MASTER

Da Vinci's Bridge in Ice

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Da Vinci's Bridge in Ice

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Colophon

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Preface

This report is the master thesis about the design and realization of Da Vinci's Bridge in Ice. Eindhoven University of Technology is conducting investigations into reinforced ice for several years. This research is a continuation of the realizations of the Pykrete Dome in 2014, and the Sagrada Familia in Ice in 2015. All these projects are executed by students from the faculty of Built Environment (Master Architecture, Building and Planning, department Building Technology).

After the successful realization of the Sagrada Familia in Ice, again Juuka and TU/e were enthusiast about building another impressive reinforced ice structure. The goal was to extend the research into reinforced ice and inflatable molds. Again a famous genie from the past functioned as an inspiration. Since the previous projects set world records, the project this time shall set another milestone in the history of constructed ice structures.

An old sketch of Leonardo Da Vinci inspired the project leaders to build a large bridge, which shall be 'World's Largest Span in Ice', with a span of 35 meters. A journey through the sources of the bridge learned us a lot about the ins and outs of the famous structure. In a museum in Milan, Italy a model inspired us to what would become the final concept for the most important parts of our bridge. From that moment, it was necessary to start searching for partners who wanted to help us to achieve our goal. The initiative for the project was very well received and many companies wanted to contribute by sponsoring materials. We also looked for cooperation with other universities for technical and organizational input.

Due to the size of the project it was clear from the beginning that we could not do everything by ourselves. Therefore, we immediately started looking for master students who could help us to elaborate the design of 'Da Vinci's Bridge in Ice'. In September 2015, a team of 10 students committed themselves to be responsible for certain parts or aspects of the building to be realized.

To realize the final construction of the 'Da Vinci Bridge in Ice' in Juuka, we needed more manpower than in previous years. The building team consisted of about 200 people. In addition to the project members, several volunteers signed up for the project, including family, friends and fellow students from our university and other universities. The municipality of Juuka also contributed considerably to the success of the project. This project would not have been possible without all the sponsoring companies, the 200 dedicated volunteers and the extraordinary patience of Veerle (also contributing as volunteer coordinator).

Although the bridge collapsed because of unusual weather, we have learned a lot and will remind it as a successful experiment. Without the help of the Juuka municipality and community, and the many volunteers, the project would not have been such a great success. The project success is visible in multiple examples. The ISCA Conference in Guimarães, Portugal, hosted a mini-symposium about building with reinforced ice. At this conference the academic relevance of the project was clearly visible. Besides this scientific contribution, the project is also nominated for the Orange Carpet Award, named a connecting, unique finalist.

For their supervision of the process of this master thesis a special thanks goes to Patrick Teuffel, Arno Pronk and Hans Lamers.

Abstract

After previous ice projects *Pykrete Dome 2014* and *Sagrada Familia in Ice 2015* a continuation of huge ice structures is executed. After creating world's largest ánd highest ice domes a new record had to be broken. Inspired by all ice experiments that had been done a sequel on previous ice structures was set up. This time the project team invested a lot in international cooperation's, even more than last time.

A new ice structure had to be designed, and after several brainstorm sessions the team decided to let them inspire by another famous genie, after Gaudi inspired the team of the ice church in 2015. While the Sagrada Familia in Barcelona is currently under construction, the inspiration of this year's project is even never built at all. In 1502 Da Vinci designed a bridge over the Bosporus in Turkey, but he never got permission by the sultan to execute his plans. It would have been the longest span (240 meters) at that time. His design had a perfect shape for recreating in ice, since his bridge was designed with only compression forces.

After rescaling the bridge (240 meters would have been unrealistic) to a span of 35 meters the project team designed, prepared and produced all necessary materials and equipment to transport them to Juuka in Finland. Juuka is a small village and was hosting last ice structures from the TU/e as well. Not only the spot was reused, also the methods had quite some similarities with previous projects. Again a huge inflatable structure was produced and functioning as a mold to cover with layers of reinforced ice. The techniques are inspired by the work of Japanese engineer T. Kokowa and the experiences of last projects.

Arriving on the prepared construction site in Juuka on the 28th December with local temperatures of approximately -15 degrees Celsius it is perfect weather to start creating the large Bridge in Ice. The 2500 m^2 inflatable, made out of a PVC coated polyester fabric, is unpacked and pulled in its right position between the 120 anchors, which were placed in the end of November when the soil was still unfrozen. A rope net covers the inflatable after that, and during inflation this rope structure pulls the inflatable in its perfect shape. In contrast to last year this time the inflatable mold has no bottom. The sides will be frozen to make them air tight and fortunately with -30 $^{\circ}$C this is going very fast. Inside the inflatable a lot of stabilizing steel cables are attached to make the huge balloon resistant against wind gusts. These cables are attached on the inside because they would obstruct the construction site too much on the outside.

Special construction to absorb an unwanted period of warm weather is placed underneath the feet of the bridge, inside the inflatable. On each side, four wooden columns are supporting the first meters of ice. After finishing these supporting columns the team starts spraying the mixture over the inflatable.

This mixture is a resulting in an ice composite. The research into reinforced ice is now running for several years. During the Pykrete Dome and the Sagrada Familia in Ice the structures were reinforced by wooden fibers, but several problems occurred. To improve the production capacity and the process a new fiber had to be used. After a lot of tests cellulose fibers turned out to be a solution to most of the problems.

The mixture of cellulose and water is produced in the small 'cellocrete factory'. During a test period in Eindhoven the goal was to create a homogeneous ice composite, with fibers of cellulose, to increase the structural properties. The goal is to create a 2% fiber weight ratio in the total Bridge. The cellulose fibers are mixed with water in a modified container, designed and built by the project team. Centrifugal pumps are connected to this container, to spray the mixture on the inflatable mold, layer by layer. This distribution and production system is cooperated with Summa College Eindhoven with the goal to produce 900.000 liters of ice composite. Compared to last year, when the moments of delay were too much and too long, the system worked flawless. During last projects they only achieved 3,97% fiber weight ratio, where their goal was 10%. At the Bridge in Ice project the goals was 2% and test results showed an achieved ratio of 1,97%. It was a big step in the research into creating reinforced ice structures.

Monitoring the inflatable was a second question mark which had to be solved. The analog method of last projects would not work out because of the more challenging facets of the

Bridge. A system was designed and built to keep the inflatable continuously filled with the same intern air pressure of 0,5 kN/m^2. The interface allowed us to in- and decrease the intern pressure at any time. Also a system was integrated which warned the team by calamities with sound alarms and light signs. By monitoring the height of the top of the bridge, with a telemeter, a detection of the creep and deformation of the bridge was possible. When the bridge would have reached enough thickness it should be able to stand on its own.

Unfortunately, during a warmer period with temperatures even above 0 $^{\circ}$C, the telemeter showed a lowering value for the bridge' height. The top should had be around 8,5 meters, but due to the warm weather the bridge was lowering to almost 7 meters. The melting process, and even rain, deformed the arcuate shape of the bridge so that it did not hold longer. On the 8^{th} of February, after six weeks of construction on site, the bridge came down. Because of the monitoring system we did see the collapse coming, so no persons were injured.

In total a group of almost 200 volunteers, 15 educational institutes, the local people from Juuka, and more than 50 sponsoring companies were disappointed about the collapse of what would have been World's Largest Span in Ice. The project as an experiment was successful, it was because of the weather that the bridge was never finished. The results in terms of used materials and methods are very promising for extending the research into reinforced ice structures.

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1. Introduction

1.1 Motivation

Continuing the successful projects ‘Pykrete Dome’ and ‘Sagrada Familia in Ice’ is a great opportunity to extend the research into reinforced ice. It took several projects, like the ones just mentioned, to prove that ice really can be used as a proper building material. The research into its disadvantages like creep behavior and processability has to be further investigated. Though, the potency building with reinforced ice offers inspired us enough to continue doing research on it. We have to take care of a lot of technical challenges to build something new and innovative out of reinforced ice, but the end result will be again something really impressive.

The research on adding fibers to ice was already done by A. Pronk, R. Houben and F. Jansen in 2013. Forthcoming out of this research was the ‘Pykrete Dome Project’ from A. Pronk, R. Pluijmen and J. Hijl, where wooden fibers were used as reinforcement in the ice of large dome structure. This ice composite, so called ‘Pykrete’, enhanced the structural properties significantly. The enhancement of reinforcing ice with wooden fibers has been proven successful in *Reinforced Ice Structures* (Janssen & Houben, 2013). Wooden sawdust in the ice composite can enhance the strength of ice by a factor 3.

With constructing the Pykrete Dome, (an ice dome of approximately 30 meter span) A. Pronk, R. Pluijmen and J. Hijl broke the record of The World’s Largest Ice Dome. Till then, the record was owned by T. Kokowa (Kokowa, 2012), who built an ice dome of 25 meters, without fiber reinforcement. For the construction they used the same technique as Kokowa. They sprayed layers of reinforced ice over an inflatable mold till the structure had enough material thickness to stand on its own. After sufficient ice was created, they deflated and removed this big ‘balloon’. The successful experiment of the *Pykrete Dome Project* (Hijl & Pluijmen, 2014) was the inspiration to create something new out of reinforced ice.

New project leaders J. Kern and T. Verberne, again under the supervision of A. Pronk, mainly focused on creating a new world record, after the largest span was set with the Pykrete Dome. This time they picked up the idea to set the record for World’s Highest Ice Dome. Antoni Gaudi’s catenary design of the famous Sagrada Familia in Barcelona inspired them for the structural design. The new record was set, with conical ice domes of approximately 21 meters high. Again Kokowa was the formal owner of this record, with a dome of 15 meters high. In *Sagrada Familia in Ice* (Kern & Verberne, 2015) you can also read about their other addition in the research into reinforced ice. They experimented with reinforcing different fabrics and ropes, which resulted in impressive structures. These experiments were mainly inspired by the work of Heinz Isler.

Figure 1: The Sagrada Familia in Ice project (Photo: Bart van Overbeeke)

All these inspirational projects were great motivations to continue the research into building with reinforced ice. In fields of design, construction methods, organization and material, there are a lot of challenging aspects to explore further. To not overload ourselves with impossible ideas, given the short time till winter came, we wanted to organize the project a bit different than last years.

Searching for a new challenge, we came to the conclusion that our current sponsors and the community of Juuka in Finland, would be interested again in an iconic building with a strong appeal. For us it had to be a new technical and scientific challenge. Combining these two starting points together with the experiments of last projects, we came up with the idea of making a model of the never build 'Bridge over the Golden Horn' by Leonardo Da Vinci.

Figure 2: Layered pykrete section of Sagrada Familia in Ice (Photo: Bart van Overbeeke)

We choose a bridge to give visitors the possibility to really 'use' an ice structure, as we were receiving the following question more and more often: *"What's the use of creating big ice structures?".* To prove an ice structure could be more than just a scenery, we were going to build a bridge people could really walk over.

Based on last projects, we would have to reduce a lot of the process delays and other unwanted events to make *Da Vinci's Bridge in Ice* a success.

1.2 Previous research

In 2013, Arno Pronk came up with the idea to use fiber-reinforced ice in practice, triggered by past research that has been conducted. The goal was to create the world's largest ice dome: the Pykrete Dome. Combining two research subjects into one experiment resulted in a very impressive ice structure. One subject was the research into the material properties of fiber reinforced ice, forthcoming out of the report of Janssen & Houben (2013). They made an inventory of what kind of fibers had to be added to an ice structure, to break the record of Tsutomu Kokowa's ice dome. Kokowa's ice dome had a span of 25 meters, built with plain ice and snow (Kokowa, 2012). Adding the fibers into the Pykrete Dome project resulted in a successful world record.

Kokowa inspired us with his technique for constructing a big 'igloo'. He inflated a big balloon, covered it with layers of ice and snow till the structure had enough mass and strength to stand on its own. After a sufficient amount of ice was created, he deflated and removed the inflatable. During the Pykrete Dome and the Sagrada Familia in Ice the same methods were used.

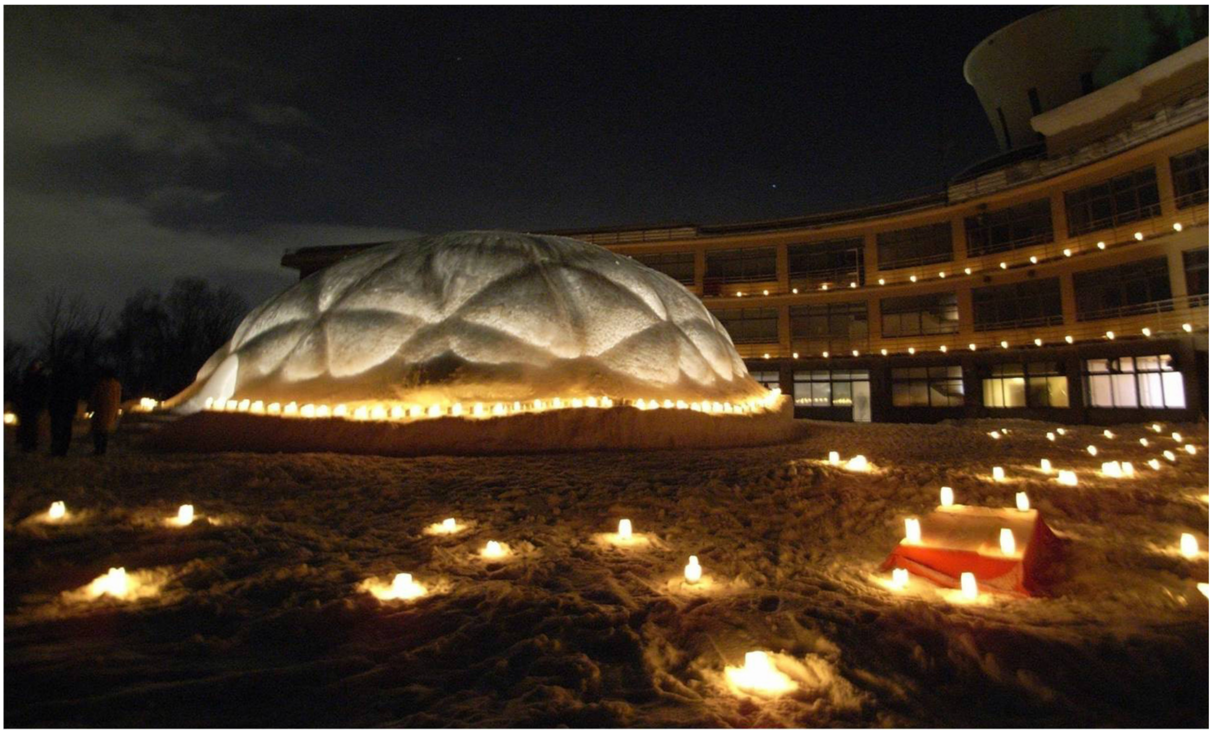


Figure 3: An ice Dome by Tsutomu Kokowa

With the Sagrada Familia in Ice as a sequel of the ice projects, led by Eindhoven University of Technology and built in Juuka, Finland, new records were broken. With this project we broke the record of world's highest ice domes; now set on 21 meters. Added some new inventions and research questions to the story made it a very successful project.

After constructing the Ice Church, there was an overwhelming support to build another ice project. And that is when we started this research. To improve the building process of our own project we had to tackle all major problems that occurred. The first problem had to do with the wooden fibers we used. Due to several reasons we definitely wanted to investigate the possibility of alternative fibers.

The enhancement of the structural properties of the ice would increase also with paper fibers, or cellulose (Bastian, 2010). Stora Enso, our sponsor of sawdust during last projects, provided us with a couple of tons of cellulose. With these fibers J. Kern and T. Verberne set up the first tests with our available equipment in Juuka, Finland (Kern & Verberne, 2015). The results were promising, so one of our main subjects would be the investigation into paper reinforced ice. The new term 'cellocrete' was born right after.

Figure 4: Finished Pykrete Dome (Photo: Joep Rutgers)

Figure 5: Sagrada Familia in Ice on the day of her opening (Photo: Bart van Overbeeke)

1.3 Problem Area

The problem area has been divided into four main subjects;

1. Shape and Structural Design
2. Construction Method
3. Material
4. Organization

Shape and Structural Design

There are not many comparable ice structures built on such a large scale. This year we wanted to enlarge our ambition again. Till last projects we used reinforced ice, but because of safety reasons everything was calculated as if it were the material properties of plain ice. This year the structure will be much larger, and therefore we really needed the enhancements of the reinforcement. To guarantee a proper ice composite is really necessary for the structural design for an even higher construction. We took into account the experiences from last year to reach an optimum in reinforced ice structures, built with an inflatable mold.

Construction Method

For the construction methods we used several familiar techniques. The projects once arose out of the idea to take the research into inflatable molds and cover them with fiber reinforced ice. We decided to continue those investigations, and not to investigate variations of those methods.

Of course we wanted to improve both main techniques. Our goal was to reduce occurred problems as much as possible, compared to last projects. The research into inflatables is already kind of extensive. Our inflatable would be significantly larger compared to last year and therefore we had to investigate how to produce, handle and control the inflatable. We have done this in cooperation with Poly-Ned BV (producing, handling) and Summa College Eindhoven (controlling).

The mixing system of last years was an improvised one. Improvisation during very low temperatures has resulted into problems. This year we wanted to do more research into the field of mixing and spraying the ice composite. We have to investigate what is the best equipment within the given boundaries of costs, availability, and usability.

This year we also have to improve our Health and Safety plan, to make sure everything will stay safe on and around the building site. During the building process of the Sagrada Familia in Ice, we already noticed that a larger group of volunteers and stakeholders is much harder to control. This year we needed stricter regulations and instructions to guarantee the safety of all people who would be involved. Part of this was already investigated by in *Veilig Bouwen met Pykrete* (Borsboom, 2015) which recommendations we took into account during our project.

Climate

During the construction process of the Dome and the Ice Church, there were several situations with unexpected or unwanted weather conditions. Usually Juuka is a cold region during winter periods. Unfortunately its climate isn't very stable. J. Hijl and R. Pluijmen had not had cold periods during the first weeks of their construction phase, and produced all ice for the dome in just the last week (Hijl & Pluijmen, 2014). J. Kern and T. Verberne had a lot of trouble with an abrupt temperature lift, combined with lots of guests (Kern & Verberne, 2015). To be prepared for all types of weather we had to be better prepared. Another problem was that it might be so cold that several machinery would not be usable anymore due to safety reasons.

Material

With the previous projects we already proved that the added fibers enhance the structural properties of ice significantly. The Pykrete Dome and Sagrada Familia in Ice were the first projects with an application of reinforced ice. During the construction of both projects several problems occurred. Due to the size of the wooden fibers the processes delayed, as too large fibers caused unwanted blockages in the spraying system. Therefore we wanted to investigate if we could come up with a different material which would run easier through our systems. We should not underestimate that the failing of our system would result into frozen equipment. The material must not have the opportunity to freeze till it is really sprayed on the structure.

Another problem during last projects was the validated fiber/weight ratio. Tests showed us that we achieved a fiber/weight ratio of about 4% in the final structure. Our goal was to achieve a ratio of 10% wooden fibers homogeneous divided through the ice, so we had to find out how to guarantee a proper fiber/weight ratio since the enhancement with the fibers is really necessary this time.

J. Kern and T. Verberne already started with the research into a different fiber; cellulose. The first tests with paper (cellulose) reinforced ice were very promising. We decided to continue that research because it might be solving several issues concerning our mixing and spraying systems.

Organization

There was no descent structure or model for such a specific organization. We have worked with a lot of international volunteers, with very different backgrounds and educations. Every volunteer had his own contribution to the project. It was our job to guide every volunteer through the project, and to get the best out of their effort. This implied that we had to make sure that every contributor enjoyed the project. We had to keep in mind that those volunteers where paying to make their journey to Juuka. It was important to treat them like volunteers, and not like our staff. Furthermore, not every volunteer had a technical background or education, so it was necessary to instruct them very well about our way of working and our safety procedures. It also occurred that someone excelled in a specific aspect which was not directly related to building an ice structure. We had to take care of volunteers out of the fields of media, event management, logistics, lodging, housekeeping, etcetera.

Besides the main project, there were several side projects created, in which we needed a lot of our knowledge, material and equipment to come to a successful result. Together it was our duty to create a variety of impressive ice projects which complemented each other. Sometimes it was difficult to let all projects run smoothly parallel to each other.

We had to make an optimal use of the location, accommodation and provided material and equipment. Most of those elements had to come from sponsoring in kind, which sort of constrained our boundaries.

Figure 6: Building site during spring (Photo: Pentti Kalinen)

1.4 Goals

The goal of this project consisted of five aspects; the research goal, the optimization, sustainability, transformations and social impact.

Show the potency of the use of reinforced ice as a building material

Within last projects e reinforced ice has been used for the first time in a large ice structure, but the design was calculated to hold with only plain ice as building material. The process of producing a proper ice composite was not optimized enough to get all benefits out of it. This year we wanted to enlarge the structure again, which made us dependent on the reinforcement of the ice. We had to produce a proper ice composite with increased material properties compared to plain ice. Showing the potency of reinforced ice as a building material has to result in a new record breaking ice structure.

Investigate the optimization of construction methods for reinforced ice structures.

Spraying a fiber reinforced mixture over an inflatable mold resulted in successful projects in the past. However, we had a lot of delay during the construction period due to several circumstances. With this project we wanted to tackle and solve all problems from last projects. Our main goal was to achieve a descent fiber weight ratio in a homogenous ice composite on a manageable inflatable.

Sustainability

Building with reinforced ice was a very sustainable experiment. The structures were temporary and built with environmental friendly materials. We had to use an environmental friendly addition as reinforcement to let nature adopt all material after and during the melting process. There were almost no dismantling costs because the structure melted naturally during spring season.

Transform problems into possibilities

"OMDENKEN"

"Helps you turn problems into opportunities. The first step is to accept the situation as it truly is by turning the problem into a fact. The second step is to say YES-AND to that fact and transform it into a new possibility."

- Berthold Gunster (1959), www.omdenken.com.

In wintertime, it is quiet in Juuka, Finland. There is almost nothing happening, nor spectacular or surprising. Therefore, a lot of people move to the larger cities in Finland like Helsinki and Kuopio. Especially young people from the countryside's.[1]

The cold winters with its short daylight is some of the reasons why the people move to the cities. But if you think different you can use this cold winter as an opportunity instead of a problem. Like the ice hotels in the north part of Finland and Sweden, were they function as tourist attraction.

With the Bridge in Ice project and all smaller projects around it, it is possible to create something special during wintertime in a small place like Juuka. Using the cold temperatures and snow to create and build, instead of fighting against it. With the last two projects a start was already made. But with the international contact with universities and companies it is possible to get Juuka and its surroundings on the map again as a region were something actually ís happening during the cold winter.

Social impact

Another important element of the project was the social impact of it. During winter the sort of tradition of building large ice structures in Juuka became very important for the inhabitants of this small village. The past project have been connecting people, companies and authorities with the international project team. Regional institutes investigated the economic stimulation of hosting the Sagrada Familia in Ice project, results were very positive and led to a new cooperation during Da Vinci's Bridge in Ice.

[1] *https://www.thl.fi/en/web/thlfi-en*

1.5 Research questions

Main research question

The research into a large span of ice focused on several aspects. First, we had to make an inventory of the necessary processes for realization. To realize such a large span we had to make the optimal profit out of the reinforcement. Therefore the research into paper reinforced ice had to be extended. All major problems of last year had to be solved to reduce process delay, and make optimal use of cold periods. For the amount of ice we had to produce, we really had to improve the construction methods. Besides all this, the inflatable mold was not only a mold anymore, as we also wanted to use it as a supporting structure. Also the shape of the inflatable had to be designed, since this was the first arcuate ice structure realized with an inflatable mold.
All these aspects were resulting in the following main- and sub question(s):

How to realize world's largest span in ice, within given boundaries?

Research question 1: Organization

How to manage and organize several processes to realize world's largest span in ice?

Research question 2: Materialization

How to use cellulose as reinforcement to improve the structural and construction properties of ice structures?

Research question 3a: Construction methods; producing an ice composite

How to use and optimize the current construction methods and processes to realize fiber reinforced ice structures?

Research question 3b: Construction methods; inflatable mold

How to produce and control a reusable inflatable construction for realizing an arcuate ice structure?

1.6 Theoretical framework

The research diverged from a large topic to our specific design. Taking Free Form Design as a starting point, it is a given fact that we used the construction method of inflatable structures again. We were still inspired by Kokawa who combined inflatables with ice structures on a large scale for the first time. We have add the large scope of researches into reinforced ice, and how to produce it, to our design, with the extension of reinforced ice with a different fiber, cellulose. We have applied the now-called 'cellocrete' to inflatable molds which resulted in a new ice structure.

An ideal design to test all these facets was an arcuate bridge out of reinforced ice, created with spraying layers of ice-composite on an inflatable mold. To give the project a proper stature, like last year, got inspired by a famous designer again.

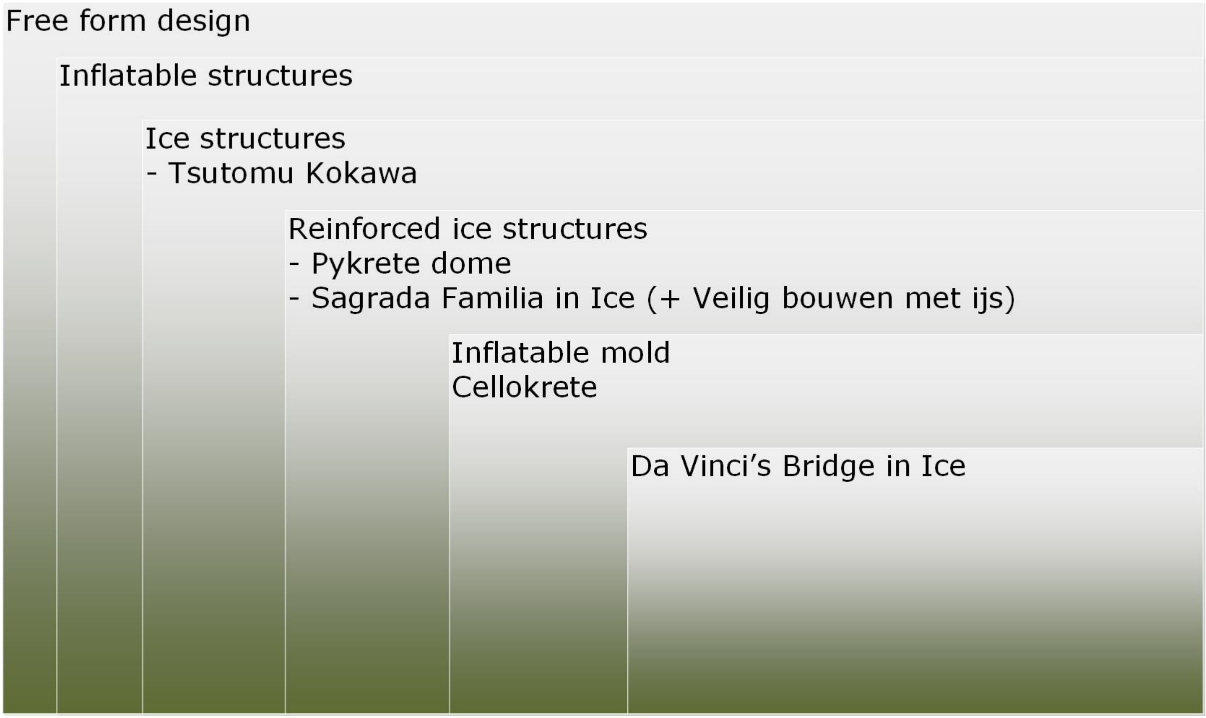


Figure 7: Theoretical framework

1.7 Boundaries and conditions

The research questions can be interpreted in multiple ways. The boundaries and conditions framed the scope of our research.

Design

The design has been inspired by Leonardo Da Vinci's idea for a bridge over the Golden Horn, as the shape of this bridge was ideal for an arcuate ice structure. However, it was not our goal to create an exact scale model of Da Vinci's sketch. We had to look for the optimal dimensions of the bridge, within the possibilities of the material properties and the available space on the building site. We had to investigate how to create a perfect arch bridge, where people can walk over safely.

Construction

Construction methods used during constructing last two major ice projects have been analyzed and improved. One of our main goals was to set up a proper 'ice composite factory' to reduce all process delays. To create such a large structure we had to produce the maximum amount of ice possible, but therefore the production and distribution of the ice composite had to run flawless. We were highly dependent on sponsoring and available equipment, so we had to make the best out of given opportunities and current contacts.

Materialization

Cellulose is a material which is investigated before as a reinforcing material in ice. Through positive test results and the availability of cellulose at our sponsor Stora Enso it was most likely to use paper fibers in our project. Other fibers have not been investigated, but we compared all 'cellocrete' results to the more comprehensive investigations of wooden fibers in ice composites.

Figure 8: Mixing wooden fibers with water in a very improvised way during the Sagrada Familia in Ice project. (Photo: Bart van Overbeeke)

1.8 Research methods

A proper division in fields of research methods was made, in that way we used different methods to achieve our goals. However, an important aspect had to be taken into account. We were going to realize an enormous structure under harsh conditions. Some elements had to be improvised in the moments were unwanted situations suddenly appeared. In our report we explained why we made some decisions, although they were sometimes not extensively investigated.

Literature research

The research contained an inventory of what is essentially needed for realizing an arcuate bridge out of reinforced ice, with the use of an inflatable mold. The literature research contained subjects like the research into the work of Leonardo Da Vinci and T. Kokowa. Most important are the reports of Hijl & Pluijmen (2014) and Kern & Verberne (2015), with the safety recommendations of Borsboom (2015) as an addition.

Experimental research

To optimize the construction methods we had to analyze last year's techniques. With scale models we improved the inflatable mold. Unfortunately, it was very difficult to test everything on a large scale within the cold conditions in which our project was realized.

Also the tests into the field of materialization were very experimental. Since we were not so familiar with building ice structures in the Netherlands, we were also not used to test the material properties of ice samples. We had to improvise with the test facilities at our laboratory at the TU/e to make them suitable for testing reinforced ice samples. Luckily we were assisted by a group of master students who did a master project in testing reinforced ice.

Model research

We have used several model-based techniques to investigate the structural properties of our designs. For different elements we used a variety of digital 3D-modelling software. A group of master students has done a major part of the calculations, since they were better experts in the field of Structural Engineering than we were. Our job was to determine what was producible as well as the combination of all elements.

Figure 9: Frozen cellocrete samples prepared for testing

1.9 Research model

The research model shows the research set up. This whole project has been about building ice structures, containing several distinguishing aspects. All inspiring researches and elements have led us to four fields of investigation. The four separable subjects were design, construction methods, materialization and organization.

A proper investigation into these subjects have resulted in the design and realization of Da Vinci's Bridge in Ice. We have been collaborating with lots of parties to achieve our goal. After realization, a significant addition of research had to be done into reinforced ice.

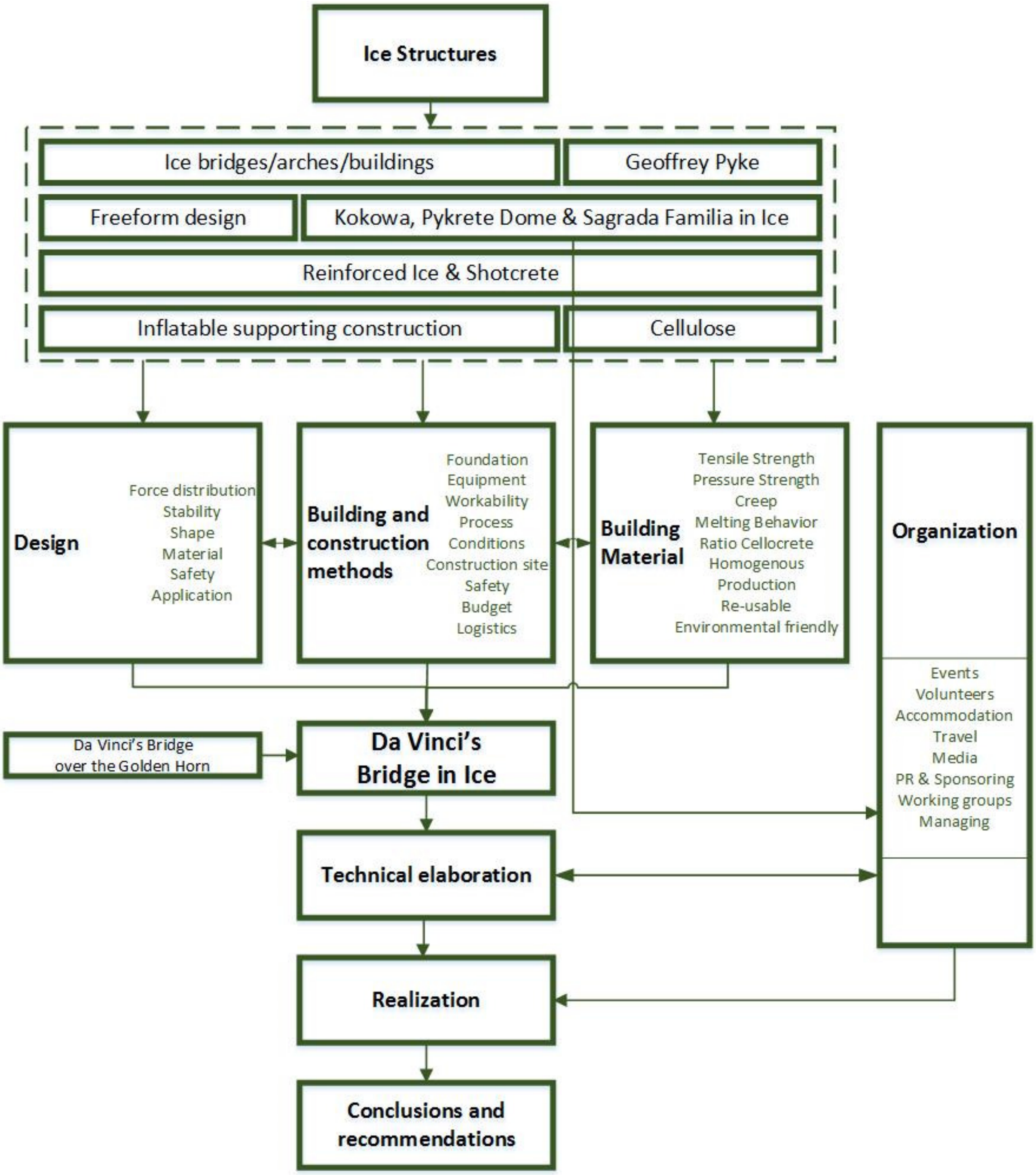
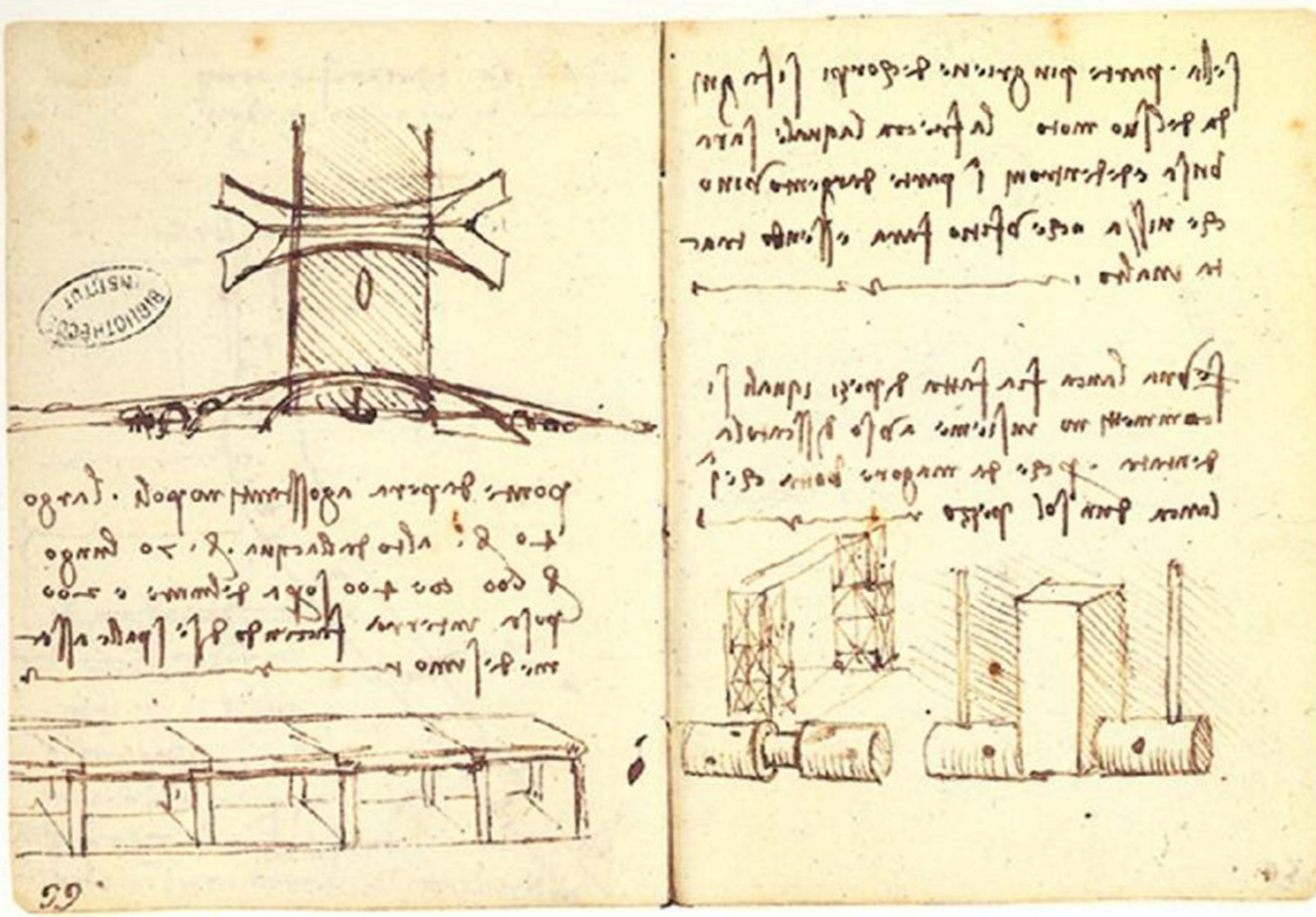


Figure 10: Research model



2. Literature research

2.1 Ice Structures

Since centuries ice and snow are used as a building material. The ice structures are used as a shelter or just for recreation and entertainment. A brief tour through the history of ice structures.

Igloo

One of the oldest ice structures known are the igloos of the Inuit (inhabitants of the artic area around Greenland, Canada and Alaska), see Figure 11 The igloo is built with massive ice-blocks that are stacked on each other. The gabs between the blocks are filled with snow (Pronk, Vasiliev, & Belis, Historical development of structural ice, 2016). Because of the insulation effect of the snow the temperature inside the igloo can reach temperatures above 0 °C with the human body as heat source (Hijl & Pluijmen, 2014).

Ice palace

In the 18th century temporary ice structure were built with massive ice blocks cut out of the river and stacked on each other. The blocks were melted to each other to create a big wall (Anderes & Agranoff, 1983).

In 1739 the first ice wall was built, see Figure 14. Even in the winter of 1887 (St. Paul Winter Carnival) at the St. Paul Winter carnival an Ice church of 42.5 high meter was build (Figure 12).

Figure 11: Inuit building an igloo

Figure 14: Building an ice wall

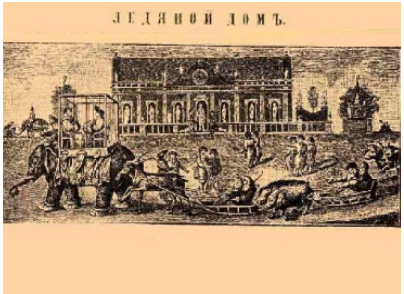


Figure 13: Building an ice wall

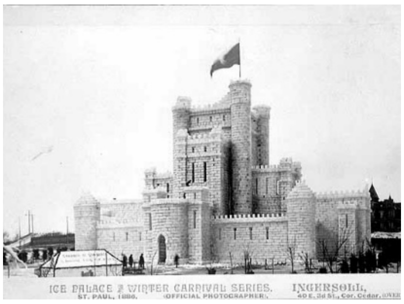


Figure 12: Ice church

Kamakura

The structures as mentioned above were getting too expensive in the late 19th century. This led to new developments. A wooden mold was filled with wet snow, sometimes reinforced with braches, and pressed together. The building was made from solid snow and therefore more as an aesthetic structure instead of an actual building (Anderes & Agranoff, 1983).

This building method looks like the way the Japanese build their Kamakura. A traditional snow hut (Figure 17). In a pile of wet snow a gap is dug out. One of the most recent structures of casted snow is the 18 meters high Snow Church in Mitterfirmiansreut (Figure 15).

Figure 17: Kamakura

Figure 16: Ice hotel

Figure 15: Snow church

The ice structured, above-mentioned, has their limitations. Ice and snow as a building material is weak and has a high creep behavior compared with the traditional building materials. Besides that, the material is strongly temperature dependent. How colder the structure how stronger the structure is (Pronk, Vasiliev, & Belis, Historical development of structural ice, 2016)

Ice as a building material can be improved with the use of reinforcement. In the Second World War Geoffrey Pyke already experimented with the use of wood fibers as a reinforcement. Combining this knowledge with the technique invented by, Heinz Isler, Kokowa and Matti Orpana, a new era of ice buildings is born (Hijl & Pluijmen, 2014). In chapter 2.3 you will have an overview of ice reinforcement and the possibilities it offers.

Figure 18: Pykrete dome under construction (Photo: Bart van Overbeeke)

2.2 Leonardo Da Vinci

The starting point of the design of Da Vinci Bridge in Ice was a sketch of Leonardo Da Vinci. In the eyes of many people one of the greatest thinkers in history. In 1502 Da Vinci drew this sketch for the Sultan Bayezid II of Turkey (Figure 19). At 220 meters, the Golden Horn Bridge would have been recognized as being the longest bridge in the world during that period. But unfortunately, the Sultan only saw Leonardo's concept as nothing more than an inconceivable plan (Rutgeers, 2015).

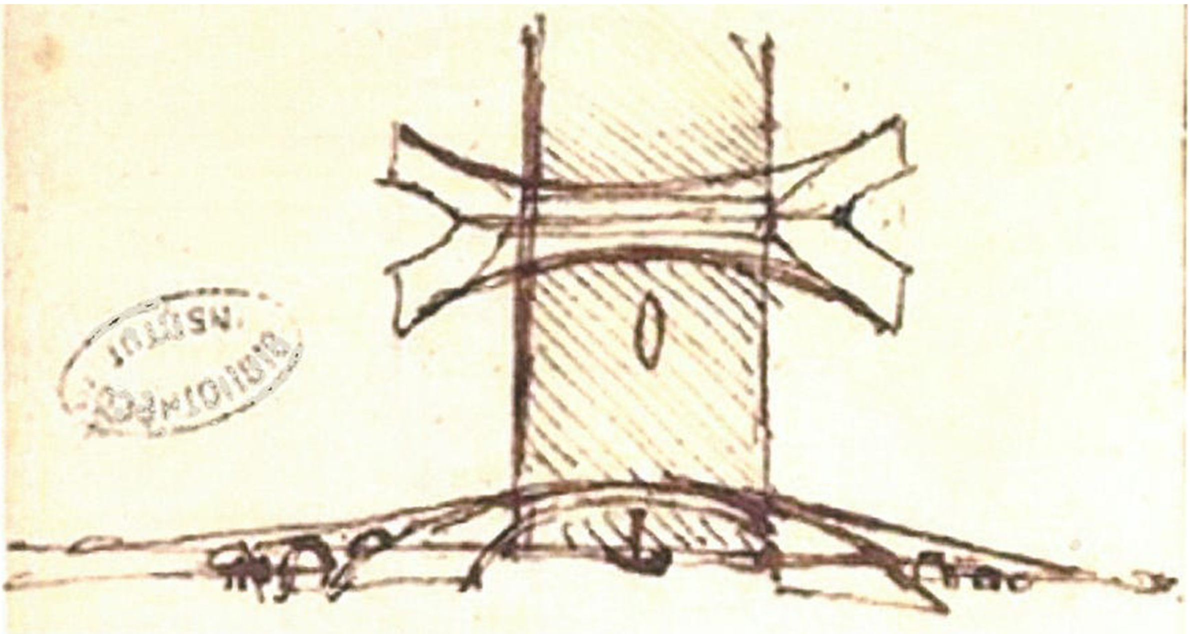


Figure 19: The sketch from Da Vinci for a bridge over the Golden Horn

Leonardo da Vinci was born in April 15, 1452 in the Republic of Florence. Today best known for his famous paintings, the Last Supper, and the Mona Lisa. But Leonardo Da Vinci was much more than an artist. He was an astronomer, sculptor, geologist, mathematician, botanist, animal behaviorist, inventor, engineer, architect and even a musician.

The sketch of the Da Vinci Bridge is called into question whether it was possible. A bridge of 220m long would not be possible with the knowledge and buildering material for that time. But today it is still an inspiration for architects and designers all around the world.

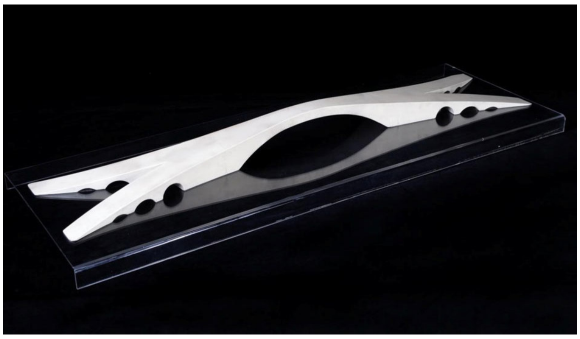


Figure 21: Model of the bridge

Figure 20: Pedestrian bridge in Norway

The Norwegian artist Vebjorn Sand designed a pedestrian bridge based on the sketch of Leonardo Da Vinci (Figure 20). In the museo Leonardiano in Milan you can find a model of the Da Vinci Bridge. A group of researchers tried to figure out how Da Vinci had planned his idea. Unless there are many ideas of how the bridge should be build nobody has find the solution yet (Rutgeers, 2015).

2.3 Reinforced ice

Reinforcing a material to increase the properties of that material is used for many years. A well-known example is reinforced concrete, where the tensile strength is increased by steel reinforcement. Depending on the type and the fiber of the reinforcement there are many possibilities to enhance the properties of the concrete. This form of enhancement of the material, by adding a fiber to a mixture, can also be used for ice. Concrete and ice have a relative high compressive strength, the added reinforcement enhance the tensile strength of the mixture (Janssen & Houben, 2013).

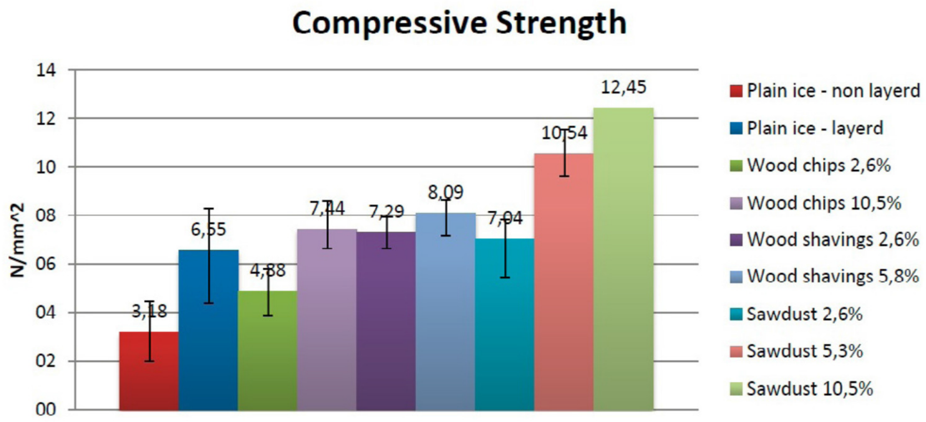


Figure 22: Compressive strength of wooden reinforced ice (Janssen & Houben, 2013)

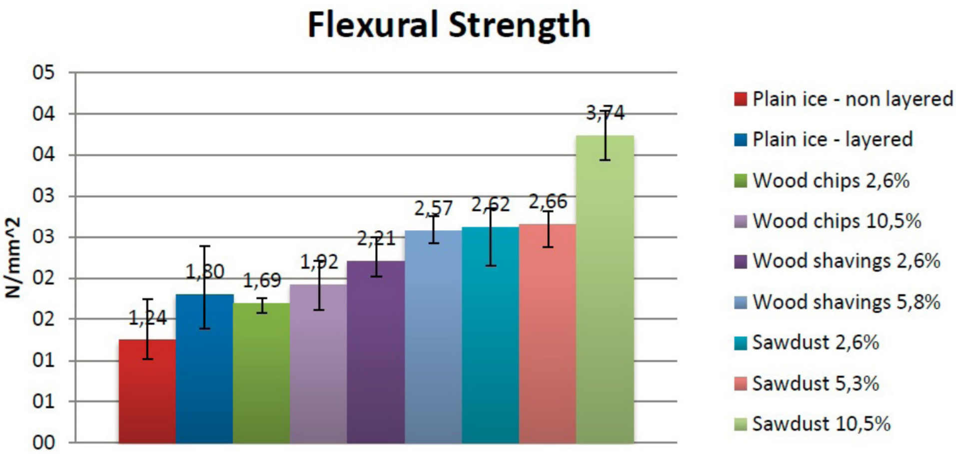


Figure 23: Flexural strength of wooden reinforced ice (Janssen & Houben, 2013)

This research led to the experiments of the Pykrete Dome and the Sagrada Familia in Ice. Both successful projects added valuable recommendations in the field of material research on ice composite. Validation showed that reinforcing the ice with wooden fibers really increases the structural properties of the material. Though, a lot of problems occurred during the production and construction processes. Most important problems are the following occasions (Kern & Verberne, 2015):

- No homogenous composite (Figure 2, Chapter 1.1)
- Achieved only 50% of the aimed fiber weight ratio inside the actual constructed material

Recommended further research could be the investigation of various fibers, such as cellulose. The dissolving fibers could led to a smoother process and a more homogeneous ice composite. Cellulose is an obvious fiber to use in our project, since it is the main manufactured product of our sponsor Stora Enso, which was providing us with sawdust during the previous projects. Besides the availability it is a sustainable material and it increases the structural properties of the material at least as good as wooden fibers (Bastian, 2010). Investing this new ‘cellocrete’ is a logical next step in the story of constructed ice structures.

3. Organization

3.1 Introduction

Since centuries ice and snow are used as a building material. The ice structures are used as a shelter or just for recreation and entertainment. A brief tour through the history of ice structures.

The projects 'Pykrete Dome' and 'Sagrada Familia in Ice' were both made possible by hard work and determination from students, volunteers, family members, friends and sponsors. Following to their example, the 'Da Vinci's Bridge in Ice' project will be a non-profit based project and made possible almost only by volunteers. Due the continuous expansions of these separate projects due to their success, the organization requirements have increased. This resulted in the founding of the Structural Ice Association (2015) and a consortium of several educations (2016) wherein students from MSc, BSc and Middle scholarship students work together.

Figure 24: Meeting at Fontys Hogescholen for recruiting supporting students

3.2 Promotion

In order to create potential cooperation's, a lot of attention and effort was put into the promotion of the 'Da Vinci's Bridge in Ice' project. Therefore, the initial plans were presented on several occasions during company and school visits in native and foreign countries. Next to these presentations on site, a press release was created. Furthermore, a website (www.structurealice.com), flyers, stickers, a Facebook page, a twitter account, an Instagram account and an information pocket were created (appendix 1 and 8). With help of these media items, we were able to recruit the necessary volunteers and sponsors like students from different disciplines, teachers, mass media and companies with specific knowledge.

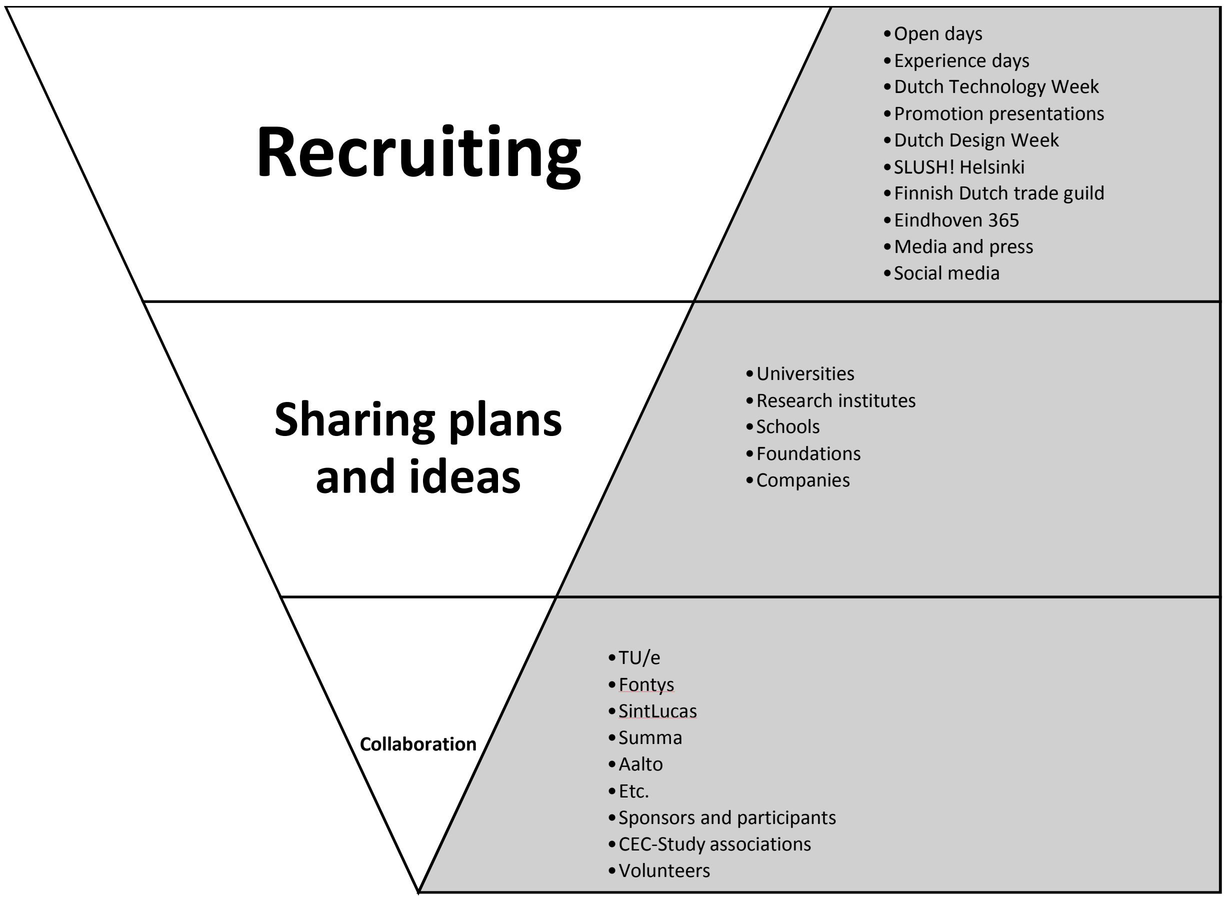


Figure 25: Forming collaborations

3.3 Collaboration

The media attention and active recruitment resulted in several cooperation’s which can be -- divided in the following groups:
- Advisory part, exchanging knowledge
- Active participation, having designed task in the project
- Sponsoring, financial or sponsoring in kind

Figure 26: Collaborations of universities and institutes

Eindhoven University of Technology (TU/e)

As initial starters of the Bridge in Ice project, the TU/e played a major role in the management of the project. Next to the project managers, Thijs van de Nieuwenhof and Roel Koekkoek, and project leader Arno Pronk, the following people and agencies played an important role:

1. 11 Master students in the fields of research & design (methodologies) who helped from the start of September 2015. They focused on four disciplines: construction technology, structural design, inflatable and material research. They were supervised by the following professors and tutors: ir. A.P.H.W. (Arjan) Habraken, ir. R. (Rijk) Blok, ir. A.D.C. (Arno) Pronk. Chapter 4 will further elaborate on this cooperation.

2. Laboratory of Structural Design at the Faculty of Built Environment, under supervision off ir. H.M. (Hans) Lamers facilitate the research equipment regarding the materials. Furthermore the department helped with purchasing of the necessary materials, production, logistics, and gave advice for the build-up.

3. The ICT department from the TU/e made available several laptops, room on the server for data and gave advice regarding the system setup. This was made possible with the help of Peter Kerkhofs and Mevr. M.J. (Marian) de Vaan.

4. Ivo Jongsma who published several items in the TU/e newspaper (De Cursor) for the Bridge in Ice project and his advice on media awareness.

5. Tom van Aarle (desk facilities), Hannie Dijsselblom (Communications Expert Center) and Karin Dorst (faculty Build Environment communications department), Study association SUPport for helping recruiting volunteers and founding module: "Innovation on Location" and CT-certificate for international experiences in which students could receive extra credits (ECTS) during their stay in Juuka.

Summa College

The Summa College exits out of 22 schools for secondary professional education and it offers over 200 studies. In one of the presentation during the recruiting period a few members of this college were interested in the Bridge in Ice project. In preparation to the presentation, an analysis was made from the previous Ice construction projects. In September 2015, two problem statements were addressed during the presentation to the Summa College:

- How to optimize the cellocrete mix-system
- How to optimize the air control system and automation for the fans

The response from Jean Paul Verhofstad (team leader Summa Engineering), and Hans van den Elzen (teacher Summa Engineering) was promising and positive. Together with mechatronic (Electrical engineering, mechanical engineering and ICT) students, the entire cellocrete mix system and the air control system were studied. Further elaboration and results are given in chapter 5.

SintLucas creative community

SintLucas evolves itself as a steady and creative community within the students' society. It connects students, teachers, alumni, employees, companies, schools and cultural institutions. Shortly after the start of the Bridge in Ice project, photographer Bart van Overbeeke (photographer Pykrete Dome 2015 and Sagrada Familia 2016) gave notice that he had no time for the Bridge in Ice project. Overbeeke was responsible for the photos and movie on site and our connection to the media. With Overbeeke leaving the project, a lot of knowledge left. It was a challenge to refill the position but give us also the opportunity to head forth a new direction regarding our media attention.

Several presentations were given for the SintLucas creative community in June 2015. Contact person Aldert Walrecht was very positive about the project which resulted in a new cooperation with SintLucas. Initially, we agreed upon taking on 1 photographer and 1 cameraman. But slowly as the projected evolved, it became clear that there we more opportunities for both parties. After an analysis on what was needed for the Bridge in Ice project regarding media attention, a selection was made how these items should be covered. This resulted in a media team existing out of 10 students and 4 teachers as supervisors. Listed are several tasks for which SintLucas was responsible:

- Project movie and photos
- Time-lapse
- Sponsor movies and photos
- Safety instruction video
- Attendance (workers) cards for the employees (volunteers) for the project
- Promotion video for participating
- Create media attention
- Attend to all social media pages
- Attend to all blogs (several broadcast stations) and website items
- Contact person for local and native media

The intense cooperation with SintLucas resulted in additional support from study program Media and Event management. From September 2015, Liselotte de Haan did her internship at the Bridge in Ice project. De Haan was partly responsible for all activities in the Bridge in Ice project. Several activities which De Haan helped organize are:

- Stand during the Dutch Design week
- Planning production process
- Planning activities during production Juuka
- Arranging permits for festivities in Juuka
- Designing posters and flyers
- The opening and closing party of the DBI project

In order to smoothen the cooperation between students from SintLucas and the Bridge in Ice project, internship contracts were made and signed by the TU/e. For these contracts, TU/e was registered as official learning company. The project leaders from Bridge in Ice project were responsible for counselling, advice and to oversee the daily activities from the ‘interns’.

