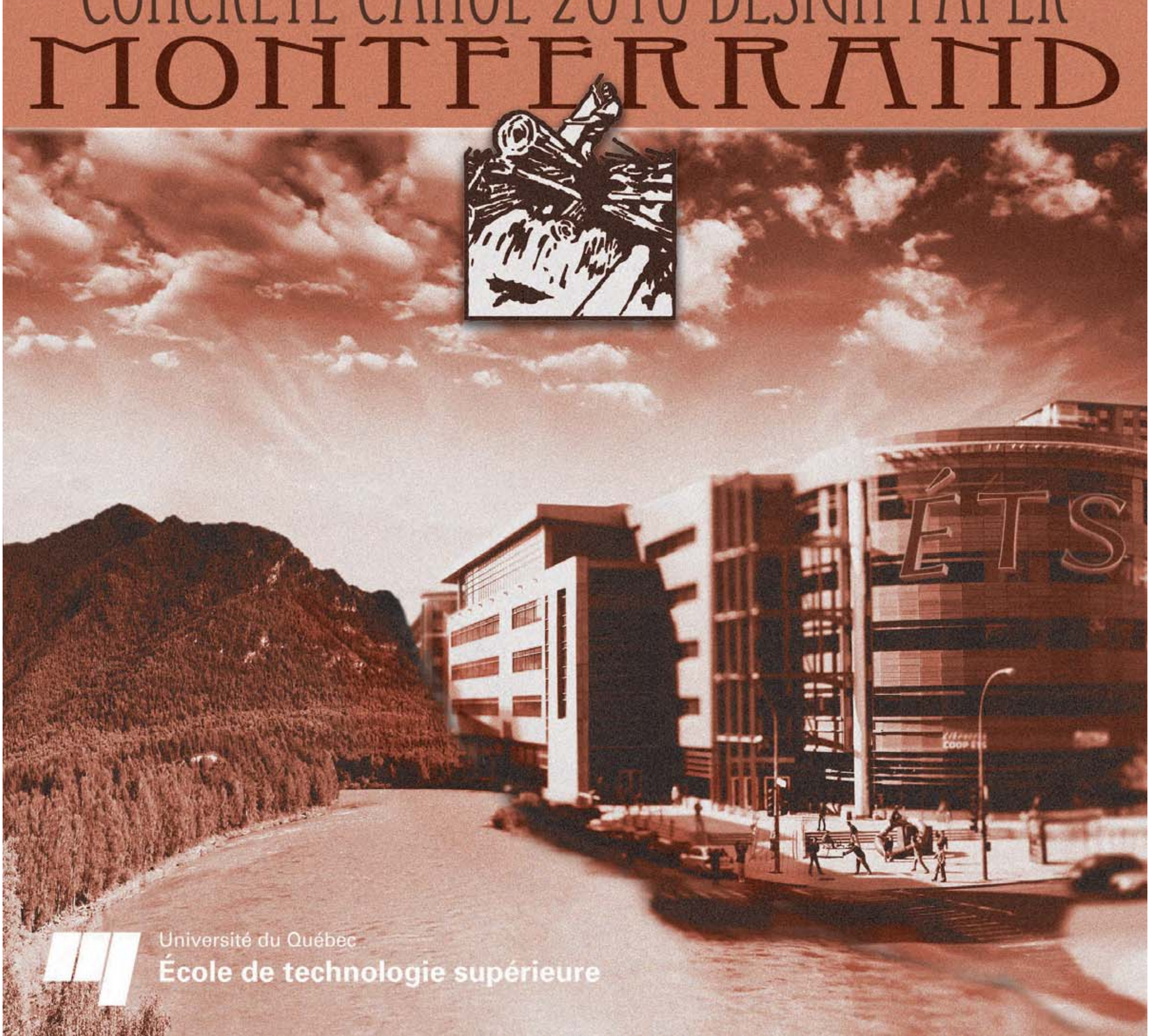
CONCRETE CANOE 2010 DESIGN PAPER

MONTFERRAND



Université du Québec
École de technologie supérieure

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Dimensions of the canoe		Reinforcements	
Length	20’	Type	Material
Width	31$^{3}/_{16}$”	Mesh	Fiber Glass GlasGrid® 8501
Depth	14” - 16”		
Thickness	½”	Rods	Woven Carbon fiber
Total Weight	180 lb		

Concrete Properties	
Use	Structural
Color	White-Gray
Density (lb/ft³)	57.12
Compressive Str. 14 days (psi)	1,798
Tensile Str. 14 days (psi)	239
Use	Finish
Color	Black, Brown
Density (lb/ft³)	58.37
Compressive Str. 14 days (psi)	1,980
Tensile Str. 14 days (psi)	160
Reinforced Concrete Properties	
Location	Hull
Reinforcements	Mesh
Deflexion after 50,000 loading cycles (2,5 kN)	0.16”
Tensile strength (psi)	971.75

EXECUTIVE SUMMARY

The École de technologie supérieure (ETS) was founded in 1974 and is now one of the leading engineering faculties in Canada. Ranking third overall in admissions, ETS is home to more than 25% of all engineering students in the province of Quebec. The school benefits from a unique partnership with the business world which greatly contributes to ETS’ reputation and popularity. The curriculum at ETS is based upon a cooperative teaching system and aims to develop new technologies for the industry.

Over the past few years, ETS’ concrete canoe team has come to be known for its perseverance and unrivaled enthusiasm. In 2007, Tomahawk hacked its way into 14th place, but most importantly walked away with the Team Spirit Award. In 2008, as hosts to the American National Championship, the Toutatis team thought the sky had fallen on their heads when their canoe broke during the final race. The fallen paddlers managed to complete the race and secure a third overall finish. Finally, in 2009, *Vintage* followed suit and chased the cup. The team obtained its highest podium ever, finishing second overall. In 2010, the team will find itself firmly rooted in its past exploits and looking to flourish to even greater heights. This will be the year that legends will be forged with brute strength and agility, with endurance and intelligence. This will be the year that people will remember the name of Joseph MONTFERRAND!

This year, MONTFERRAND’s objectives list was short and simple: to go beyond expectations and win the American National Championship. Considering the relative success of the team’s past endeavors, it was decided early on that they needed to build upon their existing expertise. Having won the Tony P. Crest Award for the Plate Destroyer, a testing module that allowed the team to test flexural strength in concrete plates vertically, the team members responsible for the concrete mixture decided that they needed a dynamic testing method. Their desire to innovate inspired them to conceive the Plate Destroyer II: a means by which they could simulate the stresses endured by the canoe throughout its life-span!

As for the analysis, the shape of the hull forced upon the team was the same as last year so they would have strong roots. The team of analysts decided to prove the usefulness of the carbon fiber rods used in the gunwales by running a comparative analysis. On the other hand, the construction methods remained relatively similar.

Finally, new areas of recycling were explored this year. Among them is freecycling, a concept that exploits the old saying that “one man’s trash is another man’s treasure”.

Even though MONTFERRAND is heading into the competitions in the shadow of most acclaimed schools, the team is aiming for the top step of the podium, all the while remembering that the bigger they are, the harder they fall!

ANALYSIS

For the past two years, the analysis team has gone above and beyond the call of duty and broken down barriers. The Toutatis and *Vintage* teams managed to validate their method of analysis by comparing theory (finite element analysis) and practice (tests with deformation gauges). MONTFERRAND's team decided to continue along the same path and therefore had a rock solid base.

This was very useful for the team's main analyst, who like the other heads of projects, was taking the lead for the very first time. The team decided to use Catia V5 in order to create a 3D model and CosmosWorks to perform a finite element analysis as they already had extensive experience with both softwares.

The designers first created a surface in the exact shape of the outside of the hull, afterwhich they extruded it by ½", effectively creating a volume model. Volume modeling was favored over surface modeling due to the higher fidelity it offers during the analysis.

As for the hydrostatic water pressure, it was then simulated according to Archimedes' theory of buoyancy. This way, the pressure exerted by the water on the hull would increase proportionally to its depth.

Last year, the paddlers were simulated using elastic foundations. The use of these limit conditions was revolutionary for the team. These supports replace conventional limit conditions with a series of springs along the surface of the canoe. They not only yield much more representative deformations, they also allow the team of analysts to stabilize the model without having to anchor any parts. For these reasons, elastic foundations would once again be applied in place of the paddlers' supports.

In order to render the analysis even more precise, the team decided to increase the density of the model's mesh in the hull for the finite element analysis (see figure 1). This was done by applying symmetric boundary conditions along the center line of the hull.

