HOW IT'S MADE: CONCRETE CANOES

CONSTRUCTION REPORT 2010

Enschede, 25 May 2010

BetonBrouwers
Study Association ConcepT
School of Civil Engineering - University of Twente

Preface

Preceding on what is coming we want to outline the amount of work that has been shifted by the BetonBrouwers[1] and everyone that bears a warm heart towards BetonBrouwen. The deadline for this construction report is approaching rapidly meaning that half a year of hard work has passed. And how....

Based on our experiences from seasons 2007 & 2008 a new design and a lightweight concrete mixture were developed for season 2009. With an in theory very competitive concrete canoe, we participated in the Dutch and German competition. Luckily it turned out that it was not only a very competitive canoe in theory but also on the water. Season 2009 became the biggest success in the history of the BetonBrouwers. By dominating the Dutch competition and by winning the men's race in Germany the BetonBrouwers became 'European Champion'! Since the German competition only takes place once in two years it means that we have to wait one year before we can defend the precious challenge cup.

Because our neighbours will be very keen on getting the challenge cup back to Germany, it means that we have to develop even better canoes. But since it is quite an investment (time, knowledge and money) to develop a new design and mould, it is decided to use the design/mould for a second season. Thereby the mould was still in a good condition and the design worked very well last season. This certainly doesn't mean we did nothing this year. In contrary, this decision gave us the possibility to already start with the development of the design for season 2011 and put extra effort in the second important pillar of a successful concrete canoe: the concrete. Besides experimenting with new concrete mixtures we did some experimenting concerning the construction method in order to explore the possibilities for next season.

Eventually all the work resulted in four new concrete canoes. With these four new canoes we will participate for the fourth time in the Dutch Concrete Canoe Challenge (BKR) in the history of the BetonBrouwers. And despite our dominance during the BKR of last year, season 2010 will still be a tense season since we don't know what our competitors did during the last year. So, were other students enjoyed their spare time, the BetonBrouwers worked hard to refurbish the mould, develop new concrete mixtures, construct four magnificent canoes and train their paddling skills in order to beat the competition for the third year in a row.

Finally we want to use this occasion to thank the people who have supported us during this project and bear a warm heart towards concrete canoeing. First of all we want to thank the PhD candidate Götz Hüsken for his fourth year of assisting us with creating a perfect concrete mixture. Second we want to thank Onno Bokhove for his input concerning the art of canoeing. Thanks to his training programme and advices we are better prepared for the races than ever before. Third we want to thank everybody assisting the BetonBrouwers with the construction of the canoes, without their assistance it would be impossible to build the canoes. Finally we want to thank all the people and companies that have supported us to achieve our goal of building four beautiful concrete canoes.

Remains us nothing else than wishing the reader a lot of pleasure with reading this report.

BetonBrouwers 2010,

Chiel de Wit	(Chairman)
Hildemar Houtenbos	(Secretary)
Rik Goossens	(Treasurer)
Casper Rood	(Public Relations)
Frank Aarns	(Event Manager)
Bart Leferink	(Webmaster)
Johan de Waard	(General Member)
Yorick Keizer	(General Member)
Sevrien Ferree	(Vice-Chairman)

[1] Translated: ConcreteBrewers

Table of Content

Introduction

In front of you lays the construction report of the construction committee 2010 of Study Association ConcepT. Since January 2010 this committee, consisting of nine 'BetonBrouwers', has put a lot of dedication and effort in designing and constructing four magnificent concrete canoes. This report has been written in order to give the construction jury a clear insight in the applied design and construction as well as its implementation. Besides it gives the sponsors and other interested people an impression of the way the concrete canoes are build. Furthermore this report serves as documentation for future members of the committee.

The phenomenon Concrete Canoe Challenge can be found in many countries in Europe and abroad. In the Netherlands the Concrete Canoe Challenge (BetonKanoRace) is organized annually under the auspices of the Dutch concrete association (Betonvereniging). During the event students from different universities, academies, colleges and other institutions from different countries, compete in their self-build concrete canoes for the precious overall victory cup. The aim of this fantastic event is to promote the multi-purpose product CONCRETE. This year the competition takes place in the centre of the Netherlands: Utrecht. There we will try to beat our competitors and achieve a hat trick by conquering the first price!

With the CT2009 as basis, the focus this season was on a better understanding of the essence of a concrete canoe and explore its boundaries. By understanding the mechanical properties, the principles behind hydraulic design and the characteristics and possibilities of concrete, an important basis is created for future seasons. This as preparation on season 2011 in which we have to defend our victory in the German competition. In this report we tried to describe the essential elements necessary to build a successful concrete canoe, that's why the report is entitled 'How it's made: concrete canoes'.

To construct successful concrete canoes, three essential elements are required. The first element is a motivated, well trained and well supported team. The second element is a optimal hydraulic design. The third element is a perfect concrete mixture. These elements form the three pillars to become successful in Concrete Canoeing and are described in the first three parts of this report. The first part covers the history of our fantastic team, it's team members and the supporting companies. The second part concerns the design of the canoe, starting with the principles it's based on followed by a mechanical analysis. In the third part the material concrete is explored. First the theoretical background is discussed after which the concrete mixtures are composed and analysed.

In addition to the first three parts, the fourth part of the report describes the process behind construction season 2010. Starting with the project planning, this part exactly describes the activities of season 2010. The part is concluded with a photo reportage. The fourth part is followed by a concluding chapter and an overview of the consulted literature. The report is concluded with three appendices. The appendices contain our contact information, background information behind the concrete mixtures and the BetonBrouwers Sport Program (sport diet and training schedule).

Besides the information in this construction report, more information about our team, our activities, our achievements and pictures & video's can be found on our new website: www.betonbrouwers.utwente.nl.

Part 1

BetonBrouwers – An honour to be part of

Success in concrete canoeing is based on three pillars. The first pillar is a solid team. Since 2007 the BetonBrouwers form the construction committee of Study Association ConcepT of the school Civil Engineering at the University of Twente. Only the real diehard Civil Engineering students with a heart of concrete, loads of motivation and a lot of persistence can become a BetonBrouwer. Before one is allowed to call himself a BetonBrouwer, he really has to earn it! That is why it's a real honour to be part of this committee! In this chapter we provide some background information about our committee, it's members and the supporting companies.

1.1 History in the Making

It all started in 2007 with a group of four students which were experimenting with fibre reinforced concrete. This project made them realise how much fame can be gained with brewing concrete. Thereby it made them clear that this fame was only achievable with blood, sweat and tears. Then dhr. Verhagen came on our path, making us enthusiastic about pre-stressed concrete. Unfortunately there were no bottles of champagne that could be deserved with experimenting with pre-stressed concrete. But on the other hand it was much better applicable in canoes, were it was about after all….

2007: Rising from the ashes

In the year 2006, Study Association ConcepT was asked by the Dutch concrete federation to organize the 30th Dutch concrete canoe challenge. Because of the 30th anniversary of this yearly race, the event in Twente had to become special and bigger than ever. A special guest was invited: the champions of the American Concrete Canoe Challenge!

To give this American team a challenge, four diehard students Civil Engineering joined forces in March 2007 to form the new construction committee of ConcepT. They called themselves the ‘BetonBrouwers’ (ConcreteBrewers). They soon concluded that the old canoe mould, at that time used for about six or seven years, had to be replaced by a new one. In combination with the mould a new construction method and concrete mixture were developed. So after months of hard work, the job was finished. In the second weekend of September 2007 three splendid canoes were shining in the Dutch evening sun. Like a phoenix rising from the ashes, the concrete canoes from Twente would turn out to be a threat to every team.

On the foggy morning of the 8th of September the races started. Although it wasn’t possible to test the concrete canoes before the race, training effort in the months before with regular canoes paid off. It proofed that the canoes from Twente did a very good job. In direct battles, canoe ‘Voortvarend’ managed to beat seven canoes on the sprint. In the sprinting races, canoeists Frank Aarns and Sevrien Ferrée managed to qualify themselves for the final run. Their competitor being the Americans from Madison Wisconsin: David against Goliath. After a thrilling race the Americans won, though it was only by a minimum of two seconds.

During the 400 meter curvy trail, the men final was again the domain of the Americans and the Dutch heroes from Twente. This time the University of Wisconsin was a competitor of another class and the Yanks won again. The story of success of the two second place prices were widely spread during the weeks that lied after. The BetonBrouwers were determined to put everything up for the next edition of the concrete canoe challenge, which was to be held in May 2008 in Delft. The story continuous...

2008: We came, we saw, we kicked ass!

After being successful on the concrete canoe challenge of 2007, the BetonBrouwers agreed that this story of success had to be continued. Together with the board of ConcepT it was decided to make the construction committee a continuous committee, resulting in less loss of knowledge. The core activity would be designing and building concrete canoes, something in which we were getting very good at. After attracting some new team members, the BetonBrouwers started to work on the new season.

For all the work we had on making the mould the year before, we decided that for 2008 the mould of 2007 was to be used again. Better concrete, a slightly different method of building canoes and making the canoes as thin as possible were the key aspects of making better canoes than the year before. Besides that, pigments were used instead of paint to colour the canoes. The road to Delft 2008 wasn't as easy as we thought though. Making the first of three new canoes took us two full days. Though, we managed to build three canoes again. The three boats were named: Veni, Vidi and Vici. These famous words of Roman Julius Caesar (I came, I saw and I conquered) would turn out to describe our canoe challenge experiences in Delft pretty well.

On the rainy morning of 17 May 2008 hell was unleashed on the waters near Delft. On the water of the 'Delfste Hout' it all had to be done; it was the day of truth. Frank and Sevrien, the top canoeist of Twente, made it to the finals at the 200 meter sprint. The teams in the other divisions, mixed and ladies, were less fortunate. A French team from Le Bourges was considered to be our only competitor. Because the 200m final was sabotaged by another team, the French won the race.

Thanks to a great lunch, arranged by our sponsor, we regained strength in our muscles and minds. We now totally focused on the 400 meter races. Besides our men, the ladies performed very well on the 400 meter distance. They made it to the finals and actually won the race. But the ladies turned counter clockwise at the buoy and were disqualified. In the semi-finals, the men showed that they could beat the French and in the final they did it again. Victory was ours! Because the jury was very pleased with our canoes and our result on the tournament, they decided to call ConcepT the overall winner of the Concrete Canoe Challenge 2009. Our goals were achieved and the success was complete. We came, we saw and we kicked ass!

2009: Conquering Europe
After the Concrete canoe challenge of 2008, the BetonBrouwers were officially Dutch champion. Though we wanted even more; not only a good reputation in Holland but also abroad. Participate at the German BetonKanu-Regatta, which was to be held in Essen on the 19th and 20th June 2009, became the new challenge of 2009. Besides that, we had to protect our title at the Dutch concrete canoe challenge in Roermond.

This year, we were up to another new challenge: a new canoe design. Using experiences from the past years, the new design was based on speed and manoeuvrability. After constructing a 1:1 wooden model of the new canoe design, we succeeded to make a nice polyester mould. Constructing the canoes was succeeded without any large problems. A new orange lightweight concrete mixture with a perfect workability resulted in a smooth construction process. The concrete combined with synthetic meshes and steel cables as reinforcement turned out to be a perfect combination. This made it possible to make walls of just 5mm thick which were still flexible and strong enough to withstand some impacts. The nice orange canoes were finished with nice and catchy names and the steel

cables in the top of the canoes were put under tension. We were ready to rock ‘n roll on the water!

On Friday the 5th of June, the transport of three nearly 6m long orange canoes to Roermond left Enschede. The next morning the races began. During the short distance (200 meter) our experienced canoe team, Frank and Sevrien, proved again to be best of the best. Without any problems, they reached the final round and won it with ease. Though, they were not the only ones to race with success. Our mixed and lady teams showed that they could paddle as well. This resulted in several prices, including one first price at the mixed teams. Also the long distance over 400 meters became the winning area of the BetonBrouwers. At the end of the day, 13 prices could be taken back to Enschede. The BetonBrouwers ruled the BetonKanoRace 2009! The results were devastating.

Two weeks later, we drove to Essen (D). The biggest challenge was yet to be come: participating in the German BetonKanu-Regatta. The first day was assigned to show the canoes to the different jury’s and other interested people. Most of the eastern neighbours were sceptical about our design: we might win on the straight, but a canoe of nearly 6m long could never make the turns. Well, we proved them wrong that afternoon by giving a little demonstration, the shock was complete.

The next morning the races began early to make sure all of the canoes could sprint for the finish. During the qualification rounds, it was clear that our success in Holland was not exclusive; every canoe in the German races fought themselves to the final rounds. Unfortunately, two of the men teams were not good enough to go beyond the quarter finals. Frank and Sevrien however won every (final) round with ease and were the first couple to qualify for the final. Also two ladies managed to paddle themselves to their final. Unfortunately the ladies weren’t able to paddle themselves to one of the first three places and finished fourth. Still a very good result!

After the ladies final, the waiting started for the men final. Although starting with a lot of confidence, the Dutch felt the pressure. The lighting start of Frank and Sevrien was again determining the course of the race. The two top canoeists from Twente eventually won the final overwhelming. Our success was complete and was rewarded with a very nice first price.

1.2 Team members

As construction committee we strive to be a continuous committee which consists of a diversity of students, meaning students from different phases of the study Civil Engineering. In this way we try to pass the knowledge to the younger members instead of inventing the wheel over and over again. In this paragraph all members of the BetonBrouwers are introduced, giving an insight in their backgrounds and their functioning within the committee.

1.2.1 Chiel de Wit alias 'Guus'

BetonBrouwer since season 2009
Current function: Chairman
Birth date: 15 April 1989

It is said that Chiel sleeps with a concrete bible besides his bed and that concrete is running through his veins. If it's true nobody knows, what we do know is that Chiel is fanatic about concrete and its applications. This passion for the material and his practical insight make him the perfect chairman of the BetonBrouwers. After the big successes in 2009, Chiel temporarily said goodbye to his beloved committee and left to Prague (Czech Republic) for half a year.

In the country with the biggest beer consumption of Europe, the inventors of Pilsner, where beer is cheaper than water, where a bottle vodka cost 5 euro and people are always drunk, Chiel felt like a fish in the water. If he actually learnt something during his Erasmus period is questioned, but it's sure that his athletic body suffered from all this cheap liquor and parties. Since our captain is determined to defeat top canoeist Frank & Sevrien this year, he had to get in shape again.

Luckily Chiel got in contact with the French culture. A diet of French bread, Brie and red wine in combination with French romance were a first step to get fit again. Unfortunately he did not stay on this 'diet' and went back to conventional methods: extensive body workouts during the indoor canoe training. Thereby Chiel is *trying* to become part of the football team 'Veld 5'. If all this effort will be enough will become clear on the 5th of June in Utrecht.

1.2.2 Hildemar Houtenbos alias 'Hilly'

BetonBrouwer since season 2009
Current function: Secretary
Birth date: 16 May 1989

Hildemar Houtenbos, among his friends better known as "Hilly", a funny name that exactly describes the person. He prefers to call himself "the Hilster" only the team doesn't accept this because this name sounds too mean for our little Hilly. Hilly was born in Bentveld, a small village close to the sea. This is where his love for canoeing started. A dislike of Hilly also started there, it is his strange diet. As a vegetarian he dislikes meat, the Betonbrouwers have no idea why he prefers carrots above frikandellen or bitterballen. We guess it will always remain a secret.

After starting his study in 2007 he decided to make part of the "BetonBrouwers" in 2008. This was the begin of the best period in his life. As a member of the "BetonBrouwers" he is responsible for making the notes during the meetings. Beside that he has to create the needed amount of fun during the construction day's. Something where Hilly is made for. Hilly's has one passion, football, in the free hours beside the "BetonBrouwers" he leads his own football team "Hilly's Angels". Beside his own team Hilly also likes to watch football on television and he thinks he is quite a good analyst, but not always. This year he made a bet with the 'Bear of Boekelo' that Ajax would become champion instead of FC Twente, this bet cost him two boxes of beer.

1.2.3 Rik Goossens alias 'Fry king Rik'

BetonBrouwer since season 2009
Current function: Treasurer
Birth date: 7 December 1987

Our very own 'fry king' was born in the city of Arnhem, but still manages to be a jolly fellow. Proud of his heritage and full of love for the game of football, he's a devoted supporter of Vitesse (sadly not a particularly good team in the Dutch Eredivisie). Rik likes to play football himself to stay in shape. His very own team (the "Grasshappers") succeeded in reaching the highest level of the internal competition on artificial grass, held within the compounds of the University of Twente. Although Rik uses football to stay in shape, he doesn't run as much as the rest of his team. Needless to say, Rik is a goalkeeper.

In our team Rik is the Treasurer, he will strictly monitor all the money streams and takes care that no Eurocent too much is spend. Another capacity of this jolly fellow, being the 'fry king', he can fry a minced-meet hot dog like you've never seen before! This is actually Rik's specialty, which really helps the BetonBrouwers perform when we are building a canoe. Nothings speeds up a building process more than the prospect of a cold Grolsch Beer accompanied by Rik's famous minced-meat hot dogs.

In short: Rik has one of the most important roles in our team. He motivates the others to always give their best effort!

1.2.4 Casper Rood alias 'The Blister'

BetonBrouwer since season 2010
Current function: Public Relations
Birth date: 17 November 1987

In November 1987 Casper was born in the most beautiful town of Limmen and surroundings: Limmen. Every weekend he returns to his hometown to drive a forklift, something he really likes to do. Casper also likes to play football every week. Together with his friends he joined the team of the BankCiTTers, in which Casper defends the goal. They made it to the first place of their league several times. Another hobby of Casper is to shout a specific word, followed by drinking beer. Fortunately, Casper is also good at paddling.

After he joined the board of Study Association ConcepT in 2009, Casper couldn't wait to join the BetonBrouwers. He knew the sphere of the committee already, as he was attendant board member of our committee during his board period. Since January this year Casper is official member of the committee, which is a benefit for the fun on the workplace. Casper laughs at everything, even if things are not funny. He especially appreciates good stories, and also likes to tell them. However, Casper can be really serious if it's necessary. As PR-commissioner of the BetonBrouwers he needs to be.

Casper can be seen as our cheerful, motivated and knowledgeable, but particular cheerful team member and with him the BKR 2010 will anyhow come to a good end.

1.2.5 Frank Aarns alias 'Prof. Arms'

BetonBrouwer since season 2007
Current function: Event Manager
Birth date: 27 December 1985

24 years ago, in the dark and evil streets of Nimwegen, a boy was born named Frank. Luckily this boy could make the cross over the river Waal to the nice village of Elst. In the shadows of the beautiful city of Arnhem, Frank became interested in the world of civil engineering. Therefore he went to Enschede where he is nowadays busy with finishing his master. Frank is one of our top athletes and together with 'The Bear of Boekelo' he was superior during the BKR 2009 and the BetonKanu-Regetta 2009 in Germany. In order to spread

the success of the University of Twente, Frank has subscribed for the Solar Team Twente. He hopes he can make the trip to Australia and let Twente be victorious in this competition as well.

For now, Frank is still the big brain of the BetonBrouwers. During half a year of studying in Norway he learned everything about concrete. Therefore he is the man who is responsible for the concrete mixtures. Our Prof. is the one who knows best how to mix the ingredients into a very nice concrete, ready for making the canoe. Frank is also responsible for managing the event, making sure that everything is properly arranged and that we have enough women to canoe for us.

Especially this last task is a specialty of Frank. Since Rik is taken, Frank is the Casanova of the BetonBrouwers. All kind of women fall in love with the deep blue eyes and the blond hairs of our National Guard. Frank will never turn away for a banging conversation all night long. So women at the BKR, be aware!

1.2.6 Bart Leferink alias 'Bartels'

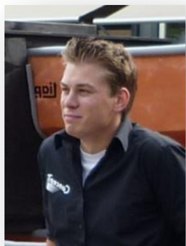
BetonBrouwer since season 2010
Current function: Webmaster
Birth date: 26 August 1988

Due to the success of the BetonBrouwers in the year 2009 and the leave of 'The Tsar' (Daniël Tollenaar) that same year, we needed reinforcements. They came in the form of Bart Leferink. Bart, born and bred in the scenic village of Haaksbergen, is a pure bred Tukker! Something Bart is very proud of. Each year consists of making carnival trailers, enjoying a lot of full glasses of Grolsch beer and screaming and shouting football-club FC Twente to victory. Especially the last aspect went very well in 2010!