Figure 27: Presenting the project at the local restaurant, by Liselotte

Fontys Hogescholen Eindhoven

Several students from Fontys Eindhoven were already involved in the Sagrada Familia in Ice project, therefore the Fontys College was asked to step in the project. The start for this cooperation was made in April 2015. A presentation was given to approximately hundred Fontys employees. Together with Simone van der Velde and Kim Snellink (Fontys Eindhoven) the following cooperation was initiated:

- Five Technical Business Study students were responsible for the sponsorship policy of the project. Unfortunately, this did not lead to the desired results, therefore the cooperation with these students was ended after several months.
- From October 2015, five ICT students worked on improving the entire website. Not only for the Bridge in Ice Project, but also for other (future) projects. This team of students, under supervision of Jan van Dijk (student Information Study) and Martijn Ruissen (Fontys ICT), made it possible to interpret and put the data of the Summa College, webcam, monitors, blog/vlogs, news articles on the website. Furthermore, the website was built in such a way that it was easily accessible and user friendly for website visitors.

Aalto University

In cooperation with Aalto University several research projects were erected. Under the supervision of Lauri Salokangas and Juha Paavola, MSc-student Syda Tabussum did research on 'cellocrete'. The research facilities at Aalto University (Espoo, Helsinki) are much better than at Eindhoven University. Therefore, binding forces between these universities has led to new insights on the subject 'reinforced ice'. Especially to the research on making good test samples, Aalto University has made a good contribution. The results can be found in chapter 6.

The University of Gent

Graduating student Bram Ronsse from the University build under supervision of prof.dr.ir. J.L.I.F. (Jan) Belis, a construction with a very thin shell, the Candela Pavilion of Ice. The Candela Pavilion was part of the Ice-track. The University of Gent made used of the materials, logistics and organization from the Bridge in Ice project. Further information regarding the Candela pavilion can be found in (Belis, et al., 2016).

Figure 28: Created Candela Pavilion, designed and build by students from the University of Gent

The University of Liège

Elke Mergny, PhD student from The University of Liège supported the Bridge in Ice with structural calculations in Abaqus. Beside the Abaqus lectures she gave to the master students, she also helped with the calculations. The results of Elke were compared with the results of the master students. The final calculations are based on this combination. The result is shown the next chapter

University of Minho

Prof. Paulo J.S. Cruz from the University of Minho lead the material research that he has been done together with the students of the University of Gent and prof.dr.ir. J.L.I.F. (Jan) Belis. This research was done during the construction of the bridge (Cruz & Belis, 2016). Samples taken directly from the foot of the bridge were tested in the laboratory of Tulikivi Oyj. The total material research is explained in chapter 6.

On 27-29 July 2016, a delegation of the Bridge in Ice project where represented at ICSA 2016 Symposium in Guimarães.

Figure 29: Da Vinci's Bridge in Ice presented at the ISCA 2016, by Paolo Cruz

KU Leuven

The University KU Leuven, under supervision of ir. A.D.C. (Arno) Pronk where responsible for the Ice-track (Figure 30). Several ice structures, sculptures and other designs were showed at the Bridge in Ice festival.

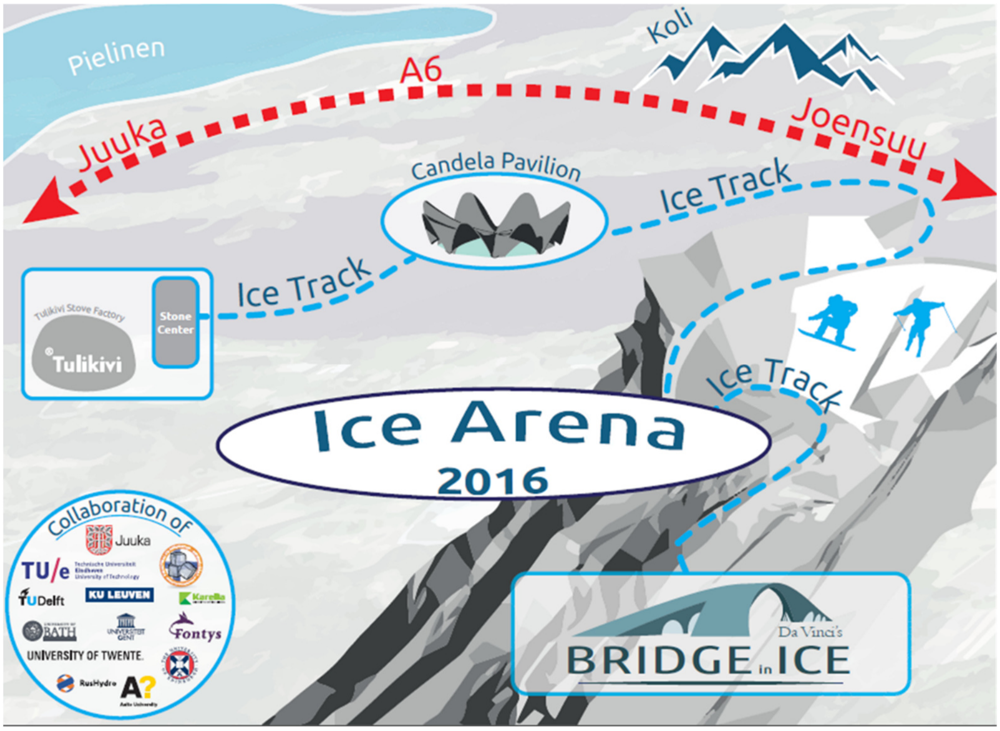


Figure 30: Artist impression of the Ice-track (Ice Arena 2016)

A map with all collaborating universities and institutes is shown below. In the appendix 2 you can find an overview of universities with its responsible tutors and contact persons.

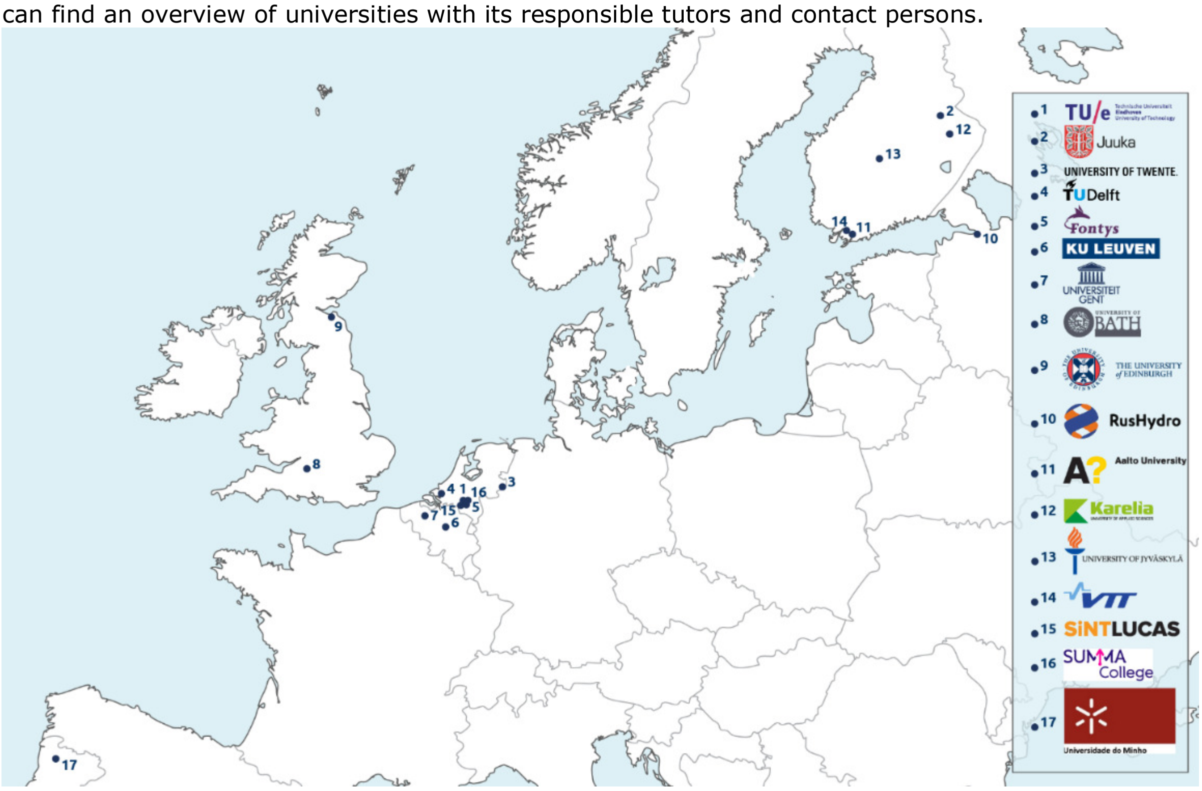


Figure 31: Map of collaborating universities and institutes

3.4 Organization model

In the first place the organization was split in different disciplines.

1. Social infrastructure, volunteer, personal, members and volunteers
2. Technology and Construction
3. Board Structural Ice Association
4. Events

In every discipline are people from: The Government & local community, Commerce, and Academic active. Each commission was responsible for their own tasks. Unfortunately, it did not work out exactly as planned. This resulted in a delay in the planning. Therefore, the whole organization was finally led by the Technical and Construction commission, under supervision of: Arno Pronk, Thijs van de Nieuwenhof, and Roel Koekkoek.

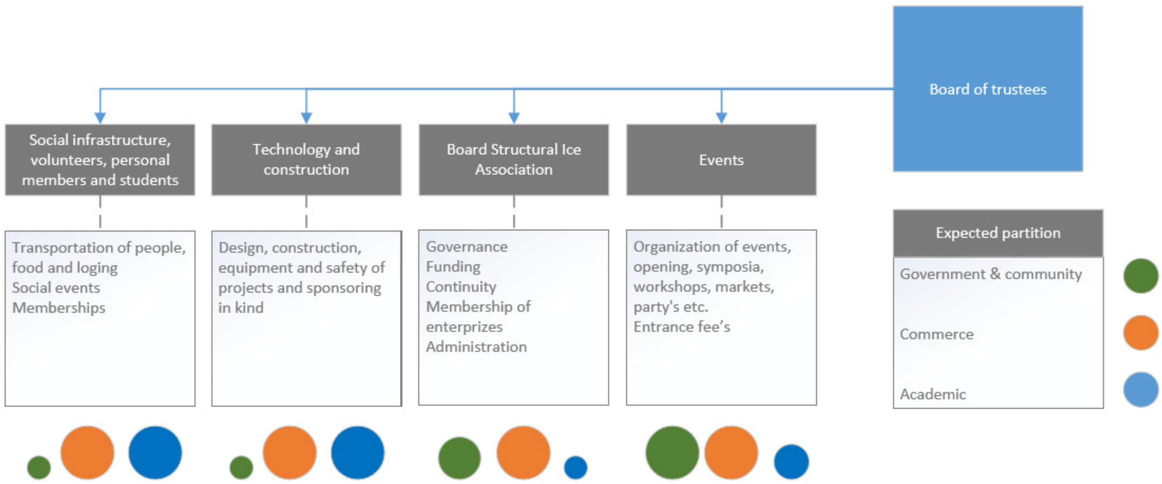


Figure 32: Organization model

3.5 Planning

In appendix 3 a full schedule of the planning is attached. A short summery is show in Table 1. A detailed planning of the construction from 28 December 2015 till 15 February 2016 is explained in chapter 6.

Table 1: Project schedule

Research phase 01-03-2015	Analyze previous project Starting Collaboration Brainstorm sessions new Design Starting Consortium
Promotion 23-04-2015	Release Bridge in Ice project, Press, Sponsor plan, Budget estimations
Design 01-06-2015	Material research Ice shell research Inflatable Research Structural calculations Final Design
Preparation 01-10-2015	Gathering Volunteers Preparing Membranes Preparing Ropes Transport Preparing Building site
Construction 28-12-2015	Building period (Chapter 6)
After Sale 15-02-2016	Presentations, Symposium Magazine July 2016

3.6 Sponsors

A non-profit project like the Bridge in Ice project is only possible with the support of Sponsors and volunteers. The role of Sponsors is important. Not only for sponsoring in cash, but especially for knowledge, expertise and material sponsoring. Due the previous projects a small network of sponsors is already created. Some of these sponsors and organization participate again. Due the continuous expansions of the DBI project the need of sponsored material grows also.

Approach

Together with the institutes from the collaboration partners, Fontys Eindhoven, Summa College, SintLucas, Structural Ice Association and all the project members we looked at companies which may be interested. In the Sponsor brochure (appendix 4) all the information about sponsor possibilities is provided.

Sponsor brochure

The Sponsor brochure is build up with different packages, Bronze, Silver, Gold and platinum, see Figure 33 and appendix 4. Each package contains several activities. For a bronze package, with a value of € 250,-, the sponsor will get a free magazine, and a small logo on the website and in our magazine in return. A Silver package contains, a free booklet and a medium logo on the website, booklet and events. And so on. Companies that sponsored materials or knowledge are converted and expressed in cash to determine their sponsor package.

A sponsor package is only available in a combination with a membership of the association.

	Sponsor packages		Platinum	Gold	Silver	Bronze
1	Free booklet(s) about Bridge in Ice	10,-	100,-	50,-	30,-	20,-
2	Small logo on website and in booklet	500,-				500,-
2	Medium logo on website, booklet and at events	1.500,-			1.500,-	
2	Large logo on website, booklet, events and inflatable (5 m^2)	2.500,-	2.500,-	2.500,-		
3	Page in booklet about Bridge in Ice	200,-	200,-	200,-		
4	Presentation about building with ice at your company[1]	400,-	400,-	400,-		
5	Blog in Cobouw-magazine	1.000,-	1.000,-	1.000,-		
6	Special *Building with Ice* sponsor movie	2.000,-	2.000,-	2.000,-		
7	Guest/lecturer at ISOFF Ice Symposium[2]	1.500,-	1.500,-			
8	VIP treatment at opening and first to walk over the Bridge[3]	5.000,-	5.000,-			
	[1] excl. (travel) costs	Total	12.700,-	6.150,-	1.530,-	520,-
	[2] excl. travel costs	Discount	3.700,-	2.150-,	530,-	270,-
	[3] if safely possible	Sponsorship amount in euros	**9.000,-[4]**	**4.000,-[4]**	**1.000,-[4]**	**250,-[4]**
	[4] sponsor packages are only available in combination with membership					

Figure 33: Sponsor possibilities

Sponsoring

During previous projects a growing network of supporting companies and institutions helped us. This network is expanded again this time with lots of knowledge and expertise. In Figure 34 you will find an overview of the required resources.

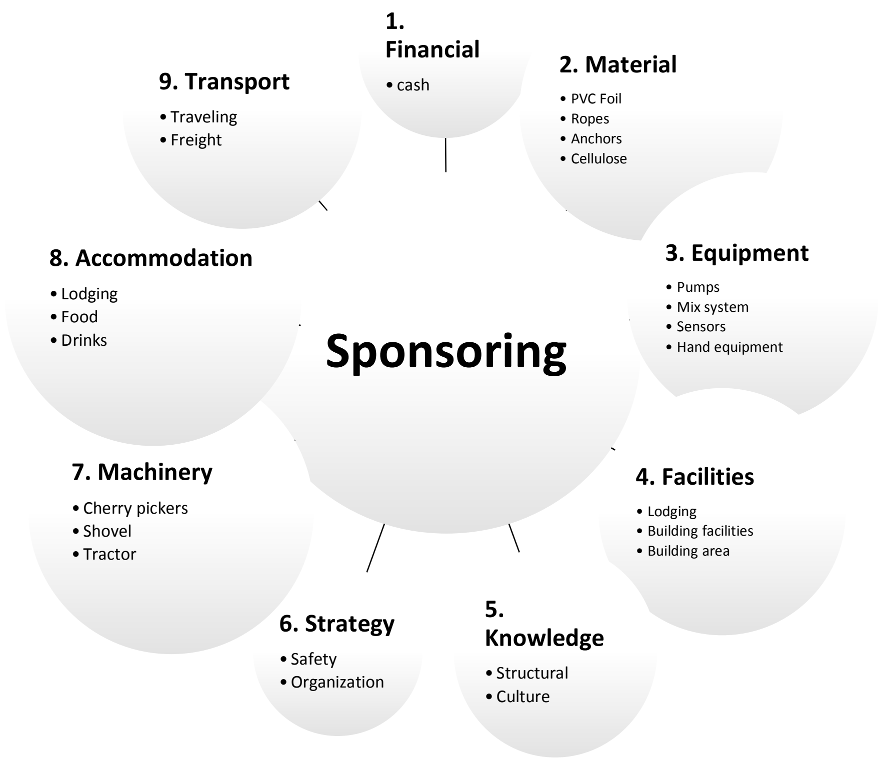


Figure 34: Overview of required sponsoring

Financial (1)

Direct financial sponsoring is often hard to receive. Though, it is very important to cover unforeseen costs and setbacks. Fortunately we did receive some financial gifts from supporting companies, convinced by our sponsor brochure. Besides gifts and grants we generated cash income by inning member contribution for the Structural Ice Association.

Material (2)

Almost all used material during preparations and construction phase was sponsored. Some examples:

- 5000 m^2 PVC-foil, sponsored by Scantarp and processed at Poly-Ned BV.
- 30.000 kg cellulose, sponsored by Stora Enso.
- 5000 m polypropylene rope, sponsored by Chr. Muller Touw BV.
- 2x 42 m steel cable (Ø 21 mm), sponsored by Mammoet.
- 100 anchors, sponsored by JLD.

We cannot mention every contributed company or institute, but again we will thank everyone for their support.

Construction Site (3)

The building site of the Sagrada Familia project was already made suitable for constructing the ice projects. We got permission to use the same site again for building the ice bridge. Extra improvements and adjustments for the purpose of the ice bridge were mostly sponsored by local contractors and contributors. Some examples:

- Extra soil improvements
- Infrastructure (water and electricity) underground
- Back-up system for electricity

Facilities (4)
During the seven weeks of construction period all volunteers needed a place to stay. We paid a small fee for using accommodation and office spaces. In the most crowded week we offered lodging to 100 volunteers and contributors.

Knowledge (5)
Information from the industry is necessary to gather enough knowledge about cultural and structural subjects.

Strategy (6)
The Bridge in Ice project has developed to a large international project. Contacts with institutes like embassy's, municipalities and local parties are very important.

Machinery (7)
During preparations and construction processes a lot of large machinery is necessary. Some examples:
- Boom lifts (resp. 26 and 21 m reach height), sponsored by Pekkaniska.
- Shovel and excavator, sponsored by Rotator & Hitachi.
- Cars and others, sponsored by e.g. Tulikivi.

Accommodation (8)
During the previous projects Pykrete Dome and Sagrada Familia in Ice the organization bought their groceries by a reduced price at local shops in Juuka. Since our amount of volunteers extended from approximately 30 to 100 (during one week), we had to professionalize in fields of food and lodging. The average prices of food and drinks are also cheaper in Holland compared to Finland, so we decided to transport a large amount of provisions to our accommodation in Juuka. This also reduced costs for logistics, since the most nearby shop was approximately 15 km away from our guesthouses. Several groceries were sponsored by companies in Holland and Belgium.

At our accommodations we could host almost 100 people at once. With cooking and dishwashing in shifts we provided everyone with proper meals, prepared in the professional kitchen of the biggest guesthouse.

Transport (9)
The transportation of (prepared) products, equipment and volunteers is mostly sponsored by (local) companies. The shipping of one 20ft container from Eindhoven to Juuka and back was sponsored by Transfennica and DB Schenker.

Opening Ceremony
To give the project more international and local allure we organized a big opening event on the 13th of February. This ice festival consisted out of several ice structures, activities, shows and parties. This day was made possible by several sponsors for:
- Shows and activities
- Performances
- Lighting
- Audio and video systems
- Food and drinks

Activities
During the seven weeks on location we organized several activities for our volunteers. It is important to relax and have fun when the daily workload reaches an extraordinary level. The activities were made possible by several local volunteers and some sponsors. This resulted in a versatile activity program:
- Shows of local bands
- Ice fishing
- Snowmobile riding
- Ice hockey
- Etc.

Media

Da Vinci's Bridge in Ice was promoted and supported by a media team. This group of students from SintLucas Eindhoven was responsible for all (social-)media contact, website, photo & film, etc. Besides all the work they have done, they also provided the project with a lot of equipment, such as:

- Camera's
- VR-devices
- Computers
- A drone

Sponsors

You can find a list of almost all sponsors in appendix 5. An overview of our main sponsors is shown in Figure 35. Not all sponsors are named, because several local contractors and initiatives contributed under the flag of one of the bigger sponsors.

Figure 35: Sponsoring companies

3.7 Budget

The growth of the project and the expanded collaborations with the large amount of sponsors made it absolutely essential to work with a proper budget estimation. The estimation is compiled with an example used in practice by a supporting property developer in Holland, Salix ProjectPartners. The budget estimation of the Bridge in Ice project consists out of six parts.

- Students and Volunteers; estimation for traveling, lodging, accommodation, food & beverage, transportation and healthcare.
- Technology and construction; permissions, materials Bridge in Ice, materials Candela Pavilion, material Snow track, material Frozen Waterfall, equipment all projects, mixing and spraying system, equipment individual projects, energy consumption, construction site, safety, insurance, facilities, logistics, research tests, management.
- Board Structural Ice Association; accommodation, administration, financial, communication, promotion, representation
- Ice Events (Juuka in Ice 2016)
- ISOFF Ice Symposium
- Masterclass

In every estimation all parts are specified, see appendix 6.

Technology and Construction

In every specification you can see the value and amount of sponsored product, and which company is contributing. All sponsoring in kind is converted to market values and taken into account in the total budget estimation.

All labor of the management team is also included. Though, these working hours are just done by volunteers. This labor is included in the estimation to show the large amount of worked hours invested in this project. In this way we could place everything in perspective. It is needless to tell that all labor by the management team is sponsored in kind by the contributor concerned.

Students and Volunteers

Contributing volunteers were allowed to decide their volunteer period by themselves. Since the construction period took seven weeks we were aware that it might be very difficult to reserve seven weeks for such a project. So everyone could contribute as long as they assumed reasonable.

Contribution fee was € 350,- for one week, every other extra week was for free. This construction was figured out to trigger volunteers for helping us more than one week. Every volunteer had to do several courses and instructions. To make the most profit out of their contribution and reduce training periods it was essential that people stayed for more than one week. Fortunately a lot of volunteers were able to help the project for more than 2 or 3 weeks. There arose some kind of core-team, consisted out of approximately 20 people, who were in Juuka for (almost) the full period. Every volunteer became a member of the Structural Ice Association.

3.8 Volunteers:

A project like Bridge in Ice is not possible without the help of volunteers. They were involved in: the building team, organization, and care team. Family, friends and students could fill in an online register form to participate in the Bridge in Ice project (appendix 7). All the information about the project and the possibilities to participate were available on the website.

The information from the registration form were directly processed in a database. With this information an occupancy rate was made. All information of the volunteer was listed, clothing size, addresses, allergies etc. For privacy reasons, this list is not included in the appendix.

All the volunteers were keep up to date by e-mail and a volunteer guide (appendix 8). The administration, contacts with volunteers, and data analyses were taken care of by Veerle Jansen (volunteer coordinator) and Tim ter Heide from Erica Project Advies (ICT support).

Organisation construction period

All the volunteers arranged their own transport to Finland. Most of the volunteers arrived on the nearest Airports, Kuopio and Joensuu. From this point the volunteers were picked up and transported to the accommodation Nunnanlahti.

The building site was located next to the factory of Tulikivi Stonecenter (sponsor). Tulikivi had several guest houses near this place. During the building period the accommodation were available for the Bridge in Ice project. Also the Stonecenter a former office with Study-rooms, presentation-rooms, lunch area, was used for the project.

Figure 36: Relaxing at the accommodation

Shift division

The construction of the bridge was a constant process. By working in shifts it was possible to work 24 hours a day. Because of climate conditions it was not allowed to work longer than 3 hours street (Borsboom, 2015). Therefore, the shift were split up in two times 3 hours with a break of 3 hours in-between. This division gif the opportunity to use the breaks for other tasks like, cleaning, cooking, groceries, diner and lunch. In total there were 5 Teams which take responsibility of 4 different dayshifts. For an example of the shift schedule take a look at Figure 37, where block 1A and 1B and block 2A and 2B are explained.

Timetable shifts			
Block 1	A	03:00-06:00	09:00-12:00
	B	06:00-09:00	12:00-15:00
Central Meeting 14:45-15:15			
Block 2	A	15:00-18:00	21:00-00.00
	B	18:00-21:00	00:00-03:00

Sauna time
19:00-21:30
12:00-14:30

Dinner time
18:00
Lunch School
10:30-12:30

Cleaning Stonecentre Kitchen
In the 3 hours between your shifts

Doors stonecenter are locked from:
17:00 - 11:00

Figure 37: Shift schedule

Shift teams 1 t/m 4 were responsible for the construction part. Shift 5 consisted of, media team, event management and volunteers that were not able to help in the regular building shifts.

Each shift team, depending of which week, consist of 1 or 2 shift leaders and between the 5-15 volunteers. Only a student from the TU/e who already was involved in the design process of the Bridge in Ice could be a shift leader.

The schedule is organized to use time as efficiently as possible. The shift changed each day with another shift inside the blocks. For example, if you worked in Block 1 you start at 3.00 AM in the morning and the next day you start at 6.00 AM and so on. The division of the shifts didn't change during the week. Except the volunteers that stay longer than one week could chose to switch after one week to work in another block. This to provide to work only in night or day shifts.

	week 5: 25-31 January						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
shift 1	1A	1B	1A	1B	1A	1B	1A
shift 2	1B	1A	1B	1A	1B	1A	1B
shift 3	2A	2B	2A	2B	2A	2B	2A
shift 4	2B	2A	2B	2A	2B	2A	2B
school lunch	shift 3	shift 4	Shift 2	Shift 1	shift 5		
shopping	shift 3	shift 4	Shift 2	Shift 1	shift 5	shift 4	Shift 3
cooking	shift 5	shift 2	shift 5	shift 3	shift 1	shift 2	shift 4
dishwash lunch	shift 1	shift 5	shift 4	shift 2	shift 3	shif 1	shift 2
dishwash diner	shift 2	shift 1	shift 3	shift 4	shift 2	shift 5	shift 1
Cleaning tulikiviklubi				**all shifts**			**x**
Cleaning Stonecentre							**x**

Figure 38: Shift planning week 5

Figure 39: Bounding all manpower to unroll the inflatable

Figure 40: Meeting with the technical working group

3.9 Safety

Most of the 200 volunteers were inexperienced and had no technical background. Because of the cooperation with different institutes and volunteers a well-organized safety plan was needed. Also to get all the building permits from the local government it was necessary to hand in a safety rapport. Together with Maureen Lubber (consultant at Arcadis), Joris Borsboom, and other master students, a safety plan and risk analyses was published (appendix 9).

Volunteers

Before the volunteers could participate in the Bridge in Ice project they had to follow some steps. All of these steps were needed to be followed and were obliged.

- Watch the "Building with Ice" instruction video
- Read the safety-report
- Watch the safety-instruction video
- Request for a personal safety identification card. Without this safety card you have no permission for entering the building site
- Follow an instruction video and a practical course for the use of large machinery.(only for the people who were chosen picked out for this course)
- Working clothes (made available by the Bridge in Ice project), helmet, and cloves ad shoes (bought by volunteer)

Safety organization

In Figure 41 a schedule of the safety structure is shown. In every shift one volunteer was responsible for the safety aspects. These so cold safety-reporters give feedback to Joris Borsboom (Safety instructor from the TU/e). Joris Borsboom worked as an independent safety instructor for the TU/e. Twice a week Joris Borsboom needed to hand in a safety report to Jari Repo. Jari Repo was the contact person between the technical department of Juuka, led by Ari Jaaranen, and the Bridge in Ice project.

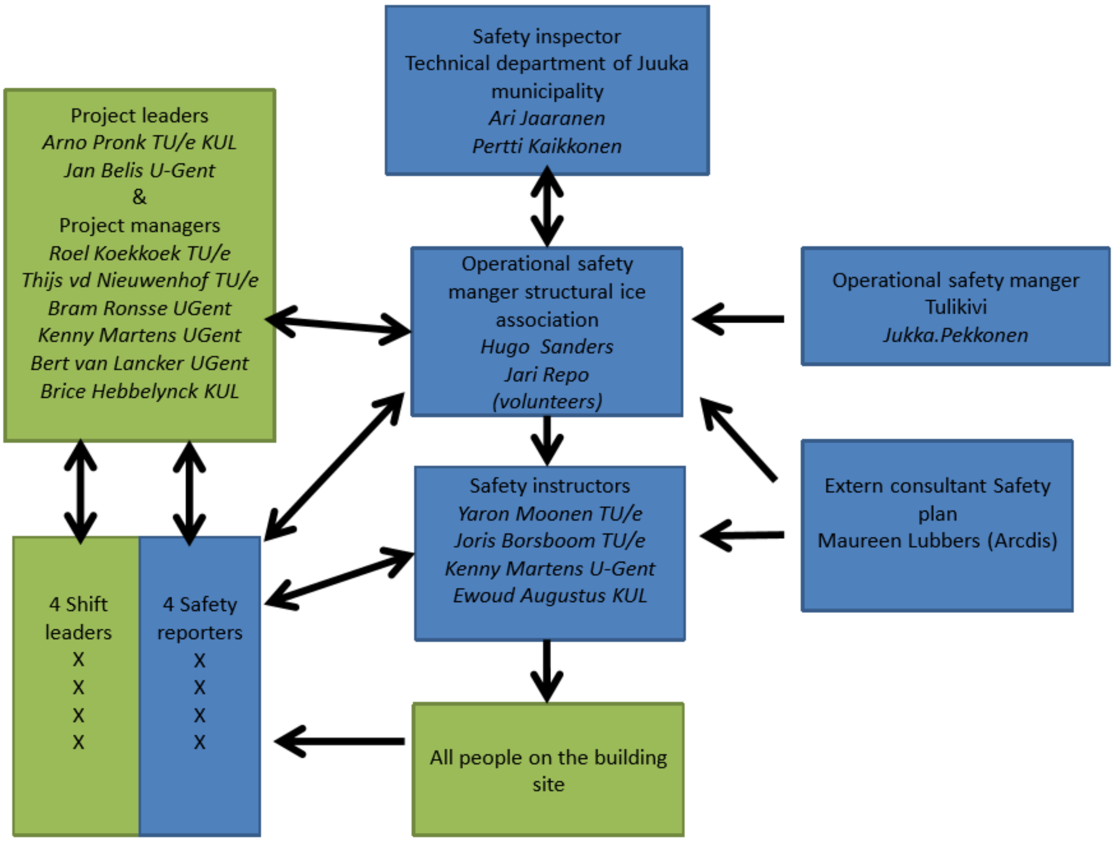


Figure 41: Safety organization

Safety building site

To guarantee safety on the construction sit the following measures were taken:

- The construction site was fenced
- The safety instructions signs were placed at the entrance of the building site
- Safety inspectors walked around on the building site
- After each shift a report log has to be filled in (Figure 42)
- Identification card was required (Figure 43)
- Heavy machinery had his own parking spot

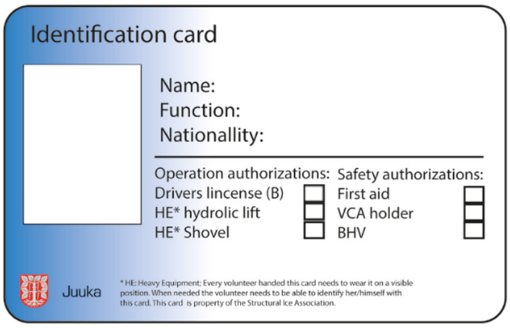


Figure 43: Identification card

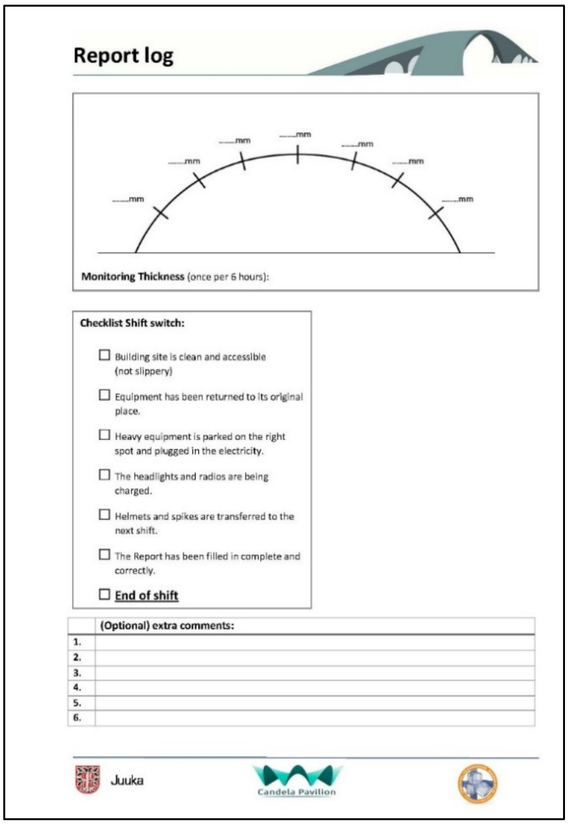


Figure 42: Report log

Figure 44: Working with safety helmets, gloves, working clothes and safety harnes

3.10 Events

Help building world largest Bridge in Ice is the mean reason for the volunteers to come over to Finland. But beside that, experience the nature, culture and habits of the local people was also important during the project. By organizing events, the local people and volunteers a brought closer together. Working in a climate with temperature around -30 °C is heavy. Therefore, relaxing moments and activities were important to stay focus at work.

Activities

Liselotte de Haan (internship Bridge in Ice), Arno Pronk and the Media –Team organized in collaboration with the local residents' events during the week. An overview of all the activities and events is shown in the magazine, (appendix 10).

Opening ceremony

On the 13th of February 2016 the big opening of the Bridge in Ice event take place. Despite the fact that the project is not ended as planned, the festivities continued. For the opening of the Bridge in Ice a festival was organized. Several artists from around the world performed on stage. The line-up of the festival is shown in Figure 45.

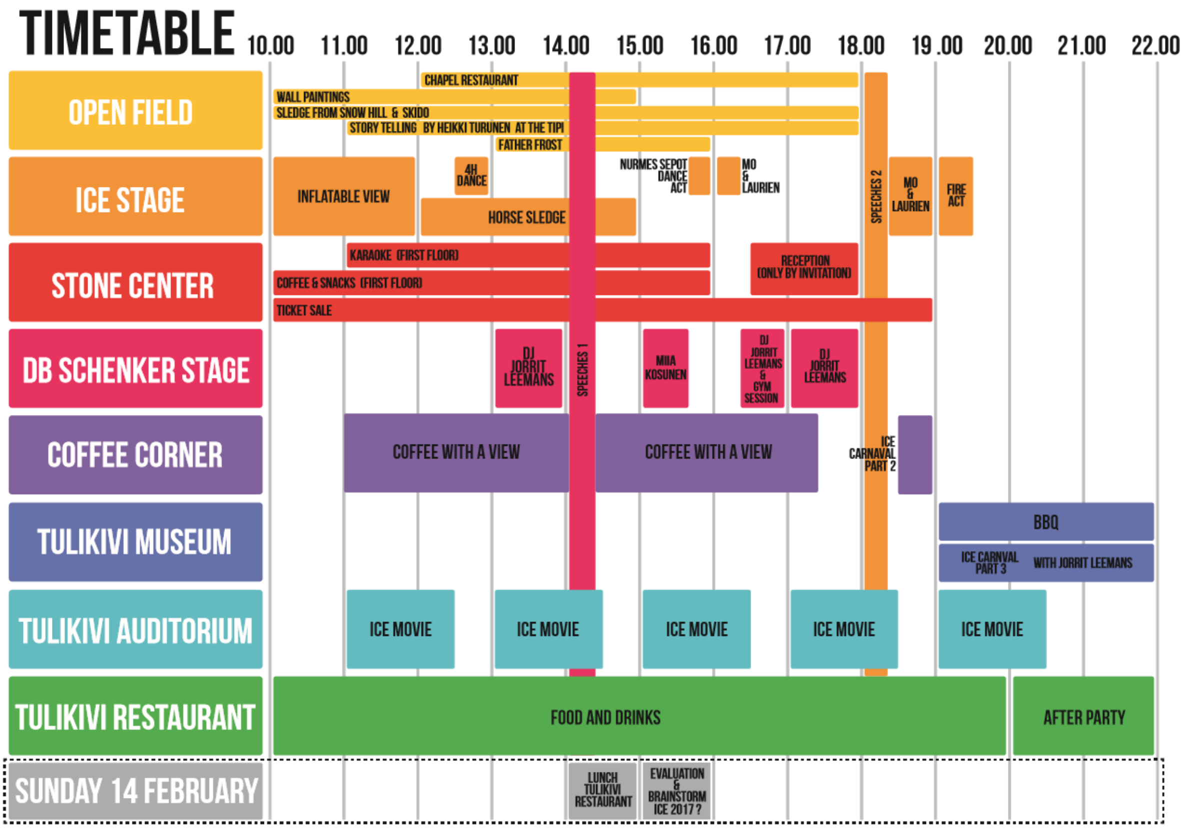


Figure 45: Timetable opening festival

3.11 Media and after-sale

The project Bridge in Ice gathered a lot of media attention. It already started in the beginning of April when the Idea of the project was launched. In almost all the Dutch newspapers and several television programs, like 'Een Vandaag', 'WNL' and 'Hart van Nederland' an item about the Bridge in Ice was shown. Even the news was picked up outside the borders.

During the building process, the media-team make all the photos and videos. Because of the growing media attention they also did the communication with the press and organized interview meetings, take care of the Facebook page, and all other social media items.
There were several journalist on location. One local newspaper from Holland 'Eindhovens Dagblad' send a journalist for one week to Juuka and followed the project on site. But also large international TV stations and newspapers like Discovery Channel and Story House Productions were interested in the plans. And even the popular internet page VICE had two articles about the project.

Several blogs were updated every week. One of them by Cobouw, a newspaper for the Dutch building industry. They posted a weekly story about the project, so people who were interested could follow it from there. The project was also popular in Finland. Several television stations came to Juuka to report about it in the news.

Some activities that were organized after the project was finished are listed below.

- Exhibition
  A photo and film exhibition was organized in the SintLucas main building, Eindhoven. And in the Vertigo building (Built Environment) at the TU/e.
- Presentations
  Guest lectures, sponsor presentation, rotary club.
- Symposium
  In July 2016, Thijs van de Nieuwenhof and Roel Koekkoek went to the ICSA 2016 symposium in Guimarães Portugal, which was organized by Paulo Cruz. The papers "Historic development of structural ice" and "Design of Da Vinci's bridge in ice" were presented.

Figure 46: Giving interviews about the progress

A total overview of all the news items is shown on www.structuralice.com.

4. Design

4.1 Introduction

Together with master students from Eindhoven University of Technology and the University of Leuven, the calculation and thereby the final design of Da Vinci's Bridge in Ice have been made. In the first part, a short summary of the design of the inflatable can be found. The second part is the calculation of the ice shell. Several influences could have had an effect on the final design of the Da Vinci Bridge in Ice. And because of a large number of uncertain properties and variables, some assumptions had to be made.

4.2 Ice shell

The optimal design of the bridge has been reached when there was an optimum force distribution and a minimum of deformation.

Assumptions

The soil of the building site was strengthened in the summer of 2015 (Kern & Verberne, 2015). The top layer of the construction site was excavated and filled with gravel and stones. It consisted of stone blocks with a diameter of 200-1000 mm, where the major part of the stones have a dimension between 200-500 mm. On top of the blocks there has been a layer of gravel with a maximum diameter of 32 mm. No ground research has been done so the soil stiffness was assumed to have a value between 2.5 – 20 MN/m^3. The soil stiffness of a standard gravel/sand mixture lays between 50 – 100 MN/m^3, because of the uncertainty there has been chosen to reduce this stiffness in the calculations (Brunschot, Lier, Mortel, & Williams, 2016).

Material properties

The material properties resulted from the material test, done in semi-controlled circumstances, are the following:

Table 2: Material properties pykrete

Material properties Pykrete, 2% cellulose		
Compression strength	Average	
	Characteristic	5.90 N/mm^2
Bending strength	Average	
	Characteristic	0.91 N/mm^2
Young's Modulus		500 M/mm^2

A more extensive research of the material properties can be found in chapter 6. Furthermore, the material properties from pykrete in earlier research have been taken into account (Brunschot, Lier, Mortel, & Williams, 2016).

Table 3: Material properties pykrete

Material properties Pykrete	
Density	980 kg/m^3

The tests, done in the laboratory of the TU/e, where not really reliable because of the doubtable circumstances, see chapter 6. Therefore, the results of the test where not taken into account. The calculations have been made with lower material properties than the numbers given in the material research (Pronk, et al., 2016).

Table 4: Material properties pykrete

Material properties Pykrete, 2% cellulose, design values	
Compression strength	1.0 N/mm^2
Tension strength	0.9 N/mm^2
Young's Modulus	500 N/mm^2

Given geometries

The starting point of the Bridge in Ice project was a sketch of Leonardo da Vinci. The building method has been the same as in earlier projects, all based on spraying an ice composite over an inflatable mold (Kern & Verberne, 2015). Besides the design and the building method also sponsoring and budget had its influence on the geometry of the Bridge.

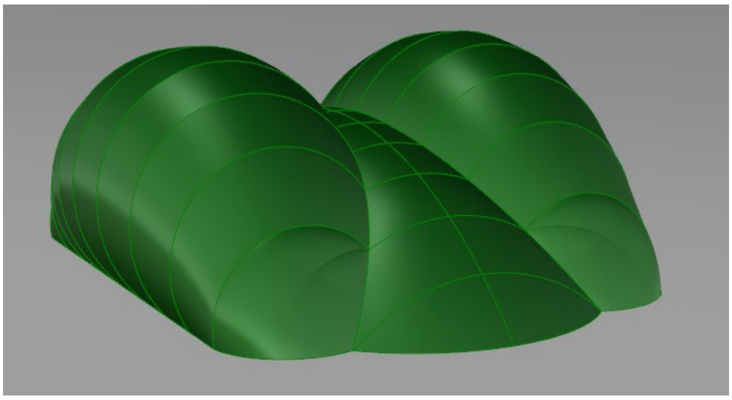


Figure 47: Impression of a possible geometry

Balloon pressure

The upward air pressure of the balloon has been 0,5 kN/m^2. Especially in the first phase of the construction the balloon had a support function. In Figure 48 is shown how the internal air pressure is supporting the bridge. Only the red part is taken into account as supporting upward air pressure (Arntz & Hermens, 2016).

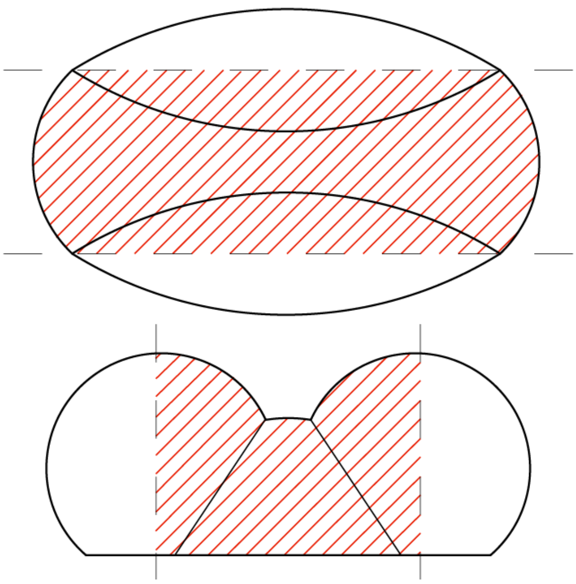


Figure 48: Sections of the inflatable mold

4.3 Calculations

Approach

To generate different ice models, the Rhino model has been redesigned with Grasshopper, a plugin for Rhino. The script for the model was generated with some of the parameters variable. This made it possible to generate a numerous of different models by adjusting the parameters.

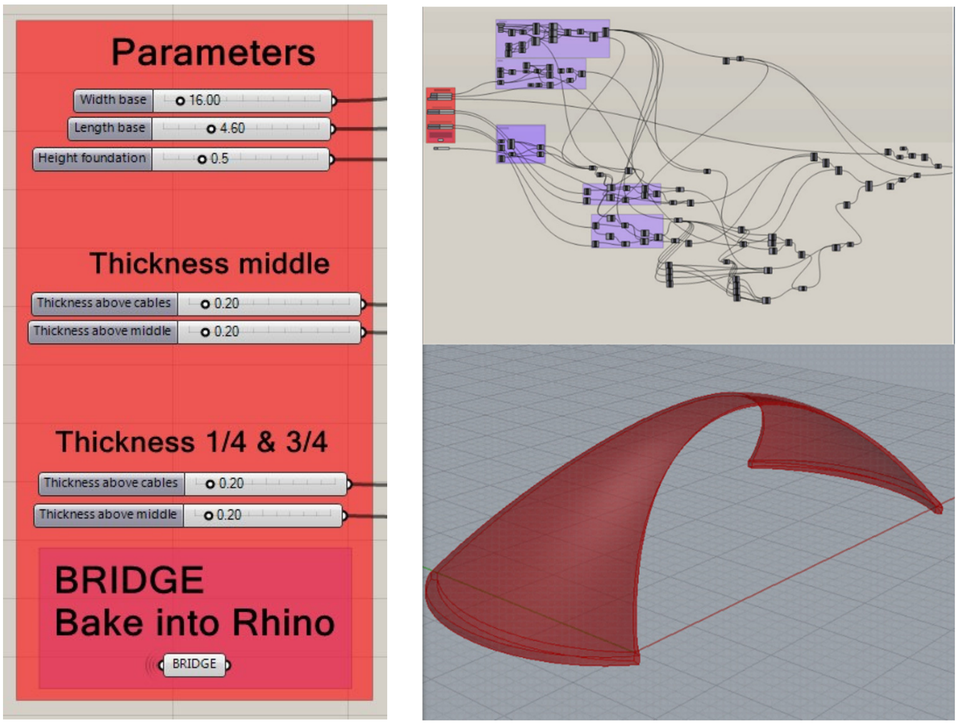


Figure 49: Rhino model of the ice shell

In short it means basically:

- Importing the balloon surface;
- Generating the shape of the top surface with variable heights;
- Extruding both the top surface and the balloon surface;
- Apply a 'solid difference';
- The solid ice layer is 'baked' into Rhino

By generating models with a variable shape, different starting points for the calculations were made (Brunschot, Lier, Mortel, & Williams, 2016).

Abaqus

Calculations on the bridge have been made in Abaqus, a Finite Element Modelling program. As mentioned above, the grasshopper models were used as a starting point for the calculations. Abaqus did not have standard units, therefore it was important to use consistent units.

Table 5: Units used in Abaqus

	value	unit
Soil stiffness	1,00E-02	*N/mm³*
Density	9,80E-10	*Tonne/mm³*
Young's modulus	500	*N/mm²*
Gravity	9810	*mm/s²*
Balloon pressure	5,00E-04	*N/mm²*
Poisson ratio	0,15	-
Force	-	*N*
Pressure	-	*N/mm²*
Stress	-	*N/mm²*
Displacements	-	*mm*

All the calculations of the different model can be found in the report by (Brunschot, Lier, Mortel, & Williams, 2016).

Final bridge

During the construction of the bridge, especially in the beginning, large deformations occurred. It was important to spray carefully and evenly on the bridge. When a 200 mm thick ice shell was produced, the effect of spraying decreased and became less important.

First we started with the base of the bridge, which would have a positive effect on the deformation. However, because of the uncertainties of creep, a large overhang of the base needed to be limited (Brunschot, Lier, Mortel, & Williams, 2016). What turned out to be the best construction order of the bridge is shown in Figure 50 (Pronk, et al., 2016).

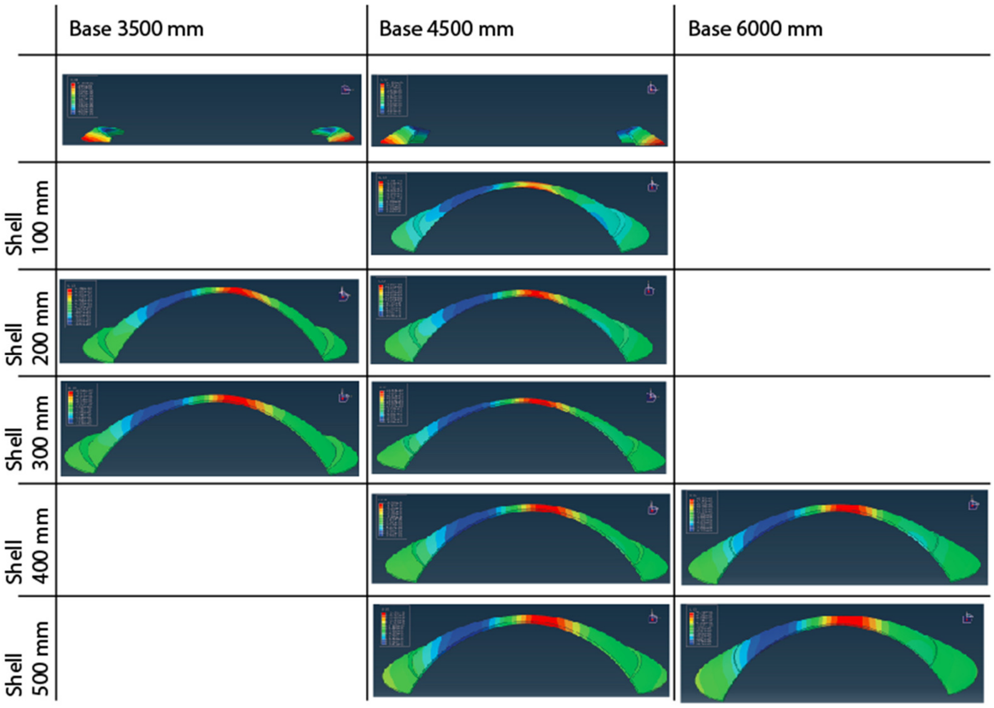


Figure 50: Sequence of construction

Several factors have influenced the shape of the bridge:

- Maximum stress and minimum deformation
- Accessibility of the bridge
- The slope of the bridge need to be walkable, so not too large.
- The building method, using an inflatable and the spraying system

Because of all the unknown factors that occurred during the building period the model needed to be sufficient for a large range of properties (Brunschot, Lier, Mortel, & Williams, 2016).

Base

With a base of 12m the slope of the bridge became 18°. A base with a longer dimension would be beneficial for the accessibility but was not achievable taking the amount of cellocrete that needs to be produced into account. The 12m base was enough to fulfil the structural part. To decrease the slope, snow was added on the starting point of the bridge. This part needed a certain weight to transport the spatter forces and did not need the structural properties of cellocrete (Pronk, et al., 2016).

Top

The final thickness of the top was 750mm. Creating the smallest thickness in the top part of the bridge, material use had to be optimized. With a thickness of 750mm the bridge fulfilled all the requirements (Pronk, et al., 2016).

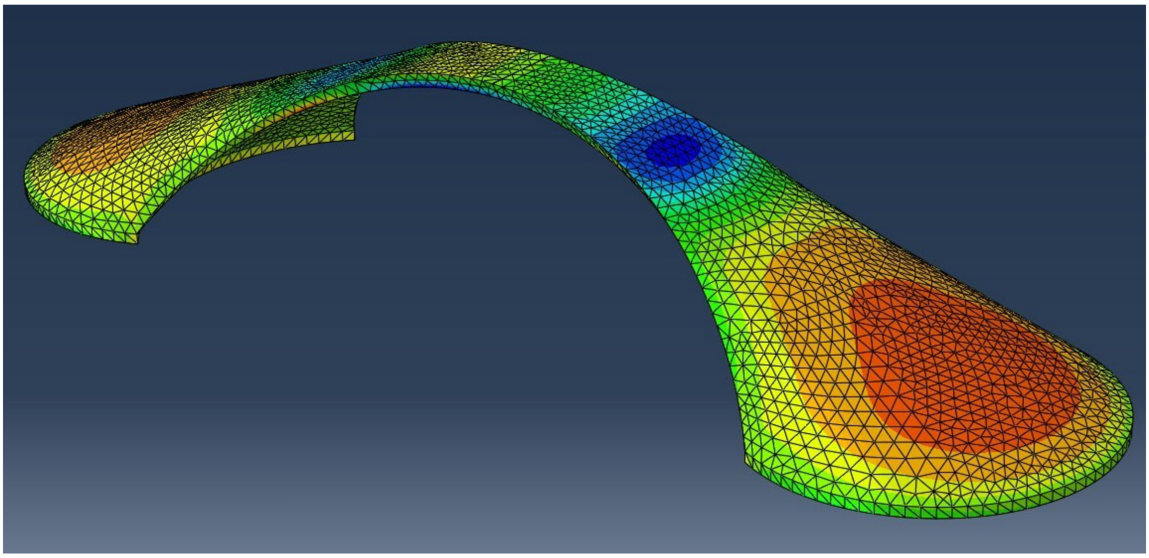


Figure 51: Final calculated design of the ice shell

4.4 Inflatable design

The inflatable consisted of a polyester fiber with a coating of PVC. A Sponsor located in Finland called Scantarp delivered 5000 m^2 of this material at Poly-Ned BV., which is a Dutch architectural textile designer. The polyester strips with a width of 2,05 meter were welded together to get a 2500 m^2 flat membrane in a stamped shape of the inflatable.

Design

The membrane of the inflatable had to be as simple as possible. A first impression of the design is shown in Figure 52. A piece of foil was hold in its shape by two ropes and some duct tape that indicated the place of the anchors. The cables put the inflatable in its right shape. The cellocrete was sprayed in between the two main cable.

Figure 52: Scale model of the inflatable principle

The inflatable was not only a mold but had also a supporting function. Spraying on top of the inflatable increased the weight on the top of it. The internal pressure in the inflatable was the only bearing capacity. It supported only the beginning of the building process as it would never hold the weight of the final bridge (Arntz & Hermens, 2016).

A schematic sketch of the inflatable is shown in Figure 54 and Figure 55. These sections were the starting point for the calculations. All the forces in the inflatable and the rope net were tension forces. The main cables in longitudinal direction were anchored at 4 places in the ground. The rope net structure was anchored at 76 places around the inflatable (appendix 11).

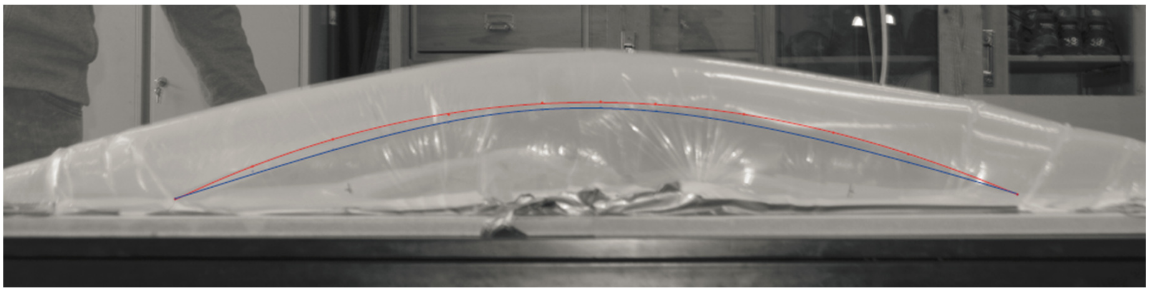


Figure 53: Side view of the inflated model, with force distribution lines

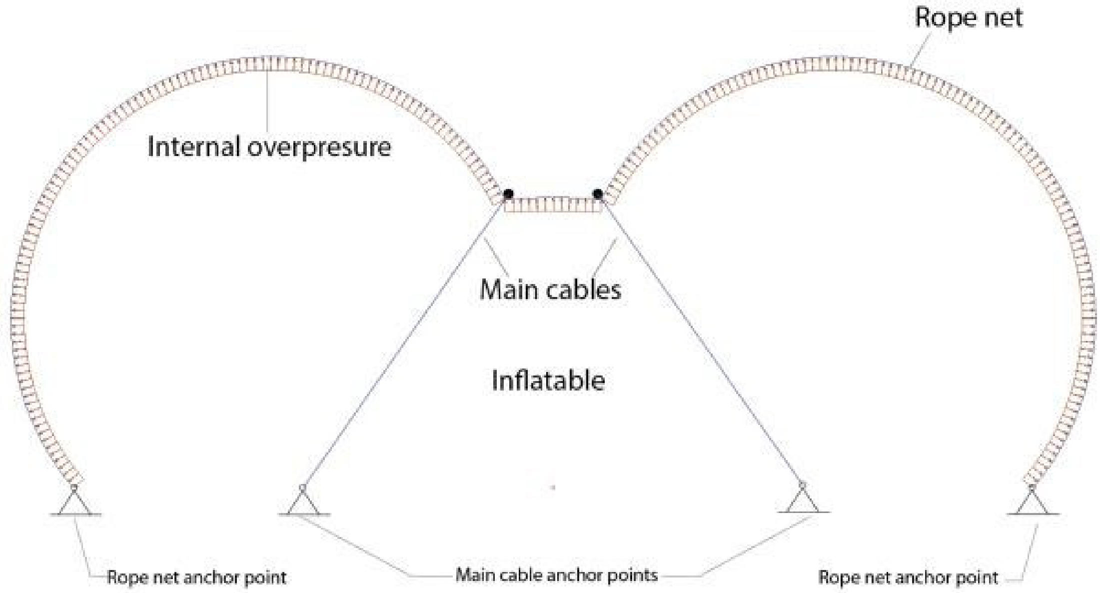


Figure 54: Cross section of the inflatable

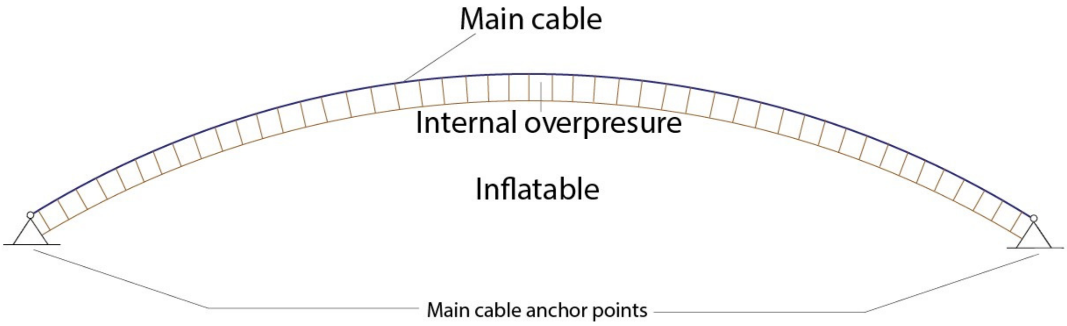


Figure 55: Section of the inflatable

Materials

The materials used for the inflatable were comparable with the materials Poly-Ned BV. uses for their inflatable halls (Arntz & Hermens, 2016).

- Membrane: polyester fiber with a PVC coating. The material is UV, mildew and rot resistant.
- Main cable: Due to the internal overpressure they have a large pre-tension. The cables have a diameter of 21 mm.

A connection between the membrane and the main cable is showed in Figure 56.

