin
422923

Jason Spencer
430991

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MCCTSX  06

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EXECUTIVE SUMMARY

The University of Michigan is an international leader in engineering education and research and has been offering classes within the College of Engineering since 1854, beginning with the discipline of Civil Engineering. The Michigan Concrete Canoe Team (MCCT) has been an active participant in the North Central Regional Conference throughout the history of the competition with a brief absence in the early 1990's. With vast improvements in the canoe strength and competition display in 2005 from a cracked canoe and felt covered boxes in 2004, MCCT 2006 strove to continue its improvement through diligent digital design, the moto of project MCCTSX-06.

Throughout the year MCCT was compelled to maintain secrecy of its three prong process comprised of the canoe shape, formwork construction, and mix design. The team was small, so tight security was accomplished utilizing the University's secure network to store project data and by only seeking internal University assistance from trusted friends of the team.

MCCTSX-06: ***Vehicle Charateristics***

Weight	190 lb
Total Length	216.0 in
Maximum Width	28.5 in
Maximum Depth	16.0 in
Average Thickness	0.75 in
Color	Dk Gray
Concrete	
Concrete Unit Weight	53.7 lb/ft^3
28-day Compressive Strength	670 psi
Composite Flexural Strength	1000 psi
Reinforcement	
Fiber Glass Mesh: Thickness	0.023 in
PVA FIbers: Length	0.375 in

The subtle facetted shape of MCCTSX-06 inspired by stealth technologies is intended to question the smooth curves of a typical canoe exterior.

Building on past design concepts and construction processes, the 2006 formwork took the cnc fabrication and modular design concept from 2005 and the construction process and materials of foam with wood ribs from 2004 to develop a sleek, continuous female mold.

The mix design was an intense process that looked to replace mesh reinforcement with fiber reinforced in order to increase canoe durability and decrease construction time as well as increase mix workability. The final product is a mix made of Haydite, EPS foam, and glass bubbles. It is a hybrid reinforcing system that utilizes a small percentage of fibers and a layer of mesh reinforcement to resist internal forces.

HULL DESIGN

With a motto of diligent digital design, it was essential that the hull design of project MCCTSX-06 be taken under substantial consideration. Although the hull had been much improved over the past three years, it was decided that MCCTSX-06 would be developed from scratch using Rhinoceros (a NURBS, Non-Uniform Rational B-Splines, modeling software that can accurately describe 3D organic surfaces) while trying to challenge the idea of what a canoe can be remembering to remaining competitive and respectful to the context in which the concrete canoe competition was founded.

The prospect of starting from nothing while daunting, allowed MCCT the freedom to explore objects like pontoon canoes, rubber ducks, race cars, and airplanes to find the inspiration for a concept that would ultimately drive the hull design. From these objects and a few brainstorming sessions, MCCT became most excited by the Stealth Bomber's unique angular shape. This lead to the subtle facetted shape and is intended to question the typically smooth curves of a canoe exterior.

Figure 1: View of a Stealth Bomber showing its unique silhouette.

With a solid concept, MCCT looked to previous years' canoes to help define critical hull dimensions of length, width, and depth. An over length of 18ft was decided upon to increase the ease of turning as well as to cut down on weight. While a short overall length inhibits speed and tracking of the canoe, for our first time paddlers we wanted the canoe to feel responsive. A max width of 28in was taken from directly from the 2005 canoe as it was manageable for paddlers to alternate sides quickly. This also gives the width to create a more flat bottomed canoe thus increase the stability of the canoe. A depth of 16in was chosen based on the waterlines of canoes from the previous three years. With this depth it was estimated that we would have around a 6in freeboard with an average canoe thickness of 0.75in.

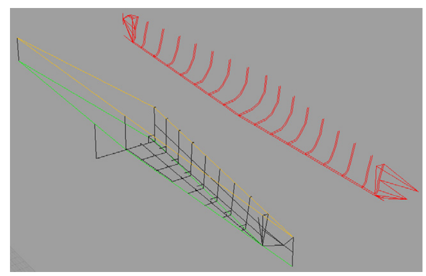


Figure 2: Framework used to create MCCTSX-06 section curves and surfaces.

Utilizing these dimensions, a diamond (yellow fig. 2) similar to that created by the Stealth's wings, became the initial shape to develop a framework to construct the canoe surfaces. The depth allowed the bottom portion of the framework to be drawn (green fig. 2) sloping 4in from the max depth in the middle to the ends of the canoe. This creates a slight "rocker" effect, increasing maneuverability. With the basic frame completed, reference lines at 1ft intervals (black fig. 2) were drawn and used to rigorously construct the section curves (red fig. 2&3). The section curves are the items that give the canoe its stable flat bottomed, facetted shape and allow 1/4 of the hulls surface panels to be constructed. This quarter is than mirrored in two directions to create the main body of MCCTSX-06.