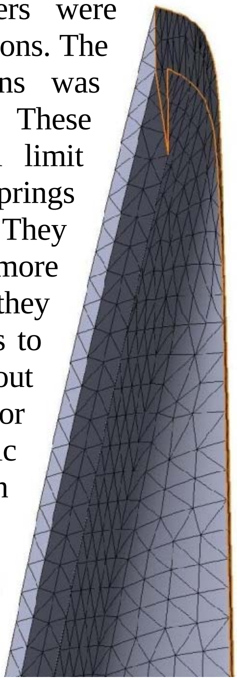


Figure 1 : *Increased mesh density for the finite element analysis*

Since the team in charge of the concrete mixture was busy trying to find a second recycled aggregate, the analysts decided to use the properties obtained from a previous team's final mixture. Seeing as how Toutatis' concrete contained two main aggregates, much like what the team had to do this year, its properties were applied for the initial analysis. Those properties are a density of 57.12 lb/ft^3 a Poisson's ratio of 0.2, an elastic modulus of 1,160 ksi, a compressive strength of 2,436 psi after 14 days of curing and a tensile strength of 418 psi.

The goal of the first analysis was to determine the critical load case for the canoe (2, 3 or 4 paddlers). The analysis performed was a static one without reinforcements. The weight of the paddlers was set at 165 lb at all times. Of the three cases studied, the 2 paddler load case presented the highest stresses in the canoe, reaching 189 psi in tension under the paddlers (see figure 2).

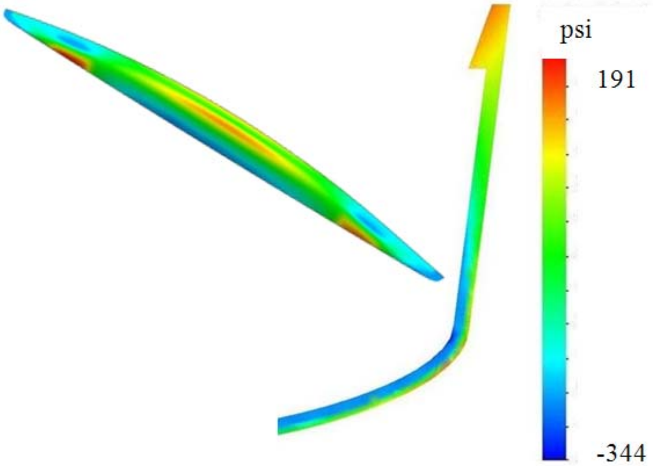


Figure 2 : *Stress repartition in the hull for the two paddler load case (left) and in the gunwales (right)*

Once the critical load case was identified, the team set out to find where the most crucial stress would be on the canoe. Basing themselves on last year's findings, they looked for an area where the stress would be present throughout the thickness of the hull. The idea behind this is that the effects of stress present on the surface of the hull would be nullified by the opposite side of the hull, which would be in compression. With this in mind, the team found that only the gunwales had tension spread through and through.

Once the team had identified the critical load case and its weak point, the team reran the analysis but with the reinforcing carbon fiber rods modelized in the gunwales. The team used an ultimate tensile strength of 212 ksi for the rods (ASTM D3039), which was found by submitting them to a tensile strength test (see figure 3). Adding the rods managed to lower the flexural stress by over 9% in the gunwales. Considering the carbon rods would increase the weight of the canoe by as little as 1%, this decrease in tensile stress seemed like a fair trade off.

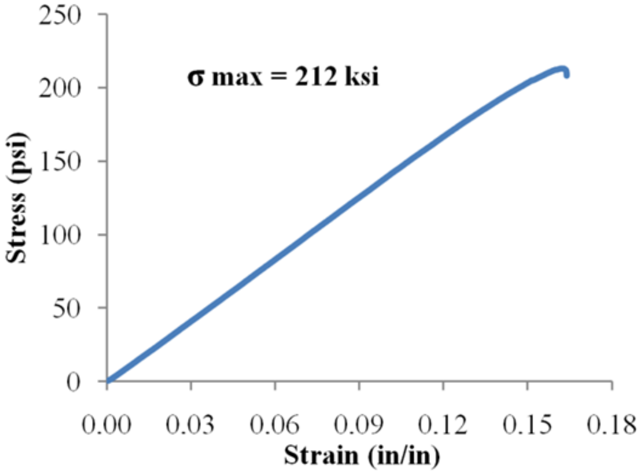


Figure 3 : *Tensile strength test on carbon fiber rod*

Following last year's dynamic research with deformation gauges performed on a hull much like MONTFERRAND's, the team of analysts opted to keep the safety factor that was established (450%). This choice was mostly motivated by the fact the *Vintage*'s concrete mix made it through three competitions. When applying this factor to their results, the team obtained a final tensile stress of 675 psi.

DEVELOPMENT AND TESTING

The rule changes this year involving recycled aggregates were major. These new rules stipulated that the final mixture would contain a minimum of 25% of two different recycled aggregates. Finding a new material to go along with Poraver® would require a significant amount of tests and a healthy number of man-hours. This new aggregate would have to be 100% recycled and its leading criterion would be a low specific gravity in order to keep the mixture's density in check.

Even though the team of designers would have to work twice as hard this year, the objectives for the final concrete mixture would not be altered. They needed to develop a concrete that would be strong enough to resist the constant battering of the paddlers, yet it would also need to be malleable and cohesive for the casting. On top of that, since the analysis had proven that the reinforcements would lower the stresses on the hull, the team wanted to respect ETS' long standing tradition of having a concrete that could float by itself. Based on these objectives and the results obtained in the analysis, the team needed to obtain a density of 56.2 lb/ft³, a tensile strength of 675 psi after 14 days of curing and a workability of at least 20 minutes to cast the canoe appropriately.

The team's first step was to find a new aggregate. Initially, they turned to recycled materials such as Haydite® and last year's canoe which had been crushed and sieved. Considering their high specific gravities, their proportions were set at 25% to obtain the lowest density possible for the concrete mixture. The mechanical properties obtained were very good, reaching around 1,780 psi for both mixes after 14 days of curing on 2" x 4" test cylinders (ASTM C39). Unfortunatlty, both mixes yielded densities varying between 64.9 and 68.7 lb/ft³ (ASTM C138) which did not meet the established criterion and were rejected.

After investing more than 3 months testing various aggregates such as polystyrene, the designers finally made a breakthrough with cenospheres, 100% recycled ceramic microspheres. An initial mix with 25% of cenospheres, 70% of Poraver® and 5% of K1 microspheres proved promising with a compressive strength of 1,595 psi and a density of 60.5 lb/ft³. Even though this did not respect the design criterion, the team of designers decided to press onward with this self floating mixture.

Now that the team had its second recycled aggregate, motivation was at an all time high. They opted to base their first mix on *Vintage*'s final concrete mixture. In order to optimize the aggregate mix, the proportion of cementitious materials was left unchanged. After setting the proportions of K1 microspheres at 5% (maximum allowed passing Sieve No.100), the team prepared over a dozen different mixtures with varying amounts of different Poraver®. Keeping in mind the cenospheres' relatively high density when compared to Poraver®, the cenospheres proportions were fixed at 25%, the minimum permited by the rules. This was done in order to ensure the final mix would have the lowest possible density. The optimized mix contained 25% of cenospheres, 70% of Poraver® (55% of Poraver® 1-2 mm and 15% of Poraver® 0,5-1 mm) and 5% of K1 microspheres. This concrete mixture obtained a compressive strength of 1,735 psi, a tensile strength of 239 psi (ASTM C496) after 14 days of curing and a density of 58.7 lb/ft³.

Now that they had established their aggregate proportions, they decided to hammer away at the cementitious materials. The designers decided to test metakaolin due to its ability to increase the concrete's compressive strength. This material would also improve the concrete's workability and aesthetics. They started by preparing mixes containing different proportions of slag and metakaolin combined with the Portland cement, even going as far as completely replacing the slag in the mixture. The results showed that by replacing a part of the slag with metakaolin, the mixture required more water. In order for the cement to have a proper hydration process, the team would have to increase the amount of water in the mix. Consequently, the amount of cement in the mix would also have to be increased to respect the water/cement ratio established in the rules. This would in effect increase in the mixture's density. The team therefore deemed this alternative unacceptable since mixes with metakaolin required more water in comparison to mixes with equal proportions of slag. Because of this, they decided to stick with their preestablished slag and cement proportions of 351.84 lb/yd³, and 374.29 lb/yd³ respectively.