Together with his comrades in Haaksbergen, he regularly visits the famous summer events in Twente. 'De Hoeve', 'Mega Piraten Festijn', 'SPU'; Bart has seen and enjoyed them all. Of course accompanied by gallons and gallons of beer. Also 'Dorf Münsterland' and 'Karpaten' are places Bart can be regularly found. Where Bart is around, the party is always a big success!

Within the BetonBrouwers, Bart has already found his place. Although never participating in a concrete canoe challenge yet, he is determined to succeed in his first race. Bart is someone who likes to make his hands dirty, but is also skilful in web design. This makes him a real addition to the team. Only the fact that the likes Pirates music (secret senders) puts a lot of tension on the nerves of other BetonBrouwers. Polka's, 'Smartlappen' and German 'Schlagers' can be heard in the BetonBrouwers' workshop when Bart gets control over the radio. Though, Bart can count of a lot of comradeship from within the BetonBrouwers. There is no doubt that he also will be a terrific BetonBrouwer in the future!

1.2.7 Johan de Waard alais 'John Doe'



BetonBrouwer since season 2008
Current function: General Member
Birth date: 2 December 1987

Johan de Waard was a predestined born civil engineer. He is born in the little town of Oud-Beijerland, with one of the biggest ports of the world (Rotterdam) in his backyard and even so the hydraulic province of Zeeland. In 2006 he became a Tukker by becoming a student at the most exciting university of the Netherlands: the University of Twente.

In 2007 Johan realized that he fitted better in an overall than in a nice suit. As a new member he immediately became chairman. Under Johan's lead the BetonBrouwers won the overall championship at the Concrete Canoe Challenge 2008 in Delft. The next year Johan became PR-commissioner and arranged most of the sponsors for season 2009, the best season so far!

During his first race as a BetonBrouwers, Johan did a great job by finishing third during the BKR 2009 in Roermond together with Chiel. He had great expectations for season 2010, but he decided to move to Canada for several months. Not to become a farmer, but to do an internship in the country of ice hockey and Eskimos. He won't be back before the race in Utrecht, so the contribution of Johan this year consists of mental support by mail.

1.2.8 Yorick Keizer alias 'Foppe'

BetonBrouwer since season 2010
Current function: General Member
Birth date: 24 April 1991

Yorick alias Foppe, is the rookie of our team. Nineteen years ago he was born in Stadskanaal, a small city in Grunn. Since he speaks exactly like football coach Foppe de Haan, he has the nickname 'Foppe'. But because of his love for Grunn and the rivalry between Grunn and Friesland, the birthplace of Foppe de Haan, he is not really contented with his nickname.

After his secondary school he left the north for the very east. He decided to study Civil Engineering and Management in the beautiful city of Enschede. A decision that directly seemed to be the right one. Before his first day in college he met the BetonBrouwers. During the introduction week he had the opportunity to paddle a bit in one of the beautiful concrete canoes of season 2009. The goal of the BetonBrouwers was to discover the maximum impact of a concrete canoe. Yorick succeeded by destroying two of our canoes. Thanks to his experiment we knew something more about the strength of our canoes.

After seven months of studying he learned enough about concrete to make him suitable for a position within the team. From then on everything went quick. After two times of helping with constructing a canoe, the team offered him a contract. because it was his dream to become a BetonBrouwer he directly signed. From then on there was another proud member of the BetonBrouwers.

1.2.9 Sevrien Ferree alias 'The Bear of Boekelo'

BetonBrouwer since season 2007
Current function: Vice-chairman
Birth date: 25 October 1987

Some say he can win a canoe race with just one arm, and drinks a box of Grolsch beer for breakfast. All we know is, he is called 'The Bear of Boekelo'. Sevrien is a man of little words but big deeds. He is a man who can't stand people who keep on bragging about how great the football club they are supporting really is. And when someone says something about a) FC Twente in a negative way b) Germans in general c) mixing concrete d) or AFC AJAX (pronounced as 020), he is really playing with fire. Just try to avoid these subjects when talking to Sevrien, except when you are looking for a "challenging conversation".

If you want to get to know Sevrien better, offer him a cold Grolsch beer and start talking about anything from the region Twente, trains, photographing, carnival or concrete canoes. It doesn't matter if he is building concrete canoes, a carnival trailer or if he is renovating or driving a classical train. Everything Sevrien does, he does with verve. He can talk about these subject with lots of passion, making these subjects relatively safe to talk about as long as you don't criticize them.

So you should be aware of Sevrien in conversation but also in the battlefield; the town canals of Utrecht. The whole paddling nation Germany is afraid of one guy; The Bear of Boekelo. With extreme skill he manoeuvres, with great speed, the concrete canoe in great tactic position. So if there is one thing you will notice in the tournament it is how tiny the back of Sevrien can look when racing him.

1.3 Reinforced by….

This paragraph is dedicated to the companies that support our project through financial sponsoring and through supplying the required materials. We want to thank these companies for reinforcing our project.

CBR - Heidelberg Cement Group
http://www.heidelbergcement.com

Besix Group
www.besix.com

Spanbeton BV
www.spanbeton.nl

University of Twente
Faculty of Engineering Technology
School of Civil Engineering
www.cit.utwente.nl

Liaver
http://liaver.com/

Bekaert
http://www.bekaert.com/

Scholz
http://www.scholz-benelux.nl/

Buildsoft
http://www.buildsoft.eu

Study Association ConcepT
www.concept.utwente.nl

Drienerlose Kano Vereniging Euros
www.euroskano.nl

Part 2

A Winning Design

The second pillar for success in concrete canoeing is developing a winning shape and an optimal construction. The formulation of some design principles serves as starting point in the design process. When this part is covered one starts to develop the shape and an optimal construction. The shape of the canoe highly determines the hydrodynamic properties of the canoe which are of major importance in winning races. Finally, the construction of the canoe is the major factor in determining the canoes mechanical properties relative to its weight, with concrete being the binding element where the whole canoe relies on.

2.1 The principles behind CT2010

In our previous challenge, the days of developing CT-BB-07 the team was still as green as grass. Due to the lack of experience, principles where derived from BetonKanoRace regulations. This framework was refined based on general mechanical principles and common sense. Experience from previous years and concepts shown by competitors from Germany and the USA have greatly improved the knowledge of concrete canoe building. In this chapter the principles are described, separating the principles for shaping the canoe from the ones related to the construction. Within these families a subdivision is made between performance criteria related to the regulations of both competitions and functional principles, related to the function of the craft. The function on his turn is related to our general objective: creating a fast, innovative and robust concrete canoe design.

2.1.1 Shape principles

Shape principles are bounded by race regulations. Within this framework many degrees of freedom remain to optimize the canoes final shape. Therefore functional principles are formulated.

Performance criteria:

- **Crew –** The canoe must be propelled by two people with single-blade-paddles.
- **Length –** The length of the canoe must be at least 4m. The maximum length of the canoe is 6m.
- **Height –** The maximum height of the canoe is 1.0m
- **Width –** The minimum width if the canoe is 0.4m. It is not allowed to construct a canoe wider than 1.0m.
- **Failure –** The canoe must be provided with air chambers which prevent the canoe from sinking after breaking or capsizing. It is not allowed that the air chambers contribute to the stiffness of the canoe. The air chambers must be removable.

Functional Principles:

The functional principles, which ultimately lead to a competitive canoe shape, are derived with help of the well documented experiences of John Winters (Winters, 2005).

- **Displacement $D_{h;max}$;** Enough volume should be created to guarantee a floating hull under all conditions. In meeting this criterion a maximum displacement is assumed of 0.270 metric tonnes (2x85 kg for paddlers plus 100 kg for the canoe) over which a freeboard of 20 cm is sufficient to prevent wave overtopping.
- **Paddle positions;** In our philosophy, backed by some of Holland's top paddlers, the two headed crew should be placed in the bow and stern as much as possible, providing optimal canoe handling. This aspect is translated into a restriction in bow and stern angles. The hull beam should not be less than 0.3 m further than 1 m with respect to the canoes bow and stern.
- **Maximum Speed u_{max};** A function of the maximum speed [knots] of the canoe in relation to the length [feet] is provided by equation 1. Longer boats do increase displacement, drag and therefore decrease acceleration and manoeuvrability. Previous experience of our team and USA competitors favours long hulls over short ones since the loss in acceleration and manoeuvrability is well compensated by higher u_{max} and therefore the hull length l_h

  $$u_{max} = 1.34 \times \sqrt{l_h} \tag{1}$$

- **Manoeuvrability and track ability;** A function of vertical curvature in the keel of the boat. The more the bow and stern are elevated relative to the boats turning point, the higher the manoeuvrability and the lower track ability. Based on earlier designs by USA competitors (Madison Concrete Canoe Team, 2008) show that a keel and bow elevation of 5 and 7.5 cm respectively give a good compromise of both aspects.
- **Resistance;** Within the hull restrictions and the optimization aspects mentioned above, the hull is designed according to the KAPER formula formulated by John Winters. With this formula velocity-resistance graph can be drawn. Different shapes are tested with help of this formula and compared with a design which earned our deep respect, the Wisconsin-Madison design of 2006 which defeated our old design fare and square during the 2006 BKR at the University of Twente. As to be seen such defeat in 2010 can only be blamed upon the paddlers, since the design out performance this design across it acceleration trajectory.

2.1.2 Construction principles

Just like the shape principles, the construction principles are bounded by the regulations. Besides the criteria derived from the regulations a set of functional principles can be formulated.

Performance criteria:

- **Concrete mixture** – The canoe must be constructed from (reinforced) concrete. The binding element must be cement (CEM I – CEM V) and the use of aggregates is obligated, although there are no restriction on the amount or particle size. Fillers and admixtures are allowed on the condition that they don't take over the binding function of the cement.
- **Reinforcement** – The strength and stiffness of the canoe must be derived from the collaboration between the concrete and the reinforcement. The percentage reinforcement is not restricted. The concrete must be the determining factor concerning the stiffness of the canoe, the reinforcement itself is not allow to have a considerable stiffness.

Functional Principles:

- **Waterproof –** The skin of the canoe must have a low porosity to such a degree that it can be considered waterproof under nautical conditions.
- **Mechanics –** Based on the expected forces on the construction, estimation can be made of its dimension (thickness) and the necessary reinforcement. Hereby it is also necessary to take into account the variable forces, following from the nautical function of the construction.

2.2 The art of shaping a concrete canoe

CT2010 is designed with the help of software package Delftship. The shape principles as defined in section 2.1.1 give clear restrictions in the optimization of the hull. Stability was guaranteed by evaluating the programs output parameter Keel Mark *KM* which is a measure for stability. This value is kept close to the value of the WM2006 which served as a proven design. The optimization function was the hulls resistance measured by the KAPER method, described by John Winters.

For the final design the resistance graph is given in figure 2.1. Though the difference in resistance might seem small, the increase in performance is 5% over the entire trajectory, which should lead to a clear victory for our fit paddlers. The secret behind this result is a keen *L/B* ratio, whereby the maximum beam is reduced to 0.71 m, just above the minimum required for the German competition. Moreover, the maximum beam is placed further to the stern, leading to a very low angle at the bow part of the hull. The length is optimized to 5.85 to ensure a high top speed at the straight. The high prismatic coefficient favours the paddlers comfort during the race, but also reduces draft, therefore the hull area which is submerged and ultimately leads to a lower resistance. The lower draft also favours manoeuvrability. The loss in track ability is compromised by a high L/B ratio. Figure 2.7 shows the hull design of CT2010.

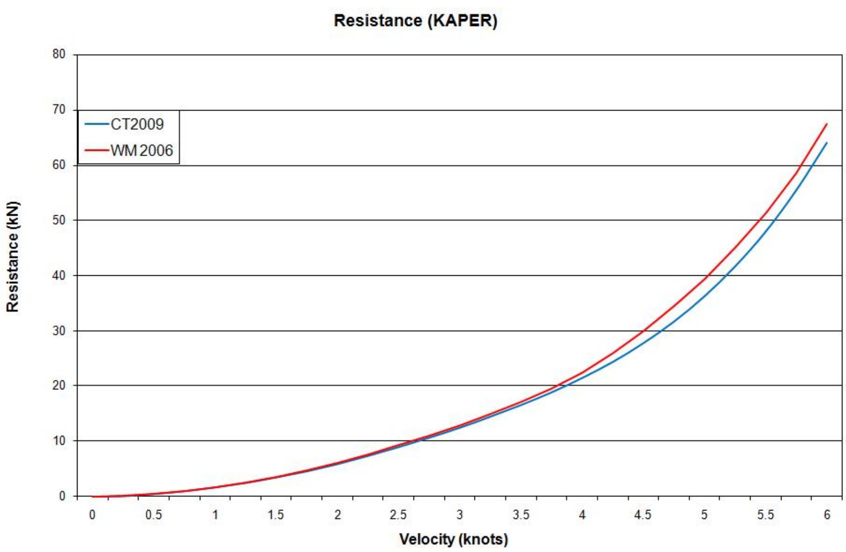


Figure 2.1 - Hull Resistance CT2010 compared to WM2006

2.3 The Secret of Strength, Stiffness and Stability

Since in our academic philosophy a well engineered design should always be backed by a sound mechanic hull assessment, we started the design of CT2007 with the necessary mechanical models to determine the canoes maximum stresses under most unfavourable conditions (BetonBrouwers, 2007). Though these models provide a good first indication of the strength required, they are also limited in the practice of concrete canoeing, since hull stresses under race conditions are hard to model.

In the academic triptych of Strength, Stiffness and Stability we based our first design on sound principles as described in the construction report of 2007. Since the CT2010 concerns a different design, a new mechanical analysis is carried out to gain insight in the forces on the hull. Over the last three years we experimented with the resulting design which brings us to an evaluation which we translated into Achilles Heels and solutions.

2.3.1 Mechanical Analysis

In order to carry out a mechanical analysis, insight in the forces acting on the hull is required. The load on the hull is determined by three components:

1. The weight of the paddlers: $F_{paddler}$ [N]
2. The weight of the canoe: F_c [N]
3. The upward water pressure: q_w [N/m]

For the weight of the paddlers, it is assumed that they weigh 850N each. Athletes are assumed to be in top condition, don't use doping and drink just one beer a day. The weight of the canoe can be determined from the hull surface, the thickness of the wall and the density of the concrete. This results in a F_c of 550N, leading to an q_c of 93kN/m. The water pressure is determined by the weight of the paddlers together with the weight of the canoe, divided by the length of the canoe: q_w = 381N/m. Concerning F_c and q_w it is assumed that they are opposite of each other, giving a resulting force: q_{res} = 288N/m.

To gain insight in the moments acting on the canoe the forces are modeled according basic mechanical principles, this can be seen in figure 2.2.

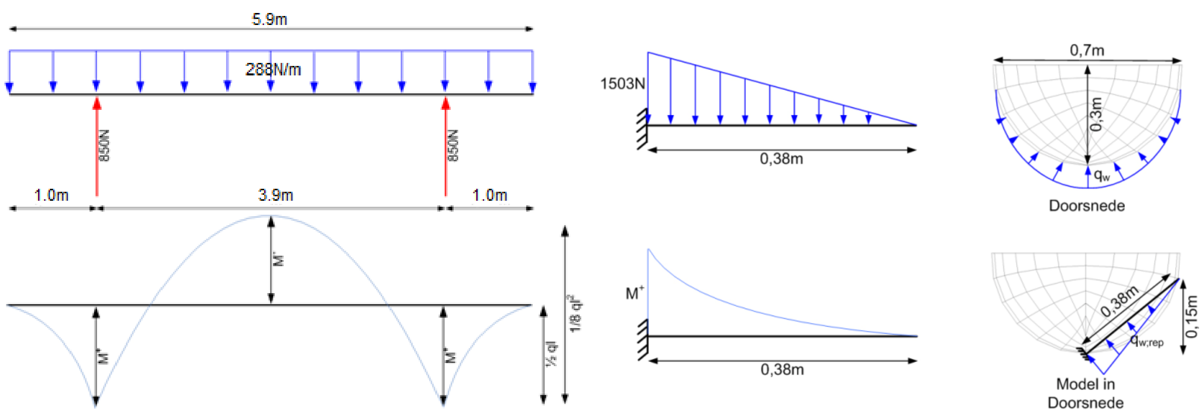


Figure 2.2: Modeling the forces and moments on the canoe

This schematic representation of the forces and moments applies for a symmetric hull with a round cross section. Although this is no real representation of our hull, this gives a good insight. To calculate the real forces acting on our canoes, the software package 'Buildsoft' is used. First the hull design was modeled in Buildsoft, the result can be seen in figure 2.3. The input for the mechanical analysis is:

- Concrete: C25/30
- Thickness of the walls: 5mm
- Density of the concrete: 1194 kg/m^3
- Weight of the paddlers: 85 kg
- Position of the paddlers: 0.75m from the bow and 0.5m from the stern.

With this input the mechanical analysis is carried out. The result of the displacement analysis and the force analysis can be seen in figures 2.4 and 2.5. This analysis doesn't take into account the loads and stresses on the canoe hull as result of transport, paddling and possible impacts.

