Shaping a Concrete Canoe

Construction Report 2009

Enschede, 25 May 2009

BetonBrouwers
Study Association ConcepT
Department 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. It is now ten minutes past midnight, i.e. 21 May, which makes me realise that the deadline for this construction report is approaching rapidly and that half a year of hard work has passed. And how....

After achieving the overall victory in Delft in 2008 it became time to outline the plans for season 2009. Based on our experiences from season 2007 & 2008 we decided to come up with a new design and a new lightweight concrete mixture. Thereby we wanted to compete abroad and decided to participate in the German competition as well.

Not forgetting the idea of prestressed concrete we started to design a canoe that is more stable, has less resistance and is better manoeuvrable through the water than the old design. Therefore our Head of Design dove into the matter and came up with a feasible and theoretical optimal design. Making a new design also meant that we had to construct a new mould. Because we preferred a smooth outer surface and reduced the number of stressed cords from 32 to 5 we constructed an outer mould. So far, so good....

The next step was to obtain a lightweight concrete mixture which is strong and has a good workability. To obtain this goal we contacted people in the concrete industry and used the experience of two PhD candidates. This resulted in a list of ingredients and eventually in three possible mixtures. After testing our goal seemed to be achieved and the optimal concrete mixture for 2009 was determined. This meant that we could start with the construction of our canoes for season 2009.

So although this will be the third year that the BetonBrouwers are participating at the Dutch Concrete Canoe Challenge called the BetonKanoRace, season 2009 will be a special one for us. Firstly, because we are participating with a whole new concept and secondly because we will be competing in the German competition, the Betonkanu-Regatta for the first time. So, were others enjoyed their spare time, the BetonBrouwers worked hard on making the new design, a new mixture, constructing four magnificent canoes and train their paddling skills in order to be competitive in the two competitions.

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 candidates Götz Husken and Martin Hunger for their third year of assisting us with creating a perfect concrete mixture. Thanks to their enthusiasm in assisting us, their expert opinion about concrete and their advices based on their own experiences with building concrete canoes, these new canoes have improved significantly compared to previous year. Second we want to thank Onno Bokhove for his input concerning the canoeing itself. Thanks to his training programme and advices we are better prepared for the races than ever before. Finally we want to thank all the people and companies that have supported us to achieve our goal of building four beautiful canoes.

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

BetonBrouwers 2009,

Chiel de Wit	(Chairman)
Hildemar Houtenbos	(Secretary)
Rik Goossens	(Treasurer)
Johan de Waard	(Public Relations)
Frank Aarns	(Event Manager)
Daniël Tollenaar	(Head of Design)
Sevrien Ferree	(Material Commissioner)

[1] Translated: ConcreteBrewers

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Introduction

In front of you lays the construction report of the construction committee 2009 of Study Association ConcepT. Since November 2008 this committee, consisting of seven '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 documentation for future members of the committee.

The phenomenon Concrete Canoe Challenge can be found in many countries in Europe and abroad. This year will become a special year for us because we are participating in two of these competitions: the Dutch and German competition. In the Netherlands the Concrete Canoe Challenge (BetonKanoRace) is organized annually under the auspices of the Dutch concrete association (Betonvereniging). In Germany this event is organized once in the two years and is initiated by the Deutschen Zementindustrie e.V.. During the events students from different academies, universities and other institutions compete in their self-build concrete canoes for the honour. The aim of these fantastic events is to promote the multi-purpose product CONCRETE. This year the competitions take place in Roermond and Essen where we will try to beat our competitors and conquer the first price!

The central element in this construction report is the number 3, derived from the triptych Strength, Stiffness and Stability which plays a crucial role in each construction project. Throughout the report a triptych can be found back: the report consists of three parts each divided in three paragraphs, which are divided in three sections were necessary. Besides the triptych the number 3 also refers to the 3 basic elements that have to be taken into account in order to achieve victory: a perfect design/construction (taking into account the Strength, Stiffness and Stability), an optimal concrete mixture and last but certainly not least training. Thereby this year is the 3rd year that the BetonBrouwers appear at the start and we will participate with 3 canoes at each event.

As mentioned this construction report is build up in three parts. In the first part the team is introduced, first of all the history of the team is presented after which the members are introduced in the second paragraph. Finally, in the third paragraph, our sponsors are mentioned. In the second part the theory behind the design is discussed. In the first paragraph the principles behind the new design are discussed. In the second paragraph the new design is explained. In the third paragraph three concrete mixtures are proposed, the test results are presented and the material status of the canoes is given. After the theoretical background in part two the practical aspect is highlighted in the third part: the realization of the design. In three paragraphs we try to give insight in everything we encountered while preparing for the races. After the concluding chapter, three appendices can be found with our contact information, background information behind the concrete mixture and a lesson paddling for dummies.

Part 1

BetonBrouwers – An honour to be part of

Since 2007 the BetonBrouwers form the construction committee of Study Association ConcepT of the department 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 prestressed concrete. Unfortunately there were no bottles of champagne that could be deserved with experimenting with prestressed concrete. But on the other hand it was much better applicable in canoes, were it was about after all….

The idea of prestressed concrete has been further developed into a feasible design. But after two years of using this method in combination with an old canoe as mould, we decided that it was time for a new mould and a new construction. Making use of our experiences from the previous years, we accepted the challenge to come up with a new design of which the result can be found in this construction report. Between 2007 and 2009 a lot has happened at University Twente in Enschede, the concrete capital of The Netherlands. To show what we did these years, an overview of our concrete campaign will be given, showing both our efforts and victories.

1.1.1 From nothing to everything

In August 2006 Study Association ConcepT gained responsibility for organizing the 30th concrete canoe challenge of the Netherlands, to be held in our hometown Enschede. To show the world of concrete canoeing that the best Dutch concrete canoes come from Twente, four diehard Civil Engineers in spe stood up in March 2007 and managed to form the new building department 'BetonBrouwers' ('Concrete brewers'). A lot of work had to be done between the first day they met each other and the day of the race, which was held in September 2007. The old canoe mould, at that time used for about six or seven years, had to be replaced by a new one.

Using the bow of an old canoe as a new mould, new concrete canoes could be made. While 'pimping' the mould and welding a steel frame on which the canoe building process would take place, a concrete mixture was developed. Called CT-BB-07, the new mixture was focused on light weight and flexibility. After some weeks of testing, the optimal composition of the concrete was found, and the canoe building process could take off.

The building process began during the summer holidays and with the help of friends and fellow students, three magnificent canoes were created. The canoes were constructed using prestressed concrete, composed of special steel cord from drawn steel wire manufacturer Bekaert and 25 kg weights from the Dutch Army. Like a phoenix rising from the ashes, the concrete canoes from Twente were a threat to every team, again. Called 'Voortvarend' ('Vigorously'), 'Kansloos' ('Chanceless') and 'Boten Anna', the boats were painted in an impressing orange/ blue, orange/ green and grey/ red colour scheme.

Although isn't wasn't possible to test the canoes properly before the race, during the eve of the race the spirits were high and the motivation was immense. Student Canoe Association Euros in Enschede made it possible to prepare our canoeists as best as possible for the race. During the summer months the Twente Canal was the domain of the BetonBrouwers and a lot of training kilometres were canoed across the water. Our muscles and minds were ready to take it up to all enemies, both foreign and domestic.

Because of the 30th anniversary of the Dutch concrete canoe challenge, the winner of the American Concrete Canoe Challenge was invited to take part in the Dutch race. Besides the 'Yanks', some German teams, a few lost Belgians and of course Dutch teams would participate. Because it was a home match to us, we had to show the spectators and the other teams that not only our canoes were made of concrete, but ourselves as well. On the foggy morning of September the 8th, hell was unleashed.

The first part of the day was assigned to the 200 meter sprint games. Although two of our canoes didn't make it to round 3 of the Sprint, our well trained canoeists Frank Aarns and Sevrien Ferrée showed everyone that they couldn't mess with our team. In direct battles, canoe 'Voortvarend' managed to beat seven canoes on the sprint. It was inevitable that the grand final would be between the BetonBrouwers and the Americans from the University of Wisconsin. The final was called David against Goliath: the winners of the American competition against the rookies from Twente. We countered with everything we had, but at the end the Yanks won the race with a minimum time distance 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 Yankees 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...

1.1.2 We came, we saw, we kicked ass!

After being succesfull on the concrete canoe challenge of 2007, we agreed that this story of succes had to be continued. With the help of a briliant marketing campaign, we managed to welcome three new team members. Together with Study Associasion ConcepT, a plan was developed in which a new constructive department had to be set up. In the future, the BetonBrouwers weren't responsible for only making concrete canoes anymore, but also for designing bridges or developing new kinds of concrete as a part of student competitions. The core activity however remained designing and building new canoes, in which we were getting very good at.

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. But how to make better canoes with the same mould? The first aspect was developing a new kind of light and flexible concrete. Besides that, we were going to use another concept of prestressing the concrete and making the canoes as thin as possible. Financial problems were no more because of a great sponsor, we had enough manpower, canoe training was still an important activity of the week and we were all highly motivated: nothing could stop the BetonBrouwers anymore.

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. Although the new concept of prestressing the concrete was developed to win some time, making the first canoe took us almost as much time as making two canoes with the old concept. Though, giving the canoes a nice colour with special pigments was succeeded. After evaluating the constructionprocess of our first 2008-canoe, we managed to smoothen the process and two new canoes were created in a very short period of time. The three boats were named: Veni, Vidi and Vici. These famoes words of Roman Julius Ceasar (I came, I saw and I conquered) were going to very well decribe our canoe challenge exprierience in Delft.

On the rainy morning of Friday the 16th May, our canoe transporter was reporting himself at the University Twente. A large Volvo truck was arranged to bring the three masterpieces of engineering from Twente to Delft. The whole trip from Enschede to Delft was driven in rain; at the time the BetonBrouwers arrived in Delft, the sun started to shine. The odds were not against us this time. After showing the canoes in the narrow canals of the old city of Delft and building a party, night fell. The day after, again hell was unleashed.

Almost a whole year of work took us to 15 May 2008. On the water of the 'Delfste Hout', it all had to be done; it was the day of truth. Frank Aarns and Sevrien Ferrée, the top canoeist of Twente, made it to the finals at the 200 meter sprint. The teams in the other divisons, mixed and ladies only, had 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 unfortunately won the race.

By having a great lunch, organized by our sponsor, we regained strength in our muscles and minds and we 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. Becuase the organisation of the race couldn't another win by the University of Twente, the ladies were disqualified for turning countre clockwise at the buoy. The men also won the race; fortunately this was approved by the jury. In the semi-finals the men already showed that they could beat the French and in the final they did it again.

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 succes was complete. We came, we saw and we kicked ass! Because of this great succes, new candidates for particpating on the BetonBrouwers were easily found. Together with the rookies, a new plan was made for 2009. A complete new design had to be made and new concrete had to be developed. Now the road was open for the BetonKanu-Regatta in Essen (D) and the Dutch Concrete Canoe Challenge in Roermond. Although a lot of effort had to be put in the canoes before we could actually race with them, there was (and still is) believe in new succes in 2009! The rest of this construction report shows the preparation for the races this year.

1.2 Team members

As construction committee we strive to be a continuous committee which consists of a diversity of students, which means students from different years. 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, it gives an insight in their backgrounds and their functioning within the committee.

1.2.1 Chiel de Wit alias 'Captain Guus'

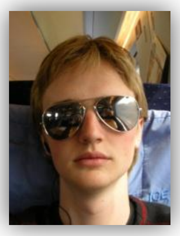
Function: Chairman
Age: 20

Chiel is one of the Rookies of the BetonBrouwers as he has joined this committee since the start of this academic year. He was the perfect guy for the function of external affairs, as he's fanatic about concrete and the making of it. Later on he took over the function of chairman and made sure that some beauties of canoes are constructed. Although Chiel likes to be in charge and be the supervisor in the field. He still is the one that's always busy with little details and the other things that have to be done. Thereby, if there is one guy who has connections, it's Chiel. So if we need something, Chiel can fix it!

