SUSTAINABILITY & INNOVATION WITH CONCRETE

CONSTRUCTION REPORT 2012 – PART 2

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Introduction

Since July 2011 this committee, consisting of nine Concrete Brewers, has put a lot of dedication and effort into the design and construction of four beautiful race canoes, a sustainable recycle canoe and a significant different, innovative, canoe. In addition to Construction Report 2012 part 1 “Concrete Canoes - How do they do it?”, this report specially addresses the sustainability and innovation projects of season 2012.

This year special attention is paid to sustainability. First of all attention is paid to the selection and amounts of the ingredients for the lightweight concrete mixture of our race canoes. But besides that the BetonBrouwers developed a concrete mixture bases on the debris of recycled concrete canoes from previous seasons. In this way literally a cradle to cradle canoe was designed.

Inspired by the innovative canoe of Eindhoven of last year which existed out of separate plates which were bolted together, the BetonBrouwers started thinking. After setting a record by constructing the lightest canoe in 2011, the new challenge for this season became an innovative canoe better than that of others in previous seasons. The idea came up to make a foldable concrete canoe. A canoe which exists out of eight concrete plates which are attached to each other with a in cured foil. With this special and innovative design we hope to obtain the innovation price 2012.

This report is written to give the construction jury a clear insight into the principles behind the sustainable recycle canoe and the innovative folding canoe. In part 1 the reasoning behind the sustainable recycle mixture is explained. In the second part the design of the folding canoe is explained. Part three of this report is a process description of the realization of both canoes.

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

BetonBrouwers 2012,

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Cindy Clevers	(Vicevoorzitter)
Simon Janssen	(Secretaris)
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Part 1

Sustainable Concrete: Recycle Canoe

This year special attention is paid to sustainability. First of all attention is paid to the selection and amounts of the ingredients for the lightweight concrete mixture of our race canoes. But besides that the BetonBrouwers developed a concrete mixture bases on the debris of recycled concrete canoes from previous seasons. In this way literally a cradle to cradle canoe was designed. In this section we highlight the development of this recycle canoe.

1.1 Selection of the ingredients

In this section the recycle mixture of our cradle to cradle canoe is composed. First the difference in objective compared to the lightweight mixture is explained. Based on the objective and the slightly changed requirements, the different materials are chosen. After this step the mixtures are composed and the best mixture is chosen.

1.1.1 The Objective

The objective of the concrete for this canoe is to make a sustainable and good workable concrete. It is desired that the recycled aggregates can be seen on the surface. This would mean that is it possible to see red, white and blue aggregate (the colours of the canoes of previous season). Another objective is to cast a green recycle logo in the back of the canoe, this instead of the Twents Ros on the race canoes.

Besides the objectives as mentioned, there are some requirements or changes to the requirements compared to the 'normal' mixture. These are:

Colour:
No explicit colour is given to the canoe. We want the concrete to have it's pure colour, this in combination with the colour from the aggregate. Also, since we want to make a recycle logo in the canoe, we want to use a bit of green concrete.

Permeability:
This objective stays the same, the concrete must be impermeable.

Density:
Since recycled aggregates are used to make this canoe, the density will be higher than for the normal race canoes. Although the recycled canoes consisted of lightweight concrete, the lightweight aggregates are crushed during the crushing of the canoes, resulting in a higher density. Therefore is decided to not have a specific requirement for the density.

Sustainability:
Over the last years the environment is getting a more and more important issue. This environmental awareness can be noticed in the concrete industry as well. Because usually our canoes are only used for racing for one year and then stored/used for expositions, the canoes are not very sustainable. This made the team think of a more sustainable way to make a concrete canoe for which not much new materials are necessary. The solution to this problem was to demolish old canoes and to reuse them in a canoe for this year. Real cradle to cradle.

Several possibilities are available to make a sustainable concrete:
- Use of recycled aggregates, preferred from a location close to prevent transportation
- Use of waste materials from other industries
- The use of sustainable cement
- Design a concrete with a high quality (concrete) so that it is not necessary to replace it. For our canoes this is no option since the canoes cannot be older than one year because the German race does not allow us to take part to their competition with canoes from previous seasons.
- Use as few concrete as possible, a high strength concrete can contribute to this, this concrete can have a high amount of cement in the mixture but because only a little amount of concrete is necessary it is still more sustainable than the regular concrete.

The aim is to use most of the possibilities as mentioned for a sustainable mixture.

1.1.2 Ingredients

The first step in composing the mixture is to select the materials. Since every material has its specific characteristics and contribution to the mixture, this chapter highlights the materials used in our canoes.

Cement:
The Heidelberg Cement Group provided us of cement, being TiOCEM I 52.5R LA – White. Although a grey cement is more sustainable, less energy is needed for production compared to white cement, we took a different approach. We searched for a cement with a positive influence on the environment. Because of the

special properties the choice was fallen on TiOCem. This cement is self cleaning and de-polluting. Because of the addition of TiO_2 in the cement, together with the sun a chemical self cleaning reaction will start. The TiO_2 also starts a reaction with lots of pollutions in the air (NOx SOx CO NH_3) the pollutions will bind to the TiO_2 and the air will be cleaner around the concrete object. This is not only good for the environment but also for our paddlers, who will have the cleanest air of the field.

This is a white cement and therefore will attribute to the best colours. Thereby the addition 'LA' is indicating that it has a Low Alkali content. This low alkali content has a positive influence on the durability of the concrete since it reduces the occurrence of AAR.

Aggregates: The procedure of making the aggregates.

Aggregates are the bearing material in concrete. It has an important influence on the concrete properties, both in the fresh- and hardened state. Aggregates can be distinguished in grain size. Sieve curves determine how much aggregate from each grain size is needed. The aim is a perfect fit for small and bigger grain sizes, such that there is no space left for air. One of the requirements for a workable mixture in combination with the reinforcement is that the aggregates should not be bigger than 1 mm. Therefore is chosen to crush our old canoes into very fine parts smaller than 1 mm.