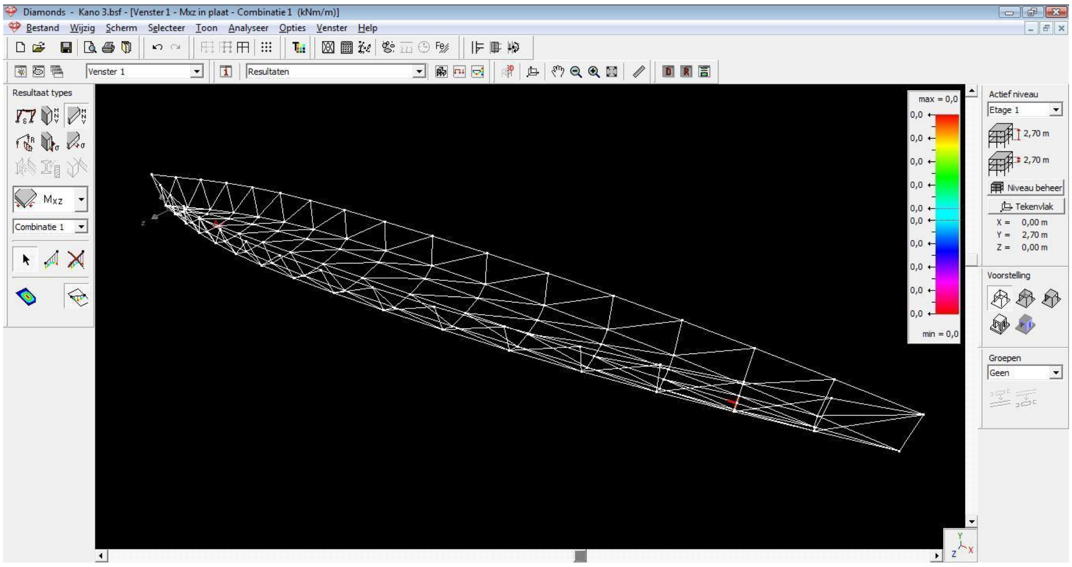


Figure 2.3: Modelling the design in Buildsoft

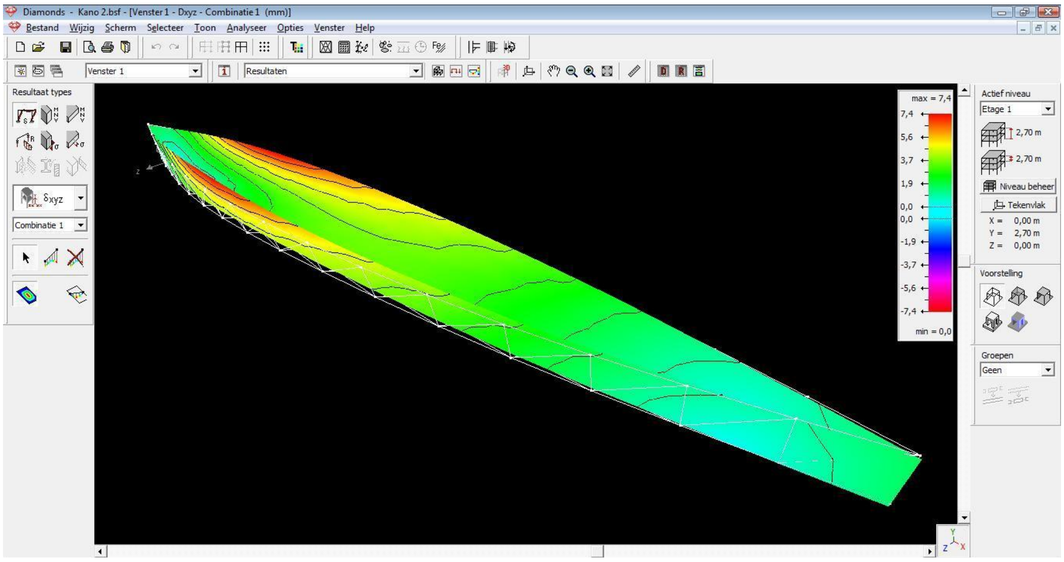


Figure 2.4: Displacement analysis

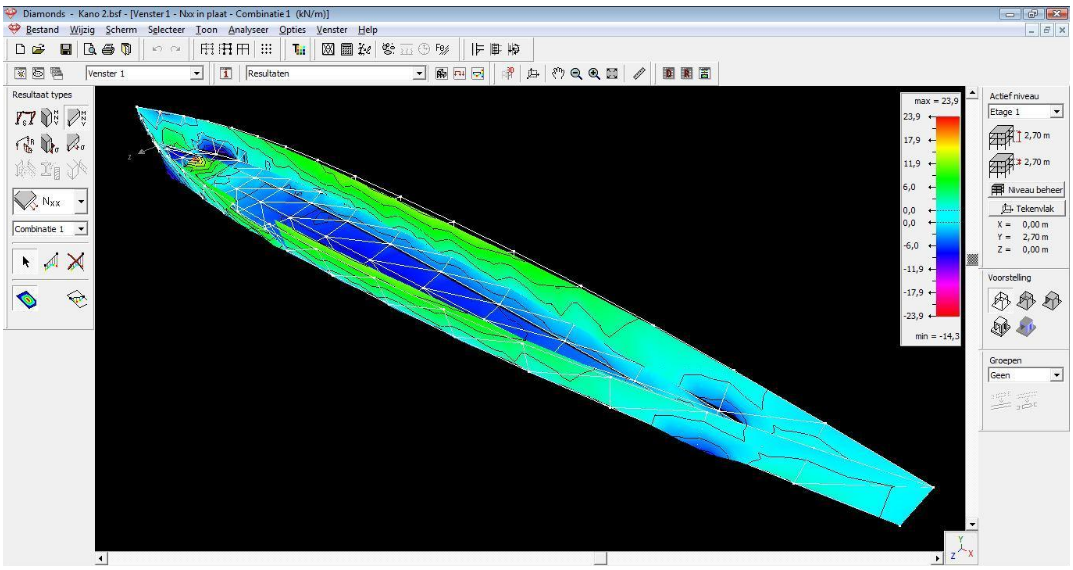


Figure 2.5: Force analysis

From the mechanical analysis that concrete with a compressive strength of 25N/mm^2 or higher is sufficient. Concerning the reinforcement it can be concluded that the largest forces in the longitudinal section occur at 2/3 of the length (figure 2.5). This is taken care of by two steel cords in top of the walls. These should compensate a normal force (σ_n) of about 0.5N/mm^2. On the position of the paddlers high forces are acting on the canoe, therefore a combination of two layers of stucco-mesh and pre-stressed cords is certainly required.

2.3.2 Achilles Heels

Overall, we conclude that concrete mixtures with a characteristic compressive strength higher than 25 N/mm^2 are sufficient in dealing with pressure stresses. Though, problems have emerged on several locations in the used hulls related to high flexural and tensile stresses. For these issues, smart reinforcement solutions are proposed.

Achilles Heel 1 – Bottom of Mid Cross section
When lifting a concrete canoe at the bow and stern the maximal momentum of the canoe is found in the mid section. When the length view of figure 2.6 is considered a critical vertical line can be drawn over which this momentum is transferred into pressure in the top and tensile stress in the bottom. To compensate for this stress a pre stress is generated of 10 kN in the bottom of the canoe by three steel cords (see figure 2.7). These cords will from now on be referred to as Type 1 Cords.

Achilles Heel 2 – Top of Mid Cross section
When the same cross section is considered problems emerge in marine conditions. When the canoe is propelled by two paddlers located in the far bow and stern, most of the downward force is applied in these locations. The upward reaction force, however, is equally distributed over the canoe hull. Over the last two years many teams have seen cracks caused by this problem. The pre-stress we applied in CT2007 worked out very well to overcome cracking of the mid section. Therefore, in CT2010 we apply two steel cords as high as possible in the hull as to be seen in figure 2.7, from now on referred to as ‘type 2’ cords. The total pre stress applied by these cords is 10 kN. In contrary to the ‘type 1’ cords which are pre stressed before pouring the mixture at the mould, ‘type 2’ cords are stressed after the concrete is sufficiently hardened with anchors at the bow and stern.

Achilles Heel 3 – Cracking under its weight and water pressure
At CT2007 we observed a crack in longitudinal direction of the canoe, shown in figure 2.6. It is believed that this crack occurs when the canoe is rested on its bottom. Since the bottom is slightly curved in both directions, the weight of the sides is transferred to the middle, which couldn’t cope with these high stresses, resulting in a crack at the inner side of the canoe. The opposite occurs when water presses on the sides of the hull. In this case the tensile stress occurs in the outer side of the hull, but over the same profile. To overcome this problem three ribbons are used to increase stiffness as shown in figure 2.7. To even further decrease this problem, the ribbons are pre stressed over the width of the canoe with a ‘type 1’ cord, shown in the same figure. These cords are pre stressed under 500 N of pre stress each.

Achilles Heel 4 – Extreme stress under race conditions
Though static evaluations can reveal some weak points in concrete canoes, extreme stresses occur under racing conditions, where the stress distributions are very dynamic. Modelling hull stresses over time is not possible, wherefore a simple philosophy is applied: ‘*if it bends, it doesn’t break!’*. Over the entire hull two layers of stucco-mesh are applied which distribute the stresses from the hull to the cords and the mechanical structure. These meshes are a combination of plastics and glass fibres with a mesh diameter of 5x5mm.

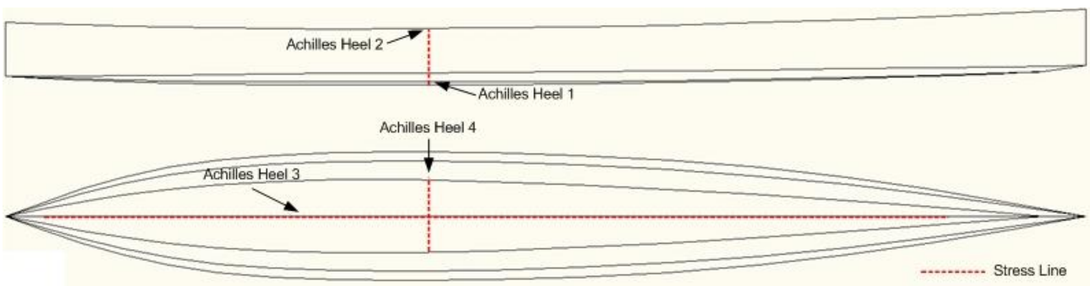


Figure 2.6: Concrete Canoe Achilles Heels

2.4 The Blueprint of CT2010

The blueprint of CT2010 is given in figure 2.6. It gives a top view, side view as well as two cross sectional views. One showing the maximum beam section and one showing a ribbon section. Incorporated are the steel reinforcement cords. The stucco-meshes are not shown.

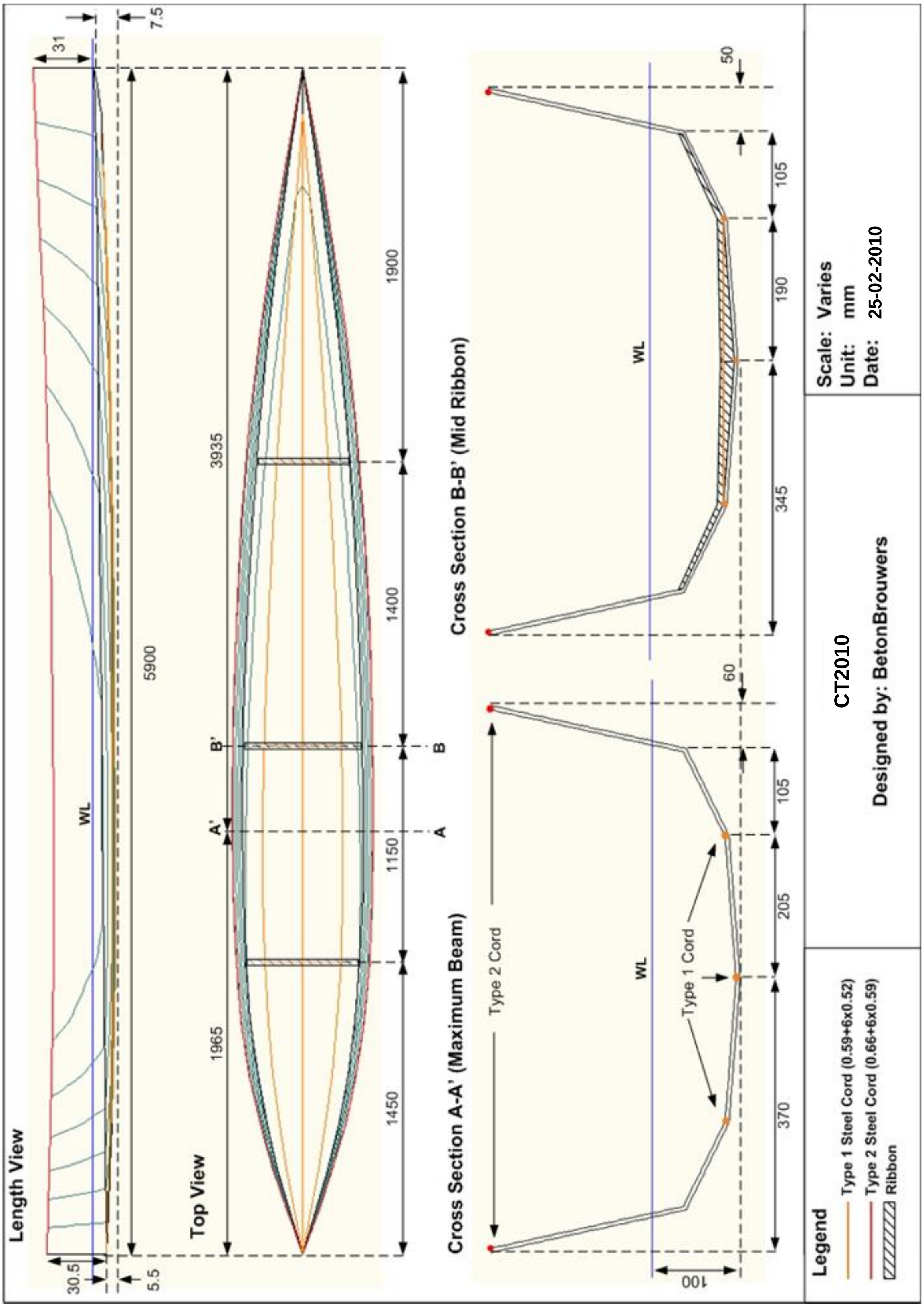


Figure 2.7: Blueprint of CT2010

Part 3

It’s all in the mix(ture)

The third pillar for success in concrete canoeing is developing an optimal concrete mixture. During their study Civil Engineering, students acquire a broad theoretical background concerning the fascinating material concrete. This background in combination with the experiences from preceding years serve as valuable input for the composition of the mixtures. Optimizing the compositions based on the particle size distribution is the last step before entering the concrete lab. During long days in the concrete laboratory the mixtures are analysed on their workability, colour and strength. The result: the optimal mixtures to serve as binding element of the canoe.

3.1 The theory behind concrete

Before one starts composing a concrete mixture, it is important to understand the principles behind the material. Therefore it is important to be familiar with the (basic) theory behind the material and/or have some experience with it. In this section the basic theory behind the material concrete is highlighted. This basic theory is derived from the compendium 'Concrete Technology 1' from the Department of Structural Engineering of the Norwegian University of Science and Technology (NTNU).

3.1.1 Concrete

In general concrete is a mixture of cement, mineral additives (such as pozzolans), aggregates (gravel, sand), water and admixtures. The coarse aggregates make up approximately 70% of volume, cement paste makes up around 30% of the volume.

Both material choice and proportions of the materials, i.e. the proportioning, determine the properties of the concrete for both fresh and hardened condition. It is possible to control this to a large extent, but improvement of one property will often lead to worsening of some other property. One will therefore constantly be facing an optimization of prioritized properties.

Cement:
Cement is the binding element within concrete. The most common used cements are Portland clinker and derivates of Portland clinker, containing slag, pozzolana or fly ash. According to their composition, the cement types are divided into five main types, being: CEM I, CEM II, CEM III, CEM IV and CEM V.

Cement mixed with water is often called cement paste. The properties of the cement paste are mainly determined by the mass ratio between water and cement, the w/c-ratio. During the reaction between cement and water a high concentration of hydroxide ions (OH^-) develops in the remaining pore solution. Hydroxide ions may react with certain types of silica that can occur in some aggregate. This may result in internal stresses that can cause expansion and cracking, known as alkali silica reaction (ASR), or more generally alkali aggregate reactions (AAR).

Mineral Additives:
The most common used additions are Fly Ash (FA), Silica Fume (SF) and blast-furnace slag, also termed pozzolans. All three of these additions are industrial by-products. When used in concrete they reduce the demand for Portland cement clinker. Hence their use is advantageous both from economic and environmental points of view – particularly w.r.t. reducing the large amounts of CO_2 emission associated with Portland cement production.

Pozzolana are active mineral additions. This implies chemical reactivity either alone or in combination with Portland cement clinker and/or its hydration products. Pozzolans are included in the mass ratio $m = w/(c+k*p)$, where k is an efficiency factor for the actual property and the actual material. Non active additions are also used extensively, and are commonly referred to as fillers, i.e. normally finer than 125µm and close to chemically inert. Note that fillers may be chemically inert, but may accelerate cement hydration by providing surfaces for precipitation of hydration products.

The pozzolanic reaction is:
$2S + 3\,CH \rightarrow C_3S_2H_3$

Thus the reactive silica in the pozzolanic material reacts with the calcium hydroxide (which is a reaction product of the Portland cement hydration) to produce more of the C-S-H binder, i.e. it leads to more efficient use of the Portland cement. The pozzolanic reaction involves somewhat greater heat release than cement hydration, but the reaction is slower – and therefore does not produce increased temperatures.

Aggregates:
Aggregates have an important influence on the concrete properties, both in the fresh- and hardened state. In our project only fine aggregates (0-1mm and 0-2mm) are used as a result of the thickness of the canoe. Important factors to keep in mind when selecting an aggregate are the material grading, the particle shape and water absorption.

In our project it is not very important to have a high durability, the canoes are used for only one year. Despite that we want to develop a high-quality concrete, and thus take into account the durability. A very important issue for a concrete that requires a high durability are Alkali-Aggregate-Reactions (AAR). AAR are reactions between certain aggregate types and the alkaline pore water in the cement paste. A certain amount of moisture is required within the concrete. During the reaction a gel is formed in the concrete. This may suck water and swell, which can lead to a volume increase and cause a characteristic crack pattern on the concrete surface after several years. Three condition must be fulfilled before AAR will occur: Alkalis, Water and Reactive aggregates.

Admixtures:
Admixtures are chemical agents added in small dosages to improve certain properties of the concrete. The European Standard (EN 934-2:2001) defines an admixture for concrete as: *"Material added during the mixing process of concrete in a quantity not more than 5% by mass of the cement content of the concrete, to modify the properties of the mix in the fresh and/or hardened state."* The European Standard classifies chemical admixtures for concrete in 11 classes, based on the main effect of the admixture on the concrete properties.

3.1.2 Lightweight concrete

To construct the concrete canoes, lightweight concrete is used. Generally speaking, lightweight concrete includes all types of concrete with density less than 2000 kg/m^3. At mixing, lightweight aggregate (LWA) will absorb water from the cement paste and a larger loss of workability in the form of slump loss than in normal density concrete results. As a consequence of the absorption into the LWA, the real or effective mass ratio (w/c or w/b ratio) is reduced. This must be taken into consideration for accurate control of mass ratio.

It has been documented that high strength LWAC generally is less permeable than normal density concrete (NDC) of the same strength class. This is first and foremost a result of an improved Interfacial Transition Zone (ITZ) between aggregate and cement paste.

3.1.3 Workability

Because of the casting technique of the concrete canoes, the workability of the concrete is a very important aspect concerning the composition. The workability of concrete depends on the properties of the constituent materials, their relative proportions and physical and chemical interactions between them. The simplest way of modeling this complex system of multiple constituents, is to consider concrete as a two-phase system consisting of a matrix- and particle phase, or described by the properties of the two phases, one liquid phase and a friction material.

- The matrix phase: consists of water, all additives, all admixtures and all particles less than 0,125mm. That is cement, pozzolana, fillers and the finest particles of the aggregate. The matrix phase can be regarded as a heavy viscous fluid and can in principle be characterized in the same way as other fluids.
- The particle phase: consists of all particles larger than 0.125mm. The particle phase is a friction material and characterized as such.

A disadvantage of the particle-matrix model is that it provides little or no information about the stability of the concrete, i.e. robustness against separation.

The properties of fresh concrete can be described by the concept workability. The workability concept may be divided into three basic elements: stability, mobility and compactability.

Stability:
Stability may be defined as the ability of concrete to retain its homogeneity through the fresh phase, both at rest and subject to loads to transport, form filling and compaction. Lack of stability may lead to separation. There are three different forms of separation. Separation of water occurs in ordinary concrete qualities, paste separation occurs mostly in high strength concrete, whereas separation of mortar and coarse aggregate occurs in both ordinary and high strength qualities.

- Separation of water, or 'bleeding' is characterized by a part of the water in the concrete flowing upwards to the concrete surface, collecting in pockets under coarse aggregate and forming a film of water at the surface.

- Paste separation can arise as one tries to obtain flowing concrete consistency and the amount of cement paste is too large compared to the amount of sand, or as the sand partly lacks the finer fractions.
- Mortar- of coarse aggregate separation or 'segregation' occurs as the coarse aggregate sinks in the concrete, and mostly results from inadequate aggregate composition by the partial or complete lack of certain aggregate sizes.

Mobility:
Mobility may be defined as the ability of the fresh concrete to move due to forces acting on it. The resistance against motion depends on:

- Friction between particles
- Internal cohesion
- Resistance to internal flow of the liquid phase

To make a continuous compactable zero-slump concrete (0-20mm), the matrix volume must typically be 20-40l/m3 larger than the void space (in the particle phase). An increase in the matrix volume means a slight increase in the distance between the particles such that the particles can move with less interaction/friction.

Compactability:
The ability to be compacted is the ability of fresh concrete to fill out the formwork and let off encapsulated air pockets during reworking. Effective compaction is one of the most important factors determining to which extent the concrete strength potential can be exploited.

3.1.4 Proportioning

Proportioning concrete means selecting materials and putting them together so that:

- The hardened concrete obtains required properties with good margin
- The fresh concrete obtains sufficient workability to be placed and compacted with the actual method
- Low risk of errors
- Economical composition is obtained

The following basic rules apply when proportioning concrete from scratch:

- The matrix composition controls the properties of the fresh concrete. The cement paste has in most cases lower durability and strength than the aggregate ("the weakest link"). Therefore the required compressive strength and durability of the concrete controls the matrix composition.
- The aggregate composition controls the properties of the fresh concrete. The properties of the aggregate (shape, particles size distribution and void content or packing) determine how large the matrix volume must be to give desired or required workability.

3.1.5 Strength

The definition of strength is as following: the strength is the average value of maximum load converted to nominal stress for a series of standardized specimens loaded until failure in a given load test-set up.

The tensile strength of concrete is low compared to its compressive strength, 10-12% for ordinary structural concrete, 4-6% for high-strength concrete. In the design of concrete structures one usually assumes that all tensile forces must be taken care of by the reinforcement. Still, for some cases, it is obvious that the tensile strength is significant. E.g. for shear capacity of concrete and for the bond towards the reinforcement or previously cast concrete. Further, the tensile strength of concrete will to a high degree govern if and how cracking possibly will occur in tensile zones, and possibly affecting the durability of the concrete.