Chiel grew up in the idyllic village Schalkwijk to the west of Utrecht, in a farmhouse. Every weekend he feels the need, the call from home, to go back to his roots. He still has the working spirit of working together with his family on the farm, the ideal place to learn to use your common sense and get your hands dirty. Just like all the other BetonBrouwers he is an active and sportive type of guy. But in contrary to fat finger Rik, he has a more athletic appearance. Another contradiction with Rik is that Chiel is, concerning football, a very dangerous last man to pass. One might start to think that these two guys are opposites of each other, but nothing is less true considering their special liking for concrete. Chiel even tries to seduce his housemates of constructing a concrete closet. This shows us that concrete can form a binding factor in a very wide sense.

As sportive type he also enjoys to jump into a canoe from time to time and practice the art of paddling. In the meanwhile he has proven to be a good captain not only on the construction site but on the water as well. Together with his equalness with the famous singer Guus Meeuwis, Chiel carries the nickname "Captain Guus". As a result of his sportive life he has become a healthy and strong guy and it's merely of practical reasons that we carry our canoes with at least two people. Anyhow it's still not clear whether we are too strong to handle or that our canoe are just too damn light.

1.2.2 Hildemar Houtenbos alias 'Vegan Hilly'



Function: Secretary
Age: 20

It was the 16th of May in the year 1989 on the beautiful beach of Zandvoort when a new kid on the block was born, Hildemar. Near the former Formula 1 circuit Hilly spend his time getting in love with speed racing. That's the reason for his registration with the BetonBrouwers, we are just that fast! Hildemar is now our secretary, responsible for the minutes of our meetings. Besides this major task he also feels responsible to take care of all the tasks nobody else would like to do. With his energetic dedication for the BetonBrouwers he is a real addition for the team.

Hilly has his own dance which is already famous in some districts of Enschede. It's a simple dance, just put your elbows in an angle of 90 degrees, put your index fingers up high and move those index fingers separately. Probably you will notice this dance during the regatta. Hilly also has his own football team, "the Hilly's Angels". This team tries to reach the top, but last month they lost against the great team "the Grasshappers", which is Rik's team. Nice fact during this game was that Hilly only played a quarter of the game, he's just not that sportive. That's also the reason why Hilly will not canoe during the regatta but will just be present to have great time.

When the BetonBrouwers are finished with building activities Hilly is the first one calling names to put on the deep fry. Everyone eats a nice "frikandel" and a "bitterbal", but Hilly is a vegetarian and so he takes care that there are also "cheese soufflés" available for him. When there are no "cheese soufflés" he also likes to eat a carrot. That's the reason we call him Vegan Hilly. Vegan Hilly hasn't got a girlfriend yet, but will probably look for his changes at the regatta. So, if you see a little boy with a great head, drinking beer and making fucked up comments, then you probably see the great Vegan Hilly from Enschede. Get on it!

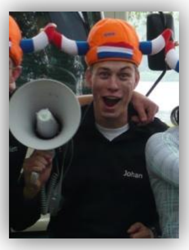
1.2.3 Rik Goossens alias 'Fry king Rik'

Function: Treasurer
Age: 21

Also Rik has become a BetonBrouwer since this year and with his happy attitude his attendance forms a positive contribution to the team. This very enthusiastic person is from the city Arnhem. Full of proud of his origin, he is a fanatically supporter of a football club which is called Vitesse. Something that is sometimes a critical point of discussion with Sevrien, who is a fanatically fan of FC Twente. His love for football is more than only be a supporter of a club. Rik likes to play a game of football himself. He is the captain of a team that calls their selves the "Grasshappers", which would be translated to "grass eaters". Something remarkable of this name is that they will never eat grass because the competition which they play is one on artificial grass. With is fat fingers it is no problem for Rik to keep every ball out of the goal. Which is one of the main reasons of the good results of the team.

In our team Rik is the one who monitors the costs, he will strictly monitors all the money streams and takes care that no cent too much is spend. If it is about building materials, travel costs or minced-meat hot dogs he will monitor everything. Talking about minced-meat hot dogs we arrive by another remarkable characteristic of Rik, his love for the deep fryer. After a day of hard work, nothing tastes better than a cold Grolsch Beer and a good minced-meat hot dog prepared by our fry king Rik. Thereby he forms a crucial link in our team. The treat of his minced-meat hot dog in prospect, keeps the team motivated and results in optimal performance. It's also a perfect way to build up energy reserves which we will need during the races.

1.2.4 Johan de Waard alias 'John Doe'



Function: Public Relations
Age: 21

After having success in 2007, the BetonBrouwers gained more respect among students and was starting to attract new members. One of the new team mates in 2007 was found in the form of Johan de Waard. Born on the 2nd of December 1987 in the little town of Oud-Beijerland near Rotterdam, he was predestined to become a civil engineer. With one of the biggest ports of the world in his backyard and 'Zuid-Holland' and 'Zeeland' as interesting civil engineering areas in the vicinity, in 2006 Johan choose to become a student at the most exciting university of The Netherlands. A good choice!

After assisting at the Concrete Canoe Challenge 2007, organized by study association ConcepT, Johan realized that he fitted better in an overall than in a nice suit. His decision to become a BetonBrouwer was accepted with great joy and he was immediately installed as chairman; a job with a lot of responsibilities. Under the leadership of Johan, the BetonBrouwers won the overall championship at the Concrete Canoe Challenge 2008 in Delft. It was a big success for this young leader. Besides having good characteristics as perseverance and the aim for a 'higher' purpose, Johan made a big mistake to become a fan of the awful football-club AJAX Amsterdam. The whole football season he had to suffer from the bad results of this clubs. Especially the fact that FC Twente finished higher on the Dutch ranking than '020', is a sensitive point. Team member Sevrien underlines this fact with great pleasure. Though Johan is a tough guy and can cope with this big loss.

In 2009 Johan will be a canoeist in the two Challenges the BetonBrouwer have to participate in. Under the all seeing eyes of two top canoeists, Johan trained hard this winter and is determined to make good results in Roermond and Essen!

1.2.5 Frank Aarns alias 'Prof. Arms'

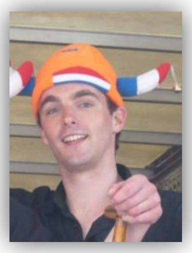
Function: Event Manager
Age: 23

With his deep blue eyes and blond hair, this sun of Adonis is born in Nijmegen in the winter of 1985. When Concrete Canoeing became something serious in the outback of The Netherlands, Frank decided to join the now famous BetonBrouwers. He soon understood how to mix workable concrete from raw materials making him a true 'brew king'. Especially his profound (and feminine) talent for cleaning came into use in the concrete lab as well as at the construction site of our project. Surely Frank's strive for perfection proved value in our 2008 overall victory, won by speed, engineering and aesthetics.

By defending Queen and Country with our National Guard Frank shows his profound fanaticism. Extensive body workouts made Frank irresistible for the ladies and more importantly contributed to our heroic victory on the gentlemen long distance challenge in 2008, where he and The Bear of Boekelo crushed French opposition. When it comes to canoe building, Frank is usually the first showing up at the construction site, calling everybody coming five minutes late. Such a dedication let to the deserved title BetonBrouwer of 2008!

Even the most perfect person has a competence to improve. For Frank this would be course keeping for sure. His first attempt keeping track in a canoe ended in crushing a canoe in quayside. Maybe this led to his later decision to become chairman of the study tour which he co organized for our student board. Here Frank let a bunch of difficult civil engineering students to South Africa. Though it is hard to separate legend from fact he must have done this with verve, since locals soon started calling him Professor Arms, a name deserved by a man of steel and concrete!

1.2.6 Daniël Tollenaar alias 'The Tsar'



Function: Head of Design
Age: 25

The 25th of October 1983 was the day that Daniël, also called Dani, saw the light of day. This makes Daniël the eldest of the BetonBrouwers. Being the eldest BetonBrouwer is a role which suits Daniël, as the pater familias he regularly encourages the youngsters to develop themselves but in the mean time he keeps an eye out to ensure the future of the BetonBrouwers is as bright or even brighter than its past. Being one of the founding fathers of the BetonBrouwers Daniël has been with BetonBrouwers since the very early beginning back in 2007. Over the years Daniël has occupied many positions within the committee. In 2007 he started as the chairman and fulfilled this role with passion. Because of the tight schedule that year he was on top of everything and took care everybody did his job as desired. This gave him reputation of "The Tsar". After being the treasurer in 2008, this year he fulfilled the role of "head of design". Over time Daniël has seen every aspect of the concrete canoe building business and has developed into a real concrete canoe guru.

But Daniël doesn't always dream about concrete canoes, he also likes to undertake non concrete related activities. One of these activities is dressing up in all green with his army boots and crawl thru the mud. Yes ladies and gentlemen, The Tsar likes to pretend to be a soldier boy, taking orders instead of giving them and guard duty are all in a weekends fun. However playing soldier isn't all Daniël does in his spare time as he also likes to play the occasional game of handball or speak Spanish, which is something the women in Spain greatly appreciate or so he makes us all believe. In between serving his country and the playing with concrete, Daniël finds the time to finally finish up his education. So when he leaves the BetonBrouwers sometime next year, the building of concrete canoes will keep on going but will never be the same without the inspiring presence of our very own concrete canoe guru.

1.2.7 Sevrien Ferree alias 'The bear of Boekelo'

Function: Material Commissioner
Age: 21

Sevrien Is one of the founders of the BetonBrouwers. Sevrien, coming from the scenic hamlet Boekelo, is a pure-bred Tukker, something he is justly very proud of. Therefore he is a huge fan of FC Twente and can gladly enjoy the local brew: Grolsch. Another local custom to which Sevrien gladly participates is exuberantly celebrating carnival, something the people in the east think they know how to celebrate (only because they've never been in the south). Because Sevrien likes to make his hand dirty, it's not for no reason he is a terrific BetonBrouwer, he helps his fellow villagers with building a splendid carnivals trailer every year. Besides his love for the local customs and his study Civil Engineering Sevrien has an ambiguous love for the army. He likes it to make fun of some of his fellow committee members with the fact that they serve their country as National Guards, but secretly he hopes to serve his country with proud himself someday. Therefore he ensures that he always finds himself in top condition. Something that is or great importance for one's canoeing performance. The combination of his brute strength and his origin, resulted since the competition of 2007 in the nickname "The bear of Boekelo". Besides that this top athlete possesses the brute force needed to let the concrete canoes fly across the finish line in leading position, also his steersmanship is of great importance. We are praised that Sevrien possesses the talent for finding the right direction. Although he sometimes looses course, for example by studying Civil Engineering in Delft, he always manages to keep the canoe in the right track. This bring us to a huge hobby of Sevrien: trains. Besides doing repairs and riding some classical trains, he loves to photograph them, something that makes him appear at the craziest times and locations in the Netherlands and abroad.

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.

1.3.1 Financial:

ENCI – Heidelberg Cement Group
http://www.heidelbergcement.com

MT&V Detachering
www.mtenv.nl

Study Association ConcepT
www.concept.utwente.nl

Besix Group
www.besix.com

1.3.2 Materials:

ENCI – Heidelberg Cement Group
http://www.heidelbergcement.com

Bekaert
http://www.bekaert.com/

Liaver
http://liaver.com/

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

Ascom Polyester
http://www.ascom-polyester.nl/

Part 2

CT2009 – A Winning Design

Success in concrete canoeing is based on three pillars. The first pillar is the formulation of some design principles serving as a starting point in the design process. When this part is covered one starts to develop a winning 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 CT2009

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 with the old concept during races and concepts shown by competitors from Germany and the USA has greatly improved the knowledge of concrete canoe building. In this chapter these 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 0.7m. 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 (DU).