One of the innovations this year was the strict mixing procedure the team set forth. In previous years, the concrete's ingredients were simply all put together, then mixed until a uniform paste was acquired. While developing the final mixture, the designers noticed some materials, namely the fibers, were not dispersed evenly throughout the concrete. After a few tests, the following sequence was established: incorporate cementitious materials and fibers, mix for 45 seconds, add latex and admixtures, mix for another 30 seconds, add aggregates, mix for a final 45 seconds. This method would ensure an even distribution of the materials, especially the fibers, in the final concrete mixture.

Afterwards, the designers took a close look at the latex and admixture proportions. The team decided to keep the same proportions as last year for these elements since tests performed with the new aggregate and cementitious materials were satisfactory. Tests with Gillmore needles were also performed and found that the mixture's workability was 21 minutes (ASTM C266). This meant that the proportions for the final mixture were 477.83 fl oz/cwt of Sika Latex R®, 182.87 fl oz/cwt of Albitol Concentrate®, 184.05 lf oz/cwt of Sika Cem 810® (with 30 % of silica fume) and 14.96 fl oz/cwt of Glenium® 7700. The latter is in line with the manufacturers recommended dosage (2 to 15 fl oz/cwt). Because of this, the design team decided to keep the same curing process as last year. They kept the canoe isolated for 2 days under polythene sheets, then 5 days of dry curing (latex coalescence) followed by 7 days in the humid chamber. This sequence allowed sufficient time for the latex's coalescence (tests performed on *Vintage*) and an optimal curing time for the cement's hydration process. The cure allowed the concrete to obtain a compressive strength of 1,798 psi after 14 days (ASTM C39) and 239 psi in tensile strength (ASTM C496).

The team was now ready to tackle the canoe's reinforcements. It was decided that the same structural reinforcements (GlasGrid® 8501 fiberglass mesh 61,18% POA and carbon rods) would be kept for the canoe following last year's successful testing with the Plate Destroyer. MONTFERRAND's team could now focus their energy on finding the best fibers, the secondary reinforcements. Last year, the team had two different fibers in their mix. The smaller of the two, Fibermesh® 150, reduced shrinkage cracks, while the larger Fibermesh® 300 offered a greater residual resistance. The team opted to remain within this two-fiber system.

The designers decided to keep the Fibermesh® 300 based on *Vintage*'s experience and instead concentrate on trying to find a fiber that could best the Fibermesh® 150.

Thus, a possible alternative to the smaller Fibermesh® 150 was tested. This new fiber was called Innegra® and offered a lower density than either previously used fibers (52.44 lb/ft³ for

Innegra® and 56.81 lb/ft³ for Fibermesh®). It was therefore used in place of the Fibermesh® 150 in the same proportions as last year's mixture along with Fibermesh® 300. Unfortunately, at equal volumes of Fibermesh® and Innegra®, the latter mix only obtained 174 psi in tensile strength (ASTM C496) compared to 239 psi in tensile strength for the Fibermesh®. The team tested varying amounts of Innegra® but to no avail. Considering both mixtures brought forth similar cohesion, the team decided to give this new fiber the axe and stick with *Vintage*'s fibers, Fibermesh® 300 and Fibermesh® 150.

After the immense success of the Plate Destroyer, the team of designers decided to push their research even further. They found an innovative new way to dynamically test vertical concrete plates. The test bench was affectionately called the Plate Destroyer II (see figure 4). This test would demonstrate the effects of fibers in a dynamic environment and help the team make an educated choice for the fiber proportions.

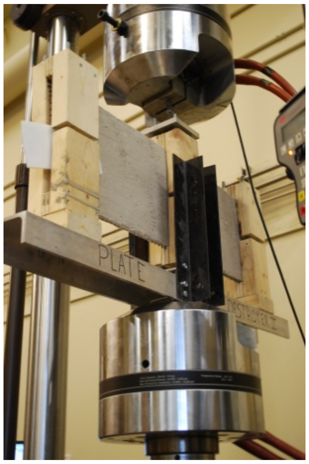


Figure 4 : *Plate Destroyer II*

The first tests performed on the Destroyer were static load tests on plates containing last year's final mixture (ASTM C78). The designers decided to base themselves on this peculiar mix in order to establish the strength needed to break the samples. When analyzing the results, they came to the conclusion that the concrete would yield after a force of roughly 5 kN was applied, after which the primary reinforcement (GlasGrid®) was solicited.

After consulting key members of the faculty, the team of designers established that a dynamic load representing 50% of the static load bearing capacity was appropriate. The dynamic load was therefore set at 2.5 kN. This way, the team would ensure that the mixture would be solicited realistically.

In order to have as much raw data as possible and to see the long term effects of the dynamic tests on each mixture, the team set the amount of load cycles at 50,000. This would in turn reveal the effects of the competitions on the canoe's concrete.

When a static force of 5 kN was applied to each type of plate, a deflexion of about 3/16" was observed. Because of this, the deformation for the dynamic tests was restricted to 3/16". This way, if this value was exceeded, the test bench would automatically stop. The criteria for the dynamic tests were accordingly set at 50,000 cycles or a maximum deflexion of 3/16".

These dynamic tests were performed on 24 plates with six different fiber proportions. These proportions were established by having different combinations of Fibermesh® 150 and Fibermesh® 300 totalling the maximal amount of fibers (0.30%/volume).

Initial tests were performed on plates containing last year's mixture (0.11%/volume of Fibermesh® 150 and 0.19%/volume of Fibermesh® 300) and plates containing a mixture with no fibers at all. The results clearly show the difference between the two, with the latter mixture reaching the maximal deflexion of 0.19" around 30,000 cycles, whereas *Vintage*'s mix had not only obtained a deflexion of only 0.13" by this point, but also managed to survive the entire loading cycle. These results essentially proved the utmost importance of these fibers in MONTFERRAND's concrete mixture.

The designers then moved on to plates containing varying amounts of fibers (see figure 5). The results showed that the Fibermesh® 300 had positive effects during dynamic tests. When looking at figure 5, it was clear that the mixes containing the most Fibermesh® 300 excelled at the dynamic tests. The unfortunate side effect of these mixes was an uneven distribution of the fibers in the mix. The designers also noticed that the results for the plates containing more Fibermesh® 150 beared a striking resemblance to the results for the plate that had no fibers at all. This confirms that the Fibermesh® 150 offers little to no advantage when it comes to tensile resistance. However, the positive effect it confers during the cure make it a necessity in the mixture. In the end, the team of designers found that the optimal fiber proportions for MONTFERRAND's concrete would be 0.11%/volume of Fibermesh® 150 and 0.19%/volume of Fibermesh® 300 because they offered the best mechanical resistance with evenly distributed fibers in the mix, coupled with reduced shrinkage cracking. These tests have allowed the team to validate the effects of both fibers in a concrete mix.

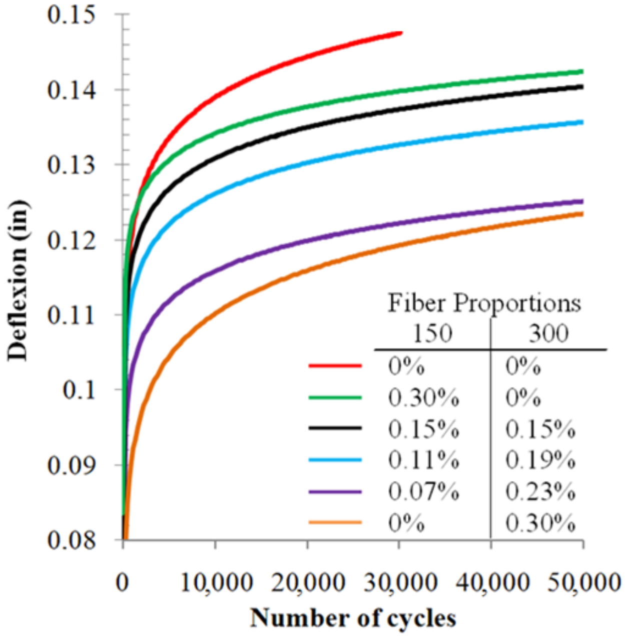


Figure 5 : *Dynamic test results on six different fiber proportions with the Plate Destroyer II*

PROJECT MANAGEMENT AND CONSTRUCTION

This year's concrete canoe team began as it usually does, with the annual start up meeting. This is a chance for the team to meet its new leaders. The leaders in turn highlight last year's strong points and shortcomings.

Considering the incredible success enjoyed last year, the same management style was kept. This meant that someone different would be put in charge of every part of the project. Due to the loss of many senior team members, seven out of a possible eight project leaders were new to the job, including the captain. Fortunately, last year's captain decided to stay onboard for consulting as a supportive member.