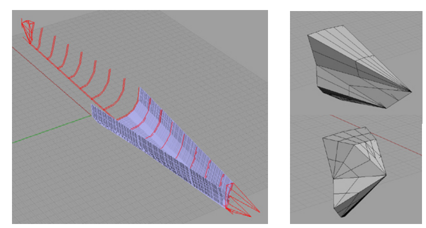


Figure 3: Canoe surfaces for body, bow(top), and stern(bottom).

The body of the canoe is an asymmetric design with the bow half of the canoe slightly longer than the stern. This allows the bow to be shaped to cut through the water with minimal disruption and the stern to be truncated creating more stability in the canoe for optimum efficiency. The facetted shape is thought not to increase the drag on the canoe because all its lines are in the direction of water flow and are slightly curved sort of giving it the ability to channel water down and away from the canoe surface.

Figure 4: Elevation of MCCTSX-06 showing rocker, asymetric facetted shape, and bow/stern shapes based on crew shell designs.

ANALYSIS

Continuing with the idea of diligent digital design, MCCT utilized for the fourth consecutive year Abaques, a finite element analysis (FEA) program, to determine an estimate for the strength of MCCTSX-06's concrete. With the hull design being created using Rhinoceros surfaces, the drawing file can simply be saved as an .iges type and imported directly into the FEA software. This gives the team a practically identical model of the canoe to analyze.

Before the canoe can make its trip into Abaques, a simple hydrostatic analysis was conducted to determine the load cases that will be used during the finite element strength analysis. The analysis utilized Rhinoceros's hydrostatic calculation capability which calculates the volume of water displaced, wetted surface area, and other data of any object when provided a reference water plane. By placing the canoe at depths varying from 4 - 10in at 1in intervals, the team used Archimedes Principle to develop a curve that would estimate the waterline knowing the weights of the occupants.

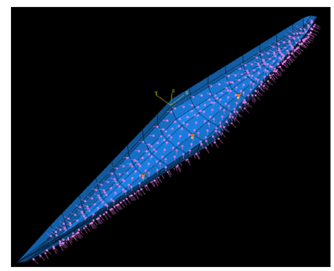


Figure 5: Applied Loads

Archimedes Principle states that any object wholly or partially summered in a fluid is buoyed up by a force equal to the weight of the fluid it displaces. Utilizing the weight of water displaced by the canoe at each level, MCCT back calculated the weight of the paddlers by subtracting the estimated canoe weight assuming a concrete density equal to 99% of water. This conservative concrete weight was to insure that the canoe weight would be overestimated even if the volume of concrete used was underestimated. Also a study varying the concrete density to our estimated design density 85% of water showed a decrease of less than 0.5in in the waterline.

From this analysis three static load conditions were implemented using a hydrostatic pressure below the water line and people of 150lbs; 1)waterline at 3.5in with 4 people; 2)waterline at 6in with 3 people; 3)waterline at 8in with three people. People were taken as concentrated loads and were placed in the wider portions of the canoe to model the seating arrangement. Abaqus has a built-in function that will adjust the water pressure based on how deep the node is below the water surface. All analysis utilized a mesh size of 1in, boundary conditions of fixed points at the location of paddlers' weight, 0.75in thick shell elements, and an elastic and isotropic material with a Possion ratio of 0.2 and a Young's modulus of 1800ksi. The modulus of elasticity was estimated from the ACI equation with equal to 600 psi, a number found from initial concrete compression tests. MCCT hoped that these conditions would show how an increase in submergence and weight in the canoe would effect stress distributions.

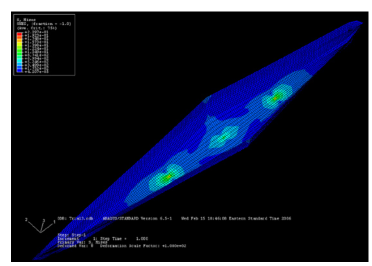


Figure 6: Miese Stress Conditions

From our analysis, we determined that we needed a concrete compression strength of 115psi and a tensile strength of 300 psi. Results below show sx(length) stress distrbution and sy(width) stress distributions.

waterline 3.5" (4 people)

von mies stress= 140psi tension
sx= 40psi tension
sy=260psi tension, 80 comp. on sides

waterline 6" (3 people)

von mies stress= 300psi tension
sx=20psi tension
sy=50psi tension, 30psi compression

waterline 8" (3 people)

von mies stress= 120psi
sx= 30psi tension, 65 psi comp. by boundary
sy= 70-100psi tension, 94 psi comp. on sides

waterline 8" (3 people) E=400ksi

von mies stress= 100-120
sx= 30psi tension, 40-65psi comp on sides
sy= 70-100psi tension, 100psi comp. on sides

DEVELOPMENT & TESTING

Baseline Concrete & Reinforcement

This year's mix was originally designed to be poured into a dual male-female form in order to control hull thickness and finish quality. This construction required an extremely plastic mix and an incorporated reinforcing scheme (i.e., fibers). Also desired, was an improvement over last year's unit weight. The first step was to isolate a workable set of aggregates and cementitious materials (CM). We began with the following:

Figure 7: Concrete materials. (left to right) Haydite, S-38, EPS, Cementisous materials

Figure 8: Mixing Concrete

Figure 9: Final Concrete Mix

Figure 10: Compression Test cylindar speciman.