The concrete should have enough strength to cope with the forces as discussed in the mechanical analysis (Part 2). Factors that influence the strength potential of the concrete are:

- Cement type: The clinker composition of the cement influences the strength potential because the clinker leads to different hydration products and structure in the cement paste.
- The fineness of the cement: Normally the strength potential will be larger at higher grinding fineness. This is due to the fact that larger reaction surfaces lead to larger degree of hydration, and thus lower porosity.

- Properties of the aggregate: The mechanical properties of the aggregate are usually not a limiting factor, but surface properties of the aggregate can have an influence. Grain shape and roughness can also influence the bond and thus mechanical properties.
- Degree of compaction: Lack of compaction causing large voids, cavities and discontinuities in the concrete, and reduced strength.
- Curing conditions: Early drying gives reduced degree of hydration and risk of cracking due to shrinkage. Both factors will lead to reduced strength.
- Temperature level: High curing temperatures is unfavorable for the porous structure formation in the cement paste and will reduce the concrete strength. Large temperature differences in the cross section lead to strain differences and possible cracking.
- Air entrainment: a good rule of thumb states that the compressive strength is reduced by 5% for each 1% air.

In general concrete becomes more brittle as the strength level increases. Concerning the concrete canoes a more flexible concrete is desired. Therefore it is important to develop a concrete that is strong enough to cope with the forces acting on it, but doesn't becomes too strong.

3.1.6 Porosity & Permeability

The internal consequences of the hydration are large changes in solid volume and thereby in the porosity. Porosity means here the internal volume that can be filled with water.

The reaction of water and cement during hydration is associated with a volume change, i.e. the volume of the reaction products is smaller than the volumes of the reactants cement and water. We assign the entire volume change to the water, which means that the chemically bound water has lost 25,4% of its volume before hydration. This is called chemical shrinkage. When looking at the permeability coefficient (K') for stationary water transport in well hardened cement paste at different w/c-ratios, and as a function of hardening time for a fixed w/c-ratio, two effect become clear:

1) Improved hydration reduces both the porosity and the continuity in the pore system, which reduces the K' with several magnitude.
2) Over a w/c-ratio of approximately 0.50 increase K' markedly with increasing w/c-ratio as the volume of capillary pores and their continuity are increasing sharply.

The general international requirement is that "watertight" concrete shall have a w/c-ratio below 0.50.

For a given w/c-ratio the permeability is increasing with D_{max} of the aggregates. The reason lies in the transition zone between aggregates and paste. Another factor that has a negative influence on the permeability is drying from early age. This is unfortunate since the surface might experience low degree of hydration and cracks might form with reduced permeability as a result. Since our canoes don't have any coating (like paint) and the walls are very thing (max 5mm), it is important to keep the permeability in mind.

3.1.7 Curing

When cement is hydrated, considerable amounts of heat develops. In most concrete structures this leads to temperature increase the first days after casting. This might give production rate benefits, but also disadvantages. High temperature results in fast hydration and thus fast strength development. The heat of curing can also lead to damage (cracking) or reduced material quality in massive structures unless the heat evolved and resulting temperature increase is not taken care of in a controlled manner. Since our canoes have very thin walls, the temperature will not reach a level at which it leads to damage.

In order to achieve a full hydration and therefore increase the impermeability of the canoe it is important that the concrete is cured in a moist environment.

3.1.8 Cracking

Concrete is a material sensitive for cracking. Generally speaking cracks develop due to:

1) Volume changes produced by the concrete itself
    a. Plastic shrinkage: caused by water evaporating from the surface of the concrete during the fresh phase. Measures against this type of shrinkage are moderate watering or covering the surface (for example with a foil).

   b. Plastic settlement: the downward (vertical) movement of the solid particles in fresh concrete. Measures are reducing the bleeding tendency and early covering to avoid evaporation.
   c. Autogenous shrinkage: the concrete's self-produced shrinkage and it is determined by the choice of constituents and the concrete mix design. The reaction between water and cement is associated with a loss in volume because the reaction product fills a lesser volume than the reactants. The phenomenon is called chemical shrinkage and is a fundamental property of cement hydration.
   d. Thermal effects: the concrete structure moves thermally, it expands during the heating phase and contracts during the subsequent cooling phase.
   e. Drying shrinkage: hardened concrete surfaces exposed to dry air will gradually dry out and develop drying shrinkage. A gradual build-up of capillary stresses and negative pore pressure is the driving force behind drying shrinkage, just as it is for plastic shrinkage, but the drying is now taking place in a stiff material. Drying shrinkage consists of a reversible and an irreversible component.
2) Degradation
3) Loads (own weight, working load, etc.)

The volume changes and cracking tendency may be strongly influenced by the concrete constituents and their volume proportions. Therefore it is important to keep these cracking mechanisms in mind when composing a concrete mixture. The reinforcement is considered to prevent cracking as a result from the loads.

3.2 Composition of the mixtures

In this section the concrete mixtures 2010 (CM2010) are composed. For the composition of a mixture is it important to know what kind of concrete you are looking for. Based on the objective the ingredients of the mixture can be determined. The second step is to proportion the materials, this is done based on the particle size distribution.

In addition to our own (basic) knowledge concerning concrete and the experiences from preceding years, a workshop was organised at the ENCI and we got some important assistance of G. Hüsken during the development process.

3.2.1 The Objective

The objective concerning the concrete mixture is to develop a white, impermeable lightweight and sustainable concrete that can cope with the forces acting on it.

Colour:
To promote white cement (a whish of our sponsor CBR, Heidelberg Cement Group), the objective is to develop a white concrete. To obtain a nice white colour all ingredients have to be as white as possible. It also excludes the use of paint.

As promotion of the white cement we want to make one special canoe. This canoe will be made with marble aggregate and will be polished after casting. This means the canoe will become heavy, but should look really great.

Permeability:
The easiest way to make the canoes watertight is to use a coating (paint, varnish, etc.). But since we want to show the material itself, the white concrete, paint is not an option. Thereby we don't want to use any other type of coating (like varnish). With a little more effort during the development of the concrete, it is possible to develop a concrete mixture that is watertight itself. Since our walls are just 5mm thick, it is important to keep the influence of the ingredients on the permeability in mind.

Density:
The lower the density of the concrete, the lighter the canoe will become. The lighter the canoe, the faster the top speed is reached, the easier the canoes can be carried and the smaller the change of cracking as result of its own weight. Enough reason to reduce the density of the concrete were possible. The density of the concrete is largely determined by the aggregate. Previous years it was required that the concrete contained sand,

nowadays all aggregate can be replaced by lightweight material, making it possible to reduce the density even more compared to previous year.

Sustainability:

Over the last years the environment is getting a more and more important issue. This environmental awareness can be noticed in the concrete industry as well. Although our canoes require small amounts of concrete and are used for just one year, there is no direct need to develop a sustainable concrete. Despite that we would like to contribute to a healthier world. Thereby concrete has an unjust negative image concerning its environmental impact. Therefore we want to develop a sustainable concrete.

Develop a sustainable concrete is a combination of three phases. During the developing phase one can chose renewable/recycled materials and/or chose local materials. For the second phase it is important that the concrete has a high quality and is durable. The longer the concrete stays in good condition (no cracks or other degradation) the longer the lifespan and the smaller the environmental impact. The third phase is the recycling phase. In case the concrete can be reused (road filling or as aggregate in new concrete) in case a construction is broken down, it is more sustainable than in case it is considered as waste.

3.2.2 Ingredients

The first step in composing the mixture is to select the materials. In this section the selected materials and their influence on the concrete are discussed.

Cement:

The Heidelberg Cement Group provided us with two types of cement, being:

- CEM I 52.5R LA – White
- CEM I 42.5N Waterproof white

Both of these cements are white and will provide enough strength. Thereby the addition ‘LA’ is indicating that it has a Low Alkali content. This means that the cement has a limited alkali content. This low alkali content has a positive influence on the durability of the concrete since it reduces the occurrence of AAR. The waterproof cement should lead to less water absorption of the concrete and thereby save weight when the canoes are in the water. In case walls would be incredibly smooth it might even result in less resistance, but this will not be achieved.

Mineral Additives:

Concerning the additives we selected two materials, being limestone powder and silica fume. The white limestone powder is non-reactive additive and serves as a filler. Thereby limestone has a positive influence on the workability of the concrete.

Silica Fume is a by-product of the smelting process used to produce silicon metal and ferrosilicon alloys. The small size makes SF a very efficient filler, which possibly serves to distribute the binder phase (C-S-H) in a more homogeneous manner in the space available. A major benefit of SF is its stabilizing effect. Tensile and flexural strength of SF concrete, cured under water, have been found to be higher than reference mixes with equal compressive strength. SF concrete is found less permeable than reference concrete of equal compressive strength. Another major advantage of SF in concrete is that it improves the resistance to chemical aggression..

Since the solid silica fume makes the concrete too grey, Cembinder 8 is used. This is white liquid substance with a solid content of 50%. Meaning that 50% of the substance is water and the other 50% is white silica fume. The Cembinder 8 improves the stability, enhances early strength, makes the concrete more cohesive and robust and enables a cement and filler reduction (which contributes to the sustainability of the mixture).

Aggregates:

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are mainly used for this purpose. For a given w/c-ratio the permeability is increasing with D_{max} of the aggregates. The reason lies in the transition zone between aggregates and paste. Thereby the thickness of our walls (< 5mm) limits the maximum particle size to 1mm. As a lightweight aggregate Liaver is used as a replacement of sand. In regard to the particle size distribution three different fractions are selected: Liaver 0.1-0.3, Liaver 0.25-0.5 and Liaver 0.5-1.0.

Besides lightweight canoes we want to make a marble canoe. To obtain the shining marble effect, it is decided to allow a larger maximum particle size. This results in a marble aggregate of 0-2mm particle size. Because of a lack of time it was not possible to acquire the most white marble available, but still the marble coming from Norway will give a nice white shining look.

Admixtures:
In this project four types of admixtures are interesting, being (super)plasticizers, air entraining admixture, retarding admixture, and pigments.

- Super plasticizers
  The main role of (super) plasticizers is to disperse flocculated cement particles in water. (Super) plasticizers can be utilized in different ways:
    - Constant strength and water content
    - Constant workability and cement content
    - Constant workability and strength
    - Increased workability

  For our purpose the super plasticizer is used to increase the workability of the concrete.

- Air entraining
  Air entraining admixtures form very small and evenly distributed air bubbles (voids) in the concrete. Air entraining admixtures are mainly added to improve the frost resistance of concrete. Use of air entrainers also leads to improved concrete workability due to the "ball bearing effect" of the air bubbles.

  Notice that the small entrained voids/pores do not easily fill with water even when the concrete is saturated. They are too big for capillary suction, so entrained air voids do not suck water. This contributes to a low permeability of the concrete and slightly reduces weight. Air bubbles that are entrapped during the mixing process, however are much bigger and have a negative influence on the permeability.

- Retarding admixture
  Chemical admixture affecting the hydration of cement to produce a delay in the process of cement paste stiffening and/or rate of hydration are termed retarding admixtures. Since the casting of the canoe takes about 5 hours, it is important that the hardening of the first batches of concrete is delayed. In this way the first chemical bonds are not destroyed during the casting process.

- Pigments
  Since the aim is to build white canoes, we add white pigment to make them even brighter white.

The use of accelerators or retarding admixtures is not necessary for the workability.

Result:
In the table below the ingredients for the concrete mixtures of 2010 are listed.

Material:	Supplier:	Details:
CEM I 52.5R LA – White	CBR	-
CEM I 42.5N Waterproof white	CBR	Water repellent
Micro Silica	Sika	Solid
Cembinder 8	Sika	Liquid, solid content of 50%
Limestone Powder	Kalksteinwerk Medenbach (CBR)	-
Liaver 0.1-0.3	Liaver	Water absorption: 1.5 mass%
Liaver 0.25-0.5	Liaver	Water absorption: 3.0 mass%
Liaver 0.5-1.0	Liaver	Water absorption: 4.0 mass%
Marble 0-2mm	CBR (Norway)	Water absorption: 1.5 mass%
White pigment (TiO_2)	Scholz	-
SikaAer Solid	Sika	Encapsuled air

Table 3.1: Ingredients concrete mixtures 2010

3.2.3 Mixtures

The second step is to determine the optimal composition. During a workshop at the ENCI in Rotterdam we gained some new ideas and composed two mixtures based on the concrete mixture of 2009. Based on the new ideas/ingredients new mixtures had to be composed. In order to determine the composition the UT Mixdesign is used. The proportioning of concrete mixtures, also referred to as mix design, covers the combination of varying ingredients to produce concrete of appropriate workability, strength and durability. The composition of a good and workable concrete mix shows that the granulometric properties of the aggregates are of utmost importance as a strong relationship exists between the granulometric properties of the aggregates and the concrete properties in fresh and hardened stage. The concrete properties are strongly influenced by the particle packing of the aggregates and the therewith connected granulometric properties. The influence of an improved particle packing on the concrete properties in fresh and hardened state is discussed manifold in literature of Brouwers & Radix (2005), Hüsken & Brouwers (2008) and Hunger (2010).

For composing the concrete mix used for the concrete canoes, the mix design concept discussed in Brouwers & Radix (2005) was used. The main purpose of this mix design concept consists in the proportioning of a performance based concrete mix. This idea is realized by the formulation of an optimization problem using the modified equation of Andreasen and Andersen (eq. (2)).

$$P(D) = \frac{D^q - D_{min}^q}{D_{max}^q - D_{min}^q} \tag{2}$$

Whereby D represents the size of the sieve used for analyzing the solid ingredients. D_{min} and D_{max} are accounting for the minimum and maximum particle size in the mix, respectively. The distribution modulus q influences the ratio between coarse and fine particles. Higher values of the distribution modulus (q > 0.5) are leading to coarse mixtures whereas smaller values (q < 0.25) are resulting in mixtures which are rich in fine particles. The variation of the distribution modulus q in combination with variations on the water to powder ratio (w/p) allows therefore for adjusting the rheological properties of the designed concrete mix as required.

The influence of these boundary conditions is considered in algorithm developed by the University of Twente which was used for composing the concrete mix. A detailed explanation of the optimization algorithm is given by Hüsken and Brouwers (2008).

The application of the algorithm requires a careful analysis of the raw materials regarding their grading. If the particle size distribution (PSD) of the raw materials is known, the raw materials are combined that they follow the given target line (eq. (2)) as close as possible.

For the determination of the different ratio’s between water and cement, binder and powder, the following formulas apply:

- Effective water cement ratio: $$w/c = \frac{M_{water}}{M_{cement}} \tag{3}$$

- Total water cement ratio: $$w/c = \frac{M_{water,hydration} + M_{water,aggregates}}{M_{cement}} \tag{4}$$

  Where ‘$M_{water,hydration}$’ = water that is available for the hydration

- Water binder ratio: $$w/b = \frac{M_{water}}{M_{cement} + k * M_{silica}} \tag{5}$$

  Where ‘k’ is the binder factor

- Water powder (<125 µm) ratio: $$w/p = \frac{M_{water}}{M_{powder}} \tag{6}$$

To save weight and to increase the concretes sustainability the cement content was reduced from 450kg/m^3 to 400kg/m^3. Besides influencing the amount of pigment (4-5% of cement mass) this influences the w/c-ratio, the w/b-ratio and the w/p-ratio. Concerning the w/b-ratio, the maximum amount of micro silica that can be taken into account concerning the water-binder factor and the minimum amount of cement should comply to the requirement:

Silica fume / cement ≤ 0.11

In case a larger amount of silica fume is used, the excess may not be counted for the 'k-factor'. In our mixtures the mass of the silica fume relative to the mass of the cement is far less than 0.11. Therefore all silica fume can be taken into account as a binder. The value of the 'k-factor' is 2. (Krikhaar, 2010).

Based on the workshop at ENCI Rotterdam, the selected ingredients and the UT Mixdesign, several mixtures are composed. Since this is an iterative process, several series of mixtures are composed and tested. Below these mixtures are shortly explained, their exact composition can be found in appendix 2.

ENCI Rotterdam:		*Adaption mixture 2009*
Mixture I	Series 0	Replacing sand by Liaver
Mixture II	Series 0	Replacing sand by Liaver and reduction of the amount of cement
Marble Mixtures:		*Marble as aggregate*
Mixture 1a:	Series 1	More coarse particles compared to mixture 1b. Micro silica as additive
Mixture 1b:	Series 1	More fines compared to mixture 1a. Micro silica as additive.
Mixture 1.1:	Series 2	Higher w/c ratio as series 1. Micro silica as additive.
Mixture 1.2:	Series 2	Higher w/c ratio as series 1. Cembinder 8 as additive.
Mixture 1.3:	Series 2	Higher w/c ratio as series 1. Limestone as additive.
Mixture 1.4:	Series 3	Combination of Cembinder 8 and Limestone as additive, not based on Mixdesign
Mixture 1.5:	Series 4	Combination of Cembinder 8 and Limestone as additive, based on Mixdesign
Mixture 1.6:	Series 4	Same as mixture 1.5, only with a marble aggregate fraction of 0-1mm.
Lightweight Mixtures:		*Liaver as aggregate*
Mixture 2a:	Series 1	More fines compared to mixture 2b. Micro silica as additive.
Mixture 2b:	Series 1	More coarse particles compared to mixture 2a. Micro silica as additive.
Mixture 2c:	Series 2	Addition of SikaAer, density below 1000kg/m^3
Mixture 2d:	Series 3	Reduction of the amount of SikaAer to 1.5 mass% of the cement.
Mixture 2.1:	Series 4	Higher w/c ratio as series 1, 2 & 3. Micro silica as additive, no SikaAer.
Mixture 2.2:	Series 4	Higher w/c ratio as series 1, 2 & 3. Cembinder 8 as additive, no SikaAer.
Mixture 2.3:	Series 4	Higher w/c ratio as series 1, 2 & 3. Limestone powder as additive, no SikaAer.
Mixture 2.4:	Series 5	Combination of Cembinder 8 and Limestone as additive, not based on Mixdesign
Mixture 2.5:	Series 6	Limestone as additive. Addition of SikaAer with a maximum of 2 mass% of cement.
Mixture 2.6:	Series 6	Combination of Cembinder 8 and limestone as additive, based on Mixdesign. Addition of SikaAer with a maximum of 2 mass% of cement.
Mixture 3.1:	Series 7	Based on mixture 2.6. Ordinary cement replaced by waterproof cement

All these mixtures were tested in the concrete lab. For each mixture the amount of Super Plasticiser required to give the mixture the perfect workability characteristics, was determined. Next a series of prisms and tiles. The prisms were tested after 28 days and based on the results (see next section), the colour and the workability of the mixtures the best mixture for our canoes could be determined.

3.3 Analysis

This section concerns the analysis of the test results. All mixtures mentioned above have been tested. Based on the experiences in the concrete lab new mixtures were developed, making the proportioning of the mixtures an iterative process.

3.3.1 Workability and Colour

Two important indicators were the workability and the colour. The workability could be tested at the moment of casting and the colour during demoulding (the day after casting). Meaning that feedback concerning these indicators was available fast, making it possible to adjust the proportioning in a short time span.

During the first series it was notice that the lower the w/c-ratio, the more difficult it became to determine the required amount of super plasticizer and a corresponding desired viscosity of the concrete. Since a low w/c-ratio results in a higher strength and therefore makes the concrete more brittle, it was decided to increase the w/c-ratio. This because it is not necessary to have a high strength concrete and a more flexible concrete is preferred. The only disadvantage is, is that a higher w/c-ratio results in a more permeable concrete. It is assumed that the effect on the permeability by increasing the w/c-ratio slightly is annulled by the positive effect on the permeability concerning Micro Silica, air entrainment and a optimal particle size distribution. By increasing the w/c-ratio, it became easier to achieve the desired workability.

Another improvement concerning the workability concerned the addition of limestone powder. In first instance the limestone powder was excluded from the mixtures, since it was not pure white and was non-reactive, it served as a filler. At the moment the limestone powder was included, the workability improved considerably. Therefore it was concluded that the limestone powder should be included in the mixture.