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[2].

- **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 0.220 metric tonnes (2x80 kg for paddlers plus 60 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 as much as possible in the bow and stern in providing optimal canoe handling. 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 length of the canoe 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 [m]

$$u_{max} = 1.34 \times \sqrt{l_h} \quad (1)$$

- **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[3] 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 2009 hull is designed according to the KAPER formula formulated by John Winters[2]. 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[3] which defeated our old design fare and square during the 2006 BKR at the University of Twente[4]. As to be seen in 2009 such defeat

[2] John Winters (2005). *The Shape of the Canoe – Designing Canoes and Kayaks*. Retrieved at 10 January from: http://www.greenval.com/jwinters.html
[3] http://www.engr.wisc.edu/studentorgs/canoe/Design%20Papers/Design_Papers.htm
[4] http://www.betonkanorace2007.nl/

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.

<u>Performance criteria:</u>

- **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.

<u>Functional Principles:</u>

- **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.

2.1.3 The goal

In contrary of the previous two years, when we use a normal canoe as mould, the goal for this year was to construct a canoe entirely designed and constructed by ourselves. Despite the old design did not perform bad, there are two main points of attention: low resistance and a good manoeuvrability. Thereby we want to innovate in regard of the reinforcement and concrete mixture. Another goal for this year is to participate in the German competition as well. This means that we have to meet the German regulations as well. In order to achieve these goals we aimed on:

Concerning the new construction:

- An outer mould, what means that we have to pour the concrete on the inside of the mould. This results in a very smooth skin of the canoe, which results in lower resistance and less work concerning the finishing touch.
- When using an outer mould, it becomes less practical to use a lot of pre-stressed cords as reinforcement. Practical considerations in combination with experience in regard of sensitivity for cracks results in the following reinforcement:
    - Prestressed cords (max 5) in the longitudinal direction
    - After-stressed cords (max 2) in the longitudinal direction
    - Pre-stressed cords (max 5) in the bottom in the cross direction
    - Two layers of mesh with a fine mesh opening (prevents large cracks).

Concerning the new concrete mixture:

- A concrete of enough strength in order to handle the forces as a result of the stressed cords, the canoeists and the nautical conditions.
- A concrete that can be considered waterproof since painting the canoe is not allowed
- A lightweight mixture. Because the canoe is longer and has a larger surface compared to previous year, the aim is to make a lightweight concrete mixture in order to maintain a acceptable weight of the canoe.
- Very important during construction is the workability of the concrete. When the workability is not right, the concrete won't stick to the walls of the mould and it will take too long to construct the entire canoe. Therefore the workability has to be taken into account during tests in the lab.
- Because the environmental awareness is becoming more and more important, the goal is to produce a sustainable mixture.

2.2 The secret of Strength, Stiffness and Stability

In this paragraph the secret behind the Strength, Stiffness and Stability is explained. Designing of a perfect concrete canoe is an iterative process. This process starts with the design of the hull, which determines the manoeuvrability, stability and resistance of the canoe. In strong correlation with the hull design the design of the reinforcement takes place. The total package of the hull design and the reinforcement form the eventual design: ConcepT 2009 (CT2009).

2.2.1 The art of shaping a concrete canoe

CT2009 is designed with the help of software package Delftship[5]. 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[2].

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. 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 2.3 shows the hull design of CT2009.

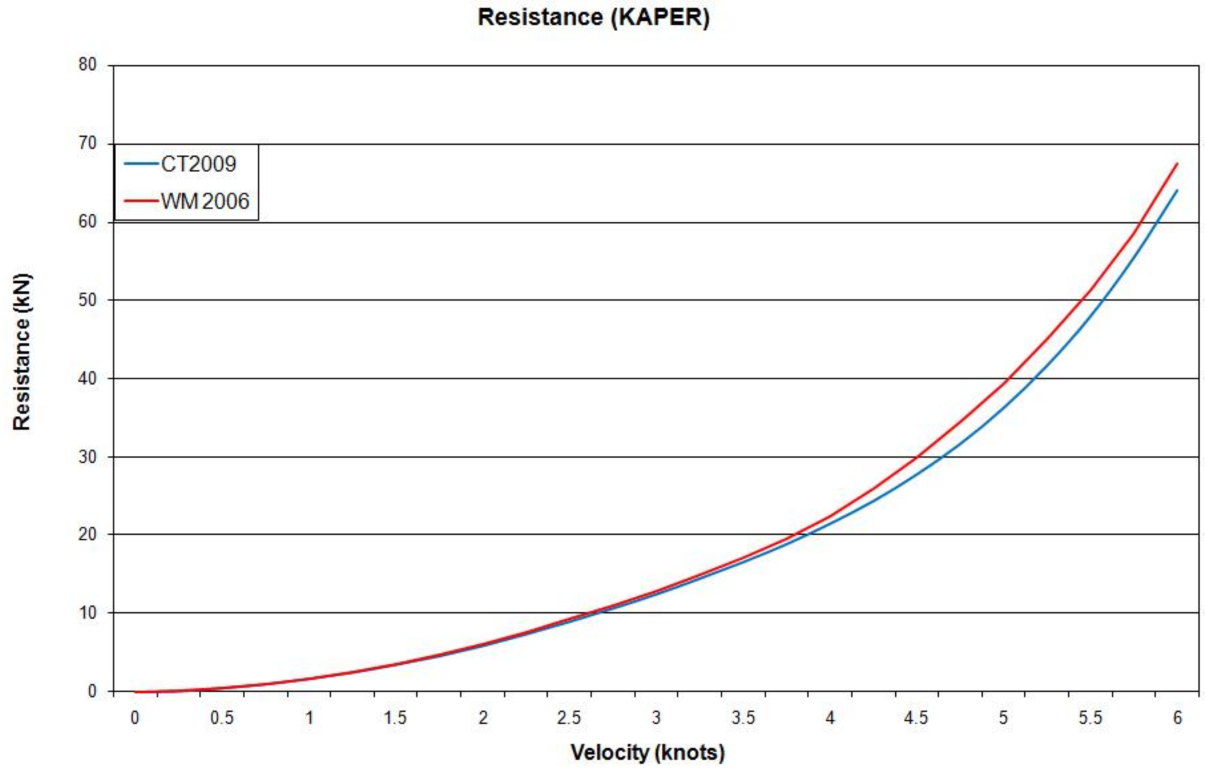


Figure 2.1 - Hull Resistance CT2009 compared to WM2006

2.2.2 Constructing: Bring in the Reinforcements!

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

[5] Software is free downloadable at: www.delftship.net

maximum stresses under most unfavourable conditions[6]. 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 our academic triangle we based our first design on sound principles described in BetonBrouwers 2006[4]. Over the last two years we experimented with the resulting design which brings us to an evaluation which we translated into Achilles Heels and solutions. Overall, we conclude from experience that concrete mixtures with a characteristic 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 2.2 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 2.3). 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 CT2009 we apply two steel cords as high as possible in the hull as to be seen in figure 2.3, 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 2.2. 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 2.3. 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.

[6] BetonBrouwers (2006). *Brouwsel onder Spanning.* Retrieveable from:
http://www.concept.utwente.nl/vereniging/commissies/bouwcommissie/Constructieverslag_BetonBrouwers.pdf

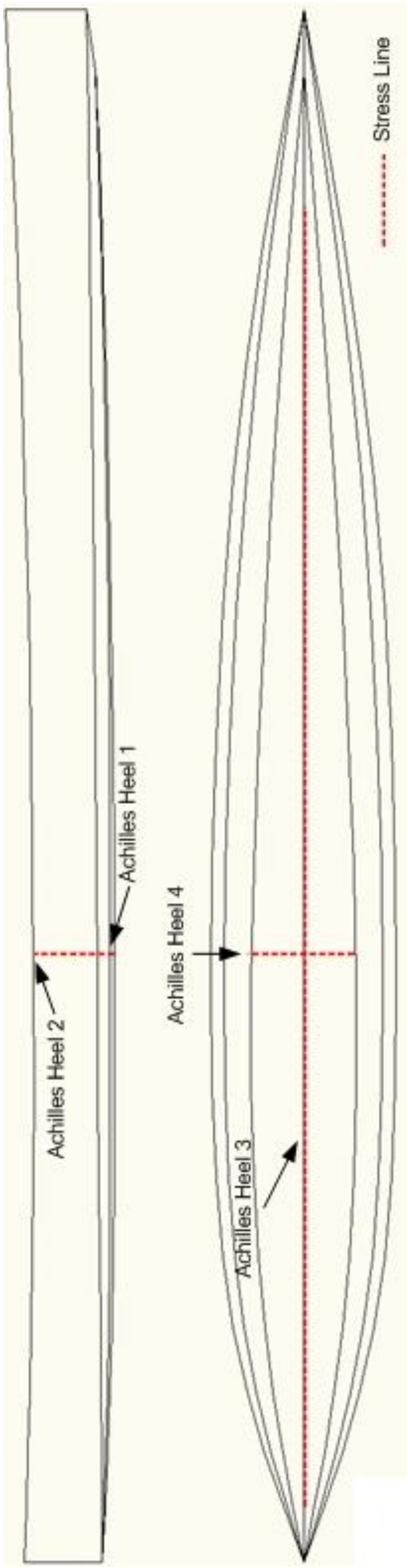


Figure 2.2 – Canoe Achilles Heels

2.2.3 Results - The Blueprint of CT2009

The Blueprint of CT2009 is given in figure 2.3. 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 reinforcements as far as cords are considered. The stucco-meshes are not shown.