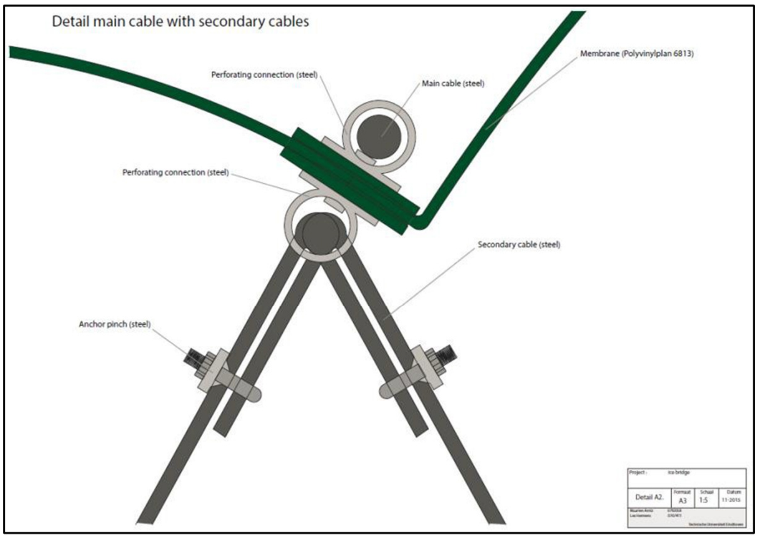


Figure 56: Detail for connecting membrane, main cables, and stabilizing cables

- Rope net: rope net is made of 12 mm Polypropylene (PP) rope.
- Anchors: It concerns three type of anchors the JLD1.0 (16kN), JLD1.2(40kN) and the JLD2.2 (220kN)
- D-Shackles and Eye nuts: The D-shackles have a working load of 85 kN, the eye screws have a working load of 9 kN
- The air blowers: CORAL (type DF/S3)

Specific information about the used materials can be found in appendix 11.

Calculations

The models were made with the program *General Structural Analysis (GSA)*. Firstly, a 2 dimensional model has been created. Then, when the right shape of the cross section was found, a 3 dimensional model was created. This model was also used to define the dimensions of the inflatable itself, rope net and the places of the anchors. The calculations where made with the master students of the TU/e. These calculations are documented in (Arntz & Hermens, 2016), and summarized in the paper by (Pronk, et al., 2016).

Models

The goal of the 2D models was to get a first idea of the forces in the structure and finding the ideal shape of the cross sections of the inflatable. The first step in creating a 2D-model was implementing the cross sections of the starting position in GSA (Figure 57)

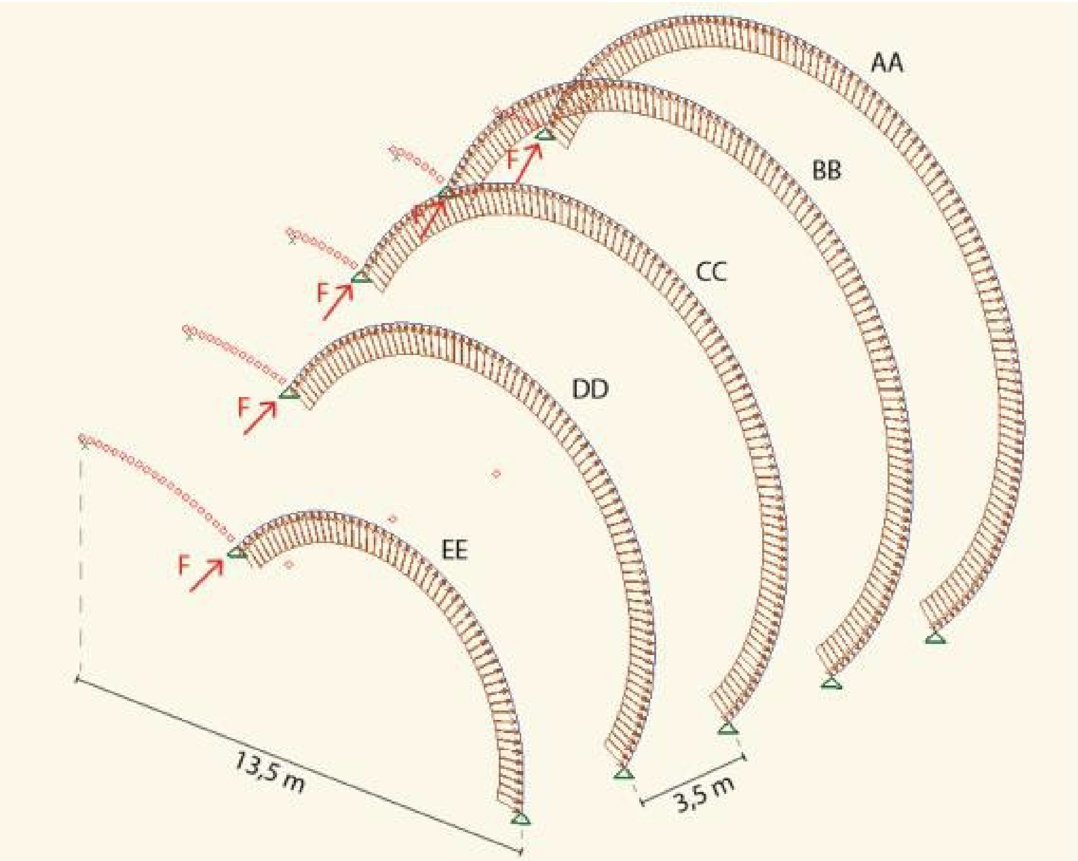


Figure 57: Modelling the forces in GSA

The Final form for the rope net is shown in Figure 58 and Figure 59.

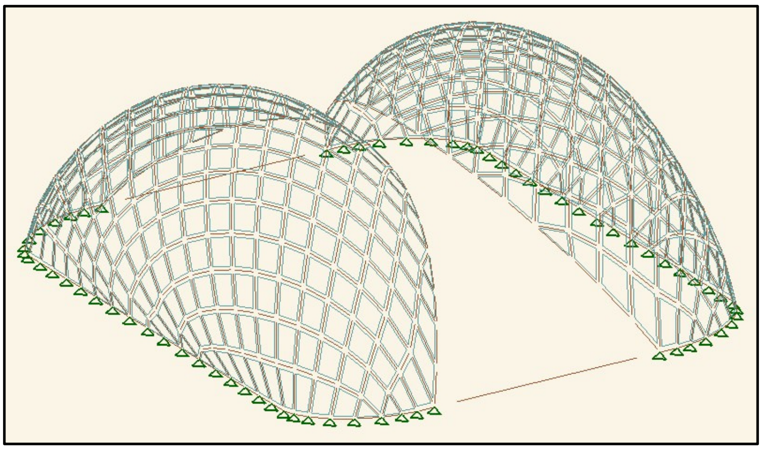


Figure 59: Designed rope structure

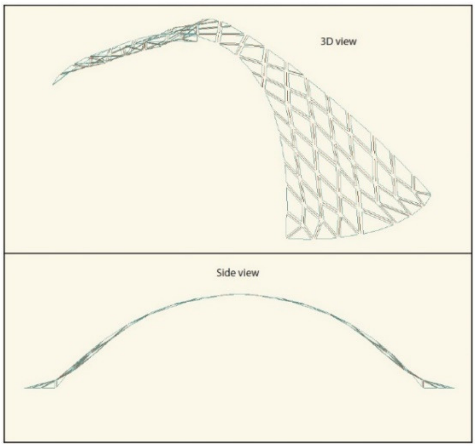


Figure 58: Middle part of rope net

Stability cables

In the earlier project heavy wind occurred during the construction phase (Kern & Verberne, 2015). To reduce a deformation due to the wind, stability cables were needed. To keep the area around the inflatable free for working space (Borsboom, 2015), all the stability cables had to be placed inside the inflatable.
The most optimal variant of placement of the cables is shown in Figure 60 (Arntz & Hermens, 2016).
All the calculations and variants can be found in the report by (Arntz & Hermens, 2016).

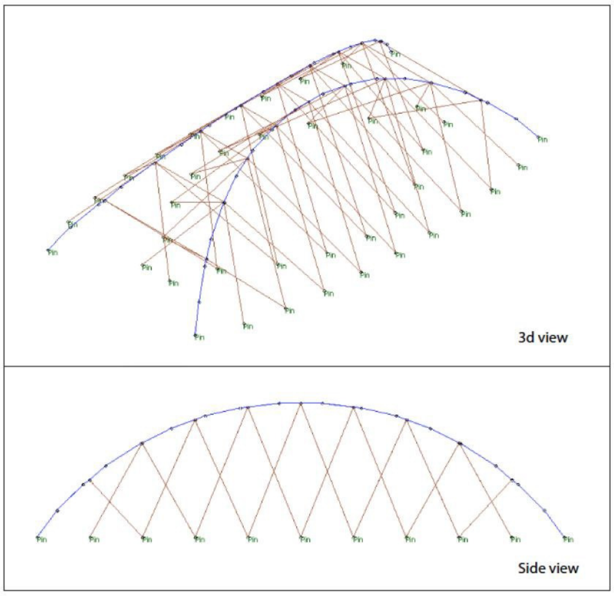


Figure 60: Design for stabilizing cables inside the inflatable

Final Model

The final model led to the 2D drawings for production of the rope-structure. See appendix for these drawings.

5. Construction management

5.1 Introduction

This paragraph describes the construction technology used to realize Da Vinci's Bridge in Ice. All systems and components used during the construction period are designed and prepared by ourselves, with support from several companies, volunteers and institutes. Most of these systems are results from evaluated methods from last projects.

Main issues that had to be solved are investigated by J. Borsboom in *Veilig bouwen met Pykrete* (Borsboom, 2015). Divided in three subjects the core problems during last projects (Pykrete Dome and Sagrada Familia in Ice) were:

Labor

- Adding fibers is physically heavy
- Spraying is physically heavy (dragging, moving and shifting of the hoses)
- Working with extreme circumstances

Equipment and inflatable

- No possibility of monitoring the intern pressure of the inflatable
- No warning when pressure suddenly drops
- No automatic back-up when power or blower fails

Material and structure

- Unknown thickness of ice layers in the construction
- Inappropriate mixing of wooden fibers and water
- No proper fiber weight ratio
- No homogeneous ice composite achieved in final structure

Figure 61: Frozen pykrete container during constructing the Sagrada Familia in Ice (Photo: Bart van Overbeeke)

5.2 Construction site

We used the exact same location as were we built the Sagrada Familia in Ice in 2015. The soil of the building site was already prepared for bearing a large (ice) structure end 2014 (Kern & Verberne, 2015).

The improvements of the site were unfortunately not executed over the total area. The back part of the site was not suitable for bearing heavy loads. After investigating the possibilities of the construction site we had to decide to rescale the bridge. The initial plan to make a span of 50 meters was reduced to one of 35 meters. The length of the building site was main reason for downscaling the bridge.

Because we already used this building site in 2015 we knew the pros and cons about it. To improve the construction phase we had to prepare the building site before the winter came. Proper preparations would reduce problems with:

- Frozen and broken electricity cables (which could not be removed before it was spring)
- Stumble over loose cables and hoses
- Unseparated use of water and electricity
- Unwanted visitors
- Blocked logistic routes

Figure 62: Overview of the building site at start of construction phase

In Figure 62 you see parts of the preparations. In appendix 12 you can find a drawing of the building site.

Anchors

In the beginning of December 120 anchors are placed in their position. Like last year's project we chose to place them in advance, to save time and to be sure the soil is not completely frozen when drilling the anchors.
From December 2nd till 4th the anchors were drilled in its position. Not only for the Bridge in Ice but also for the Candela Pavilion. The anchors are drilled into the same blasted rock bedding which was applied for the Sagrada Familia in Ice.

In the appendix 12 you find a drawing of the anchor plan and the specifications of the anchors. We used the same methods and anchors like previous projects.

Figure 63: Drilling anchors

5.3 Composite and inflatable

The distribution of water and electricity would run through cables and pipes under the groundwork. This results in a reduced risk of failure and demolishing.

Previous years, we used just one large mixing container (Figure 64), for mixing, distribution of the material and spraying. This turned out to be not an optimal solution. Four main problems occurred, which resulted in construction delay and low quality building material (Kern & Verberne, 2015).

- The size of particles of the delivered sawdust. Large wooden particles cause obstructions in the hoses. This is one of the main reasons for the research in alternative fibers.
- The outside temperature, which resulted in frozen parts in the mixing container
- There were no accurate mixing blades installed so lot of accumulations arose.
- Material wasn't properly mixed, which resulted in an inhomogeneous material and a too low fiber weight ratio. (av. 3,97%, goal was 10%).

Figure 65: Trouble with outlet

Figure 64: Frozen mixing container

To tackle these problems we came up with several solutions. The solutions are designed with given boundaries in the field of costs, practice, reliability and usability and in cooperation with Summa College Eindhoven and several sponsors.

Production and distribution of ice composite

First we separate two functions.
Mixing, creating a homogeneous mixture with the right fiber weight ratio of cellulose fibers, 2%.
Buffering, create a buffer of building material to provide a continuous building process. The buffer container will contain several outlets from where we spray on the ice-structures.

For the mixing container we use two IBC-tanks. Each tank has a capacity of 1000 liters. With adding 20 kilograms of cellulose fibers to 980 liters of water we can produce a proper fiber weight ratio of 2%. We use two tanks to allow one tank to cut and mix the cellulose plates to dissolve decently, while we fill up the other tank. Tests had shown that it takes about 30 minutes of mixing to produce homogeneous mixture. After mixing the tap will be opened in the bottom part of the IBC-tank, to let the mixture flow into the buffer container. At this temp we can produce an

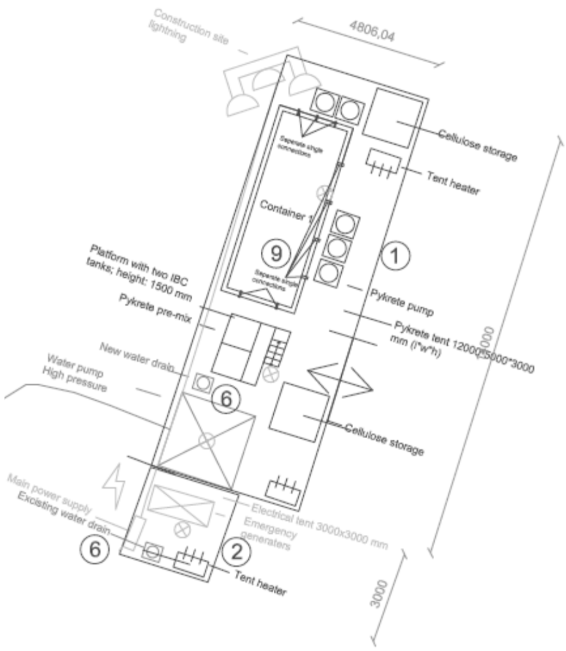
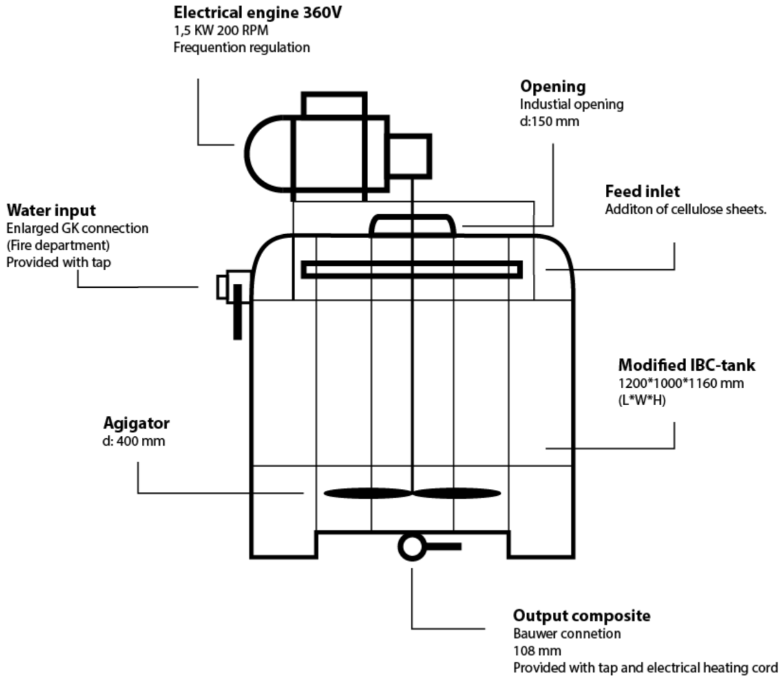


Figure 66: Building site, zoomed in on 'mixing area'



average 4000 liters of cellocrete mixture each hour. This temp will be sufficient since we calculated that we had to produce an average of 2 m^3 of ice composite per hour. The IBC-tanks are placed above the buffer container, to reduce the amount of equipment we would need. In this way gravity will help us, instead of pumps, and gravity works always.

The design is shown in Figure 68. In the end we worked with a platform right above the buffer container, to reduce also the pipelines from the IBC-tanks to the buffer container.

Figure 67: Modified IBC-tank

The buffer 'tank' contains out of an available 9 m^3 open container. With eight outlets it is possible to spray with several pumps at once. The extra outlets can also be used as a backup for keep the mixture moving. In the undesired case of failing mixing blades it is possible to keep the mixture moving with just pumping it round and round.

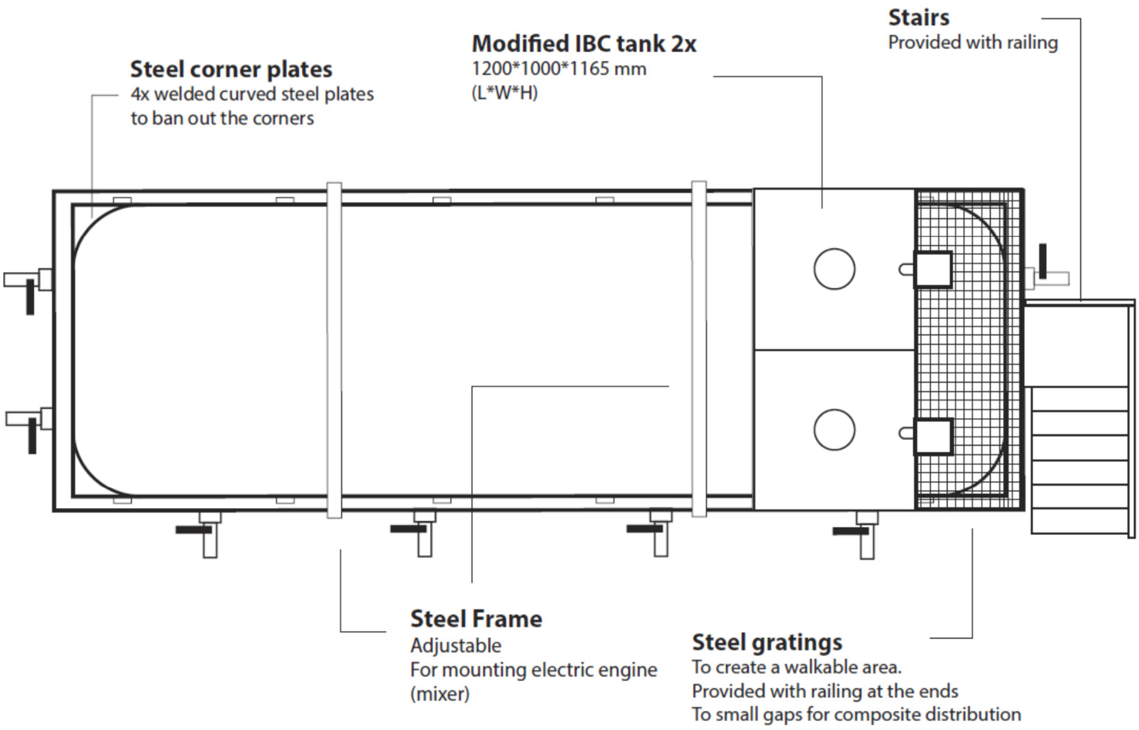


Figure 68: Drawing of mixing system

It is important to keep the mixture moving in both the tanks and the container, to prevent it from freezing and to guarantee a homogeneous mass. Although the tent around the system is heated, very low temperatures may cause freezing problems in and around the system.

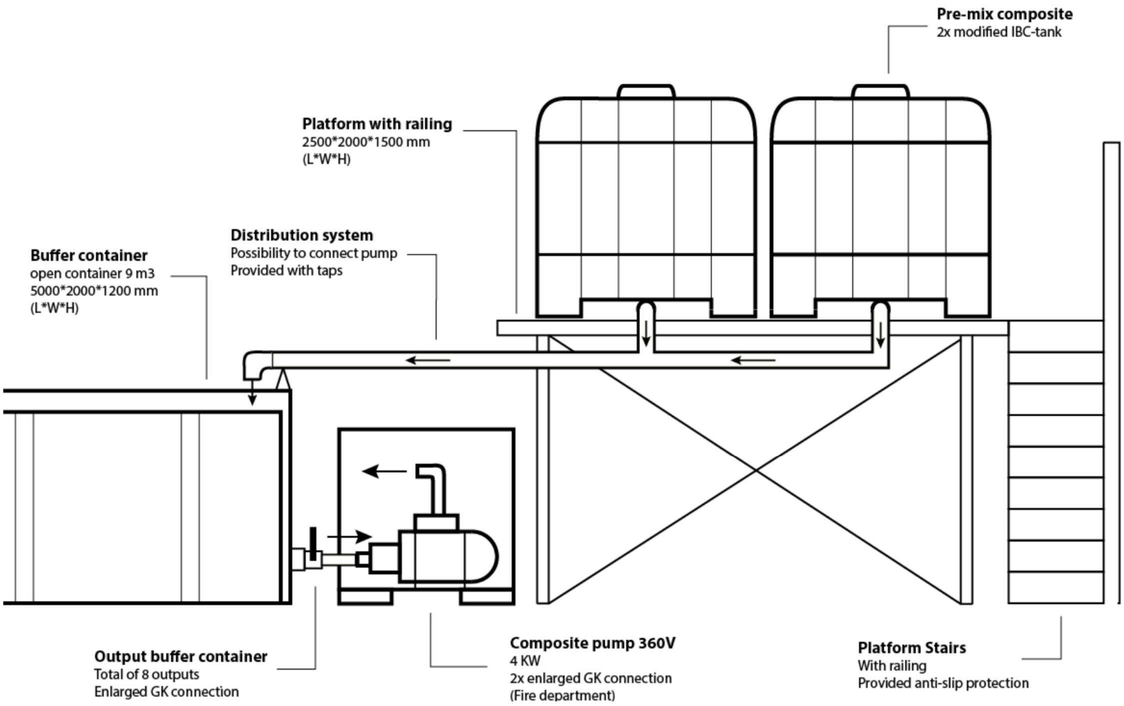


Figure 69: Distribution system

To tackle the problem of frozen equipment and mixture, and to reduce the work load and labor conditions for all volunteers, the whole system is placed in a heated tent. Main benefit is that we don't have to prepare the system for operating during extreme cold temperatures (-30 °C). Everything can be used in its standard manner, so risks of failures are reduced.
Also the pumps and computers for powering the mixing blades are only working at a temperature of + 0 °C.
The tent also offers place to the back-up generator, necessary in case of a power shut down. Such a generator will only work at temperatures above 0 °C, because of the fluids inside the motor.
Rest of the electrical systems are positioned outside the tent, to separate the 'wet' and the 'dry' systems to disturb each other.

The tanks are provided with a mixer. The mixer is driven by an electromotor. Because of the viscosity of the mixture we chose a relatively low speed (rPM). Several tests at EasyCool BV, together with Summa College, resulted in an optimal speed and type of blade. The blades are so designed that they do not only keep the mixture flowing, but also for cutting the cellulose plates. The rotation speed of the blades is adjustable by the frequency inverter, each tank separately. The output is placed at the bottom, to let the mixture flow right into the buffer container underneath it.

The buffer container contains eight outlets, for connecting centrifugal pumps to it. With those pumps we can distribute the produced mixture from the mixing system to the structure. The pumps have a capacity of 4,5 kW, and are provided by EasyCool BV. At their workplace in Holland we tested the pumps with our mixture, to see which distance we achieve with spraying.

These spray tests showed us that a proper circulation of the mixture is also important to secure the flow in the hoses, not only to prevent the material from freezing or inhomogeneity. To create a good circulation in the buffer container we applied several modifications to the container of last year.

- We rounded the corners, to prevent the mixture from accumulate on the edges.
- We added two large blades slightly above the bottom of the container, rotating on a low speed.

The outlets to the centrifugal pumps are positioned above the mixing blades. In that way the mixing container will never be empty and the mixture will always flow.

With using two mixers rotating in opposite direction the mixture is always flowing. The blades will be driven by two electrical motors with a power capacity between 6 and 10 kW.

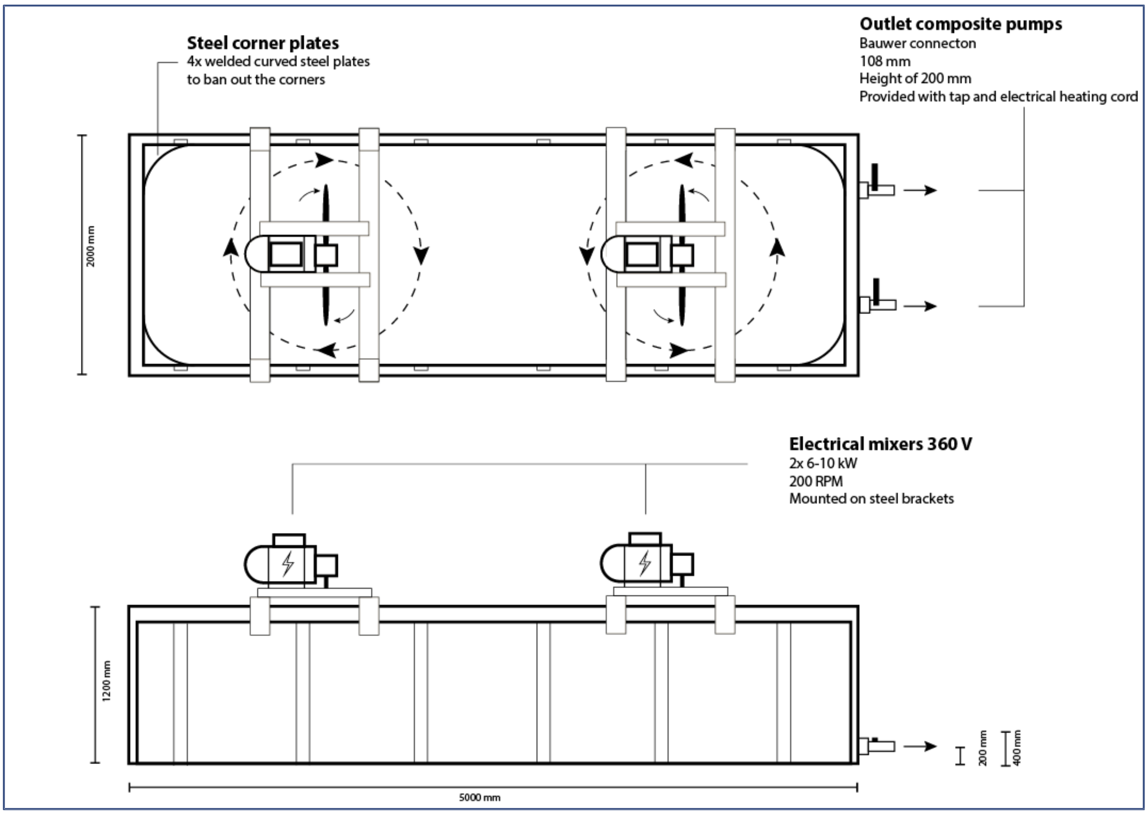


Figure 70: Mixing system of the buffer container

When the rotating system fails we can use the centrifugal pumps and a couple of the outlets as a back-up system to keep the mixture flowing.
After considering several concepts for producing the mixture the most efficient within given boundaries as cost, time, transport, availability and usability, we designed the final version of the 'cellocrete-factory'. We decide to put the IBC-tanks on top of the buffer container to reduce pipelines, and to minimize the space we would need in the tent.

We prepared as much as we could in Holland, and assembled all mixers on the big buffer container in Juuka. During our preparations in Holland the Finnish volunteers already adjusted the buffer container. They welded rounded steel plates in the corners, and installed 8 outlets.

The platform, with the stair, was also added already before we arrived in Finland. The steel bars for the big mixers were prepared, but they kept them adaptable.

On site

Assembling the system on site caused no big troubles. After transporting all prepared equipment from Holland to Juuka, we started with positioning the buffer container at its right place. Lifting the container from the ground as designed, to prevent direct contact with the freezing cold ground. The roof of the tent turned out to be a little bit too low for fitting the mixers on top of the IBC-tanks, but this problem was tackled with some improvisations. The buffer container, with its platform and outlets, was provide by the Finnish volunteers. We only had to assemble the mixers to it. Therefore we had to do some welding.

In a couple of days the 'cellocrete-factory' was totally tested and set up. The whole system worked perfectly and there occurred no drastic problems. All four mixers did not shut down for the total construction period, and the main centrifugal pump for spraying was not even replaced once. Also the amount of material we were producing was more than sufficient.

Figure 71: Mixing container

Heating the tent with diesel heaters worked well. We only had to realize a chimney, for ventilation and protecting a healthy environment.

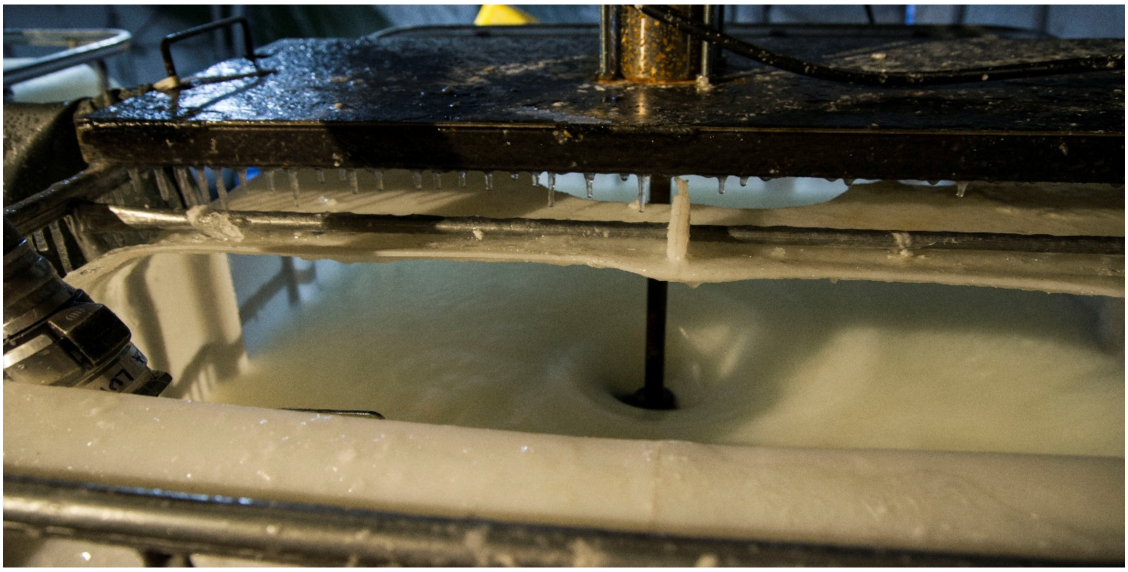


Figure 72: Creating the mixture in an IBC-tank

Production and controlling the inflatable mold

In previous years, we have used a similar inflatable mold principle. The pressure in these balloons was never pre-determined or measured. During the construction of the Pykrete Dome (2014) and the Sagrada Familia in Ice (2015), the pressure was just 'measured' by hand, by pushing into the surface of the inflatable.

This method is, of course, not reliable and therefore there were no
conclusions too compare. There might also occur some unsure or unsafe situations when the inflatables aren't fully under control. The pressure in the balloon is both crucial for the strength and for stability of the inflatable, and uncertainties will cause delay in the processes.

For constructing such a large ice-structure as Da Vinci's Bridge in Ice we need to design several improvements for the inflatable mold technique. Improvements are needed for the inflatable itself, the process for inflation, and the system for control and measurement.

Important thing in this system would be the continuity of the system. Since we experienced several power cut-downs during last projects, due to melting snow or falling trees, we need a proper back-up system. Without an emergency back-up, the inflatable will deflate during a power shut off, which will result in a deformation of the supporting mold. Ice which is not thick enough to hold itself will break, which will delay the construction process.

Based on previous projects the improvements which are needed to realize are:

- Continues measurement and monitoring the intern pressure of the inflatable
- Monitoring and regulating the air blowers
- Providing an emergency back-up system
- Monitoring deformations of the inflatable mold
- Detection system, with alarm and lightning signs, for warning during unwanted situations
- A proper check valve
- A descent control environment

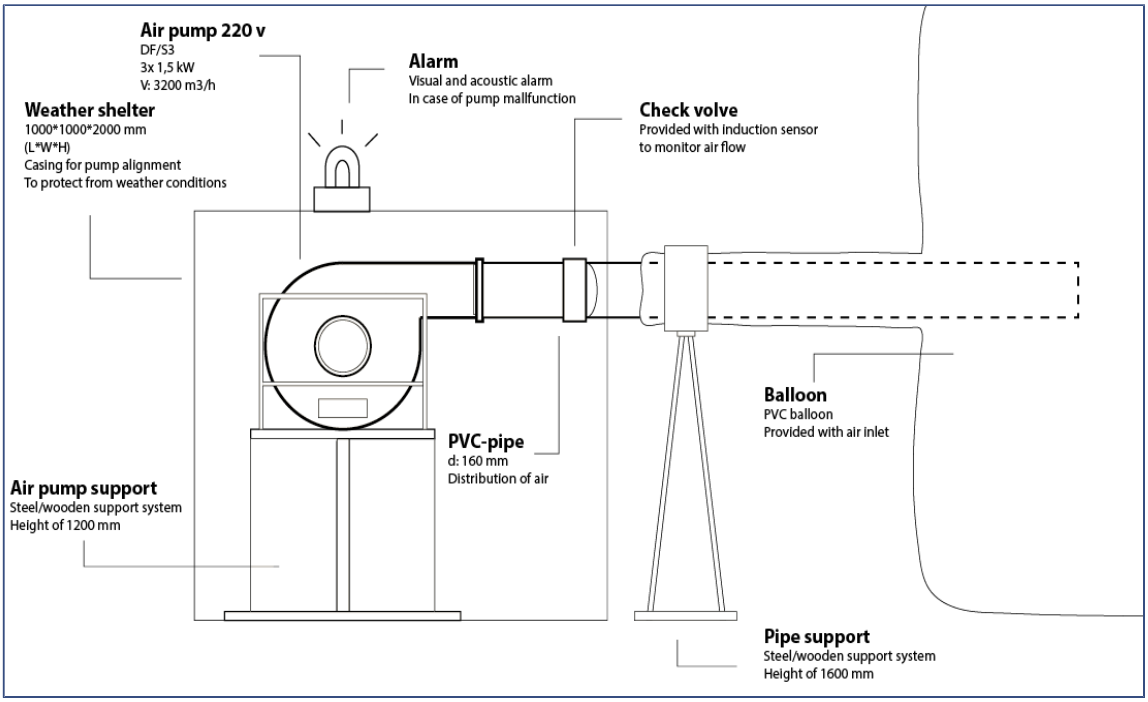


Figure 73: Drawing of air blower construction

Measuring and monitoring the intern air pressure

To ensure a properly working process it is important that the pressure in the balloon will be monitored. Therefore a system will be designed to measure the real time intern air pressure in the inflatable. Keeping the intern pressure on a continue level, where all the construction calculations are based on, is important to guarantee sufficient support, no process delay and a descent safety level.

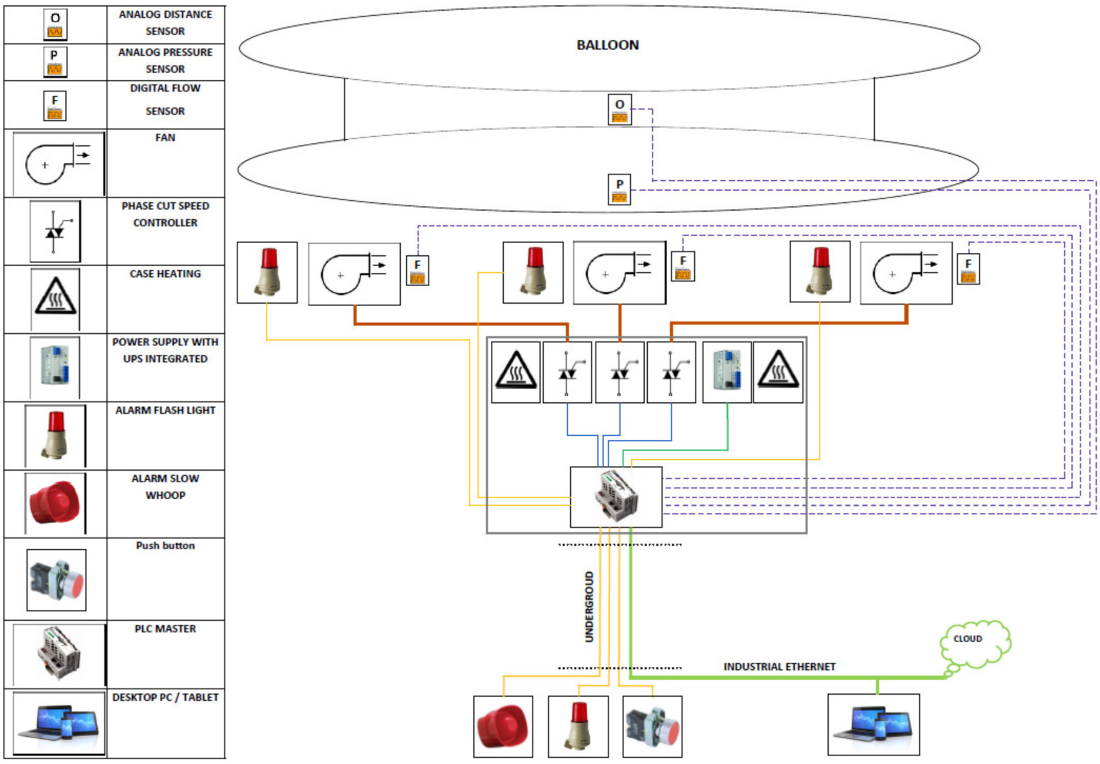


Figure 74: Measuring and monitoring scheme

Air blowers and backup

The air blowers are the engine of the project. Failing air blowers will immediately lead to a lowering inflatable and a quick decreasing of the support under the structure. We must always keep the air blowers running, including back-up and alarm system. For the unwanted situation of a power shut down, which often happens in Finland during winter time (melting snow, falling trees), we need an emergency generator.

We did have generators last projects, only then we had to start them by hand. This caused several dangerous situations. When the power failed, all the lights shut down. This caused total darkness on the building site, but in the mean time you had to run to the emergency generators, on an icy working site, to keep the blowers running. This year the inflatable is not only used a mold, but as supporting structure. When the blowers fail, the whole structure will collapse, and the project is over.
Therefore we arranged a backup generator which automatically starts when power fails. The generator is placed in the heated tent on the building site.

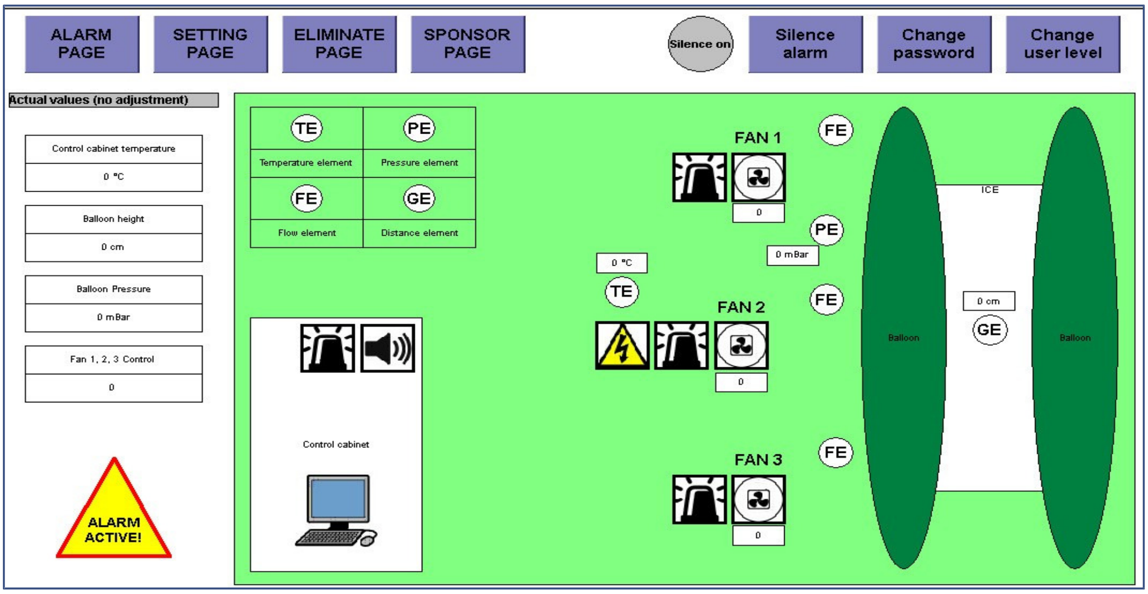


Figure 75: Monitoring interface

Deformations

The deformations of the inflatable are reliable indications of the actual status of the balloon. We can say something about deflection and strength when we are able to measure some deformations. Therefore we will place a telemeter underneath the structure, inside the inflatable. At this way we can measure how far the top of the bridge is lowering during construction process. Due to the relatively high costs of such equipment, we couldn't measure at ¼ and ¾ part of the bridge, which are also critical points in the structure.

Feedback

Crucial is the feedback of the monitoring system. Inflatable and blowers will be connected to one medium for monitoring. In cooperation with Summa College Eindhoven we designed a HTML-based system, which is manageable by all volunteers. The system will give us all information continuously during construction phase.

Figure 76: Inflatable control room

When the situation is changing unexpected below or over set limits the system will warn us with alarms and signals. During construction phase there always has to be someone on the building site with sufficient knowledge of all processes. This shift leader has to be able to react quickly on every situation. Even during warmer periods, when we do not spray material on the structure, there has to be at least two people for guarding the system. Above all, the air blowers always has to keep doing their job.

Figure 77: Control cabinet

Check valve

A proper check valve is needed for back-up. When an air blower unfortunately fails, the largest air leak is the blower itself. To tackle this problem we installed a check valve on every air outlet, which is also connected to the monitoring system. In case of shut check valve, the monitor warns us of a failing blower. Good thing is that the other two blowers will immediately start running faster, so the intern pressure stays on the same level.

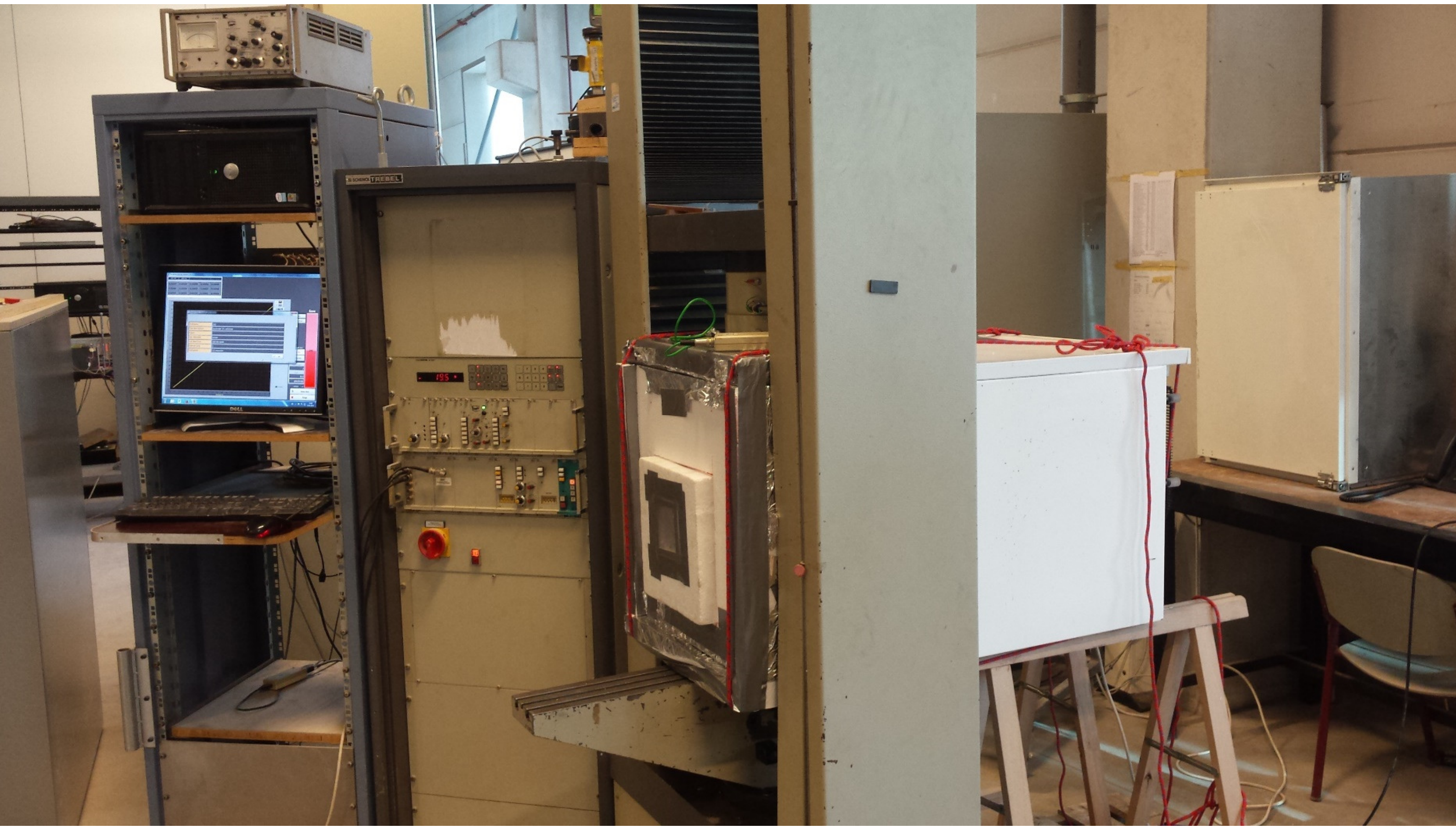
Sensors

The intern pressure will be measured by a sensor. The sensor can be placed everywhere inside the inflatable, since the intern pressure shall be divided equal everywhere. To avoid measuring errors by direct air flows the sensor is placed away from the air inlet. Via a pneumatic hose the sensor is connected to the monitoring system.

The deformations of the inflatable can explain a lot about the current status of the membrane, the intern pressure and the air blowers. When the top of the inflatable is lowering, something is probably not functioning properly. Reduction of the intern pressure, will cause the top of the inflatable to go downwards, and will also lead to a lower supporting strength.

Monitoring the deformation is not only a back-up for noticing pressure loss, it will also inform us about the strength of the structure and its support. It may warn us when the structure is not in the optimal shape anymore. If the structure differs too much of the calculated shape the strength will decrease drastically. In chapter 4 the optimal shape of the bridge is explained.

In Veilig Bouwen met Pykrete (Borsboom, 2015) the author recommends several systems for monitoring deformations of ice-shells, such as 123dCatch. Unfortunately, due to financial and planning reasons, we had to work with more basic tools to measure some deformation. In corporation with SICK we integrated a telemeter in the software we used for controlling the inflatable. This telemeter is placed underneath the top of the inflatable, so that we could monitor the lowering of the top of the ice-structure. Using this automatic sensor ensured that we did not have to go inside the inflatable itself, which was always risky because of short pressure loss. Also at the end of the constructing period it may be too dangerous to work inside the inflatable because of the heavy ice-load on top of it.


TREBEL

6. Material research

6.1 Introduction

Reinforcing a material to increase the properties of that material is used for many years. A well-known example is reinforced concrete, where the tensile strength is increased by steel reinforcement. Depending on the type and the fiber of the reinforcement there are many possibilities to enhance the properties of the concrete. This form of enhancement of the material, by adding a fiber to a mixture, can also be used for ice. Concrete and ice have a relative high compressive strength, the added reinforcement enhance the tensile strength of the mixture (Janssen & Houben, 2013). Research has been done on reinforcing ice with soil, wood or other particles in order to increase its mechanical strength and reduce its brittle behavior. However, the *reinforced ice* use as a structural material is still a rather experimental field.
After the successful experiments with the Pykrete Dome and the Sagrada Familia in Ice, we decided to pick up the research where our predecessors left it. During that projects they had a lot of difficulties with the size of the wooden fibers, which delayed the construction phase with several long periods. To optimize the building process we had to come up with a better idea.

Figure 78: Cut cellocrete samples, prepared for testing

6.2 Previous research

After the Sagrada Familia in Ice was realized, the project leaders headed back to Juuka for expanding the research in reinforced ice.

Ice- cellulose composite

An experiment described by A. Bastian, 2010 concludes that Pykrete formulated with paper dust is significantly stronger than that formulated with saw dust; and Pykrete that is 14% by weight paper dust is just as strong as some concretes and has a strength to weight ratio of up to four times that of concrete (Bastian, 2010).

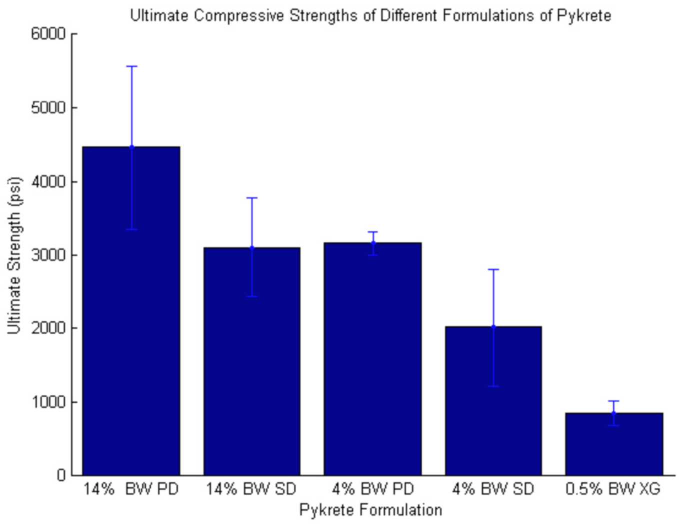


Figure 79: Comparison the ultimate strength of a water - 14% paper dust, 14% sawdust, 4% paper dust, 4% sawdust and 0,5% xantan gum suspensions

Fortunately, cellulose was produced in the same factory as where we got our sawdust from. Main project sponsor 'Stora Enso' provided a couple tons of cellulose plates, for starting the research to alternative fibers.

Tests during the Sagrada Familia project showed the potential of cellulose immediately: *'The results of cellulose reinforced ice samples show a lot of potential. The average improvement of the compressive strength compared to pykrete is significantly higher, with only a fiber weight ratio of approximately 5%. The highest split strength of the cellulose samples is obtained in the mixture with a fiber weight ratio of approximately 10%. Compared to the ice samples a maximum compression strength improvement of 224% and a maximum split strength improvement of 312% is achieved by adding cellulose as a reinforcement material.'* (Kern & Verberne, 2015).

We had our doubts about the test conditions, which might had caused in too positive test results. Strength tests were done at a high speed, and could be a bit inaccurate. We decide to trust in the potential of cellulose, but to test everything ourselves first.

6.3 Cellulose

Most important of the Bridge in Ice project, is that we were going to build it for real. We had to find an optimum in usability, availability and material properties. For example, if a fiber weight ratio of 10% fibers turns out to not flow through the centrifugal pumps at all, it would be useless for us.

During tests at EasyCool BV in May 2015 the centrifugal pumps were tested about their capacity. We smoothly pumped a mixture with a fiber weight ratio till 5% through it. With a descent length of hoses connected to it, approximately 80 meters. Only factor that was not simulated compared to the actual situation in Finland was temperature.

The results were easy transferrable to the tests about structural properties. Maximum fiber weight ratio had to be 5%. Everything below that percentage would be an advantage in costs, usability and capacity.

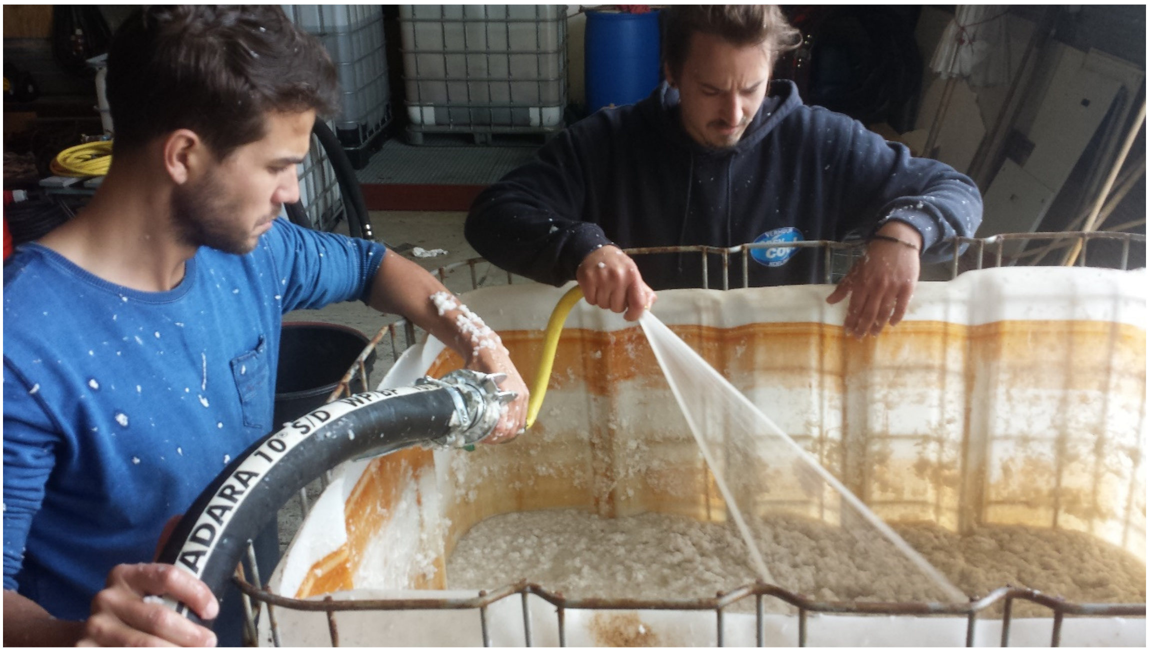


Figure 80: Johnny Klepper (EasyCool BV) and Roel testing pumps

6.4 Material tests

In the laboratory of the department of Structural Design at TU/e everything is tested, after we did the first exploring test at Eurofrigo in Venlo (a cooling warehouse). Using the equipment and test materials of the laboratory for making proper samples and testing the cellocrete material. Main goal was to determine the best fiber weight ratio in perspective of structural properties, but also in terms of costs, availability and usability. A more detailed description about how the samples are produced and tested can be found in *Ice-cellulose composite research for the Bridge in Ice* (Mileika, Dam, Mok, & Lenaers, 2016). For a proper comparing also plain ice blocks were tested. After the tests with the centrifugal pumps we decided to limit the fiber weight ratio to 5%, but for a more complete story we tested also samples of 6% and 8% fiber weight ratio cellulose fibers in the mixture.

In this paragraph you can read the general conclusions from the tests which were documented in (Mileika, Dam, Mok, & Lenaers, 2016).

Conclusions of the first compression test

The maximum pressure of the compression bench was a limitation to measure the compression of the samples accurately. All plain ice samples fully crushed before reaching the maximum of 5 kN loading. In comparison, none of the samples with the cellulose reinforcement fully crushed. The samples of 4% reinforcement showed the most uniform performance. Surprisingly, the samples of 6% reinforcement show less loading capacity than those of 4%. This could be due to the pressure limitations of the testing device. Thus for the next test, the device must be adjusted and the pressure must increase in order to reach the true maximum load bearing. The fluctuation of the results can depend on the homogeneity of the suspension used.

All reinforced samples show deformations up to at least 13 mm. Some samples show very little deformation, however this cannot be concluded as a characteristic value of a certain reinforcement percentage. A sample of 8% was tested three times to the maximum pressure and showed to have a maximum capacity of 72,5 kN loading. However, the testing of this sample does not yet show any reliable relation between the loading and the deformation.

Figure 81: Compression test at Eurofrigo

Conclusions of the second compression test

Due to some reasons, such as inaccuracy and inhomogeneity, a lot of samples might be unreliable at the first compression tests in the cooling warehouse of Eurofrigo. Therefore a second compression test was set up, this time at the laboratory with an improvised cooling box around the compression bench.

The best performance for the compression properties was achieved by a sample of 4% reinforcement. The average value of the compressive strength after test 2 of the samples filled with 2% reinforcement gives 4,77 N/mm^2, samples of 4% gives 4,44 N/mm^2, samples of 6% gives 3,59 N/mm^2 and samples of 8% gives 2,73 N/mm^2. The results for samples filled with plain ice reached only a value of 0,83 N/mm^2.
In general a mixture with cellulose fiber reinforcement performs about twice as good on compressive strength than sawdust. The performances will even be better with higher weight percentage of the cellulose reinforcement. This is a promising observation for the future of cellulose-reinforced ice.
These results seem to be unreliable. However, in comparison to recent researches our findings differ. Other ways of calculating and checking must be carried out. This might cause an issue with the calibration of the compression bench. Thus, a new method needs to be approached.

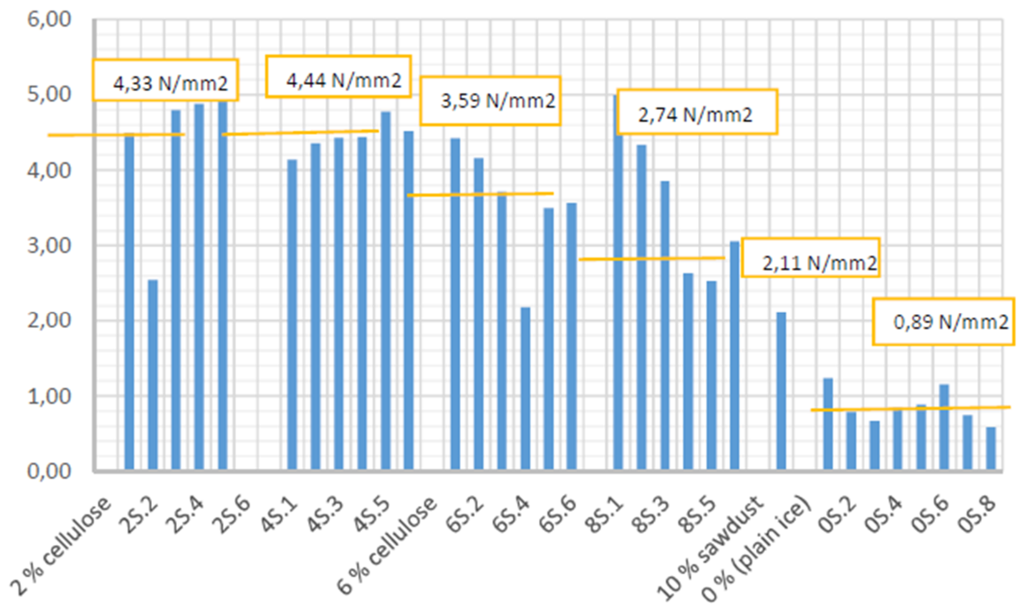
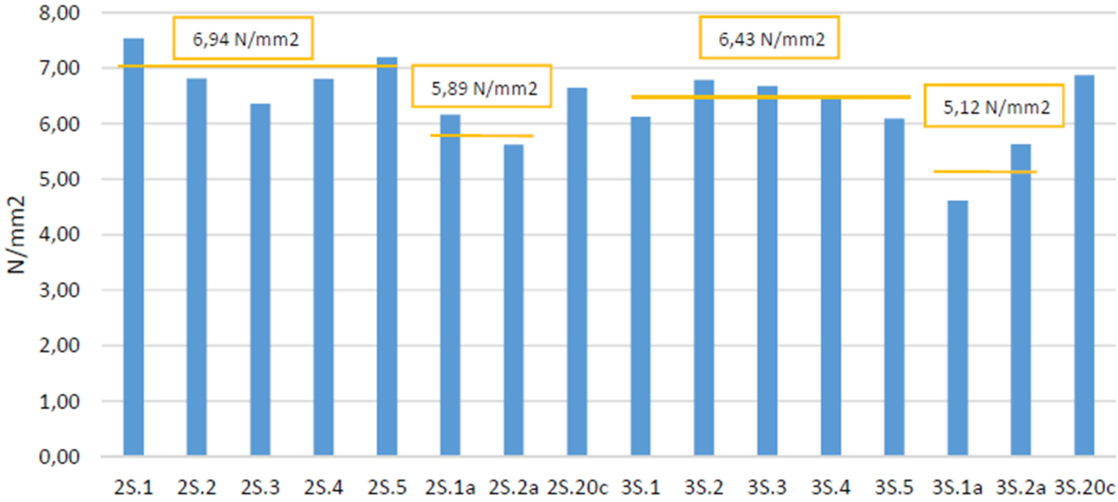


Figure 82: Results of the second compression tests

Conclusions third compression test

The third test was done with a compression bench closed by a box with an inside temperature of 0 °C. The results showed better and more uniform values. The new method of samples preparation where the samples build up from different layers improved the performance of the ice-cellulose composite respectively.
The loading (compression) speed of the testing device is a considerable influence on the load bearing capacity and the compressive strength of the composite.
The rising of the environment temperature during the test is of less importance than the temperature of the contact surfaces of the testing.