Next on the agenda were the annual recruitment activities held in September. Since only 13 members returned from *Vintage*, recruiting rookies was a priority to ensure the continuity of the team. In total, 14 new students joined the project. This was the direct result of an aggressive recruiting campaign.

The management team had been trained by having tasks delegated to them in previous years. Having found this experience incredibly beneficial, the team decided to integrate first year members in the same way and delegate tasks directly to them. For example, first year members were tasked with building the canoe's supports and keeping the website up to date. This would greatly alleviate the workload for senior members, considering that out of the 27 students, only half had participated in the Concrete Canoe beforehand. In doing so, they would also be training the team's future leaders.

During the first meeting, a list of overall objectives and goals was presented so the new team could move forward as a whole with a common mindset. It's at this time that the newer members were informed of the financial implications. The new treasurer demanded that everyone approach sponsors in order to gather at least 500 dollars (materials or funds). They would also have to participate in all of the fundraising events.

The 2010 budgetary estimates were based on last year's final expense report. This estimate was considered reliable since the expenses planned resembled last year's expenses. Comparatively, both canoe projects had nearly identical construction costs and similar travel plans that included travelling twice by land and once by air. The final budget for the team this year was roughly 50,000$ (see figure 6).

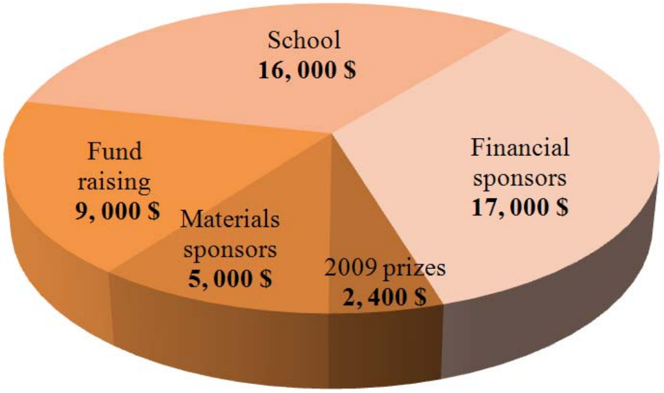


Figure 6 : *Sources of income for Montferrand's team*

Managing the entire schedule proved to be a tricky aspect of the project. Since the management team was still relatively inexperienced, it was hard to accurately estimate the time needed for all the different sections (see figure 7). This explains why most time estimates were exceeded. As an example, the construction process had a very slow start, but eventually picked up speed and managed not to finish too far behind schedule.

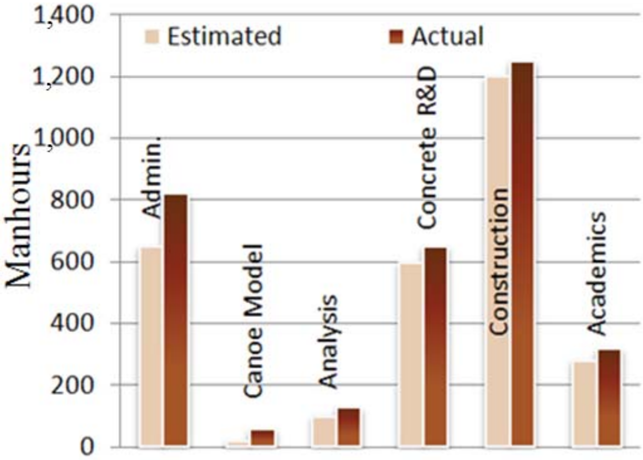


Figure 7 : *Time distibution as of May 1st*

The management team began by listing all the elements that could potentially delay the project. Considering that the side projects (product display, canoe rack and cutaway section) came at a very late stage last year, the team decided to pay close attention to these projects this year. From there, a few dates and milestones were set. Then, they established the critical path, which goes as follows: finishing the mold for the first canoe (for the American competitions), choosing the final concrete mixture, casting of the first canoe, finishing the mold for the second canoe (for the Canadian competition), casting of the second canoe, sanding and finishing first canoe, sanding and finishing of the second canoe. Since the American canoe was in pristine condition after the first competition, the team opted to save time and use it for all three competitions.

To ensure the team remained on track, weekly meetings were held. The management team would relay to the captain how far along they were in their respective duties. If anyone seemed to be lagging behind schedule, more resources were attributed to their part of the project. In order to accurately follow the progression of each activity, a journal of all the hours logged by the different tasks in the previous week was kept. As of May 1st, over 3,000 hours had been spent lumbering through the workload. Of those hours, nearly half were devoted to construction.

Once again, the shape of the canoe's hull was imposed by the organizing committee. Since the shape was the same as last year's, it allowed the team to save valuable time by not only basing the analysis on last year's results, but also by reusing the fiberglass canoe for the paddlers' training. This unfortunately meant that rookie team members would not have a chance to get some hands on experience by building a practice mold. The older team members would have to be very strict when performing their routine quality control inspections throughout the project.

Much like the past two years, the team opted for a male mold for the canoe's hull. The main factors involved in this decision are the lowered costs and shortened construction time that this type of mold offers. 154 sections of 1.5" thick extruded polystyrene were used to create each mold. This material was chosen because it is rigid, lightweight, easy to work with and most of all, affordable. Once the mold was assembled, it was sanded to smoothen out irregularities. During the sanding process, gauges were used all along the hull to make sure the official shape was maintained. It was then covered in successive layers of drywall compound and sanded once more to obtain an even smoother surface. When the canoe's mold was as the team expected it, it was covered with coats of surfacing primer and then wax to ease the unmolding process.

The use of rubber gauges last year to shape our gunwales proved incredibly valuable and time saving. The team therefore decided to use a similar type of gauge made of polyurethane that was cast in a laser cut steel mold (see figure 8).

Due to the large number of first year members, many precautions were taken during the casting of the concrete canoes. First of all, everyone was attributed a specific task by the captain. During the actual casting, senior members were interspersed within the younger members so that consistency could be ensured in their work.

Figure 8 : *Polyurethane gauges for the gunwales*

Thickness gauges helped the team lay the concrete in two distinct layers separated by the fiberglass mesh all over the canoe and by the carbon rods in the middle of the gunwales. The inner layer is 7/32" thick and the outer layer is ¼" thick. The team responsible for the final concrete mixture provided constant quality control and took samples throughout the casting process to ensure a steady density, hardening time, and to make cylinders for compressive strength tests. With all these time saving methods in play, the sanding time was cut down dramatically. Coupled with great resource management by the captain, this allowed the team to make up for some of the lost time due to the general lack of experience at the beginning of the project.

After the 14 days of curing, the sanding process began. Initially, 24" wooden blocks covered with grit 24 sanding paper were used to smoothen out any rough edges. During the sanding process, another set of gauges was used to ensure the canoe would keep the official shape. Through progressively finer grits, the team eventually achieved the desired texture. They could now unmold the canoe and begin sanding the interior. The depressions formed by the inserts in the mold were then filled with colored concrete. Final sanding was performed with a specialized rotary tool equipped with grit 3,000 sanding paper. Handcut vinyl stencils were then applied to the hull before airbrushing the acid based stain on the canoe. The canoe's construction officially ended when it was covered in sealer.

Since our health and security officer was now also our captain, the safety of the members in the workplace was at the forefront of the team's concerns. Great attention was paid, especially towards the younger members to ensure that they always had the appropriate safety materials (gloves, glasses, masks, etc.) and that they operated safely and cautiously within the workplace.

INNOVATION AND SUSTAINABILITY

Vintage truly raised the bar for the team's analysis to a whole new level last year with the introduction of the Plate Destroyer. This test bench was used to test flexural strength in vertical concrete plates in order to simulate the efforts induced in the gunwales. The Destroyer eventually earned the Tony P. Crest Award for Innovation. In order to remain a pack leader, ETS' concrete canoe team would have to aim high and innovate in all aspects of the project.

From the very beginning of the year, it was clear amongst the team that the Plate Destroyer had to be pushed beyond its limits. The test bench, although innovative, had a major flaw: it did not accurately represent the life cycle endured by the gunwales. This lead the team to modify the Destroyer. In order for it to dynamically test flexural strength in vertical concrete plates, much had to change. This makeover was accompanied by a brand new name for this innovative test bench, the Plate Destroyer II. The results allowed the designers to make a better choice when it came to fiber proportions.