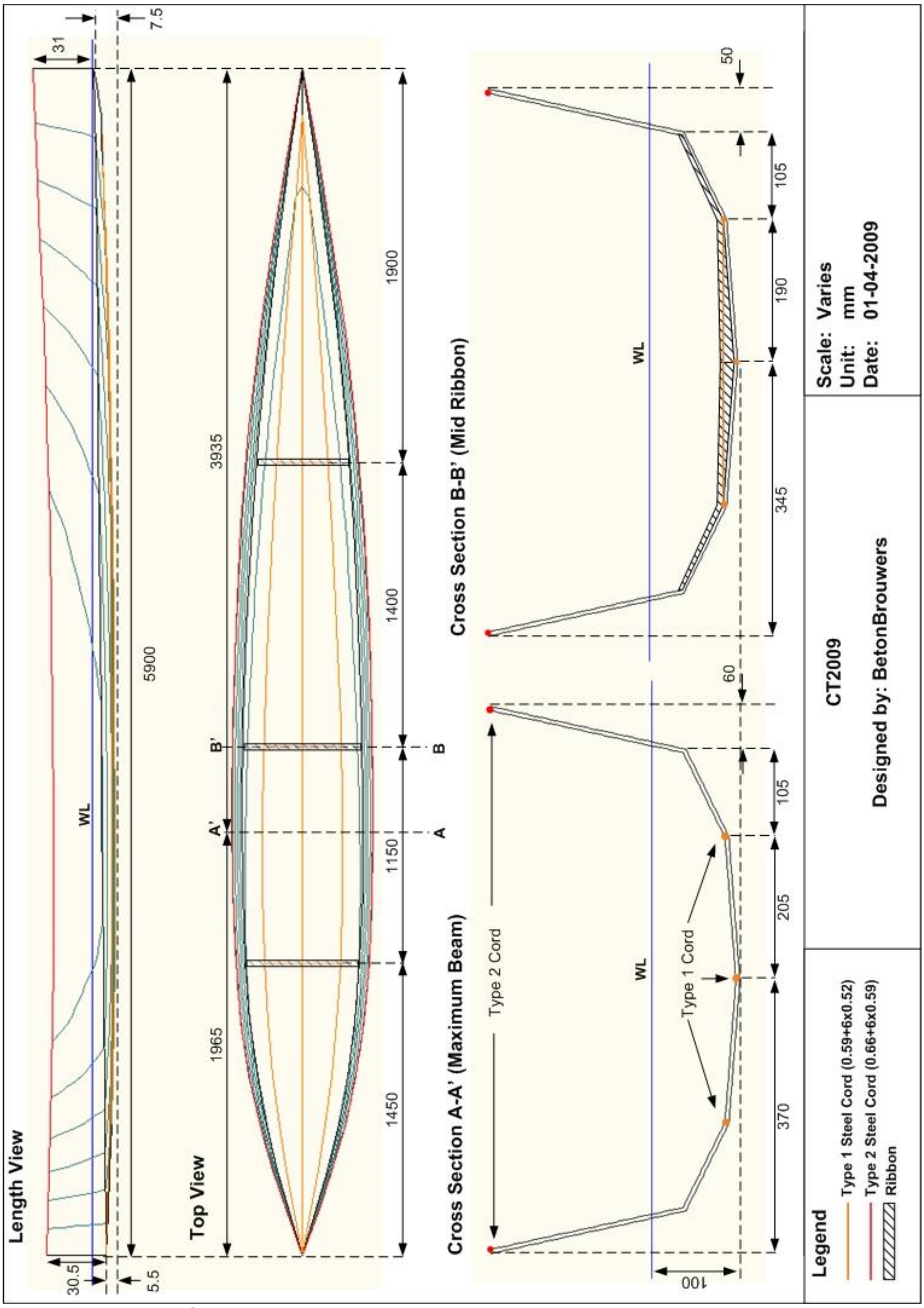


Figure 2.3 – Blueprint of CT2009

2.3 The binding element: CM2009

This paragraph is dedicated to the binding element of our canoes: the Concrete Mixture 2009 (CM2009). The concrete mixture is the third key element in order to construct a successful canoe. In the first section the required ingredients of the mixture are discussed. Based on the chosen materials three mixtures are composed in order to find an optimal composition. In the second section concerns the breaking and crushing, e.g. testing, of the samples. Based on the results the best mixture is selected. Finally the material status of the canoes is given in de last section of this paragraph.

2.3.1 Mixing the materials

Taking into account the rules and regulations concerning the concrete mixture and the demands & wishes derived from paragraph 2.1, the search for the optimal mixture fitting to the CT2009 started. This search for the holy grail is done in collaboration with Götz Husken, a PhD candidate at the University of Twente.

Determine the ingredients:

The first step is to determine the required ingredients. Because of the participation to the Betonkanu-Regatta, it is not allowed to use any paint. This means that the mixture determines the colour of the canoe and if the canoe is waterproof. This makes it important to obtain a optimal particle size distribution. To give the canoe a nice colour, pigments have to be used. Because the small particles determine the colour of the mixture, the preference was to obtain white materials while this results in a brighter colour.

Because the new design means that the canoe is longer and has a larger surface than previous years, it is important to save as much weight as possible. Therefore lightweight aggregates were selected and the goal was set to construct walls with a maximum thickness of 5mm. As a result of the thin walls (>5mm) combined with the fact that the canoe has to become waterproof without paint, the good adhesion to the pre-stressed cords and the fine mesh opening, the nominal particle size is determined on 1mm.

<u>Binding element:</u>

As binding element, the same cement is used as previous year: CEM I 52.5R LA White. This white Portland cement with a high starting strength (indicated by the 'R') and a Low Alkali content (max 0.6% for CEM I) is ideal for our canoe. This cement is suitable for the use of traditional granulates/fillers without a risk of a lethal reaction between the alkali of the cement and the granulates/fillers. Thereby it has a high compressive strength and thereby is able to withstand possible high forces. Thereby because it is a white cement, the colour will become brighter.

<u>Fillers:</u>

As fillers limestone powder and micro silica are selected. These very fine-grained materials are added to the concrete mix to improve the properties. They result in a higher surface to volume ratio, a much faster pozzolanic reaction and a better particle size distribution. Because the small particles determine the colour of the mixture, these fillers are white to attain a brighter colour.

<u>Aggregates:</u>

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are mainly used for this purpose. Because the largest particle size is determined on 1mm, fine sand (Sand 0-1) is used. In order to make the mixture lighter than previous years, Liaver is used as a lightweight 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.

<u>Admixtures:</u>

Admixtures are materials in the form of powder of fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In regard of our mixture two admixtures will be used: pigments and Super Plasticiser.

To give the canoe it's nice colour pigments are used. Because we are a Dutch team and we will participate in the German competition, the colour orange suited best. In order to attain a nice orange colour, yellow and red pigments are added to the mixture.

To give the mixture better workability characteristics Super Plasticiser is added to the mixture. Super Plasticiser is a high-range water-reducing admixture and increases the workability of plastic or "fresh" concrete, allowing it to be placed more easily and with less consolidating effort. The Super Plasticisers are a class of plasticizers which have fewer deleterious effects when used to significantly increase workability. Alternatively, plasticizers can be used to reduce the water content of a concrete while maintaining workability. This improves its strength and durability characteristics.

Hydration:
Of course also water is added to the mixture, otherwise no reaction would take place and the mixture would consist of dry powders. Combining the water with the cement forms a cement past by the process of hydration. The cement paste glues the aggregates together, fills voids within it and allows it to flow more easily. Less water in de cement paste will yield a stronger, more durable concrete (less permeable). On the other hand, more water will give an easier-flowing concrete. The optimal amount lays between a water to powder ratio (w/p) of 0.3 – 0.5, concerning Portland cement a w/p of 0.5 is the best according to the theory. The use of impure water can cause problems, therefore the best quality water is used, water from the same spring as the water for the famous Grolsch Beer.

Concluding from the above the overview of ingredients is shown in table 2.1. These ingredients are used to compose three different mixtures which are exposed to further investigation.

Material:	Function:
CEM I 52.5R LA White	Binding element
White Limestone Powder	Improve properties
Micro Silica (White)	Improve properties
Sand 0-1	Form the bulk of the concrete
Liaver 0.1-0.3	Lightweight replacement of sand.
Liaver 0.25-0.5	Lightweight replacement of sand.
Liaver 0.5-1.0	Lightweight replacement of sand.
Pigments (yellow and red)	Give the canoe its beautiful colour
Water	Hydration

Table 2.1: Ingredients for the CM2009

Developing different mixtures:
The second step is to determine the optimal composition. 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 [1, 2][7].

For composing the concrete mix used for the concrete canoes, the mix design concept discussed in [1] 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)).

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

[7] [1] 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).
[2] 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.

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 [2].

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.

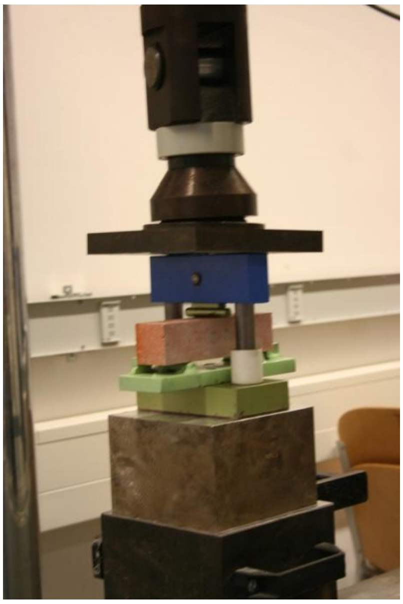
Based on the selected ingredients and the UT Mixdesign, 3 mixtures are proposed. These three proposed mixtures and the argumentation are:

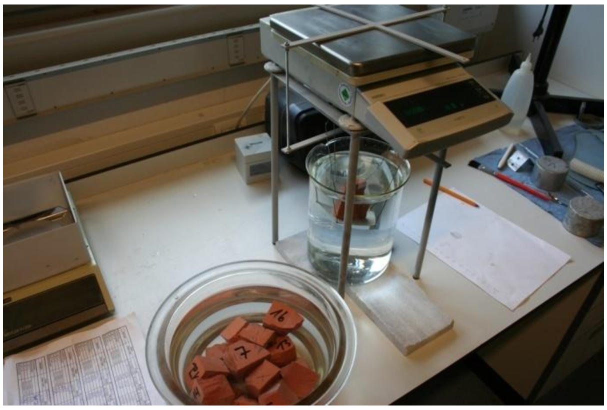
1) CM2009-1: In this mixture consists of 10% sand 0-1. The Liaver 0.1-0.3 and 0.5-1.0 are used as replacements for the sand. By leaving out Liaver 0.25-0.5 there won't be an overlap with the other fractions. The gap between 0.3 and 0.5 is probably filled by the other ingredients. Thereby it is one variable less in the mixture.
2) CM2009-2: As well as in the first mixture the sand percentage is 10%. This time all three fractions of Liaver are added to the mixture. With this mixture we make sure that the Liaver 0.25-0.5 will fill up the gap between 0.3 and 0.5.
3) CM2009-3: In this mixture the sand percentage is determined on 20%. This is done because of some uncertainties in the Dutch regulations at that time. Thereby sand has some preferable characteristics above the Liaver: it has a better bonding with the other materials because the rougher surface and it is stronger. The remaining part was completed with the three Liaver fractions.


With these three mixtures we went to 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, cubes and slabs was produced of each mixture. These samples would be tested after 28 days and based on the results (see next section) and the workability of the mixtures the best mixture for our canoes could be determined.

2.3.2 Breaking and crushing

In this paragraph the results of the different test are discussed. While making the test samples we already took notice of the workability of each mixture. Combined with the results from the test we can make a well considered decision concerning the best concrete mixture for 2009. Three types of samples were produced and four types of tests are conducted, being: flexural strength, compressive strength, density and elasticity. Below the result of these tests are mentioned.



Prisms

The prisms are used for multiple tests. The first test is the flexural strength. The flexural strength was tested with a 3 point bending test. With the two remaining pieces of the prisms the compressive strength was tested and with the larger remainings of this test the density measurement was carried out. In the table below (table 2.2) the test results from the different tests are shown, it concerns the averages. The exact test results can be found in appendix B.

	Mix 1	Mix 2	Mix 3
Flexural strength	7,0 N/mm	9,3 N/mm	10,3 N/mm
Compressive strength	35,4 N/mm	39,1 N/mm	48,6 N/mm
Theoretical density	1285.7 kg/m^3	1288.3 kg/m^3	1387.6 kg/m^3
Measured density	1492.9 kg/m^3	1539.6 kg/m^3	1751.4 kg/m^3

Table 2.2: Test results(averages) of the prisms.

What can be concluded is that mix 1 has the lowest and mix 3 has the highest strength. On the other hand, mix 3 has a higher density compared to the other two mixtures. This is logical because it contains double the amount of sand. It is interesting to see the difference between the theoretical density and the measured density. The cause of this difference is not clear, but the concrete is still lighter than previous years.

Cubes

The cubes are used to test the compressive strength of the mixtures. The average compressive strength per mixture is shown in table 2.3. When these values are compared to the values in table 2.2. we can see that the compressive strength concerning the cubes is considerably higher. The reason is that the cubes are still intact and the tested remainings of the prisms are already exposed to earlier tests and can be weakened as a result of this. This makes the test of the cubes more reliable.

	Mix 1	Mix 2	Mix 3
Compressive strength	46,9 N/mm	51,4 N/mm	49,1 N/mm

Table 2.3: Average compressive strength (cubes)

Slabs

Of each mixture a plate was produced of +/- 4mm thick containing two layers of fiberglass 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 would to be tested on elasticity.

In order to perform the planned test we needed a displacement-guided compression-test machine. We only had access to pressure-guided compression-test machine, this meant we had to modify the compression-test machine in order to be able to test the slabs. After an afternoon of modifying the compression-test machine, we had to conclude it was not accurate enough and it was not possible to test the slabs with the available facilities. Despite this drawback we were determined to test the slabs and started thinking about a solution. In 2007 we had done a project concerning fibre reinforced concrete in cooperation with BAS bv, a high-tech company specialized in developing and test new types of concrete. So because the required machinery was not available at our University, we successfully contacted BAS bv.