General conclusions of compression tests

During the research numerous difficulties occurred in preparation and testing of the samples. Due to the vulnerable structure of the material and its reactions to temperature, we faced a number of setbacks by preparing, freezing and testing of the samples. The best method of testing we achieved is to create a block of composite in manufactured waterproof boxes and then saw or drill out the samples.
The testing and preparation of the first test could easily be influenced by human errors. Due to the fact that the values were not elaborated digitally. During the second test, this effect was minimized, but still needs to be taken in consideration as an influence to the results.
Considerations of finding a more permanent testing location at the TU/e campus, such as a laboratory, are preferable. Research of reinforced ice is an interesting and rather unexplored field of material and has been an interest of the structural design groups of the university for several years in a row now. A permanent location solution is expected to be useful in the following years.

Conclusion of bending test

The E-modulus appeared to be slightly higher than plain ice. However, the reinforced samples seem to regain the strength after the first crack occurs. When looking at plain ice, this does not happen and the sample fails at the first crack.
The stresses in reinforced ice are (sometimes more than) three times higher than the stresses in plain ice.
The flexural strength of 2% reinforced ice is twice as high as plain ice. The flexural strength of 3% reinforced ice is three times as high as plain ice.
The deflection of reinforced ice is higher than plain ice. This is a logical result of the regaining of the strength of reinforce ice, as explained earlier.

Figure 83: Sawing blocks of cellocrete at the laboratory

Conclusion of creep test

A reliable conclusion cannot be made from our results. Just one sample is not enough to say something about a material. However, what is very important is to keep the temperature below zero.
From previous tests (compression and bending) the assumption that ice deforms a lot around freezing point is again proved. Although this does not say anything about the stiffness of the material at -20°C.

6.5 Comparing results

During the tests the following conclusions appeared which will have a big influence on the load bearing capacity:

- Temperature - the lower the temperature the better the results, with a radical value.
- Casting in layers - the more layers the better the result –the material is more homogenous and the mixture has less water and air enclosures
- Loading speed – loading at a slower speed causes lower load bearing capacity and less compressive strength.

Also important is the conclusion that a higher percentage of fibers does not result in better structural properties. The possible explanation of this phenomena could be less water/air enclosures and larger homogeneity than of higher percentage of cellulose

Comparing to other research

Together with the research team the following comparisons are reported (Mileika, Dam, Mok, & Lenaers, 2016):

Sagrada Familia in Ice (cellulose), TU/e (2015)
Method: Teun Verberne and Jordy Kern used the method compared to compression test 1. Using PVC pipes with a cover, different samples can be made of the same measurements.

Results: Teun and Jordy did different tests, one test with an outdoor temperature of -6 °C, and one test with a temperature of -18 °C, using a freezer. When comparing to the results done in this report, differences are shown: where Teun and Jordy got the best results with a 4,97% reinforced ice mixture, this report gets 2% reinforced ice mixture as best. Also the heights of the maximum values differ. This report shows an average value of 6,97 N/mm^2 at 2% cellulose. The other research shows a top value of 9,79 N/mm^2 at freezer conditions, and 7,41 N/mm^2 at outside conditions with the 4,97% cellulose mixture.

Veilig Bouwen met Pykrete (wood fibers), TU/e (2015)
Method: Joris Borsboom got the samples out of the Sagrada Familia after it was built. Samples of 100x100x100 mm were made.

Results: Theoretical values of 7,45 N/mm^2 were not obtained. Instead a mean value of 3,96 N/mm^2 were concluded (compared to 6,97 N/mm^2 of 2% cellulose). It can be concluded that the cellulose reinforced ice is stronger than wood fiber reinforced ice.

Reinforced Ice Structures (wood fibers), TU/e (2013)
Method: Frank Janssen and Remy Houben also used cylinder shaped molds to make the samples. Using a heating gun, the samples were taken out of these molds. This is the same method as described in compression test 1. The main difference is that Frank and Remy compressed with a speed of 3-9 mm/min and put a hydraulic compression device in the freezer (where we used a climate box to control the temperature). Beside this, the height of their samples was 1,5 times bigger that in this report.

Results: When comparing to compression test three in this report (most reliable) big differences can be seen. Where, in this report, the maximum value of 6,97 N/mm^2 is obtained, Frank and Remy got 12,45 N/mm^2. This can't be compared that easy, since the value of 12,45 is obtained by 10,5 % sawdust. However, these big differences may be the result of the much bigger speed of compressing. This report amplifies the hypothesis that higher values are obtained when compression faster. The value of 6,97 N/mm^2 is obtained at a speed of 1,5 mm/min, this may explain the big difference.

Andreas Bastian (saw dust and paper dust), Swarthmore College (USA) (2010)
In the study report of material research The Mechanical Properties of Select Formulations of Pykrete Augmented with an Emulsifier in Uniaxial Compression (2010) compares compression strength of pykrete reinforced by saw dust and paper dust.

Method: 3 samples of each 400 ml in 3 inch cylindrical compression testing cylinders were prepared, with proportion of 4% and 14 % paper dust, 4 % and 14 % saw dust and 0.5 % addition of xanthan gum, mixing with a rotary mixer, stirring and freezing for 24 hrs. The samples were tested with a hydraulic universal testing machine using cooled steel and caps with rubber seats to distribute the loads across the end of the sample.

Results: The results of Bastian A. indicate that several formulations of Pykrete are as strong as concrete in compression and even have higher strength to weight ratios (Bastian, 2010). The compression strength of the samples was concluded as follows: 4% paper dust 21,4 N/mm^2; 14% paper dust 30,7 N/mm^2; 4% saw dust 13,8 N/mm^2; 14% saw dust 16,6 N/mm^2; 0,5% xantan gum addition 5,8 N/mm^2.
Thus the best results were achieved with 14% paper dust; however, 4% paper dust compared to 14% saw dust indicates comparable compression strength. The research by Bastian A. achieves much higher values of the compressive strength than this this report.

Comparison of bending tests

Flexural strength

Reinforced Ice Structures (wood fibers), TU/e (2013)
In the material research done by Frank and Remy the flexural strength of wooden fibers is tested. The material was applied in layers of 2 mm and consisted of water, snow and reinforcement material. The molds for the beam samples were made of shuttering plywood, divided into 5 equal spaces with a dimension of 700x200x100 mm. A 52 metric ton hydraulic cylinder in a steel frame is used to perform the experiments. The highest value that was measured for flexural strength (3,74 N/mm^2) was with use of sawdust with weight percentage of 10,5%. In comparison with our research done with cellulose the value is rather high. These big differences may be the result of the higher speed of compressing. Frank and Remy tested the samples with a testing speed of 3-6 mm/min. Another reason that could explain the difference in results is that Frank and Remy used a three-point-bending test. This testing method is less accurate compared to a four-point-bending test, because a four-point bending test has a pure bending zone. When a beam fails in this zone, it can only fail due to bending. In a three-point-bending test the beam fails mostly in combination of shear and bending.
When comparing the saw dust with cellulose, the conclusion can be drawn that sawdust needs a relatively high weight percentage (10,5%), cellulose respectively 3% to perform the highest flexural strength.

Comparison of creep tests

Since the test conducted in this research regarding creep did not work out well, comparisons cannot be made. However, since creep behavior is considered leading in ice structures, other research, conducted at the Aalto University in Finland, will be briefly discussed.

Research at the Aalto University was conducted by research assistant Syda Tabassum. She also supported the project as a volunteer during construction period. Using a leaver arm, samples consisting of 2% and 4% cellulose were tested for 10 days. Stresses of 0,5 and 0,25 MPa were used at temperatures between -10 and -11 °C. Results are shown in de figure below.

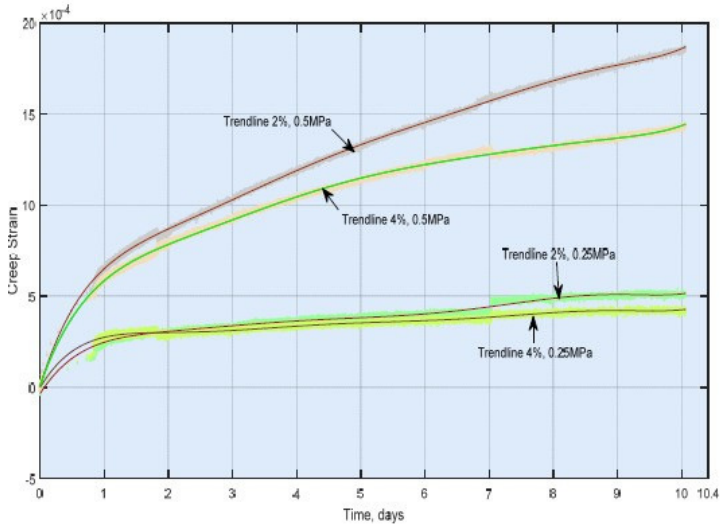


Figure 84: Creep tests

From Figure 84 it can be seen that 2% has a larger creep rate than 4% cellulose mixture.

This difference is more clear at a stress of 0,5MPa than at 0,25 MPa. With a length of 155 mm and a creep strain of 5*10-4, the total negative elongation will be around 0,2 mm at a stress of 0,25 MPa.
Due to many variables which influence the creep strain (temperature, amount of stress, duration of the test), comparing this with other materials is not made. Besides, only four samples are tested here, which means the results are not completely reliable. However, 0,2 mm deflection on a sample of 155mm seems very small. When comparing to the research conducted by L. Makkonen in 1994, who stated that creep is significantly over time when exposed to high temperatures, these results give rise to some discussion, since the creep appears to be small when exposed to a constant temperature (Makkonen, 1994).


SUOMEN
KIVIKESKUS

7. Realization

7.1 Preparations; November – December 2015

In the beginning of November 2015 the preparation started with producing the inflatable. The construction of the inflatable was prepared at Poly-Ned, Steenwijk in Holland. With n group of 12 students the PVC coated polyester fiber was welded together in one week. A rolled pack of 2500 m^2 foil was ready for transport, weighing 1600 kg. The steel details for the stabilizing cables were already attached, to save time on the building site.

At the start of December 120 anchors are placed with a local contractor on the building site in Nunnanlahti (Juuka), Finland. The rocky ground caused some problems with broken anchors. Roel did this job with Bram Ronsse, project leader for the Candela Pavilion of the University of Gent, while Thijs was leading the group of students in Eindhoven doing other preparations. In three days all anchors were placed before it started to freeze.

In the same time the rope-net was made at the MetaForum of the TU/e. The ropes have been cut off at the right distance and all knots were marked. The nodes are pinned together with tie-wraps.

All the prepared material was stored at the Structure Laboratory Eindhoven. On the 19th of December a 20-feet container was packed with: construction material, equipment, food, and personal stuff. Everything was tied and labeled and ready for transport to Finland with truck and freighter.

7.2 Week 1; 28th December 2015 – 3rd January 2016

On the 28th of December the first group of volunteers and students arrived in Nunnanlahti, Juuka Finland. The guest houses of Tulikivi were used as accommodation for the seven weeks of construction period. A meeting with the local volunteers and a short tour over the building site was the start of this project.

Immediately after arriving a start was made with unpacking the container. All the materials that were shipped from Holland to Finland were placed in its designed position. A start with installing all necessary equipment and materials, like the mixing system and heated tent, was made. A thin layer of foil was placed to cover the ground floor and prevent the inflatable from air leakage through the soil. The inflatable was unrolled in its position, between the 120 anchors. Afterwards the rope net and the main cables were attached to the anchor points.

To get familiar with the construction methods the volunteers built some small side projects like the ‘bubble igloo’, and helped the local people with creating their wall of snow.

7.3 Week 2; 4th – 10th January

A first test of inflation was done to check if the rope net, main cables and the inflatable where in its right position. Also the air blowers needed some adjustments to work properly. In the same time the heated tent was finished that would cover the mixing system. The mixing system was almost totally prepared in Holland and needed only to be assembled on site. A first badge of cellocrete was made to test all the equipment. Some adjustment were done; like covering the electric engine and a safety railing was applied at the top of the container.

During inflation, some problems occurred. There was not enough capacity from the air blowers and a lot of air leakage around the bottom part of the balloon. After sealing the bottom with an ice floor, tying the rope net, the inflatable got in its designed shape. Eventually the air blowers where placed in its final position and connected with the control room.

7.4 Week 3; 11th – 17th January

A little door was created at the side to enter the inflatable easily. The stability cables, to insure the inflatable would stay in its optimal shape, where connected to the earlier attached steel eyes in the top, and to the anchors in the ground. The sensors that were measuring the height of the balloon were installed. Some little holes in the PVC foil needed to be repaired. The columns, who were prepared on site, were lifted inside the balloon and placed in their position. After stabilizing the columns and pre-tensioned all the cables the inflatable was ready. At the end of week 3, a little behind schedule, a start was made with spraying the cellocrete mixture layer by layer on the inflatable mold. The feet of the ice bridge became visible.

7.5 Week 4; 18th – 24th January

Exactly at the moment the spraying had started, the amount of available volunteers decreased. The media team, till that moment busy with film, footage and promotion, and other organizing volunteers like the intern Liselotte and coordinator Veerle, helped us every shift, day and night. A maximal production was necessary, to make optimal use of the temperatures colder than -30 °C. After a full week of spraying a layer of more than 1 meter was created at the feet of the bridge. To validate the cellocrete mixture some test were done in the laboratory of Tulikivi. Meanwhile, the frozen waterfall, the ice church, and the Candela Pavilion made progress.

7.6 Week 5; 25th – 31st January

Unfortunately, after one week of spraying, the temperature increased from -30 to + 2 °C in just two days. Some little problems occur during this time. It was important to keep the inflatable fee of snow on top. Al lot of snow fall would increase the load on the inflatable. The snow was removed with air blower and shovels, with the help of the boom lifts.

For just four days the temperature was dropping a few degrees. Just enough to start spraying again and connect the two produced bridge feet. With a temperature of -8 °C the ice was growing just slowly. The meltdown from the previous days caused also some noticeable deformations.

7.7 Week 6; 1st – 7th February

During this week the group of volunteers consisted out of almost 100 people. Unfortunately the temperature was rising again to +2 °C. It even started raining. A large deformation was getting visible. Because of safety reasons, nobody except the guard shift were allowed on the building site.

Luckily the projects designed by the students from KU Leuven and University of Gent did achieve their final goals. They could not built everything, but some nice results were conducted. Some of these projects were totally melt down just before their opening events.

7.8 Week 7; 8th – 14th February

On February 8 2016, around 4:00 AM, the inflatable could not handle the pressure anymore. Through the rain and warmer weather the load on the inflatable was too high and the inflatable torn open. In just a few seconds the bridge was collapsed. There were no calamities of people harmed because of the monitoring system that had warned us of a lowering bridge a few days before collapse. Cleaning the building site and stuffing the container was wat was left.

To celebrate the successful experiment the decision was to keep the opening show running on the 13th of February. A burning man was created to thank all volunteers, companies and institutes that supported the project.

0.1

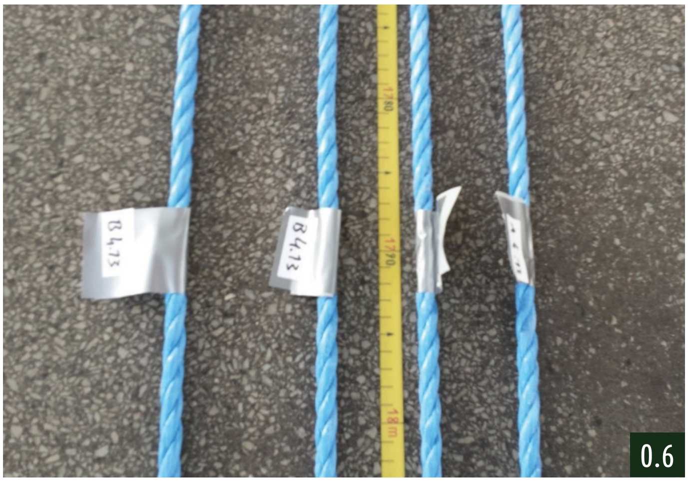
Production of the inflatable (2500 m², 1600 kg) at Poly-Ned BV, Steenwijk Netherlands.

0.2

Drilling anchors, Nunnanlahti, Juuka Finland

0.5

Production of the rope-net at MetaForum in Eindhoven



0.6

Measuring, labeling and cutting approximately 3 km of propylene rope

0.9

All equipment and material ready for transportation to Juuka

0.10

Packed mixing system

120 anchors in its position

The four main anchors, placed at a depth of 2 meters

The rope-net is fastened with tie-wraps

Divided in three elements, ready for transport

The 20 feet container, sponsored by Transfennica, was fully packed

Loaded truck ready for transportation to the harbor of Antwerp

Aerial photo of Juuka, Finland

Accommodation, with the possibility to host almost 80 people

The modified container, with storage space for all equipment and tools

Unloading the big inflatable

Unfolding the rope structure over the inflatable

Connecting the rope net to all anchor points to make ready for inflation

1.3

The first group of volunteers

1.4

Unloading the container, with the help of the shovel, sponsored by Hitachi and Rotator

1.7

Unrolling the inflatable, which was a very heavy job

1.8

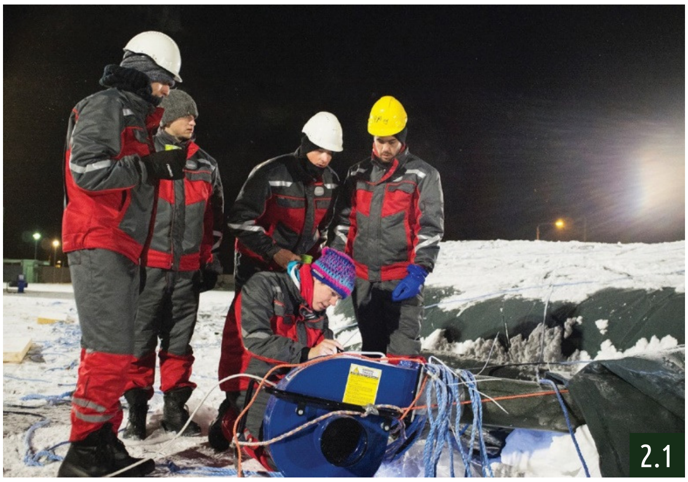
Pulling the inflatable in its exact position between the anchorpoints

1.11

A side project; to get familiar with all techniques and materials we let volunteers practice with creating this ‘bubble igloo’. This igloo is also made with an inflatable mold

1.12

Finish volunteers created a huge wall of snow, to reduce the amount of fences we would need and to set up a cool snow area



2.1 Connecting the air blower to the inflatable to start inflating

2.2 First volume of air inside the inflatable mold

2.5 Connecting all prepared installations to the main cupboard on the building site

2.6 A created door in the balloon, to get inside the inflatable. By the internal pressure the door closed itself.

2.9 The tunnel after inflatable was removed

2.10 Installing the cellocrete mixing system

2.3

First contours of the mold visible

2.4

Deliverance of 30.000 kg of cellulose plates

2.7

Another side project; creating a tunnel with the inflatable of last year. This tunnel would be the entrance to the snow track.

2.8

Making snow with the snow canon.

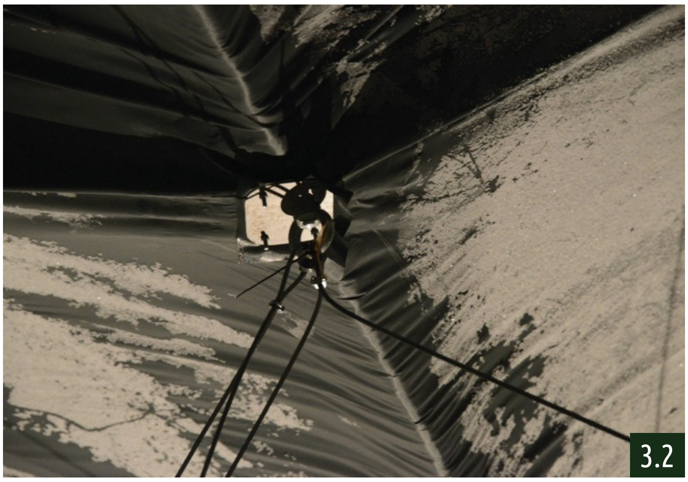
2.11

Connecting all pumps for distributing the cellocrete mixture to the inflatable, with the help of the Summa College students

2.12

The second group of volunteers, picture taken inside the inflatable mold

Connecting steel cables inside the inflatable, to make it stable against wind gusts



Detail of steel connection

Connecting the columns to the inflatable

Positioned columns inside the inflatable to support the bottom part of the bridge

The side parts of the inflatable are made air tight with snow on the outside, and ice on the inside. The caravan is the control room for measuring and monitoring the inflatable.

Volunteers spraying first layers of cellocrete on the inflatable mold

3.3

Steel cables for stabilizing just before tensioning

3.4

Prepared wooden parts for the extra supporting columns

3.7

Final position of the air blowers and connected to the inflatable

3.8

The balloon almost fully inflated

3.11

Mixing the cellulose fibers to a homogeneous 2% fiber weight ratio mixture

3.12

Side project; creating a huge frozen waterfall on the walls of the quarry

Feet of the columns are blocked by steel pins drilled into the ground, to prevent the columns from slipping away

Volunteers moving the hoses to the other side of the Bridge, to continue spraying. On the right side the water house for pumping water from the quarry

Putting cellulose plates in the mixing tanks, 45 plates for every 1000 liter of cellocrete

Side project; creating snow church by the Finish volunteers, with a wooden mold.

Frozen waterfall is growing every day. The black stripes are from flushed sand, and will vanish later on

Working day and night to make optimal use of the cold period. Besides that, the production systems cannot be stopped to prevent them from freezing

Spraying the mixture on the bottom part of the Bridge. Temperatures lay between -35 and -25 degrees Celsius this week.

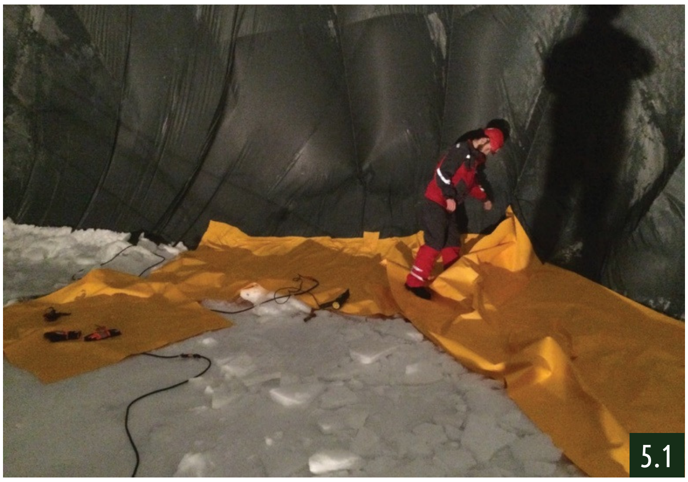
Moving cellulose plates to the production area

Cutting cellocrete blocks from the Bridge, for testing in the laboratory

The bottom parts are fully sprayed, waiting for another cold period to connect them together and spray the top part of the bridge

Overview of the building site. In the background the use of the boom lifts visible for the first time. Till than we could not use them because of temperature restrictions (only usable with temperatures above -23 degrees Celsius. In front a heated container.

Another project; a team of students from the University of Gent had started with their Candela Pavilion. Using our methods, materials and equipment.



Solving are leakage inside the inflatable. Due to sharp breaking ice floes some small holes in the bottom part of the inflatable occurred. Welding a piece of foil to it made the balloon air tight again

Another problem; the inside steel cables were tensioned to tight, occurring in a torn top part of the inflatable around the connection to the main cables. Again welding a new piece of foil was enough to save everything

Filling boom lifts with gasoline

Sometimes equipment or vehicles were frozen and reparations were necessary.

Sawing cellocrete blocks of 100x100x100 mm, with the machinery of the Tulikivi Stove factory.

Compression tests of the cellocrete blocks in the laboratory

5.3

Removing snow from the Bridge and the inflatable, to reduce the carried load. In this week the temperatures were rising to almost 0 degrees Celsius, which occurred lots of trouble as leakage and heavy snow load

5.4

With leaf blowers blowing away snow from the inflatable. Volunteers were fastened to the boom lifts to make it possible to walk over the inflatable

5.7

An overview of the front part of the building site, with in the front the Candela Pavilion under construction

5.8

Opening Ice-Track. Created coffee house for events. This is one of the side projects were students of KU Leuven were committed to.

5.11

The media team, with students from Sint Lucas Eindhoven, working day and night on all footage, PR and events.

5.12

Kids from the elementary school in Juuka visiting the Bridge in Ice project. Watching a movie about building with ice in the meeting aria of the project.

6.1

Going up with the boom lift, to measure the current thickness of the Bridge in the top part

6.2

Creating a slope on the bottom part, to make people walk over the bridge

6.5

Side project; designed and build by students from KU Leuven, with support of all other volunteers

6.6

These side projects were positioned all along the snow track. This one is made with a small inflatable mold

6.9

Trying to close the top part of the Bridge. You might notice the sagging of the Bridge at some points

6.10

Because of the too high temperatures not all sprayed mixture was freezing. In the sagged parts of the Bridge the water accumulated. Here you see us pumping out water from the top part of the inflatable

6.3

Holding guard shifts in the control room, with temperatures of -2 degrees Celsius it was unfortunately not cold enough to spray more layers of cellocrete on the Bridge

6.4

The group of volunteers in the most crowded week. Fun fact: Roel, Thijs and Veerle are not on this picture because they were arranging more beds (sponsored by local people) for the 98 (!) volunteers that would be present that evening

6.7

This project consisting of a ‘chicken wire’. Sprayed with water it gave a nice result

6.8

Start spraying again, with temperatures of -5 degrees Celsius it might be to warm, but with current weather forecast this might be our last chance to spray the top part of the Bridge

6.11

The sagged part resulted in a deformed arch, which was structural highly inappropriate

6.12

The inflatable of the Candela Pavilion deflated, with a thin ice shell as a result

7.1

ISOFF Ice symposium, attended by several professors and other interested persons

7.2

The monitoring system was warning us that the top part of the Bridge was slowly coming down. We were able to close the bridge, but the structural shape did not form a proper arch, which made the Bridge weak

7.5

We were warned by alarms and flashing signs, and also by our monitoring system. This resulted in the fact that no one was injured during the collapse of the Bridge

7.6

Cleaning the building site to let the scheduled opening festival go on

7.9

The lighted ice church from the inside

7.10

The burning man on fire, between the feet of the (what had to be) Bridge

Unfortunately, in the very early morning of February 8, the balloon collapsed due to the warm weather. The constructed ice lost all its strength with these high temperatures

The inflatable was torn open over 25 meters. The feet of the Bridge, supported by the columns, held. They marked the imagination of how impressive the Bridge would have been.

Creating an chimney of large ice blocks, cut from the Pielinen lake

The 5 meter high burning man, with its reference to Leonardo Da Vinci, placed on the chimney

It symbolized the project and was one of the highlights of the festival

We would like to thank everyone who was involved in this incredible project!

8. Validation

8.1 Introduction

The design of the Bridge in Ice is compared with the actual structure just before collapse. Because of the early collapse of the bridge it was not possible to validate the final structure. With the data gathered in the period before the collapse it is still possible to validate the process, dimensions of the inflatable, ice shell and material properties.

8.2 Results

Ice shell

The amount of produced cellocrete was measured in two ways.

- Till which part of the inflatable the cellocrete reached
- Thickness of the shell

The amount of cellocrete on the base is measured by comparing a point from the base with reference points nearby the bridge. The data from the report-logs are showed in Table 6. At the top the thickness of the ice shell is measured by drilling holes through the ice.

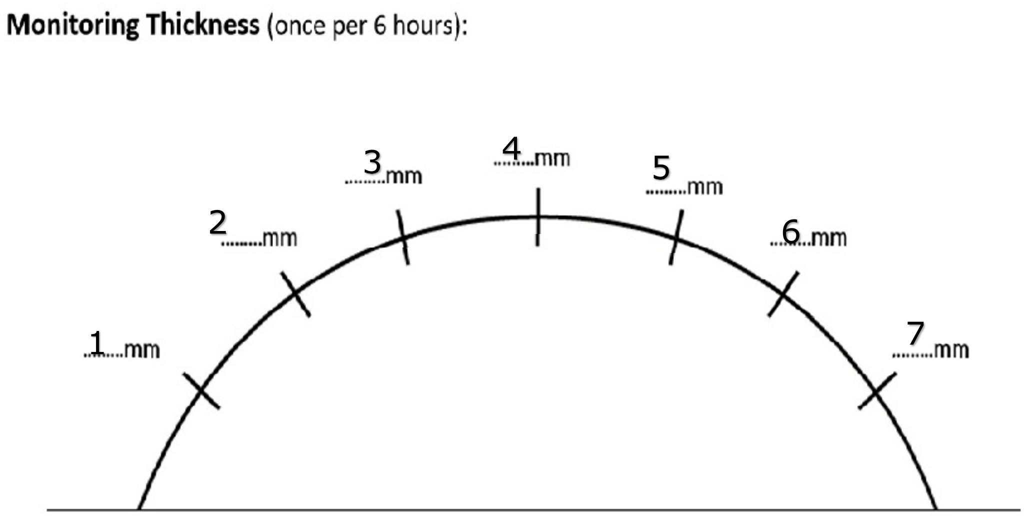


Figure 85: Measuring points

Table 6: Monitoring thickness of ice shell

Date/Measuring point	1	2	3	4	5	6	7
14-1-2016	100	0	0	0	0	0	100
16-1-2016	200	0	0	0	0	0	200
17-1-2016	600	200	0	0	0	200	600
18-1-2016	800	200	0	0	0	200	800
19-1-2016	1000	300	0	0	0	300	1000
20-1-2016	1300	400	0	0	0	400	1300
21-1-2016	1500	400	0	0	0	400	1500
22-1-2016	1700	400	0	0	0	400	1700
23-1-2016	1800	450	0	0	0	450	1800
Guardshift							
1-2-2016	1900	450	50	20	50	450	1850
2-2-2016	2000	500	80	50	80	500	2000
3-2-2016	2100	550	100	80	100	550	2100
4-2-2016	2200	550	150	100	150	550	2200
5-2-2016	2300	600	250	150	250	600	2300
6-2-2016	2500	600	300	200	300	600	2500
Guardshift							
8-2-2016	**Collapse 4.00 AM**						

After the first layer of cellocrete is stuck on the inflatable the thickness of the ice will increase rapidly. Especially in the colder periods. In the days from 18 till 20 January it was possible to spray constantly without breaks.
On top of the flat panels, arise by sagging of the base, cellulose piled up. The measured values on these points are misleading (see data at measuring point 2). After the first guard shift period it was necessary to spay carefully. Only the top part and the base needed to be sprayed to avoid an extreme load of cellocrete at point 2.

Figure 86: Deformations in the top

Inflatable

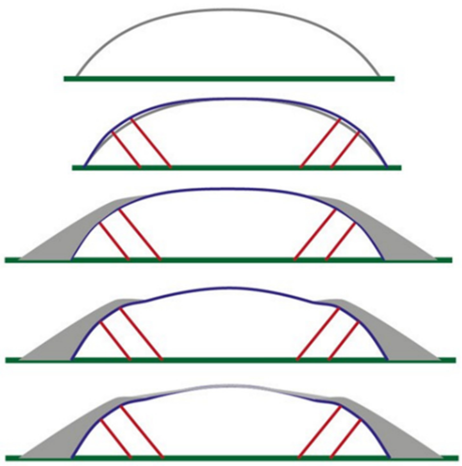


Figure 87: Scheme of deformations of the bridge

The height of the balloon was measured by a sensor placed inside the balloon. After full inflation the top part 8600 mm high. A little lower than designed. Besides the height of the middle part of the inflatable nothing of the actual created shape of the inflatable is measured.
But some of the differences between designed and build were clearly visible.
The side parts of the inflatable were to flat. Furthermore, the stability cables inside the inflatable was pre-tensioned by hand and further tensioned by building up the internal air pressure. However, this building up had led to deformations in the main cable. These deformations were caused by too much tension in the stability cables. These deformations also caused small ditches on the surface of the inflatable in the middle part.

Collapse

Forty-three days after the start of construction of the Da Vinci’s Bridge in Ice the inflatable could not hold the pressure anymore and turned open. During the construction phase the base was build up too high, the base exceeded the columns by approximately two meters. Hereby the end of the base was not supported by these props that were placed. When the temperature increased several problems occurred. While the props were placed to tackle a warmer period, they were not able to support the overhang of the base.
With the increasing temperature the material properties of the cellocrete decreased significantly. The stiffness of the material decreased which resulted in large deformations altering the shape of the balloon.

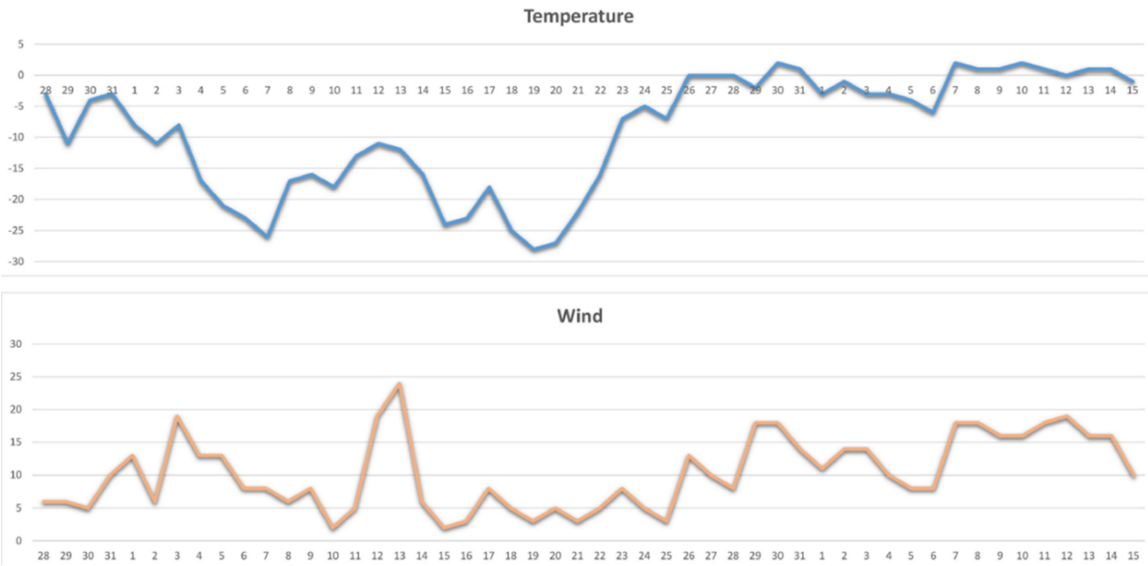


Figure 88: Weather development during construction (www.wunderground.com)

After this warmer period the arch was closed in an attempt to finish the bridge. After a short, colder period the second warm period occurred. The higher temperatures caused the seal (to keep the inflatable air tight), made of ice, inside the balloon to melt, resulting in air leaks that could not be compromised by the air blowers. Therefore the intern pressure dropped, resulting in a lower support function, causing extra deformations.

Timeline

13-23 January:	Spraying cellocrete on base
24-31 January:	Temperature was increasing, part after the columns starts to deform.
01-06 February:	Final attempt to close the top part, because of the high temperature water accumulate in the small ditches between the main cables.
06-08 February:	Pressure was dropping down, ice was melting. Cellocrete lost its strength and the high of the middle part was coming down with cm per hour.
08 February:	final high of the middle part around the 6,80 m-------Collapse
09-15 February:	Cleaning building site, Plans for deflation were not necessary any more (appendix 13).

Besides the increasing temperature a few design mistakes also contributed to the deformations of the bridge and finally failure.

Air leakage

- The extra 2,5 meter membrane to cover the ground and make the inflatable air tight was too short.
- The membrane was not long enough to cover the strain in the ropes.
- Because of the extremely cold weather the membrane was very stiff and hard to control.
- The design of an inflatable with no bottom cover, in a cold region, causes problems with inflation

Shape inflatable

- The shape was not optimal. Some tie-wraps did not break, which obstruct the rope net to move independently (and find its own perfect shape), and led to an unwanted shape of the inflatable at some points.
- Some of the ropes were too long and needed to be shortened
- Find the right pre-tensioning of the stability cables.
- Membrane and supporting rope-net must be able to move independently. They were connected to each other by the steel detail with the connected stabilizing steel cables.

Working on site

- The short preparation time forced us to finish some preparations on site. Working on site with temperatures of -30 °C leads to delays. Some equipment is not usable at all at those low temperatures.

In conclusion, the increasing temperature, the above mentioned problems that occurred, and the design mistakes that were taken are the reasons of collapse.

8.3 Structural strength of cellulose

A significant amount of ice samples, extracted from the Bridge and Lake Pielinen, was tested. The cubes from Lake Pielinen functioned as comparison. The samples were tested under compression with following variables:

- Displacement rates
- Temperature
- Orientation
- Layer from which they were extracted

The importance of those parameters is made evident by the results.

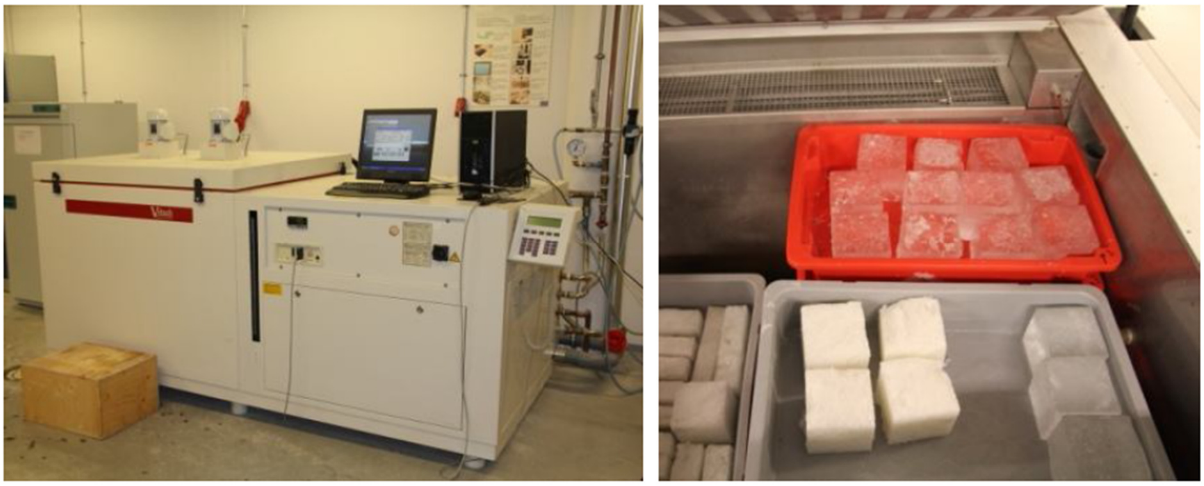


Figure 89: Equipment at Tulikivi for testing with ice and cellocrete samples

Figure 90: Roel cutting blocks from the bridge

In the following tables the results are shown.

Table 7: Compressive strength of the specimens stored at -8 °C and tested at a displacement rate of 0,2 mm/s (in MPa)

Cellulose-ice composite ①	Ice (vertical)			Ice (horizontal)
	Layer 1 ②	Layer 2③	Layer 4 ④	Layer 4⑤
5.57	2.37	4.24	2.49	1.66
5.17	3.51	3.16*	3.10	1.73
5.56	3.52	3.05	3.19	1.51
4.96	2.67	3.90	3.33	1.90
5.44	3.44	1.78	2.38	1.74
5.31	2.48	3.48	2.56*	1.65*
6.06	2.74	3.34	2.71	1.33
6.38	2.64	3.29	2.27	1.79
6.43	2.08	3.28	2.11	1.32
5.63*	2.76*	2.27	2.10	1.43
5.65	2.82	3.18	2.62	1.61

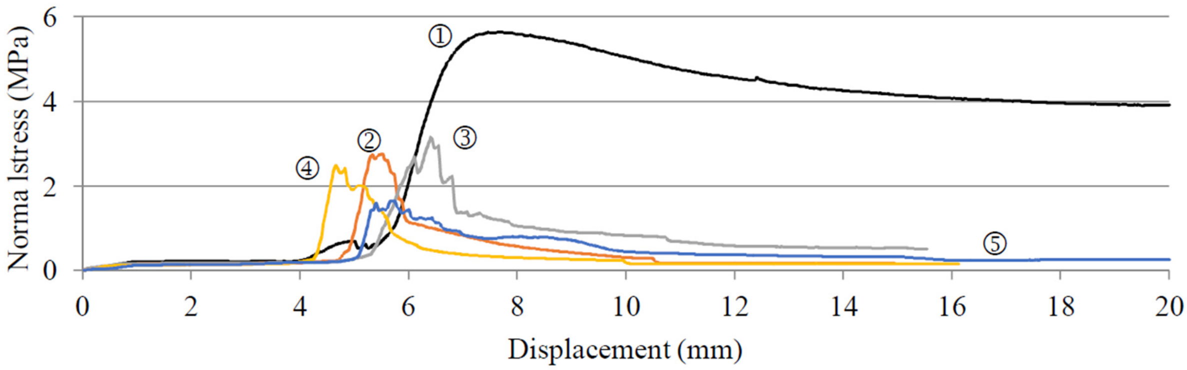


Figure 91: Curves of the specimens stored at -8°C and tested at a displacement rate of 0,2 mm/s

Table 8: Compressive strength of the specimens stored at -8 C and -12 C and tested at a displacement rate of 0,5 mm/s (in MPa)

Cellulose-ice composite		Ice (layer 4)			
		Vertical		Horizontal	
-8ºC	-12ºC	-8ºC	-12ºC	-8ºC	-12ºC
①	②	③	④	⑤	⑥
6.64	8.64*	3.90	2.47	1.42	2.08
6.28	7.55	2.80	2.50	1.41*	1.50
7.70	7.76	3.06	2.72	1.15	1.29
6.44	7.16	2.02	3.65*	1.69	1.32
8.22	7.84	3.52	2.80	1.31	1.95
7.41	10.04	3.44	2.87	1.12	1.48
7.95	7.88	3.92	3.96	1.44	0.99
7.60	7.64	4.37	4.76	1.01	1.96
6.90	8.93	2.25	4.75	1.42	1.86
7.07*	9.70	3.32*	4.46	1.72	1.60*
7.22	8.31	3.26	3.49	1.37	1.60

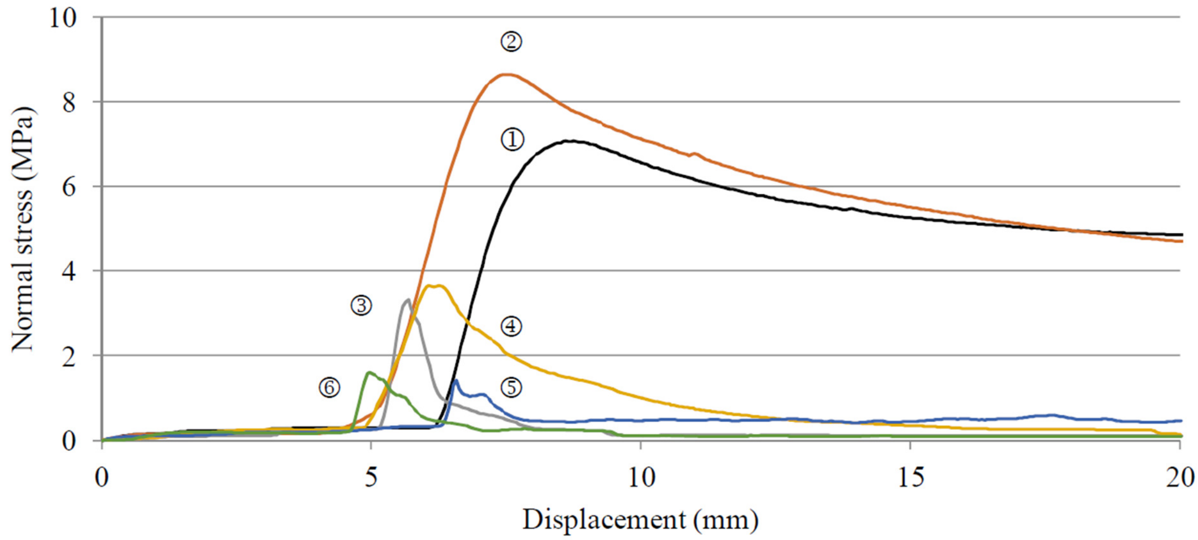


Figure 92: Curves of the specimens stored at -8ºC and -12ºC and tested at a displacement rate of 0,5 mm/s

In Table 7 and Table 8 is shown that the cellocrete cubes had a significantly higher compressive strength compared to the ice blocks from the lake (Cruz & Belis, 2016).


Tulikivi
Tulikivi

9. Evaluation

9.1 Conclusion

The goal of this research was to show the potency of reinforced ice as a building material and to investigate the optimization of construction methods for reinforces ice structures. This research is done by means of a case study; Da Vinci's Bridge in Ice.

The ambition of constructing the Bridge in Ice was to create world's largest span in Ice. Unfortunately, the weather conditions made it impossible to finish the bridge. Despite the collapse of the bridge at the 8th of February 2016 the case study has shown the potency of the material cellocrete and its construction methods.
The research conducted to realize the Bridge in Ice, can be categorized into four main subjects; the organization, the structural design, building technology and material research. The evaluation of the project is also divided into these categories. And gives answers to the main and sub-questions:

How to realize world's largest span in ice, within given boundaries?

Organization

The key of organizing a project like Bridge in Ice is to form a collaboration with: several students and professors from MSc, BSc and Middle scholarship, more than 50 companies, the support of the local government, and volunteers. Combining these knowledge made it possible to set up a project like Bridge in Ice, explained in chapter 3. Even it was the third time in Juuka, commitment with the community plays an important role. This all summarizes the answer to the first sub question:

How to manage and organize several processes to realize world's largest span in ice?

Structural design

Continuously monitoring the intern pressure and the deformations of the inflatable mold and the ice shell of the bridge gives the opportunity to react fast and to adjust were necessary. Despite the extra measures that were taken to overcome a warmer period, it was not sufficient for those weather conditions; a climate-dependent supporting structure is difficult to control, explained in chapter 4.

How to produce and control a reusable inflatable construction for realizing an arcuate ice structure?

Building method

Designing a professional mixing system whereby the influence of the climate is minimized. The necessary systems are explained in chapter 5. The mixing system was well prepared and tested. Every element we designed functioned as we expected and was easy to manage by all volunteers. The problems mentioned in the first paragraph of chapter 5 were solved, so the construction period was not delayed.

How to use and optimize the current construction methods and processes to realize fiber reinforced ice structures?

Material

The material properties were better than assumed during the calculations. The intended mixture ratio of 2% cellulose was practically reached, also the assumed compression strength of 1,0 N/mm^2 was easily obtained. The first tests resulted in an average mixture ratio of around 2% and a compression strength with an average of 8 N/mm^2. The cellocrete is also homogeneous and no snow was needed to add. The cellocrete already reacts as a sponge. The material properties of cellocrete are however strongly dependent on the temperature, at higher temperature the strength of the material decreases significantly. The material properties are explained in chapter 6.

How to use cellulose as reinforcement to improve the structural and construction properties of ice structures?

9.2 Recommendations

Organization

Combining different disciplines (the technical construction, organization, and materialization) at the same time had impact on communication. Recommendation would be to do more research into large organizations structures. The organization of this project is a very difficult one, with a large variety of stakeholders: authorities, volunteers, students, companies, etc. To lead such a various group of contributors, in uncommon conditions, is a big challenge. More research into the synergy between such groups could increase productivity and efficiency.

Construction method

Mixing system
The container worked flawless, but some improvements can be made. For example;
The platform consist out of steel grid, fixed above the big buffer container. The steel grid floor made it dangerous for tools and other equipment to fell through the platform in the mixture.

Spraying system
It might be useful to do research into a mobile spraying system. With such a system it is possible to create ice structures on multiple locations.

Construction site
Reduce all needed construction time on site. Working with the cold circumstances is hard. The production of the supporting columns inside the inflatable took a lot of time. If they were prepared in Holland a lot of construction time might have been reduced.

Inflatable
Reserve time for testing the inflatable mold. The inflatable was inflated for the first time in Finland, under uncommon circumstances. With testing it on a large scale in Holland we could have reduced some start up troubles, which could have save construction time.

It is wisely to choose a more climate-independent supporting structure. The inflatable was made air tight by cover the bottom side with ice. With uncommon warmer periods the strength decreases drastically. When the air tightness is not functioning anymore, the supporting function of the inflatable is disappearing.

Stability
To attach the stabilizing steel cables took a lot of time. The necessity of these stabilizing cables was not visible during construction phase. It might have been a better option to not attach them and immediately start spraying, so that there was more time for the ice to grow.

Material

Further research to set up material properties. With testing the ice samples from Lake Pielinen and the Bridge it is made visible that temperature has a large influence on the material strength. Influence of temperature on the material strength. The creep behavior is still not decently investigated. More research has to be done into the creep behavior, to guarantee a safe possibility of using an ice structure like the Bridge in Ice.
Despite the fact that the test with cellulose as a reinforcement were convincingly. Cellulose had also its disadvantages like: waste, price, and transport. Other reinforcement materials needed to be further researched.

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11. Appendix

01. Promotion pack
02. Collaboration
03. Planning
04. Sponsor brochure
05. Sponsors
06. Budget estimation
07. Registration form
08. Volunteer guide
09. Health and Safety plan
10. Bridge in Ice magazine
11. Material properties
12. Drawings preparations Bridge in Ice
13. Deflation plan

Da Vinci's Bridge in Ice

Appendix

R. Koekkoek
T.A.H. van de Nieuwenhof
Master Thesis

March 20, 2017
Eindhoven University of Technology


BRIDGE in ICE
Juuka, Finland
28 December 2015 - 14 February 2016
VOLUNTEERS WANTED
HELP US CONSTRUCT A WORLD RECORD!
€ 350,- (excl. travel)
for one week or more!
5 ECTS: 7RC50 Innovatie op Locatie WINTER EDITION!
In CT-Certificate program! info@structuralice.com, or at SUPport, VRT 5
5 ECTS: 7A100 International Experience
info@structuralice.com, or at SUPport, VRT 5
Info meeting 3 December 20.00 Trappenzaal
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Collaboration of
Juuka
SUPPORT
TU/e Technische Universiteit Eindhoven University of Technology
UCL Université catholique de Louvain
TUDelft
UNIVERSITY OF TWENTE.
UNIVERSITY OF BATH
KU LEUVEN
UNIVERSITEIT GENT
UNIVERSITY OF JYVÄSKYLÄ
SUMMA College
RusHydro
Aalto University
Karelia
SINTLUCAS
Fontys
VTT
Juuka
BRIDGE in ICE
Candela Pavilion
Finland


BRIDGE in ICE
September - January
2015 - 2016
WE WANT YOU
TO BE PART OF WORLD'S LARGEST BRIDGE IN ICE
Collaboration of
Juuka
SUP PORT
TU/e Technische Universiteit Eindhoven University of Technology
UCL Université catholique de Louvain
TUDelft
UNIVERSITY OF TWENTE.
UNIVERSITY OF BATH
KU LEUVEN
UNIVERSITEIT GENT
UNIVERSITY OF JYVÄSKYLÄ
SUMMA College
RusHydro
Aalto University
Karelia
SINTLUCAS
THE UNIVERSITY OF EDINBURGH
Fontys
VTT
Mail voor info over vrije studiepunten, projecten en internships naar:
info@structuralice.com
Wij zoeken ondersteuning in:
Techniek, Media, Eventmanagement en ICT
Wanneer: donderdag 3 sept. 12.30 - 13.30
Locatie: TU Eindhoven, gebouw Vertigo, lokaal 9.06
Juuka
BRIDGE in ICE
STRUCTURAL ICE ASSOCIATION
Candela Pavilion
Finland

Social media

Website:	structuralice.com
Instagram:	www.instagram.com/bridge_in_ice
Facebook:	www.facebook.com/bridgeinice
Twitter:	twitter.com/structural_ice
YouTube:	www.youtube.com/bridgeinice
Flickr:	www.flickr.com/photos/structuralice

Structural Ice Association ◊ World's Largest Span in Ice ◊ www.structuralice.com ◊ Juuka 2016 ◊ TU/e Eindhoven University of Technology ◊

Da Vinci's

BRIDGE in ICE

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Da Vinci's Bridge in Ice

World's Largest Span in Ice

TU/e

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Project Manager

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Da Vinci's
BRIDGE in ICE

Appendix 2

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010		**University/Organization**	**Telephone**		**Adress**	**Contrubution**
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		Contact				
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011		**University/Organization**	**Telephone**		**Adress**	**Contrubution**
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		Contact				
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		Ari Jaaranen(technical director)	040 104 2601 / 013472123	ari.jaaranen@juuka.fi	**Email and Website**	
					www.juuka.fi	
015		**University/Organization**	**Telephone**		**Adress**	**Contrubution**
		Bridges Finland 2016				promo
		Contact				

					Email and Website	
016		**University/Organization** RusHydro **Contact** Vasiliev, Nicolai	**Telephone** (+)79219404465	 nicolaivasiliev@hotmail.com;	**Adress** RusHydro , The B.E. Vedeneev VNIIG, Inc., St Petersburg, Russia **Email and Website**	**Contrubution** Research
017		**University/Organization** SUPport study association **Contact** Pieter van Nunen chairman 2015/2016	**Telephone** +31 6 14886151	 p.v.nunen@student.tue.nl	**Adress** **Email and Website** www.support.tue.nl	**Contrubution** Support
018		**University/Organization** VTT **Contact** Kari Kolari Senior Scientist, D. DC (Tech)	**Telephone** +358 20 722 6682(T) +358 50 566 5672(M)	 kari.kolari@vtt.fi	**Adress** **Email and Website**	**Contrubution** Research
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021		**University/Organization** UCLouvain **Contact** Elke Mergny	**Telephone** (+)32 472538696	 elke.mergny@uclouvain.be	**Adress** **Email and Website**	**Contrubution** Support
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					Email and Website	
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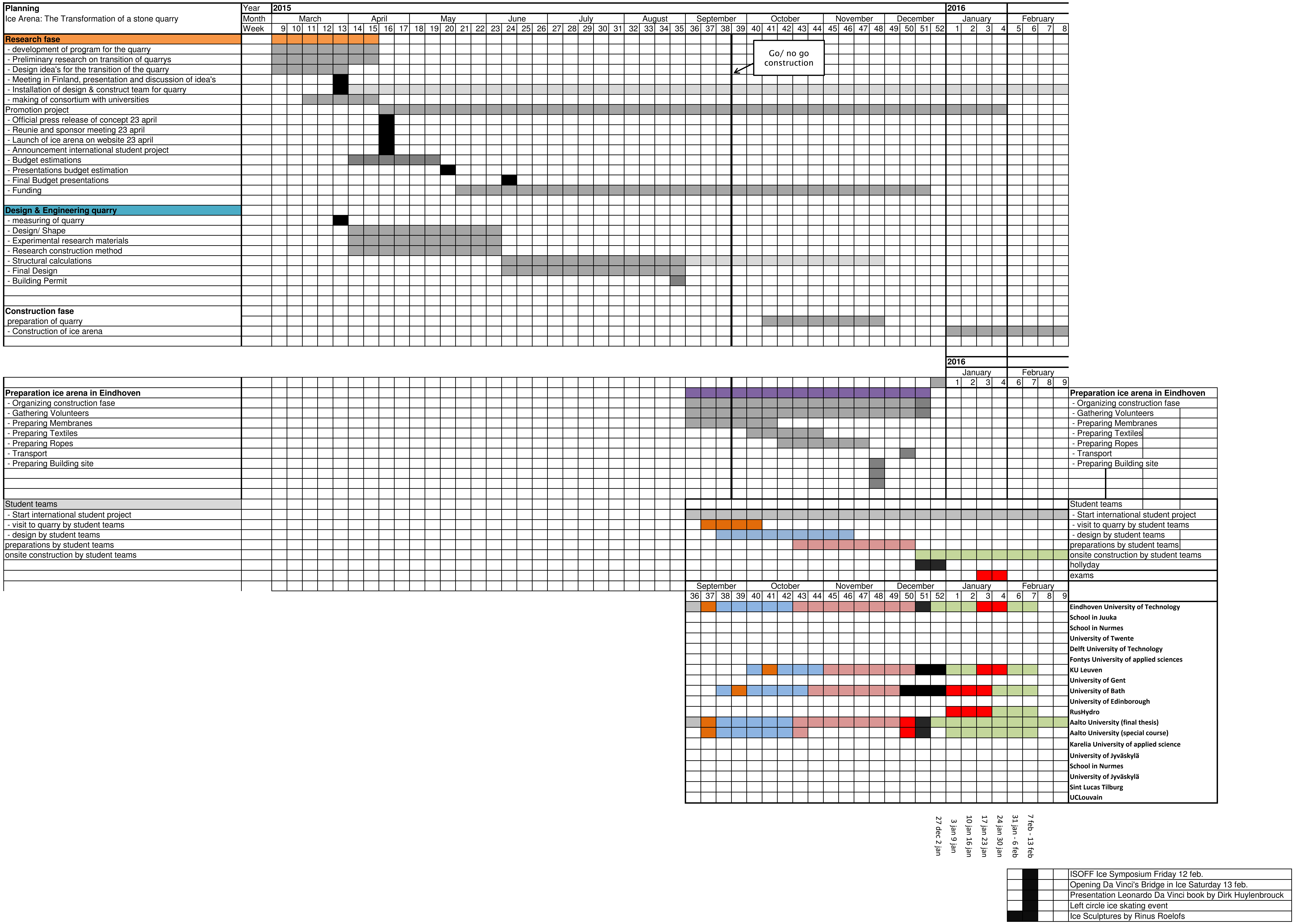
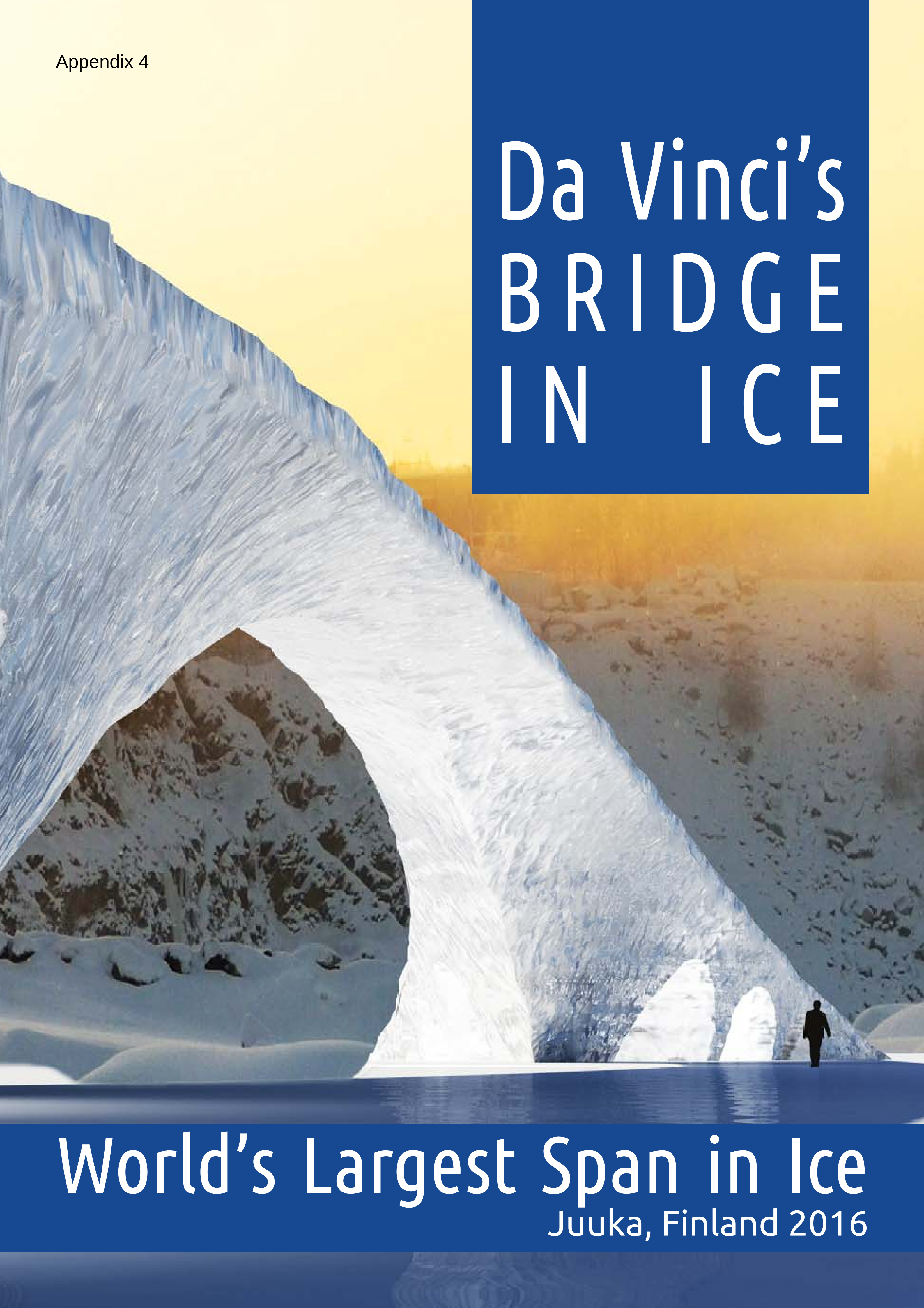
Appendix 3



Planning
Ice Arena: The Transformation of a stone quarry
Year 2015 2016
Month March April May June July August September October November December January February
Week 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8
Research fase
- development of program for the quarry
- Preliminary research on transition of quarrys
- Design idea's for the transition of the quarry
- Meeting in Finland, presentation and discussion of idea's
- Installation of design & construct team for quarry
- making of consortium with universities
Promotion project
- Official press release of concept 23 april
- Reunie and sponsor meeting 23 april
- Launch of ice arena on website 23 april
- Announcement international student project
- Budget estimations
- Presentations budget estimation
- Final Budget presentations
- Funding
Go/ no go construction
Design & Engineering quarry
- measuring of quarry
- Design/ Shape
- Experimental research materials
- Research construction method
- Structural calculations
- Final Design
- Building Permit
Construction fase
preparation of quarry
- Construction of ice arena
2016
January February
1 2 3 4 6 7 8 9
Preparation ice arena in Eindhoven
- Organizing construction fase
- Gathering Volunteers
- Preparing Membranes
- Preparing Textiles
- Preparing Ropes
- Transport
- Preparing Building site
Student teams
- Start international student project
- visit to quarry by student teams
- design by student teams
preparations by student teams
onsite construction by student teams
hollyday
exams
September October November December January February
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 6 7 8 9
Eindhoven University of Technology
School in Juuka
School in Nurmes
University of Twente
Delft University of Technology
Fontys University of applied sciences
KU Leuven
University of Gent
University of Bath
University of Edinborough
RusHydro
Aalto University (final thesis)
Aalto University (special course)
Karelia University of applied science
University of Jyväskylä
School in Nurmes
University of Jyväskylä
Sint Lucas Tilburg
UCLouvain
27 dec 2 jan
3 jan 9 jan
10 jan 16 jan
17 jan 23 jan
24 jan 30 jan
31 jan - 6 feb
7 feb - 13 feb
ISOFF Ice Symposium Friday 12 feb.
Opening Da Vinci's Bridge in Ice Saturday 13 feb.
Presentation Leonardo Da Vinci book by Dirk Huylenbrouck
Left circle ice skating event
Ice Sculptures by Rinus Roelofs

Appendix 4

Da Vinci's BRIDGE IN ICE



World's Largest Span in Ice

Juuka, Finland 2016

After the great experience in Finland (Sagrada Familia in Ice, January 2015) the project team will return to Juuka for a new ice-project. We've now picked up the idea to realize world's largest ice-bridge.