Since the shape of MONTFERRAND's hull remained unchanged when compared to *Vintage*'s, the analysis left little room for innovation. The team of analysts, however, saw differently with the opportunity to expand on an already solid base from last year. They saw fit to demonstrate the effects of the reinforcing carbon rods in the gunwales.

As for the mold, gauges were used every 12" as well as on the canoe during every process to ensure precision. This year, the team also used laser cut metallic molds to create gauges for the gunwales.

In the same stride as last year, recycling was fully integrated into the project. Bins were scattered through the workplace in order to separate wood, plastic, metal, polystyrene, organics and other waste produced by the project. The collected materials could either be reused in other parts of the project or simply sent to the appropriate recycling centers, effectively reducing our waste production. Furthermore, this year's extruded polystyrene offered by one of our sponsors was actually a factory defect which would have gone to waste had we not reused it in our project.

Finally, MONTFERRAND's team decided to exploit another aspect of sustainable development: Freecycling. Freecycling is based on the fact that one man's trash is another man's treasure. By rummaging through the garbage and visiting waste recovery centers, the team managed to gather enough raw materials to save an estimated 400$. This money was mostly saved due to the materials being reused in the product display.

ORGANIZATION CHART

MARIE-ANDRÉE BARDIER
CAPTAIN &
HEALTH AND SAFETY OFFICER
Represent the student club within the school, plan the team's activities, ensure constant quality control, communicate vital information to the team and watch over the team members' well being

JEAN-MICHEL MALO
CONSULTANT
Help the team make important decisions

CHRISTIAN MAILLÉ
TREASURER
Follow up on sponsorship deals with team members and manage the budget

DOMINIC PELLERIN
CORPORATE AFFAIRS
Organize fund raisers and purchase promotional items

VINCENT SPERBER
ANALYSIS
Perform the canoe's finite element analysis and experimental deformation tests

ÉRIC LACHANCE-TREMBLAY
CONCRETE R&D
Order materials, develop the concrete mixture, select the reinfocements and perform laboratory tests

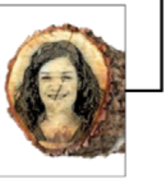
GUILLAUME BÉLANGER
CONSTRUCTION & AESTHETICS
Supervise the construction of the molds, create the canoe's aesthetics and manage the workshop

EMMANUEL DION
TECHNICAL PRESENTATION
Build the product display, the canoe's support rack and the cutaway section

PHILIPPE GATIEN
DESIGN PAPER &
ORAL PRESENTATION
Write the techical paper, the engineer's notebook and translate all other documents
Prepare the oral presentation, the video and select the orators

OLIVIER LALONDE RENAUD
MULTIMEDIA
Update the team's website, prepare the posters and banners, take pictures and videos throughout the project

ÉMILIE FLEURY-LAVIGNE
TRAINER
Train the paddlers indoors and outdoors, follow the paddlers progress and select the paddlers



TEAM MEMBERS

Marie-Andrée Bardier
Olivier Béland
Alexandre Casabon
Britanny Cayer
Andrew Crossley
Jean-Philippe Dionne
Alix Dupont-Huot
Jean-Philippe Fafard
Émilie Fleury-Lavigne
Simon King
Mathieu Laberge
Olivier Larouche
David Legendre
Maude Lussier-Marchand
Christian Maillé
Jean-Michel Malo
Jean-Luc Martel
Dominic Pellerin
Kevin Poirier
Sabrina Sigouin
Caroline Thibault