Cementitious Materials – Option 1

- Portland Cement (Type 3) : used to offset strength retarding properties of Fly Ash and Silica Fume.
- Fly Ash (Type C): required by the rules, useful for filling voids, decreasing permeability, and increasing long-term strength gain.
- Silica Fume: similar to Fly Ash, but less dense.

Aggregates

- Haydite Expanded Slate (Grade A): similar strength and gradation to normal sand (2NS) but 30% less dense.
- 3M S-38 Glass Bubbles: high isostatic crush strength and low specific gravity.
- Microlite Expanded Perlite: similar density to S-38 with coarser gradation.

Admixtures : Superplasticizer and Air Entrainer used as required.

Mix Development

Baseline unreinforced compressive strength results were impressive showing around 1100 psi. However, the yield unit weight was barely floatable. Also the mix was not plastic enough to accept our required fraction of reinforcement fibers and the water to cementitious materials ratio was two to three times higher than allowed by the rules.

Absorption and specific gravity tests on our aggregates showed that the expanded perlite absorbed several times its own weight in water thus increasing its effective specific gravity, the unit weight of the concrete, and most importantly breaking the rules. A new ultra-lightweight aggregate with similar gradation was required.

MCCT began to produce our own lightweight aggregate by blending chunks of extruded polystyrene in water. The product was light but very coarse, meaning the resulting concrete would have large, compressible voids. While, consulting departmental research groups for other ideas a large, unneeded quantity of industrial grade Expanded Polystyrene (EPS) was found. The EPS was a much lighter and finer material than MCCT had been producing, but within the gradation limits that were needed to keep our composite aggregate in accordance with ASTM standardC33.

The EPS was tested for its specific gravity and a 60 lb/ft3 mix was designed. The actual product weighed closer to 50 lb/ft3. Carefully study of a cylinder cross sections and batch vs. yield volumes led the team to conclude that the hydrophobic EPS was entraining more air than originally designed. Further batching, produced final proportions with air content between 15 and 20%, compressive strengths near 600 psi, and a unit weight near 55 lb/ft3.

Reinforcing

Although the use of PVA Fibers was initially intended as the sole method of reinforcement, MCCT had troubles including a sufficient volume fraction of fibers in our mix to provide consistent fiber distribution. Fibers in excess of 1% by volume caused disassociation of the mixture ingredients and prevented the mix from being formed into a monolithic, continuous composite. As a result, the team looked to having a hybrid reinforcement scheme that includes PVA fibers at 0.7% by volume to increase the toughness and ductility of MCCTSX-06 final concrete mix design. Since, fibers were unsuitable as the sole method of reinforcement, the team looked to past years mesh systems. They were typically between 3 and 6 layers which made it difficult to keep hull thickness similar. It was thought that, because the mix was workable with a small percentage of fibers that only one layer of 6 oz Fiberglass mesh could be used to provide adequate flexural strength for the canoe. Tests were conducted using the final mix design with 1 and 2 layers of reinforcement to check the flexural strength against finite element analysis results.

Figure 11: Plate test Preperation w/ mesh.

Admixtures

To help improve our mix properties, MCCT utilized superplasticizer, air entrainer, and latex modifier admixtures. The first is Superplasticizer which aids in the disbursement of fibers within the concrete. The recommended dosage is up to 18 fl oz/cwt using typical concrete materials (i.e. no Silica Fume). MCCT used a dosage of 30floz/cwt. We increased the dosage to combat the stiffening effects of reinforcing fibers and high fines content of the concrete produced by using Silica Fume, Fly Ash, and S-38. The second is air entrainer which was a required component for this year’s competition. The recommended dosage is as low as ¼ floz/cwt. The final dosage used is ¼ floz/cwt. We used the minimum dosage because the lightweight, hydrophobic aggregate and high superplasticizer dosage entrained sufficient fractions of air without the use of an air entrainer. The final admixture was latex modifier to try and increase bonding to the forms and mesh reinforcement during construction. The recommended dosage from its manufacturer was unavailable, but through consultation and experimentation a final dosage of 11 floz/cwt was used. We used this amount towards the end of mixing to decrease the effects of the superplasticizer, while maintaining plasticity required by PVA, to increase the effective concrete-fiberglass bond, and to increase overall flexural strength.

Final Results

Overall our final concrete mix utilized in the construction of MCCTSX-06 had a 3 day compressive strength of 400 psi. Considering the strength-gain effects of Type III cement, fly ash, silica fume, and haydite aggregate, the ultimate compressive strength should be between 600 and 800 psi. However, the 3 day strength is sufficient for the predicted service loads of the canoe based on our finite element analysis. The ultimate value will be determined prior to regional competition after a full curing time is given to specimens taken at the time of construction.