The team (started at Eindhoven University of Technology) consists of several international universities, volunteers and companies, operating as the Structural Ice Association.To build the 50-meter span ice-bridge, based on a design by Leonardo Da Vinci, we need your support. The shape of Da Vinci's design seems to be very appropriate for building with reinforced ice on inflatable molds, the techniques we use. We extended them with new inventions to construct the biggest single-span structure in ice ever realized.
With this brochure we want to show you the possibilities for your company to be involved. Together we can make Da Vinci's Bridge in Ice a success story.

Sponsor packages

To realize a new world record we want to cooperate with you. Your company can support us with knowledge, material, equipment, production facilities or with a financial contribution. To give an indication of the possibilities there are five sponsor packages composed.

As a main sponsor we will meet you to discuss about the possibilities for offering you the most suitable package.

What do we offer?

Meet the engineers of the future

A team of several multidisciplinary and motivated students, including graduating master students and PhD-researchers, from 12 different Universities all over Europe, will work on the design of the Bridge in Ice and other ice projects for 7 months.

The project team consists of the best graduated bachelor students in Building Technology, Construction Technology and Structural Design.
Supervised by a group of 20 professors and academics.

All results during the research and engineering phase will be reported in academic papers and presented at the ISOFF Ice Symposium on Feb. 12th 2016, in Juuka Finland.
During construction from late December 2015 till opening on Feb. 13th the team will consist of approximately 100 volunteers, most of them (future) engineers.

Gain publicity in multiple ways

Advertisement at public activities about the ice projects can be easily arranged. Your companies' name can be shown on the TU/eXperience Days, on other international Universities and during construction phase on the building site.

The Bridge in Ice project will be broadcasted on national and international television. Last year we were picked up by several news bulletins, blogs, papers, radio stations, and even Discovery Channel Canada broadcasted us.

Be part of the Structural Ice Association and its network

The SIA is a result from a corporation between Eindhoven University of Technology and the municipality of Juuka, Finland. During the years several international Universities and Institutes participated and they all promised their contribution for the projects in 2016.

Meet the other (international) sponsors in our network. We like the idea of sharing knowledge and networks with each other.

Get known by every student, your potential employees, at Eindhoven University of Technology, and the other contributing institutes.

Be part of a world record!

Membership

You can support us by becoming a member of the Structural Ice Association. For us it's very important to keep every member involved in the project. Every member shall:

- Frequently recieve a newsletter to keep you informed about the latest developments.
- Get free entrance to the Ice Arena during the opening.
- Be able to join a tour through the Ice Arena incl. a walk over the Bridge in Ice, guided by its builders.[3]
- Invitation for the reunion and the press release of the plans for 2017, at Eindhoven University of Technology.
- Receive a magazine about the Bridge in Ice

Memberships are valid for your whole family, all your housemates or your entire enterprise.

Fees

Family/housemates membership	50,-
Small and medium-sized enterprises (SMEs)	200,-
Large-sized enterprises membership	1000,-

Enterprises with a membership have the ability to exploit a booth at the Ice Paradise.

Besides becoming a member you can choose a sponsor package to extend your support and contribution in realizing world's largest span in ice!

	Sponsor packages		Platinum	Gold	Silver	Bronze
1	Free booklet(s) about Bridge in Ice	10,-	100,-	50,-	30,-	20,-
2	Small logo on website and in booklet	500,-				500,-
2	Medium logo on website, booklet and at events	1.500,-			1.500,-	
2	Large logo on website, booklet, events and inflatable (5 m^2)	2.500,-	2.500,-	2.500,-		
3	Page in booklet about Bridge in Ice	200,-	200,-	200,-		
4	Presentation about building with ice at your company[1]	400,-	400,-	400,-		
5	Blog in Cobouw-magazine	1.000,-	1.000,-	1.000,-		
6	Special *Building with Ice* sponsor movie	2.000,-	2.000,-	2.000,-		
7	Guest/lecturer at ISOFF Ice Symposium[2]	1.500,-	1.500,-			
8	VIP treatment at opening and first to walk over the Bridge[3]	5.000,-	5.000,-			
	[1] excl. (travel) costs	Total	12.700,-	6.150,-	1.530,-	520,-
	[2] excl. travel costs	Discount	3.700,-	2.150-,	530,-	270,-
	[3] if safely possible	Sponsorship amount in euros	**9.000,-[4]**	**4.000,-[4]**	**1.000,-[4]**	**250,-[4]**

[4] sponsor packages are only available in combination with membership

Contact us at info@structuralice.com
Visit us on www.structuralice.com
Or call Arno Pronk (TU/e)
(+)31 6 25080151

Da Vinci's BRIDGE in ICE

Contact us at info@structuralice.com
Visit us on www.structuralice.com
Or call Arno Pronk (TU/e): (+)31 6 25080151

Appendix 5

Material and equipment Sponsors

001	**Company**	**Address**	**Telephone**	**Sponsor info**
	Sanders Project Adviezen	Jan Steenlaan 89	+31 (0)6 532 765 10	Juuka contact
	Contact	6717 TB	**Email and Website**	Health & Safety report
	Hugo Sanders	Ede	hugo@sanders-projectadviezen.nl	
		Netherlands	www.sanders-projectadviezen.nl	BRONZE
002	**Company**	**Address**	**Telephone**	**Sponsor info**
	Chr. Muller Touw	Nijverheidsweg 8	+31 (0)481 365240	5,5 KM 12mm pp rope
	Contact	6226 NG	**Email and Website**	€ 2000,-
	Marcel Pasman	Elst	m.pasman@cmtropes.com	
		Netherlands	www.chrmullertouw.nl	SILVER
003	**Company**	**Address**	**Telephone**	**Sponsor info**
	Groente & Fruit José	Van de Poelstraat 10A	+ 31 (0) 6 515 48 180	Food and Financial
	Contact	5761 BW	**Email and Website**	
	Kos van de Nieuwenhof	Bakel	kosvandenieuwenhof@kpnmail.com	
	José van de Nieuwenhof	Netherlands	www.groentefruit.eu	BRONZE
004	**Company**	**Address**	**Telephone**	**Sponsor info**
	Scantarp	Lukkosalmentie 4	+358 44 588 1149	PVC fabric
	Contact	70420 Kuopio	**Email and Website**	3600 m2
	Ilkka Rovamaa		ilkka.rovamaa@scantarp.fi	
			www.scantarp.fi	
005	**Company**	**Address**	**Telephone**	**Sponsor info**
	Eurofrigo	Egtenrayseweg 35	+31(0)6 23369703	Freezing cell in Holland for
	Contact	5929 PH	**Email and Website**	ice testing
	Paul Adams	Venlo	Paul.Adams@Eurofrigo.com	
		Netherlands	www.eurofrigo.com	BRONZE
006	**Company**	**Address**	**Telephone**	**Sponsor info**
	Transfennica			Transportation of 40ft container
	Contact		**Email and Website**	Antwerpen-Kotka-Antwerpen
	Rogier Heijnsbroek	Helsinki	Rogier.Heijnsbroek@transfennica.com	
		Finland	http://www.transfennica.com/	
007	**Company**	**Address**	**Telephone**	**Sponsor info**
	Stora Enso	Kanavaranta 1	Mobile +358 400 786659	Cellulose fibres 35 tons
	Contact	F1-00101 Helsinki	**Email and Website**	
	Kirsi Seppäläinen	Finland	kirsi.seppalainen@storaenso.com	
	Harri Snellman		www.storaenso.com	
008	**Company**	**Address**	**Telephone**	**Sponsor info**
	Pekkaniska	Pekkaniska Oy	Mobile +358 50 464 8208	Boom lifts
	Contact	Tiilipojanlenkki 1-5	**Email and Website**	JLG 510aj + JLG 800aj
	Jussi Kopsala	01720 Vantaa	www.pekkaniska.com	
		Finland	jussi.kopsala@pekkaniska.com	
009	**Company**	**Address**	**Telephone**	**Sponsor info**
	Arcadis	Postbus 220	M. +31 6 2706 0185	Health & Safety plan
	Contact	3800 AE Amersfoort	**Email and Website**	
	Maureen Lubbers	The Netherlands	maureen.lubbers@arcadis.com	
			www.arcadis.com	
010	**Company**	**Address**	**Telephone**	**Sponsor info**
	Easycool	Talmalaan 5	+ 31(0)6 520 381 80	Provides us 6 spraying pumps

		Contact Jom Klepper	3761 AK Soest Netherlands	**Email and Website** jklepper@easycool.nl www.easycool.nl	Including hoses and connections Helped a lot with testing during design **SILVER**
011	MAMMOET	**Company** Mammoet **Contact** Wim van Beek	**Address**	**Telephone** +1 780 449 0552 **Email and Website** Wim.van.Beek@mammoet.com www.mammoet.com	**Sponsor info** Main Steel cables ans transport
012	JLD INTERNATIONAL	**Company** JLD **Contact** **Jos Karsten** Directeur	**Address** Energiestraat 6 1135 GD EDAM, The Netherlands	**Telephone** T. +31 299 622 396 **Email and Website** Jos@JLDinternational.com www.JLDinternational.com	**Sponsor info** Anchors JLD1.0 80x(16kN), JLD1.2 40x(40kN) JLD2.2 8x(220kN)
013	METALLI PALVELU HARTIKAINEN OY	**Company** Metalli Palvelu **Contact** Kari Hartikainen	**Address**	**Telephone** **Email and Website** www.metallipalvelu.fi kari.hartikainen@metallipalvelu.fi	**Sponsor info** Metal repair works, various materials
014	Tulikivi	**Company** Tulikivi **Contact** Heikki	**Address** Nunnanlahti Finland	**Telephone** **Email and Website** www.tulikivi.fi heikki.vauhkonen@tulikivi.fi	**Sponsor info** Building site, office and accommodation working clothes
015	ROTATOR	**Company** Rotator **Contact** **Kirsi Ahonen**	**Address** Tuottotie 4, PL10 33961 Pirkkala Finland	**Telephone** Gsm +358 50 575 6617 **Email and Website** kirsi.ahonen@rotator.fi www.rotator.fi	**Sponsor info** Shovel, excavator
016	HITACHI Inspire the Next	**Company** Hitachi **Contact** Wilbert Blom Manager International Sales	**Address**	**Telephone** Mobile: +31 (0)6 53371558 **Email and Website** Wilbert.Blom@HCME.com www.hcme.com	**Sponsor info** Shovel
017	Tujanranta Consultants	**Company** Tujanranta **Contact** Tuula and Jan	**Address**	**Telephone** **Email and Website** www.tujanranta.com jan.graafmans@gmail.com	**Sponsor info** Contact persons Juuka Advise, local network, accommodation
018	SIOEN	**Company** SIOEN **Contact**	**Address**	**Telephone** **Email and Website** http://www.sioen.com/	**Sponsor info** Welding PVC membrane Pavilion
019	Poly-Ned Textielarchitectuur	**Company** Poly-Ned **Contact** Edwin Molenaar Bert Boezelman	**Address** Oostermeentherand 16 8332 JZ Steenwijk Netherlands	**Telephone** +31 (0) 521 320240 **Email and Website** emolenaar@polyned.nl www.polyned.nl	**Sponsor info** Welding PVC membrane Bridge Steel cables, foil, pump, knowledge

No.	Company	Contact	Address	Telephone	Email and Website	Sponsor info
020	AON	Jorden de Boer		(+)31 (0)10 448 7805 m +31 (0)6 532 009 79	Jorden.de.Boer@aon.nl	Insurrance
021	DB Schenker	Jonna Stenberg		www.logistics.dbschenker.fi	myynti.kiitolinja@dbschenker.com jonna.stenberg@dbschenker.com	Transport and a 40ft heated container
022	Kuvauskallinen					Various technical Support
023	Juuan Ivi oy				www.juuanlvi.fi posti@juuanlvi.fi	Plumbing Various water management works, expertise
024	Bevers	Jan Bevers			info@janbevers.nl	Various test equipment and materials
025	Cofely	Patrick van Vugt			patrick.van.vugt@cofely-gdfsuez.nl	Electrical components 1080
026	HSA Oy				www.hsaoy.com myynti@hsaoy.com	Automatic system for back-up power
027	MACO	Roberto Maffei		Mobile: +39 349 51 17 082	design@macotechnology.com	Sensor and monitor equipment 400
028	Pielisen maanrakennus				www.pielisenmaanrakennus.fi seppo@pmoy.fi	Site construction, groundwork, equipment, expertise
029	Saher Aidat					Fencing materials and expertise

No.		Company / Contact	Address	Telephone / Email and Website	Sponsor info
				www.saher.fi saher@saher.fi	
030		**Company** Sick **Contact** Mark Krijzer Chris Jorna	**Address**	**Telephone** **Email and Website** Mark.Krijzer@sick.nl Chris.Jorna@sick.nl	**Sponsor info** Sensor and monitor equipment 1050
031		**Company** Erica Project Advies **Contact** Tim ter Heide	**Address**	**Telephone** +31(0)651582715 **Email and Website** Erica.project.advies@xs4all.nl	**Sponsor info** Administration and support
032		**Company** van Doorn **Contact** Ewoud Heijman	**Address**	**Telephone** **Email and Website** ewoud.heijman@vandoren.nl	**Sponsor info** Electrical components 12000
033		**Company** Wago **Contact** Diederick Nab	**Address**	**Telephone** **Email and Website** Diederick.Nab@wago.com	**Sponsor info** Electrical components 6800
034		**Company** Josek **Contact**	**Address**	**Telephone** **Email and Website** www.josek.fi info@josek.fi	**Sponsor info** Funding of local coordination, expertise
035		**Company** Ahlsell **Contact** Reijo Paaso	**Address**	**Telephone** **Email and Website** www.ahlsell.fi reijo.paaso@ahlsell.fi	**Sponsor info** Valves
036		**Company** Hydlub **Contact**	**Address**	**Telephone** **Email and Website** www.hydlub.fi matti.tuominen@hydlub.fi	**Sponsor info** Technical Support
037		**Company** Juuan vankila **Contact**	**Address** Vepsänjoentie 2, 83900 Juuka, Finland	**Telephone** +358 10 3687950 **Email and Website** juuka.vankila@om.fi	**Sponsor info** Coffee cabin and garbage shelter
038		**Company** Kuljetus Jari Nevalaine **Contact** Jari Nevalaine	**Address**	**Telephone** **Email and Website**	**Sponsor info** Transportation services
039		**Company**	**Address**	**Telephone**	**Sponsor info**

		Offroadtarvike			Vehicles, equipment, expertise
		Contact		**Email and Website**	
				www.offroadtarvike.fi	
				posti@offroadtarvike.fi	
040		**Company**	**Address**	**Telephone**	**Sponsor info**
		Pielisen Kuljetus ja Jätehuolto			Garage repair works and transportation services
		Contact		**Email and Website**	
				toimisto@pielisenkuljetus.inet.fi	
041		**Company**	**Address**	**Telephone**	**Sponsor info**
		Sähkö-Jarska			Electrician, expertise and equipment
		Contact		**Email and Website**	
				www.sahkojarska.fi	
				jari.jehkonen@sahkojarska.fi	
042		**Company**	**Address**	**Telephone**	**Sponsor info**
		Vaarojen Sanomat			Various technical support
		Contact		**Email and Website**	
043		**Company**	**Address**	**Telephone**	**Sponsor info**
		Valokuvaaja Pentti Kallinen			Various technical support
		Contact		**Email and Website**	
				www.kuvauskallinen.fi	
				penttikallinen@pp.inet.fi	
044		**Company**	**Address**	**Telephone**	**Sponsor info**
		Fincopper Mr Boman			Shredder equipment
		Contact		**Email and Website**	
		Martti Boman			
045		**Company**	**Address**	**Telephone**	**Sponsor info**
		Pentti Mansikkaviita			Snow making expertise & equipment
		Contact		**Email and Website**	
046		**Company**	**Address**	**Telephone**	**Sponsor info**
		Universiteitsfonds			Financial Sponsor
		Contact		**Email and Website**	

Financial en Supporting Sponsors

047		**Company**	**Address**	**Telephone**	**Sponsor info**
		International Association of Ice and Snow Sculpures			
		Contact		**Email and Website**	
			Netherlands		
048		**Company**	**Address**	**Telephone**	**Sponsor info**
		VTT			

		Contact Kari Kolari	Finland	**Email and Website**	
049		**Company** Embassy of the Netherlands in Finland **Contact** Venla Virkamaki	**Address** Erottajankatu 19B 00130 Helsinki Finland	**Telephone** +358 9 228 920 **Email and Website** venla.virkamaki@minbuza.nl finland.nlambassade.org	**Sponsor info** Host meetings Helsinki SLUSH contact Sends ambassador at opening
050		**Company** Municipality of Juuka **Contact**	**Address**	**Telephone** **Email and Website** www.juuka.fi kirjaamo@juuka.fi	**Sponsor info** funding and various in-kind support
051		**Company** North Karelia Regional Council **Contact**	**Address**	**Telephone** **Email and Website** www.pohjois-karjala.fi kirjaamo@pohjois-karjala.fi	**Sponsor info** funding of local coordination and tourism development
052		**Company** Vaarojen Sanomat **Contact**	**Address**	**Telephone** **Email and Website** www.vaarojensanomat.fi toimitus@vaarojensanomat.fi	**Sponsor info** local media and promotion

calculation: buildingcosts

03 technology & construction	Part	Description	Amount	M1/M2/M3/pieces	Duration (days	Costs per unit	Total sponsored	Costs - sponsored	Total costs	Subtotal	Covered by Juuka kuunta	To be asked	Asked	Confirmed	Rejected	Sponsor/own	Responsible	Remarks	30-nov	15-dec	30-dec	15-jan	30-jan	15-feb	28-feb	15 march	30 march	15-apr	30-apr	15 mai	30 mai	total
																																0
1	**Permissions**									€ 2.250,00																						0
1,1	Bridge in Ice	building permission	1	pieces		0	0	0	0		0					Juuka kunta	Ari, Arno, Thijs, Roel															0
1,2	Pavilion	building permission	1	pieces		0	0	0	0		0					Juuka kunta	Ari, Arno															0
1,3	Snowtrack/rest	building permission	1	pieces		0	0	0	0		0					Juuka kunta	Ari, Arno															0
	enviromental report, water managment		1	pieces		750	1.500	0	1.500		1500					Juuka kunta			1500													1500
1,4	Event	event permissions (	1	pieces		750	750	0	750		750					Juuka kunta	Johanna, Heidi, Arno		750													750
																																0
2	**Material Bridge in Ice**									€ 32.020,00																						0
2,1	Anchors	anchors for rope pa	100	pieces		15,00	1.500	0	1.500							JLD	Arno															0
2,2	Main anchors	anchors for middle	4	pieces		30,00	120	0	120							JLD	Arno															0
2,3	Guy anchors	anchors for securin	6	pieces		30,00	180	0	180							JLD	Arno															0
2,4	Main cables	steel main cables	120	m		5,00	0	600	600							Mammoet?	Arno (Mammoet) Thijs, Roel															0
2,5	Rope	rope net	5000	m		1,00	5.000	0	5.000							Chr.Muller to	Thijs, Roel															0
2,6	Rope	rope support	300	m		1,00	300	0	300							Chr.Muller to	Thijs, Roel															0
2,7	Membrane	pvc foil 650 gr/m2	2500	m²		3,00	7.500	0	7.500							Scantarp/Poly	Arno (Scantarp), Thijs, Roel (Polyned)															0
2,8	Cellulose	cellulose plates m3	35	m³		300,00	10.500	0	10.500							Stora Enso	Arno, Matti					0										0
2.9	construction site	earth moving works			5		5.900	0	5.900		5900					Juuka kunta			5900			0										5900
2.10	storage container	repiar work on the existingcontainer					420	0	420		420					Juuka kunta			420													420
3	**Material Pavilion**									€ 1.920,00																						0
3,1	Anchors	anchors for rope pa	8	pieces		15,00	120	0	120							JLD	Arno en Bram															0
	extra steel for anchors					300,00	0	300	300							juuka kunta			0													
3,2	Rope	rope net	100	m		1,00	100	0	100							Chr.Muller to	Bram, Thijs, Roel															0
3,3	500	pe foil (? Thickness)	1000	m²		0,20	200	0	200							Scantarp/Poly	Bram															0
3,4	Cellulose	cellulose plates m3	4	m³		300,00	1.200	0	1.200							Stora Enso	Arno, Matti															0
																																0
4	**Material Snow Park**									€ 10.088,00																						0
4,1	Snow	electricity costs for	5000	m³	10	150,00	1.500	0	1.500		1500					Juuka kunta	KU Leuven/Jyvaskyla, Arno						1500									1500
4,2	Constructions	snow moulds (plyw	70	m2		1.188,00	1.188	0	1.188		1188					Koskisen saha	Matti, Heidi		1188													1188
4,3	Excavator	filling the moulds w	1	pieces		500,00	500	0	500		500					Pielisen Maar	Matti						500									500
4,4	Tourism facilities	e.g. walls, playgrounds. Signs,	1			5.000	5.000	0	2.000		5000					Juuka kunta, I	Matti, Heidi						5000									5000
4,5	Lightning	lights along snowtra	1	pieces		3.000	0	3.000	3000							Tulikivi/Philip	KU Leuven/Jyvaskyla, Arno					3000										3000
4,6	Sculptures	leonardo domes bij	1	pieces		1.500	0	1.500	1500							KU Leuven	Arno, Rinus Roelofs, Juuka, Dirk Huylebrouck					1500										1500
4,7	Log house(?)	inclusive transport .	1	pieces		400	200	200	400		200					Juuka kunta	KU Leuven/J	if a log house	200													200
																																0
5	**Quarry Snowtrack & Ski slope**															Tulikivi?		The land-owner Tulikivi will														0
																																0
6	**Material Frozen waterfall**									€ 6.000,00																						0
6,1	Viewpoints		1	pieces		2500	2500	0	2.500		2500					Juuka kunta, T	KU Leuven/Jyvaskyla, Arn		2500													2500
6,2	Waterfall		1	pieces		2000	1.000	1.000	2.000		2000					Tulikivi, Juuka	KU Leuven/Jyvaskyla, Arn		2000													2000
6,3	Lightning waterfall		1	pieces		1500	0	1.500	1.500							Tulikivi/Philip	KU Leuven/Jyvaskyla, Arno															0
																																0
7	**Equipment all projects**									€ 25.000,00																						0
7,1	Airblowers	cap. 45m3 / min, sp	1	pieces		0,00	0	0	0		0					Juuka kunta	Thijs, Roel, I	Is one spare blower sufficient?														0
7,2	Electricity backup	2 electric connectio	3	pieces	50	2.100,00	6.300	0	6.300							Transfennica/	Matti															0
7,3	shovel / forklift	shovel	2	pieces	50	60	6.000	0	6.000							Hitachi	Thijs, Roel, Matti/Arno															0
7,4	Boomlift	telescopic boomlift	2	pieces	50	70	4.600	2.400	7.000							**Pekkaniska**	Arno??				2.400											2400
7,5	Pick up truck	for pulling the snow	1	pieces	50	60	3.000	0	3.000							Timo Lippone	Thijs, Roel, Matti															0
7,6	Forklift		0	pieces	50	60	0	0	0							Tulikivi	Thijs, Roel, Matti															0
7,7	Chainsaw		2	pieces	20	15	600	0	600							Local farmers	Thijs, Roel, I	"buy" chainsaw work from local farmers														0
7,8	Wheelbarrow	without flat tire!	1	pieces		100	100	0	100								Thijs, Roel, Matti															0
7,9	Other	small (hand-)equipr	1	pieces		1.000	500	500	1.000								Technical co	inventarisation list has to be made				500										500
7,10	Other	repair work & back-	1			1.000	1.000	0	1.000		1.000					Juuka kunta				500			0									500
8	**Equipment Mixing + Spraying system**									€ 8.270,00																						0
8,1	Pre-mix tank	IBC tank or similar	2	pieces		50	100	0	100							summa	Thijs, Roel, Matti															0
8,2	Container	for mixing cellulose	2	pieces		500	1.000	0	1.000		0					Pielisen kuljet	Thijs, Roel, Matti															0
8,3	Mixing system	pump or propellor,	2	pieces		160	320	0	320							summa colleg	Arno Yaron															0
8,4	Spray pumps		3	pieces		1.200	3.600	0	3.600							Easycool/Eno	Thijs, Roel, J	asking for type at Easycool														0
8,5	Fire hoses	range 20 m	10	pieces		0	0	0	0		0					Juuka kunta	Thijs, Roel, I	check														0
8,6	Spraying nozzles		4	pieces		0	0	0	0		0					Juuka kunta	Thijs, Roel, Matti, Jari, Ari															0
8,7	Schredder	for cutting cellulose	1	pieces	50	60	3.000	0	3.000							matti	Thijs, Roel, I	has to be tested														0
8,8	Mixing by hand	mortar mixer	1	pieces	50	5	250	0	250							Jari Nevalaine	Thijs, Roel, Matti															0
																																0
9	**Equipment Bridge in Ice**									€ 3.700,00																						0
9,1	Airblowers	cap. 45m3 / min	2	pieces		0	0	0	0		0					Juuka kunta	Thijs, Roel, Matti															0
9,2	IBC Tank	covering air blower	2	pieces		0,00	0	0	0		0					Juuka kunta, I	Thijs, Roel, Matti															0
9,3	Sensoring air blower	alarming by electric	4	pieces		200,00	800	0	800							summa	Thijs, Roel, Yaron, Summa															0
9,4	Nanometers	measuring air press	2	pieces		200,00	400	0	400							summa	Thijs, Roel, Yaron, Summa															0
9,5	Crane	mobilecrane for de	1	pieces		2.000	2000	0	2.000							mammoet	Arno, Matti															0
	support of the inflatable		1	pieces		2.000	0	500	500													500										500
10	**Equipment Pavilion**									€ -																						0
10,1	Airblowers	cap. 45m3 / min	1	pieces		0,00	0	0	0		0					Juuka kunta	Thijs, Roel, Bram, Matti															0
10,2	IBC Tank	covering air blower	1	pieces		0,00	0	0	0		0					Puljonki-Nest	Thijs, Roel, Bram, Matti															0

Bridge in Ice

calculation: buildingcosts

11	**Equipment Snowtrack/Sleigh Slope/Frozen waterfall**									€ 1.600,00	
11,1	Snow plow on shove	rotary snowplow	1	pieces		100	100	0	100		100
11,2	Snow lance	improvements of sr	1	pieces		1.500	1.500	0	1.500		1500
11.3	transport snow cannon koli										0
12	**Consumption**									€ 11.000,00	
12,1	Water		4000	m^3		0	0	0	0		0
12,2	Electricity	kWh use	50	kW	1250	0,14	3.000	5.750	8.750		3000
12,3	Fuel		1500	litres		1,50	0	2.250	2.250		
13	**Construction site**									€ 9.528,00	
13,1	Construction site rer	Tulikivi site rent	1	pieces		500	500	0	500		500
13,2	High pressure water	pump	1	pieces		0	0	0	0		0
13,3	Water supply	water pump inc. ho	1	pieces		0	0	0	0		0
13,4	Water connections	fire brigade like cor	3	pieces		200	600	0	600		600
13,5	Cupboard	electricity divider <-	1	pieces		0	0	0	0		0
13,6	Electricity cables	in lenghts of 25 to 5	500	m^1		1,50	750	0	750		750
13,7	Cable under the grou	to other side of con	1	pieces			0	0			0
13,8	Electricity poles	with RCD <- what is	4	pieces		250	1.000	0	1.000		1000
13,9	Construction lights	poles of 50m high v	4	pieces		0	0	0	0		0
13,10	Worklights	for lighting up sevel	5	pieces		20	100	0	100		
13,11	Tech. (pump) house	heated place to cor	1	pieces		2.000	600	0	600		600
13,12	Storagehall	min. 50 m2, dry anc	1	pieces		1.000	2.178	0	2.178		2.178
13,13	Site hut (caravan)	heated caravan for	1	pieces		0	0	0	0		0
13,14	Piping works	piping to get water	1				1800	0	1.800		1800
	heating in pining works						2900				2900
13,15	Site maintenance	snow ploughing, cle	1	pieces	20	150	1.000	0	1.000		1000
13,16	Cleaning after constı	clean up building si	1	pieces	3	1.000	0	1.000	1.000		
13,17	Cleaning after touris	Clean up building si	1	pieces	7	2.000	1.000	-1.000	0		1.000
14	**Safety**									€ 11.220,00	
14,1	Guards	what do these guar	5	persons	5	150	3.750	0	3.750		
14,2	Fences		400	m^1	50	0,05	2.000	0	2.000		400
14,3	Railing	along bridge sides	150	m^1	50	0,10	0	750	750		
14,4	Gravel, sand	roads, walkways, br	15	times		70	400	650	1.050		400
14,5	Headlights		15	pieces		10	0	150	150		
14,6	Helmets & winter hats "pipo"		25	pieces		10	250	0	250		
14,7	Safety harness	for working with bo	6	pieces		25	150	0	150		
14,8	First aid kit		2	pieces		60	0	120	120		
14,9	Monitoring during cc	measuring and mor	1	pieces		2.000	2.000	0	2.000		
14,10	Monitoring after ope	measuring and mor	1	pieces		1.000	1.000	0	1.000		1.000
15	**Insurance**									€ 1.000,00	
15,1	Building and event insurance		1			1.000	1000	0	1.000		
16	**Facilities**									€ 7.860,00	
16,1	Office	rent Stone Center o	1	pieces	50	80	2.000	2.000	4.000		2.000
16,2	Shoes	for loan	20	pieces		120	0	2.400	2.400		
16,3	Clothes	for loan	50	pieces		0	0	0	0		
16,4	Gloves		100	pieces		10	1.000	0	1.000		
16,5	Music installation		1	pieces		0	0	0	0		
16,6	Firewood		25	m^3		0	0	0	0		
16,7	Webcam	for streaming	2	pieces		200	400	0	400		400
16,8	Coffee machine	coffee machine in s	1	pieces		30	30	0	30		30
16,9	Heater	heater in site hut	1	pieces		30	30	0	30		30
17	**Transport**									€ 8.400,00	
17,1	in Holland before		1	pieces		1.200	1.200	0	1.200		
17,2	Antwerp-Kotka-Antwerp		1	pieces		2.500	2.500	0	2.500		
17,3	in Holland after		1	pieces		800	800	0	800		
17,4	Kotka- Juuka-Kotka		2	pieces		300	2200	0	2.200		
	Anchors							400	400		
17,5	Expert service	technical travelling	4	pieces		75	0	300	300		
17,6	Other		1	pieces		1.000	0	1.000	1.000		
18	**Testing**									€ 500,00	
18,1	Freezingcell researcl	in Venlo at Eurofrig	1	pieces	15	0	0	0	0		
18,2	Material and equipment cost		1	pieces		500	500	0	500		
18,3	Laboratorium test	Stone Center	1	pieces	4	0	0	0	0		
18,4	Laboratorium test	Eindhoven, Gent, H	1	pieces		0	0	0	0		
19	**Travelling**									€ 4.500,00	
19,1	June	preparation trip 2-9	3	persons	8	500	1500	0	1.500		
19,2	October	preparation trip 7-1	4	persons	4	600	2400	0	2.400		
19,3	November/Decembe	preparing building s	1	persons	5	600	600	0	600		
20	**Management**									€ 256.536,44	
20,1	Arno Pronk		1	persons	50	960	48.000	0	48.000		
20,2	Thijs van de Nieuwenhof		1	persons	50	0	0	0	0		
20,3	Roel Koekkoek		1	persons	50	0	0	0	0		
20,4	Liselotte de Haan	internship events fr	6	months		170	1.020	0	1.020		

												0
11												0
11,1	Asko/Juuka ku	Asko, Arno, Jari			100							100
11,2	Juuka kunta, .	Arno, Matti			1500							1500
11.3					0							0
												0
12												0
12,1	Juuka kunta, '	Arno, Ari										0
12,2	Juuka kunta, (	Arno, Hugo							3000			3000
12,3	ask Neste or S	Thijs, Roel, Matti			562,5	562,5	562,5	562,5				2250
												0
13												0
13,1	Tulikivi/Juuka	Arno, Hugo										0
13,2	Juuka kunta	Thijs, Roel, Matti										0
13,3	Juuka kunta, '	Thijs, Roel, I	Risto Hirvonen, P. Mansikkaviita									0
13,4	Nurmes Fire b	Thijs, Roel, I	Nurmes fire brigare		600							600
13,5	Juuka kunta	Thijs, Roel, Matti, Ari										0
13,6	Juuka kunta	Thijs, Roel, Matti			750							750
13,7	Juuka kunta	Thijs, Roel, Matti, Ari										0
13,8	Juuka kunta/T	Thijs, Roel, Matti			1000							1000
13,9	Juuka kunta	Thijs, Roel, Matti, Ari										0
13,10	Tulikivi	Thijs, Roel, Matti		100								100
13,11	Juuka kunta	Thijs, Roel, Matti		600								600
13,12	Juuka kunta	Thijs, Roel, Matti		2178								2178
13,13	Juuka kunta	Thijs, Roel, Matti										0
13,14	Tulikivi, Juuka kunta			1800								1800
				2900								
13,15	Structuralice	Tuula, Ari		1000		0	0	0	0	200		1200
13,16	Structuralice,	Arno, Thijs, Roel					1.000					1000
13,17	Structuralice	Arno, Thijs,	How to collect the pulp and where to take it?							-1.000	1.000	0
												0
												0
												0
												0
												0
14												0
14,1		Arno, Ari				0	0	0	0	750		750
14,2	??	Arno, Ari, M	If Turva-aidat not availa	400								400
14,3		Arno, Thijs, Roel, Matti, Ari						750				750
14,4	Tulikivi/Juuk	Thijs, Roel, Matti		400								400
14,5		Thijs, Roel, Matti		150								150
14,6	Pekkaniska	Arno										0
14,7	Pekkaniska	Arno										0
14,8		Thijs, Roel		120								120
14,9	TU/e	Arno, Jari										0
14,10	Juuka kunta	Ari	possibly financed from ticket fees								1.000	1000
												0
15												0
15,1	AON	Arno										0
												0
16												0
16,1	Juuka kunta,	Arno, Heidi	not renting the 2nd floc	4000								4000
16,2	Elmo sport??	Thijs, Roel		2.400								2400
16,3	Tulikivi	Arno, Thijs, Roel										0
16,4	volunteers	Thijs, Roel										0
16,5		Thijs, Roel										0
16,6	Juuka volunte	Thijs, Roel, Matti										0
16,7				400								400
16,8		Thijs, Roel, Matti		30								30
16,9		Thijs, Roel, Matti		30								30
												0
17												0
17,1	Mammoet/tu	Thijs, Roel										0
17,2	Transfennica	Arno										0
17,3		Thijs, Roel								0		0
17,4	mammoet	Arno, Matti										0
				400								
17,5		Arno, Matti	what is this?				300					300
17,6		Arno, Matti				200	200	200	200	200		1000
												0
18												0
18,1	Eurofrigo	Arno										0
18,2	TU/e	Thijs, Roel, SD Research										0
18,3	Geological Re	Arno										0
18,4	Universities	Arno, Hans Lamers, Thijs, Roel										0
												0
19												0
19,1	TU	Arno, Thijs, Roel, Hugo										0
19,2	TU	Arno, Thijs, Roel, Hugo										0
19,3	TU	Arno, Thijs, Roel, Hugo										0
												0
20												0
20,1	TU/e	Arno										0
20,2	Student	Roel										0
20,3	Student	Thijs										0
20,4	TU/e, Sint Luc	Thijs, Roel										0

Bridge in Ice

calculation: buildingcosts

20,5	Matti Tuominen		1	persons	40	480	19.200	0	19.200							Volunteer, as	Matti															0
20,6	Jari Repo		1	persons	40	480	19.200	0	19.200							Volunteer, association																0
20,7	Hugo Sanders		1	persons	25	480	12.000	0	12.000							Volunteer, as	Hugo															0
20,8	Ari Jaaranen		1	persons	15	200	0	0	0		0					Juuka kunta	Hugo	in-kind support									3000					3000
20,9	Assistance by fire brigade		2	persons	10	480	9.600	0	9.600																							0
20,13	Film	supervisors (from S	2	persons	25	480	24.000	0	24.000							Sint Lucas	Thijs, Roel															0
20,14	Film	students (from Sint	2	persons	25	0	0	0	0							Sint Lucas	Supervisors Sint Lucas, Thijs, Roel															0
20,15	Photography	supervisors (from S	2	persons	25	480	24.000	0	24.000							Sint Lucas	Thijs, Roel															0
20,16	Photography	students (from Sint	2	persons	25	0	0	0	0							Sint Lucas	Supervisors Sint Lucas, Thijs, Roel															0
																																0
20,17	Volunteers		30	persons	50	60	90.000	0	90.000							Volunteers	Everyone															0
	unforseen juuka kunta						0	0	0		0											0	0	0	0	0						
	not in budget of juuka covered by ass		1.646				0	1.646	1.646													329	329	329	329	329						1646
	unforseen association						0	7.870	7.870													1574	1574	1574	1574	1574						
	Total						**370.506**	**36.786**	**401.392**	**401.392**	**43.646**							**total out**	14458	17408	6913	8166	10966	3416	5103	2053	5000	0	0	0	0	73482,44
																		bank association	0	2770	563	8166	3966	3416	2103	2053	0	0	0	0	0	23036,44
																	Arno, Thijs,	**Juuka kunta**	14458	14638	3950		7000		3000		5000					48.046
																		TU/e			2400											2400
	Financial sponsor target								36.786									total	14458	17408	6913	8166	10966	3416	5103	2053	5000	0	0	0	0	73482,44
	Date: 13 december 2015 break even																															

Appendix 7

Be part of the Bridge in Ice Project

* Required

1. **I will be part of the Da Vinci's Bridge in Ice Project as? ***
   Please select one of the options. You wil go to next page after submitting.
   Mark only one oval.

   - Volunteer, including individual membership: 350€ *Skip to question 2.*
   - Individual Membership: 50€ *Skip to question 24.*
   - Membership for Companies: 200€ or 1000€ *Skip to question 34.*

Volunteer

General information

We only use this information for contacting you or in case of emergency. We don't give this information to third parties.

2. **First Name ***

3. **Last Name ***

4. **Gender ***
   Mark only one oval.

   - Male
   - Female

5. **Date of birth ***
   Example: December 15, 2012

6. **Address ***

7. **Postal code ***

8. **City ***

9. **Country ***

10. **Email Address** *

11. **Confirm Email Address** *

12. **Phone number** *

13. **Organisation**

14. **Type**
Check all that apply.

- [ ] Student
- [ ] Teacher
- [ ] Other: ____________________

15. **Relation of** *
Let us know if you have a relation to someone of the people below. We will take this into acount when we make the schedules.
Mark only one oval.

- ( ) Arno Pronk
- ( ) Thijs van de Nieuwenhof
- ( ) Roel Koekkoek
- ( ) Bram Ronsse
- ( ) Other: ____________________

16. **Driving license** *
Mark only one oval.

- ( ) Yes
- ( ) No

Project Information:

17. **Which week are you available** *

We are building from the 28th of December till the 14th of February. We will work in shifts 24/7. To make a proper planning we would like to know which week(s) you are planning to help us. It's not obligated to arrive in the weekends. It's just an indication.

Check all that apply.

- [ ] week 1 (28 Dec - 03 Jan)
- [ ] week 2 (04 Jan - 10 Jan)
- [ ] week 3 (11 Jan - 17 Jan)
- [ ] week 4 (18 Jan - 24 Jan)
- [ ] week 5 (25 Jan - 31 Jan)
- [ ] week 6 (01 Feb - 07 Feb)
- [ ] week 7 (08 Feb - 14 Feb)

18. **Arrival date**

Only when you already know

Example: December 15, 2012

19. **Departure date**

Only when you already know

Example: December 15, 2012

20. **How do you want to participate** *

More options are possible

Check all that apply.

- [ ] Care team
- [ ] Building team
- [ ] Student supervisor
- [ ] Other:

21. **Shoe size** *

as an indication for the size of the work shoes(eu standard size)

22. **Clothing size** *

as an indication for the size of the work suits

Check all that apply.

- [ ] XS
- [ ] S
- [ ] M
- [ ] L
- [ ] XL
- [ ] Other:

Other Information:

23. **If you have questions or information that is relevant please let us know**
(allergies,diet,handicap)

Skip to "Welcome in our team!!."

Individual Membership

As a member of Rakennejää ry/Structural Ice association you support its activities and contribute to its objectives. You can get information via our newsletter. Members of the association are informed about all activities: Entrepreneur members get more visibility in happenings, projects and the website of the association.

Name and Function

24. **First name** *

25. **Surname** *

26. **Title** *

27. **Function** *

28. **Company name** *

Personal Information

29. **Adress** *

30. **Zip code** *

31. **Town** *

32. **Phone** *

33. **Email Address** *

Skip to "Welcome as a member!."

Membership for Companies

As a member of Rakennejää ry/Structural Ice association you support its activities and contribute to its objectives. You can get information via our newsletter. Members of the association are informed about all activities: Entrepreneur members get more visibility in happenings, projects and the website of the association.

34. **Membership fee 2015** *

Mark only one oval.

- SMEs (small and medium enterprises): 200€
- Large enterprises: 1000€

35. **First name** *

36. **Surname** *

37. **Title** *

Company Information

38. **Function** *

39. **Company name** *

40. **Adress** *

41. **ZIP code** *

42. **Mailbox nr.**

43. **Email Address** *

44. **Website** *

General information

After receiving your registration, companies
receive an invoice.
Invoices do not include VAT

Skip to "Welcome as a member!."

Welcome as a member!

We are very greathfull for your support.

Membership secretary:
Ms. Anna-Liisa Nykyri;
p. +358 503 707 823
e-mail: Anna-liisa.nykyri@altili.fi

Stop filling out this form.

Welcome in our team!!

Thank you for subcribing us. We keep you updated about the project. If you have a question don't hesitate to e-mail or Phone us.
We are verry greatfull with your support. Follow the process on www.structralice.com and on our Facebook page. We are also active on Twitter and Instagram.

Appendix 8

Juuka

BRIDGE ICE

Candela Pavilion

Finland

JUUKA IN ICE

Juuka, Finland

28 December 2015 - 14 February 2016

VOLUNTEER GUIDE

HELP US CONSTRUCT A WORLD RECORD!

STRUCTURAL ICE ASSOCIATION - RAKENNEJÄÄ RY - WWW.STRUCTURALICE.COM

Collaboration of

SUP PORT

Juuka

TU/e Technische Universiteit Eindhoven University of Technology

UCL Université catholique de Louvain

TU Delft

UNIVERSITY OF TWENTE.

UNIVERSITY OF BATH

KU LEUVEN

UNIVERSITEIT GENT

UNIVERSITY OF JYVÄSKYLÄ

SUMMA College

RusHydro

Aalto University

Karelia UNIVERSITY OF APPLIED SCIENCES

THE UNIVERSITY OF EDINBURGH

SINTLUCAS CREATIVE COMMUNITY

Fontys

VTT

COLOPHON

This information guide contains the necessary information for visiting the place of Juuka, Finland, during the construction of Da Vinci's Bridge in Ice, Candela in Ice and all other ice-projects during winter 2016, further mentioned as Juuka in Ice.

Construction Date
28 December 2015 - 14 February 2016
Juuka, Finland

Involved researchers

ir. Arno Pronk	TU/e and KU Leuven
ir. Rijk Blok	TU/e
ir. Arjan Habraken	TU/e
ing. Cor de Bruijn	TU/e
prof.Dr.-Ing. Patrick Teuffell	TU/e
Dr. D. Huylebrouck	KU Leuven
prof.dr.ir. Jan Belis	Ghent University
Kenny Martens	Ghent University
Bert van Lancker	Ghent University
prof. Nicolai Vasiliev	RusHydro
prof. Juha Paavola	Aalto University
prof. Lauri Salokangas	Aalto University
Syda Tabassum	Aalto University
Elke Mergny	UC Louvain
dr. John Orr	University of Bath
prof. Remo Pedreshi	University of Edinborough
prof. Paulo Cruz	Universidade do Minho
dr. Kari Kolari	VTT
Jean Paul Verhofstad	Summa College
Hans van den Elzen	Summa College
Aldert Walrecht	Sint Lucas

Contact
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Website: www.structuralice.com

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Eindhoven University of Technology
De Groene Loper 6: Vertigo
5612 AZ
Eindhoven, Netherlands
Post: Postbus 513 5600 MB Eindhoven

Address building site/office Finland
Tulikivi Stone Center/Kivikeskus
Joensuuntie
1226
Nunnanlahti, Finland

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PROJECT STAFF on SITE

Bridge in Ice

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Thijs van de Nieuwenhof	t.a.h.v.d.nieuwenhof@student.tue.nl
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safety instructor	+31 (0)6 22 02 99 12

Candela in Ice

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Snowtrack

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Brice Hebbelynck	brice.hebbelynck@student.kuleuven.be
student contact	+32 (0)478 43 23 78

PROJECT COORDINATION

Explotation and technical coordination

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municipality of Juuka	+358 (0) 401 04 26 01

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Media, film and photography

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photo and film crew (in Finland)	+31 (0) 6 26 78 18 69
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Contact person in the Netherlands

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chairman study association SUPport, contact at TU/e	+31 (0) 6 14 88 61 51

On page 56 you will find more contact information regarding the trip to Finland.

STRUCTURAL ICE ASSOCIATION

Building with ice is one of the most environmental-friendly ways to make a building. There is a long tradition in making igloos, but the technical improvements for making ice buildings is a new field with just a handful of researchers.

Tsutomu Kokawa has created several ice domes in the north of Japan with a span up to 25 meters. The igloos are lower but have a wider span compared to other domes. Kokawa manipulated the inflatable at the outside with cables. In this way he realized geodesic domes with a grid of ice beams with optimized shell elements in between the surface of the grid. Matti Orpana made a 15m span igloo with an inflatable mould. Arno Pronk constructed an artificially cooled igloo with an inflatable mould in 2004. Lancelot Coar realized a wobbly structure with fiberglass bars and hanging fabric as a mould for an ice vault.

In January 2014 Pronk realized an ice dome with a span of 30 meters with students of the TU/e. The dome was partly realized with fiber-reinforced ice composites in Finland. The goal of research was to prove that ice composites can be constructed on site by spraying. Ice composite is 3 times stronger and 10 times tougher than regular ice. Not all of the possibilities of the material have been researched. The use of ice composites in the design of large-span bridge is the topic of this year's project. The goal is to realize an ice composite bridge with a span of 35 meter in Finland in the winter of 2016. Students and volunteers will work together with an interdisciplinary and international team.

If this project succeeds, the structure will be a new record.

Ghent University will design and construct the Los Manantiales Restaurant by Felix Candela in ice. The 1958 shell structure was built in Xochimilco in Mexico City. This restaurant is one of the most well-known buildings by Candela. The original building is 42 meter in diameter and 8.25 meter high. The ice building in Juuka will be made on an inflatable mould and will have a span of about 15 meter.

Beside the bridge and the pavilion there will be a snow track alongside an old quarry. Along the 70 meters deep quarry we will make a frozen waterfall you can see from the snow track. The snow track will lead you among several icy experiments, as it's a real ice-paradise. You will have a splendid view over this part of Finland. The Catholic University Leuven will be responsible for this part.

Further on in this booklet you will find a drawing of the venue with the park, snow track alongside the quarry and several view points where you can see the frozen waterfall. The entrance of the park is the stone center with a gift shop, the offices of the Structural Ice Association with storage, bathrooms, museum, lecture room, etc.

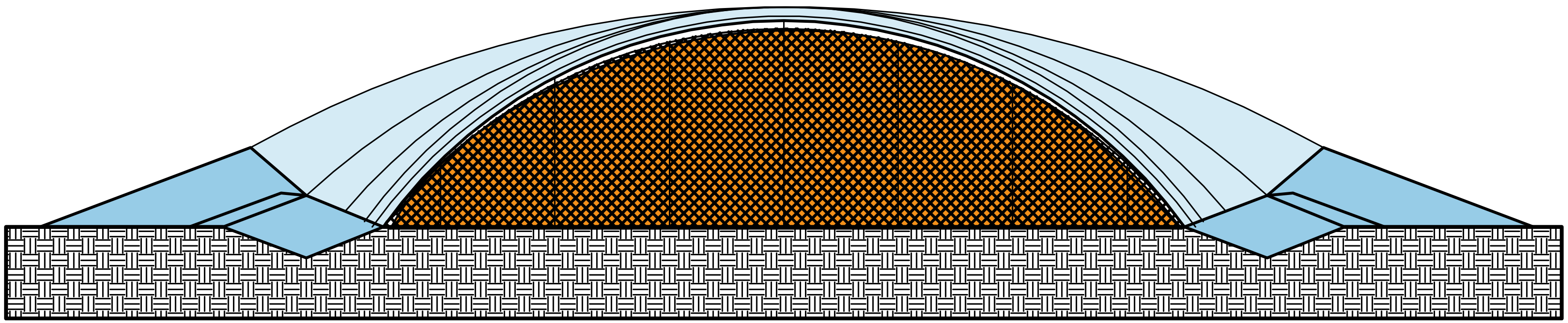
The Structural Ice Association in cooperation with the municipality of Juuka and the Eindhoven University of Technology are the organizers of the ice events in Juuka.
A team of about 150 people will realize the ice projects in 7 weeks time in Juuka.
The construction on site will start at 28 December and the opening of the bridge is scheduled on 13 February.