After the first samples of the crushing and sieving was present it was the task to determine the properties of the aggregates. The density and the particle size distribution were most important properties.

Density. The density was derived by measuring the volume of water what fits in a small bucket. Afterwards a measured amount of aggregates was put in this bucket and the rest was filled with water. With the volume of the bucket, the weight and the volume of the water together with the aggregates and the density of water (1000 kg/m^3) the density can be calculated. The density of the aggregates turned out to be 1.88 kg/dm^3.

Particle size distribution. First a representative sample was taken from the aggregates. Afterwards according to EN-933-1 the aggregates were sieved.

Mineral additives

Mineral additives are fine substances (<63µm) which can be added to the concrete to increase the amount of fine material. Mineral additives can be inert (non-reactive) or pozzolana, which means the substance becomes solid after the reaction with water and calcium hydroxide. The most common used mineral additives are fly ash, silica fume and pozzolans. All three of these additions are industrial by-products. When used in concrete they reduce the demand for clinker. Hence their use is advantageous both for economic and environmental point of view, i.e. reducing the large amounts of CO_2 emission associated with cement production.

Two mineral additives existed in this concrete: the first mineral additive are the fines from the recycled aggregate, the second mineral additive is Silica Fume. Silica fume is selected because of the following reasons:

- The small grain size increases the strength
- The small grain size decreases the permeability
- It is a sustainable product, it is a rest product from the chip industry.
- It contributes to the final strength of concrete, because of its puzzolan activity.

Admixtures:

Admixtures are parts of the concrete composition (<5 mass%), who achieve a significant modification in the properties of the cement paste and/or the concrete. In our concrete three types of admixtures are used retarding admixture, super plasticizer (GL 51) and pigments.

Super plasticizer. The main role of (super) plasticizers is to disperse flocculated cement particles in water. (Super) plasticizers can be utilized in different ways:

- Constant strength and water content
- Constant workability and cement content
- Constant workability and strength
- Increased workability

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

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

Pigment. In order to get a green recycle logo in the canoe, Scholz was asked for a green pigment. The following pigment will be used: Chrome Oxide Green (Scholz).

1.1.3 Result

In the table below the ingredients for the concrete sustainable mixture of 2012 are listed.

Material:	Supplier:	Details:
TioCEM I 52.5R LA – White	CBR	-
Kano puin 0-1 (recycled aggregates)	BetonBrouwers	-
Chrome Oxide Green	Scholz	-
Plasticizer GL51	Basf	-
Retarder	Cugla	Add 0.3% of cement weight

Table 1.1: Ingredients concrete mixtures 2012

1.2 Mixtures

The second step is to determine the optimal composition. In total three different mixtures were composed. The first mixture was composed based on only cement and recycled aggregates 0-2mm. Because the workability of the mixture was really bad, the decision was made to use aggregates 0-1. This time in combination with some extra filler to get a better particle size distribution. Also another mixture was composed in which also Liaver was used. This mixture was composed in case we were not able to make enough recycled aggregates before construction of the canoe.

Combined mixtures		***Choosing the to use materials***
Mixture 2.1	Series 4	Only Cement and Kano puin (0-2)
Mixture 3.1	Series 5	Cement, kano puin (0-1), liaver, silica fume
Mixture 3.2	Series 5	Cement, kano puin, silica fume.

Table 1.2: Composed mixtures

All these mixtures were tested in the concrete lab. For each mixture the amount of Super Plasticiser required to give the mixture the perfect workability characteristics, was determined. From each mixture three prisms were made, besides we filled some small plastic boxes with concrete and mesh to obtain the permeability and the workability. The prisms were tested after 28 days and based on the results (see next section), the colour the workability and the density of the mixtures the best mixture for our canoes could be determined. Because there were enough crushed aggregates and the workability was good the mixture composed out of cement, kano puin (0-1) and Silica Fume was chosen (mixture 3.2).

1.3 Analysis

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

1.3.1 Workability

During the production of the test samples the workability was tested. Of the first mixture, the workability was really bad, even with the use of a lot of super plasticizer the workability could not be make ok. Therefore the second mixtures were composed: mixtures with a maximum grain size of 1 mm. This turned out to be much better for the workability of the concrete. There was no difference in workability with the mixture were the liaver was added. Because both mixtures were good, the liaver mixture, mix 3.1 was the back-up mixture in case not enough aggregates were present.

1.3.2 Density & Strength

The density of the mixtures was no issue for this type of concrete. Still the densities were measured, the result can be found in table 1.3. The flexural strength was tested with a 3 point bending test. With the two remaining pieces of the prisms the compressive strength was tested.

The table below shows the density of each mixture and the flexural - and the compressive strength after 28 days of curing. The first mixture proved to be really strong. This in combination with a lack of time and a bad wcf for mixture 1 (reducing the strength), mixtures 3.1 and 3.2 were not tested on compressive and flexural strength. Since no high strength is required in combination with the reasons mentioned above this was neither tested after casting.

Mixture:	Density [kg/dm^3]*:	Flexural Strength [N/mm^2]:	Compressive Strength [N/mm^2]:
Mixture 1	1.68	5,8	35,95
Mixture 3.1	1.61	-	-
Mixture 3.2	1.81	-	-

Table 1.3: Density and average strength of the mixtures (measured).*

1.3.3 Conclusion

Finally was chosen for mixtures 3.2, this is the mixture without liaver and a good workability. Thereby it was one of the best mixtures according to our sustainability requirements.