Figure 12: CanoeTest Section w/ mesh layer

The composite flexural strength (First Cracking) was tested to be about 900 psi. This value is sufficient avoid damage under predicted service loads.

Our composite flexural strength (Ultimate) was tested around 1300 psi. This value is achieved at very low strain values due to the combined effects of the PVA fibers and fiberglass mesh. Given this strength at relatively low levels of damage, the canoe could successfully weather a number of unforeseen extreme loading conditions they could be seen during transportation.

The final unit weight (plastic) of the concrete was 54lb/ft3. This value was 7% lower than designed due to the unexpected increase of entrained air. Given the satisfactory strength results and preliminary experiments on the permeability of canoe test sections, this lower value is beneficial.

CONSTRUCTION

Building on past design concepts and construction processes, the formwork for MCCTSX-06 combined the concepts from the 2004 and 2005 formworks to develop a sleek, continuous female mold. Keeping in touch with the project motto of diligent digital design the team wanted to utilize the cnc (computer numerical control) router that was a key component in the 2005 fabrication process. Also it was found that the modular design concept from 2005 aided in the ease of form removal. For the materials and piecing together process MCCT looked to the foam and wood ribs formwork from 2004. Foam was decided upon because in can be cut on the cnc router quickly, it is light, it can be hand modified, and it accepts a body filler material. A female form was decided upon because it gives us the ability to cast the desired angular exterior surfaces of the canoe.

Since the canoe hull designed was modeled in the digital world, its shape could also be used to make a digital model of the formwork. Using the concepts above it was decided that the formwork would be constructed from pieces of 2in rigid insulation foam, glued together into 18in long modules and separated by 0.5in MDF (medium density fiberboard) wood ribs. The 2in pieces of foam and 0.5in MDF were cut using the cnc router from section curves developed by slicing the computer model canoe width wise at the necessary intervals. After being cut with the cnc router, the 2in foam pieces are roughly shaped with a taper using an electric hot wire since the cnc router can not cut at an angle. The foam pieces are than glued together and sanded smooth. After smoothing, 2-3 coats of bondo body filler are applied to fill any holes and create the completely smooth surface for casting.

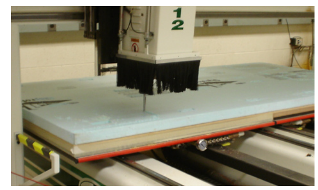


Figure 13: CNC Router

Figure 14: Foam Pieces

The main body of the canoe is comprised of 10@18in foam modules and 8 MDF ribs that are both 18.5” tall. To cut down on material waste the foam modules decrease in width from the middle to the ends every 3ft as the width of the canoe decreases. The ends making up the remaining 3’ of the canoe are made from two 6in halves that are milled by the cnc and glued together.

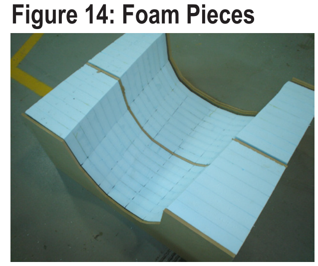


Figure 15: Foam Modules

The foam modules and wood ribs are designed to be aligned and assembled together with 2x4 wood studs on a 21.5” tall table. There are 3@12ft studs on the bottom screwed to the table, and others on each of the 2 sides. All the pieces are simply held together through compression via small angle brackets screwed into the wood studs at each wood rib. Finally, at each of the joints a final bondo layer is applied and sanded smooth to make the form one continuous piece. The bondo is than sealed using 3-4 coats of shellac to act as a bond breaker. For further protection to sticking concrete the shellac is coated with a light layer of oil.

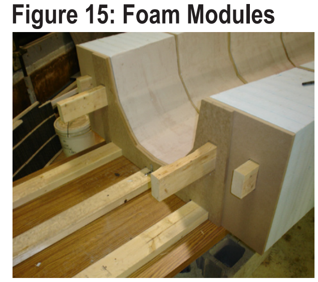


Figure 16: Form Assembly

For the construction of the canoe mesh was cut into pieces 38in wide (roll size) so that they fall about 1” from the top edge of the canoe and overlap between 3 and 5in. During construction of the canoe, the concrete was mixed by a single team of 4 (3 to measure materials, 1 to combine) people wearing respirators. This ensured that each batch was virtually identical. A concrete layer of between 0.375in and 0.5in was applied to the form surface, followed by the mesh and another layer of concrete the same thickness. The mesh and second layer of concrete were worked/pressed together thoroughly to ensure proper adhesion. For each layer the thickness was measured by one person constantly during the placement process using a homemade depth gauge made from an 1/8in diameter steel rod. The interior surface and canoe top edge were smoothed by a team of 2, using trowels after the general placement was completed.

The canoe was cured by covering it with plastic sheet attached to the table via staples. The concrete was sprayed 2-3 times per day with water for the first 6 days of curing and had 10@8oz cups of water on the interior to keep the moisture content of the air high during the full 14 days of curing.