CONSORTIUM

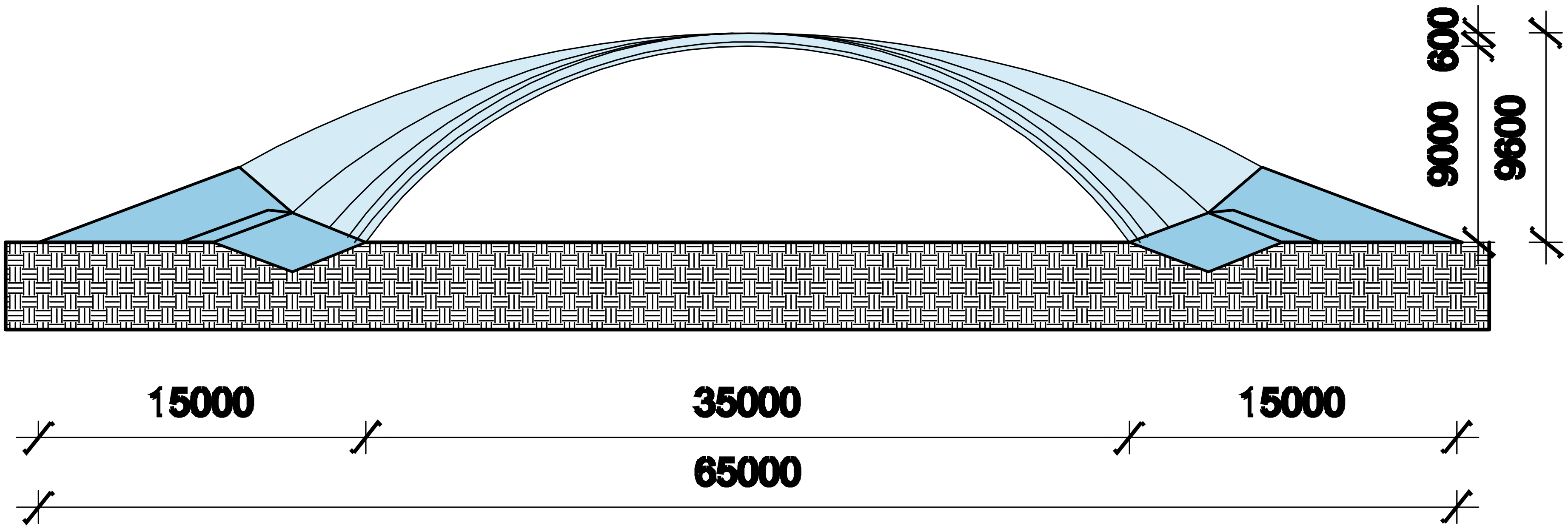

1 TU/e Technische Universiteit Eindhoven University of Technology
2 Juuka
3 UNIVERSITY OF TWENTE.
4 TUDelft
5 Fontys
6 KU LEUVEN
7 UNIVERSITEIT GENT
8 UNIVERSITY OF BATH
9 THE UNIVERSITY of EDINBURGH
10 RusHydro
11 Aalto University
12 Karelia UNIVERSITY OF APPLIED SCIENCES
13 UNIVERSITY OF JYVÄSKYLÄ
14 VTT
15 SiNTLUCAS
16 SUMMA College
17 Universidade do Minho


Da Vinci's BRIDGE IN ICE
Da Vinci's
BRIDGE in ICE

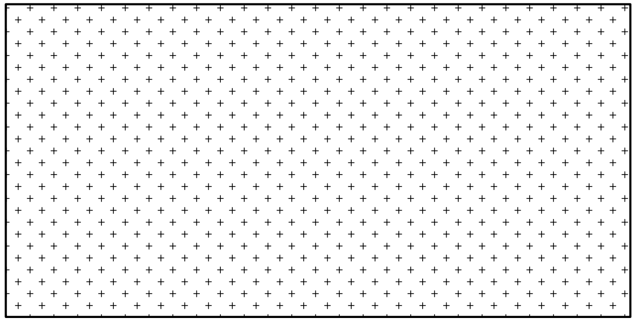
DESIGN WITH INFLATABLE



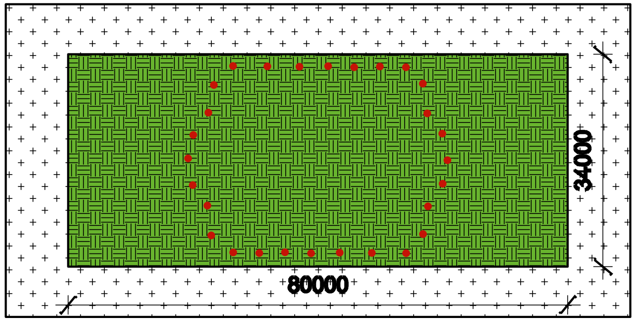
DESIGN WITHOUT INFLATABLE



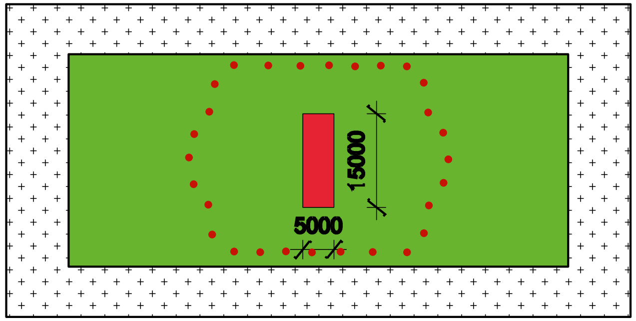
CONSTRUCTION METHOD



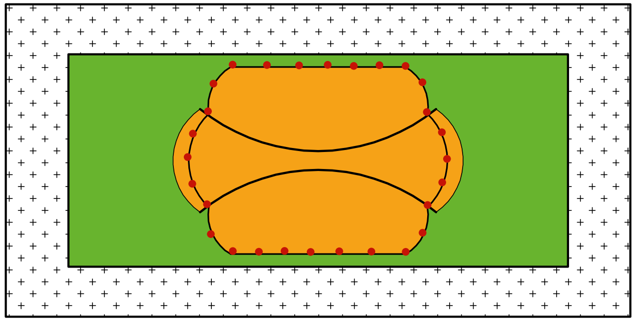
- Building site



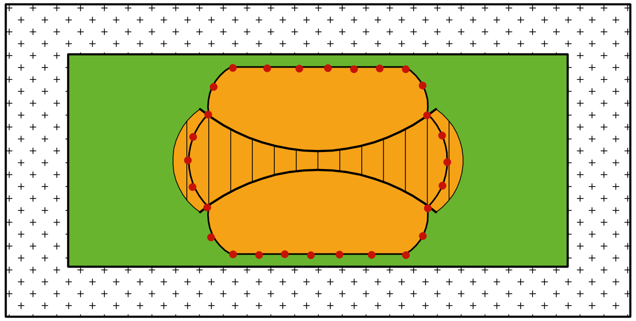
- Prepare groundwork
- Place anchors



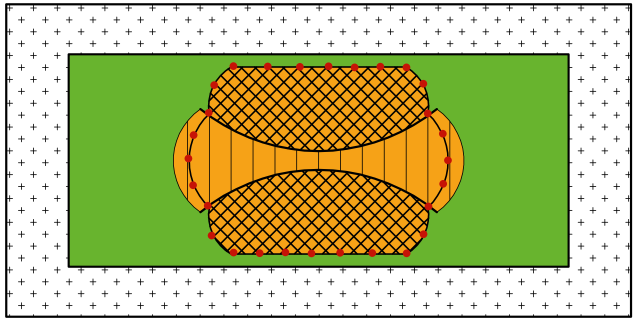
- Unfold inflatable



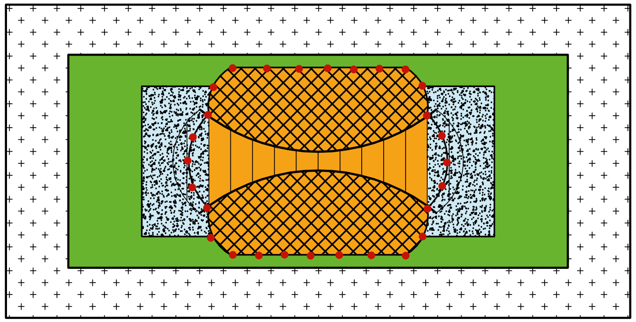
- Unroll inflatable
- Attach main cables to main achorpoints



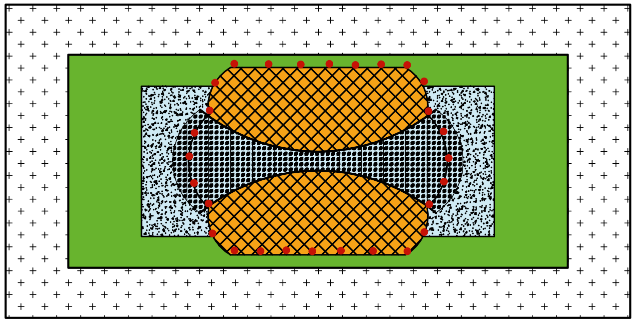
- Connect main cables



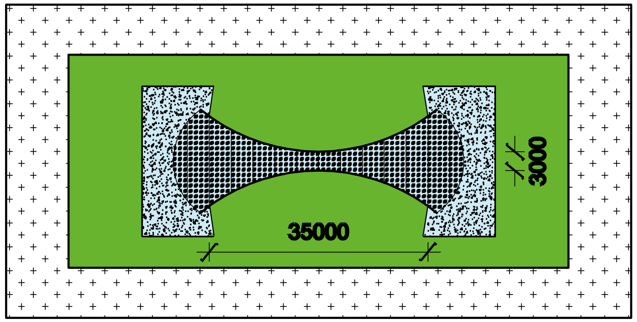
- Attache ropestructure to main cablestructure
- Connect ropestructure to inflatable



- Inflate inflatable
- Create ice mass at foundation

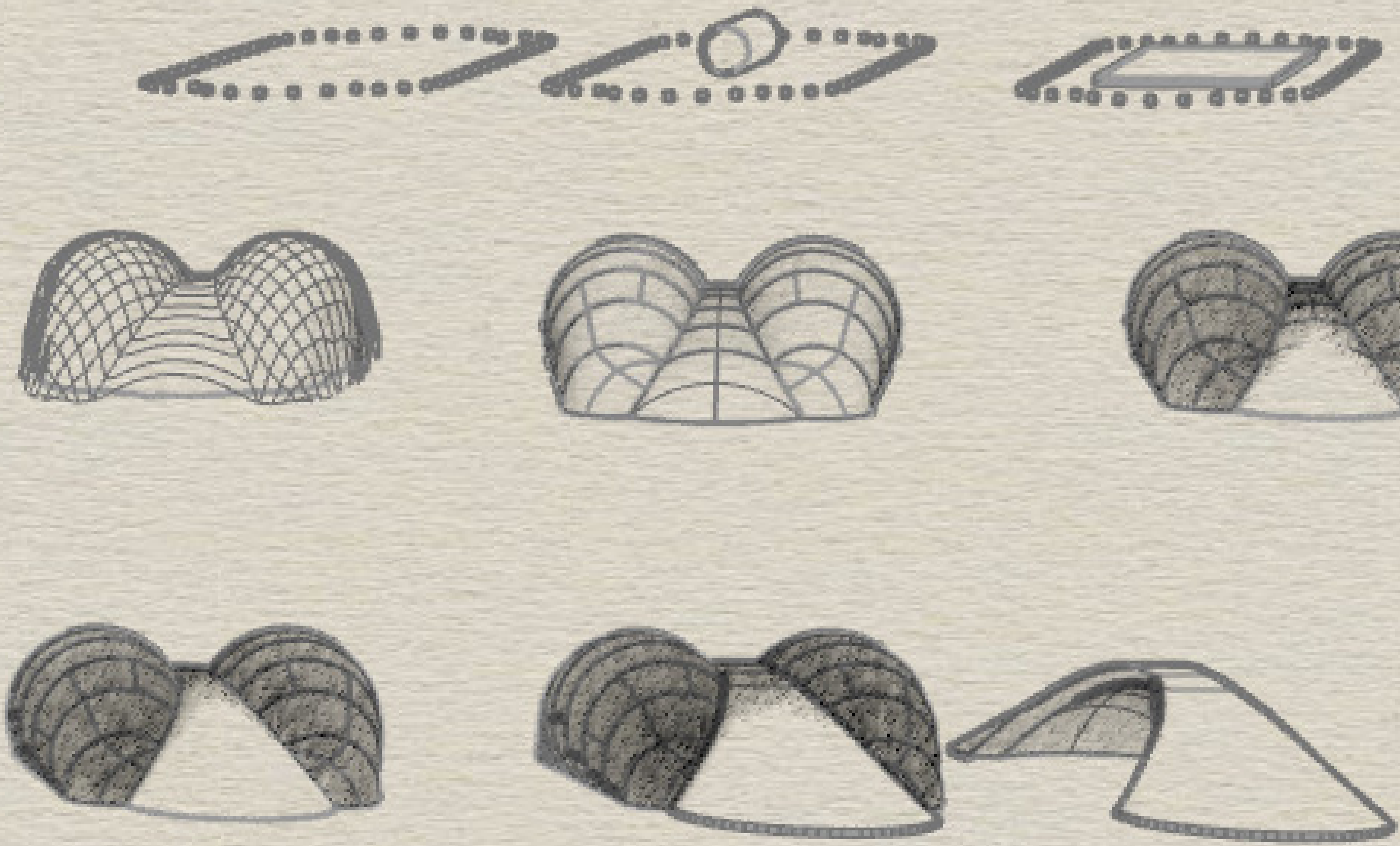


- Spraying reinforced ice layer by layer



- Deflate and remove inflatable and ropestructure

CONSTRUCTION METHOD



CANDELA IN ICE

SNOWTRACK

JUUKA

LOCATION

Distance between Eindhoven (NL) and Juuka (FI).

Building world's largest span in ice has to be done in a region where it's cold enough to construct such a large ice structure. Juuka, Finland, is one the coldest areas in Europe with temperatures ranging from -15 to -30 degrees Celsius during winter, perfect for constructing an ice structure like the 'Da Vinci's Bridge in Ice'.

Juuka in Finland.

The ice structure will be built on private property owned by Tulikivi, the world's largest manufacturer of heat-retaining fireplaces.

JUUKA

Juuka is Municipality of North Karelia, a province in Eastern Finland. The municipality has 5089 inhabitants and has an area of 1.846,57 sq. km, of which 344,78 is water. The hills alternate with views of the Lake Pielinen, which is an example of typical Finnish traditional landscape. The lake is the fifth largest lake in Finland. Juuka is known for its wood processing, soapstone fireplaces, local crafts ceramics, nature and miss Finland 2011.

Juuka is a very important partner in the realization of all ice projects last and this years. Tulikivi made their accommodation available and prepared the construction site for building the ice-bridge and others. We're supported by a large number of local companies, volunteers and associations in Juuka.

More info on Juuka can be found at: *www.juuka.fi*

"Weapon" of Juuka.

Pictures page 26, clockwise:

View from houses 1 and 2,

Winter Market,

Lake Pielinen,

Original Finnish soapstone fireplace,

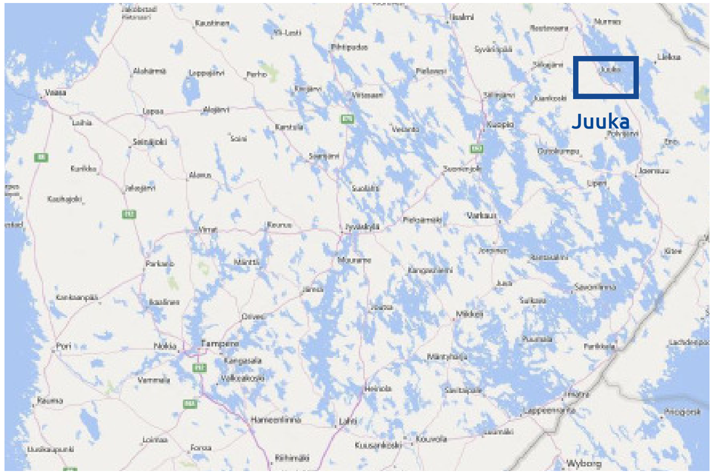
Nature in Juuka Finland.

Miss Finland 2011,

Nature in Juuka Finland,

Church in Juuka.

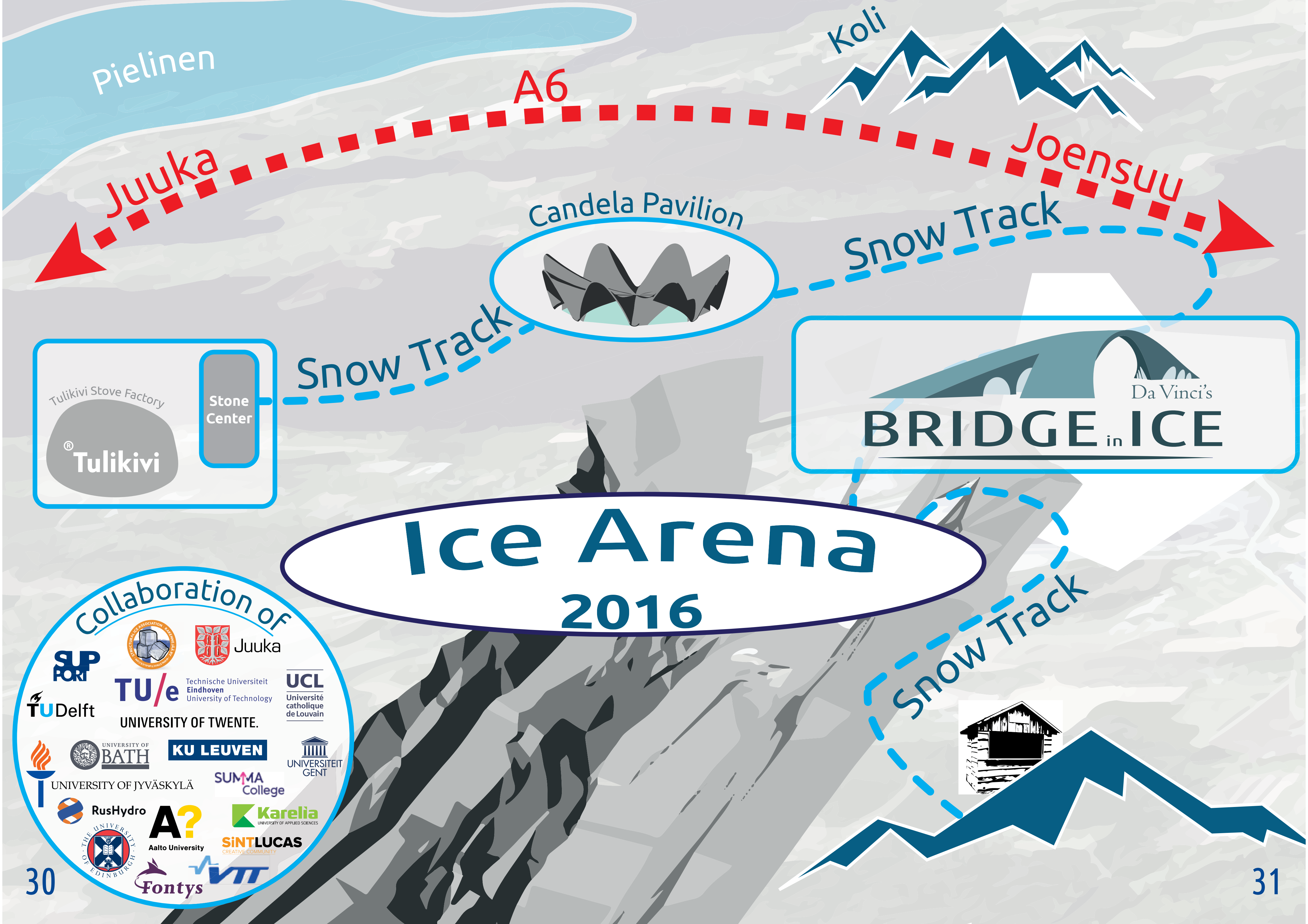
Juuka and the Ice Campus.



Ice Campus; facilities and accommodation.

Numbers in the map:

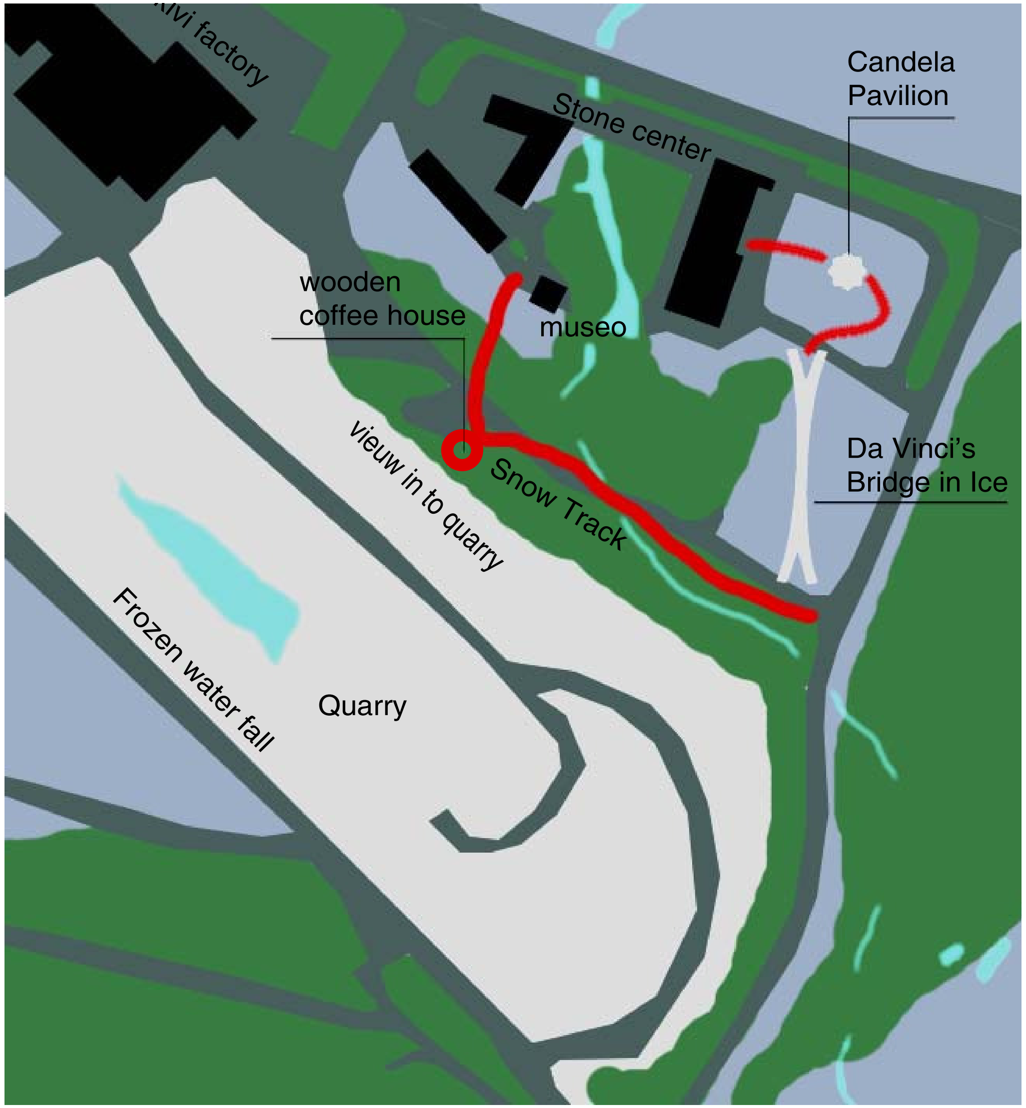
1) Building site Da Vinci's Bridge in Ice
2) Wintermarket
3) Building site Candela in Ice
4) Stone center
5) Parking
6) Tulikivi Restaurant
7) Snowtrack (route between all events and structures)
8) Viewpoint and coffee house
9) Quarry with frozen waterfall
10) Museum
11) Tulikivi factory
12) Gas station and small shop
13) House 1 (Tulivikivi Klubi)
14) Lake Pielinen
15) House 2 (Sopusärkkä)
note: 16) House 3 is available in Juuka Center (Vanhatie 8)


Pielinen
Koli
A6
Juuka
Joensuu
Candela Pavilion
Snow Track
Snow Track
Snow Track
Tulikivi Stove Factory
Tulikivi
Stone Center
Da Vinci's
BRIDGE in ICE
Ice Arena
2016
Collaboration of
Juuka
SUP PORI
TU Delft
TU/e Technische Universiteit Eindhoven University of Technology
UCL Université catholique de Louvain
UNIVERSITY OF TWENTE.
UNIVERSITY OF BATH
KU LEUVEN
UNIVERSITEIT GENT
UNIVERSITY OF JYVÄSKYLÄ
SUMMA College
RusHydro
Aalto University
Karelia
SINTLUCAS
THE UNIVERSITY OF EDINBURGH
Fontys
VTT

BUILDING SITE

The ice campus is property of Tulikivi Company. It's situated in Nunnanlahti, a small village part of the Municipality of Juuka. Around the ice campus you'll find several buildings we're allowed to use, and the building site for the Ice-Bridge, Pavilion, Snow track and other ice events. The dimensions and location of the building site are perfect for the conditions of the project. Also part of the Tulikivi Stonecentre is available for us. The Stonecenter will be the entrance building for the Juuka in Ice events. At the Stonecenter we will have an office with internet, class room, (movie) theatre, exhibition space, souvenir shop, bar and laboratory for testing ice. We'll have an office with internet and wifi. In Nunnanlahti is one shop. Juuka is about 13 kilometres away. In Juuka you'll find a supermarket, pharmacy, hardware store, etc. (see previous map)

Pictures of the building site, made in summer time



The building site like it should be, there might be some changes during the project. This is just a graphic image, not everything is on right scale.

SHIFT PLANNING

Like last year we plan to make four groups, each group is a shift that will work for three hours. In one day you work two shifts. After each shift you have 3 or 15 hours of spare time. In this time you can participate with activities and also sleep and eat. Depending on the number of participants this shift division can change. Shift 1+2 and 3+4 will switch every day.

We might also change shifts in weekends, to prevent people from working only at night. If there are more people available, we might work with other systems, to reduce the work load.

Below you our shift proposal, but you will be informed about the definitive system.

Three pictures of hard workers at last year's Sagrada Familia in Ice

BUILDING EQUIPMENT

We're trying to improve our whole construction system. This year for the first time we'll have a almost fully automatic mixing system. Last years there was a lot of trouble with freezing hoses and nozzles, frozen people and stucked pumps. We've tried to discard all those problems with arranging better equipment.

Everyone will be instructed on site about how to work with the systems off this year. Every shift will have shiftleader(s), who are allready involved in the preparations of the project. During your shift we'll determine which tasks fits you best, and we're trying to keep everyone satisfied with their contribution, but as always: safety first.

TIME SCHEDULE AND EVENTS

The most importants dates are shown below, on the building site there will be a detailed planning of what should be done at that specific day.
Besides the construction planning we've a wide spread of activities and events during the 7 weeks.

DAY	ACTIVITY	TIME	LOCATION
28.12.15	ARRIVE FIRST VOLUNTEERS		
29.12.15	START BUILDING ICE-BRIDGE POSITION INFLATABLE		
31.12.15	NEW YEAR'S EVE	21.00	Nunnanlahti school & Petra
01.01.16	NEW YEAR'S DIVE & BRUNCH	13.00	Nunnanlahti
02.01.16	START SPRAYING ICE		
04.01.16	OPENING EXHIBITIONS STONE CENTER	17:00	Nunnanlahti
05.01.16	OPENING ICE INFO CORNER	12:00	Petra
06.01.16	EPIPHANY	11.00	Nunnanlahti & Juuka
09.01.16	BALLOON PARTY	17.00	Nunnanlahti
16.01.16	WINTER OLYMPICS HIGHEST POINT PARTY	11.00 17.00	Nunnanlahti
23.01.16	LOWLANDS PARTY	17.00	Nunnanlahti
25.01.16	START BUILDING PAVILION AND SNOWTRACK		
30.01.16	OPENING SNOWTRACK & COFFEE CABIN / PREMIERE PARTY 'Die Schneekonigin'	13.00 17.00	Nunnanlahti
01.02.16	START WORKSHOP ICE DOMES BY Dr. D. HUYLEBROUCK		Juuka
06.02.16	OPENING CANDELA PAVILION BOOK PRESENTATION & MATH PERFORMANCE BY Dr. D HUYLEBROUCK MOVIE NIGHT 'Die Schneekonigin'	13.00 17.00 19.00	Nunnanlahti
11.02.16	ICE CARNAVAL	17.00	Nunnanlahti
12.02.16	ISOFF Ice Symposium	10:00	Nunnanlahti
13.02.16	OPENING DA VINCI'S BRIDGE IN ICE	13.00	Nunnanlahti

A more detailed description of every event will be presented online. Besides that, there will be a lot of other events during the weeks after the opening for other interested people.

TRAVEL INFORMATION & COSTS

For volunteers it's possible to arrive and depart everyday during the whole construction period. Try to make groups, for efficient journeys. Information about travelling can be found later in this booklet.

The costs will be €350,- per person for one week. Every extra week will be same price (so 7 weeks is also €350,-), so stay as long as possible!

Prices are included:
- Sufficient food
- Lodging
- Several entertainment and activities
- A great experience!

Prices are excluded:
- Flights (to Helsinki or Joensuu/Kuopio)
- Bus transfer Helsinki-Joensuu
- Safety shoes
- Working gloves

*We're trying to arrange some deals for shoes/gloves

Everyone should arrange their own travel to Juuka.

This is what we suggest:

1. Book a flight to Helsinki
(KLM, Finnair, AirFrance, AirBaltic)
2. Take the Onnibus to Joensuu
(www.onnibus.com)
3. In Joensuu we will pick you up by bus or car.
Let us know by mail when you arrive in Joensuu.
4. You might prefer flying over bus drive. Than we suggest to continue your flight from Helsinki to Joensuu or Kuopio.
After your landing you will be picked up.
5. It is also possible to hire your own car at the airport.

We as the project team will arrive Monday 28th December in the evening.
It's possible to arrive everyday (day and night) during the whole building period.

When you arrive you will be informed and guided through the accomodation by the projectmembers or other volunteers.

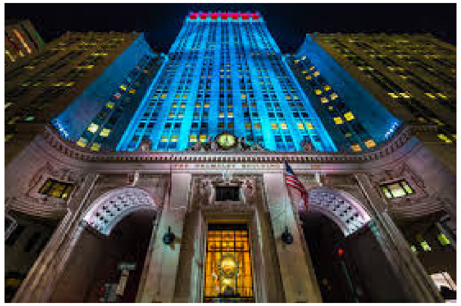
OPENING

There will be a party every saturday (see previous time schedule).

The grand opening will be on 13th of February. The bridge will be richly illuminated by color changing LED lights . Besides of that, few small icedomes, a snowtrack, a frozen waterfall, a huge pavilion and several ice sculptures are realized that will adorn the opening. For now, the time for the official opening of the dome will be at 1:00 P.M.

After the official ceremonies there is time for relief of all the hard labour together with the people of North Karelia and other invited people. There will be a festive drink on the success of this record attempt, all kind of activities and opening acts. In the evening a band and a DJ will continue the party.

After this beautiful evening we will sleep for the last time in our beds and the next day fly back home.



Illumination of the ice-projects

Fireworks at the opening

Party at the big opening

PURCHASE OF CLOTHING

Below you will find a cheap offer of the local sports shop in Juuka for work clothes that is necessary when the temperature is -15 °C or lower. Students, staff and volunteers could consider things to purchase. We would like to know the items of your interest. We will make a order list of the different items and sizes. For shoes we would like to recommend choosing a larger size for additional socks. The deadline for ordering is at the 30th of November.

Sport -Kone Halonen Oy / Elmo Sport Juuka
Väyryläntie 1
83900 Juuka
Tel. 0505934933
E-mail:sportkonehalonen@gmail.com

Waterproof and warm gloves 100% water and windproof sheet gloves to work or leisure.
Light warm lining , this glove fit excellently
For wet and cold circumstances, Excellent grip. SIZE 10-11
Price 15€ including tax 24%

SIEVI Peter XL S2 Safety boots
Boots made of durable and water-resistant PU-coated leather. Warm fleece lining. Steel toecaps protect toes from compression and impact hazards. The slip-resistant and flexible polyurethane sole is resistant to oil and a number of chemicals. The wide XL fit gives toes plenty of room. SIZE 39-47
Price 93€ including tax 24%

Type: Technical underwear. Material comfortable, warm, flexible and quite thick 100% polyester. Keep skin dry very well.
Size: XS - 3XL
Material: 100% polyester. colour: black.
Price 20€ including tax 24%

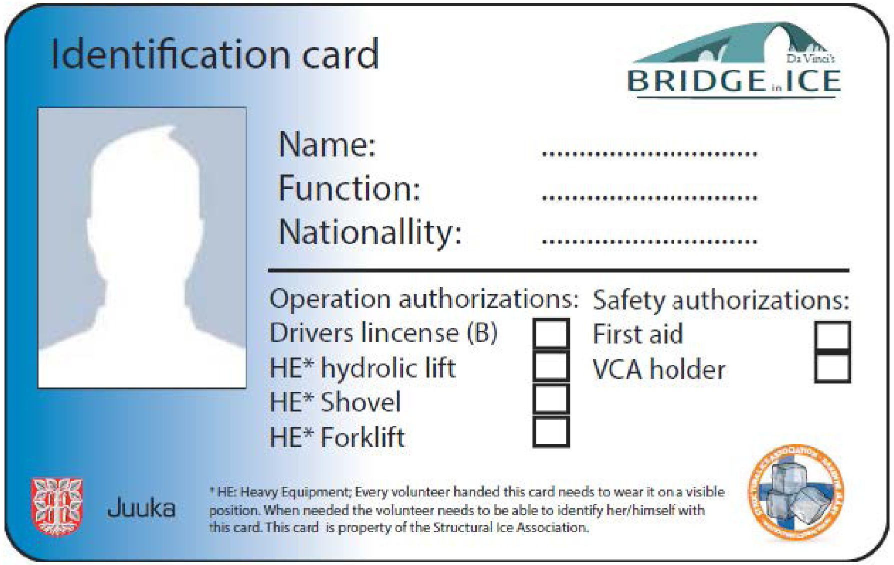
Super warm insole, cover 100 % wool.
Aluminium foil keep and protect cold effectively.
Size: 36-47
Price 6€ including tax 24%

There's a very large safetyplan for this year's project.
The purpose of this plan is to describe the project and the additional risks that come with the project. This plan is constructed to prevent risks and incidents to work on a safe, healthy and responsible way.

Every volunteer or visitor has to be informed about the do's and don't in this plan.
We're working with several safety instructors, on site you'll be provide with more information.

Every worker/volunteer of the project will be registered and receive an identification card as presented below. It is compulsery to wear the card visible at all time.

The card will be personalized with the correct data and will function as identification.
The card contains information about the authorizations and safety capabilities.
Entering and leaving the building site must be reported by the active shift leader. He will log the present people on the building site in the construction trailer log. It is the shift leader's responsibility to know at every moment how much, and which people are present at the site.
Visitors always need to check in at the buildings site, even if they already registered in the Tulikivi Stone Center.
The safety instructors and the overall safety coordinator are the only ones authorized to change the authorization information on the ID- card.



First aid-providers can be recognized by the indication on the identification card. A First aid- provider will be always standby. This means that a First aid- provider needs to arrive on location within 10 minutes when needed. The Telephone numbers will be provided in the Construction trailer (Alarm Card). In major incidents the Alarm number (1-1-2) should be called first.

At organized events at least one First aid-provider will be directly present at the snowtrack, or in the Tulikivi Stone Centre.

At any time there needs to be a First Aid Kit (FAK) available at the building site. This FAK will be visually stationed in the Construction trailer. Every use of the FAK needs to be registered in the Construction trailer log. It is the responsibility of the shift leader to register all the used products. It is the responsibility of the Overall safety coordinator to inspect the FAK weekly. The FAK needs to replenish as fast as possible.

The FAK will also be available after completion of the project. A second FAK will be available at the Tulikivi Stone Center at all time. This FAK will also be inspected weekly by the Overall safety coordinator.

Protocol:
1. Provide first aid and avoid further injuries (Vehicle collision, breakage of structure / falling objects etc.)

2. Warn the active first aid-provider and call 1-1-2, Provide information about the accident and which emergency service is needed (police, fire department, ambulance).
Always sent one person to a recognizable location to direct the emergency services in the right direction.

3. Make sure the victim is not alone and that he is being treated.

4. Directly contact the safety coordinator after an incident. The safety coordinator also needs to be contacted by near-accidents.

5. The overall safety coordinator and the organization will make a report of the incident to improve the situation and safety.

6. Make sure that the site is clear of danger so the work activities can be resumed (if the emotional aspect allows this).

CONDITIONS

In addition to the practical benefits that Juuka offers us in terms of accommodation and other things, we find in Juuka also the required climatic conditions needed to build the ice-projects. In other words; freezing cold. The average temperature in January is about -12 °C. However, there are also outliers to -35 °C. Incidentally, this will be a more dry cold, making the wind chill is something more pleasant than the indicated temperature. Because the weather and the physical efforts are constantly changing during the construction in Juuka, it is not always easy to determine what clothes you should wear. Therefore we recommend you to dress in layers. Depending on the activity you can customize your clothes on the circumstances. We recommend thermal under wear to purchase (do not buy cotton). Here is a list of tips and stuff we recommend as necessary:

Wool pads help against the cold.

Batteries
Batteries can behave different from what we're used to, be aware of fastly empted batteries or refusing devices.

Vaseline on your face
By putting a layer of vaseline on your face you create a layer where the cold do not can go through very well. It also avoids that your skin will be dry. Many face cream are based on water, what makes the cold worse.

Carpet as a shoe sole
We recommend to cut an piece of carpet in the shape of your foot and to put this in your shoes. It will keep your feet warm. It is also possible to buy wool pads, these have the same effect.

Heat leaves the body through the head
50% of the heat leaves the body through the head. Don't forget to take a good hat. A ski mask, balaclava or a Russian hat are good examples.

Travel insurance
In case of accidents you have to take care of your own expenses. Check your travel insurance and see if they cover the circumstances in Finland and the project you are contributing too as a volunteer. A travel insurance that will cover winter sports is recommended.

Swimwear
We have several saunas to warm up and a spa with swimming pool in Koli, so we recommend swimming clothing.

Packing list
This packing list gives an overview of important stuff when visiting Finland. In addition to the indicated stuff everyone should remember to carry own clothing (leisure, flipflops, etc.) and facilities (toilet bag, etc.).

Snow Boots; Buy a good pair of solid snow boots that are suitable for the indicated temperatures.

Pads; As indicated the wool pads in the shoes can help against the cold.

Thermal (preferably wool) underwear with long sleeves. Depending on the period (1-4 weeks) it is advisable to bring an extra set.

Gloves; This includes good gloves that are suitable to work with plenty of water and snow. It is also recommended to have an additional set of thin gloves under your (work) gloves.

Socks; Both thin socks as warm skiing socks. Thus, it is possible to attract an extra layer in cold conditions. Also here are socks with a high percentage of wool (merino) for winter conditions recommended.

Hat & Scarf; Make sure most of your face is covered. A balaclava can well apply.

Backpack; May apply when working on the construction site or when you go to have an activity.

Sleeping bag; As indicated, there are beds and pillows available but the blankets are not there. It is therefore necessary that everyone takes their own sleeping bag and if desired, fitted sheet. Despite the cold outside temperatures, it is not necessary to have a sleeping bag for these conditions, one for temperatures from 5 °C to 10 °C will be sufficient.

Thermos bottle; To carry hot drinks to different locations.

Winter Sports Clothing; Think of fleece sweater, ski pants and ski jacket.

Sunglasses or ski goggles

Towels

Passport and travel documents

WHAT TO DO WHEN FROZEN?

Prevention

Wear appropriate clothing in cold conditions. If you arrive from a warm climate in a cold area, let your body adjust to the change. Make sure that your hands, feet, nose and ears are protected, and avoid drinking large amounts of alcohol before and during prolonged exposure to cold. Without the write measurements you will be exposed to very low temperatures and your skin can freeze. The places with the greatest risk of freezing are the hands, feet, nose and ears. People with problems of blood circulation, such as atherosclerosis, do have a much greater risk.

Freezing

Freezing can be recognised by hardened, pale and cold-feeling parts of the skin that are exposed to cold for some time. In the area seems to be no dexterity more, but there is probably a sharp, persistent pain. If the place thaws, the skin turns red and sore. In severe cases, the supply of blood to the affected area stops and the blood vessels are seriously damaged. The damage can only recover if the freezing is treated immediately. Therefore, in such a situation, visit a doctor as soon as possible.

These hands are not dirty, frozen hands are a problem.

In the winter it can be very cold in Finland.

Emergency treatment

Someone with frozen hands and feet can also suffer from hypothermia (lower bodytemperature). Determine if this is the case, and treat those symptoms first.

The warm-up process

If the fingers, ears or other areas are frozen, then go to a area where the temperature is higher. Preheat the hands by to keep them under the armpits. If the nose, ears or face are frozen, heat those spots by covering them with warm hands (with gloves on). If during heating the skin sparkles and a burning feeling arises, this means that the circulation takes off. If the numbness during the warming up process persists you have to inform a medical expert immediately.

Do not rub the affected area. If the feet are affected, then walk no more: let them dangle and wait for help.

In case immediately assistance is not possible you have to heat frozen hands in water with a temperature of between 37.5 °C and 40.5 °C. Do not use any other source of heat (such as a heating pad), because the tissue, even if it is by the cold become desensitized, nevertheless can burn. There may even occur burnings at temperatures, that can be easily tolerated under normal circumstances. Do not smoke! Nicotine causes the blood vessels to constrict, which can reduce the circulation.

Do not put your hands in too hot water.

ACCOMMODATION

In Juuka we are allowed to use three different houses. They are all on a distance that can be walked.

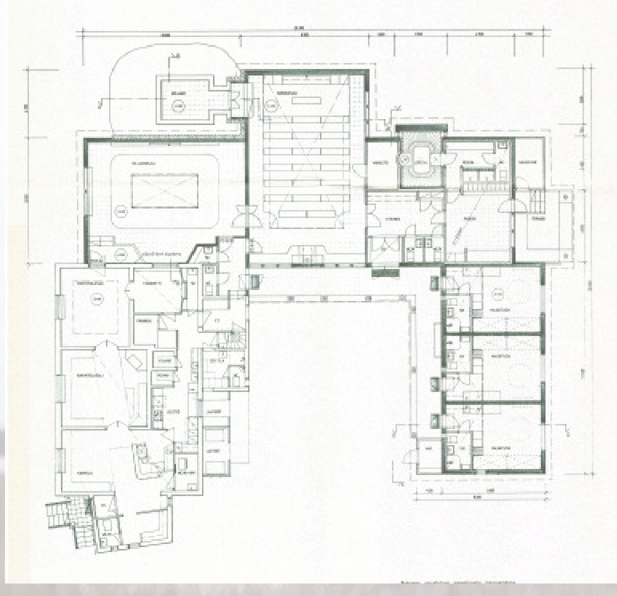
In the houses there is a kitchen, a table to play billiard, a sauna, bathroom, beds etc.

Two houses are situated at the lake Pielinen. Here you can find some pictures of the houses.

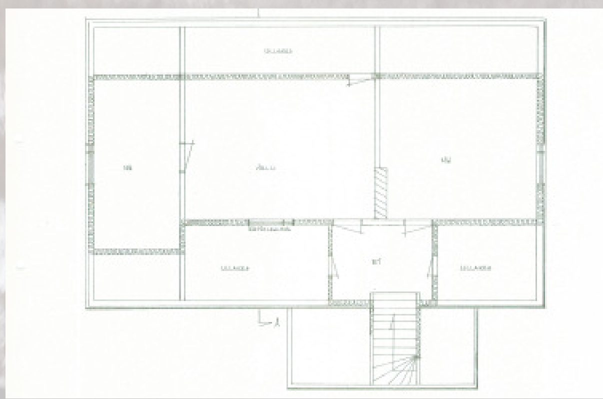
We're able to use a third house in Juuka, in the very crowded periods.
(picture on the right below)

Some pictures of our accommodation.

Tulikiviklubi

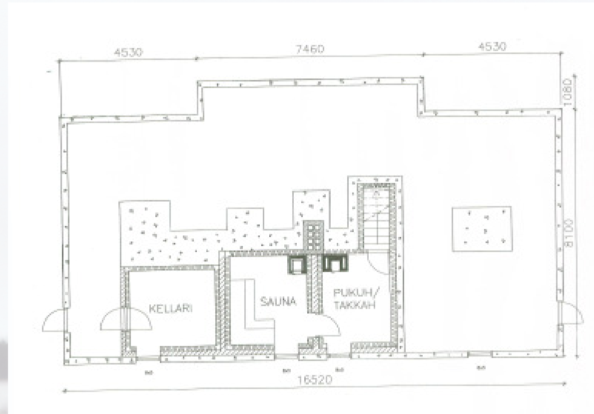


Ground floor

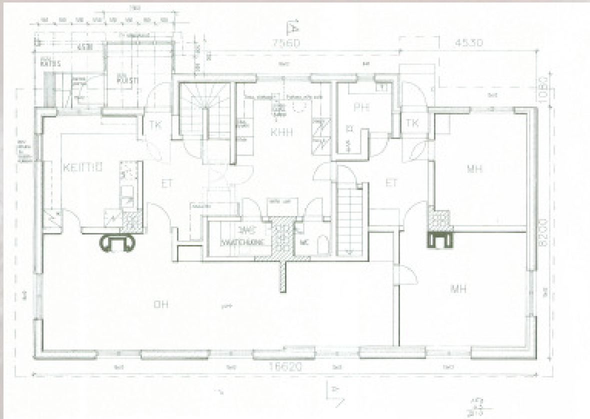


First floor

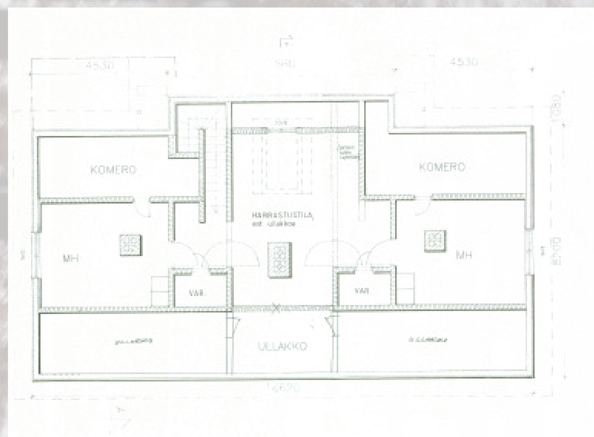
Sopusärkkä



Basement



Ground floor



First floor

FOOD AND DRINKS

An overview of daily eating pattern following the Finnish culture:

Breakfast [7.00-9.00]

Lunch [11.00-13.00] - this is often an extensive hot meal.

Dinner [17.00-18.00] - often less extensive, for example bread, although a second hot meal as a soup is also possible. In addition the Finnish people eat something light in the evening, such as yoghurt.

From the 4th of January, a group of maximum 20 volunteers are allowed each (school) day to have a lunch for free in the restaurant of the local primary school. Another opportunity is to eat the lunch at the restaurant of the Tulikivi showroom at the ice campus. This last option will charge you a reduced price of about 5 euro. You can also prepare a meal by yourself in the kitchen of the cottages.

In the weekend the care crew will be cooking in the cottages. Each shift will prepare the other meals for themselves. In the morning this could be a sandwich and in the evening there will be a meal to fill the stomach slightly more. For example a fried egg or something like that. There is enough to eat and drink in the cottages for everyone to provide your meals. Besides there will be some snacks and soft drinks in the cottages.

Common meals include fish (mainly salmon), meat or potatoes. There are many other meals possible. If you have a special diet, please inform the care crew who will provide the supply of food.

Food: Roasted salmon.

Drinks: A typical Finnish beer, Koff.

Food in Finland.

ACTIVITIES

In addition to the working it is possible to organize all kinds of activities, for example a snowmobile trip. For those who just want to warm up after the hard labour, Finland has a lot of saunas. For the real vikings among us, it is also possible to go ice fishing or dive into the water by making a hole in the ice. A visit to a Finnish hunting lodge where you can prepare your own food is not to be missed.

For the winter sports enthusiasts, 27 km from the ice campus there is a small ski resort (Koli). Depending on the amount of snow you can enjoy skating or cross country skiing everywhere around the lake. Who is not such a sport lover, can always enjoy the nature and environment during the beautiful twilight.

Many activities will be arranged in Finland by the inhabitants of North Karelia.

Skiing in Finland.

Racing with a snowscooter.

Sitting on a bucket on the lake; ice fishing.

Trip with sled dogs.

Dive in the frozen lake of Pielinen.

SPONSORS AND PARTNERS

Of course this project would not be possible without our sponsors. We thank the sponsors in advance for the commitment and interest in the project.

Below, there is an overview of the companies that participated to the realization and organization of the project.

CONTACT

The contact details below are meant for questions or discrepancies related to the trip to Finland.

Overall project responsibility and direct contacts
Name: Arno Pronk
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Email: r.koekkoek@student.tue.nl
Mobile phone: +31 (0)6 18 48 89 62

Name: Thijs van de Nieuwenhof
Email: t.a.h.v.d.nieuwenhof@student.tue.nl
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Volunteer, accommodation and transportation
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Special thanks to: Dennis, Teun and Jordy, Tuula and Jan, for their contribution to this (and last year's) guide!

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Appendix 9

ARCADIS Design & Consultancy for natural and built assets

HEALTH & SAFETY PLAN BRIDGE IN ICE

11 JANUARI 2016

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1 INTRO

1.1 Occasion

For the third year in a row the Eindhoven University of Technology, 14 others education facilitates and the Juuka council will cooperate in building with fiber reinforced ice. The project will consist of an ice route with different landmarks. The biggest landmarks will be a bridge of ice (designed by inspiration from Da Vinci's design) and an ice pavilion.

1.2 Purpose safety & health plan

The purpose of this plan is to describe the project and the additional risks that come with the project. This plan is constructed to prevent risks and incidents to work on a safe, healthy and responsible way.

1.3 Content

H3 Tasks and responsibilities

H4 Bridge

H5 Pavilion

H6 Frozen waterfall+ snowtrack

H7 Exploitation

H8 Emergency procedure

2 TASKS AND RESPONSIBILITIES

2.1 Legal framework

Bases on the legalization of labor conditions, the H&S plan will be available at all time. Also an overall coordinator (CSC) will be present and always standby to react on situations.

2.2 Contact persons

Central Safety Coordinator (CSC)

Contact person : Jari Repo / Hugo Sanders
Telephone : +358 407577999
E-mail : jari.repo@pp2.inet.fi

Bridge in Ice

Contact person : Arno Pronk *(project leader)*
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Pavilion

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Contact person : Bram Ronsse *(project manager)*
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Snowtrack+ waterfall

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Exploitation

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Contact in the Netherlands

Contact person	:	Pieter van Nunen
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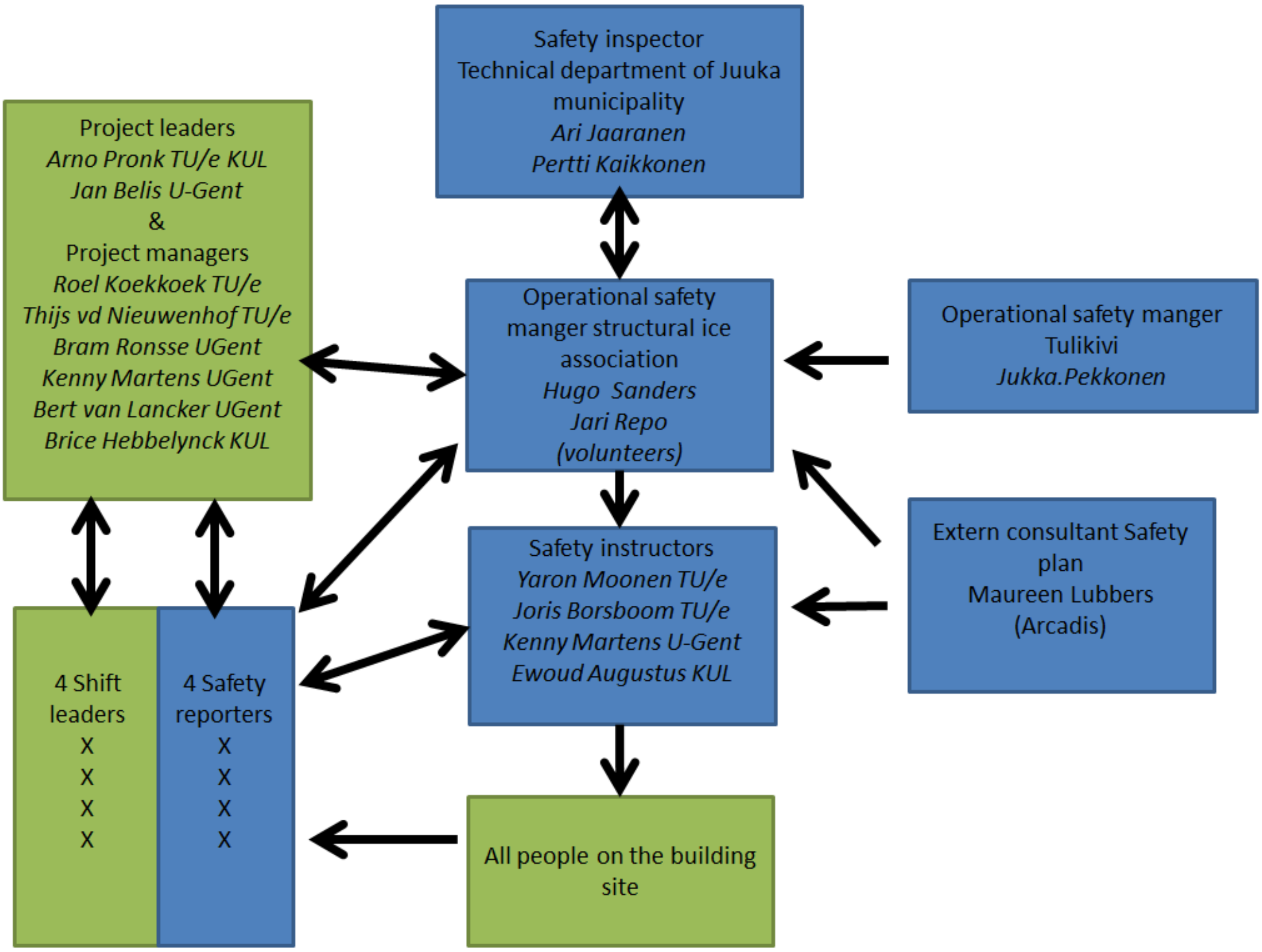
2.3 Appointments

Organization

The safety organization is pointed out in the organized scheme.



The safety department will consist of a Central Safety Coordinator (CSC). He will be the first to contact in any situation about safety and health.

Two external safety inspectors will be appointed by the Juuka council. They will have a monitoring role for the whole construction progress. Any problems or contact will run through the CSC.

An external safety manager from Tulikivi will ensure a safe usage of the terrain and Tulikivi buildings. Any problems or contact will run through the CSC.

The CSC will communicate directly with the project team and the shifts.

Every shift will contain a shift leader and a safety reporter. The safety reporter will report any unsafe situation to the shift leader. The shift leader will contact the CSC. All major safety situations have to be reported to the CSC after resolving.

The CSC, safety instructors and the project management will operate individually because of the difference in interest. External safety managers (1 from Tulikivi and 2 from the Juuka Council) will judge the safety themselves and report to the CSC. In turn, the CSC will brings 2 reports each week to the Juuka Council. This report is arranged together with the safety reporters and the safety instructors.

Tasks of safety coordinator:

- Ensure that the safety requirement are met
- Instructing new workers and visitors
- Intervening in risky situations (shutting down work progress)
- Ensure that only authorized persons enter the site

Unsafe situations that can result in small injury or malfunction in the near future are mentioned as minor risks situations.

In minor risk situations the coordinator is considered to inform the shift leader. It is the shift leader's responsibility to solve the risk situation on a responsible way. The coordinator will see to that.

Unsafe situations that can result in immediate serious injury are mentioned as major risks situations.

In major risk situations the coordinator is able to intervene by shutting the work process down. The work will be continued when the unsafe situation is resolved

Further organization models are added in the attachments.

Visitors

Visitors are allowed form the beginning of the construction till the end if the safety conditions allows it. Visitors are only allowed in an organized way and with the presence of a guide. The guide must have had the safety instruction and be aware of the dangers and risk of the site. He/she can be one of the workers or volunteers. The visitor will receive a clear map which indicates safe zones to walk and the rules of the site. Visitors needs to register themselves when they arrive a when they leave by the active shift leader. The first contact point for tour visitors will be the Tulikivi Stone Centre.

2.4 Planning

See attachment

3 GENERAL RULES

3.1 Intro

In addition to specific rules, the following general rules apply on the basis of the design or the phase of implementation.

3.2 Building site

The building site is protected from unauthorized persons.

Entering the building site is only permitted with the proper equipment (see 3.3 Personal protection).

Entering and leaving the building site must be reported to the active shift leader.

Every worker/visitor must have taken part of an overall instruction about dangers and safety at the building site. After this introduction a general declaration will be signed by each worker/volunteer. This declaration states that the volunteer has taken part of the introduction, and is responsible for its own choices and behavior. The worker will also sign to live by the rules of the construction site. Part of the instruction will be a separate training for tying the right knots. This is essential to avoid delays and dangerous situations while working with ropes.

Every worker/visitor knows to whom an incident or unsafe situation should be reported.

Alcohol, drugs, and other narcotics are absolute forbidden on the building site. Workers/visitors under the influence of alcohol or drugs will be dismissed from the building site.

It is important that a clean and organized building site is respected. It is the responsibility of the active shift leader to ensure this. Every shift transfer the building site needs to be safe and workable (see 3.5 meetings – shift transfer). Every used equipment needs to be returned to its original place to avoid delays and injuries

Workers are not allowed to work outside for a longer period than 3 hours. Workers must take a break of at least 20 minutes after this time span before continuing the work.

At least one person should be responsible for the safety for every 50 people on the building site.

An overview of the general rules will be present in the construction trailer.

3.3 Personal protection and equipment

Entering the building site is only permitted with the proper equipment. The work equipment consist of:

- Safety shoes; at least safety class S1; with anti-slip spikes when needed.
- Proper recognizable working outfit
- Helmet; Shift leaders will wear a white helmet for recognition.
- Watertight work gloves
- Headlight; 2 people per shift
- Radio; when needed (see 3.4 heavy equipment)
- Identification card; visually present

Every builder need to be recognizable by its working gear and identification card. At all-time at least 2 workers need to have a fully charged head light in case of power failure.

A helmet is needed to counter the danger of falling object. An exceptions on this rule will be the construction of the ice track. A helmet on the ice track is only necessary when the hydraulic lift is being operated. When entering the quarry, a helmet will also be compulsory.

Radios are needed to communicate with operators of heavy equipment. At the end of every shift the used radio's and head lights need to be charged in the construction trailer. The new shift will use another fully charged set. It is the active shift leader's responsibility to ensure that the devices are charged.

Visitors are only allowed when they are guided by an authorized worker, and stay on the designated route. This route will be indicated by a floor map that is handed to every visitor. This floor map will also contain the (safety) rules of the building site.

3.4 Heavy equipment

Overall

It is very important that every type of equipment is used properly and is returned to its original position. This is very important to prevent delays and irritations. After use equipment should be cleaned and put back on its original place so it can be used immediately in the future.

Training

For the operation of the heavy equipment the project team will compose a training for each vehicle. The purpose of this training is to operate the device in a safe and responsible way. It is absolutely forbidden to operate heavy equipment without the provided training. The trained builder needs to be in the possession of a normal driver's license to ensure a safe and responsible use. The shift leaders will bring forward, in consultation with the project team, builders who are capable of operating a specific vehicle. After successfully passing the training the builder will be logged and able to operate the (pre-trained) vehicle. The builder and the trainer will sign a form to ensure he is ready and knows how to operate the machine. The operation will be from then on the operator's responsibility.

The trainers will be appointed by the project team. Also the trainers needs to be in the possession of a normal driver's license. Apart from that it is essential that they have experience operating the devices.

Operating

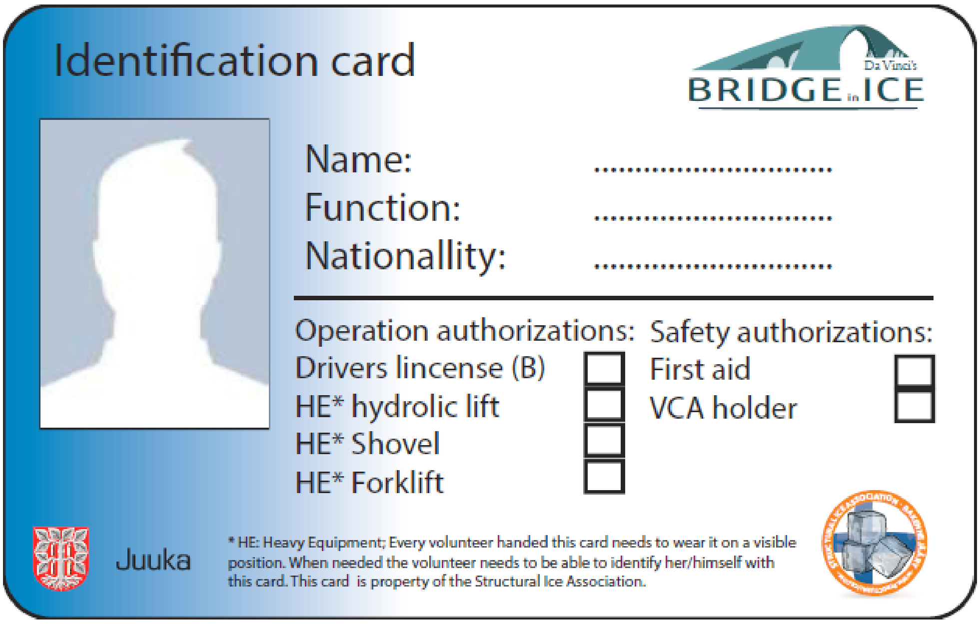
It is very important that every device is threatened treated well and responsible. After every usage the device needs to be placed in the right parking spot and connected to the power supply. It is the operator's responsibility to inform the shift leader about (possible) failures of the device such as a critical fuel level.

The operated heavy equipment consist of:

- Wheel loader
- Bobcat
- Crane
- Forklift
- Boom lift 15 m
- Boom lift 24 m

3.5 Identification

Every worker/volunteer of the project will be registered and receive an identification card as presented below. It is compulsery to wear the card visible at all time.



The card will be personalized with the correct data and will function as identification. The card contains information about the knowledge and safety capabilities.

Entering and leaving the building site must be reported to the active shift leader. He will log the present people on the building site in the construction trailer log. It is the shift leader's responsibility to know at every moment how much, and which people are present at the site.

Visitors always need to check in at the buildings site, even if they already registered in the Tulikivi Stone Center.

The safety instructors and the overall safety coordinator are the only ones authorized to change the authorization information on the ID- card.

3.6 Meetings

All meetings need to be logged and recorded. The meetings will be divided in: safety and risk introduction, building site meetings, structural, shift switches, overall meetings, safety meetings and other meetings.

Safety and risk introduction

Frequency: Every new builder, every major process change

Presence: Safely instructor; new builders

Logged: Identification log; office log

Every builder will receive a standard introduction about the safety and health risks on the building site. This will consist of a presentation and/or a video. Together with a tour of the building site (Building site meeting) this will complete the total instruction.