Material:	Mass [kg]	Volume [dm^3]	Additional information:	
CEM I 52.5R LA White	600,0	195,4	Density Glenium 51:	1.1kg/m^3
Silica fume	80,0	34,3		
Kanopuin 0-1	825,1	438,9	w/c ratio:	0.45
Water	270,0	270,0	w/b ratio:	0.40
Super plasticizer	4,0	3,6	w/p ratio:	0.34
Air		50,0		
Total	**1809,1**	**1000,0**		

Table 1.4: Composition of mixture 3.2

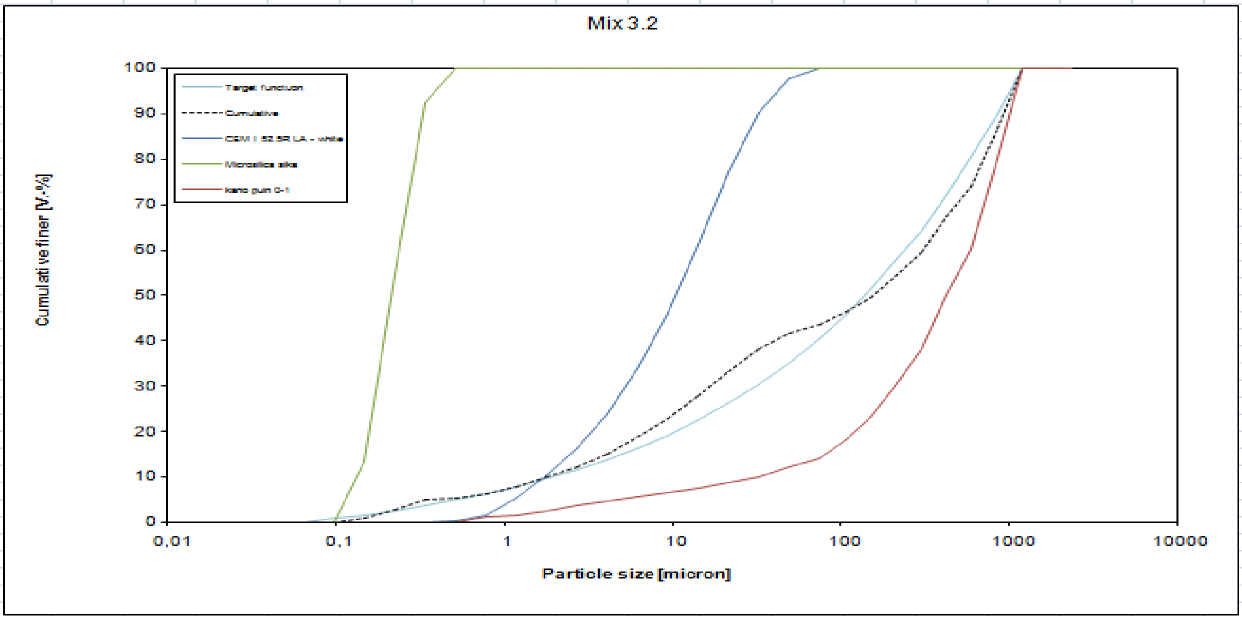


Figure1.1: Particle Size Distribution of mixture 3.2

This mixture is sustainable in the following ways:

- Use of recycled aggregates, we constructed our own recycled aggregates and therefore no energy was wasted by transport of this. Thereby the recycled aggregate consists of old concrete canoes.
- Use of waste materials from other industries, the use of silica fume contributes to the strength and the waste materials of other industries is used.
- The use of sustainable cement. The cement used, TiOCEM is a white sustainable cement, which cleans the air from NO_x.
- Use as little concrete as possible, in comparison to other teams, our canoes are built from only 50 litres of concrete, this results in a very low use of materials. And not using materials is the best way to be sustainable. A canoe which is made from 100 litres of concrete with only 400 kg/m^3 of cement is thereby still less sustainable than our canoe.

1.4 The recycle logo

This year's race canoes are made with a red Twents Ros casted in the black canoes. For our sustainable recycle canoe we used the same principle, but this time a green recycle logo was casted (see picture below).

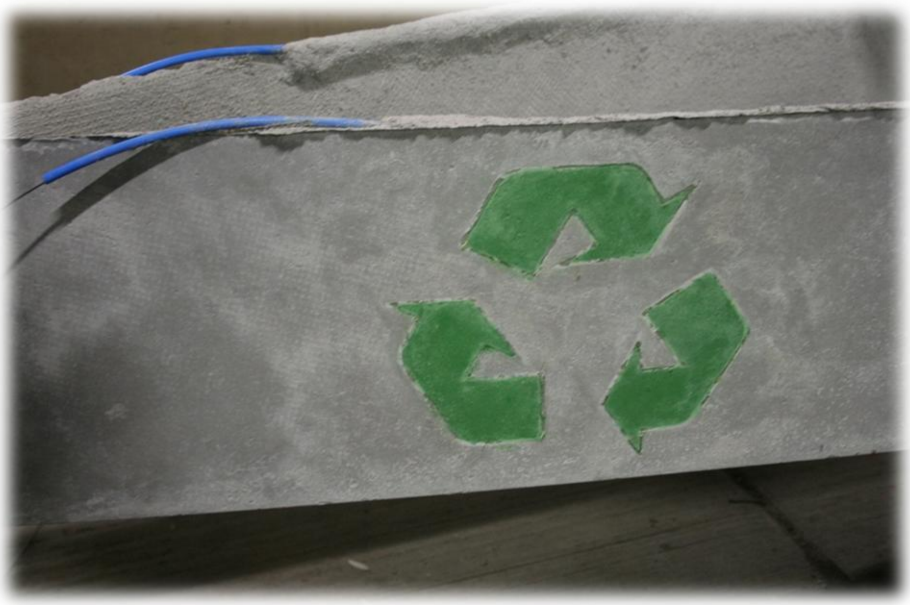


Figure 1.2: Recycle logo in canoe

1.5 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 a big air balloon of 65 litres is used. Furthermore tubes are placed on the edges for aesthetics and safety (prevents scratches from sharp edges). Finally the name, sponsors and number are painted on the walls. In the table on the next page (table 1.5) the material status of our canoes is given, in this table all used materials and their specification are mentioned.