The assistance of BAS made it possible to perform the test and gave an indication of the elasticity of our slabs. The results of the test can be seen in appendix B. Our expectation was that the slabs would show significant cracks at a displacement of +/- 1cm and that they would break eventually. But as the test results show, all three our mixtures were very flexible, more than we expected. Despite a displacement of 7cm and more, the slabs only showed minor cracks. Eventually the slabs were bended in such a way that they were pushed from the bracings. This made us conclude that the collaboration between the concrete mixtures and the meshes formed a perfect basis for our concrete canoes, regardless of the mixture.

We want to thank BAS bv for their assistance and thereby making it possible to test the slabs.

Conclusion:

When looking at the flexural and compressive strength of the mixture we can conclude that all mixture are within the required strength range. Mixture 3 is the strongest of the three and mixture 1 is the weakest. When looking at the density it is the other way around: mixture 1 is the lightest and mixture 3 the heaviest. Taking into account the elasticity of the slabs we can conclude that all three mixtures in collaboration with the mesh are very elastic and not much difference can be found. While producing the samples we took notice of the workability of the mixtures and it became clear that mixture 2 has the best workability compared to the other two mixtures. Taking this into account in combination with the low density and its high strength, we decided to use mixture 2 for our canoes. The exact amounts of the different ingredients in mixture 2 are shown in table 2.4. Unfortunately we did not reach the goal of producing a sustainable concrete mixture for this year. Although sand is a renewable resource and Liaver is produced in a sustainable way, the other materials are still not-sustainable. On the other hand, not reaching the goal this year provides a opportunity for improvement for next season.

Material:	Supplier:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	CBR	146.1	450.0
Limestone powder	Kalksteinwerk Medenbach (CBR)	66.4	180.0
Micro Silica	Sika (CBR)	19.3	45.0
Sand 0-1	Zandmaatschappij Twenthe	40.5	106.8
Liaver 0.1-0.3	Liaver	300.2	180.1
Liaver 0.25-0.5	Liaver	55.0	29.7
Liaver 0.5-1.0	Liaver	124.4	56.0
Bayferrox 920 (yellow)	Scholz	5.1	13.5
Bayferrox 110 (red)	Scholz	2.6	6.7
Water		220.5	220.5
Air		20.0	
Total:		**1000.0**	**1288.3**

Table 2.4: CM2009, the concrete mixture used for the canoes of 2009.

2.3.3 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 some isolation 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 2.5) the material status of our canoes is given, in this table all used materials and their specification are mentioned.

Element:	Material:	Specification:	Amount:	Total:
Concrete	CEM I 52.5R LA White	3,08 kg/l		20.25 kg
	Limestone powder	2,71 kg/l		8.10 kg
	Micro Silica	2,33 kg/l		2.03 kg
	Sand 0-1	2,64 kg/l		4.82 kg
	Liaver 0.1-0.3	0,60 kg/l		8.21 kg
	Liaver 0.25-0.5	0,54 kg/l	45l	1.33 kg
	Liaver 0.5-1.0	0,45 kg/l		2.54 kg
	Bayferrox 920 (yellow)	2,65 kg/l		0.61 kg
	Bayferrox 110 (red)	2,64 kg/l		0.30 kg
	Water	1,00 kg/l		9.92 kg
	Air	-		- kg
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	20m
	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	Black	1 l	1l
	Isolation tube	-	12 pcs	12 m
	Glue	Glue bars	12 pcs	12 pcs
	Seating foam	-	2 pcs	2 pcs

Table 2.5: The material status

Part 3

Wir sind dabei! A process description of construction year 2008/2009

In this third part of the report the focus is on the process of construction year 2008/2009. 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 chapter 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!

3.1 The Mission

As you already know, we will take part to the Dutch and the German competition this year. Because of our success last year in the Dutch competition (see paragraph 2.1) we would like to prolong our title as 'overall champion' this year in Roermond. It is a hard way to the top but it is harder to stay on the top, and that is just what our main goal will be this year.

This means that In Roermond our goals are:

- The main goal:
  - I. Be victorious at the gentlemen's sprint race
  - II. Be victorious at the gentlemen's long race
  - III. Win the prize for best constructor
- The sub-goals (is the opportunity arises):
  - I. Be victorious at the mixed sprint race
  - II. Be victorious at the mixed long race
  - III. Be victorious at the ladies sprint race
  - IV. Be victorious at the ladies long race

It is clear that our mission in the Dutch competition is to be dominant in the gentlemen's competition and we hope to become the best constructor of 2009. And of course when there will be a small opportunity to get one of the other prizes, we will take it with both hands.

In Germany we will be the newcomers. In Essen our main goal is to participate and experience the German competition, just for the experience and to look further than the Dutch competition. Therefore taking part is of more importance than winning. But, this doesn't mean we won't compete for the prizes, in contrary, our team has two top athletics, who will not hesitate if the opportunity to win in Germany arises.

This means that in Essen our goals are:

- The main goal:
  - I. Compete
  - II. Top 3 classification in the gentlemen's race
- The sub-goals:
  - I. Win the prize for best constructor
  - II. Top 3 classification in the ladies race

It is clear that our mission in the German competition is competing and have a good performance in the gentleman's competition. The prize for the best constructor and a good performance in the ladies competition are desired as well.

With this mission in mind the BetonBrouwers went to work as described in the next paragraphs!

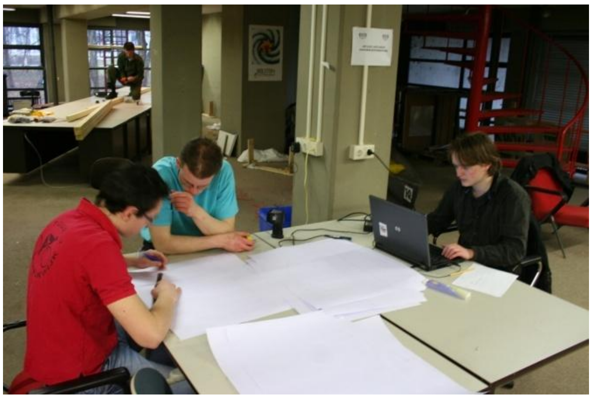
3.2 From brilliant plans to winning canoes

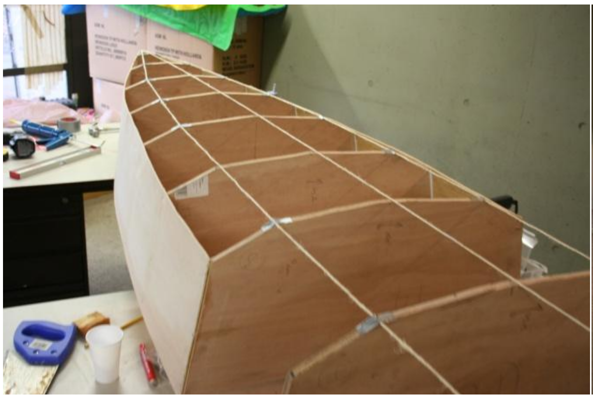
Every mission starts with a plan, for this year it was making a totally new canoe. A canoe which should be perform better than the old one. Because the old mould concerned an inner mould, the outer surface of the canoe required a lot of work, while the inner surface was very smooth. Therefore the goal for the new canoe was making a outer mould which would result in a smooth skin of the canoe. The nice thing is that we build the canoe from design until the finishing touch all by ourselves. In this paragraph a description is given of the hard work that is performed by the BetonBrouwers to get from the brilliant plans to the hopefully winning canoes.

3.2.1 From drawing to mould

After the previous season we started with making brilliant plans for the coming season. This meant that we had to start with making a new concept: the CT2009. Based on our experiences from the previous years, the information derived from construction reports from the USA and the software Delftship, our Head of Design started designing a new canoe. After optimizing all parameters and determining the perfect shape that suited the wishes and requirements the design was finished. With this new concept we could start with making a new mould.

In first instance we tried to make the mould in collaboration with a specialized company, this turned out to become too expensive. Therefore we decided to make the mould ourselves. The first thing that had to be done was to convert the drawing in Delftship to an AutoCAD drawing. Because we wanted a outer mould, we had to make a model of the canoe itself in order to make a polyester mould around it. Therefore we made cross-sections in AutoCAD. These cross-sections (40) of the design where printed out, drawn on wooden plates and sawn out. These sections were placed on a large beam and secured. Because the end result relied on our accuracy a lot of measurement took place were to put each section before securing it. Thereby we check if the section were level and rectangular onto the beam by placing a square beer mat against it, see right bottom picture. With all the sections in the right place, the model still had no skin. Therefore large wooden sheets were cut an placed over the sections. The gaps and grooves were filled, the entire construction was sand-papered and the model was finished.



From the model we had to make a polyester mould. This was done in collaboration with a company specialized in polyester constructions (Ascom polyester). We put the model on a large van in the early morning and drove it to Beek and Donk (in the southern part of the Netherlands), were Ascom is located. Arrived in Beek and Donk we started with preparing the mould by filling the remaining gaps and grooves and sand-paper it again until it became very smooth. The following step was to put the model in a special black paint which would seal the wood and prevent it from absorbing the coming layers and give it a even smoother surface.

After the black layer dried a second layer could be placed on. This layer was a liquid alcohol based emulsion which evaporated very fast, once this emulsion dried it formed a very thin plastic layer on the model. With this very thin plastic bag around our model, the demoulding had to become easier. Now the real work could start. The next layer was a resin that formed the first layer of the polyester mould, it would form the inside of the mould and had a nice blue colour. In the time this layer had to dry we started cutting polyester strips. From the moment the blue resin was dry we started with placing the first polyester mats on the model and put resin over it. This had to be spread and mixed with the mats by rolling over it. After removing the air bubbles between the glass fibres, the next mat could be placed on top. In this way we worked from front to back and in the end 3 layers of polyester were placed. Now we had to wait until the resin hardened.




After a couples of our waiting until the polyester was hardened enough we separated the polyester mould from the wooden model (with the help of a crane). The last thing to do was cleaning the mould from the plastic foil and place everything on top of the van. After a long drive back to the BetonBrouwers Headquarter, a long and hard day of work came to an end. After all the hard work, as described in this section, we had a very nice mould which took us about 300 man-hours of hard work.

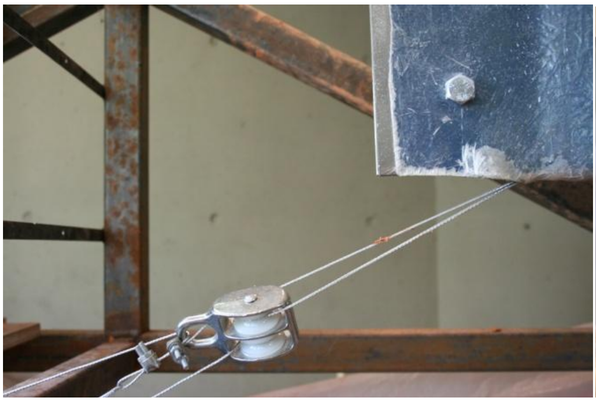
3.2.2 Blood, sweat and tears

How the mould is constructed is already explained, now it's time to unfold the story how, with this mould, a concrete canoe can be constructed. As earlier explained we created a mould where the concrete will be putt on the inside, on the contrary to last year. With method had its advantages and on the other hand some disadvantages. But bear in mind the advantages of the end result; a canoe with a smooth outer surface and a modelled, calculated shape. Ideal for a win in one or more categories.

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 to put the "demoulding oil" in the mould. The water based demoulding oil was placed with a plant spray. With a plant spray we often sprayed a long 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 depositing, 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 the concrete. This means that all materials can be weighted in the right proportions and the mix can be made. First the dry materials are put into the mixer. Starting with the cement, micro silica and the limestone powder. This is followed by the sand, Liaver and the pigments. When these materials are mixed properly the water is added.