Figure 3.1: Colours of limestone (left), Micro

When looking at the colour it soon became clear that the micro silica had a negative influence on the appearance. Since the smallest particles determine the colour, the micro silica contributes to appearance of the concrete. Despite the addition of white pigment, the concrete became light grey in case micro silica was added. Because the positive influence of micro silica on the concrete properties, we didn't want to exclude it. Therefore we looked for an alternative. The alternative became Cembinder 8. This is a white liquid substance with a solid content of 50%. Meaning that 50% is water and the other 50% is white micro silica. In this way micro silica could be included in the mixture without any negative effect on the colour.

3.3.2 Strength

Because of the workability and the colour, several mixture were not applicable for our canoes. Therefore only the remaining suitable mixtures are tested concerning their strength. Since the equipment at our University was not working as a result of missing parts and is not really made for testing flexural strength, the testing took place at the laboratory of Rokramix Enschede. The flexural strength was tested with a 3 point bending test. With the two remaining pieces of the prisms the compressive strength was tested.

The table below shows the density of each mixture and the flexural - and the compressive strength after 28 days of curing. It concerns the averages, the exact test results can be found in appendix B.

Mixture:	Density [kg/m^3]:	Flexural Strength [N/mm^2]:	Compressive Strength [N/mm^2]:
Mixture I	1171	Not available	36.3
Mixture II	1120	Not available	33.1
Mixture 1.2	2291.9	11.01	70.90
Mixture 1.3	2267.8	8.11	53.10
Mixture 1.4	2291.9	9.64	67.20
Mixture 1.5	2231.9	8.92	58.12
Mixture 1.6	2175.0	8.33	51.73
Mixture 2.2	1096.8	5.51	26.69
Mixture 2.3	1222.0	5.53	28.11
Mixture 2.4	1171.0	5.36	32.76
Mixture 2.5	1205.9	4.90	27.85
Mixture 2.6	1194.0	5.25	33.22
Mixture 3.1*	1194.0	4.66	25.25

Table 3.2: Density and average strength of the mixtures (tested after 14 days).*

As can be seen in table 3.2 the marble mixtures have an average compressive strength slightly higher than the strength of the cement (52,5N). The strength of the lightweight mixture is considerably lower. This can be subscribed to the effect of the SikaAer and the use of Liaver as aggregate. Meaning that for the marble mixtures, the cement determines the strength and for the lightweight mixtures the aggregate in combination with an weakened paste strength determine the strength.

Figure 3.2: Test Facility at Rokramix

Figure 3.3: Broken test samples

Concerning the marble mixtures, it can be noticed that mixtures 1.2 and 1.4 have a higher strength compared to the others. When looking at the proportioning of these mixtures compared to the others it can be noticed that they both contain considerably more micro silica. This supports the fact that the micro silica, as described in the theory, contributes to the strength development of the concrete. When looking at the strength of the lightweight mixtures no large differences can be seen, this because the aggregate determines the strength.

Concerning the densities there are no big differences within the same types of concrete. Compared to previous year a weight reduction of about 7-8% is obtained. Unfortunately not enough to reach a density of around 1000kg/m^3. To develop a concrete with a lower density while not losing too much strength and keep a nicely workable mixture, several more iterations are required. These iterations were not made because of a lack of time. But the iterations that are made gave us a lot of insight in the properties/influence of the materials within the concrete. With this knowledge we can improve the concrete for next season.

Previous year plates were produced of +/- 4mm thick containing two layers of fibreglass mesh. In order to prevent disturbance at the edges, three slabs of 450mm x 150mm x 4mm were cut from each plate. These slabs would represent the walls of the canoe and were tested on elasticity at BAS bv. These plates turned out to be very flexible and therefore fulfil our requirements abundantly.

Since it requires a lot of effort and time to produce these slabs for the vast amount of mixtures this year and to test these slabs, we argued if this test was necessary again. Because the reinforcement is similar to that of last year and the concrete shows similar characteristics as that of last year, we expect that the concrete will show the same flexibility. Therefore it was decided not to put a lot of effort in testing the flexibility again.

3.3.3 Conclusion

Concerning the workability of the mixtures it can be concluded that the mixtures containing the limestone powder have a better workability than the mixtures lacking the limestone powder. For the marble mixtures it is found that mixtures 1.3 and 1.5 have the best workability. Concerning the lightweight mixtures it is found that mixtures 2.3, 2.5, 2.6 and 3.1 have the best workability. Of these mixtures only 1.5, 2.6 and 3.1 contain a combination of the limestone powder and micro silica (Cembinder 8). Since the positive effect of the micro silica on the concrete properties, it is desired to select a mixture containing micro silica/Cembinder 8.

When looking at the colour of the mixtures it can be concluded that all mixtures without the solid micro silica have a nice white appearance. Concerning the strength of the mixtures it can be concluded that all mixtures are within the required strength range.

Combining the experiences concerning the workability, the white appearance, the strength and the flexibility of the concrete, it can be concluded that mixtures 1.5, 2.6 and 3.1 are the most appropriate mixtures for our concrete canoes. The proportioning of these mixtures, additional information and their particle size distribution is shown below.

Mixture 1.5:

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	111.8	296.4
Marble 0-2mm	460.2	1219.6
White Pigment (TiO2)	5.1	20.0
$Water_{total}$	255.8	255.8
$Water_{add}$	238.6	238.6
Air	20.0	
Total:	**1000.0**	**2231.9**

Additional information:	
Glenium 51:	0.3kg/m^3
w/c ratio:	0.64
w/b ratio:	0.53
w/p ratio:	0.30
Pigment:	5% cem. mass
Air:	2%

Table 3.3: Mixture 1.5

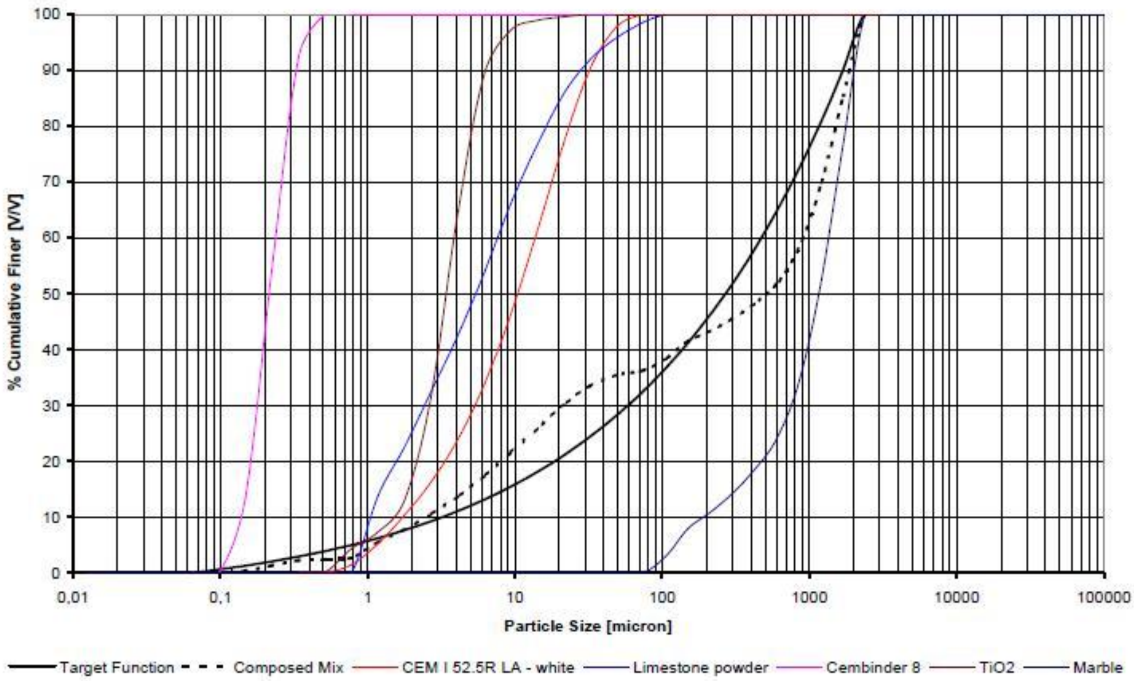


Figure 3.4: Particle Size Distribution mixture 1.5

Mixture 2.6:

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White / CEM I 42.5N Waterproof White	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	94.0	249.0
Liaver 0.1-0.3	234.2	140.5
Liaver 0.25-0.5	114.0	61.6
Liaver 0.5-1.0	128.9	58.0
White Pigment (TiO2)	5.1	20.0
SikaAer	40.0	8.0
Water$_{total}$	216.8	216.8
Water$_{add}$	199.6	199.6
Air	20	
Total:	**1000.0**	**1194.0**

Additional information:	
Glenium 51:	1.3kg/m^3
w/c ratio:	0.54
w/b ratio:	0.45
w/p ratio:	0.30
Pigment:	5% cem. mass
Natural air:	2%
Entrained air:	4%

Table 3.4: Mixture 2.6 & Mixture 3.1

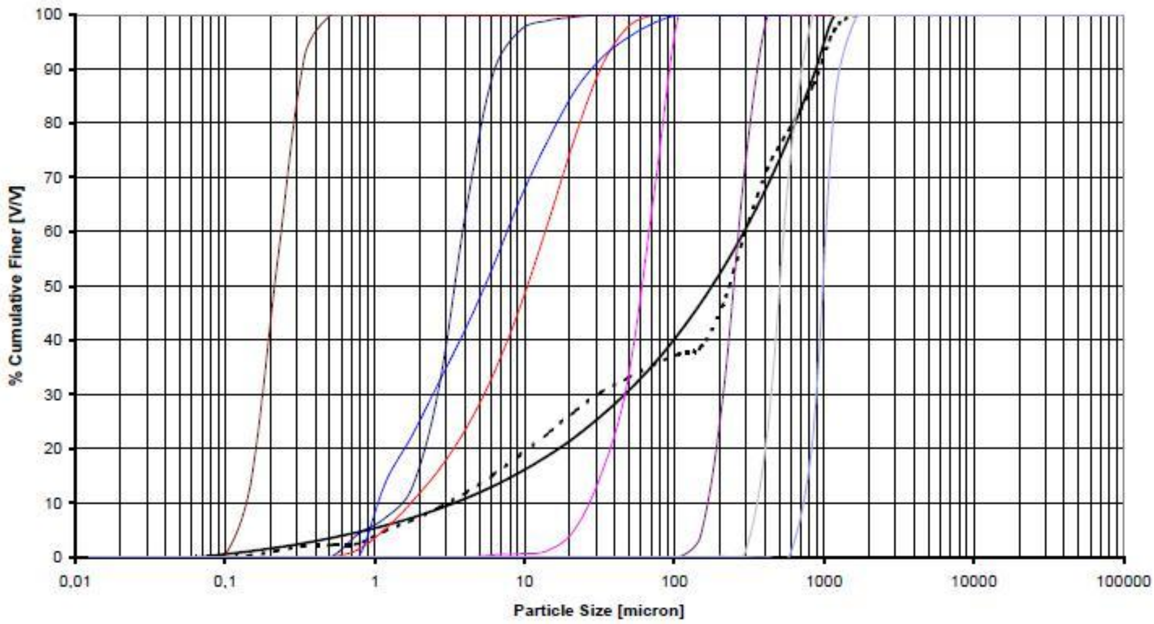


Figure 3.5: Particle Size Distribution mixture 2.6

3.4 Material Status

While the construction (reinforcement) and the concrete mixture are known, only the materials for the finishing touch remain. Because the canoes are not allowed to sink in case of breaking or capsizing, air chambers are needed. Therefore two big air balloons of 65 litre are used. Furthermore tubes are placed on the edges for aesthetics and safety (prevents scratches from sharp edges). Finally the name, sponsors and number are painted on the walls. In the table below (table 3.5) the material status of our canoes is given, in this table all used materials and their specification are mentioned.

Element:	Material:	Specification:	Amount:	Total:
Marble Concrete	CEM I 52.5R LA White	0.400 kg/l	45l	18.000 kg
	Limestone powder	0.296 kg/l		13.336 kg
	Cembinder 8	0.048 kg/l		2.167 kg
	Marble 0-2mm	1.220 kg/l		54.884 kg
	White Pigment (TiO2)	0.020 kg/l		0.900 kg
	$Water_{add}$	0,239 kg/l		10.737 kg
	Air	-		- kg
Lightweight Concrete	CEM I 42.5N Waterproof White	0.400 kg/l	45l	18.000 kg
	Limestone powder	0.249 kg/l		11.205 kg
	Cembinder 8	0.048 kg/l		2.169 kg
	Liaver 0.1-0.3	0.141 kg/l		6.323 kg
	Liaver 0.25-0.5	0.062 kg/l		2.772 kg
	Liaver 0.5-1.0	0.058 kg/l		2.610 kg
	SikaAer	0.008 kg/l		0.360 kg
	White Pigment (TiO2)	0.020 kg/l		0.900 kg
	$Water_{add}$	0.200 kg/l		8.982 kg
	Air	-		-
Reinforcement	Steel cord 0.59+6x0.52 Ø=4.40 mm^2 MBL=5016N	1140 N/mm^2	20m	20m
	Steel cord 0.66+6x0.59 Ø=5.0 mm^2 MBL=7560N	1540N/mm^2	12m	12m
	Stucco-Mesh	5x5mm	2 layers	13.5 m^2
	Anchor plate	250X100mm	2 pcs	2 pcs
	Anchor connection ironware	-	4 pcs	4 pcs
Air chambers	Air bags	65l	2pcs	130l
	Connection ironware	-	8 pcs	8pcs
	Steel cord 0.59+6x0.52 Ø=4.40 mm^2 MBL=5016N	1140 N/mm^2	4 m	4m
	D shackle	-	8 pcs	8 pcs
Completion	Paint	Dark blue	1 l	1l
	Tube	-	2 pcs	12 m
	Seating foam	-	2 pcs	2 pcs

Table 3.5: Material Status Concrete Canoes

Part 4

A process description of construction year 2010

In this fourth part of the report the focus is on the process of construction year 2010. From a nice design on a computer screen to a beautiful concrete canoe requires a lot of blood, sweat and sometimes even tears. Things sometimes seem to work in theory, but practice can prove otherwise. That's why it is important to be creative, flexible and always looking for solutions. This part gives a clear insight in the construction process of our canoes and everything that comes along with it. But only building a beautiful concrete canoe doesn't guarantee victory during the race. That's why also training plays an important role in our way to success!

4.1 Project Planning

This first section of the process description gives more insight in the project planning behind the construction of our concrete canoes. First of all an indication is given of the time spent on this time consuming hobby. This is followed by a Gantt Chart, giving insight in the duration of the activities and the moment they took place. Finally a insight in the required resources for the construction of a concrete canoe is given.

4.1.1 Time spent

From the start of the season we recorded the time spent on the project. This was done for 7 categories, being:

- Management: With management we means everything from meetings, sending e-mails, arranging sponsors, make and update the website, etc.
- Training: Many hours have been spent in the swimming pool (during the winter) and on the Twente Canal (spring). Over the season we recorded how many of us joined the weekly trainings of 1.5 hours.
- Mould: At the start of the season the mould is refurbished. The time spent on plastering, sand papering and varnishing was recorded.
- Concrete: This year a lot of effort was put in developing a new concrete. This category includes all hours spent in the concrete lab for testing mixtures, casting samples and cleaning.
- Construction: during the season five canoes have been constructed. This means prepare the mould, cast the concrete and demould the canoe. In total this is by far the most time consuming.
- Finishing Touch: After demoulding, a finishing touch is required. At this moment the canoes can be post-tensioned, the marble canoe could be sand papered/polished and the logo's could be painted on.
- Construction Report: To give a clear insight in the way the canoes are constructed this construction report had to be written.

Figure 4.1 gives a good indication how much time is spent on these 7 categories throughout the season.

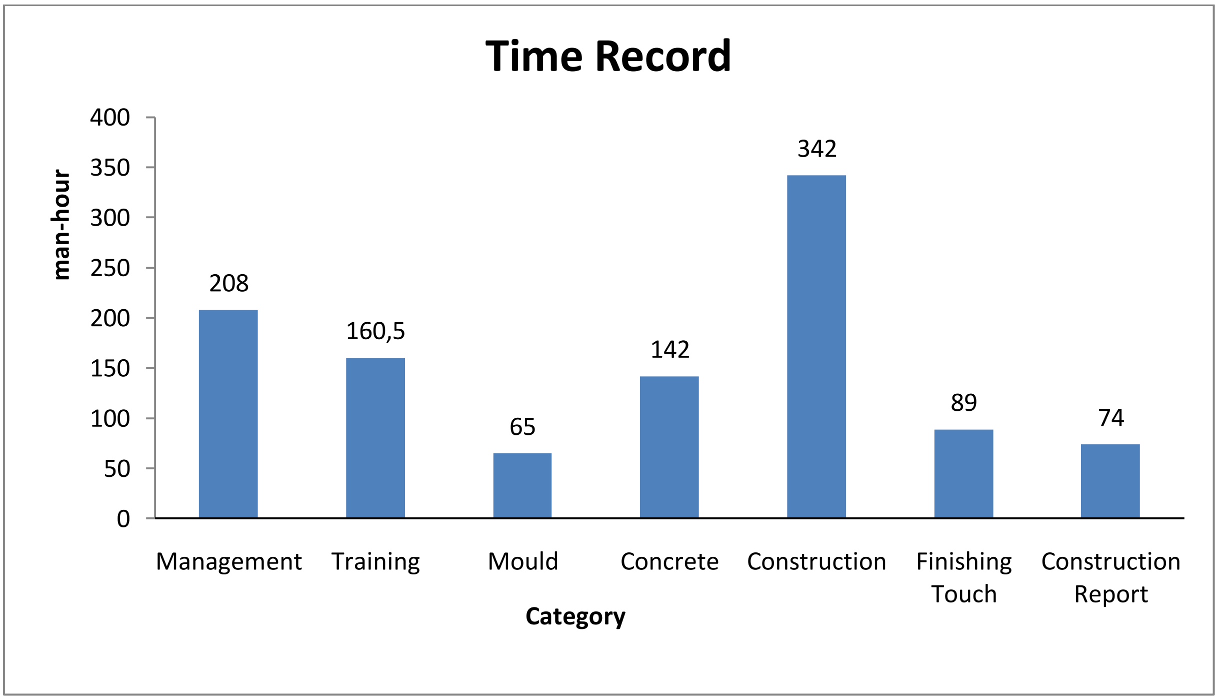
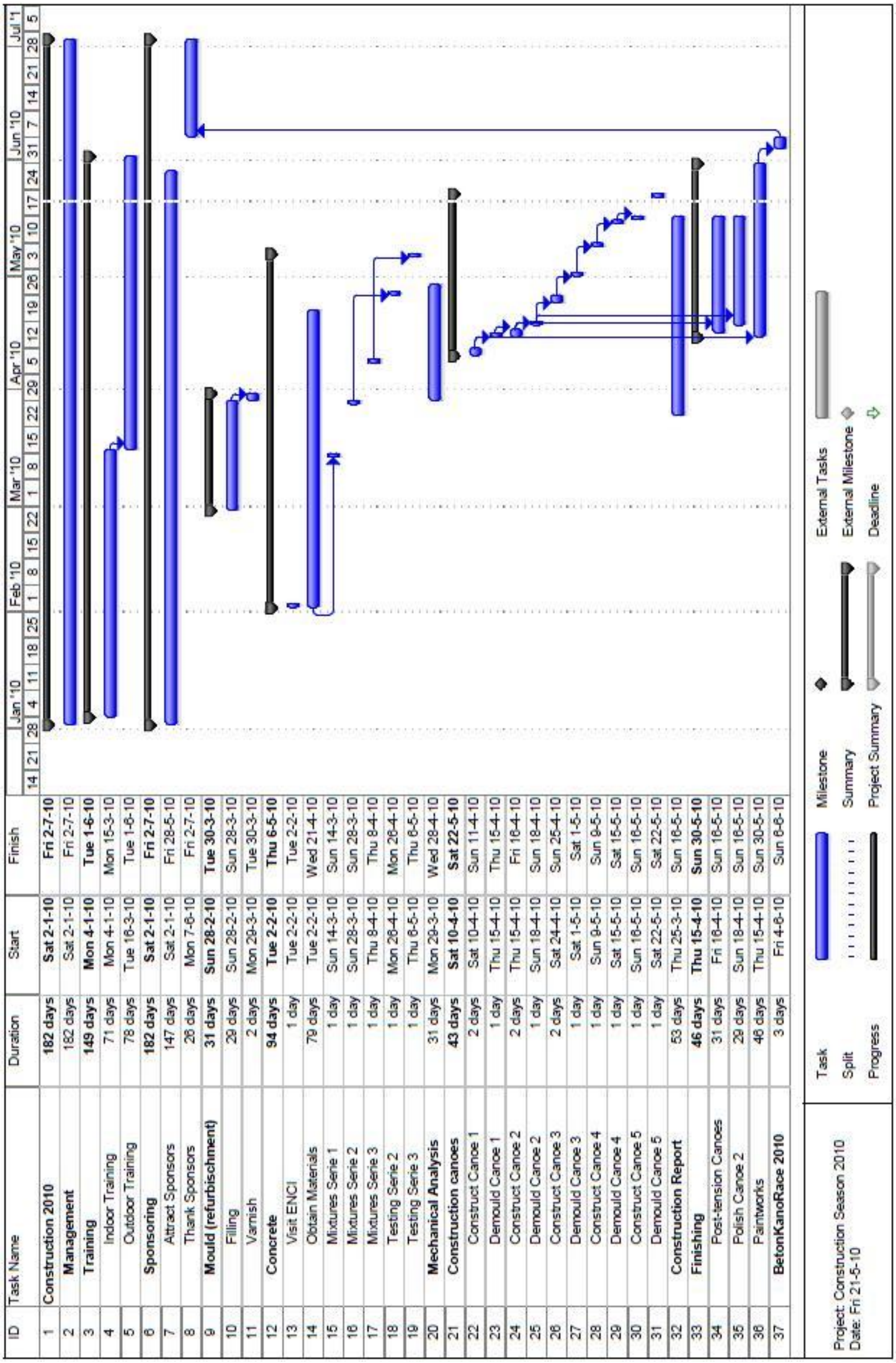


Figure 4.1: Time Record

As can be seen in figure 4.1 a lot of time has been spent. In total 1080,5 man-hours have been spent to be completely ready for the concrete canoe challenge. During the most time consuming activity, the actual construction of the canoes, we luckily gained some help from other active members of our study association.