Element:	Material:	Specification:	Amount:	Total:
Recycle Concrete	CEM I 52.5R LA White	0.6 kg/l	50l	30 kg
	Silica fume	0.08 kg/l		4.0 kg
	Kanopuin 0-1	0.825kg/l		41,2 kg
	Water	0.270 kg/l		13,5 kg
	GL 51	0.004 kg/l		0.2 kg
	Air	0.00 kg/l		0 kg
Reinforcement	Steel cord 0.59+6x0.52 Ø=4.40 mm^2 MBL=5016N	1140 N/mm^2	18m	18m
	Steel cord 0.66+6x0.59 Ø=5.0 mm^2 MBL=7560N	1540N/mm^2	12m	12m
	Stucco-Mesh	4x4mm	2 layers	13.5 m^2
	Anchor plate	250X100mm	2 pcs	2 pcs
	Anchor connection ironware	-	4 pcs	4 pcs
	Tube for reinforcement	4x6 mm	2x 6 m	12 m
Air chambers	Air bags	65l	1pcs	65l
	Connection ironware	-	4 pcs	4pcs
	D shackle	-	4 pcs	4 pcs
Completion	Paint	Dark blue	1 l	1l
	Tube	-	2 pcs	12 m
	Seating foam	-	2 pcs	2 pcs

Table 1.5: Material Status Recycle canoe

Part 2

Innovation in Design: Folding Canoe

Inspired by the innovative canoe of Eindhoven of last year which existed out of separate plates which were bolted together, the BetonBrouwers started thinking. After setting a record by constructing the lightest canoe, the new challenge for this season became an innovative canoe better than that of previous seasons. The idea came up to make a foldable concrete canoe. A canoe which exists out of eight concrete plates which are attached to each other with a in cured foil. Early in the season the design process started and the result is a canoe which is very easy to transport.

2.1 Objective

The special objective for this season is to make an innovative canoe which is easy to transport and for which only a short time is necessary to make it ready for paddling. With a special and innovative design we hope to obtain the innovation price 2012.

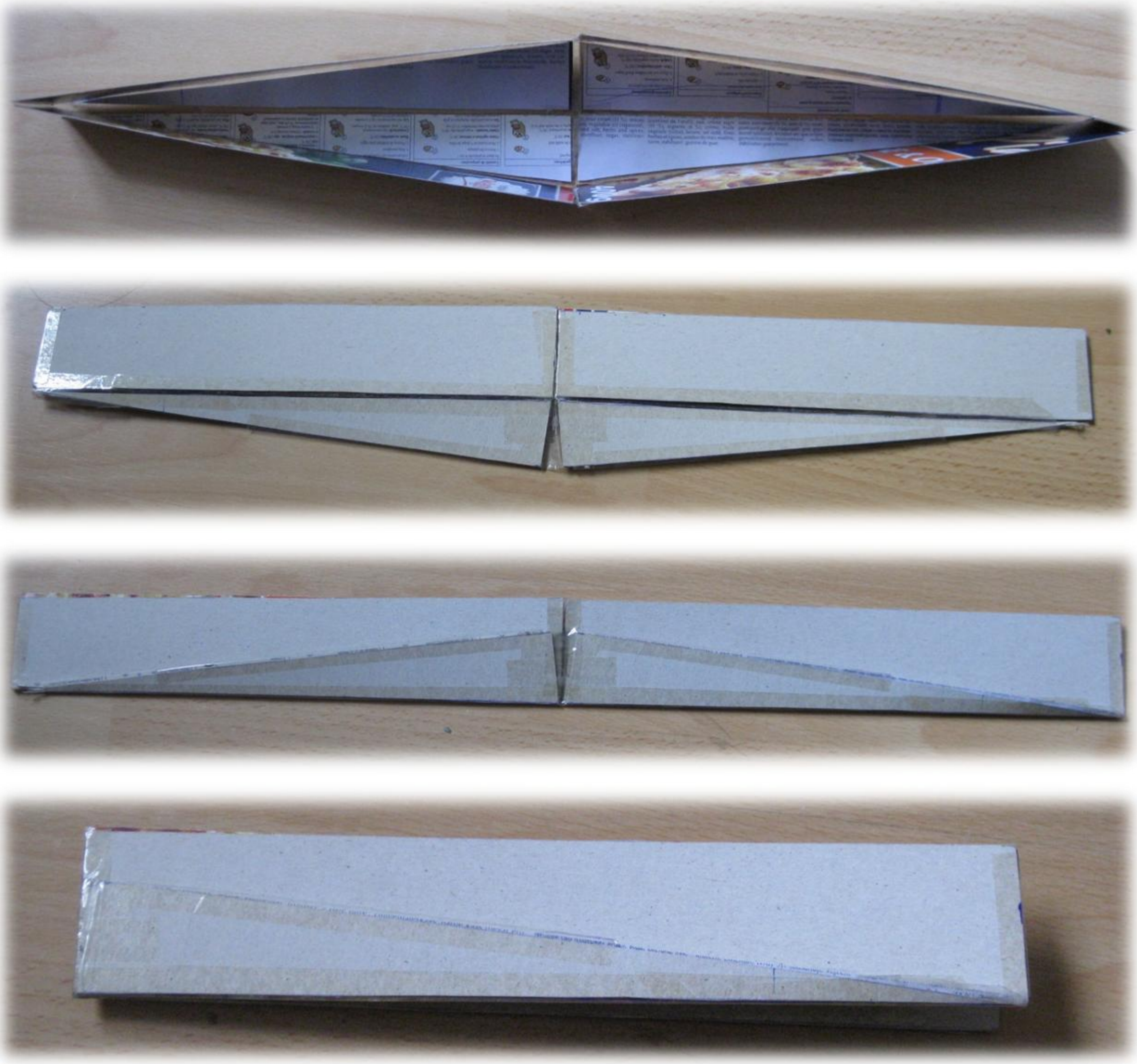
2.2 Design

The design phase was started directly after the concrete canoe challenge in Eindhoven. Soon some different designs were present. These designs were first worked out in scale models from paper and tape.