Upon form removal the canoe will be slurred with a mix similar to the one used in construction to fill any small holes and wet sanding to give the canoe a smooth finish. It will than be given two coats of acid wash stain to give its final black/dark grey color. White lettering will be applied to the exterior. Finally two coats of clear sealer will be applied finishing the sleek look of MCCTSX-06.


Figure 17: Mesh prep

Project Management

Project MCCTSX-06 is a small team comprised of 4 main members and headed by a captain. With limited participation, MCCT 2006 decided to take a three prong attack and focused its efforts on the canoe shape, formwork design/construction, and mix design. It was felt that these were the most important aspects that would allow the team to be successful.


Figure18:FinishPlacement


Figure 19: Canoe Curing

From the small group of main members, 1 took on the role of manager organizing the mix design tasks while the captain focused on organizing canoe shape design and formwork design/construction tasks. These two managers essentially acted independently from one another scheduling time on their own to complete the tasks and teach younger members. This worked well with the small team. For the first time Team/Administrative and Competition Display were run by one manager on a part time level of involvement and invisible to the main members of the team. The captain and manager were selected based on commitment, interest, and experience to each of the tasks.

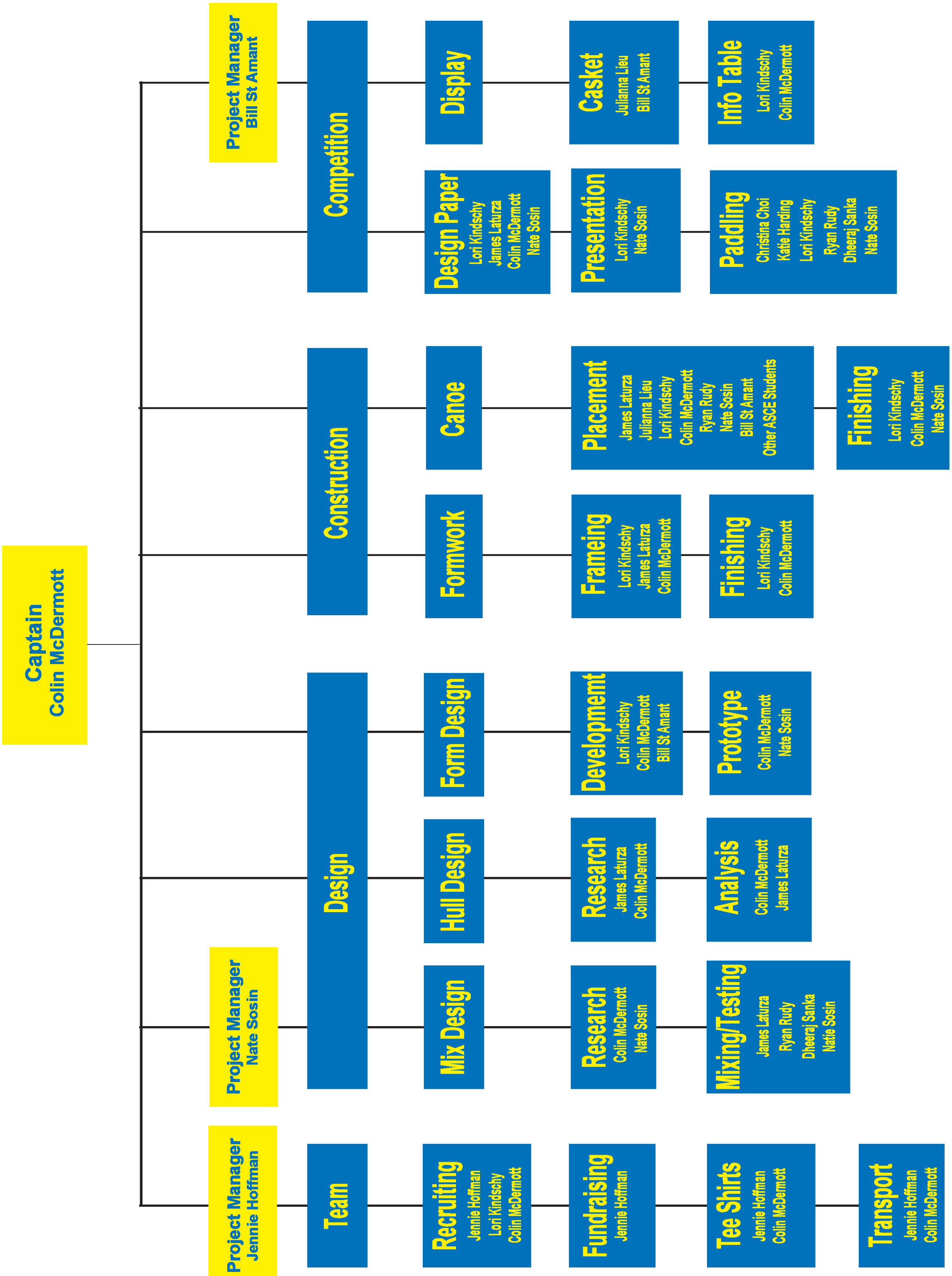
Project MCCTSX-06 had a maximum budget of $1,200 for canoe and formwork material construction costs, printing, tee-shirts, and transportation to the competition. The budget was set based on the amount of money that was currently in the teams financial accounts at the end of last year's competition. Being informed of full departmental support budget was little concern.