4.1.2 Gantt Chart

The oldest formal planning technique in use today is the bar chart, also termed Gantt Chart. On the next page the Gantt Chart of season 2010 is shown (figure 4.2). This chart shows what is to be done and when it is to be done. When the number of activities is not too great, like in this project, the bar chart is perfectly satisfactory….



ID	Task Name	Duration	Start	Finish
1	**Construction 2010**	**182 days**	**Sat 2-1-10**	**Fri 2-7-10**
2	**Management**	182 days	Sat 2-1-10	Fri 2-7-10
3	**Training**	**149 days**	**Mon 4-1-10**	**Tue 1-6-10**
4	Indoor Training	71 days	Mon 4-1-10	Mon 15-3-10
5	Outdoor Training	78 days	Tue 16-3-10	Tue 1-6-10
6	**Sponsoring**	**182 days**	**Sat 2-1-10**	**Fri 2-7-10**
7	Attract Sponsors	147 days	Sat 2-1-10	Fri 28-5-10
8	Thank Sponsors	26 days	Mon 7-6-10	Fri 2-7-10
9	**Mould (refurbischment)**	**31 days**	**Sun 28-2-10**	**Tue 30-3-10**
10	Filling	29 days	Sun 28-2-10	Sun 28-3-10
11	Varnish	2 days	Mon 29-3-10	Tue 30-3-10
12	**Concrete**	**94 days**	**Tue 2-2-10**	**Thu 6-5-10**
13	Visit ENCI	1 day	Tue 2-2-10	Tue 2-2-10
14	Obtain Materials	79 days	Tue 2-2-10	Wed 21-4-10
15	Mixtures Serie 1	1 day	Sun 14-3-10	Sun 14-3-10
16	Mixtures Serie 2	1 day	Sun 28-3-10	Sun 28-3-10
17	Mixtures Serie 3	1 day	Thu 8-4-10	Thu 8-4-10
18	Testing Serie 2	1 day	Mon 26-4-10	Mon 26-4-10
19	Testing Serie 3	1 day	Thu 6-5-10	Thu 6-5-10
20	**Mechanical Analysis**	31 days	Mon 29-3-10	Wed 28-4-10
21	**Construction canoes**	**43 days**	**Sat 10-4-10**	**Sat 22-5-10**
22	Construct Canoe 1	2 days	Sat 10-4-10	Sun 11-4-10
23	Demould Canoe 1	1 day	Thu 15-4-10	Thu 15-4-10
24	Construct Canoe 2	2 days	Thu 15-4-10	Fri 16-4-10
25	Demould Canoe 2	1 day	Sun 18-4-10	Sun 18-4-10
26	Construct Canoe 3	2 days	Sat 24-4-10	Sun 25-4-10
27	Demould Canoe 3	1 day	Sat 1-5-10	Sat 1-5-10
28	Construct Canoe 4	1 day	Sun 9-5-10	Sun 9-5-10
29	Demould Canoe 4	1 day	Sat 15-5-10	Sat 15-5-10
30	Construct Canoe 5	1 day	Sun 16-5-10	Sun 16-5-10
31	Demould Canoe 5	1 day	Sat 22-5-10	Sat 22-5-10
32	**Construction Report**	53 days	Thu 25-3-10	Sun 16-5-10
33	**Finishing**	**46 days**	**Thu 15-4-10**	**Sun 30-5-10**
34	Post-tension Canoes	31 days	Fri 16-4-10	Sun 16-5-10
35	Polish Canoe 2	29 days	Sun 18-4-10	Sun 16-5-10
36	Paintworks	46 days	Thu 15-4-10	Sun 30-5-10
37	**BetonKanoRace 2010**	3 days	Fri 4-6-10	Sun 6-6-10

Figure 4.2: Gantt Chart

….and thus it is by far the most common technique used to plan and control work on smaller projects. It is a good communication medium, as the chart forms a clear picture of the project. This makes the Gantt Chart ideal to plan and control our project. By using this chart it is clear for al team members what is to be done and when. Since this chart is digitally made (MS Project), it is easy to update and keep the project under control.

In their simplest form the basic planning techniques are used to determine what is to be done when it is to be done; this is not sufficient for project planning and control. They must also be used to determine who does what and when, as it is absurd to plan the work on a project, without planning and controlling the resources required, primarily manpower. Therefore insight is given in the resource planning concerning the most complicated and complex activity during the season: the casting of a concrete canoe.

4.1.3 Resource Planning

Casting of the concrete canoes is the most demanding activity concerning resource planning. Therefore the resource planning for this activity is outlined in this section. First of all the required manpower is considered. For casting a concrete canoe 10 people is the optimum amount. With more people there is not enough space to work and with less people the process is slowed down.

About two hours before casting the preparations start:

- 1 person oiling the mould
- 2 people placing the steel cords
- 1 person preparing the first batch of concrete (weighing 10litre)

After the preparations the mixing process starts and therefore also the casting process. This is an continuous process of weighing the materials, mixing them and casting.

- 1 person weighing and mixing of the materials
- 8 people casting
- 1 person cutting and placing the mesh. This starts after the first batch of concrete is casted.

When all concrete is casted the finishing process starts:

- 4 to 5 people take care of the finishing: scraping away excess concrete and smoothen the edges.
- 3 to 4 people place paper on the concrete after the finishing. The paper is sprayed with water for optimal curing.
- 1 person, our Fry King, is preparing some delicious snacks during the finish and curing activities. These can be enjoyed in combination with a delicious cold beer when all work in done.

This results in a resource diagram as shown in figure 4.3 below.

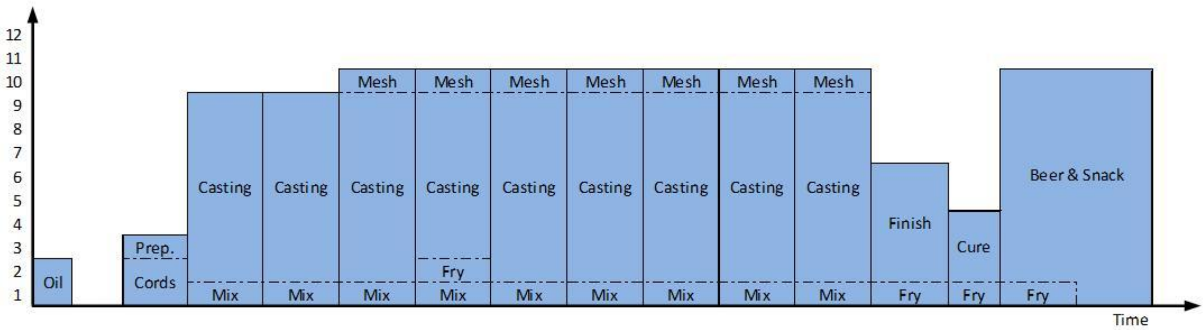


Figure 4.3: Resource Diagram of manpower required for casting a canoe

Besides manpower also materials are required, these material resources for casting a canoe are listed below:

- Oil: biodegradable demoulding oil is used to oil the mould. This oil doesn't influence the colour of the concrete neither the bonding effect of paint.
- Steel cord: the steel cord is part of the reinforcement and is attached to the steel frame on which the mould is resting. In total 25 metre of Ø=4.40 mm^2 cord and 16 metre of Ø=5.0 mm^2 cord is required
- Concrete: in total 50litre of concrete is mixed. In the end about 45 litre is used for the canoe and about 5 litre is wasted by cleaning the mixer and during construction.
- Mesh: in total 13.5m^2 of stucco mesh is placed in the canoe. Because of the shape of the mould, some mesh is wasted. Therefore a minimum of 15m^2 mesh is required for one canoe.
- Vaseline & Gloves: to protect the skin from drying out as a consequence of casting concrete the people who are casting rub in their hands with Vaseline and wear latex gloves to protect their hands. About 50ml Vaseline and 70 gloves are required for casting a canoe.

- Paper: for curing and cleaning purposes half a roll of paper towel is used.
- Soda: hydration is important. Therefore a minimum of 7.5 litre soda is consumed during a day of casting.
- Beer & snacks: after the hard work is done, the human body needs to recover. The best way to do this is with beer & snacks. An average of 1 box of beer, 20 frikandellen, 12 burgers and 40 bitterballen are consumed.

The listed resource above have to be present on site before the construction of a canoe can start. Since our team consists of eight, since the 16th of May nine, people, this is not sufficient to construct a canoe. Thereby not all members can be present each time. This makes it necessary to arrange external people before we can construct a canoe. Luckily there are more people with a fascination for concrete within our study association.

4.2 In preparation of construction

Before construction of the canoes can start, preparations have to be taken. Previous year this meant that a new mould had to be constructed and a concrete mixture had to be developed. Since it is quite an investment (time, knowledge and money) to develop a new design and mould, it was decided to use the design/mould for a second season and start on a new design for season 2011. The consequence of this decision is that the old mould had to be refurbished. Thereby a new concrete mixture was developed. The process behind these two activities are described below.

4.2.1 The refurbishment of the mould

Last year, four amazing canoes were constructed based on a new concept. After the races in Roermond and Essen, we could conclude that the shape of the canoe is close to perfect. The mould itself was far from perfect. During the construction there was the time pressure to get the model done. This resulted in some irregularities: there were some wood nerves in the mould and after making four canoes the surface of the mould was damaged. Making a canoe with this mould would not result in a really smooth canoe. To improve the canoes we decided to refurbish the mould. After sanding the surfaces and filling the holes with a bumper repair kit, the surface was totally smooth and was painted by a car painter. The whole process was done in five steps:

Step 1: Sanding the mould

To make the surface ready for filling the mould had to be sanded first. The very first thing done was cleaning it really good. After that the real process could begin. Sanding is a special job normally done be people educated for it. We decided to collect some information from the internet and do it ourselves. There was started with sanding paper type 120, this paper is essential to remove the largest irregularities, good sanding with type 120 will result in a smooth mould. After type 120, the scratches done by this paper were removed by the types 220 and 320. Now the mould was ready for the next step: filling.

Step 2: Filling with a bumper repair kit.

Now the surface was ready, the filling could start. The selection of the filling material was a difficult process. There are a lot of different filling materials, the task was to find one suitable for our mould. Because making and demoulding a concrete canoe is tough process, the mould should be resistant to a lot of vibrations. All normal fillers fail at this characteristic, by too much vibrations they lose their strength and burst open. Broken filler should be catastrophic for the mould and would result in a worse canoe than before. After some good conversations with a filler consultant, a bumper repair kit was chosen. This filler special made to be resistant to a lot of vibrations was the perfect choice for our mould.

The filling was done by technique which was found by the method of trial and error. First the filler had to be created, the two components had to be mixed to create a hardening filler. The filling was done with special “filling knifes”. First a layer of filler was put on the mould, and then the excess was scraped off. The whole canoe was done by this technique, the next step would be sanding the irregularities of the filler to create a really smooth surface.

Step 3: Sanding the filler

As told before filler had to be sanded to create a totally smooth surface. This was done by sanding papers 220 and 320. Doing the sanding the idea came to make the mould perfect by another time of filling. So far so good, the next step is filling the last irregularities.


Step 4: Filling again

The BetonBrouws strive to perfection, this is seen in this step! The first layer of filler was almost perfect but not good enough, it takes some time but it will finally result in a quicker canoe. So why not filling again. The whole canoe was filled again by the same process as described in step 2.

Step 5: Sanding till ready for painting

Now it was sure the filling was perfect done. The final sanding could start. Started was with the same procedure as in step 3, with papers 220 and 320. But to make the mould well prepared for painting an almost polished mould was needed. After paper 320, papers 400, 500 and 600 were used to sand the filler. Sanding paper 600 made the surface so smooth that only a thin layer of paint would make the mould shine. And that was what we wanted, a shining mould!



Step 6: Painting

The last step was the step with only a bit work, but it was really essential to create a good mould. Because good painting is really complicated we decided to ask some car painters if they would like to help us with our canoe. The car painter 'Stoeten' was able to paint the mould for a reasonable price. After bringing the mould in the morning, the paint was dry in the afternoon and the mould could be picked up again. Now we were able to construct our first canoe in a shining mould!

4.2.2 The development of a concrete mixture

The development of the new concrete mixture started with a brainstorm about the objectives we wanted to achieve this year (see section 3.2.1). It was decided that this year would be an experimental year in which we wanted to explore the possibilities to reduce the density of the concrete even further, without affecting its properties. Thereby we wanted to make the concrete more sustainable and to see if we could make a bright white concrete. The new mixture should be an important step towards the mixture of season 2011.

Step 1: Workshop at ENCI Rotterdam

With these objectives we went to the ENCI in Rotterdam. First an introduction about the company and cement was given after which we discussed our objectives for the new concrete. When our objectives, and their consequences for the mixture, were clear it was time to stretch our legs and see the cement factory. In the afternoon we composed two new mixtures based on the mixtures of 2009 and went into the laboratory. First the water absorption of the aggregate was determined. With this knowledge the new mixtures were tried. In the end the right workability was obtained and test prisms were casted. Loaded with new knowledge and ideas concerning our concrete mixture we went back to Enschede.






Step 2: Obtaining the materials

From this moment we had a good insight in the materials we wanted to use/test. The materials we didn't posses were ordered, being the cement, limestone powder, micro silica, white pigment, lightweight aggregate and marble. In order to make the concrete as white as possible, we tried to obtain Poraver instead of Liaver. This because Poraver is a lightweight aggregate with comparable properties as Liaver only its white instead of grey. Unfortunately we didn't manage to obtain the Poraver, meaning that we had to use Liaver as aggregate for the lightweight mixture. Another slight setback was the marble. The marble was not as white as we expected it to be. Thereby it had to be dried and sieved before it was ready to use. This meant that a lot of time was spent on drying but especially sieving all the marble to a fraction of 0-2mm. Thereby the sieve curve of the marble was determined in order to process it in the Mixdesign.

Step 3: The iterative process of proportioning mixtures

While waiting on the other materials several mixtures were composed in cooperation with PhD Götz Hüsken. At the moment all materials arrived, the testing could start. Many hours were spent to achieve the right workability and a bright white colour. Since the development of a perfect concrete mixture is an iterative process, many adjustments were made concerning the proportioning and tested. In total 19 mixtures have been tested. Due to the lack of time it was not possible to do more iterations and test more mixtures.


Step 4: Test the mixtures on strength
The final step was to test the mixtures on the their flexural and compressive strength. Only the mixtures with an acceptable workability and a white colour were tested. Since the equipment at our University was not working as a result of missing parts and is not really made for testing flexural strength, the testing took place at the laboratory of Rokramix Enschede. The flexural strength was tested with a 3 point bending test. With the two remaining pieces of the prisms the compressive strength was tested.

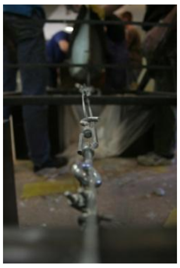
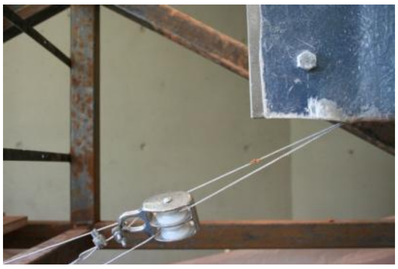

4.3 Constructing beauties

Above it is explained how the mould is refurbished and how the concrete mixture was developed. In this section it is explained how this concrete mixture in combination with the reinforcement and the refurbished mould result in beautiful concrete canoes. The following points are important for successful casting:

- Adequate formwork quality
- Concrete workability
- Casting technique
- Curing conditions

Throughout the description of the casting process below, these points can be recognized.

At the start of creating a concrete canoe stands a cleaned mould. This clean mould is placed on a steel framework, which forms the work platform during construction. The idea of the mould is that it will give the concrete the right shape and that the concrete canoe can be taken out of it. When we have the clean mould in place it is time for oiling the mould. The water based demoulding oil is sprayed onto the mould. The oil was sprayed onto the mould some time before poring the concrete would take place, this for creating a possibility for the water to evaporate. In the mould, on the bottom, three steel cords are placed, intended for pre-stressing. One cord is going through the middle while the other two cords run through the corners of the bottom. Besides three cords in longitudinal direction, also three cords in cross direction were placed. These cords are intended to make the cracks in the longitudinal direction smaller or even disappear. The cords were hold in position with the help of little holes in the mould and the use of iron wire. After placing the cords, they were put on tension (not with the final force because the mesh has to be placed underneath the cords). After this it is almost time for starting the casting, but first we need to try rub the surface in with grease and on the other hand to make the cords grease free. This for obvious reasons.


When we got the mould in the condition of a greased surface and ungreased cords it's time for casting. This means that all materials can be weighted in the right proportions and the mixture can be made. First the dry materials are put into the mixer. We use a batch mixer, type forced action mixer, whereby the concrete is mixed by paddles rotating through the concrete. When the dry materials are mixed properly the liquids are added. This created a stiff mix of materials. To make obtain the right workability Super Plasticizer (SP) is added. The process of adding the SP is a delicate matter. A little bit too much turns the mixture in a white soup and is far from ideal, but a little bit too less makes the mixture to dry and not workable either. But, when the right consistency if found, the mixture is ready to be processed.



For a strong and flexible canoe the section of the canoe will be layered as follows; a thin layer concrete – mesh (underneath the cords) –another layer of concrete – mesh again – and eventually the last layer of concrete. This process will go step by step starting in the front and working towards the back of the canoe. The challenge with this process is that it needs a constant flow of concrete, because the layer concrete won't dry out in such degree that it won't adhere with the next one. As an experiment, we have tried to construct a canoe with just one layer of mesh and with very thin wall (3mm). Only on the position of the canoeists two layers of mesh were used. This canoe eventually weight just 32kg! Unfortunately the construction turned out to be too weak to cope with the forces acting on it during lifting and the experiment failed. Luckily we learned from this experiment and had time to construct a fifth canoe.



As told earlier in this report we used five cords per canoe. The remaining two cords are placed on the top of the walls of the canoe during the process. When the concrete had enough time to harden these cords are stressed afterwards. While working from front to the back three ribs were created at the location where the cords in cross direction are located. After reaching the back of the canoe the cords could be put on the right tension. This was done by pushing the framework apart with the use of two jacks. After a check if everything stayed in place after stressing the cords and scratch away the surplus concrete, the canoe was considered finished. When all this is done, it's time to create an ideal atmosphere for the concrete to cure, this means creating a high humidity. This was done by wrap the concrete with paper and spray this paper wet. Finally a foil was put over the mould sealing the canoe. During wrapping the canoe with paper some delicious snacks were fried. Meaning that after the work was done everybody could enjoy a cold Grolsch beer and the snacks from our very own Fry King.