2.2.1 Choice for design

Two different designs were worked out. The first is a design which consists of 8 plates which are connected with each other by using a foil (ConcepT 1). The second design was a design which consists of a big amount of triangles which can all be folded together to one triangle which is really easy to transport (ConcepT 2).

For both designs a study was done on the buoyancy, the ease of construction and the quality in terms of folding ability. Finally was chosen for ConcepT 1. Mainly because this one was expected to be possible to build. ConcepT 2 was expected to be very complicated to construct. Thereby the stability of ConcepT 2 was really bad. This design is unstable because this design consists of triangular section shape. ConcepT 1 on the other hand consists of a rectangular section shape and is thereby very stable in the water. After this choice ConcepT was worked out further.



Figures 2.1 – 2.4: Folding a scale model of ConcepT 1 from paper

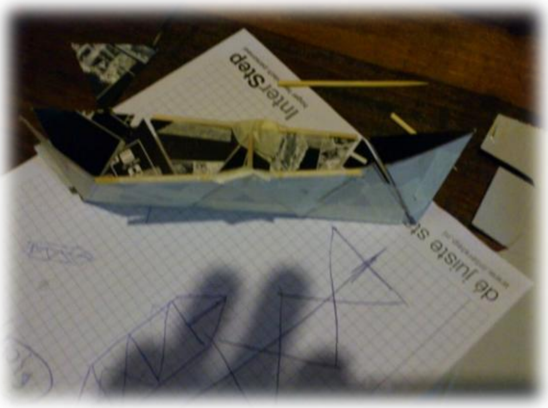


Figure 2.5: ConcepT 2 unfolded

Figure 2.6: ConcepT 2 folded

2.2.2 Final design

Based on the scale model of ConcepT 1 the design was worked out into further detail. The final design of the canoe was because of the minimal length and width according to the regulations. The final design was a cutting plan for the foil which needed to be casted into the 8 plates. In order to make the canoe water tight all the foil needed to be cut out of one piece of foil.

During the design of the cutting plan several difficulties arose:

- Because of the thickness of the plates, the joints between the different plates need to have a certain thickness to make folding possible.
- Because the foil needs to be cut out of one piece in the middle of the canoe some extra foil needs to be present. Because the plates go downwards.

The final design was a cutting plan for the canoe and is showed below (figure 2.8), the gray hatched part will be the joints between the different plates of the canoe. The not hatched parts will be put in the concrete in order to make the canoe water tight. In the parts where the foil is casted into the concrete, the foil is provided with holes for a better attachment to the concrete plates.

Figure 2.7: Digital model of the folding canoe

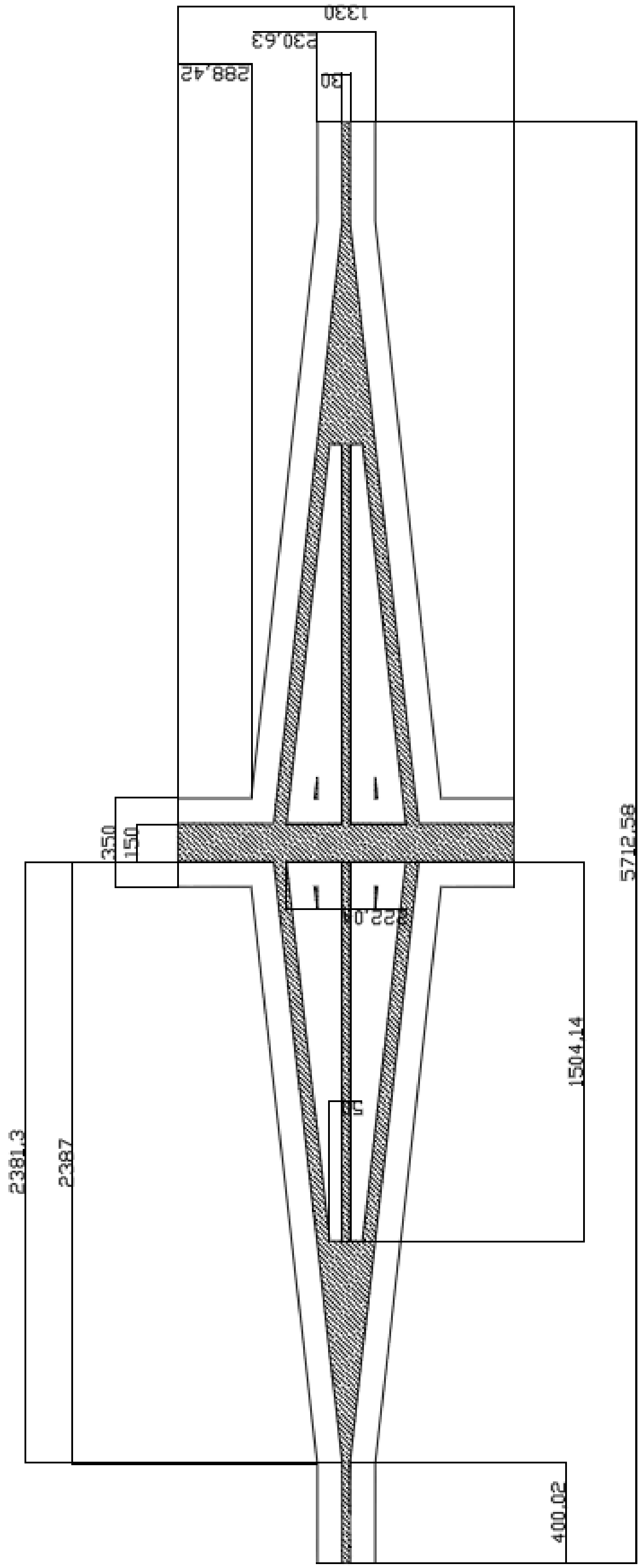


Figure 2.8: Cutting plan of the folding canoe

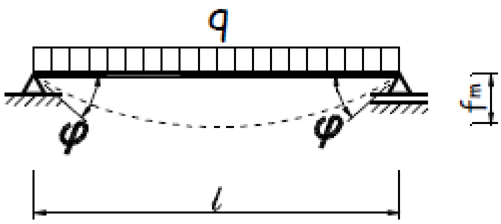
2.3 The strength

In general our canoes are one monolith construction, in this way the strength during transportation is always high enough because of the U shape. However this canoe is transported in a different way and so it is wise to calculate if a plate is strong enough to bear its own weight. This paragraph will deal with the calculation of the strength of the canoe. Therefore one of the plates of the canoe is assumed to be a beam on two points, which has to bear its own weight.