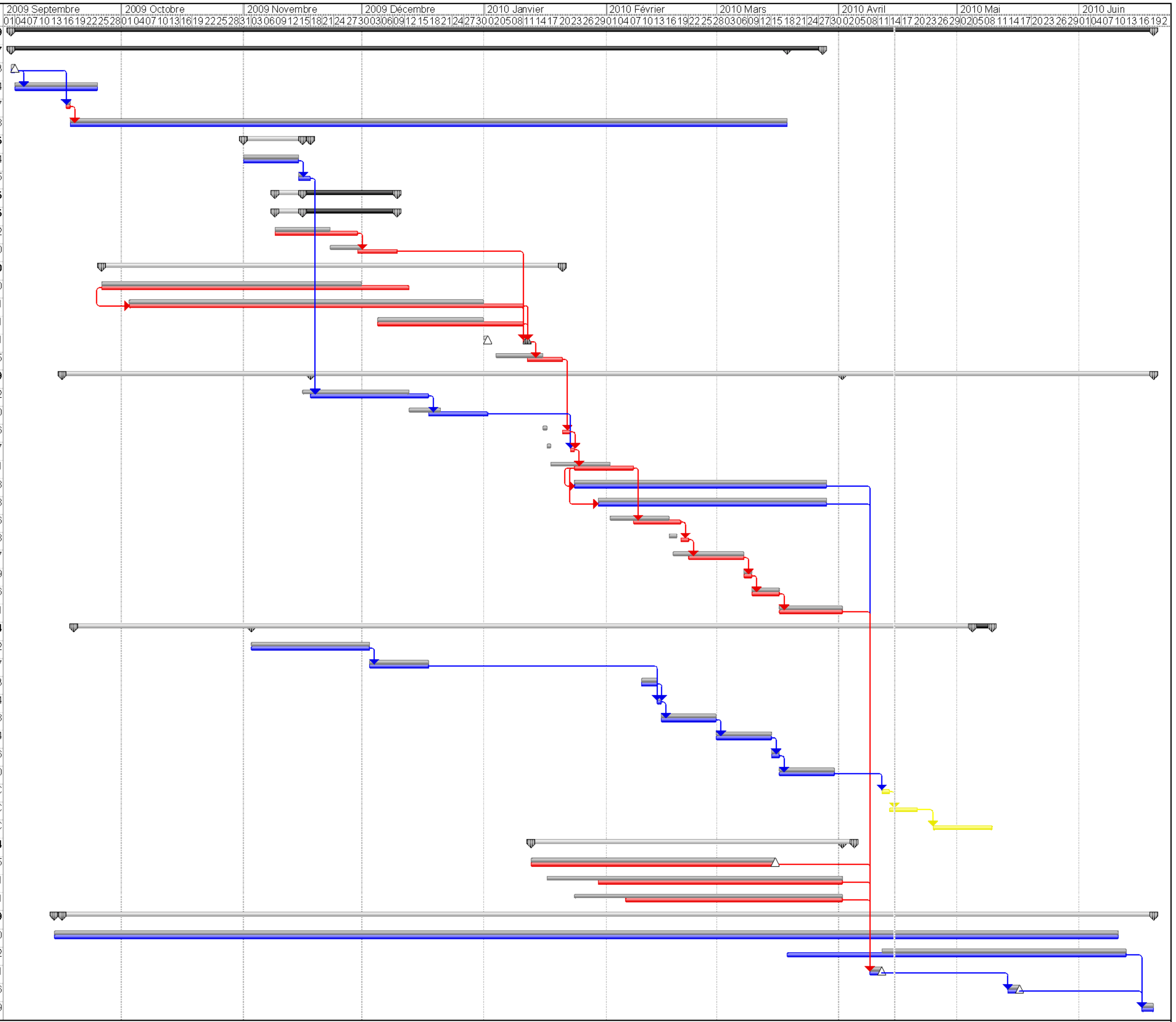
PADDLERS

Britanny Cayer
Émilie Fleury-Lavigne
Sabrina Sigouin
Caroline Thibault

Alexandre Casabon
Alix Dupont-Huot
Christian Maillé
Jean-Luc Martel

PROJECT SCHEDULE

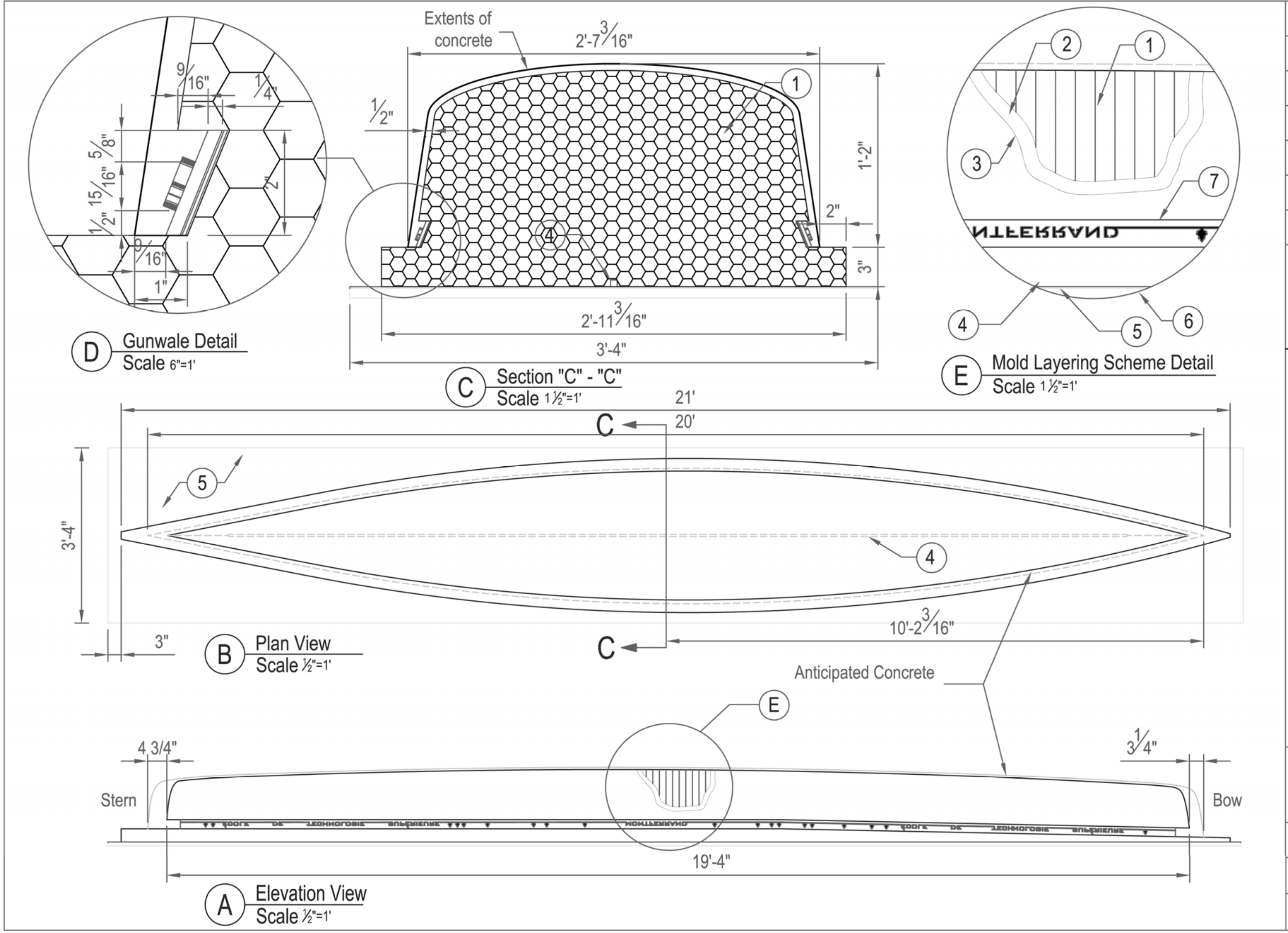
N°	Tâches	Duration	Start	Finish	Baseline start	Baseline finish
1	**Concrete Canoe 2009-2010**	**290 jours**	**Jeu 09-09-03**	**Sam 10-06-19**	**Jeu 09-09-03**	**Sam 10-06-19**
2	**Management**	**197 jours**	**Jeu 09-09-03**	**Jeu 10-03-18**	**Jeu 09-09-03**	**Sam 10-03-27**
3	Start Up Meeting	1 jour	Jeu 09-09-03	Jeu 09-09-03	Jeu 09-09-03	Jeu 09-09-03
4	Team Recruitement	21 jours	Ven 09-09-04	Jeu 09-09-24	Ven 09-09-04	Jeu 09-09-24
5	First Team Meeting	1 jour	Jeu 09-09-17	Jeu 09-09-17	Jeu 09-09-17	Jeu 09-09-17
6	Search for Sponsors and Sund-Raising Activities	182 jours	Ven 09-09-18	Jeu 10-03-18	Ven 09-09-18	Jeu 10-03-18
7	**Hull Design**	**17 jours**	**Dim 09-11-01**	**Mar 09-11-17**	**Dim 09-11-01**	**Dim 09-11-15**
8	Final Hull Design (SolidWorks)	14 jours	Dim 09-11-01	Sam 09-11-14	Dim 09-11-01	Sam 09-11-14
9	Printing of Mold's Drawings	3 jours	Dim 09-11-15	Mar 09-11-17	Dim 09-11-15	Dim 09-11-15
10	**Analysis**	**31 jours**	**Lun 09-11-09**	**Mer 09-12-09**	**Lun 09-11-09**	**Dim 09-11-15**
11	**Finite Element Analysis (COSMOSWorks)**	**31 jours**	**Lun 09-11-09**	**Mer 09-12-09**	**Lun 09-11-09**	**Dim 09-11-15**
12	Identify Critical Load Case	21 jours	Lun 09-11-09	Dim 09-11-29	Lun 09-11-09	Dim 09-11-22
13	Simulate Carbon Rods in Gunwales	10 jours	Lun 09-11-30	Mer 09-12-09	Lun 09-11-23	Lun 09-11-30
14	**Development and testing**	**117 jours**	**Sam 09-09-26**	**Mer 10-01-20**	**Sam 09-09-26**	**Mer 10-01-20**
15	Order Materials for Tests	78 jours	Sam 09-09-26	Sam 09-12-12	Sam 09-09-26	Lun 09-11-30
16	Tests on Concrete	100 jours	Sam 09-10-03	Dim 10-01-10	Sam 09-10-03	Jeu 09-12-31
17	Testc on Reinforcements	37 jours	Sam 09-12-05	Dim 10-01-10	Sam 09-12-05	Jeu 09-12-31
18	Selection of Final Mixtures and Reinforcements	1 jour	Lun 10-01-11	Lun 10-01-11	Ven 10-01-01	Ven 10-01-01
19	Order Materials for the Canoe	9 jours	Mar 10-01-12	Mer 10-01-20	Lun 10-01-04	Ven 10-01-15
20	**Construction - Montferrand**	**135 jours**	**Mer 09-11-18**	**Jeu 10-04-01**	**Mer 09-09-16**	**Sam 10-06-19**
21	Mold Construction	30 jours	Mer 09-11-18	Jeu 09-12-17	Lun 09-11-16	Sam 09-12-12
22	Sanding of Drywall Compound	15 jours	Ven 09-12-18	Ven 10-01-01	Dim 09-12-13	Dim 09-12-20
23	Prepare Concrete Mixtures	2 jours	Jeu 10-01-21	Ven 10-01-22	Sam 10-01-16	Sam 10-01-16
24	Casting of the Canoe	1 jour	Sam 10-01-23	Sam 10-01-23	Dim 10-01-17	Dim 10-01-17
25	Curing	15 jours	Dim 10-01-24	Dim 10-02-07	Lun 10-01-18	Lun 10-02-01
26	Product Display and Support Fabrication	64 jours	Dim 10-01-24	Dim 10-03-28	Dim 10-01-24	Dim 10-03-28
27	Casting and Preparation of the Cutaway Section	58 jours	Sam 10-01-30	Dim 10-03-28	Sam 10-01-30	Dim 10-03-28
28	Exterior Sanding	12 jours	Lun 10-02-08	Ven 10-02-19	Mar 10-02-02	Mar 10-02-16
29	Unmolding	2 jours	Sam 10-02-20	Dim 10-02-21	Mer 10-02-17	Jeu 10-02-18
30	Interior Sanding	14 jours	Lun 10-02-22	Dim 10-03-07	Jeu 10-02-18	Dim 10-03-07
31	Casting of Colored Concrete	2 jours	Lun 10-03-08	Mar 10-03-09	Lun 10-03-08	Mar 10-03-09
32	Curing	7 jours	Mer 10-03-10	Mar 10-03-16	Mer 10-03-10	Mar 10-03-16
33	Finishing with Stain and Sealer	16 jours	Mer 10-03-17	Jeu 10-04-01	Mer 10-03-17	Jeu 10-04-01
34	**Construction of Canadian Competition Canoe**	**188 jours**	**Mar 09-11-03**	**Dim 10-05-09**	**Sam 09-09-19**	**Mar 10-05-04**
35	Mold Construction	30 jours	Mar 09-11-03	Mer 09-12-02	Mar 09-11-03	Mer 09-12-02
36	Sanding of Drywall Compound	15 jours	Jeu 09-12-03	Jeu 09-12-17	Jeu 09-12-03	Jeu 09-12-17
37	Prepare Concrete Mixtures	4 jours	Mer 10-02-10	Sam 10-02-13	Mer 10-02-10	Sam 10-02-13
38	Casting of the Canoe	1 jour	Dim 10-02-14	Dim 10-02-14	Dim 10-02-14	Dim 10-02-14
39	Curing	14 jours	Lun 10-02-15	Dim 10-02-28	Lun 10-02-15	Dim 10-02-28
40	Exterior Sanding	14 jours	Lun 10-03-01	Dim 10-03-14	Lun 10-03-01	Dim 10-03-14
41	Unmolding	2 jours	Lun 10-03-15	Mar 10-03-16	Lun 10-03-15	Mar 10-03-16
42	Interior Sanding	14 jours	Mer 10-03-17	Mar 10-03-30	Mer 10-03-17	Mar 10-03-30
43	Cancelled task - Casting of Colored Concrete	2 jours	Lun 10-04-12	Mar 10-04-13	NC	NC
44	Cancelled task - Curing	7 jours	Mer 10-04-14	Mar 10-04-20	NC	NC
45	Cancelled task - Finishing with Stain and Sealer	15 jours	Dim 10-04-25	Dim 10-05-09	NC	NC
46	**Academics**	**79 jours**	**Mer 10-01-13**	**Jeu 10-04-01**	**Mer 10-01-13**	**Dim 10-04-04**
47	Design Paper and Engineer's Notebook	62 jours	Mer 10-01-13	Lun 10-03-15	Mer 10-01-13	Lun 10-03-15
48	Technical Presentation	62 jours	Sam 10-01-30	Jeu 10-04-01	Dim 10-01-17	Jeu 10-04-01
49	Oral Presentation	55 jours	Sam 10-02-06	Jeu 10-04-01	Dim 10-01-24	Jeu 10-04-01
50	**Competitions**	**279 jours**	**Lun 09-09-14**	**Sam 10-06-19**	**Mer 09-09-16**	**Sam 10-06-19**
51	Indoor Training	270 jours	Lun 09-09-14	Jeu 10-06-10	Lun 09-09-14	Jeu 10-06-10
52	Outdoor Training	86 jours	Ven 10-03-19	Sam 10-06-12	Lun 10-04-12	Sam 10-06-12
53	Upstate New-York Conference (Albany)	3 jours	Ven 10-04-09	Dim 10-04-11	Ven 10-04-09	Dim 10-04-11
54	National Canadian Conference (Toronto)	3 jours	Ven 10-05-14	Dim 10-05-16	Ven 10-05-14	Dim 10-05-16
55	National American Conference (California)	3 jours	Jeu 10-06-17	Sam 10-06-19	Jeu 10-06-17	Sam 10-06-19