After at least one day of hardening the canoe could be demoulded. To do this the prestressed cords have be cut at the point where they exit the mould. The next step is to turn the mould around and remove all steel wire coming out of the mould. When all connection are removed, the mould can be bended outwards and lifted, leaving a beautiful concrete canoe on the floor. At this moment the two upper cords can be post stressed. This is done by placing two metal plates on the bow and stern of the canoe and attach the cords to them with the use of a bold. By turning the bolds the cords gets tensioned and the canoe is compressed. The tension is gradually increased until the required tension is reached. By increasing the tension in several steps the concrete can ‘get used to’ the new forces acting on it. In the meanwhile it is important that the canoe is cured properly. Meaning that the canoe is covered in foil and once in a while is sprayed with water.

Concerning the marble canoe the next thing is sand-paper with coarse sandpaper. This removed the first thing layer of cement paste, exposing the marble aggregate. It also exposed air voids. To fill these voids a special mixture was created and rubbed on the canoe. By removing the excess paste with a filler knife, the voids stayed nicely filled. The next step was to sand-paper the walls with fine sandpaper, making the walls smoother. To make the walls shine and to give the marble look the walls were polished. This makes the walls look very nice and they become really smooth.


In this stage of the construction, the names, the sponsors and start numbers were painted onto the canoes. On top of the walls tubes are placed as protection against sharp edges and because of the aesthetics. At the wall some bolds are constructed in order to attach the air chambers to, these air chambers consist of large balloons. Now the canoes themselves are finished and ready for the battle. But, we are not finished yet. There are still some things that have to be taken care of. The first thing is that is under construction at the moment is a fourth canoe bearer. In these bearers the canoes can be transported and stored safely and on site we can carry them easily without damaging them. The second thing that we want to construct are some foam seat for the canoeists to sit on and to distribute the forces of the canoeists more equally towards the bottom.

4.4 Canoeing Skills

The canoe itself is only a part of the success which can be gained; without training the making of a concrete canoe is a waste of time. Besides having knowledge to build a canoe, the technique to paddle a canoe is an extremely important factor.

Already during our first Concrete Canoe Challenge in 2007, we proved to be 'best of the rest' with some hours of training in advance. With the help of Euros Kano (the Canoe Association in Enschede), we managed to train some time on the Twente Canal. A special canoe trainer showed us special techniques and strengthened our muscles and enlarged our power of endurance. As said, the training proved to work and it was decided to continue this cooperation and become a member of Euros Kano.

This means that since the summer of 2007 we train throughout the entire year. During the autumn/winter period the weekly training takes place in the indoor swimming pool of the University and during the spring/summer period the weekly training takes place on the wild waters of the Twente Canal. Together with the improved canoes, we trained hard to form a deadly combination of trained canoeists and well build canoes.



During the winter the muscles are trained and the condition is kept in shape. Thereby also the paddle technique can be refined, using special indoor training paddles and a wooden constructions fixed to the side of the pool. Besides the paddling the indoor training consist of a lot of push ups, sit ups and dips to gain strength. Between the intensive body workouts, swimming prevents the muscles from getting sour and is good for the condition.

At the start of spring the swimming pool is exchanged by the Twente Canal. In aluminium Canadian canoes the BetonBrouwers encounter the Twente Canal. For the new paddlers this is the moment of some important (safety) lessons:

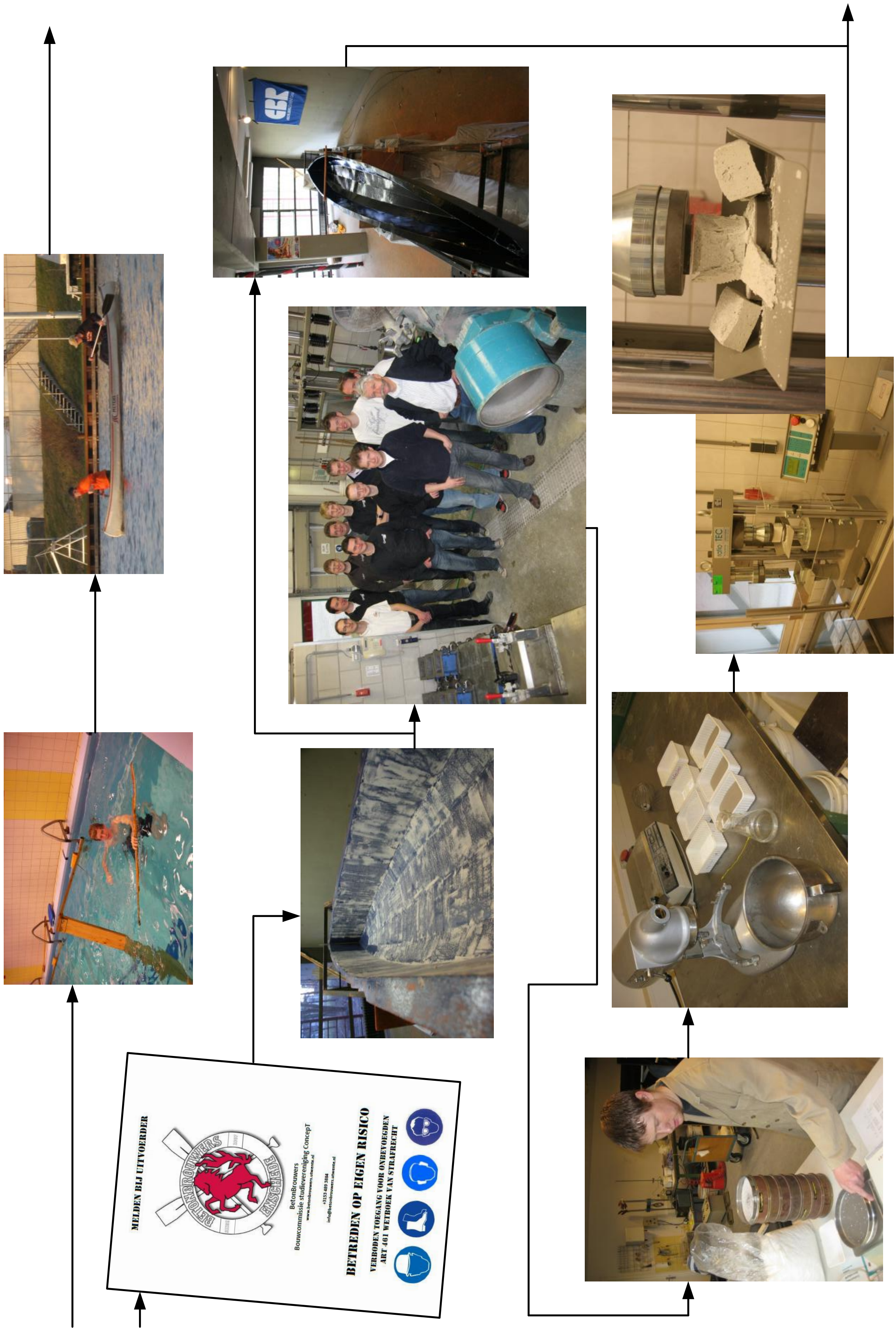
- Lesson 1: In case of a thunderstorm the training is cancelled. In all other weather conditions, the training continues.
- Lesson 2: Always register in the logbook. Write down the time of departure and the time of return.
- Lesson 3: When on the water, never lose your paddle! Our motto: my paddle, without me, is useless. Without my paddle, I'm useless.
- Lesson 4: Keep your balance, don't fall into the water. Despite the Canadian canoes are relatively stable, it is important to keep your balance. Especially when it is cold, the risk of falling into the water should be avoided at all costs. Thereby the water doesn't looks very attractive to swim in...
- Lesson 5: Avoid getting close to fishermen. It isn't a pleasure when a fishermen gets you on his hook.

With these lessons in mind the BetonBrouwers paddle the Twente Canal, practicing sprints, endurance races, turning and accelerate. To get used to the feeling of the concrete canoe, our top canoe of season 2009, 'Das Phantom', was transported to the water sports complex. This gave us the possibility to train in a concrete canoe preceding on the race in the canals of Utrecht.

In the construction report of last year a lesson "paddling for newbie's" was given by 'Prof. Arms' and 'The Bear of Boekelo'. In this construction report the BetonBrouwers Sports Program can be found in appendix C. With this special Sports Program one can achieve the perfect athletic body required for optimal performance on the water.

4.5 Photo Collage

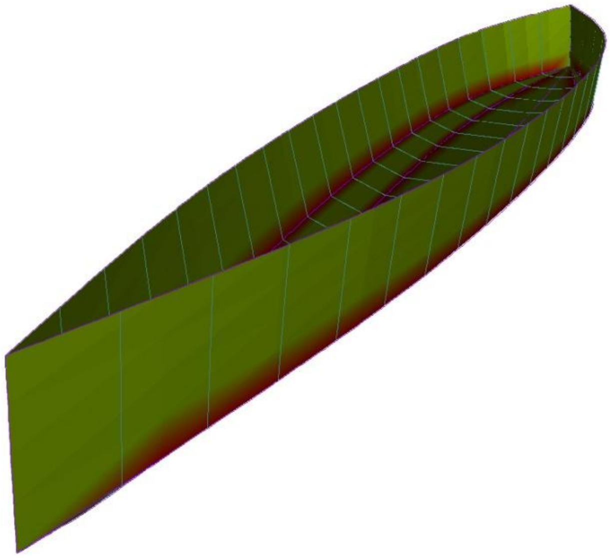
On the next pages a photo collage shows all activities during season 2010 in a chronological order. On our website www.betonbrouwers.utwente.nl more pictures concerning the construction of our concrete canoes can be found.


MELDEN BIJ UITVOERDER
BetonBrouwers
Bouwcommissie studievereniging ConcepT
BETREDEN OP EIGEN RISICO
VERBODEN TOEGANG VOOR ONBEVOEGDEN
ART 461 WETBOEK VAN STRAFRECHT


FOKKE & SUKKE
Arrive at the BetonKanoRace
So this is...
the competition?
22
University of Twente.
CBR
Liaver

Concluding

In the first part of this report we said that only the real diehard Civil Engineering students with a heart of concrete, loads of motivation and a lot of persistence can become a BetonBrouwer. This certainly has proven to be true. If we look back on what we have reached in the last six months within the scarce spare time of just eight students, it is really something to be very proud of and shows the loads of motivation and dedication. So without questioning we can conclude that building concrete canoes is a very time consuming hobby, but that a lot of satisfaction can be gained. And although no study credits can be gained, it is a real addition to the standard curriculum while it provides a perfect learning environment in regard of putting theory into practice, think creative and always look for solutions.



The goal this year was to optimise the mould and the concrete mixture, with the design of 2009 as basis. Thereby we already put our focus on season 2011. Meaning that the year would become a year of experimenting as a preparation for next season. By experimenting with the concrete compositions, the reinforcement and the smoothening of our canoes we gained important knowledge which we can apply next season.

During the Concrete Canoe Challenge we will know if the modified design performs better than that of previous year. At least the walls are smoother, the canoes are lighter and the paddlers are better trained than before. It is a very satisfying thought that when we look at the canoe, we can say that everything from the design until the mould and from the first batch of concrete until the finishing touch is done by ourselves. No matter if it becomes a great success or a big failure, it absolutely was a wonderful project to work on! But of course we hope to put a crown on our work with some heroic and memorable victories and return with some nice Cups to Enschede.

Finally we want to outline that it was real fun and instructive but also very time consuming to write this construction report. Hopefully it will contribute to the precious construction price and provide a clear view on how our canoes have been constructed. We hope you have enjoyed reading this construction report.

Literature

Al-Jibouri, S. (2009). *Planning & Control of Construction Projects 2009-2010*. University of Twente.

BetonBrouwers (2006). *Brouwsel onder spanning.* Studievereniging ConcepT, Universiteit Twente.

Brouwers, H.J.H. and Radix, H.J. (2005), *Self-compacting concrete: theoretical and experimental study*. Cement and Concrete Research 35, pp 2116-2136, Erratum, ibid 37, p. 1376 (2007).

ENCI (2006). *Wit portlandcement – CEM I*. Heidelberg Cement Group.

Hartsuijker, C. (2001). *Toegepaste Mechanica deel 2: Spanningen, vervormingen, verplaatsingen.* Den Haag: Academic Service.

Hunger, M. (2010). *An Integral Design Concept for Ecological Self-Compacting Concrete.* Technische Universiteit Eindhoven.

Hüsken, G. and Brouwers, H.J.H. (2008). *Earth-moist concrete: application of a new mix design concept*. Cement and Concrete Research, vol. 38, pp. 1246-1259.

Winters, J. (2005). *The Shape of the Canoe – Designing Canoes and Kayaks*. Retrieved at 10-01-2009 from: http://www.greenval.com/jwinters.html

Krikhaar, H.M.M. (2010). *Betonpocket*. ENCI, Mebin en Sagrex. ENCI B.V.

Madison Concrete Canoe Team (2008). *Design Papers.* University of Wisconsin. Obtained on 20 November 2008 from http://www.engr.wisc.edu/studentorgs/canoe/Design%20Papers/Design_Papers.htm

Murphy, M.L. de, Lissenden, C. & Xiao, C. (2009). *Technology Evaluation on Characterization of the Air Void System in Concrete*. Pennsylvania Transport Institute

Norwegian University of Science and Technology (2009). *Concrete Technology 1*. Trondheim. Stefan Jacobsen.

Vitro Minerals (2009). *Portland Cement and Pozzolans, Technical Background for the Effective Use of VCAS Pozzolans in Portland Cement Concrete.* Retrieved on 25-01-2010 from http://www.vitrominerals.com/general-pozzolan-technical-information.pdf

Appendices

Background information

In this section of the report you will find the appendices. These appendices provide some background information for the people interested. First of all the contact information of Study Association ConcepT, the Chairman and the Event Manager of the committee is given. In the second appendix the background information behind the concrete mixtures is given. Finally a balanced sports program is included, providing the necessary ingredients for top athletes like the BetonBrouwers.

Appendix A: Contact Information

In this appendix the contact information is provided of Study Association ConcepT, our Chairman (and team captain), Chiel de Wit, and Event Manager Frank Aarns.

Study Association ConcepT
Study Association of the department Civil Engineering (& Management) at the University of Twente.

A: Horst C-016 C-018
Postbox 217
7500 AE Enschede
T: +3153 489 3884
E: ConcepT@ConcepT.uwente.nl
I: www.ConcepT.utwente.nl

Chiel de Wit
Chairman BetonBrouwers

A: Campuslaan 21-314
7522 NC Enschede
T: +316 1366 7282
E: m.j.g.dewit@student.utwente.nl
I: www.betonbrouwers.utwente.nl

Frank Aarns
Event manager BetonBrouwers

A: Olieslagweg 95
7521 HZ Enschede
T: +316 4383 1276
E: f.aarns@student.utwente.nl
I: www.betonbrouwers.utwente.nl

Appendix B: In search of the optimal Mixture

This appendix contains more detailed information concerning the different mixtures that have been composed and tested. First the composition of all mixtures is shown, after which the test results are given.

Compositions:

ENCI – Mixture I:

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	146.1	450
Micro Silica	66.4	45
Limestone powder	19.3	180
Liaver 0.1-0.3	315	189
Liaver 0.25-0.5	57	31
Liaver 0.5-1.0	130	59
Water	216.0	216.0
Air	50.0	
Total:	**1000.0**	**1171**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.48
w/b ratio:	0.40
Air:	5%

Table B.1: Composition Mixture I

ENCI – Mixture II:

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	19.3	45
Limestone powder	66.4	180
Liaver 0.1-0.3	341	204
Liaver 0.25-0.5	61	33
Liaver 0.5-1.0	140	63
Water	192.0	192.0
Air	50.0	
Total:	**1000.0**	**1120**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.48
w/b ratio:	0.39
Air:	5%

Table B.2: Composition Mixture II

Mixture 1a

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	48.9	129.5
Marble 0-2mm	617.5	1636.5
White Pigment (TiO2)	4.1	16
Water	179.7	179.7
Air	20.0	
Total:	**1000.0**	**2361.6**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.45
w/b ratio:	0.37
Pigment:	4% cem. mass
Air:	2%

Table B.3: Composition Mixture 1a

Mixture 1b

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	63.0	167.0
Marble 0-2mm	595.5	1578.2
White Pigment (TiO2)	4.1	16
Water	187.5	187.5
Air	20.0	
Total:	**1000.0**	**2348.75**

Additional information:	
Glenium 51:	n.a
w/c ratio:	0.47
w/b ratio:	0.28
Pigment:	4% cem. Mass
Air:	2%

Table B.4: Composition Mixture 1b

Mixture 1.1

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	68.0	180.3
Marble 0-2mm	563.7	1493.8
White Pigment (TiO2)	4.1	16
Water	214.3	214.3
Air	20.0	
Total:	**1000.0**	**2304.5**

Additional information:	
Glenium 51:	2.8kg/m^3
w/c ratio:	0.54
w/b ratio:	0.37
Pigment:	4% cem. mass
Air:	2%

Table B.5: Composition Mixture 1.1

Mixture 1.2

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	137.8	192.9
➢ Solid content	68.9	160.7
➢ Water content	68.9	68.9
Marble 0-2mm	568.5	1506.6
White Pigment (TiO2)	4.1	16.0
Water$_{total}$	208.6	208.6
Water$_{add}$	139.7	139.7
Air	20.0	
Total:	**1000.0**	**2291.9**

Additional information:	
Glenium 51:	4.6kg/m^3
w/c ratio:	0.52
w/b ratio:	0.29
Pigment:	4% cem. mass
Air:	2%

Table B.6: Composition Mixture 1.2

Mixture 1.3

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400.0
Limestone powder	100.3	265.9
Marble 0-2mm	509.2	1349.3
White Pigment (TiO2)	4.1	16.0
Water	236.5	236.5
Air	20.0	
Total:	**1000.0**	**2267.8**

Additional information:	
Glenium 51:	0.4kg/m^3
w/c ratio:	0.59
w/b ratio:	n.a.
Pigment:	4% cem. mass
Air:	2%

Table B.7: Composition Mixture 1.3

Mixture 1.4*

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	68.9	96.5
➢ Solid content	34.5	80.4
➢ Water content	34.5	34.5
Limestone powder	34.5	91.3
Marble 0-2mm	568.5	1506.6
White Pigment (TiO2)	4.1	16.0
Water$_{total}$	208.6	208.6
Water$_{add}$	174.2	174.2
Air	20.0	
Total:	**1000.0**	**2291.9**

Additional information:	
Glenium 51:	3.2kg/m^3
w/c ratio:	0.52
w/b ratio:	0.37
Pigment:	4% cem. mass
Air:	2%

Table B.8: Composition Mixture 1.4

Mixture 1.5

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	111.8	296.4
Marble 0-2mm	460.2	1219.6
White Pigment (TiO2)	5.1	20.0
$Water_{total}$	255.8	255.8
$Water_{add}$	238.6	238.6
Air	20.0	
Total:	**1000.0**	**2231.9**

Additional information:	
Glenium 51:	0.3kg/m^3
w/c ratio:	0.64
w/b ratio:	0.53
Pigment:	5% cem. mass
Air:	2%

Table B.9: Composition Mixture 1.5

Mixture 1.6

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	128.4	340.1
Marble 0-1mm	409.2	1084.4
White Pigment (TiO2)	5.1	20.0
$Water_{total}$	290.3	290.3
$Water_{add}$	273.1	273.1
Air	20.0	
Total:	**1000.0**	**2175.0**

Additional information:	
Glenium 51:	0.3kg/m^3
w/c ratio:	0.73
w/b ratio:	0.60
Pigment:	5% cem. mass
Air:	2%

Table B.10: Composition Mixture 1.6

Mixture 2a

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	83.0	220.0
Liaver 0.1-0.3	330.6	198.4
Liaver 0.25-0.5	31.7	17.1
Liaver 0.5-1.0	239.7	107.9
White Pigment (TiO2)	4.1	16.0
Water	161.0	161.1
Air	20.0	
Total:	**1000.0**	**1120.4**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.38
w/b ratio:	0.19
Pigment:	4% cem. mass
Air:	2%