2.3.1 Dimensions

Width= 0,4m
Thickness: 0,01 m
Length plate: 2,4 m
Density concrete: 15 kN/m3
Load= 0.4*0.01*15=0,06 kN/m

2.3.2 Maximum bending moment (middle)



$$M_m = \tfrac{1}{8} q l^2$$

M = 1/8*0.06*2.4^2
M = 0.0432 kNm

$$\sigma = \frac{M}{W}$$

$$W = \frac{1}{6} * b * h^2 = \frac{1}{6} * 0.4 * 0{,}01^2$$

$$\sigma = \frac{0.0432}{\frac{1}{6} * 0.4 * 0{,}01^2} = 6{,}48\ N/mm^2$$

2.3.3 Conclusion

The maximum stress in the plate when holding its own weight will be 6,48 N/mm^2. This can be either tension or compression (depending on the direction in which it bends). For compression the concrete is strong enough, the mixture of 2011 is used for this canoe and this has a strength of about 28N/mm^2. Since this is more than 6,48 N/mm^2. The concrete in combination with the glass fiber reinforcement is assumed to be strong enough to cope with the tensile stresses. To be sure we will transport the folding canoe on its side, using their height for maximum flexural rigidity.

During paddling the downward force on the bottom as a result of its own weight and that of the two paddlers is partly dissolved by the upward force of the water pressure. Thereby we placed three layers of glass fiber reinforcement. This was done in such a way the it can cope forces in all directions, by using the orientation of $[0, 45, 0]_T$. To reduce the local force on the bottom plates by the paddlers, their weight will be spread by the seating.

2.4 The foil

In order to make a foldable canoe a material is necessary to be used as joint. At first was thought of materials used in the construction industry, like water tight joints. However we quickly realized that these joints usually have thickness of 2 cm, what would mean that the walls would become very thick, making the canoe very heavy and not easy to handle. The ease of handling and transport was one of the goals of this canoe!

The idea came up to contact TenCate, a company specialized in foils. Ten cate was willing to send us some samples of strong and water tight tent foil. With this samples some tests were done, as can be seen in figures 2.9 and 2.10.

The holes were made in the foil at certain places to make small columns of concrete. The shear forces necessary to pull the foil through the concrete will be very high because this column is only the thickness of the foil. After putting the samples in the concrete the samples were tested with a Newton meter with a maximum force of 200 N. The both foils of Ten Cate resisted this force easily and since this force was only applied over 5 cm of length of the foil. It was concluded to be strong enough to use in the canoe. Since there was a choice for two foils the one with the largest water resistance was chosen.

Figure 2.9: Test samples foil

Figure 2.10: Test of foil in combination with concrete

2.5 Material Status

For the construction of the folding canoe we used the concrete mixture of season 2011. Further we used glass fiber mesh as reinforcement and a foil to keep the canoe together. In the table below the material status of the folding canoe is shown.

Element:	Material:	Specification:	Amount:	Total:
Lightweight Concrete	CEM I 52.5R LA - white	0,550 kg/l		49,5 kg
	Liaver 0.1-0.3	0,121 kg/l		10,89 kg
	Liaver 0.25-0.5	0,053 kg/l		4,77 kg
	Liaver 0.5-1.0	0,050 kg/l		4,50 kg
	SikaAer	0,008 kg/l	90l	0,720 kg
	Pigment	0,028 kg/l		2,48 kg
	Water	0,206 kg/l		18,56 kg
	Gl 51	0,000 kg/l		0,000 kg
	Vertrager (0,3% cement gewicht)	0,002 kg/l		0,149 kg
	LPS A94	0,001 kg/l		0,0634 kg
Reinforcement	Stucco-Mesh	4x4mm	3 layers	17 m2
Foil	Ten Cate All season residential WM 1	280 g/m2	10 m2	2,8 kg
Floating Device	Rope	white	6 m	6 m
	Floating concrete block	prism	1 pc	1 pc
Completion	Seating foam	-	2 pcs	pcs
	Paint	Dark blue	0,25 l	0,25l

Table 2.1: Used materials in the foldable canoe

Part 3

A process description

In this third part of the report the focus is on the process of the realisation of the recycle canoe and the folding canoe. From a nice idea to a beautiful concrete canoe requires a lot of blood, sweat and sometimes even tears. Things sometimes seem to work in theory, but practice can prove otherwise. That's why it is important to be creative, flexible and always looking for solutions. This part gives a clear insight in the construction process of our canoes and everything that comes along with it.

3.1 <u>Realisation of the recycle canoe</u>

In this paragraph the realisation of the recycle canoe is highlighted. The first step is crushing the old canoes, the second step is to determine the best mixture and the final step is to construct the canoe.

3.1.1 Crushing old canoes

The first step towards recycle canoe is crushing of the old canoes into an aggregate with in maximum particle size of 1mm. This means that canoes form previous seasons had to be destroyed.


The following procedure was used to get from the old canoes to a fine aggregate:

1. Use a hammer to remove the concrete from the reinforcement
2. Collect all the broken concrete parts,
3. Sieve by hand 4 mm → Crush fraction >4 mm (the residue)
4. Sieve by hand 1 mm → Crush fraction > 1mm (the residue)
5. Sieve crushed fraction <1mm

These steps are shown in the pictures below. It turned out to be a very time consuming activity to get from a destroyed canoe to a crushed fraction smaller than 1mm.