This created a stiff mix of materials. To make sure the mixture is workable the Super Plasticizer (SP) is added. The process of adding the SP is a delicate question. A little bit too much turns the mixture in a orange soup and is far from ideal, but a little bit too few 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 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 were 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 harden, 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 and thereby sealing the canoe. After at least one week the next step will be demoulding and after-stress the two upper cords!

3.2.3 The final touch

The last and final phase of constructing a concrete canoe concerns the final touch. The first thing is demoulding the canoe. When this is done the two upper cords can be put on tension 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 next thing is sand-paper the outer wall with very fine sandpaper and the inner wall with rough sandpaper. This makes the walls look nicer and they become nice smooth. On top of the walls isolation 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.

In this stage the names, the sponsors and start numbers were painted onto the canoes. The names of the canoes are: ‘De Twentse Ros’, ‘De Oranje Nassau’, ‘The Flying Dutchman’ and ‘Das Phantom’. In the table below a short explanation behind these names is given.

Name:	Explanation:
De Twentse Ros	The Twentse Ros is the symbol of the region Twente, where the University of Twente is located, and can be found in the logo of the BetonBrouwers.
De Oranje Nassau	‘De Oranje Nassau’ refers to the Dutch kingdom, while the Royal Family carries the name Oranje Nassau.
The Flying Dutchman	‘The Flying Dutchman‘ to a Dutch ghost ship that would harass other sailing ship around the Cape of Good Hope since 1676.
Das Phantom	‘Das Phantom’ refers to Roy Makaay, a Dutch football player which played in the Bundesliga. He was given this name because most of the time he scored out of nothing. We hope the same applies for us in the German concrete canoe competition.

Now the canoes themselves are finished and ready for 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 are three nice canoe supports/carriers. In these support 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 plates where the canoeists can sit on and which distributes the forces of the canoeists more equally towards the bottom. The last thing is something we still have to construct and concerns a top secret highly classified special project which will be shown during the presentation of the canoes towards the public.

3.3 It is not all about the canoe itself

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 canoe with it is an extremely important factor. Therefore in our starting year 2007, the help of some canoe experts was hired.

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 become a member of Euros to train the whole next winter. Until the end of the fall of 2007 our two top canoeists, Frank and Sevrien, trained outside on the canal. Although the next race was held in May of the next year, we were determined to improve our canoe skills even more.

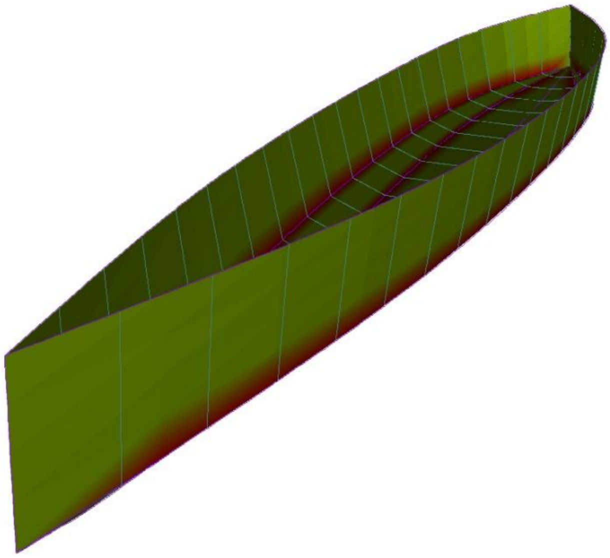
After the winter reached Twente, the training was moved to the indoor swimming pool of the University. Using special indoor training paddles and wooden constructions fixed to the side of the pool, we could train our muscles. Almost every Monday between November and March was used to train. Together with the improved canoes, we were ready to form a deadly combination of trained canoeists and well build canoes. At the Concrete Canoe Challenge 2008 in Delft, our efforts of the winter and spring were rewarded. Again it was proved that training was a very important aspect of the concrete canoe project.

The winter period of 2008/ 2009 again was used to train hard and to improve ourselves, as far as possible. In the beginning of May we decided that knowing how to deal with a slalom trail was a new challenge. For this reason we developed our own slalom trail in the harbour of Enschede. Concrete elements were used as weight and air balloons as buoys. The buoys let us develop a plan how to deal with the slalom. This will of course be implemented in the German Betonkanu-Regatta in Essen. Competitors: eat your heart out!

Because we really like to fight for our victories, we show our competitors how to paddle and especially how not to do so. 'Prof. Arms' and 'The Bear of Boekelo' give a short introduction in paddling in Appendix C.

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 seven 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 points 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 of design a new canoe and thereby building a new mould, brought us a lot of challenges and new experiences. But 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.

During the two Concrete Canoe Challenges we will know if the new design performs as good in practice as it will do according the theory. 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 provides a clear view on how our canoes have come to life. We hope you have enjoyed reading this construction report.

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 provided. In the second appendix the background information behind the concrete mixture is given. Finally, in the third appendix, the two diehard BetonBrouwers 'Prof. Arms' and ' The bear of Boekelo' will give a short lesson in paddling for newbie's.

Appendix A: Contact Information

In this appendix you can find the contact information of Study Association ConcepT, where this construction committee is part of. Besides that, the contact information of the Chairman of our committee and team captain, Chiel de Wit, is mentioned. Finally the contact information of the Event Manager of the committee, Frank Aarns is provided.

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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 the different mixtures is shown in tables B1, B2 and B3. The corresponding particle size distribution is shown in the graphs in figures B1, B2 and B3.

Mixture 1: CM2009-1

Material:	Supplier:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	CBR	146.1	450.0
Limestone powder	Kalksteinwerk Medenbach (CBR)	66.4	180.0
Micro Silica	Sika (CBR)	19.3	45.0
Sand 0-1	Zandmaatschappij Twenthe	40.6	107.0
Liaver 0.1-0.3	Liaver	331.1	198.6
Liaver 0.5-1.0	Liaver	152.9	68.8
Bayferrox 920 (yellow)	Scholz	5.1	13.5
Bayferrox 110 (red)	Scholz	2.6	6.8
Water		216.0	216.0
Air		20.0	
Total:		**1000.0**	**1285.7**

Table B1: Composition mixture 1

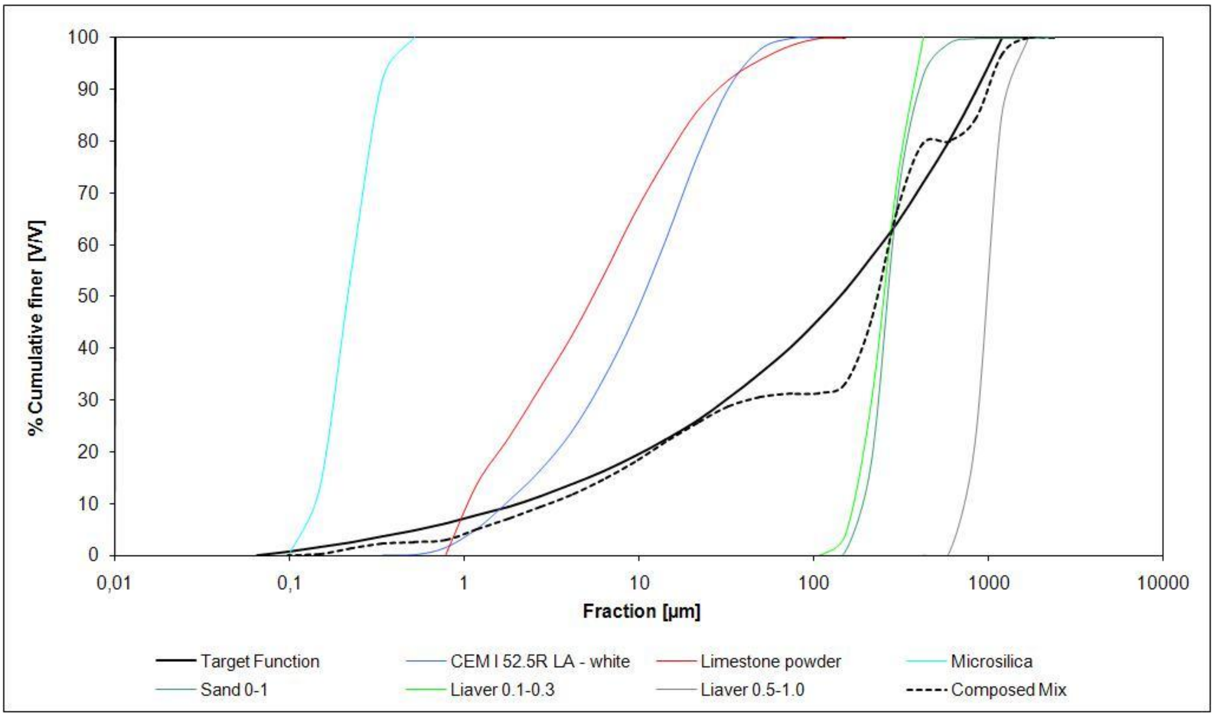


Figure B1: Particle size distribution mixture 1

Mixture 2: CM2009-2

Material:	Supplier:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	CBR	146.1	450.0
Limestone powder	Kalksteinwerk Medenbach (CBR)	66.4	180.0
Micro Silica	Sika (CBR)	19.3	45.0
Sand 0-1	Zandmaatschappij Twenthe	40.5	106.8
Liaver 0.1-0.3	Liaver	300.2	180.1
Liaver 0.25-0.5	Liaver	55.0	29.7
Liaver 0.5-1.0	Liaver	124.4	56.0
Bayferrox 920 (yellow)	Scholz	5.1	13.5
Bayferrox 110 (red)	Scholz	2.6	6.7
Water		220.5	220.5
Air		20.0	
Total:		**1000.0**	**1288.3**

Table B2: Composition mixture 2

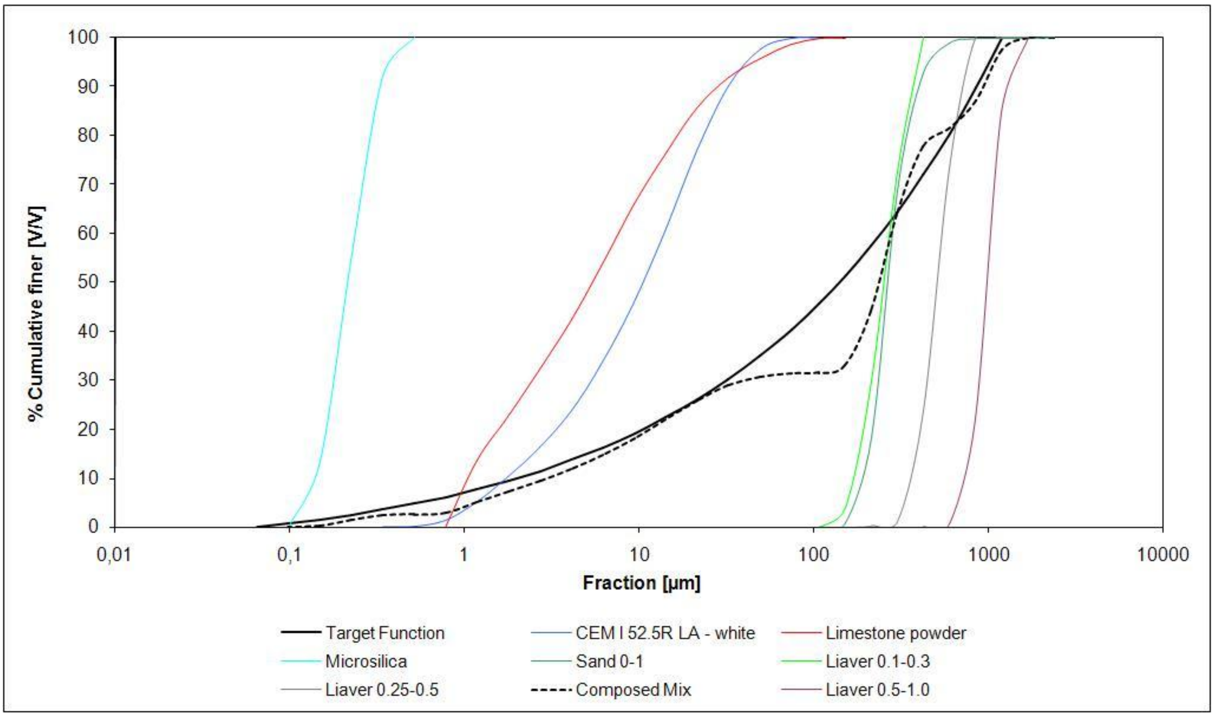


Figure B2: Particle size distribution mixture 2

Mixture 3: CM2009-3

Material:	Supplier:	Volume [dm^3]	Mass [kg]
CEM I 52.5R LA White	CBR	146.1	450.0
Limestone powder	Kalksteinwerk Medenbach (CBR)	66.4	180.0
Micro Silica	Sika (CBR)	19.3	45.0
Sand 0-1	Zandmaatschappij Twenthe	88.2	232.5
Liaver 0.1-0.3	Liaver	253.3	152.0
Liaver 0.25-0.5	Liaver	50.1	27.1
Liaver 0.5-1.0	Liaver	124.0	55.8
Bayferrox 920 (yellow)	Scholz	5.1	13.5
Bayferrox 110 (red)	Scholz	2.6	6.7
Water		225.0	225.0
Air		20.0	
Total:		**1000.0**	**1387.6**