Table B.11: Composition Mixture 2a

Mixture 2b

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	50.8	134.7
Liaver 0.1-0.3	316.7	190.0
Liaver 0.25-0.5	53.0	28.6
Liaver 0.5-1.0	286.0	128.7
White Pigment (TiO2)	4.1	16.0
Water	139.6	139.6
Air	20.0	
Total:	**1000.0**	**1037.6**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.33
w/b ratio:	0.21
Pigment:	4% cem. Mass
Air:	2%

Table B.12: Composition Mixture 2b

Mixture 2c

Material:	Volume [dm³]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	48.0	127.2
Liaver 0.1-0.3	175.7	105.4
Liaver 0.25-0.5	155.1	83.7
Liaver 0.5-1.0	134.6	60.6
White Pigment (TiO2)	4.1	16.0
SikaAer	186.5	37.3
Water	146.2	146.2
Air	20.0	
Total:	**1000.0**	**976.4**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.35
w/b ratio:	0.22
Pigment:	4% cem. Mass
Natural air:	2%
Entrained air:	18.7%

Table B.13: Composition Mixture 2c

Mixture 2d

Material:	Volume [dm³]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	80.4	213.1
Liaver 0.1-0.3	332.8	199.7
Liaver 0.25-0.5	93.4	50.5
Liaver 0.5-1.0	146.1	65.7
White Pigment (TiO2)	4.1	16.0
SikaAer	32.5	6.5
Water	160.9	160.9
Air	20.0	
Total:	**1000.0**	**1112.3**

Additional information:	
Glenium 51:	n.a.
w/c ratio:	0.38
w/b ratio:	0.19
Pigment:	4% cem. mass
Natural air:	2%
Entrained air:	3.3%

Table B.14: Composition Mixture 2d

Mixture 2.1

Material:	Volume [dm³]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Micro Silica	78.2	207.3
Liaver 0.1-0.3	315.5	189.3
Liaver 0.25-0.5	31.9	17.2
Liaver 0.5-1.0	231.2	104.0
White Pigment (TiO2)	4.1	16.0
Water	189.3	189.3
Air	20.0	
Total:	**1000.0**	**1123.1**

Additional information:	
Glenium 51:	8.7kg/m³
w/c ratio:	0.45
w/b ratio:	0.23
Pigment:	4% cem. mass
Air:	2%

Table B.15: Composition Mixture 2.1

Mixture 2.2

Material:	Volume [dm³]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	158.4	221.8
➢ Solid content	79.2	184.8
➢ Water content	79.2	79.2
Liaver 0.1-0.3	319.4	191.6
Liaver 0.25-0.5	31.7	17.1
Liaver 0.5-1.0	233.2	105.0
White Pigment (TiO2)	4.1	16.0
$Water_{total}$	182.5	182.5
$Water_{add}$	103.3	103.3
Air	20.0	
Total:	**1000.0**	**1096.8**

Additional information:	
Glenium 51:	9.2kg/m³
w/c ratio:	0.44
w/b ratio:	0.24
Pigment:	4% cem. mass
Air:	2%

Table B.16: Composition Mixture 2.2

Mixture 2.3

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Limestone powder	119.7	317.2
Liaver 0.1-0.3	232.6	139.6
Liaver 0.25-0.5	56.5	30.5
Liaver 0.5-1.0	215.6	97.0
White Pigment (TiO2)	4.1	16.0
Water	221.6	221.6
Air	20.0	
Total:	**1000.0**	**1222.0**

Additional information:	
Glenium 51:	1.4kg/m^3
w/c ratio:	0.54
w/b ratio:	n.a.
Pigment:	4% cem. mass
Air:	2%

Table B.17: Composition Mixture 2.3

Mixture 2.4*

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	119.7	167.6
➢ Solid content	59.9	139.6
➢ Water content	59.9	59.9
Limestone powder	59.9	158.6
Liaver 0.1-0.3	232.6	139.6
Liaver 0.25-0.5	56.5	30.5
Liaver 0.5-1.0	215.6	97.0
White Pigment (TiO2)	4.1	16.0
$Water_{total}$	221.6	221.6
$Water_{add}$	161.8	161.8
Air	20.0	
Total:	**1000.0**	**1171.0**

Additional information:	
Glenium 51:	3.5kg/m^3
w/c ratio:	0.54
w/b ratio:	0.33
Pigment:	4% cem. mass
Air:	2%

Table B.18 Composition Mixture 2.4

Mixture 2.5

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Limestone powder	113.6	301.0
Liaver 0.1-0.3	227.8	136.7
Liaver 0.25-0.5	115.4	62.3
Liaver 0.5-1.0	127.9	57.5
White Pigment (TiO2)	5.1	20.0
SikaAer	40.0	8.0
Water	220.3	220.3
Air	20.0	
Total:	**1000.0**	**1205.9**

Additional information:	
Glenium 51:	
w/c ratio:	0.54
w/b ratio:	n.a.
Pigment:	5% cem. mass
Natural air:	2%
Entrained air:	4%

Table B.19: Composition Mixture 2.5

Mixture 2.6

Material:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	94.0	249.0
Liaver 0.1-0.3	234.2	140.5
Liaver 0.25-0.5	114.0	61.6
Liaver 0.5-1.0	128.9	58.0
White Pigment (TiO2)	5.1	20.0
SikaAer	40.0	8.0
Water$_{total}$	216.8	216.8
Water$_{add}$	199.6	199.6
Air	20	
Total:	**1000.0**	**1194.0**

Table B.20: Composition Mixture 2.6

Additional information:	
Glenium 51:	1.3kg/m^3
w/c ratio:	0.53
w/b ratio:	0.45
Pigment:	5% cem. mass
Natural air:	2%
Entrained air:	4%

Mixture 3.1

Material:	Volume [dm^3]	Mass [kg]
CEM I 42.5N Waterproof white	129.9	400
Cembinder 8	34.4	48.2
➢ Solid content	17.2	40.1
➢ Water content	17.2	17.2
Limestone powder	94.0	249.0
Liaver 0.1-0.3	234.2	140.5
Liaver 0.25-0.5	114.0	61.6
Liaver 0.5-1.0	128.9	58.0
White Pigment (TiO2)	5.1	20.0
SikaAer	40.0	8.0
Water$_{total}$	216.8	216.8
Water$_{add}$	199.6	199.6
Air	20	
Total:	**1000.0**	**1194.0**

Table B.21: Composition Mixture 3.1

Additional information:	
Glenium 51:	1.6kg/m^3
w/c ratio:	0.53
w/b ratio:	0.45
Pigment:	5% cem. mass
Natural air:	2%
Entrained air:	4%

Test Results

In the tables below the test results concerning the Flexural and the Compressive Strength are given for each composed mixture.

Specimen	Date Cast	Date Test	Age	Strength [N/mm^2]
Mixture I	02-02-2010	03-02-2010	1	9.9
Mixture I	02-02-2010	09-02-2010	7	28.8
Mixture I	02-02-2010	02-03-2010	28	36.3
Mixture II	02-02-2010	03-02-2010	1	13.6
Mixture II	02-02-2010	09-02-2010	7	26.3
Mixture II	02-02-2010	02-03-2010	28	33.1

Table B.22: Test results Compressive Strength Mixtures I & II

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm^2]
Mix 1.2.1	28-03-2010	26-04-2010	29	40	40	5.190	12.16
Mix 1.2.2	28-03-2010	26-04-2010	29	40	40	4.283	10.04
Mix 1.2.3	28-03-2010	26-04-2010	29	40	40	4.622	10.83
Mix 1.3.1	28-03-2010	26-04-2010	29	40	40	3.468	8.13
Mix 1.3.2	28-03-2010	26-04-2010	29	40	40	3.504	8.21
Mix 1.3.3	28-03-2010	26-04-2010	29	40	40	3.409	7.99
Mix 1.4.1	28-03-2010	26-04-2010	29	40	40	4.067	9.53
Mix 1.4.2	28-03-2010	26-04-2010	29	40	40	4.394	10.30
Mix 1.4.3	28-03-2010	26-04-2010	29	40	40	3.878	9.09
Mix 1.5.1	08-04-2010	06-05-2010	28	40	40	3.856	9.04
Mix 1.5.2	08-04-2010	06-05-2010	28	40	40	3.887	9.11
Mix 1.5.3	08-04-2010	06-05-2010	28	40	40	3.679	8.62
Mix 1.6.1	08-04-2010	06-05-2010	28	40	40	3.476	8.15
Mix 1.6.2	08-04-2010	06-05-2010	28	40	40	3.647	8.55
Mix 1.6.3	08-04-2010	06-05-2010	28	40	40	3.547	8.31

Table B.23: Test Results Flexural Strength Marble Mixtures

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm^2]
Mix 1.2.1.1	28-03-2010	26-04-2010	29	40	40	112.870	70.54
Mix 1.2.1.2	28-03-2010	26-04-2010	29	40	40	109.847	68.65
Mix 1.2.2.1	28-03-2010	26-04-2010	29	40	40	110.147	68.84
Mix 1.2.2.2	28-03-2010	26-04-2010	29	40	40	115.330	72.08
Mix 1.2.3.1	28-03-2010	26-04-2010	29	40	40	115.433	72.15
Mix 1.2.3.2	28-03-2010	26-04-2010	29	40	40	116.993	73.12
Mix 1.3.1.1	28-03-2010	26-04-2010	29	40	40	85.750	53.59
Mix 1.3.1.2	28-03-2010	26-04-2010	29	40	40	84.590	52.87
Mix 1.3.2.1	28-03-2010	26-04-2010	29	40	40	83.603	52.25
Mix 1.3.2.2	28-03-2010	26-04-2010	29	40	40	83.747	52.34
Mix 1.3.3.1	28-03-2010	26-04-2010	29	40	40	87.653	54.78
Mix 1.3.3.2	28-03-2010	26-04-2010	29	40	40	84.447	52.78
Mix 1.4.1.1	28-03-2010	26-04-2010	29	40	40	111.757	69.85
Mix 1.4.1.2	28-03-2010	26-04-2010	29	40	40	104.817	65.51
Mix 1.4.2.1	28-03-2010	26-04-2010	29	40	40	104.443	65.28
Mix 1.4.2.2	28-03-2010	26-04-2010	29	40	40	103.743	64.84
Mix 1.4.3.1	28-03-2010	26-04-2010	29	40	40	111.493	69.68
Mix 1.4.3.2	28-03-2010	26-04-2010	29	40	40	108.843	68.03
Mix 1.5.1.1	08-04-2010	06-05-2010	28	40	40	92.680	57.92
Mix 1.5.1.2	08-04-2010	06-05-2010	28	40	40	91.030	56.89
Mix 1.5.2.1	08-04-2010	06-05-2010	28	40	40	96.153	60.10
Mix 1.5.2.2	08-04-2010	06-05-2010	28	40	40	92.743	57.96
Mix 1.5.3.1	08-04-2010	06-05-2010	28	40	40	92.187	57.62
Mix 1.5.3.2	08-04-2010	06-05-2010	28	40	40	93.133	58.21
Mix 1.6.1.1	08-04-2010	06-05-2010	28	40	40	85.073	53.17
Mix 1.6.1.2	08-04-2010	06-05-2010	28	40	40	83.450	52.16
Mix 1.6.2.1	08-04-2010	06-05-2010	28	40	40	81.747	51.09
Mix 1.6.2.2	08-04-2010	06-05-2010	28	40	40	81.750	51.09
Mix 1.6.3.1	08-04-2010	06-05-2010	28	40	40	81.623	51.01
Mix 1.6.3.2	08-04-2010	06-05-2010	28	40	40	92.967	51.85

Table B.24: Test Results Compressive Strength Marble Mixtures

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm^2]
Mix 2.2.1	28-03-2010	26-04-2010	29	40	40	2.367	5.55
Mix 2.2.2	28-03-2010	26-04-2010	29	40	40	2.507	5.88
Mix 2.2.3	28-03-2010	26-04-2010	29	40	40	2.175	5.10
Mix 2.3.1	28-03-2010	26-04-2010	29	40	40	2.255	5.29
Mix 2.3.2	28-03-2010	26-04-2010	29	40	40	2.385	5.59
Mix 2.3.3	28-03-2010	26-04-2010	29	40	40	2.430	5.70
Mix 2.4.1	28-03-2010	26-04-2010	29	40	40	1.746	4.09
Mix 2.4.2	28-03-2010	26-04-2010	29	40	40	2.371	5.56
Mix 2.4.3	28-03-2010	26-04-2010	29	40	40	2.745	6.43
Mix 2.5.1	08-04-2010	06-05-2010	28	40	40	2.231	5.23
Mix 2.5.2	08-04-2010	06-05-2010	28	40	40	1.775	4.16
Mix 2.5.3	08-04-2010	06-05-2010	28	40	40	2.266	5.31
Mix 2.6.1	08-04-2010	06-05-2010	28	40	40	1.906	4.47
Mix 2.6.2	08-04-2010	06-05-2010	28	40	40	2.119	4.97
Mix 2.6.3	08-04-2010	06-05-2010	28	40	40	2.691	6.31
Mix 3.1.1	22-04-2010	06-05-2010	14	40	40	1.984	4.65
Mix 3.1.2	22-04-2010	06-05-2010	14	40	40	1.955	4.58
Mix 3.1.3	22-04-2010	06-05-2010	14	40	40	2.031	4.76

Table B.25: Test Results Flexural Strength Lightweight Mixtures

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm^2]
Mix 2.2.1.1	28-03-2010	26-04-2010	29	40	40	42.330	26.46
Mix 2.2.1.2	28-03-2010	26-04-2010	29	40	40	46.373	28.98
Mix 2.2.2.1	28-03-2010	26-04-2010	29	40	40	41.890	26.18
Mix 2.2.2.2	28-03-2010	26-04-2010	29	40	40	41.740	26.09
Mix 2.2.3.1	28-03-2010	26-04-2010	29	40	40	40.557	25.35
Mix 2.2.3.2	28-03-2010	26-04-2010	29	40	40	43.337	27.09
Mix 2.3.1.1	28-03-2010	26-04-2010	29	40	40	43.490	27.18
Mix 2.3.1.2	28-03-2010	26-04-2010	29	40	40	43.230	27.02
Mix 2.3.2.1	28-03-2010	26-04-2010	29	40	40	48.260	30.16
Mix 2.3.2.2	28-03-2010	26-04-2010	29	40	40	47.147	29.47
Mix 2.3.3.1	28-03-2010	26-04-2010	29	40	40	44.643	27.90
Mix 2.3.3.2	28-03-2010	26-04-2010	29	40	40	43.090	26.93
Mix 2.4.1.1	28-03-2010	26-04-2010	29	40	40	51.047	31.90
Mix 2.4.1.2	28-03-2010	26-04-2010	29	40	40	53.037	33.15
Mix 2.4.2.1	28-03-2010	26-04-2010	29	40	40	52.703	32.94
Mix 2.4.2.2	28-03-2010	26-04-2010	29	40	40	51.867	32.42
Mix 2.4.3.1	28-03-2010	26-04-2010	29	40	40	54.903	34.3
Mix 2.4.3.2	28-03-2010	26-04-2010	29	40	40	51.107	31.94
Mix 2.5.1.1	08-04-2010	06-05-2010	28	40	40	44.560	27.85
Mix 2.5.1.2	08-04-2010	06-05-2010	28	40	40	42.400	26.50
Mix 2.5.2.1	08-04-2010	06-05-2010	28	40	40	46.537	29.09
Mix 2.5.2.2	08-04-2010	06-05-2010	28	40	40	43.720	27.33
Mix 2.5.3.1	08-04-2010	06-05-2010	28	40	40	43.383	27.11
Mix 2.5.3.2	08-04-2010	06-05-2010	28	40	40	46.760	29.23
Mix 2.6.1.1	08-04-2010	06-05-2010	28	40	40	56.703	35.44
Mix 2.6.1.2	08-04-2010	06-05-2010	28	40	40	54.157	33.85
Mix 2.6.2.1	08-04-2010	06-05-2010	28	40	40	50.937	31.84
Mix 2.6.2.2	08-04-2010	06-05-2010	28	40	40	49.153	30.72
Mix 2.6.3.1	08-04-2010	06-05-2010	28	40	40	55.527	34.70

Mix 2.6.3.2	08-04-2010	06-05-2010	28	40	40	52.410	32.76
Mix 3.1.1.1	22-04-2010	06-05-2010	14	40	40	40.523	25.33
Mix 3.1.1.2	22-04-2010	06-05-2010	14	40	40	42.063	28.29
Mix 3.1.2.1	22-04-2010	06-05-2010	14	40	40	43.817	27.39
Mix 3.1.2.2	22-04-2010	06-05-2010	14	40	40	41.323	25.83
Mix 3.1.3.1	22-04-2010	06-05-2010	14	40	40	36.280	22.67
Mix 3.1.3.2	22-04-2010	06-05-2010	14	40	40	35.147	21.97

Table B.26: Test Results Compressive Strength Lightweight Mixtures

Appendix C: BetonBrouwers Sports Program

To achieve the perfect balance between mental and physical health during the BetonKanoRace, the BetonBrouwers have developed a strict sports program. This program contains two parts, a healthy diet and a training schedule.

Diet:
Athletes such as the BetonBrouwers have a need for a specific and balanced diet to make sure that the performance during the training and the BKR is optimal. In this diet, it is important to make sure that both protein and vitamins are present, to ensure that the nutritional value of the diet is balanced with the training. When used as a supplement to a varied, balanced and healthy lifestyle this diet is designed to respond to the requirements of immediate muscular effort, particularly during sports competitions. The diet is a tested and controlled formula. It contains an optimised carbohydrate mix, it replaces minerals lost by sweating and has an anti-doping guarantee. For this diet an excellent Fry King is of great importance!

Breakfast
Without breakfast, your body will start processing at a late stage of the day, with this the fat burning capacities of the body will start later on the day. With a healthy breakfast of carbohydrates and egg whites (for example a fried egg and 2 kaassoufflés) you have a good start of the day. Make sure you wash this down with enough fluids to eliminate the hang-over of last night.

Lunch
This course should contain a lot of egg whites and carbohydrates, because egg whites are the building blocks of our muscles. It is important to make sure your muscles get enough egg whites to stay in good health. Therefore a burger in combination with kaassoufflés are ideal. These can be combined with a nice glass of milk.

Before training / dinner
Before training it is important to get enough calories. This means a nutrient and energetic meal. Therefore it is advised to eat a combination of frikandellen with French fries. Since a good hydration is of great importance as well, the meal can be combined with a cold beer.

After training
This is the most important moment of the day. The body is exhausted from the day and the intensive training and needs to regain strength. Therefore a mix of beer and bitterballen form a good basis.

Training schedule:
Important: Before starting with the interval training, always make sure that you paddle at least 1,5km as a warming up. For the cooling down, make sure that you paddle at least 1,5km after the interval training. Complementary to the warming up and cooling down, stretching exercises can be done on shore.
Endurance training (very long training)
- 60-90 minutes of technical and powerful paddling.
- 4-10-12-15-12-10-4 minutes at 90-95% power with break= 4minutes at 60% power.
- The route should be at least 15km long.

Interval training (endurance)
- 1-2-3-4 minutes with break =3 minutes // 5 minute break // 4-3-2-1 minutes with break =3 minutes
- 5x3 minutes with break = 3 minutes // 5 minute break // 4x2 minutes with break = 2 minutes // 5 minute break // 4x1 minute with 1 minute break
- 10x400 meters with break of 400 meters
- 5x1200 meters with break of 4 minutes

Interval training (sprint)
- 10x1 minute with break = 1 minute // 5 minute break // 10x30 seconds with break = 30 seconds // 5 minute break // 1km = 30-60-90-120 seconds with break = 30 seconds
- 2x500 meters = 15-30-45-60 seconds with break = 30 seconds
- 2x1000 meters = 30-60-90-120 seconds with break = 30 seconds
- 5 minute break after each 500 and 1000 meter sprint

- 2x500 and 2x1000 meters at 95% power // 10 minute break

Additional information:

- Always take time for a good cooling down (paddling and stretching).
- During the breaks, make sure that you paddle technically (without power).
- During 100% power, give everything, but make sure you maintain technically correct strokes.