Building site meetings

Frequency: Every new builder, every major process change

Presence: Safely reporter; Builders; Shift leaders

Logged: Construction trailer log

When encountering new workers on the building site, shift leaders need to introduce them to the building site itself. This will consist of a tour over the site. In this meeting the rules of the building site pointed out again. It is important that this meeting will be repeated for every builder or whit a massive change in the operations on site. With these meetings builders will be familiar with routing, resources, equipment and dangers on the building site.

Pre-general meeting

Frequency: Every day 15:45 o'clock

Presence: Project management; Shift leaders; Safety instructors

Logged: Office log

This meeting will be held to prepare for the overall general meeting. In this meeting the shift leaders can point out the biggest problems and struggles they want to discuss in the general meeting. Also safety will be a repeating chapter in these meetings.

General meeting

Frequency: Every day 16:00 o'clock

Presence: Everybody involved with the construction

Logged: Office log

In this meeting will point out the building strategy for the next 24 hours based on the weather forecast.. The meeting is also the only moment on each day that all the workers and coordinators can discuss progress and difficulties during their shifts.

Process control, difficulties and possible dangers will be the most important part of these meetings.

Shift switches

Frequency: Every change of shift

Presence: Safely reporter; Shift leaders

Logged: Construction trailer log

Every switch of shift the shift leaders will meet to discuss the progress. In this meeting every aspect of the building site need to be discussed. For example dangerous situations, usage of fuel and troubles in the process. Everything needs to be logged in the Construction trailer log. This to prevent delays, mistakes and accidents. The most important issues will be mentioned in the 'General meeting'. It is the shift leader's responsibility to inform the shift members about the process.

Safety meetings

Frequency: Two times a week

Presence: Safely instructors, SCS, external safety managers

Logged: Office log

Two times a week a safety report will be constructed with the proceedings on the building site. Risks and dangers are being discussed and evaluated. In this meeting a report will be constructed to inform the Council of Juuka about the current safety status.

Overall meetings – Ice association

Frequency: on occasion

Presence: Ice association; Project management; CSC

Logged: Ice association log

These meetings will ensure an overview about the whole ice arena. Main parts of these meetings will be bookkeeping and budget control; Coordination of entrepreneurs at the ice park and overall coordination.

3.7 Construction log / Report log

The construction log will be used to document the progress of the built. The shift leader is responsible for filling in the construction log.

Construction reports

For the safety during the exploitation it's important to document anomalies that arise during the building phase. These anomalies may affect the strength of the construction when it's finished. Anomalies that should be logged are: big cracks, a partial collapse etc.

Safety reports

All accidents need to be written down in the construction log. The municipality of Juuka needs to be informed about these accidents. And when these accidents are written down actions can be taken to prevent them from happening again.

4 BRIDGE IN ICE

4.1 Design

In the beginning the bridge will be supported by an inflatable. The pressure in this inflatable is very important to avoid a pre-constructional collapse of the bridge. Therefore a system will monitor the balloon pressure and the working of the air pumps.

The bridge will be designed to foot traffic only. A maximum of 15 people at a time is allowed on the bridge. A warden is needed to ensure this number is not exceeded. There is no need for a building permission because the ice bridge is a temporary construction without a roof.

The steep gradient of the bridge will be lowered using snow. The project team will take measurements to prevent slipperiness on the steep gradient when necessary.

The bridge will be secured using fences and fall protection.

The creep of the bridge will be measured during the construction phase with an optic distance meter. As long as this creep shows a linear relationship, there is no problem. After completion the creep will be measured by the Juuka council (see 7.1).

4.2 Building method

The bridge will be constructed using fiber reinforced ice. There for, cellulose paper will be mixed with water to create an ice composite.

An inflatable will serve as mold for the bridge. Layer by layer the ice composite will be sprayed on the inflatable, forming a solid ice bridge. After removing the balloon, the bridge is finished.

When the inflatable is in use there at least 2 volunteers need to be present at the building site. This is to prevent a dangerous situation due to the pressure in the balloon.

Before construction a plastic sheet will cover the ground. After demolition and melting of the bridge the remains can easily be packed together. By leaking the water out of the composite, the remains can easily be discharged with the regular paper waste and recycled.

During the construction process it is not allowed to dump the cellulose through the sewers. The unintentionally spilled cellulose will be filtered out of the sewer using 2 settling tanks.

4.3 Building site layout

See attachment

4.4 Risks in design and construction

See attachment

5 PAVILION

5.1 Design

The Pavilion will be used to walk in/under. The Pavilion is designed to carry a heavy snow load. When the snow fall is extreme the snow needs to be removed from the pavilion.

The creep needs to be measured after finishing the construction (see 7.2)

5.2 Building method

The pavilion will be constructed using fiber reinforced ice. There for, cellulose paper will be mixed with water to create an ice composite.

By leaking the water out of the composite, the remains can easily be discharged with the regular paper waste.

An inflatable will serve as mold for the pavilion. Layer by layer the ice composite will be sprayed on the inflatable, forming a solid ice structure. After removing the balloon, the pavilion is finished.

When the inflatable is in use there at least 2 volunteers need to be present at the building site. This is to prevent a dangerous situation due to the pressure in the balloon. The 2 volunteers can be the same as the ones who are guarding the bridge.

Before construction a plastic sheet will cover the ground. After demolition and melting of the pavilion the remains can easily be packed together. By leaking the water out of the composite, the remains can easily be discharged with the regular paper waste and recycled.

During the construction process it is not allowed to dump the cellulose through the sewers. The unintentionally spilled cellulose will be filtered out of the sewer using 2 settling tanks.

5.3 Building site layout

See attachment

5.4 Risks in design and construction

See attachment

6 SNOWTRACK &FROZEN WATERFALL

6.1 Design

The snow track will be the route through the various ice structures. The frozen waterfall will be constructed on two sites of the quarry. The Frozen waterfall will be fenced of so no individual can fall of the edge.

The whole entrance to the quarry will be secured using fences to prevent falling and unauthorized entrance.

6.2 Building method

A snow machine and a shovel will be used to create a clear route for the ice track.

The frozen waterfall will be constructed using a water connection. By simply letting the water over the edge into the quarry a frozen waterfall will be created.

Working around the frozen water falls is only allowed when temperature is under the freezing point. This is important to avoid falling ice.

Working inside the mine is only allowed with permission of Tulikivi. This permission will be given by the operational safety coordinator of Tulikivi.

6.3 Building site layout

See attachment

6.4 Risks in design and construction

See attachment

7 COMPLETION PHASE

7.1 Construction

The builders will make notes of deviations in the ice construction that form during the construction phase (big cracks etc.). These deviations will be inventoried so that the wardens/guides can monitor the spots where the deviations occurred more closely.

After the bridge is completed the creep of the ice will be monitored. The creep gives an indication of the loadbearing capabilities of the construction. Monitoring will take place visually and by means of measuring.

Visual monitoring will be done by eye. Ice and snow constructions show a big visual deformations before collapse.

The second monitoring method is measuring the creep. This can be done by using an optic distance meter or a rope hanging under need the ice bridge. A more detailed instruction of these measuring methods can be found in the attachments.

7.2 Organisation

The municipality of Juuka will decide when the ice structures aren't safe anymore. The safety depends on the weaher (temperature) and the creep of the ice construction.The creep can be measured by the method described in 7.1.

7.3 Risks during usage phase

The bridge will be designed to foot traffic only. A maximum of 15 people at a time is allowed on the bridge. A warden is needed to ensure this number is not exceeded.

The project wardens/guides will take measurements to prevent slipperiness on the steep when necessary. They can use gravel or sawdust to make a surface on which people can walk safely.

The bridge will be secured using fences and fall protection.

Sticking out of the ground so that snow can cover it up and also a deep in the ground so that it will remain at the same height even when the snow melts

8 HEALTH AND EMERGENCY

8.1 Emergency card

The following emergency card will be displayed in the construction trailer. It contains information about the local emergency authorities.

ARCADIS

8.2 ALARMCARD

Version 2015 – 0.7

ALARM :	**1-1-2** police / fire department / ambulance
Organisation:	Ice association
Contact person:	xxx To be decided
Telephone number:	xxx To be decided
Adress building site:	Tulikivi Oyj Joensuuntie 1226 83900 Juuka, Finland
Overall Safety Coordinator:	Jari Repo
Telephone number:	+358 (0) 407577999
Organisation:	Arno Pronk
Telephone number:	+31 (0) 625080151
First aid contact	
Contact person:	Liselotte de Haan , Joris Borsboom
Telephone number:	+31 (0) 614157485 , +31 (0) 622029912
SAFETY INSPECTION:	Tel 1: Ari Jaaranen (+)358 401042601 — Tel 2: Pertti Kaikkonen (+)358 401042620
Usefull numbers:	
Local Docter:	Juuka Health Care Center First Aid Clinic +358 40104 899
Local Police:	1 1 2
Local Fire department:	1 1 2

EMERGENCY PROCEDURE

1. Provide first aid and avoid further injuries (Vehicle collision, collapse of structure / falling objects etc.)
2. Warn the active first aid-provider and call 1-1-2, Provide information about the accident and which emergency service is needed (police, fire department, ambulance). Always sent one person to a recognizable location to direct the emergency services in the right direction.
3. Make sure the victim is not alone and that he is being threated.
4. Directly contact the safety coordinator after an incident. The safety coordinator also needs to be contacted by near-accidents.
5. The overall safety coordinator and the organization will make a report of the incident to improve the situation and safety.
6. Make sure that the site is clear of danger so the work activities can be resumed (if the emotional aspect allows this).

8.4 Physical health

Working outside

The shifts are divided in 3 hours work, 3 hours rest and 3 hours work. Workers are permitted to stay outside for a maximum of 3 hours with temperatures below freezing point. After these 3 hours a break of at least 20 minutes needs to be taken.

When a worker/volunteer is not feeling well, or shows any signs of hypothermia, the shift leader needs to be immediately informed. The worker/volunteer will stop working immediately and go to a warm space to avoid further injuries. An active First aid-provider will assess whether a doctor should be informed or not.

Wind chill index

The wind causes a cooling effect on the skin. This effect may be expressed as a wind chill temperature. The wind chill temperature defines the ambient temperature, which at a certain wind speed produces the same cooling power (sensation) as the actual environmental conditions. In the next table the values of the wind chill temperature are given for certain wind speeds and outside temperatures.

Table D.1 — Cooling power of wind on exposed flesh expressed as a comparative wind chill temperature (t_{WC}) at a defined wind speed of 4,2 km · h^{-1}

v_{10}		t_a °C										
km·h^{-1}	m·s^{-1}	0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
5	1,4	−2	−7	−13	−19	−24	−30	−36	−41	−47	−53	−58
10	2,8	−3	−9	−15	−21	−27	−33	−39	−45	−51	−57	−63
15	4,2	−4	−11	−17	−23	−29	−35	−41	−48	−54	−60	−66
20	5,6	−5	−12	−18	−24	−31	−37	−43	−49	−56	−62	−68
25	6,9	−6	−12	−19	−25	−32	−38	−45	−51	−57	−64	−70
30	8,3	−7	−13	−20	−26	−33	−39	−46	−52	−59	−65	−72
35	9,7	−7	−14	−20	−27	−33	−40	−47	−53	−60	−66	−73
40	11,1	−7	−14	−21	−27	−34	−41	−48	−54	−61	−68	−74
45	12,5	−8	−15	−21	−28	−35	−42	−48	−55	−62	−69	−75
50	13,9	−8	−15	−22	−29	−35	−42	−49	−56	−63	−70	−76
55	15,3	−9	−15	−22	−29	−36	−43	−50	−57	−63	−70	−77
60	16,7	−9	−16	−23	−30	−37	−43	−50	−57	−64	−71	−78
65	18,1	−9	−16	−23	−30	−37	−44	−51	−58	−65	−72	−79
70	19,4	−9	−16	−23	−30	−37	−44	−51	−59	−66	−73	−80
75	20,8	−10	−17	−24	−31	−38	−45	−52	−59	−66	−73	−80
80	22,2	−10	−17	−24	−31	−38	−45	−52	−60	−67	−74	−81

The shaded areas refer to the different classes of risk according to Table D.2.

Table D.2 — Wind chill temperature (t_{WC}) and freezing time of exposed skin

Classification of risk	t_{WC} °C	Effect
1	−10 to −24	Uncomfortably cold
2	−25 to −34	Very cold, risk of skin freezing
3	−35 to −59	Bitterly cold, exposed skin may freeze in 10 min
4	−60 and colder	Extremely cold, exposed skin may freeze within 2 min

If the wind chill temperature falls within the category 3 or 4 all building activities are suspended. The risk of frostbite is too high under these conditions.

Beaufort scale	Min. wind speed [m/s]	Max. wind speed [m/s]
1	0,3	1,5
2	1,6	3,3
3	3,4	5,4
4	5,5	7,9
5	8,0	10,7
6	10,8	13,8

The weather forecast will be a daily subject in the general meeting (see 3.5 Meetings). At this moment also the WCI will be reviewed to ensure a safe building environment.

8.5 Medical assistance

First aid

First aid-providers can be recognized by the indication on the identification card. A First aid- provider will be always standby. This means that a First aid- provider needs to arrive on location within 10 minutes when needed. The Telephone numbers will be provided in the Construction trailer (Alarm Card). In major incidents the Alarm number (1-1-2) should be called first.

At organized events at least one First aid-provider will be directly present at the snowtrack, or in the Tulikivi Stone Centre.

At any time there needs to be a First Aid Kit (FAK) available at the building site. This FAK will be visually stationed in the Construction trailer. Every use of the FAK needs to be registered in the Construction trailer log. It is the responsibility of the shift leader to register all the used products. It is the responsibility of the Overall safety coordinator to inspect the FAK weekly. The FAK needs to replenish as fast as possible.

The FAK will also be available after completion of the project. A second FAK will be available at the Tulikivi Stone Center at all time. This FAK will also be inspected weekly by the Overall safety coordinator.

8.6 Emergency protocol

1. Provide first aid and avoid further injuries (Vehicle collision, breakage of structure / falling objects etc.)

2. Warn the active first aid-provider and call 1-1-2, Provide information about the accident and which emergency service is needed (police, fire department, ambulance).

   Always sent one person to a recognizable location to direct the emergency services in the right direction.

3. Make sure the victim is not alone and that he is being threated.

4. Directly contact the safety coordinator after an incident. The safety coordinator also needs to be contacted by near-accidents.

5. The overall safety coordinator and the organization will make a report of the incident to improve the situation and safety.

6. Make sure that the site is clear of danger so the work activities can be resumed (if the emotional aspect allows this).

ATTACHMENTS

1. Organization of safety
2. Global schedule
3. Construction log / Report log
4. Office log / Report log
5. Risk and measurements
6. Measuring creep
7. Events
8. Site map

ORGANIZATION OF SAFETY

GLOBAL SCHEDULE

CONSTRUCTION LOG / REPORT LOG

OFFICE LOG / REPORT LOG

RISK AND MEASUREMENTS

MEASURING CREEP

After the bridge is completed the creep of the ice will be monitored. The creep gives an indication of the loadbearing capabilities of the construction. Monitoring will take place visually and by means of measuring.

Visual monitoring will be done by eye. Ice and snow constructions show a big visual deformations before collapse.

The second monitoring method is measuring the creep. This can be done by using an optic distance meter or a rope hanging under need the ice bridge. There are 3 stages of creep: primary, secondary and tertiary.

- The primary creep will occur while building the bridge and when the balloon is deflated. The deformations leading to the primary creep happen relatively fast.
- The secondary creep is linear. During this stage the construction will be safe to use.
- The tertiary stage of creep, during this stage fracture will occur. During tertiary creep it isn't safe to use the construction.

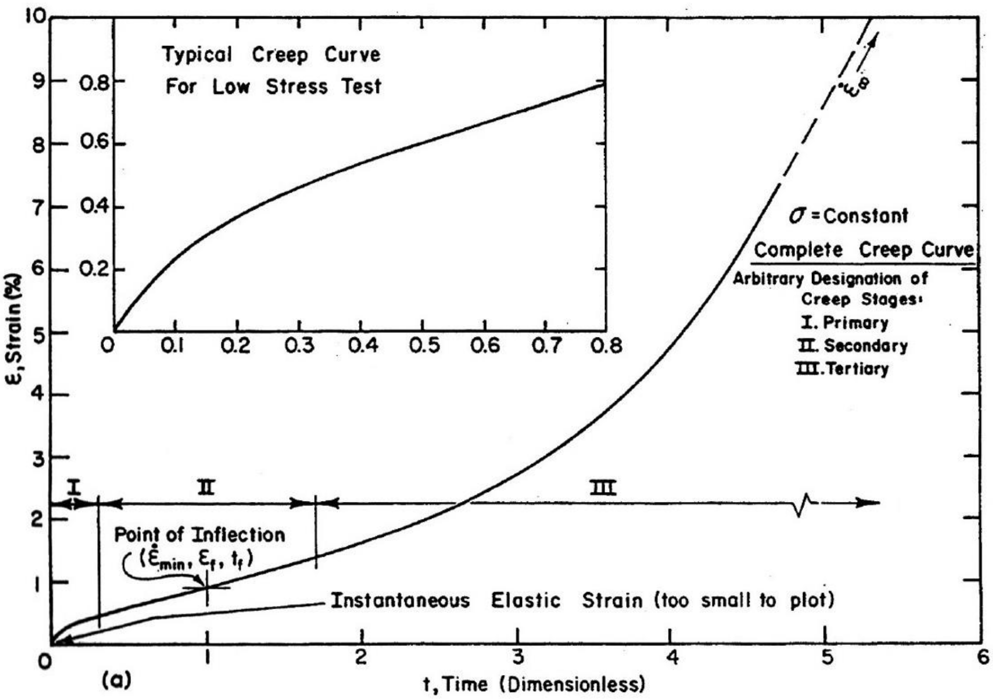


Figure 1 The three stages of creep; primary I, secondary II and tertiary III.

Optic distance meter to measure the creep.

When using the method it is important to measure each day at the same spot. These spots need to be marked well on the ground and on the bridge. These markings need to stay visible even after a period of snow or high temperatures (melting).

The measurements are recorded in an Excel chart. This way it is easy to plot a graph and see of the creep is linear (secondary creep) or exponential (tertiary creep)

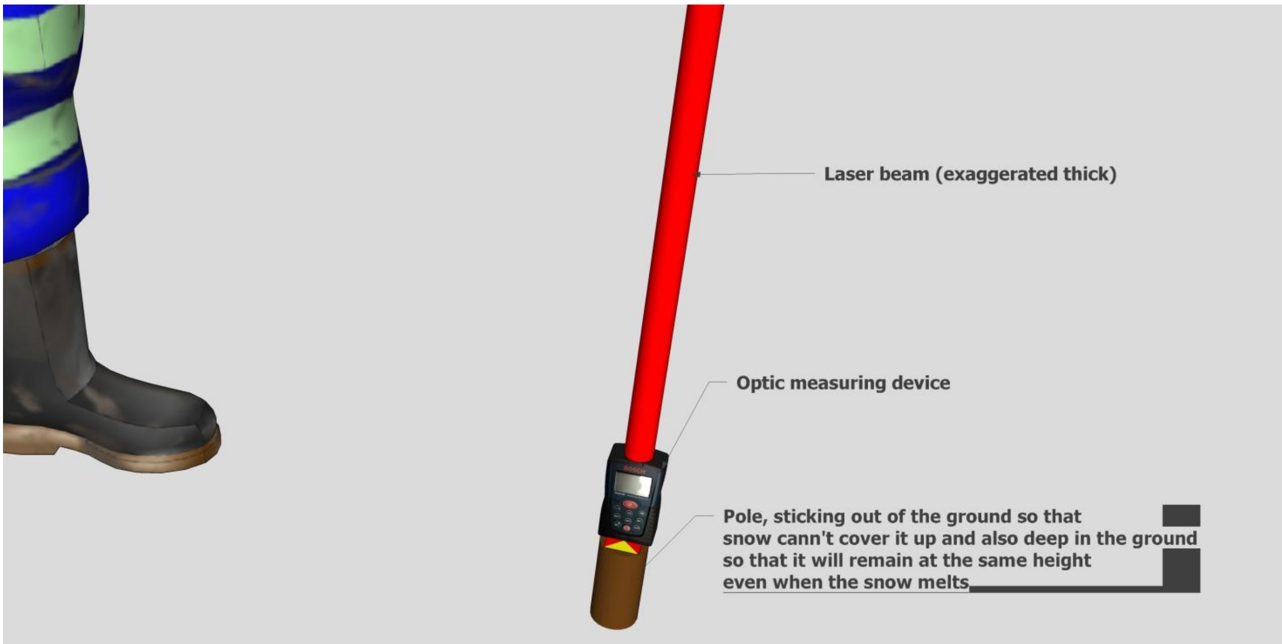


Figure 2 Optic distance meter to measure the creep

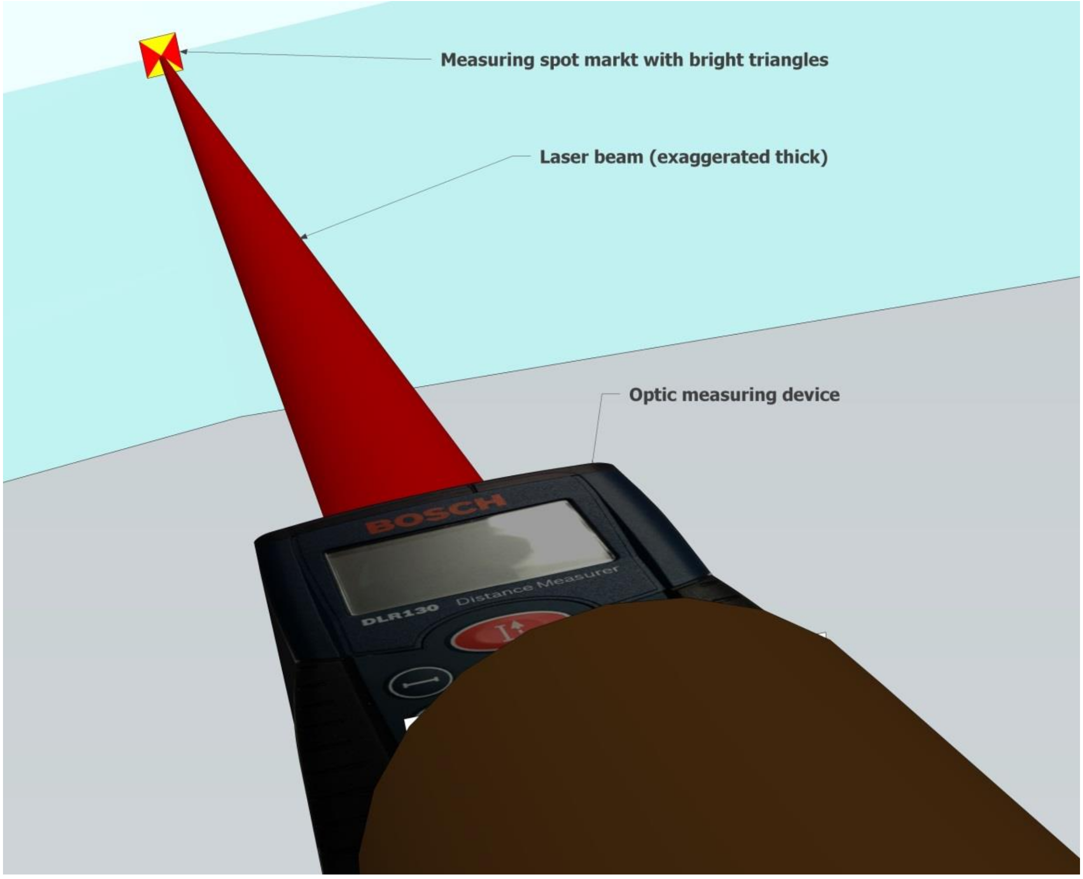


Figure 3 Optic distance meter to measure the creep

Using a rope to measure creep.

A rope with a weight will hang under need the bridge. Next to this rope stands a ruler. On the rope a spot is marked red. On day one, there will be written down on which height the red spot is hanging. Due to creep the red spot will descend, using the ruler one can write down how much the red spot descends each day.

The measurements are recorded in an Excel chart. This way it is easy to plot a graph and see of the creep is linear (secondary creep) or exponential (tertiary creep)

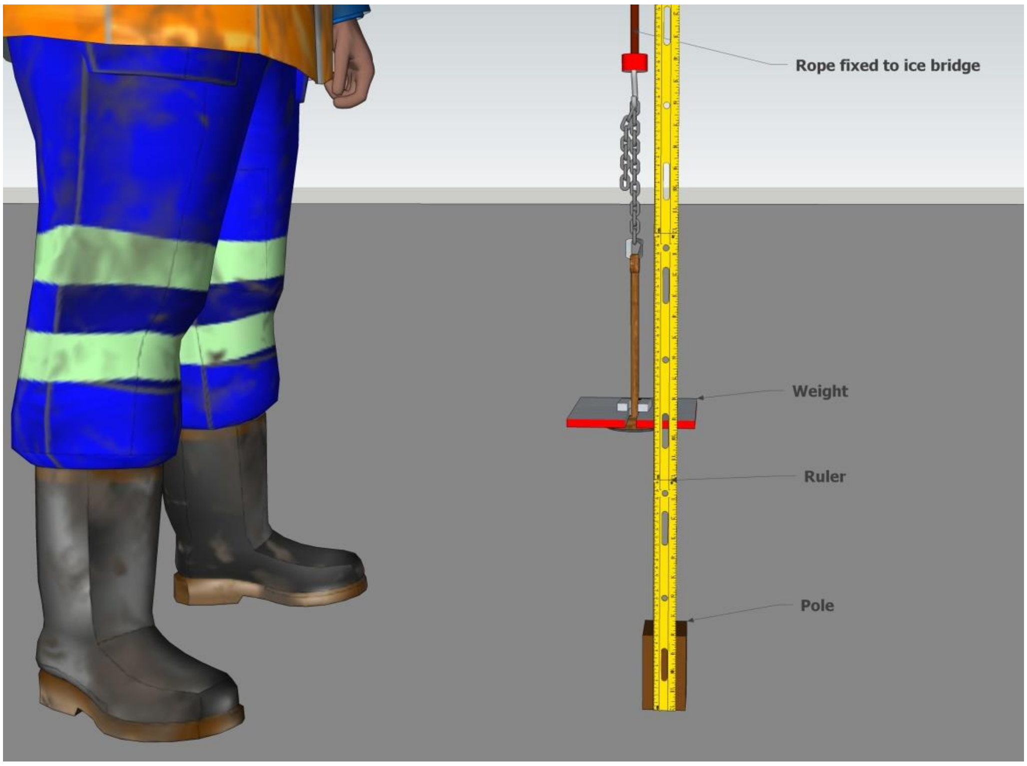


Figure 4 Using a rope to measure creep

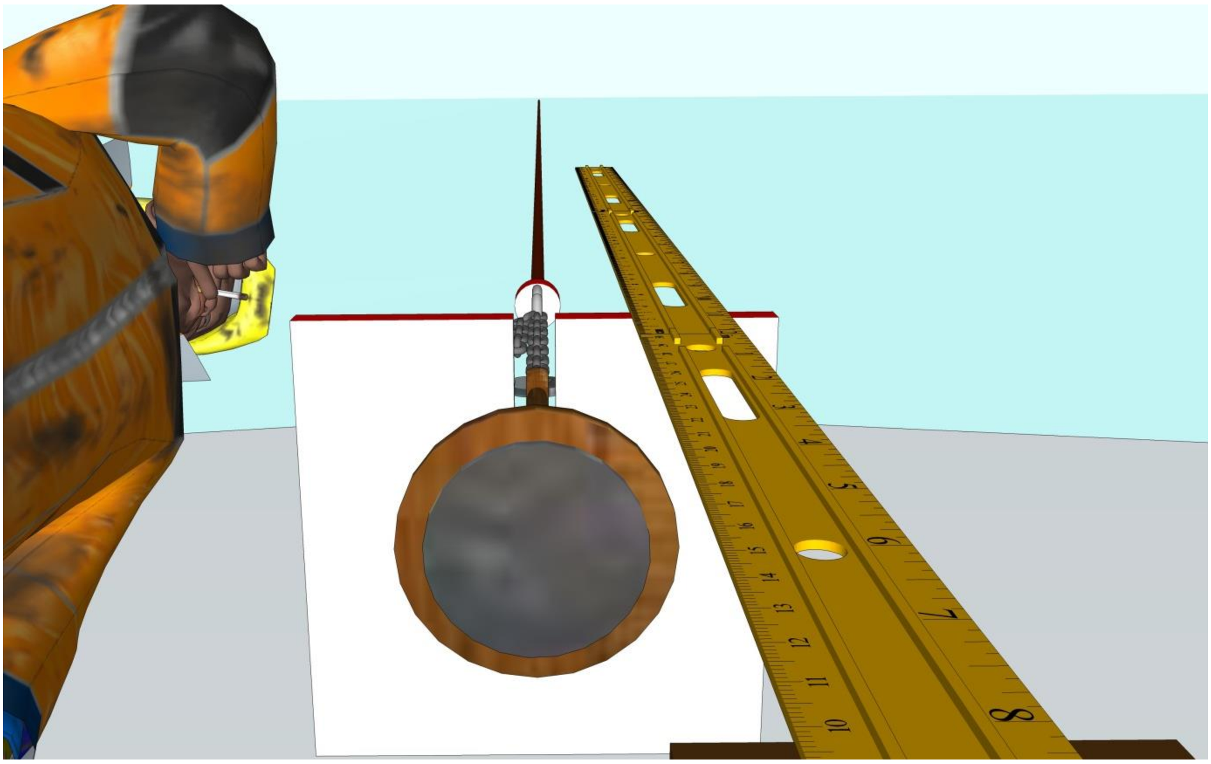


Figure 5 Using a rope to measure creep

The creep behavior of ice was also studied by a Japanese professor Kokawa. Kokawa used two different methods to study the creep behavior of ice domes the methods are show in figure 2 and 3. The method show in figure 2 is a lot like the rope method described on the previous page.

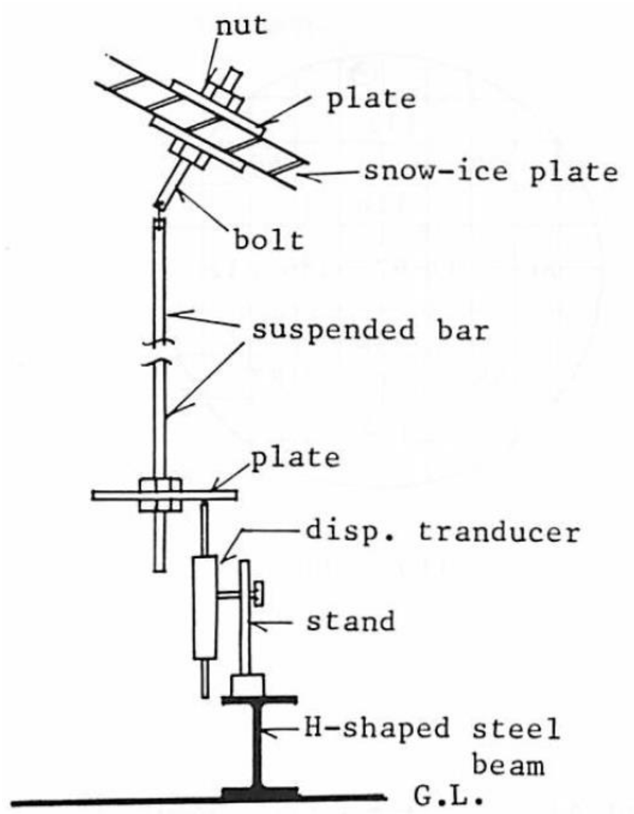


Figure 6 Measuring method used by Kokawa

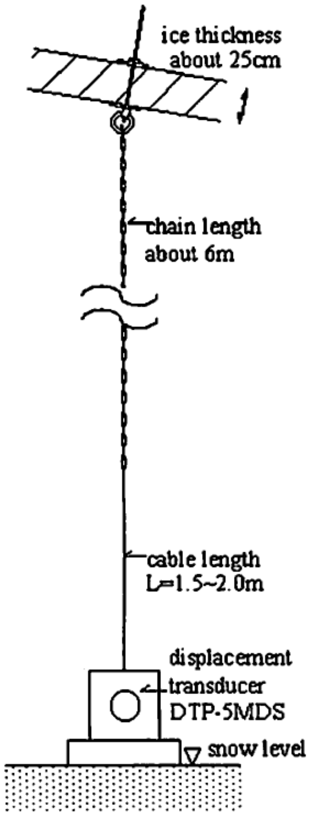


Figure 7 Measuring method used by Kokawa

The measurements obtained by Kokawa trough these measuring methods looked like the graph shown in figure 4. This is approximately a linear line.

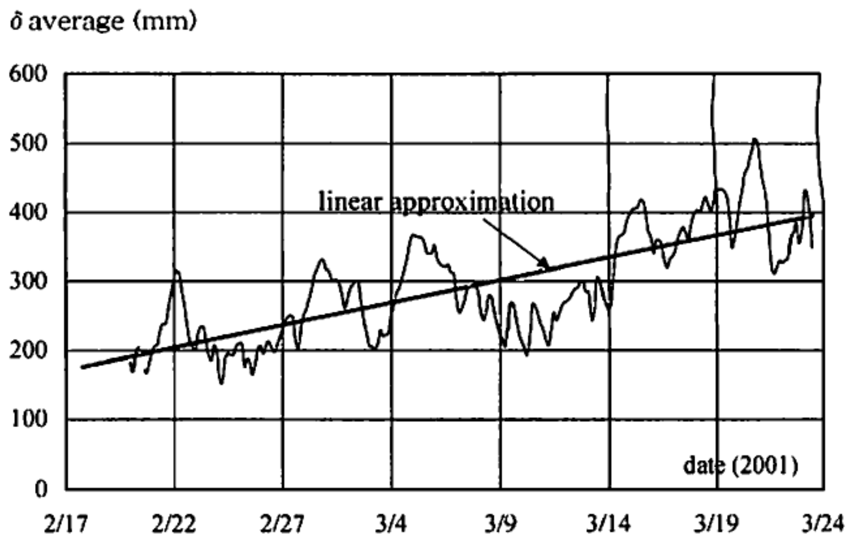


Fig. 20 Linear approximation of displacement curve

Figure 8 measurements of creep during experiments of Kokawa

EVENTS

SITE MAP

General rules

Building site

- Every worker/visitor must have taken part of an overall instruction about dangers and safety at the building site.

- Entering the building site is only permitted with the proper personal protection.
  - Safety shoes; at least safety class S1; provided with anti-slip spikes when needed.
  - Proper recognizable working outfit
  - Helmet; Shift leaders will wear a white helmet for recognition.
  - Watertight work gloves
  - Headlight; 2 people per shift
  - Radio; when needed
  - Identification card; visually presented

- Entering and leaving the building site must be reported by the active shift leader.

- It is important that a clean and organized building site is respected. Used equipment needs to be returned to its original place to avoid delays and injuries.

- Workers are not allowed to work outside for a longer period than 3 hours. Workers must take a break of at least 20 minutes after this time span before continuing the work.

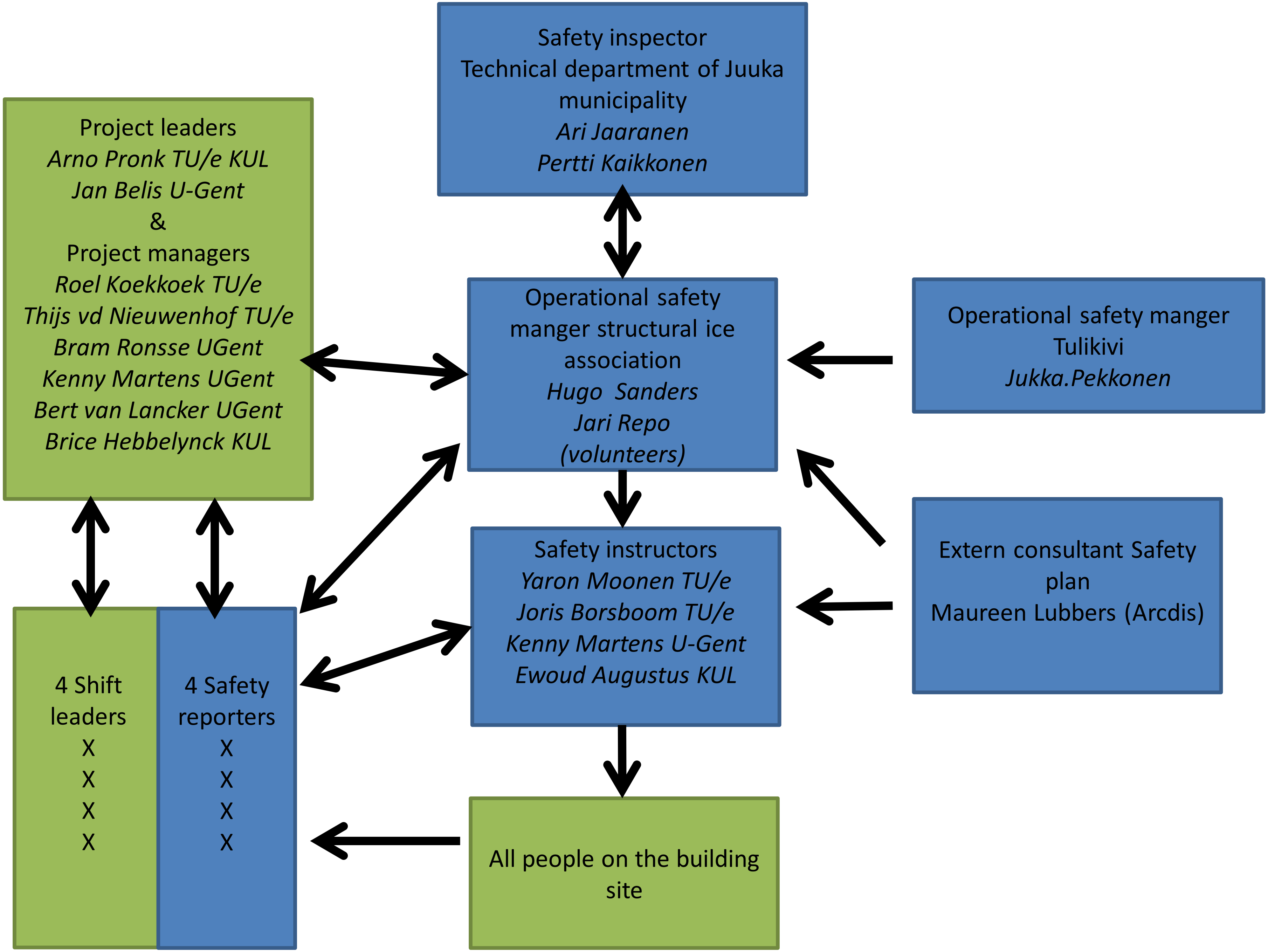
- Alcohol, drugs, and other narcotics are absolute forbidden on the building site. Workers/visitors under the influence of alcohol or drugs will be dismissed from the building site.

Heavy equipment

- It is very important that every type of equipment is well used and is returned to its original position.

- For the operation of the heavy equipment the project team will compose a training per vehicle to operate the device on a safe and responsible way. It is absolutely forbidden to operate heavy equipment without the provided training.

- After every use the device needs to be placed in the right parking spot and connected to the power supply.


Safety inspector
Technical department of Juuka municipality
Ari Jaaranen
Pertti Kaikkonen
Project leaders
Arno Pronk TU/e KUL
Jan Belis U-Gent
&
Project managers
Roel Koekkoek TU/e
Thijs vd Nieuwenhof TU/e
Bram Ronsse UGent
Kenny Martens UGent
Bert van Lancker UGent
Brice Hebbelynck KUL
Operational safety manger structural ice association
Hugo Sanders
Jari Repo
(volunteers)
Operational safety manger Tulikivi
Jukka.Pekkonen
Safety instructors
Yaron Moonen TU/e
Joris Borsboom TU/e
Kenny Martens U-Gent
Ewoud Augustus KUL
Extern consultant Safety plan
Maureen Lubbers (Arcdis)
4 Shift leaders
X
X
X
X
4 Safety reporters
X
X
X
X
All people on the building site

Staff
Arno Pronk
Dirk Huylenbrouck

Project managers
Brice Hebbelynck

Shift leaders + Safety reporters
Michiel Degronde. Forrest cave
Lien Vanholm pavilion
Brice Hebbelynck Gridshell + Ice lamp
Joni vandevelde Ice labyrinth
Francis Thaler Interlocking carboard pavilion

Safety instructor
Ewoud Augustus

Technische Universiteit Eindhoven
University of Technology

Staff
Arno Pronk
Arjan Habraken
Rijk Blok

Project managers
Roel Koekkoek
Thijs van den Nieuwenhof

Shift leaders + Safety reporters
Yaron Moonen
Lex Hermens
Maarten Arntz
Freek Mortel (van de)
Kayleigh Williams
Maikel Brunschot
Artheur Lier (van)
Patrick Lenaers
Shelin Mok
Thomas Dam
Ieva Mileika

Safety instructor
Yaron Moonen
Joris Borsboom

UNIVERSITEIT GENT

Staff
Jan Belis

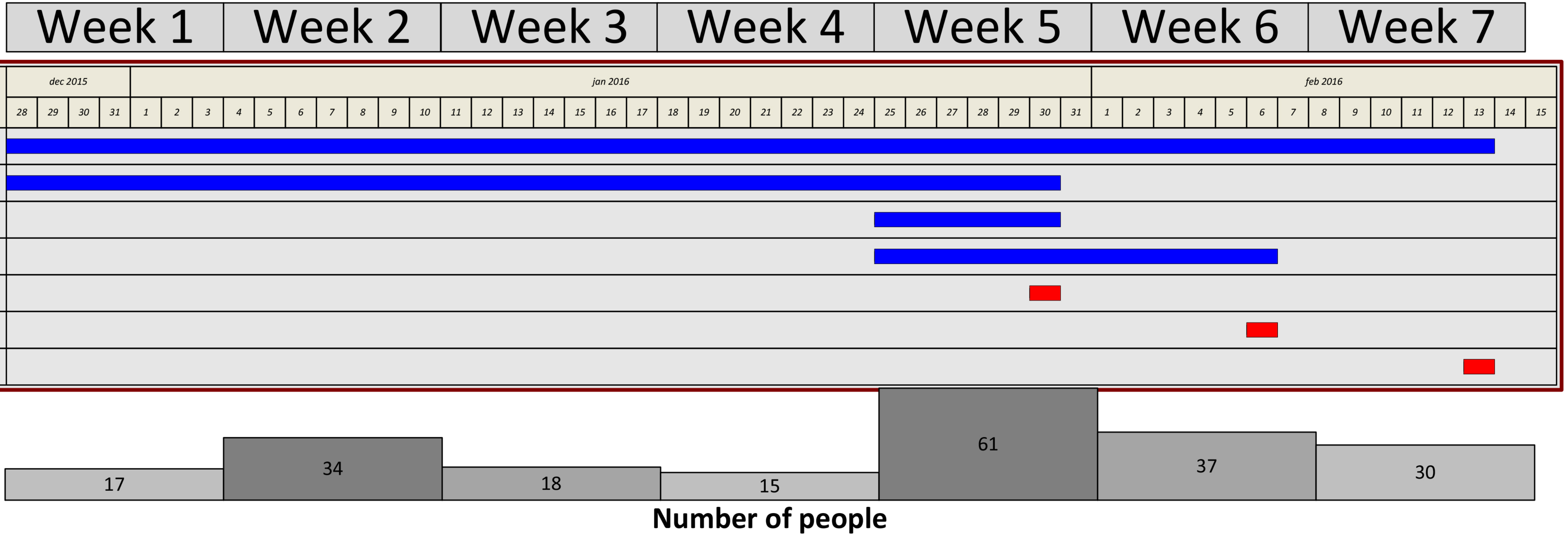
Project managers
Bram Ronsse
Kenny Martens
Bert van Lancker

Shift leaders + Safety reporters
Kenny Martens
Bert Van Lancker
Bram Ronsse
Jan Belis

Safety instructor
Kenny Martens

Schedule building period Ice project Juuka
Date modified: 27-11-2015

ID	Task Name	Start	Finish	Duration
1	Bridge in Ice	28-12-2015	13-2-2016	48d
2	Frozen waterfall	28-12-2015	30-1-2016	34d
3	Snowtrack	25-1-2016	30-1-2016	6d
4	Candela Pavilion	25-1-2016	6-2-2016	13d
5	Opening Snowtreck + Frozen waterfall	30-1-2016	30-1-2016	1d
6	Opening Candela Pavilion	6-2-2016	6-2-2016	1d
7	Opening Ice Bridge	13-2-2016	13-2-2016	1d



Report log

Construction trailer

Time: From...............till............
Date (dd-mm-yyyy): ....
Building site (encircle): Bridge/Pavilion/Track

Shift number: ....
Shift leader: ....
Safety member: ....

	Presence at construction site: **Name:**	**Time of arrival**	**Time of departure**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			

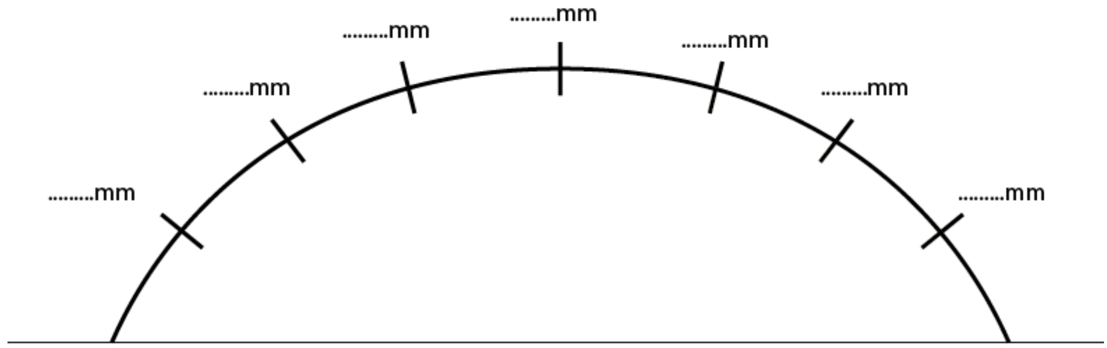
	Reports:
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

Juuka

Candela Pavilion

Report log

Monitoring Thickness (once per 6 hours):



Checklist Shift switch:

- ☐ Building site is clean and accessible (not slippery)
- ☐ Equipment has been returned to its original place.
- ☐ Heavy equipment is parked on the right spot and plugged in the electricity.
- ☐ The headlights and radios are being charged.
- ☐ Helmets and spikes are transferred to the next shift.
- ☐ The Report has been filled in complete and correctly.
- ☐ **End of shift**

Use and replenishment:

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	(Optional) extra comments:
1.	
2.	
3.	
4.	
5.	
6.	

Office log

General log form

Time: From..............till............
Date (dd-mm-yyyy): ....
Meeting type: ....

Chairman: ....
Secretary: ....
Safety member: ....

	Presence at meeting: **Name:**		**Name:**
1.		**11.**	
2.		**12.**	
3.		**13.**	
4.		**14.**	
5.		**15.**	
6.		**16.**	
7.		**17.**	
8.		**18.**	
9.		**19.**	
10.		**20.**	

Overall meeting guideline :

1. Preformed points previous meeting
2. Progress and problems
3. Announcements
4. Safety
5. Weather forecast
6. Survey
7. Compose tasks
8. **End of Meeting**

	Announcements:
1.	
2.	
3.	
4.	
5.	
6.	

7.	
8.	
9.	
10.	

	Tasks	Responsible
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Safety Plan

Annex 1	**General risks**	Risks during the whole building period
Annex 2	**Risks during construction**	Risks during the construction of specific ice structures

Da Vinci's Bridge in Ice
2016

Unwanted event				Preventing event	
Activity	**Risk**	**Cause**	**Consequence**	**Measures**	**Category**
General					
Working next too water	Falling in water	Slip and fall into water	Hypothermia	• Place barrier in the form of fences / balustrade • Fall protection (harness) • Always work with 2 persons near water	2 4 1
Working with water hose	Person gets wet	A fracture in the water hose	Hypothermia	• When a person gets wet he/she should immediately go to a warm room	3
Walking on site	Difficult to reach workplace	Obstacles on workplace (water hose, cables)	Physical injury	Lay cables and hoses organized/ ordered	3 2
Walking over building site	Person slips and falls	Ice and snow on construction site	Physical injury	• Use gravel to give surface more roughness • Wear shoes with ice spikes	2 4
Location in general	Unwanted presence of outsiders	Public location, easily accessible, insufficient fencing	Leads to unsafe situations	• Place fences • Place signs • Cards with name and photo for authorized persons	2 3 4
Location in general	Construction site and roads inaccessible	Snow and ice	Equipment can't reach the desired location	• Clear snow with snow plow • Use gravel to create traction • Mark roads and obstacles	2 2 3
Working next to power lines	Breaking or falling of the power lines	Hitting electricity pole or wires	Power failure	• Illuminate cables • Workers aware of presence cables	3 1
Snow storm or fog	Accidents due to poor visibility	Insufficient lighting	• Physical injury • Damage to equipment	• Places enough lights on construction site • Wear fluorescent/reflective clothing • Decide to suspend working activities	2 4 1
Working in cold conditions (<-15 ° c)	Frostbite to limbs	Exposure to low temperatures (< -10 °C) and wind	• Frostbite • Physical injury	• Wear protective clothing • Presence of heated room on construction site • Do not work when the wind-chill index is in zone 3 or 4	4 3 1
Driving equipment	Equipment slides off the road	Not aware of slippery conditions	• Physical injury • Damage to equipment	• Drive with appropriate speed • Snow chains • Road markings (reflectors)	1 3
Hoisting / vertical transport	Falling load	Lack of attention	Physical injury	• Only workers that are essential to the lifting activities should be on the building site • Do not walk underneath lifted loads • Use approved lifting materials & equipment	1 3 3

Horizontal transport (driving equipment)	Collision	Lack of attention Lack of visibility	Physical injury	• Workers are aware of blind spot driver • Sound signals, informers/beepers for driver and alarm beepers at movement machine (parts) • Light signals • Drive with appropriate speed (at walking pace)	4 3 3 1
Informing	Accident due to lack of knowledge about dangers	Not aware of existing dangers	Physical injury	• Inform workers/volunteers well before they start building (tour over construction site, presentation) • Place warning signs, information boards where needed	3 3
During shift	Drunk/tipsy on construction site	Consuming alcohol at building site of before shift	• Physical injury • Damage to equipment	• Do not drink alcohol on construction site • Do not drink before shift	1 1
Tying knots	Knot that isn't strong enough	Wrong knot	Physical injury	• Instruction about knots	1

Category 1: Danger minimized, the chance that it will occur has been made smaller

Category 2: Keep the danger away from the worker.

Category 3: Keep the worker away from the danger.

Category 4: Personal protective equipment

Unwanted event				Preventing event	
Activity	**Risk**	**Cause**	**Consequence**	**Measures**	**Category**
Phase I - Preparations for building the Bridge in Ice (28-12-2015 until 07-01-2016)					
Moving the balloon manually	Excessive physical stress	Lifting to heavy, lifting in a wrong position	Physical injury	• Use auxiliary tools • Use sufficient workers to perform a heavy task	1 2
Walking on site	Falling / tripping over ground anchor	Ground anchor partly sticks out of the ground	Physical injury	• Ground anchors are marked to make them better visible	2
Working inside the balloon	Fainting inside the balloon	• Not enough oxygen • Claustrophobia	Physical injury	• Always go inside with 2 persons • Carry a knife to cut a hole in the balloon in case of emergency • Tell people you're inside	1 4
Working inside the balloon	Getting stuck inside the balloon	Not able to find or reach the exit	Physical injury	• Always go inside with 2 persons • Carry a knife to cut a hole in the balloon in case of emergency • Tell people you're inside	2 4
Moving rope net manually	Excessive physical stress	Lifting to heavy, lifting in a wrong position	Physical injury	• Use auxiliary tools • Use sufficient workers to perform a heavy task	1 1
Attaching ropes	Get open hands	Steel connections ropes	Physical injury	• Wear Gloves	4
Moving rope net	Fall	Tripping over rope	Physical injury	• Move at a slow pass • Walk outside of the rope net	1 1
Inflating balloon	Balloon get's blown away by a wind gust	• Balloon is not fixed properly • Unexpected wind gust	Construction process is disturbed an delayed	• Anchor balloon properly • Monitor weather forecast • When the wind speed is to high deflate the balloon (wind speed beaufort scale 6)	1 1
Inflating balloon	Anchors break due to a wind gust	Peak load on some anchors	Construction process is disturbed an delayed	• Monitor weather forecast	1
Inflating balloon	Pressure to high	Weld will tear apart	Construction process is disturbed an delayed	• Pressure gauge • Constantly observe membrane tension	1 1
Phase II - Building Da Vinci's Bridge in Ice (04-01-2015 until 12-02-2015)					
Working at a height	Worker falls from height	Stumble	Physical injury	• Wearing and using safety harness	4
Working alongside ice structure	• Falling object • Falling ice	• Carelessness when handling tools at a height • Movement of balloon looses ice	Physical injury	• Wearing helmet and safety shoes • If not necessary don't walk under need balloon and keep 5 meter distance	4
Working at a height with a boom lift	Boom lift runs out of fuel	Not in time to refuel the boom lift	Workers are stuck at a height this increases risk of hypothermia/frostbite	• At the start of the shift check fuel level • Check if there is enough reserve fuel present	1 1

Building with temperatures below 0 °C	Ice on work clothes	Ice formation due to the spraying of water and pykrete	Complicates movement of worker	• Prevent that water or pykrete reaches workers • Presence of a heated room on the building site	1 3
Working with water/pykrete hose	High physical load	• Not using equipment/ auxiliary tools • Working with too few people	Physical injury	• Use auxiliary tools • Use sufficient workers to perform a heavy task (use KIM-method to evaluate if there are sufficient persons)	1 1
Equipment is parked at building site	Ice buildup on equipment	Ice formation due to the spraying of water and pykrete	Damage to equipment	• Do not park machines in the vicinity of the spraying or snow lances • Covering machines when they are parked in the vicinity of the spraying or snow lances	3
Using the snow plow	A foot or hand gets stuck in the snow intake	Lack of attention	Physical injury	• Don't come near snowplow • When the snow plow is on don't come close to the snow inlet	1
Using gas burner for defrosting	• Burned skin • Gas cylinder explodes	• Using the burner wrong • Flammable materials in neighborhood	Physical injury	• Only instructed workers that know what they doe can use the gas burner • Wear protecting clothing • Remove flammable and/or explosive materials • Sufficient fire extinguishers present	1 4
Working with snow Lances	High-pressure hose comes loose (pressured air and water 20 bar)	Hose isn't connected properly	Physical injury	• Before the pump is turned on check connections of the hoses	1
High temperatures (> 0 °C) melting	Melting of snow and ice	High outside temperature	Weak ice	• Keep 20 m distance from ice structure	3
High temperatures (> 0 °C) melting	Melting of snow and ice	High outside temperature	Greater chance of power failure	• Emergency aggregate present	1
High temperatures (> 0 °C) melting	Melting of snow and ice	High outside temperature	Refreezing of melted snow and ice produces very slippery patches	• Use gravel to give surface more roughness	2
Spraying water continuously to prevent freezing	Tree falls due to ice formation	Water should continue to flow therefor it is sprayed into the bushes	• Physical injury • Damage to equipment	• Do not spray in the direction of trees	1
Using a balloon as mold	Balloon deflates	Fan failure or a leak	Thin ice breaks and falls	• Place sensors that give a warning when air pressure is lost inside the balloon	3
Using a balloon as mold	Balloon get's blown away by a gust of wind	• Balloon is not fixed properly • Unexpected wind gust	Construction process is disturbed an delayed	• Anchor balloon properly • Keep an eye on the weather forecast	1 1
Using water to build	Water pipes or water/pykrete hose freezes	Low outside temperature (> 0 °C)	No supply of water or pykrete	• Continuous flow of water/pykrete • Isolate pipes • Heat pipes	1 2 2
Phase III - Building Da Vinci's Bridge in Ice + Pavilion Calatrava (25-01-2016 until 12-02-2016)					
Identical as Bridge in Ice					

Phase III - Building Da Vinci's Bridge in Ice + Pavilion Calatrava + Making Ice track (01-02-2016 until 12-02-2016)					
Spraying water at ropes	Falling of the cliff	Slippery surface	Physical injury	• Keep distance from edge (marked with balustrade) • Safety fence • Using a safety rope with harness	3 3 4
Phase IV - Clearing building site and Exploitation (13-02-2015 until unknown)					
Walking toward the ice structure	Person slips and falls	Slippery ground	Physical injury	• Use gravel to give surface more roughness	2
Walking on the bridge	Person slips and falls	Slippery ground and height difference	Physical injury	• Use gravel to give surface more roughness • Safety fences that are secured to the ground	2 3

Category 1: Danger minimized, the chance that it will occur has been made smaller

Category 2: Keep the danger away from the worker.

Category 3: Keep the worker away from the danger.