Based on 2005 schedule the captain put together a proposed schedule that would be used to gauge project MCCTSX-06 throughout the year. It was considerably less ambitious than its predecessor with major milestones consisting of completing the mix design by January 1, 2006, completing the formwork by February 1, 2006, and casting the canoe by February 7, 2006. This scheduling tactic, focusing on design and prototyping in the first semester and construction in the second semester, was believed would give the team adequate time to thoroughly explore hull and formwork design concepts and develop a concrete mix that would be ideal for casting a canoe. It would also allow the team about 3 weeks to construct the formwork to a higher quality of finish than in past years. It was felt that this would lead to having to spend less time on the finishing of the canoe exterior.

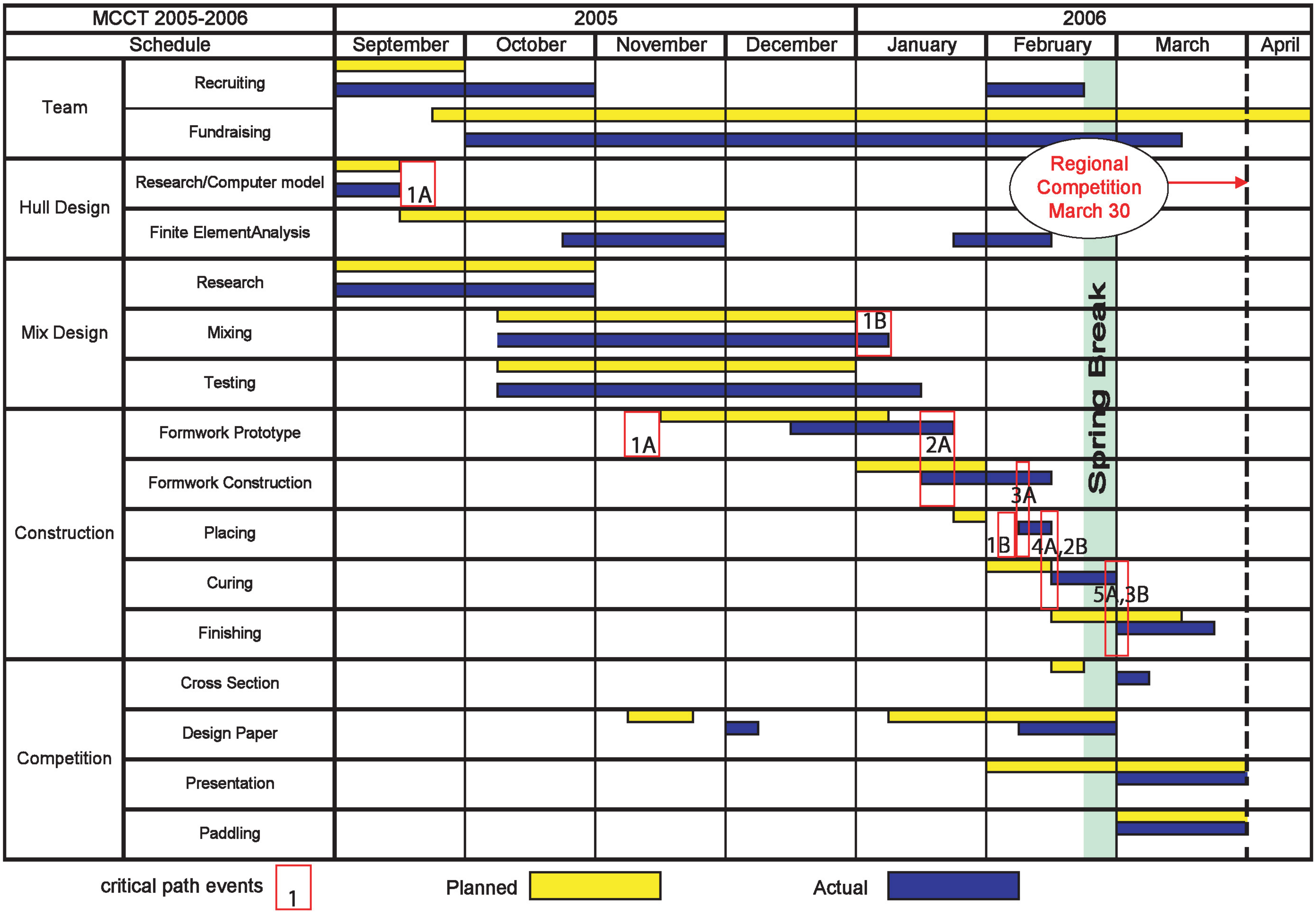
Despite the lack of man power, in the first semester project MCCTSX-06 managed to hold productive brainstorming sessions form design and complete a quality concrete mix design. MCCT was unable to complete prototyping before the break leaving the project 1.5-2 weeks behind schedule. As the second semester started, the team picked up the pace trying to make up time lost, but was only able to make up 2-3 days and scheduled a new goal of casting the canoe the weekend before spring break. With diligence in constructing the formwork MCCT was able to meet that goal.