Table B3: Composition mixture 3

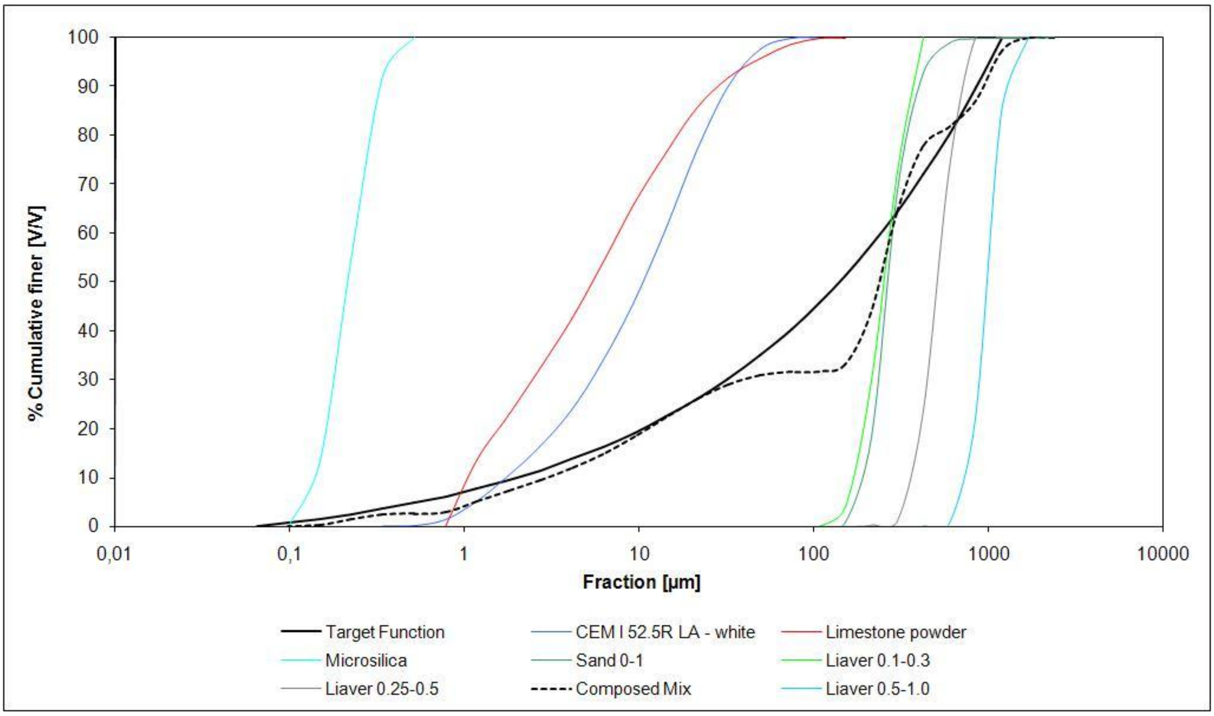


Figure B3: Particle size distribution mixture 3

Test Results

In order to be able to make a well considered choice which mixture to use for the concrete canoes, the different mixtures have gone through a series of tests. In this section the test results are presented.

Flexural Strength

In table B4 the Flexural Strength of the different mixtures is shown. The averages are: Mix 1: 7,0 N/mm, Mix 2: 9,3 N/mm and Mix 3: 10,3 N/mm. The result of specimen Mix 3_1 (shown in red) is not taken into account because an error occurred during the test.

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Cor. Force [kN]	Strength [N/mm]
Mix 1_1	09-02-2009	09-03-2009	28	40.09	40.13	2.822	2.834	6.5
Mix 1_2	09-02-2009	09-03-2009	28	40.29	40.30	2.996	3.008	6.9
Mix 1_3	09-02-2009	09-03-2009	28	39.84	40.20	3.214	3.226	7.5
Mix 2_1	09-02-2009	09-03-2009	28	40.31	40.02	4.586	4.598	10.6
Mix 2_2	09-02-2009	09-03-2009	28	40.81	40.18	3.352	3.364	7.6
Mix 2_3	09-02-2009	09-03-2009	28	40.86	40.22	4.286	4.298	9.7
Mix 3_1	09-02-2009	09-03-2009	28	40.28	40.09	1.678	1.690	3.9
Mix 3_2	09-02-2009	09-03-2009	28	40.44	40.17	4.306	4.318	9.9
Mix 3_3	09-02-2009	09-03-2009	28	40.08	40.24	4.630	4.642	10.7

Table B4: Test results Flexural Strength

Compressive Strength

In table B5 the Compressive Strength of the different mixtures is shown concerning the prisms. The averages of the different mixtures are: Mix 1: 35,4 N/mm, Mix 2: 39,1 N/mm and Mix 3: 48,6 N/mm.

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm]
Mix 1_1_1	09-02-2009	09-03-2009	28	40	40	49.88	31.2
Mix 1_1_2	09-02-2009	09-03-2009	28	40	40	60.15	37.6
Mix 1_2_1	09-02-2009	09-03-2009	28	40	40	55.25	34.5
Mix 1_2_2	09-02-2009	09-03-2009	28	40	40	56.15	35.1
Mix 1_3_1	09-02-2009	09-03-2009	28	40	40	59.65	37.3
Mix 1_3_2	09-02-2009	09-03-2009	28	40	40	58.40	36.5
Mix 2_1_1	09-02-2009	09-03-2009	28	40	40	59.90	37.4
Mix 2_1_2	09-02-2009	09-03-2009	28	40	40	61.20	38.3
Mix 2_2_1	09-02-2009	09-03-2009	28	40	40	62.85	39.3
Mix 2_2_2	09-02-2009	09-03-2009	28	40	40	62.15	38.8
Mix 2_3_1	09-02-2009	09-03-2009	28	40	40	67.80	42.4
Mix 2_3_2	09-02-2009	09-03-2009	28	40	40	61.85	38.7
Mix 3_1_1	09-02-2009	09-03-2009	28	40	40	75.75	47.3
Mix 3_1_2	09-02-2009	09-03-2009	28	40	40	79.95	50.0
Mix 3_2_1	09-02-2009	09-03-2009	28	40	40	75.40	47.1
Mix 3_2_2	09-02-2009	09-03-2009	28	40	40	79.00	49.4
Mix 3_3_1	09-02-2009	09-03-2009	28	40	40	79.25	49.5
Mix 3_3_2	09-02-2009	09-03-2009	28	40	40	77.65	48.5

Table B5: Test results Compressive Strength (prisms)

In table B6 the Compressive Strength of the different mixtures is shown concerning the cubes. The averages of the different mixtures are: Mix 1: 46,9 N/mm, Mix 2: 51,4 N/mm and Mix 3: 49,1 N/mm.

Specimen	Date Cast	Date Test	Age	Width [mm]	Height [mm]	Force [kN]	Strength [N/mm]
Mix 1_1	16-02-2009	16-03-2009	28	50	50	106.1	42.4
Mix 1_2	16-02-2009	16-03-2009	28	50	50	125.8	50.3
Mix 1_3	16-02-2009	16-03-2009	28	50	50	119.5	47.8
Mix 2_1	16-02-2009	16-03-2009	28	50	50	133.5	53.4
Mix 2_2	16-02-2009	16-03-2009	28	50	50	129.0	51.6
Mix 2_3	16-02-2009	16-03-2009	28	50	50	123.0	49.2
Mix 3_1	16-02-2009	16-03-2009	28	50	50	127.0	50.8
Mix 3_2	16-02-2009	16-03-2009	28	50	50	109.6	43.8
Mix 3_3	16-02-2009	16-03-2009	28	50	50	131.3	52.5

Table B6 Test results Compressive Strength (cubes)

Density measurements

In table B7 the density of the different mixtures is shown. The averages of the different mixtures are: Mix 1: 1492.9kg/m^3, Mix 2: 1539.6kg/m^3 and Mix 3: 1751.4kg/m^3.

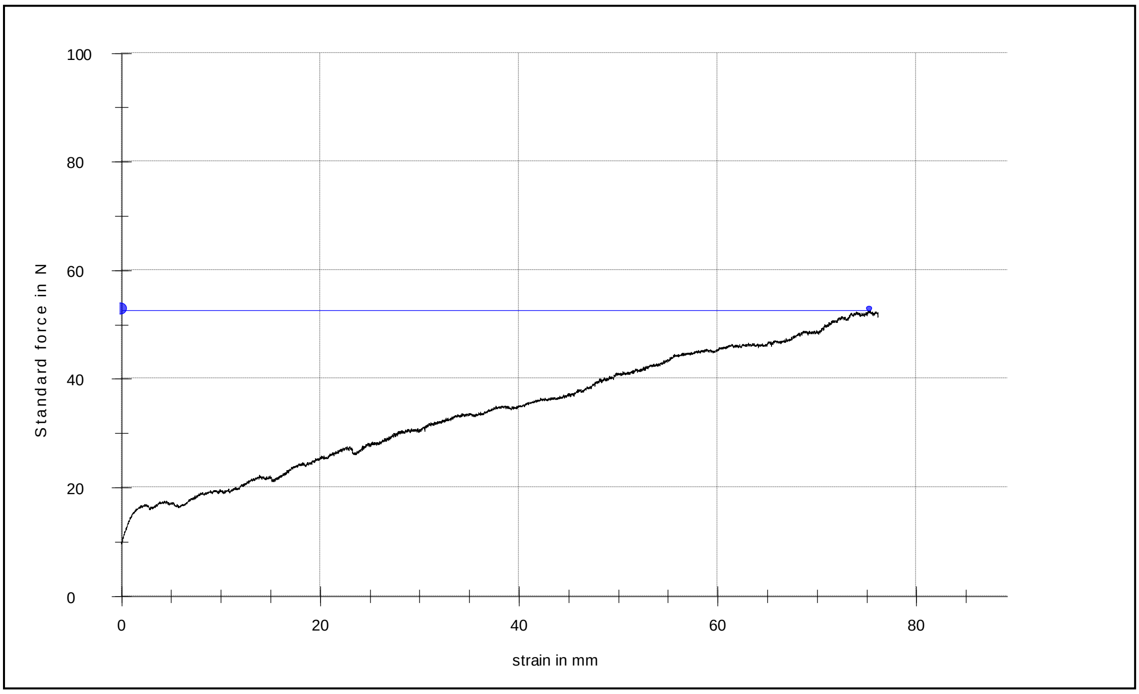
Prism ID	Specimen	$M_{air,wet}$ [g]	$M_{air,dry}$ [g]	$M_{underwater}$	R_{dry} [g/cm^3]	R_{wet} [g/cm^3]	Water Absorption [wt.%]	Porosity [Vol. %]
1	Mix 1_1_1	98.7	89.4	29.6	1.492	1.426	10.4	13.5
2	Mix 1_1_2	46.5	41.4	13.9	1.502	1.424	12.3	15.6
3	Mix 1_2_1	67.2	60.6	19.9	1.486	1.418	10.9	14.0
4	Mix 1_2_2	74.5	67.4	22.1	1.485	1.419	10.5	13.5
5	Mix 1_3_1	61.6	55.5	18.6	1.501	1.430	11.0	14.2
6	Mix 1_3_2	94.4	85.9	28.4	1.491	1.427	9.9	12.9
7	Mix 2_1_1	93.4	85.1	29.1	1.517	1.450	9.8	12.9
8	Mix 2_1_2	29.3	26.2	9.3	1.547	1.462	11.8	15.5
9	Mix 2_2_1	89.3	80.5	28.8	1.554	1.473	10.9	14.5
10	Mix 2_2_2	89.4	81.3	28.1	1.525	1.455	10.0	13.2
11	Mix 2_3_1	75.0	68.1	24.0	1.541	1.468	10.1	13.5
12	Mix 2_3_2	76.2	68.8	24.6	1.553	1.474	10.8	14.3
13	Mix 3_1_1	57.6	51.8	22.5	1.764	1.638	11.2	16.5
14	Mix 3_1_2	105.5	96.3	40.8	1.732	1.627	9.6	14.2
15	Mix 3_2_1	67.4	60.7	26.5	1.771	1.645	11.0	16.4
16	Mix 3_2_2	105.8	96.1	41.3	1.750	1.637	10.1	15.0
17	Mix 3_3_1	52.8	47.4	20.4	1.752	1.626	11.4	16.7
18	Mix 3_3_2	82.7	75.1	32.0	1.739	1.628	10.1	15.0