Montferrand 2010

Cancelled task	🟨	Critical task	🟥	Milestone	●	Summary	▬
Task	🟦	Baseline	▬	Baseline Milestone	○	Baseline Summary	▭

MOLD DESIGN DRAWING



No.	Qty.	Description
1	154 ct	1 ½" Extruded Polystyrene
2	3 gal	Drywall Compound
3	½ gal	Surfacing Primer
4	17 lf	½" x ½" HSS Tube
5	72 sf	Corrugated Plastic
6	72 sf	¾" Plywood
7	40 lf	Inserts for gunwales : -⅛" x 2" Laminate -¼" «Vitaflex 30» Urethane Band

MONTFERRAND

Mold Design Drawing

Drawn by : Christian Maillé

DATE : 2010-03-15

Sheet : 1 of 1

APPENDIX A – REFERENCES

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Table B1 Structural Concrete Mixture

Batch Size (ft^3): 0.105		**Proportions as Designed §**		**Batched Proportions**		**Yielded Proportions**	
Cementitious Materials	Specific Gravity*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
1. White Portland Cement Type: GU	3.150	374.29	1.904	1.43	0.007	373.48	1.900
2. Silica Fume^ (Sikacem 810®)	2.200	22.45	0.164	0.09	0.001	22.41	0.163
3. Slag Cement	2.600	351.84	2.168	1.35	0.008	351.07	2.164
Total of All Cementitious Materials		748.59	4.235	2.87	0.016	746.96	4.227
Fibers							
1. Fibermesh® 150	0.910	1.72	0.030	0.01	0.000	1.71	0.030
2. Fibermesh® 300	0.910	2.86	0.051	0.01	0.000	2.86	0.050
Total of All Fibers		4.59	0.081	0.02	0.000	4.58	0.081
Aggregates							
1. Microspheres K1 Abs.:0%;MC:0%	0.138	20.15	2.340	0.08	0.009	20.11	2.335
2. Cenospheres Abs.:0%;TH:0%	0.950	100.77	1.700	0.39	0.007	100.55	1.696
3. Poraver® 0.5-1 mm Abs.:2%;MC:0%	0.520	60.46	1.863	0.23	0.007	60.33	1.859
4. Poraver® 1-2 mm Abs.:2%;MC:0%	0.440	221.70	8.075	0.85	0.031	221.21	8.057
Total of All Aggregates		403.09	13.979	1.54	0.054	402.21	13.948
Water							
Batched Water	1.000	0.	0	0	0	0	0
Absorbed water from All Aggregates	1.000	-5.64	-0.090	-0.02	0.000	-5.63	-0.090
Total Water from All Admixtures	1.000	297.71	4.770	1.14	0.018	297.06	4.759
Total Water		292.07	4.679	1.12	0.018	291.44	4.669
Solids Content of Latex Modifiers							
1. Albitol Concentrate®	1.075	40.16	0.599	0.15	0.002	40.07	0.597
2. Sika Latex R®	1.090	34.98	0.514	0.13	0.002	34.91	0.513
3. Sikacem 810® (latex only)	1.050	22.46	0.343	0.09	0.001	22.41	0.342
Total Latex		97.61	1.456	0.37	0.006	97.39	1.453
Admixtures	% Solids	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)	Amount (fl oz)	Water in Admix. (lb)	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)
1. Glenium 7700® Wt./gal: 8.880	25.00	14.96	5.47	0.43	0.021	14.96	5.46
2. Albitol Concentrate® Wt./gal: 8.621	45.00	182.87	49.09	5.24	0.188	182.87	48.98
3. Sika Latex R® Wt./gal: 8.454	15.00	477.83	198.23	13.69	0.759	477.83	197.80
4. Sikacem 810® Wt./gal: 10.958	50.00	184.05	44.92	5.27	0.172	184.05	44.82
4. Pigments Specific Gravity 4.600	100.00	0.00	0.00	0.00	0.000	0.00	0.00
Cement-Cementitious Materials Ratio		0.50		0.50		0.50	
Water-Cementitious Materials Ratio		0.39		0.39		0.39	
Flow (flow table). %		44		42		42	
Air Content. %		10.0					
Density (Unit Weight). lb/ft^3		57.43		57.12		57.12	
Gravimetric Air Content. %				10.8		10.8	
Yield. ft^3		27.000		0.104		27.000	

Abs. = Absorption; MC = Batched moisture

¤ Water content of admixture.

§ Oven dry (non-SSD)