Overall it is estimated that MCCT utilized 40 man hours for hull design, 50 hours for formwork design, 100 hours formwork construction, 10man@4hours canoe construction, 4man@3hours form removal, and 15 hours for finishing.

ORGANIZATION CHART



PROJECT SCHEDULE



APPENDIX A: REFERENCES

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APPENDIX B: MIXTURE PROPORTIONS

Table B1: Mixture Proportions

		Proportions as Designed		Batched Proportions		Yielded Proportions	
Batch Size: Approx 1 ft^3	Specific Gravity	Amount (lb/cy)	Volume (cf)	Amount (lb)	Volume (cf)	Amount (lb/cy)	Volume (cf)
Cementitious Materials							
Portland Cement Type III	3.15	449	2.28	16.7	0.08	423	2.15
Fly Ash Type C	2.40	96	0.64	3.6	0.02	91	0.60
Norchem Silica Fume	2.30	96	0.67	3.6	0.02	91	0.63
C.M. Totals:		641	3.60	23.8	0.13	605	3.39
Fibers							
PVA Fiber	1.30	15	0.19	0.6	0.01	14	0.18
Aggregates							
3M S-38 Glass Bubbles Absorption < 0.1% Batched Moisture < 0.1%	0.38	41	1.73	1.5	0.06	39	1.63
EPS Absorption < 0.1% Batched Moisture < 0.1%	0.05	32	10.23	1.2	0.38	30	9.65
Haydite A Absorption = 14.6% Batched Moisture = 12.1%	1.85	507	4.40	18.8	0.16	478	4.14
Aggregate Totals:		580	16.36	21.5	0.61	547	15.43
Water							
Batched Water	1.00	239	3.83	8.9	0.14	226	3.61
Total Free Water - Aggregates	1.00	61	0.98	2.3	0.04	58	0.93
Total Water - Admixtures	1.00	14	0.22	0.5	0.01	12	0.19
Total Water:		315	5.04	11.6	0.19	296	4.74
Admixtures	% Solids	Amount (fl oz/cwt)	Water in Admix. (lb/cy)	Amount (fl oz)	Water in Admix. (lb)	Amount (fl oz/cwt)	Water in Admix. (lb/cy)
Master Builders Glenium 3030	5%	29.8	11.8	6.44	0.4	27.1	10.10
Master Builders AE90	5%	0.2	0.1	0.06	0.0	0.2	0.09
Dow Liquid Latex Modifier	55%	10.6	2.0	2.53	0.1	10.6	1.88
Cement-CM Ratio		0.70			0.70		0.70
Water-CM Ratio		0.49			0.49		0.49
Slump, in.		1.0			0.6		0.6
Air Content, %		7%			12%		12%
Density (Unit Weight), pcf		58			54		54
Gravimetric Air Content, %					12%		
Yield, cf		27.0			1.1		27.0