Table B7: Test results density measurements

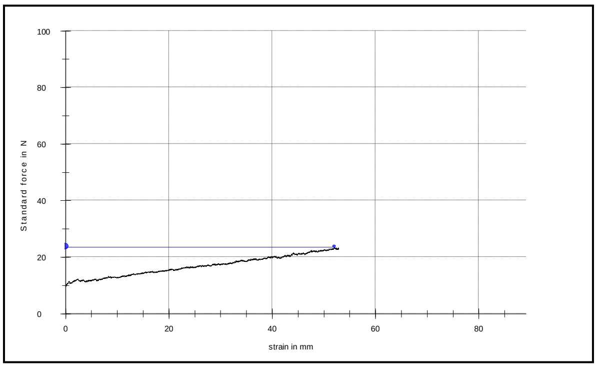
Elasticity Slabs

Besides the standard tests with concrete prisms and cubes, also a number of slabs have been tested, as mentioned in section 2.3.1. Below the graphs are shown as result of the tests at BAS bv. As can be seen the slabs were to flexible and didn't break but were pushed of the bracings. Because all slabs showed the same behaviour, only the first graph is shown on larger scale (see next page).

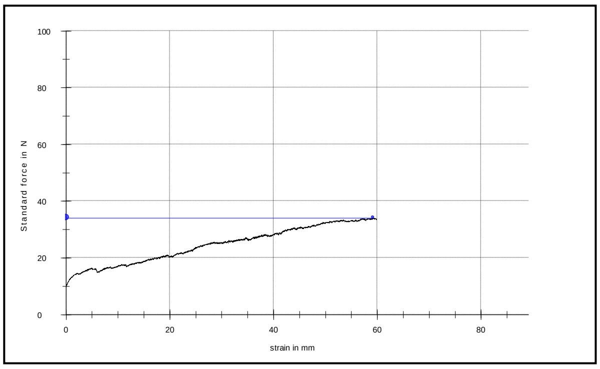
Mix 1 – Nr. 6



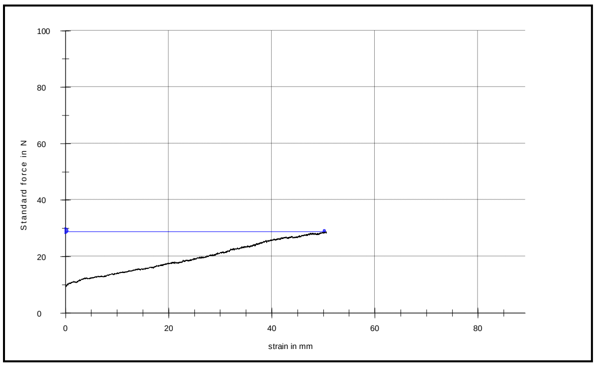
Mix 1 – Nr. 7



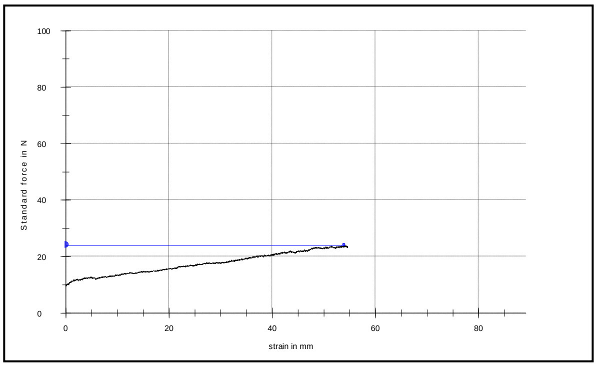
Mix 1 – Nr. 8



Mix 2 – Nr. 9

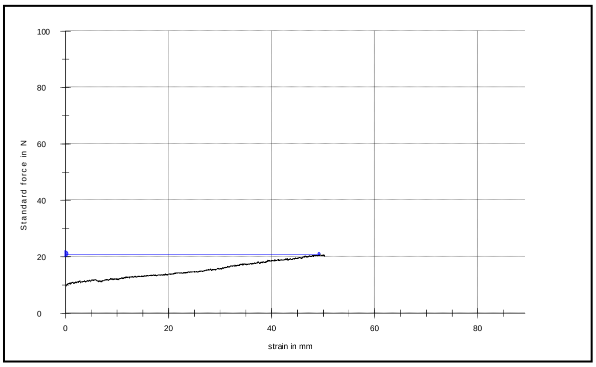


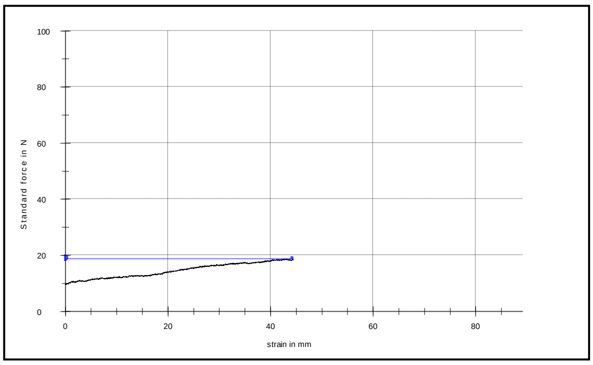
Mix 2 – Nr. 10



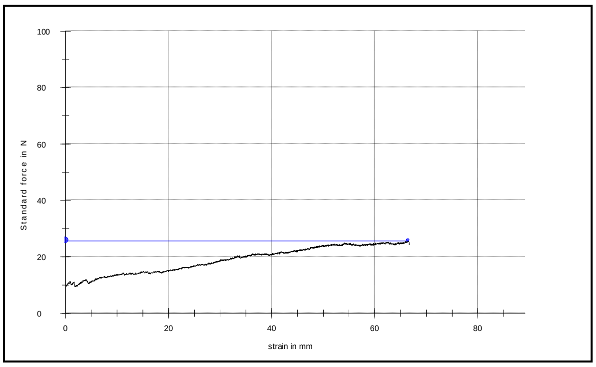
Mix 2 – Nr. 11

Mix 3 – Nr. 13

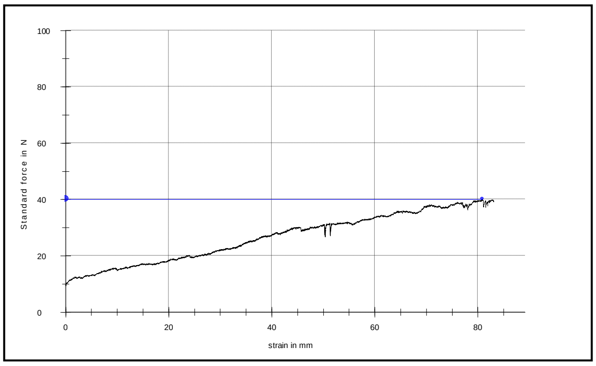




Mix 3 – Nr. 14



Mix 3 – Nr. 15



Appendix C: Paddling for dummies by 'Prof. Arms' and 'The Bear of Boekelo'

As two experienced concrete canoeists, 'Prof. Arms' and 'The Bear of Boekelo' will provide some basic tips and tricks about paddling a canoe. In collaboration with Euros Kano (the Canoe Association in Enschede) these men train during the winter at the indoor swimming pool of the University and during the summer they practice their skills on the beautiful Twente Kanaal. This in order to be well prepared for the yearly concrete canoe challenge. Based on their experience they tried to describe the basic ideas behind the canoeing technique. In order to give some clear insight in the proper techniques and positions, the tips and tricks are supported by pictures taken during the winter practices at the indoor swimming pool.

You and your partner should paddle each stroke at the same time, on opposite sides of the canoe. The paddler in the bow of the boat chooses a side and sets the pace, while the paddler in the stern follows the pace and steers the canoe. The bow paddler should switch sides in a regular pattern to reduce fatigue, and should paddle slowly enough to give the stern paddler a little extra time to steer.

SAFETY FIRST: If you are not sure if you can swim, it is strongly recommended to wear floating armbands (Schwimmflügel) or a life jacket!

POSITION: Always make sure you are sitting stable so you won't fall out your canoe, like shown in the upper right picture. There are three regular positions. The easiest one is to sit on your bottom. The second is to sit on your knees. The third and most efficient position is shown in the upper left picture.

HOLDING THE PADDEL: It is important to hold a grab on the paddle in the right way. One hand should be just above the blade of the paddle and the other hand should be on the grip, like shown on the middle left picture. NOTE: Never hold the paddle like is shown in the bottom right picture. Always be sure that you hold the paddle with the grip on top and the blade in the water.

STROKES: There are many different strokes for paddling canoes – too many to list. The basic stroke: First, find your proper grip by holding the paddle out in front of you at arm's length, then grabbing the top grip of the paddle with one hand and moving your other hand down the shaft of the paddle until your hands are shoulder width apart. Be sure to keep your shaft hand loose enough that the shaft can rotate when you pull the paddle towards you!

SPECIAL MANOUVRES: If you want to make a special manoeuvre (making a turn or keep competing canoes away from you), make explosive movements (as shown in the upper left picture) and be sure that you can move you paddle freely (avoid situations like shown in the upper right picture).

NO LEANING: Always keep your shoulders inside the gunwales of the boat. If you have to reach for something, try to use your paddle.

CAPSIZING: It doesn't matter how good you are, every paddler flips over eventually. Adding grab handles or perimeter lines to your boat can make it easier to get back in. Know and practise both self and assisted rescues.

DON'T PANIC: Even if you're stuck upside-down in a kayak, take a moment to calm yourself before you do anything, if at all possible.

Thanks' for paying attention to this important lesson in the basics behind canoeing, hopefully it will result in a lot of fun when putting it into practice!