* Specific gravity provided were evaluated by team

^ Silica Fume from Sikacem 810®

Table B2 Black Concrete Mixture

Batch Size (ft^3): 0.105		**Proportions as Designed §**		**Batched Proportions**		**Yielded Proportions**	
Cementitious Materials	Specific Gravity*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
1. White Portland Cement Type: GU	3.150	375.92	1.912	1.43	0.007	374.72	1.906
2. Silica Fume^ (Sikacem 810®)	2.200	22.56	0.164	0.09	0.001	22.48	0.164
3. Slag Cement	2.600	353.37	2.177	1.35	0.008	352.24	2.171
Total of All Cementitious Materials		751.85	4.254	2.87	0.016	749.44	4.241
Fibers							
1. Fibermesh® 150	0.910	0	0	0	0	0	0
2. Fibermesh® 300	0.910	0	0	0	0	0	0
Total of All Fibers		0	0	0	0	0	0
Aggregates							
1. Microspheres K1 Abs.: 0 %; MC: 0 %	0.138	20.24	2.351	0.08	0.009	20.18	2.343
2. Cenospheres Abs.: 0 %; TH: 0 %	0.950	101.21	1.707	0.39	0.007	100.89	1.702
3. Poraver® 0.5-1 mm Abs.: 2 %; MC: 0 %	0.520	60.73	1.871	0.23	0.007	60.53	1.866
4. Poraver® 1-2 mm Abs.: 2 %; MC: 0 %	0.440	222.66	8.110	0.85	0.031	221.95	8.084
Total of All Aggregates		404.84	14.039	1.54	0.054	403.55	13.994
Water							
Batched Water	1.000	0.00	0	0.000	0	0.000	0
Absorbed water from All Aggregates	1.000	-5.67	-0.091	-0.022	0.000	-5.650	-0.091
Total Water from All Admixtures	1.000	299.01	4.790	1.140	0.018	298.054	4.775
Total Water		293.34	4.699	1.118	0.018	292.404	4.684
Solids Content of Latex Modifiers							
1. Albitol Concentrate®	1.075	40.34	0.601	0.154	0.002	40.211	0.599
2. Sika Latex R®	1.090	35.13	0.517	0.134	0.002	35.022	0.515
3. Sikacem 810® (latex only)	1.050	22.56	0.344	0.086	0.001	22.483	0.343
Total Latex		98.03	1.462	0.374	0.006	97.716	1.458
Admixtures	% Solids	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)	Amount (fl oz)	Water in Admix. (lb)	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)
1. Glenium 7700® Wt./gal: 8.880	25.00	14.96	5.50	0.43	0.021	14.96	5.48
2. Albitol Concentrate® Wt./gal: 8.621	45.00	182.87	49.30	5.24	0.188	182.87	49.15
3. Sika Latex R® Wt./gal: 8.454	15.00	477.83	199.10	13.69	0.759	477.83	198.46
4. Sikacem 810® Wt./gal: 10.958	50.00	184.05	45.11	5.27	0.172	184.05	44.97
4. Pigments Specific Gravity 4.600	100.00	17.06	0.00	0.49	0.000	0.00	0.00
Cement-Cementitious Materials Ratio		0.50		0.50		0.50	
Water-Cementitious Materials Ratio		0.39		0.39		0.39	
Flow (flow table). %		44		42		42	
Air Content. %		10.0					
Density (Unit Weight). lb/ft^3		58.68		58.37		58.37	
Gravimetric Air Content. %				10.8		10.8	
Yield. ft^3		27.000		0.10		27.000	

Abs. = Absorption; MC = Batched moisture

¤ Water content of admixture.

§ Oven dry (non-SSD)

* Specific gravity provided were evaluated by team

^ Silica Fume from Sikacem 810®

Table B3 Brown Concrete Mixture

Batch Size (ft^3): 0.105		Proportions as Designed [§]		Batched Proportions		Yielded Proportions	
Cementitious Materials	Specific Gravity*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
1. White Portland Cement Type: GU	3.150	375.92	1.912	1.43	0.007	374.72	1.906
2. Silica Fume^ (Sikacem 810®)	2.200	22.56	0.164	0.09	0.001	22.48	0.164
3. Slag Cement	2.600	353.37	2.177	1.35	0.008	352.24	2.171
Total of All Cementitious Materials		751.85	4.254	2.87	0.016	749.44	4.241
Fibers							
1. Fibermesh® 150	0.910	0	0	0	0	0	0
2. Fibermesh® 300	0.910	0	0	0	0	0	0
Total of All Fibers		0	0	0	0	0	0
Aggregates							
1. Microspheres K1 Abs.:0%;MC:0%	0.138	20.24	2.351	0.08	0.009	20.18	2.343
2. Cenospheres Abs.:0%;TH:0%	0.950	101.21	1.707	0.39	0.007	100.89	1.702
3. Poraver® 0.5-1 mm Abs.:2%;MC:0%	0.520	60.73	1.871	0.23	0.007	60.53	1.866
4. Poraver® 1-2 mm Abs.:2%;MC:0%	0.440	222.66	8.110	0.85	0.031	221.95	8.084
Total of All Aggregates		404.84	14.039	1.54	0.054	403.55	13.994
Water							
Batched Water	1.000	0.00	0	0.000	0	0.000	0
Absorbed water from All Aggregates	1.000	-5.67	-0.091	-0.022	0.000	-5.650	-0.091
Total Water from All Admixtures	1.000	299.01	4.790	1.140	0.018	298.054	4.775
Total Water		293.34	4.699	1.118	0.018	292.404	4.684
Solids Content of Latex Modifiers							
1. Albitol Concentrate®	1.075	40.34	0.601	0.154	0.002	40.211	0.599
2. Sika Latex R®	1.090	35.13	0.517	0.134	0.002	35.022	0.515
3. Sikacem 810® (latex only)	1.050	22.56	0.344	0.086	0.001	22.483	0.343
Total Latex		98.03	1.462	0.374	0.006	97.716	1.458
Admixtures	% Solids	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)	Amount (fl oz)	Water in Admix. (lb)	Amount (fl oz/cwt)	Water in Admix. (lb/yd^3)
1. Glenium 7700® Wt./gal: 8.880	25.00	14.96	5.50	0.43	0.021	14.96	5.48
2. Albitol Concentrate® Wt./gal: 8.621	45.00	182.87	49.30	5.24	0.188	182.87	49.15
3. Sika Latex R® Wt./gal: 8.454	15.00	477.83	199.10	13.69	0.759	477.83	198.46
4. Sikacem 810® Wt./gal: 10.958	50.00	184.05	45.11	5.27	0.172	184.05	44.97
4. Pigments Specific Gravity 4.600	100.00	17.06	0.00	0.49	0.000	0.00	0.00
Cement-Cementitious Materials Ratio		0.50		0.50		0.50	
Water-Cementitious Materials Ratio		0.39		0.39		0.39	
Flow (flow table). %		44		42		42	
Air Content. %		10.0					
Density (Unit Weight). lb/ft^3		58.68		58.37		58.37	
Gravimetric Air Content. %				10.8		10.8	
Yield. ft^3		27.000		0.10		27.000	

Abs. = Absorption; MC = Batched moisture

¤ Water content of admixture.

[§] Oven dry (non-SSD)

* Specific gravity provided were evaluated by team

^ Silica Fume from Sikacem 810®

Table C.1 : Aggregate Gradation Table

Aggregate : **Microspheres**
Sample Weight : 10.0 g
Specific Gravity : 0.138
Fineness Modulus : 0.01

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	0.0	0.0	100.0
No. 30	0.60	0.0	0.0	100.0
No. 50	0.30	0.0	0.0	100.0
No. 100	0.15	0.0	0.0	100.0
No. 200	0.08	0.1	0.1	90.0

Table C.2 : Aggregate Gradation Table

Aggregate : **Sieved Cenostar® cenospheres 0.3-0.6 mm**
Sample Weight : 143.0 g
Specific Gravity : 0.950
Fineness Modulus : 1.89

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	0.0	0.0	100.0
No. 30	0.60	0.1	0.1	99.9
No. 50	0.30	141.6	141.7	0.91
No. 100	0.15	1.3	143.0	0.0
No. 200	0.08	0.0	143.0	0.0

Table C.3 : Aggregate Gradation Table

Aggregate : **Sieved recycled glass beads Poraver® 0.5-1 mm**
Sample Weight : 190.2 g
Specific Gravity : 0.52
Fineness Modulus : 2.67

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	0.0	0.0	100.0
No. 30	0.60	128.1	128.1	32.6
No. 50	0.30	62.1	190.2	0.0
No. 100	0.15	0.0	190.2	0.0
No. 200	0.08	0.0	190.2	0.0

Table C.4 : Aggregate Gradation Table

Aggregate : **Sieved recycled glass beads Poraver® 1-2 mm**
Sample Weight : 131.9 g
Specific Gravity : 0.44
Fineness Modulus : 3.49

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	65.4	65.4	50.4
No. 30	0.60	66.0	131.4	0.4
No. 50	0.30	0.5	131.9	0.0
No. 100	0.15	0.0	131.9	0.0
No. 200	0.08	0.0	131.9	0.0

Table C.5 : Aggregate Gradation Table

Aggregate : **Composite blend**

Fineness Modulus : 2.72

	Percent Finer (%)				
Sieve	**Microspheres**	**Cenostar® cenospheres 0.3-0.6 mm**	**Poraver® 0.5-1 mm**	**Poraver® 1-2 mm**	**Composite Blend**
3/8 inch	100.0	100.0	100.0	100.0	100.0
No. 4	100.0	100.0	100.0	100.0	100.0
No. 8	100.0	100.0	100.0	100.0	100.0
No. 16	100.0	100.0	100.0	50.4	72.7
No. 30	100.0	99.9	32.6	0.4	35.1
No. 50	100.0	0.91	0.0	0.0	5.2
No. 100	100.0	0.0	0.0	0.0	5.0
No. 200	90.0	0.0	0.0	0.0	4.5
Ratio (%)	**5**	**25**	**15**	**55**	**100**

Figure C.1 : Gradation Curves