APPENDIX C: GRADATION CURVES AND TABLES

Figure C1: Aggregate Gradation Curves

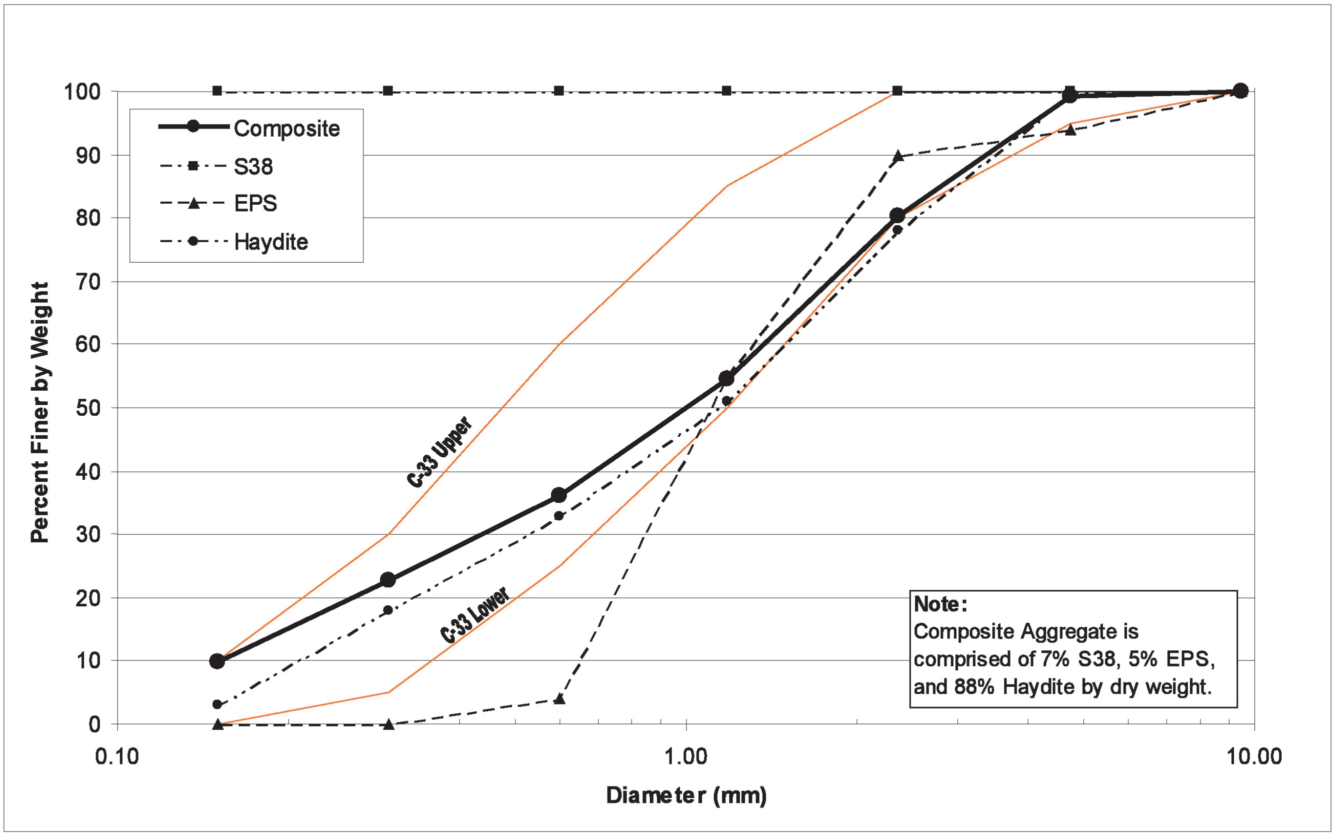

Table C1: Composite Aggregate Calculations

No.	D (mm)	% Passing Lower	% Passing Upper	Composite	Factored % Finer by Weight S38	EPS	Haydite		
3/8"	9.50	100	100	**100.0**	7.0	5.0	88.0		
4	4.75	95	100	**99.2**	7.0	4.7	87.5		
8	2.36	80	100	**80.2**	7.0	4.5	68.7		
16	1.18	50	85	**54.6**	7.0	2.8	44.9		
30	0.60	25	60	**36.2**	7.0	0.2	29.0		
50	0.30	5	30	**22.8**	7.0	0.0	15.8		
100	0.15	0	10	**9.7**	7.0	0.0	2.7		
				Weight Factor:	7%	5%	88%	*totals*	**Composite SG**
				cm^3 per Kilo:	184	1400	580	2164	**0.47**
				Grams per Kilo:	70	70	870	1010	
				Proportion	7%	7%	87%		
				SG:	0.38	0.05	1.50		

Table C2 - C4: Aggregate Gradation Tables

Aggregate: S38 Glass Bubbles **Sample Weight:** 120g
Specific Gravaity: 0.38 **Fineness Modulus:** 0

No.	D (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	% Finer
3/8"	9.50	0	0	100
4	4.75	0	0	100
8	2.36	0	0	100
16	1.18	0	0	100
30	0.60	0	0	100
50	0.30	0	0	100
100	0.15	0	0	100

Aggregate: EPS Foam **Sample Weight:** 16g
Specific Gravaity: 0.05 **Fineness Modulus:** 3.57

No.	D (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	% Finer
3/8"	9.50	0	0	100
4	4.75	0.96	0.96	94
8	2.36	0.62	1.58	90
16	1.18	5.60	7.18	55
30	0.60	8.15	15.33	4
50	0.30	0.60	15.93	0
100	0.15	0	15.93	0

Aggregate: Haydite **Sample Weight:** 500g
Specific Gravaity: 1.5 **Fineness Modulus:** 3.18

No.	D (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	% Finer
3/8"	9.50	0	0	100
4	4.75	3.20	3.20	99
8	2.36	106.80	110.00	78
16	1.18	135.10	245.1	51
30	0.60	94.20	339.3	32
50	0.30	70.70	410	18
100	0.15	74.50	484.5	3

Aggregate: Composite **Sample Weight:** 100g
Specific Gravaity: 0.47 **Fineness Modulus:** 2.97

No.	D (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	% Finer
3/8"	9.50	0	0	100
4	4.75	0.78	0.78	99
8	2.36	19.10	19.88	80
16	1.18	25.52	45.40	55
30	0.60	18.43	63.83	36
50	0.30	13.37	77.20	23
100	0.15	13.10	90.3	10

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