The final result of crushing and sieving was 60kg of aggregate as can be seen in the picture below.

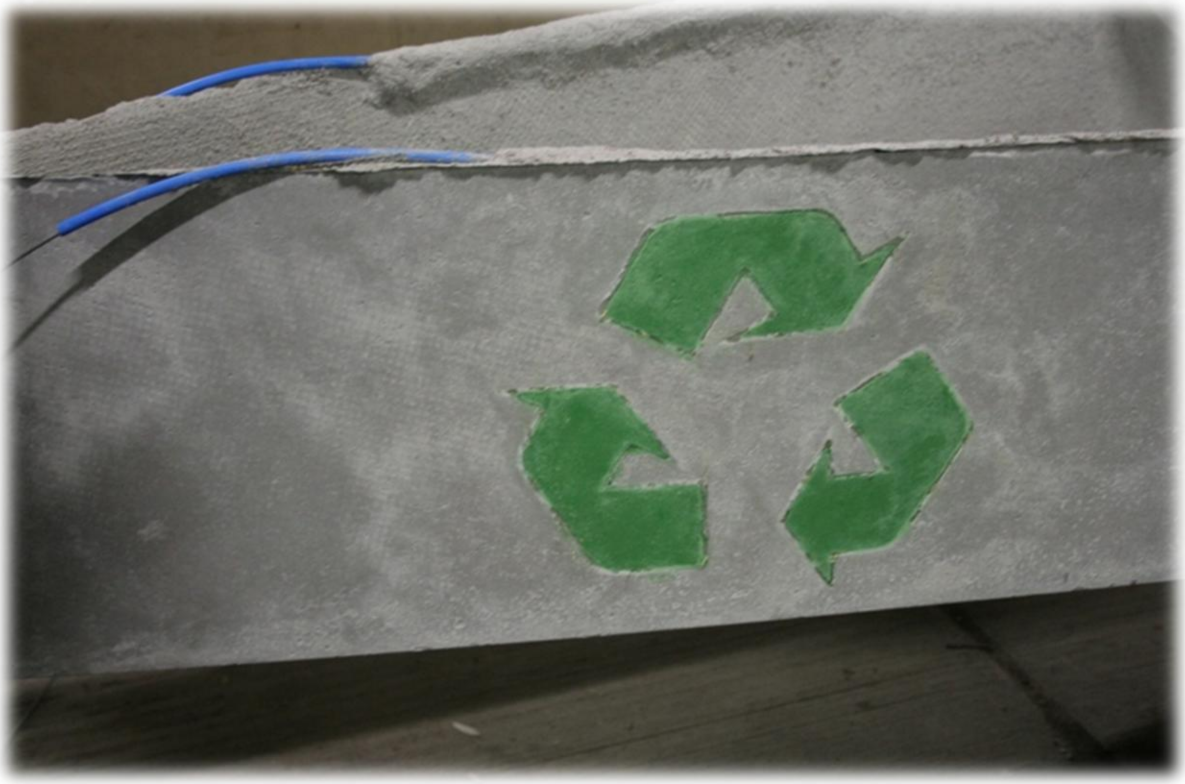
3.1.2 Testing the aggregate

After the canoes were crushed and sieved, the composition of the mixture could start. The first step was to determine the sieve curve of the new aggregate. Based on the sieve curve several mixtures were developed. This meant the start of a series of test. An important factor in the development is the workability of the concrete. With small batches we optimised the mixture based on the workability, the permeability and the sustainability. To test the workability and permeability the most promising mixtures were casted in a plastic box in combination with some reinforcement. In this way we could compare the mixtures and test their permeability. Finally some strength tests were carried out to check if the concrete was strong enough.

3.1.3 Casting the recycle canoe

Based on the developed concrete mixture the recycle canoe could be casted. The first step in casting is the recycle logo. After the outline was in place the green concrete could be placed. When the green concrete was in place it could be covered with the regular (white/grey) concrete.





In general the process of casting the recycle canoe is the same as casting one of the race canoes. The only difference was the concrete mixture and thereby a slight difference in workability.

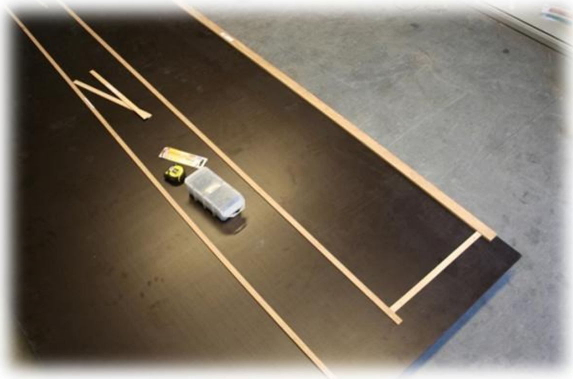
3.2 Realisation of the folding canoe

The construction of the foldable canoe went plate for plate. First the walls were made and then the bottom. In order to be sure the canoe could be made some important parts of the foldable canoe were made in a scale model. It turned out to be possible to make and therefore was started with the construction of the real canoe.

3.2.1 Formwork

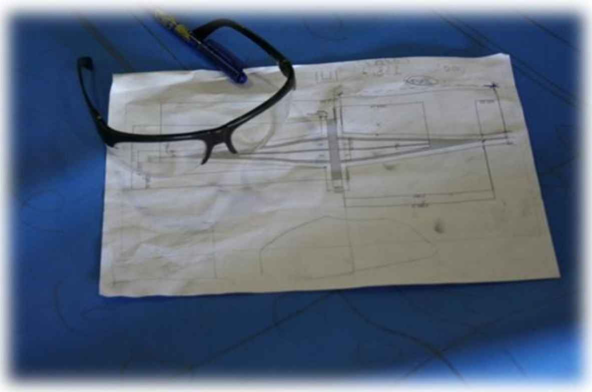
The first steps in constructing the folding canoe are building the formwork and prepare the foil. The formwork of the folding canoe is really straightforward. A big plate formed the basis for all plates. In order to give this plate some stiffness, to be sure that the concrete walls would become straight, a frame was constructed underneath the plate. On top of the plate the outline of the walls was made with thin slats.

After the walls were casted the plate was cut in two and the outline of the bottom plates was fixed on top of the plates. In this way we could cast the bottom in one time.


3.2.2 Foil

Another preparation for casting concerned the foil. First the foil had to be cut in the right size. After that the cutting plan as mentioned in paragraph 2.2 had to be drawn out and the contours of the foil could be cut. The final step was to mark and make the holes that would give the foil a better bond to the concrete.



3.2.3 Casting

With the formwork and foil ready the casting of the folding canoe could start. This was done wall by wall. A wall was build up as following: 1) Layer of concrete, 2) Mesh, 3) Foil, 4) Layer of concrete, 5) 2x mesh and 6) Last layer of concrete. To increase the bond of the foil with the concrete even more small strips of glass fiber mesh were threaded through the holes.

For the first to plates the biggest challenge was to get the foil in the exact right position and keep it that way during casting. After the first two walls another challenge arose In addition to the increasing difficulty of positioning the foil, being the limited space (especially in the points). Also a construction was required to keep the already casted walls in the right position above the wall that had to be casted. On the next pages pictures are shown of the casting of the several walls.





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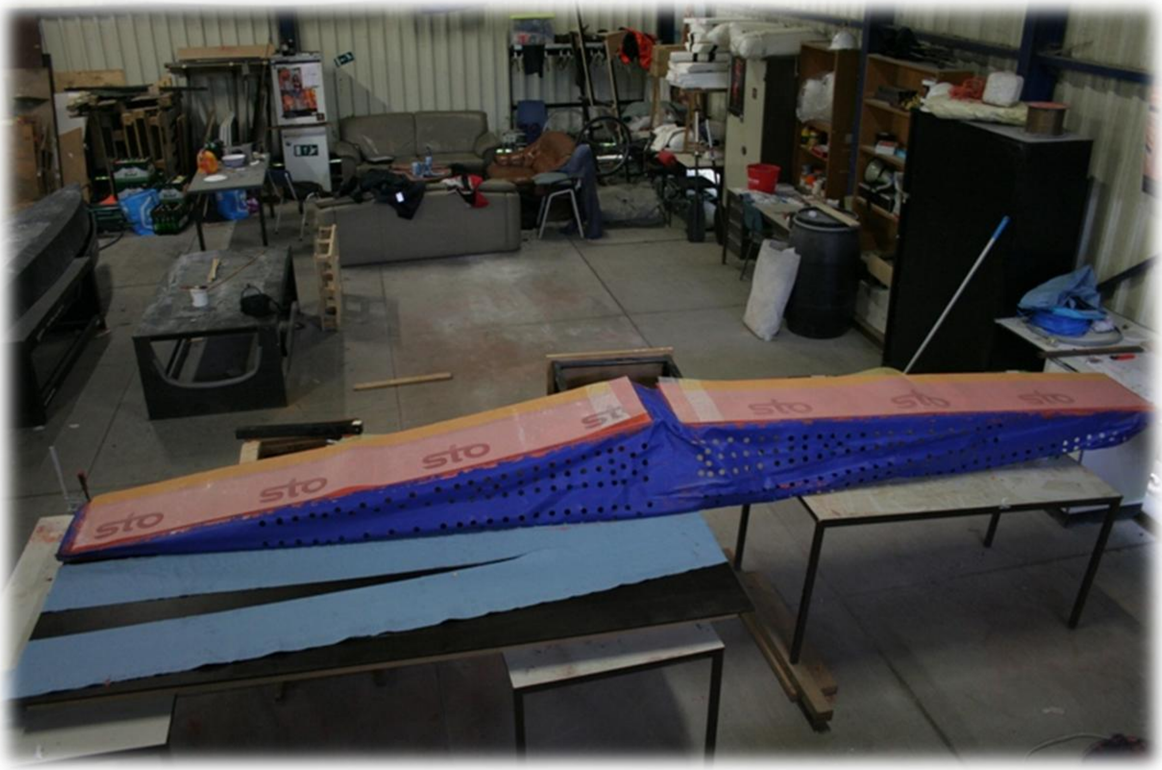

After all walls were casted it was time to cast the bottom plates. First the formwork was adapted. After this the casting was the same as for the walls: 1) layer of concrete, 2) mesh, 3) Place the foil over the concrete, 4) layer of concrete, 5) 2x mesh and 6) last layer of concrete. The advantage was that the bottom was quite accessible from above and thereby, in regard to the last two walls, easy to cast. Again the tricky part was positioning the foil. Also it occurred that a measurement error was made, meaning that we had to glue the foil.

3.2.4 Fixate and finishing touch

After casting the bottom the folding canoe was almost finished. After dismantle the canoe from the formwork we tested if the canoe could be folded properly. Luckily it turned out that the canoe could be folded, although it was tight. This proved that it was good to incorporate some margin in the design of the seams.

Since the walls can move a little in comparison to each other because of the seams, a construction had to be made to fixate the walls. A concrete box that can be placed in the middle of the folding canoe was constructed. When fixed to the walls this box fixates the walls.

The final step is the application of the various printing.

Concluding

In this second part of the BetonBrouwer Construction Report 2012 the principles behind the recycle canoe and the folding canoe are highlighted. We hope that this report has given a good overview of all considerations, ideas and used techniques.

With our recycle canoe we tried to make visible that sustainability and concrete canoes can go hand in hand. With the inset of our concrete mixtures, the balanced choice of the type and quantity of ingredients, we hope to have shown that attention is paid to the environment and that also in concrete canoeing it is possible to construct in a environmental conscious way.

With our innovative canoe we think to have construct a unique concept with which we can compete for the innovation price 2012.

The construction of these two special projects have given us new experiences, new knowledge and although they both were very time consuming were definitely worth working on.