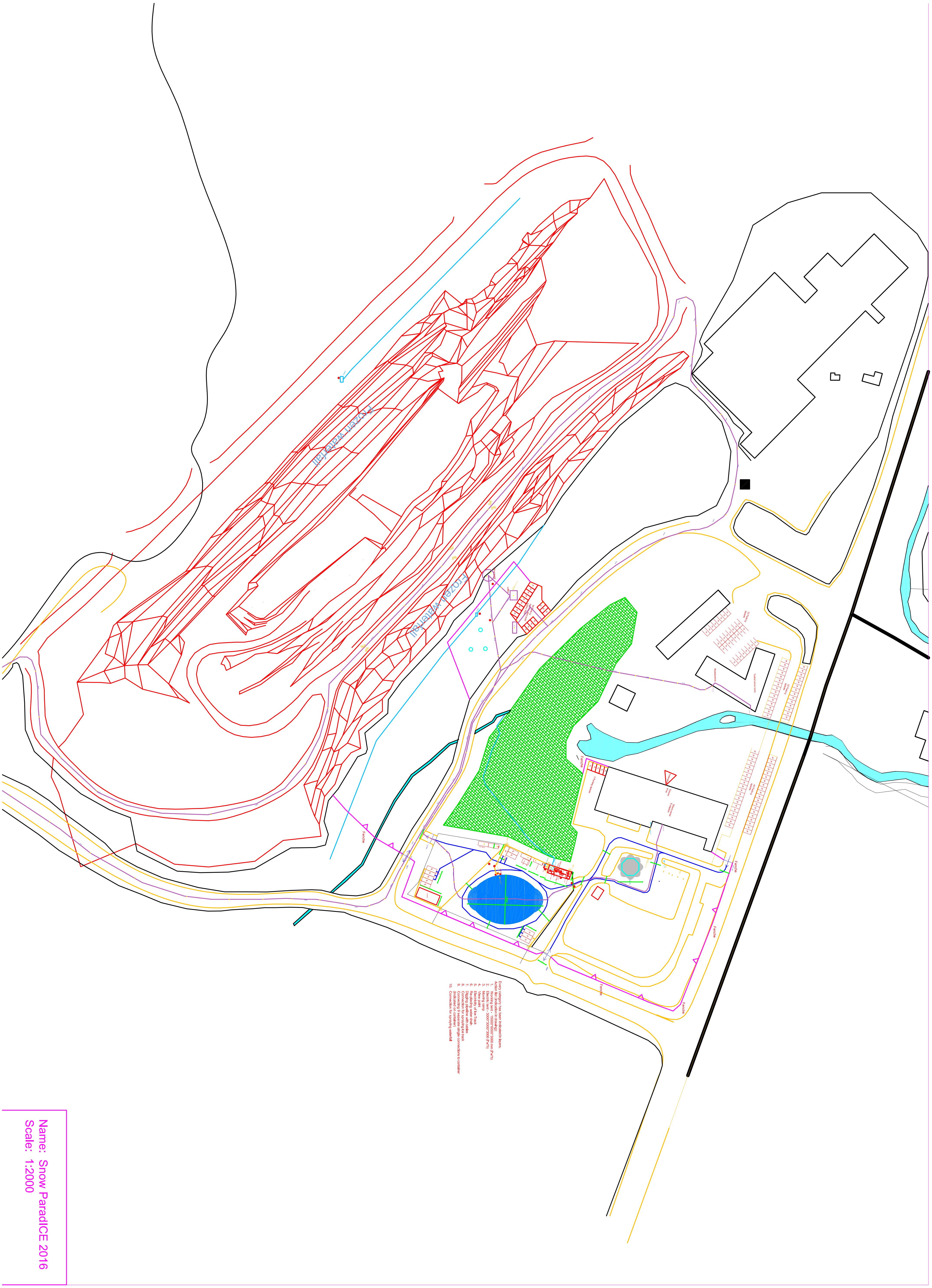
Category 4: Personal protective equipment

Bridge in Ice

calculation: buildingcosts

Item		Part	Description	Amount	M1/M2/M3/pieces	Duration (days) / Costs per unit	Responsible
1	day	time					
	4 january to 15 march		exhabition by stone center	10000	visitors	1	Tulikivi thier part in enterance fee
	4 january to 15 march		collection of entrence fee for snow paradice by volunteers, cleaning safety e	10000		1	Arno, Heiddi, Johanna, Liselotte
	31 December (Thursday)	21.00	New Years Eve party in Nunnanlahti school 21:00 and Restaurant Petra unt	500		1	Sirpa Salminen and vilage of nunnanlathi
	1 January (Friday)	13.00	New Year's Breakfast at 13. In the balloon if possible.	100		1	Liselotte
	4 January (Monday)	17.00	opening of exhibitions. Shop and ticket sale in stone center	50		1	Tulikivi Oyj, Gallerist J Haapalainen, kauko kortelainen Juuka-S
	5 january Tuesday	12.00	opening ice info corner at Petra				Arno, Pasi, Lisselotte & Sirpa Salminen, Koli Activ Oy, Pe
	6 January (Wednesday)	11-18?	Epiphany, local holy day popular among Russian tourists, possible small.	200	visitors	1	Tulikivi Oyj, Pilke Oy,JuuU, JuuJä(Sport clubs)
	8 january (Friday)	12.00	talk at ice info corner in Petra				Arno & Pasi (sanomat)
	9 January (Saturday)	17.00	Balloon party (party inside the balloons, if possible). Maybe some Juuka-Seu	200		1	Liselotte,students eindhoven
	12 january Tuesday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	15 january Friday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	16 January (Saturday)	17.00	"Lowlands" party in Nunnanlahti & Petra	300		1	Lisselotte & Sirpa Salminen, Koli Activ Oy,
	16 January (Saturday)	11-18?	Winter olympics	300		1	Pilke Oyj
	19 january Tuesday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	22 january Friday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	23 January (Saturday)	17.00	"Highest point" party. Juuka-Seura /Juuka-Association activities in the aftern	300		1	Liselotte
	26 january Tuesday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	28/29 January (Thursday/Friday)		Schoolkids of Juuka of Juuka visit Nunnanlahti	part of budget by Juuka Kunta			Municipality,Heidi & Hugo
	29 january Friday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	30 January (Saturday)		Coffee cabin design&construct of the snowtrack	1		1	Ku Leuven
	30 January (Saturday)	13.00	opening of the snowtrack and coffee corner by KU Leuven	350		1	Ku Leuven
	30 January (Saturday)	17.00	Evil ice queen + movie (fee for movie 5 euro)	50		1	Linda Zilliacus, Arno Liselotte
	1-5 febr.		workshop davinci domes by Dirk Huylenbrouck with school childeren of Juuka				Heidi Dirk
	2 february Tuesday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	4 February (Thursday)		Little children come to Nunnanlahti	part of budget by Juuka Kunta			Heidi & Hugo
	5 february Friday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	5/6 February (Friday/Saterday)	19.00	Evil ice queen movie (fee for movie 5 euro)	50		1	Linda Zilliacus, Arno Liselotte
	6 February (Saturday)	13.00	opening of the candela pavilion U-Gent	350		1	Jan & Bram
	6 February (Saturday)	17.00	book presentation and math performance.				Dirk Huylenbrouck & Heidi
	9 february Tuesday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	11 februari Thursday	17.00	Ice Carnaval	350		1	Teun & Jorrit
	11/12/13 february (Thu./Fri./Sat	19.00	Evil ice queen movie (fee for movie 5 euro)	50		1	Linda Zilliacus, Arno Liselotte
	12 february Friday	12.00	talk at ice info corner at Petra				Arno & Pasi (sanomat)
	12 February Friday	13.00	workshop for children Geometric Constructions bridges by hart	part of budget by Juuka Kunta			Kristof Fenyvesi
	12 February Friday	17.00	ISOFF-conference in Tulikivi Auditorium	own budget, see 06			Arno Pronk Liselotte
	10 – 14 February (from Wednesday till Sunday)		Sustainability bootcamp by Fred Sanders	own budget, see 07			Fred Sanders + Heidi
	13 February (Saturday)		*Opening of the bridge. Doors open at 13 and close at 19.	2000			Heidi , Laurien, Mo, Arno, Johanna, Liselotte
	specification opening bridge		sound system	1		1	Heidi , Laurien, Mo, Arno, Johanna, Liselotte
			lightning	1		1	Heidi , Laurien, Mo, Arno, Johanna, Liselotte
			art direction	1		1	MO en Laurien Liselotte
			stage	1		1	Heidi , Laurien, Mo, Arno, Johanna, Liselotte
		12.00	Intermediate program starting at 13: playback music, talk host, live intervie	1		1	Johanna
		12.00	Student DJ	1		1	Universities Liselotte
		15.00	The official opening ceremony, major, arno etc	1		1	heidi
		15.20	Snow blowing in paradice by Laurien	1		1	MO en Laurien, Lisselotte
			Voice of Finland Winner Miia Kosunen,	1		1	Heidi & Johanna
			Dance act	1		1	MO en Laurien Lisselotte
			fire act	1		1	MO en Laurien Lisselotte
			fire works & national hymns or similar	1		1	Heidi & Johanna
			VJ	1		1	MO en Laurien Lisselotte
			total cost for opening at 13 february	15.300			
		11.00	Opening party in the evening, in petra	Not in our budget			Sirpa Salminen
	20/21 February sat/sun		Tulikivi- days, organized by Tulikivi, contact person Arja Lehikoinen @tulikiv	350		1	Arja thier part in enterance fee
	27 February sat		North Karelia cuisine & family weekend.	500		1	Johanna thier part in enterance fee
	27.2.		Band Rasinkangas plays for children.	500		1	Johanna thier part in enterance fee
	5 March		Business Fair, Juuka entrepeneurs	500		1	Matti thier part in enterance fee
			Juuka Karaoke Club presents " Limperin Muori"	500		1	
	12 March	11.00 18.00	ICE-Rock & Snowland closure party. Duudsnons show?	500		1	Johanna thier part in enterance fee
	13 March		Final Day; Ice breaker or Meld down?	500		1	Johanna thier part in enterance fee
			total amount of paying vistors for special events	**7400**			Arno & Heidi
			regular visitors	2600			
						total	
		garntee fund		11%	percent		
		Financial costs Ice Events					
		Total costs Ice Events					
		Date: 7 september 2015					

Item		Part	Description	Amount	M1/M2/M3/pieces/persons	Duration (days) / Costs per unit	Responsible
1		**Income event**					
1,1		Visitors	single tickets	5100	persons		Arno, Heidi, Johanna, Liselotte
		Visitors	single tickets	3000	pers. (reduced fee)		
		Visitors	seasonal tickets Free enterance (for events organized by the association)	600	persons		
		Visitors	seasonal tickets Free enterance (for events organized by the association)	200	pers. (reduced fee)		
		Visitors	groups	700	persons		
1,1		Visitors	groups	400	pers. (reduced fee)		Arno, Heidi, Johanna, Liselotte
1,2		Entrepeneurs	entrepeneurs exploit booth during Ice Events	10	pieces		Heidi, Johanna,
					average price		
		Total		**10000**	**visitors**		



Frozen waterfall
Frozen waterfall
Name: Snow ParadICE 2016
Scale: 1:2000

Appendix 10

Da Vinci's BRIDGE IN ICE

Chr. Muller Touw bv
FOR ALL YOUROPE

PEKKANISKA

Poly-Ned
Textielarchitectuur
www.polyned.nl

SANDERS
PROJECT ADVIEZEN

Tulikivi

Universiteitsfonds Eindhoven

HITACHI
Inspire the Next

ROTATOR

DB SCHENKER

ahlsell

BEVERS

COFELY
GDF SUEZ

HSA Oy

maco technology

PIELISEN MAANRAKENNUS

SAHER-AIDAT

VAN DOREN ENGINEERS BV

VANKILATUOTE
RIKOSSEURAAMUSLAITOS
VALMISTAJA
Ylitornion vankila
www.vankilatuote.fi

WAGO

ARCADIS

Groente Fruit José

AON

VERHUUR easy cool KOELING

EUROFRIGO B.V.

SCANTARP

storaenso

TRANSFENNICA

Tujanranta Consultants

MAMMOET

JLD INTERNATIONAL

METALLI PALVELU HARTIKAINEN OY

SIOEN

HydLub Oy
Hydraulics & Lubrication Consulting

Kuvauskallinen.fi

JOSEK

juuan lvi oy
(013) 470 768, Kirkkotie 5, 83900 Juuka

SICK
Sensor Intelligence.

Erica Project Advies

Vaarojen Sanomat

Da Vinci's
BRIDGE in ICE

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Structural Ice Association

In 2013, Arno Pronk came up with the idea to use fiber-reinforced ice in practice, triggered by past research that have been conducted. The goal was to create the world's largest ice dome, the Pykrete Dome. Hugo Sanders, founder of Sanders Projects Consultancy, was involved early in the project because of his connections in Finland and especially in Juuka, an area that is ideal for such an ice project. As co-initiator of this project, Hugo Sanders plays an important role in the ice projects in Juuka. His friend Jari Repo was the technical foreman in the first project. Other persons of great importance to the success to this project were Matti Tuominen and Ari Jaaranen.

The 'Pykrete Dome' project really had a great impact on the municipality of Juuka. The success of the project could lead to an annual event. This of course requires some organization, not only from the Technical University of Eindhoven, but especially from the municipality of Juuka. They supported this vision and together we (started to) develop future ice projects for Juuka . In the winter of 2015 and 2016, Matti Tuominen was the technical foreman from Juuka. Without the help of the municipality of Juuka and the above-mentioned persons in particular, the ice projects could not have been realized.

To organize a series of ice events we developed an association. The task of the association is to form a legal organization for annual ice events. The association will cooperate with the entrepreneurs, Governmental organizations, schools, universities etc. The goal of the association is to spread and stimulate similar research and experiments also to other places.

Consortium

The Eindhoven University of Technology has been the leading partner in this project. Different disciplines within the faculty of 'Built Environment' worked together to achieve a new inspiring ice project: 'Da Vinci's Bridge in Ice'. The faculty and university were very enthusiastic and together with University Funding Eindhoven (UFe) they were willing to support the project. From the Eindhoven University of Technology the project was supervised by Patrick Teuffel, Arno Pronk, Rijk Blok and Arjan Habraken. The tutors are all part of the chair Innovative Structural Design (ISD) with leading professor Patrick Teuffel and project leader Arno Pronk.

Like in previous years we invited other universities in the Netherlands and abroad to participate in the ice projects in Juuka.

In September 2014, the Ghent University became involved in the project. A group of Structural Design students, led by Professor Jan Belis, made structural calculations for the design of the ice cathedral. In January 2015, these students also helped to construct the ice domes in Finland. This year, they realized their own project the Candela pavilion in ice. Students from KU Leuven realized various experimental pavilions along an ice track leading to a frozen waterfall in the Quarry of the Tulikivi stone factory. Furthermore, The Summa College, Sint Lucas and Fontys in Eindhoven have been involved, as well as students and teachers of other universities. Below you find a list of all other universities that have been involved.

- RusHydro
- TU Delft
- TU/e
- University of Bath
- The University of Edinburgh
- Fontys
- Juuka
- Karelia Ammattikorkeakoulu
- KU Leuven
- Pohjois-Karjalan Maakuntaliitto – Regional Council of North Karelia
- ETH zürich
- Summa College
- University of Jyväskylä
- Universidade do Minho
- Aalto University
- Sint Lucas Creative Community
- Support Study Association Building Technology
- VTT
- Bridges Finland 2016 – University of Jyväskylä
- Universiteit Gent
- UCL Université catholique de Louvain

Juuka, Finland

Juuka is a municipality of North Karelia, a province in Eastern Finland. The ice structure will be built on private property owned by Tulikivi, the world's largest manufacturer of heat-retaining fireplaces.
The 'Pykrete Dome' and 'the Sagrada Familia in Ice' projects really had a big impact on the municipality of Juuka. The success of the projects could be a starting point for an annual event. This of course requires some organization, not only from the Technical University of Eindhoven, but especially from the municipality of Juuka. The mayor of Juuka, Pekka Pietiäinen, supported this vision and together with the local volunteers they formed the driving force for new ice projects in Juuka. The municipality was able to arrange sponsors and a subsidy. The budget of this financial contribution was spent under the responsibility of the steering committee Karelia Ice Pie.

Without the help of the municipality of Juuka the 'The Bridge in Ice' project could not have been realized.

Who
Joensuu Regional Development Company JOSEK Ltd specialises in business counselling for small and medium-sized enterprises, marketing of the region and development of business in different industries. The company operates in the Joensuu region.
What & How
Our role is to bring together ideas and operators. We have been involved in the Juuka ice construction projects from the beginning. A large number of companies, organisations and communities that serve ice construction have been created in Juuka.
Such activity is the best way to practice collaboration and getting to know each other. In future, these emerging networks will be important tools as we create more work and livelihood to North Karelia and Juuka.
In our opinion, the project has in that respect exceeded the targets that were set for it by more than 100%.
To Whom
The Bridge in Ice has played an important role in bringing together enterprises, education institutions and other operators in Finland as well as between Finland and the Netherlands.
This year, we have also had operators from e.g. Belgium, the UK and Russia.
The Bridge in Ice project has contributed considerably to reaching one of our key goals, the internationalisation of our region.
Future
In our region, there is already a knowledge base and a favourable attitude towards development in the fields of the forest-based bioeconomy, travel and tourism, and construction. From the point of view of North Karelia and Juuka, it is especially important to promote collaboration in those industries.
Jouni Luoma and Jouko Piirainen, JOSEK Ltd

JOSEK

Juuka

'As the new mayor of the Juuka municipality, I am interested in what the municipality and its people stand for. Juuka is known for the soapstone industry, Lake Pielinen and during the recent years for ice building. This has brought international visibility to Juuka. Nowadays ice building has become a part of the personality and profile of our town.
The task of the sciences is the search for truth and to explain what the world is like. The task of the arts is to give visibility and content to the world. Their joint creativity gives us social capital and contributes to our well-being. This project has brought together science and art. At the same time it has brought together people from all over Europe. Here in our small northern municipality, this has succeeded in mutual co-operation between builders and local volunteers. Our thanks go out to the Eindhoven University of Technology, the Aalto University and other universities from Belgium, Great Britain, Portugal, Switzerland and Finland. Thank you to hundreds of volunteers, businesses from our region and to all who sponsored and participated in the project.'
Markus Hirvonen, Mayor of Juuka Municipality

Building with Ice

In September 2003, I have built an igloo for an exhibition in Amsterdam. Building an igloo in the summer was a great challenge that could be realized with the help of a freezing machine of EasyCool BV. Building with ice has never lost my interest since, so when we got the opportunity to realize the greatest igloo in the world in Finland, in the winter of 2014, we took it with both hands. It was the first major project using fibre-reinforced ice for building purposes. The use of fibre-reinforced ice made it possible to build a dome with a diameter of 30 meters and the highest dome of 21 meters in the Sagrada Familia in ice project. Da Vinci's Bridge in ice is a sequel to these projects.

It gave us the opportunity to explore new building possibilities for fibre-reinforced ice. Just as concrete can be reinforced with steel rods or fibres, ice can be reinforced with wood or paper fibres. It can increase the compressive and tensile strength of ice by three times more. Ductility can even be increased 20 times.

Geoffrey Pyke has been the first to discover the possibilities of reinforced ice. During the Second World War, this technique was used to reinforce the ice on lakes around St. Petersburg in order to make the ice strong enough for allied aircraft to land on. Since then, a few studies have been carried out, but the technique has never been applied in practice. In my view this is regrettable. The use of fibre-reinforced ice has numerous possibilities compared to plain ice.

For example, fibre-reinforced constructions can be much more slender and have a longer span compared to plain ice.

Of course we could not assure that we will succeed in delivering the 'Da Vinci's Bridge in Ice ' in seven weeks. As with Da Vinci the process and the idea are more important than the result of one project. Beside the bridge, we were proud to have managed several other projects by different universities and local residents of Juuka.

In the past years,the construction of the 30 meter igloo and Sagrada Familia were a toss-up(?). We needed every minute and despite the 'hot' weather we managed to succeed. Last year, we had 3 weeks longer and were with a bigger group of people. However, the challenge was also much bigger. Much depended on the weather and the enthusiasm and perseverance of everyone involved. In theory the project would have worked, however a week of 3 degree and rain destroyed the ice constructions just before the scheduled opening.

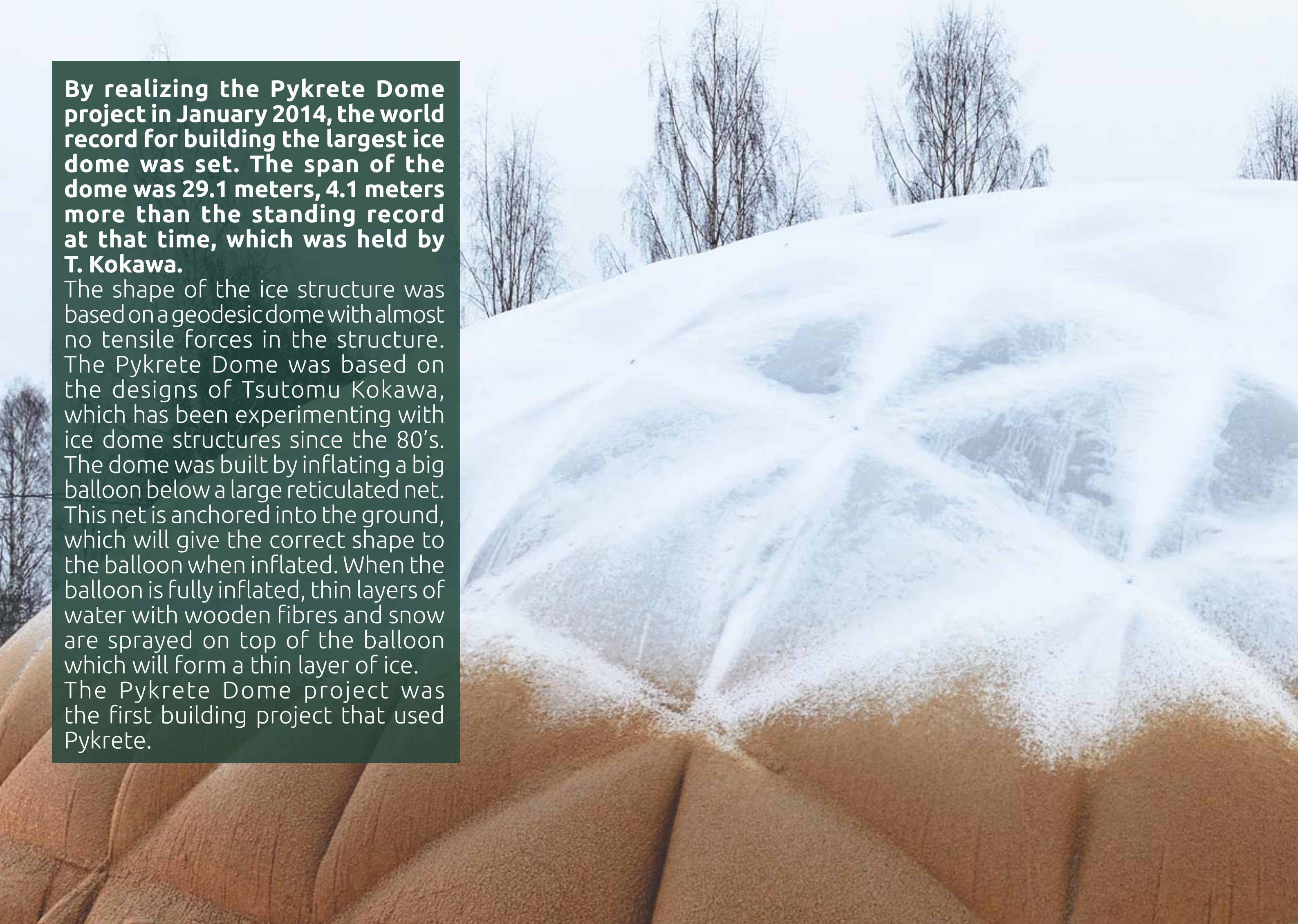
Arno Pronk

Pykrete Dome

By realizing the Pykrete Dome project in January 2014, the world record for building the largest ice dome was set. The span of the dome was 29.1 meters, 4.1 meters more than the standing record at that time, which was held by T. Kokawa.

The shape of the ice structure was based on a geodesic dome with almost no tensile forces in the structure. The Pykrete Dome was based on the designs of Tsutomu Kokawa, which has been experimenting with ice dome structures since the 80's. The dome was built by inflating a big balloon below a large reticulated net. This net is anchored into the ground, which will give the correct shape to the balloon when inflated. When the balloon is fully inflated, thin layers of water with wooden fibres and snow are sprayed on top of the balloon which will form a thin layer of ice.

The Pykrete Dome project was the first building project that used Pykrete.




SAHER-AIDAT

Sagrada Familia in Ice

SAGRADA FAMILIA IN ICE

The 'Sagrada Familia in Ice' is based on the design of the real Sagrada Familia by Antoni Gaudí. The Sagrada Familia is designed by a model with suspended chains, which is better known as catenary design. A suspended chain or rope will always get the shape of a smooth curve, meaning that the chain is only subjected to tension and absolutely no pressure. If the curve of the chain is turned upside down, it means the shape is only subjected to pressure and absolutely no tension. The principle of catenary design can be very interesting when building with ice, because ice has very low tensile strength.

The design of the 'Sagrada Familia in Ice' consists of the big tower with a height of 30m (34m with cross), the nave with a height of 12m and the four towers of 21m (2x) and 18m (2x).

Introduction

After the successful projects 'Pykrete Dome' and "Sagrada Familia in ice" ,we started to make new plans for the winter of 2016. Searching for a new challenge, we came to the conclusion that our sponsors and the community of Juuka in Finland, would be interested in an iconic building with a strong appeal. For us it had to be a new technical and scientific challenge. Combining these two starting points and based on the experiments of the last project, we came up with the idea to make a model of the never build Brigde over the Golden Horn by Leonardo da Vinci.

A visit to the sources of the bridge in Milan in Italy, inspired us to what would become the final concept of a model based on the most important parts of this bridge. From that moment, it was necessary to start searching for partners who wanted to help us to achieve our goal. The initiative for the project was very well received and many companies wanted to contribute by sponsoring materials. We also looked for cooperation with other universities for technical and organizational input.

Due to the size of the project it was clear from the beginning that we could not do everything by ourselves. Therefore, we immediately started looking for master students who could help us to elaborate the design of 'Da Vinci's Bridge in Ice'. In September 2015, a team of 10 students committed themselves to be responsible for certain parts or aspects of the building to be realized.

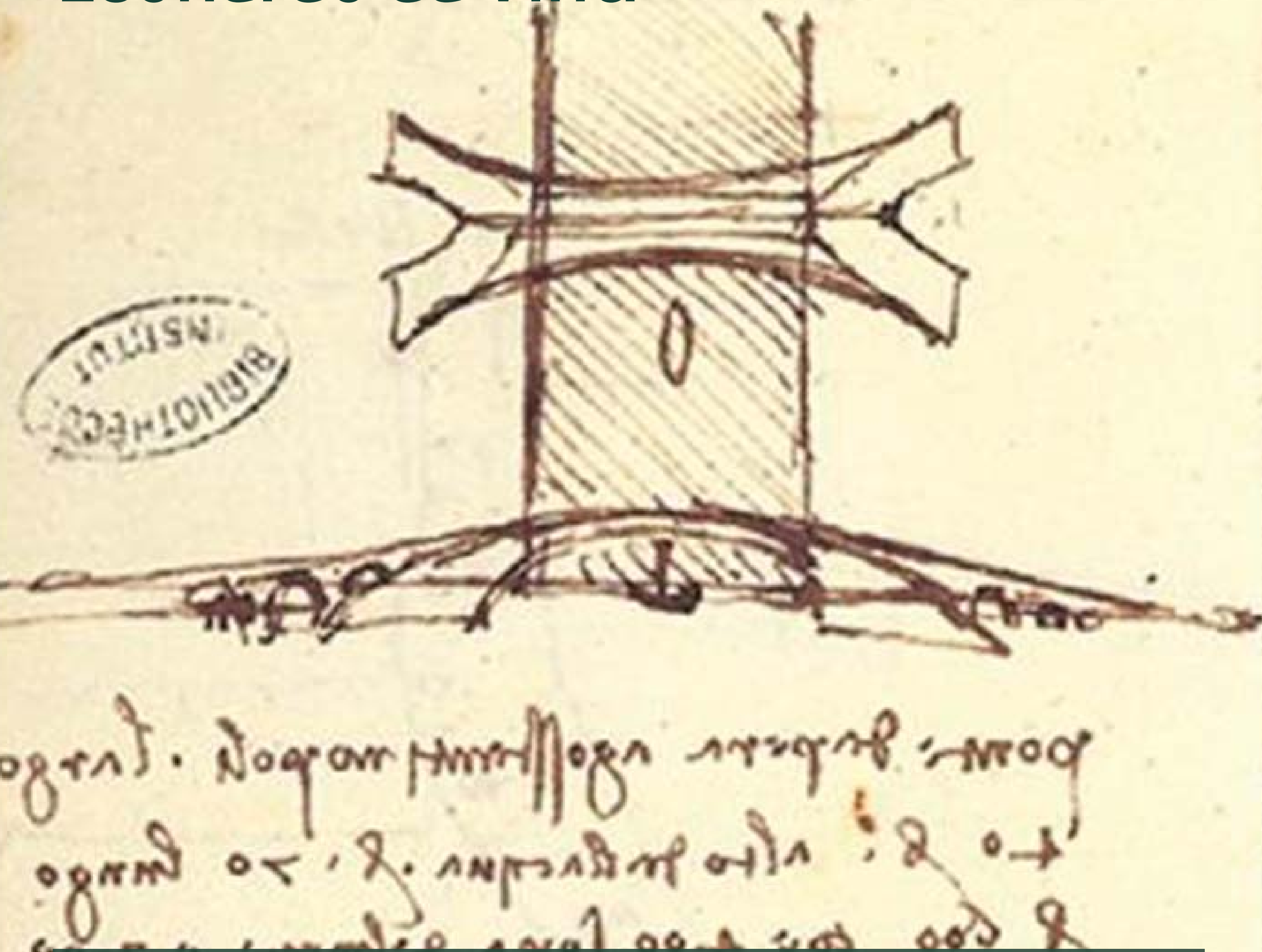
To realize the final construction of the 'Da Vinci Bridge in Ice' in Juuka, we needed more manpower than in the previous years. The building team consisted of about 180 people. In addition to the project members, several volunteers signed up for the project, including family, friends and fellow students from our university and other universities. The municipality of Juuka also contributed considerably to the success of the project. Although the bridge collapsed because of unusual weather, we have learned a lot and see it as a successful experiment. Without the help of the Juuka municipality and community, and the many volunteers, the project would not have been such a great success.

By means of this booklet we want to thank everyone who was involved in the project. We hope that this booklet is a nice memento to the great achievement that we have received all together.

Thank you very much for your efforts and support!
Happy readings,

Roel Koekkoek, Thijs van de Nieuwenhof and Arno Pronk

Leonardo da Vinci



For the Bridge in Ice we have found our inspiration in a well-known genius. Leonardo di ser Piero da Vinci, more commonly Leonardo da Vinci or simply Leonardo (15 April 1452 – 2 May 1519), was an Italian polymath whose areas of interest included invention, painting, sculpting, science, music, mathematics, engineering, literature, anatomy, geology, astronomy, botany, writing, history, and cartography. Besides all these interest he also has been called the father of architecture.

Leonardo da Vinci designed a stone bridge in 1502 for the sultan of Istanbul with a span of 240 meters, which has never been built. At that time people thought such a big span could not be realized. The design turned out to be so interesting that there has been done a lot of research on the 'Galata Bridge'. Even some full-scale models were constructed. In 2001 a pedestrian bridge in wood, based on Leonardo's design, has been built in Norway, as well as some small ice bridges.

On Thursday 24 September, Arno Pronk went to Milan to visit the Museo Nazionale Scienza E Technogia Leonardo Da Vinci. In this museum, a model of the Ponti De Galata bridge, as designed by Leonardo Da Vinci, can be found. Claudio Giorgione (conservator) and Vincenzo Iannone showed the model that was made by Alcide De Rizzardi in 1955.

Bridge design

The starting point for the design of the bridge in ice is based on a design made by Leonardo Da Vinci. The original design from the 16th century was developed to span the Golden Horn in Istanbul. This design would have had a span of 240 meters and a width of 24 meters. It consisted of three geometrical principles, namely, a pressed-bow, a parabolic curve and a keystone arch. The bridge would have had the largest span of that time, if the sultan of Turkey would have had approved it.

A scale model (1:6) of the Da Vinci Bridge from ice was our goal. Several factors have influenced the final design. We operated as a non – profit organization and depended on sponsors, participants and the available material and equipment. Research into fiber reinforced ice is still in its early stages, which means that a lot of material properties are unknown. Together with structural engineers and our participants we started this challenge. During the design process more and more got clear. The research group came up with interesting results and de structural engineers calculated uncountable options. With this knowledge we were able to get to a final design: a bridge with a free span of 35 meters, a total length of almost 70meters and 10 meters high.


GJERSTAD

Transport

Friday 18 December 2015 was the big deadline for all of us. A 20 feet container of Transfennica had to be filled with all our equipment and prepared materials.
Beside all the stuff we needed for the bridge in Ice, Candela pavilion and the Snowtrack, also our private goods where transported with this container. Even food for seven weeks was packed. After 3 hours the container was fully loaded and ready for transport. We also met our colleges from Belgium and all the members of the media team. It felt we already were on our trip to Finland.
During the building period, we had a lot of help of the local volunteers. With pickup trucks and mini vans they delivered all the equipment we needed. One of our big sponsors DB Schenker installed a 20 feet heated container where we could store materials and drink a cup of coffee.
Two months after building the Bridge in Ice the container came back to Antwerp. Without the help of all the sponsors we would not have been able to manage the transport of our goods this properly.

"DB Schenker stands for the transportation and logistics activities of Deutsche Bahn employing people in 140 countries worldwide. We at DB Schenker want to build bridges between people and help local actors pay it forward. DB Schenker offers expertise in land, air and ocean transport as well as in contract logistics. We are on top of the game when operating in freezing conditions and on icy roads of eastern Finland. We wanted to support the Bridge in Ice volunteers to reach their dream by providing them with a trailer to store equipment during building process. The same trailer transformed into a stage for the grand opening giving us all a first seat row in the ceremony. We also encouraged our own employees to volunteer in the building process giving us all a chance to be part in something bigger. Even though the weather didn't act on our behalf this year we are dazzled to see how devoted the volunteers and people in Juuka were in taking the most out of it all. We wanted to inspire everybody to connect and be involved in a piece of ice building history. And that is exactly what we succeeded in achieving."
Pasi Ripatti, Head of Communications and Marketing

DB SCHENKER

TRANSFENNICA

MAMMOET

Building site

Last year we were also part of the ice adventure. After the construction of world's highest Ice Dome of 21 meters we definitely wanted more. Besides breaking a new world record,we found a lot of new opportunities. One of the thing we wanted to improve was the building side. The preparation of the year before was amazing, but as this year the project will be bigger,we needed it better organised.

In the beginning of December 2015, we were already in Juuka to place the anchors which were supplied by JLD International, a Dutch company which operates a lot in the Netherlands.

The first day we put out the locations of the anchors on the building site, which was already prepared by the municipality of Juuka. Together with the local contractor Pielisen Maanrakennus, we finished this job in a couple of days.

This year we worked with computer controlled air vans and an electric mixing system, and therefore needed some adjustments to the electricity network. For example, an automatically generator was installed, with the help of HSA oy and HydLub oy. Eventhough we had a whole team of mechanics from Summa College from Eindhoven in the 2 and 3 week, there were many things that needed to be done in advance. So with our drawings Metalli Palvelu, a local company that provides engineering and steel construction services, delivered a nice piece of work.

During the building period we needed some heavy machinery, Hitachi, Rotator and Pekkaniska delivered a crane, shovel and two cherry pickers. With the right training we were allowed to use these machine on the building side. For all of us it was a huge experience to work with such impressive machinery.

Quote Finnish volunteer;
"It was nice to show the foreign group how Finnish people built snow walls and snow and ice constructions.
Special was that I and other volunteers could help and follow the students with their research experiments.
Welcome again!"
Pentti Kallinen

Construction and Building Technology

Mechatronics students of Summa Engineering in Eindhoven, The Netherlands, have helped building a machine to make the Cellocrete pulp and the control system to inflate the balloon. The technical installation, which was crucial for the success of the project, turned out to work as required on all fronts.

In order to make the cellulosepulp we used an IBC-container on which a large mixer was mounted.

With a frequency convertor we varied the speed of an electric motor and we determined the optimal speed, power and the blade combination at which the cellulose sheets were best mixed with the water.

These IBC-containers were placed on top of a 12m³ container. When the cellocrete pulp is mixed, the mix container can easily be emptied above the collecting container. In the collecting container the pulp should be kept in motion so that it does not sag and/or freezes. Again, we found a similar solution in the form of two large agitators.

"In summary, working on this project was a very satisfying for the students because they could really apply their knowledge and skills. Working under extreme thermal conditions was an interesting experience that will not likely be forgotten"

Hans van den Elzen,
Summa College


Pump 1

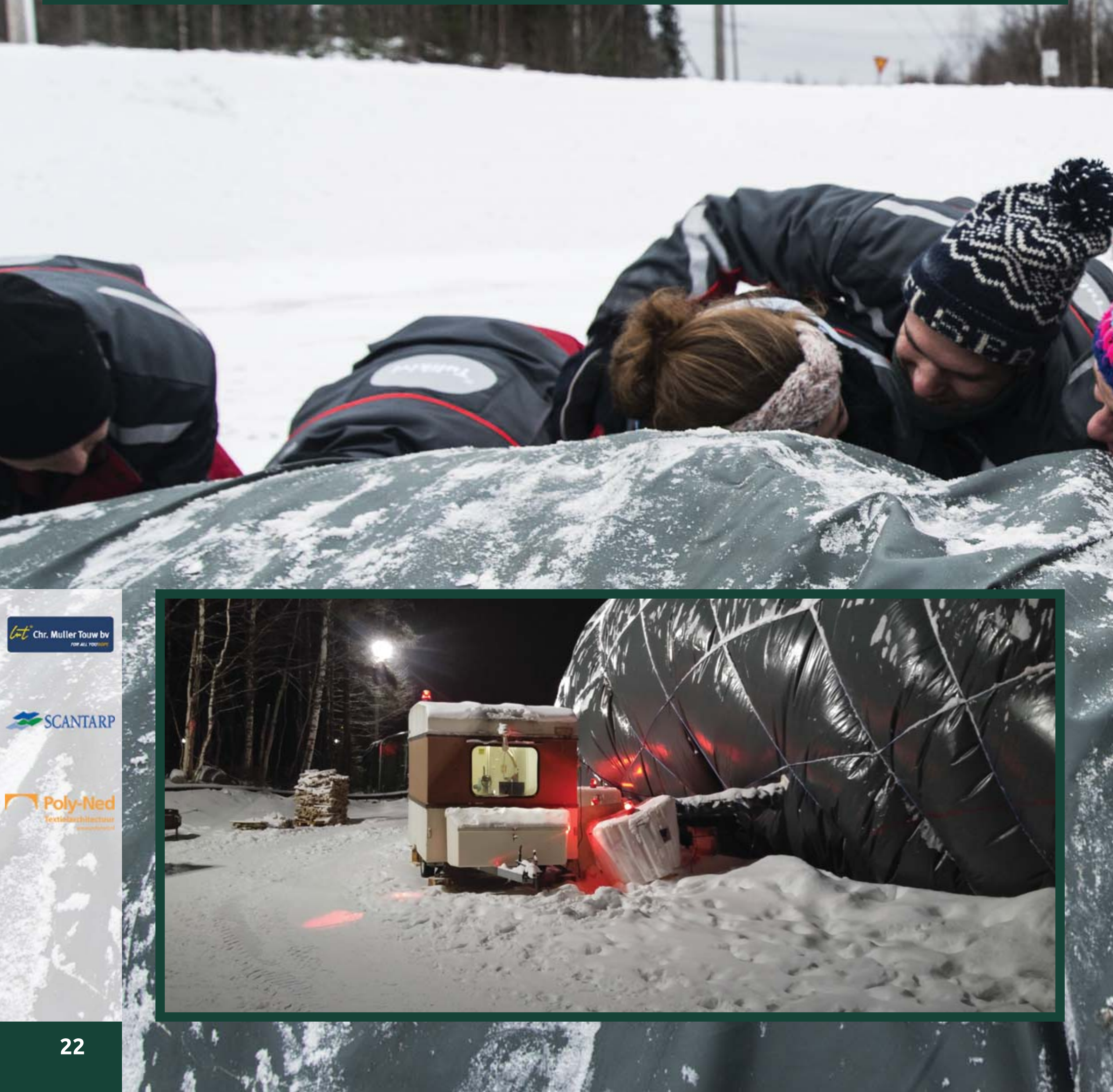
Inflating the balloon

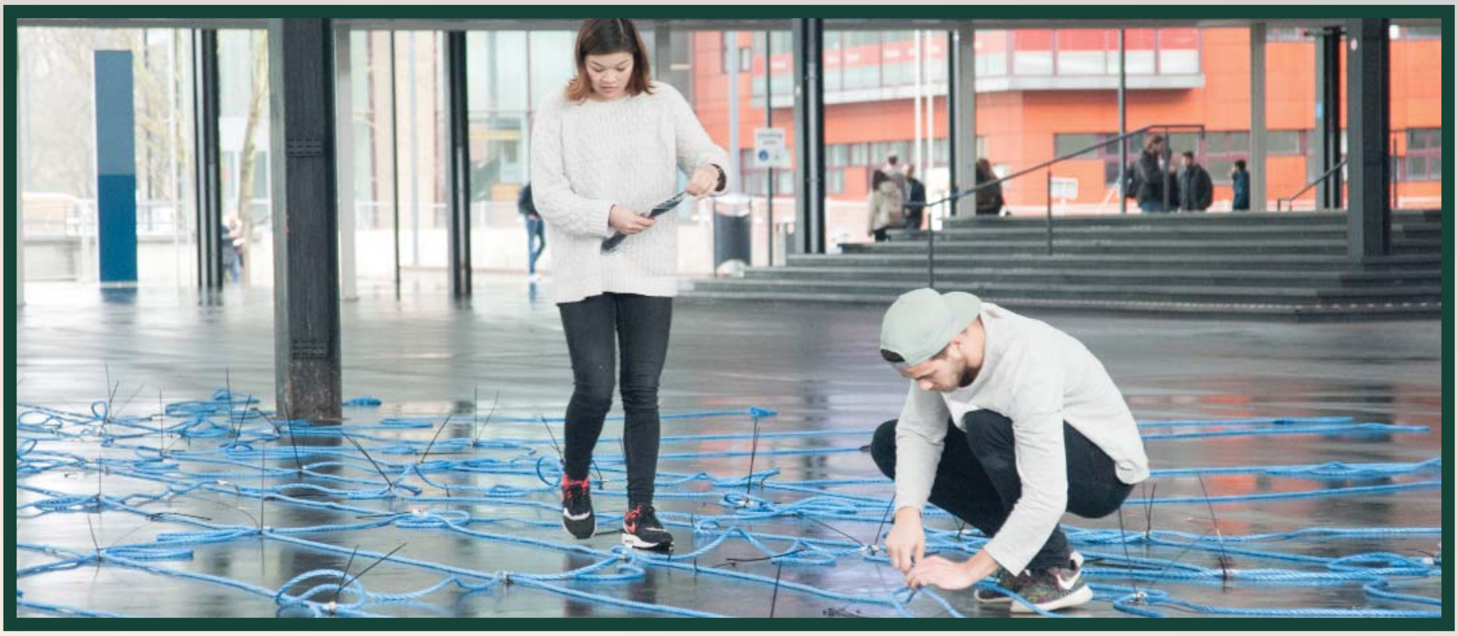
To inflate the balloon, three 1,5 kW fans were used. Initially, the fans should rotate at a capacity of 100%, but as the pressure in the balloon becomes higher, the fan speed is controlled in such a way that the pressure in the balloon remains at 5 mBar.

To realize this pressure sensor, a controller and a control module for each fan were required.

The alarm signal had to be observed from a distance and therefore it was reported by light and sound signals. All control equipment was built in a cabinet. Besides the mentioned control components this cabinet also contains a heating element, power circuit breakers, various relays and a UPS system. The UPS maintained the power to secure control/regulation in case of power failure.

Together with Sick, Van Dooren Engineering, Wago, Cofely and Maco technologys, Summa College have provided us an important piece of engineering.

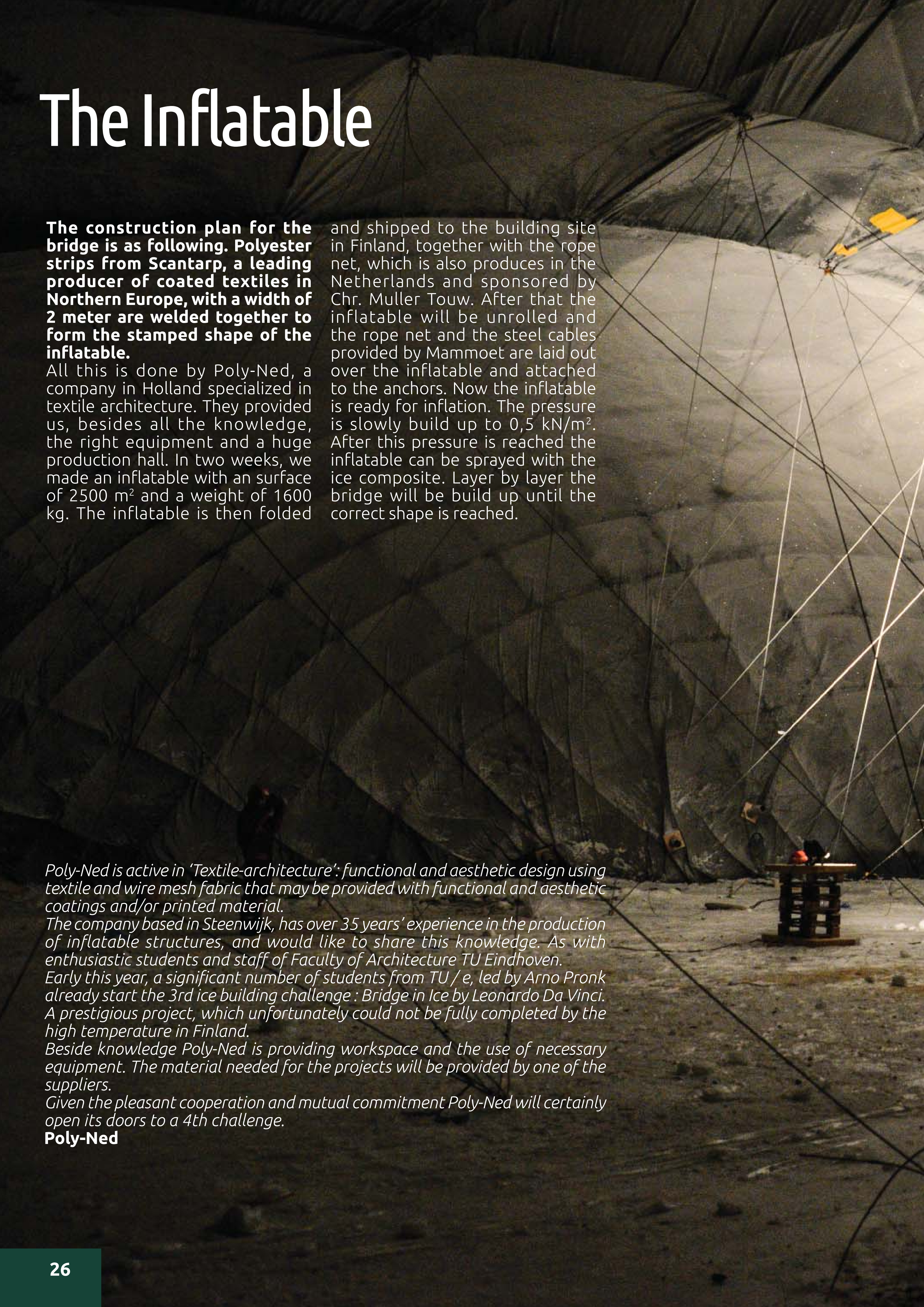





The Inflatable

The construction plan for the bridge is as following. Polyester strips from Scantarp, a leading producer of coated textiles in Northern Europe, with a width of 2 meter are welded together to form the stamped shape of the inflatable.

All this is done by Poly-Ned, a company in Holland specialized in textile architecture. They provided us, besides all the knowledge, the right equipment and a huge production hall. In two weeks, we made an inflatable with an surface of 2500 m^2 and a weight of 1600 kg. The inflatable is then folded and shipped to the building site in Finland, together with the rope net, which is also produces in the Netherlands and sponsored by Chr. Muller Touw. After that the inflatable will be unrolled and the rope net and the steel cables provided by Mammoet are laid out over the inflatable and attached to the anchors. Now the inflatable is ready for inflation. The pressure is slowly build up to 0,5 kN/m^2. After this pressure is reached the inflatable can be sprayed with the ice composite. Layer by layer the bridge will be build up until the correct shape is reached.



Poly-Ned is active in 'Textile-architecture': functional and aesthetic design using textile and wire mesh fabric that may be provided with functional and aesthetic coatings and/or printed material.
The company based in Steenwijk, has over 35 years' experience in the production of inflatable structures, and would like to share this knowledge. As with enthusiastic students and staff of Faculty of Architecture TU Eindhoven.
Early this year, a significant number of students from TU / e, led by Arno Pronk already start the 3rd ice building challenge : Bridge in Ice by Leonardo Da Vinci. A prestigious project, which unfortunately could not be fully completed by the high temperature in Finland.
Beside knowledge Poly-Ned is providing workspace and the use of necessary equipment. The material needed for the projects will be provided by one of the suppliers.
Given the pleasant cooperation and mutual commitment Poly-Ned will certainly open its doors to a 4th challenge.
Poly-Ned

Working conditions

The building site of the 'Bridge in Ice' is located on the property of Tulikivi, the largest stone processing company in Finland, and the largest manufacturer of heat-retaining fireplaces in the world. The Tulikivi terrain was perfect for the building site of the 'Bridge in Ice' due to the visibility, accessibility and the various facilities. It was possible to use the Stone Center building as our office and we had access to a professional lab for testing ice samples.

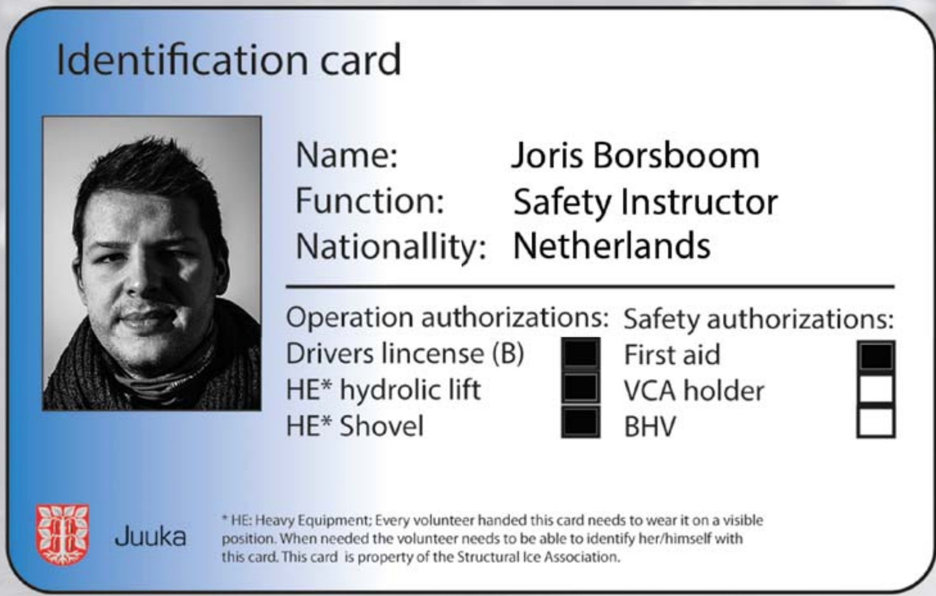
Different mines are located around Tulikivi, where work continuous even during the winter. This is possible because of the special suits that are worn by the miners. Tulikivi has made these suits available for all builders of the 'Bridge in Ice'.

In addition to the building site and work suits, Tulikivi also ensured the accommodation for the volunteers. Tulikivi has several houses in the area of the building site, intended as holiday homes for employees. During construction of the Bridge in Ice, Tulikivi has made two cottages available with a total of 75 sleeping places. The facilities in the cottages were excellent, with a professional kitchen, a room with pool table and several saunas. For those who wanted to cool down after the hot sauna there was even an ice hole in the frozen lake. Because of the huge interest in this project we had also an extra accommodation in Juuka city centre. In addition to the work suits we also needed gloves and scarves to stay warm. A local sport shop named Elmo Sport provides all kind of clothes for reasonable price for the volunteers.

"Through one of our clients, we have become involved in the Bridge Ice project. The question was whether Arcadis could help with a safety plan. The ice-projects have grown over the years. So this includes also a more professional approach to safety.
After our introduction to the team we started with the format for a security plan. There is not only taking care of the bridge in ice to consider, but also hiking trail and its surroundings. The result was a security plan that was practicable for both the organization and the Finnish regulator.
In February we spent a few days on site to see the security plan in practice, which was actually a work site inspection. It was interesting to make a contribution from a different aspect and we are satisfied that they take safety seriously on de building site and around it."
Arcadis

"I have been involved in the ice construction projects in the last two years now. I have provided equipment to the staff through my company as well as organized leisure time activities to them. These projects (Sagrada Familia in Ice and Ice Bridge) have been extremely interesting and community enriching events. They have surely enlivened Juuka's January and February that can otherwise be quite grey and quiet months. And even though the projects haven't been fully completed, the publicity each has brought has been very positive overall. I, for example, have had many new contacts with the builders involved in these projects. For all the local people in Juuka and nearby towns, this international atmosphere has been something new and interesting. I sincerely hope that these kinds of international projects will also be held in the future and that they will bring positive ideas and innovations to Juuka and whole country of Finland. With these words, I wish amazing and warm summer to all who have been participating in the ice projects!"
Jani Halonen, Finnish entrepreneur

Safety



The organisation of the building site was an important part of the project. Due to the limited space on the site, it was necessary to organize it as efficiently and safely as possible.

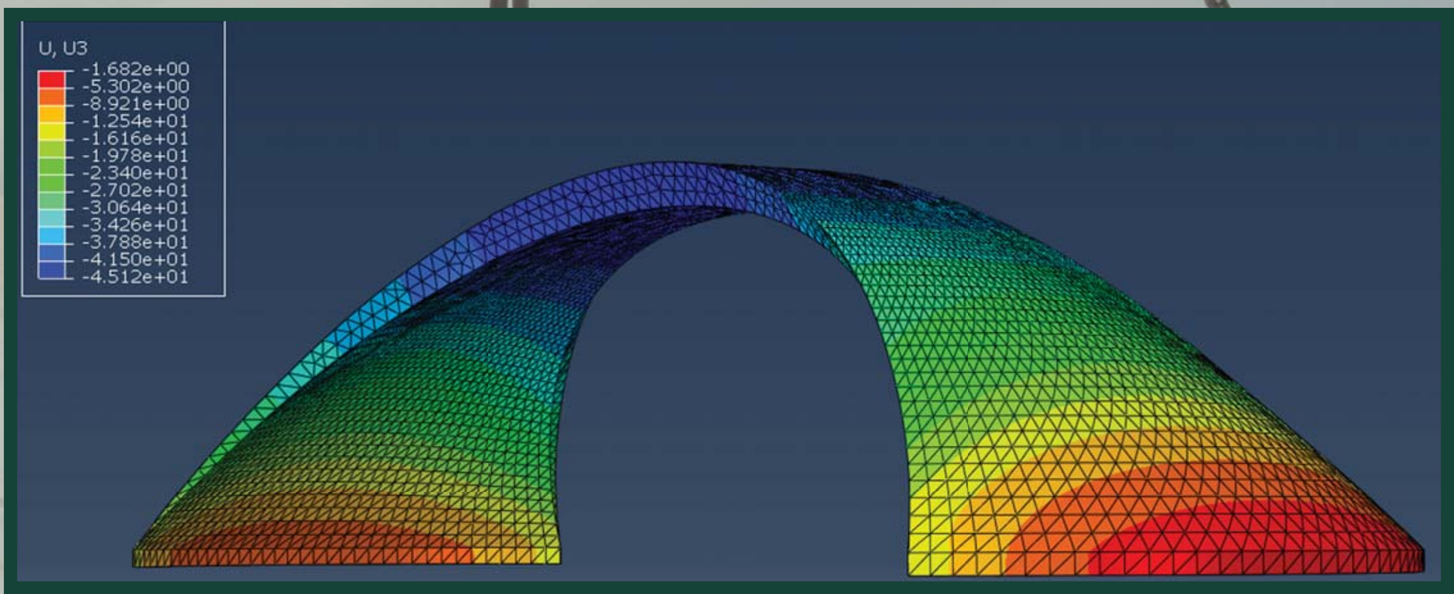
Safety is an important aspect in a project in which you are almost completely dependent on volunteers. The minimal safety requirements that we had set were to oblige the use of a helmet and safety shoes, while we also made sure that everyone could wear proper clothing for the extremely cold conditions. Furthermore, it was important to make sure no unexpected visitors would enter the building site. Therefore Saher-Aidat sponsored fences to place around the building site. Of course people were welcome to visit, even during the construction, but they were only allowed on the site together with someone from the building team to escort them. This is all mentioned in a safety plan provided by our students in cooperation with Arcadis. Safety is an important aspect, but a good insurance policy for the entire project and project team is from equally importance. AON, a leader in risk management, employee benefits and insurance, has sponsored the insurance of the project.

Structural design

The optimal shape of the bridge depends on several factors, including the maximum stress and maximum deformation. However practical parameters also have an influence, like the accessibility of the bridge. The intention of the project is that people should be able to walk over the bridge, therefore the slope of the bridge cannot be too large. Due to the building method of spraying layers of pykrete, the construction phase should also be taken into account, as not all shapes can be build. The balloon sets the boundary conditions for the bridge, and while the balloon is tailor-made, this mould has its boundaries. With the chosen building method, it is also necessary to check the model for eccentricities, it is almost impossible to prevent an asymmetric shape. Therefore, it is necessary to select a range for which the model will still have enough load bearing capacity. Because of the large amount of unknown properties, several safety factors are applied, also for the final shape there will be a large range for which the model needs to be sufficient.

TU/e

UCL Université catholique de Louvain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Material research

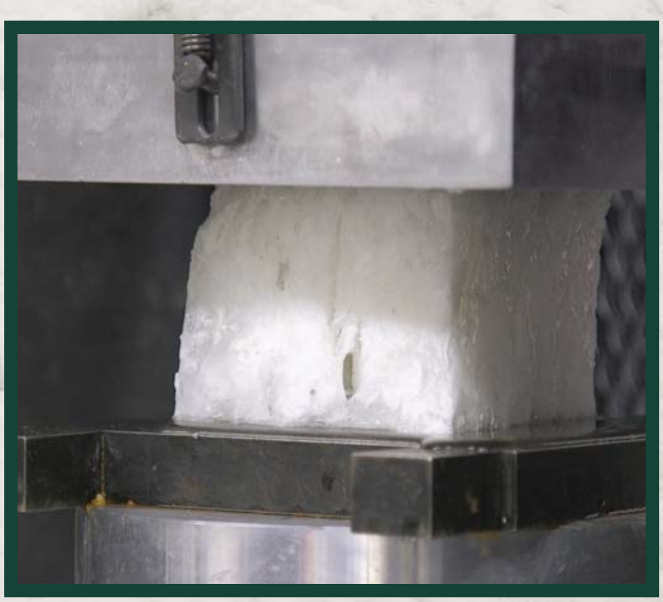
Reinforcing a material to increase the properties of that material is used for many years. A well known example is reinforced concrete, where the tensile strength is increased by steel reinforcement. Depending on the type and the fibre of the reinforcement, there are many possibilities to enhance the properties of the concrete. This form of enhancement of the material, by adding a fibre to a mixture, can also be used for ice. Concrete and ice have a relative high compressive strength, the added reinforcement enhances the tensile strength of the mixture.

Research has been done on reinforcing ice with soil, wood and other particles in order to increase its mechanical strength and reduce its brittle behaviour. However, the reinforced ice use as a structural material is still a rather experimental field.

The application of materials snow and ice as natural building materials has been used for ages. Indigenous arctic people have used ice and snow as a construction material for a long time The oldest and best-known ice construction is the igloo, made by Inuit (Eskimo).

The aesthetic and environmentally friendly behaviour of ice as a building material has drawn the professional attention of researchers and designers mostly since mid-20th century.

Together with Universities from all over the world we did research on cellulose fibre reinforced Ice. We want to thank Tulikivi for offering their research centre and Stora Enso for providing 30 tons of cellulose.



Cellocrete

In a world concerned by the impact of global warming and the need of urgently move to more rational practices and ways of life, initiatives such as the workshop "Juuka in Ice" are excellent examples of what can be done to achieve a better future. It shows us clearly how we can get more with less resources.

This project is much more than an eloquent demonstration of how to build sustainable ephemeral structures: it is also a really unique example of a huge platform of volunteer work, done by students and professors of different European countries, in an incredible cooperative atmosphere. It also deserves a special mention the enthusiastic way the project has been progressively adopted by the locals and how they are so proud of it.

More than the absolutely amazing expected results, the processes and the lessons learned in such an unpredictable exercise deserve the efforts to actively participate in it. I consider it a very special combination of ambition and simplicity, organization and spontaneity, applied research and creativity.

I am a Civil Engineer and I have been a Professor of Structures for a long time in the School of Architecture of the University of Minho, in Portugal. My scientific activity is particularly devoted to contribute to the efficient use of traditional materials and their judicious combination by exploring innovative technological, constructional and structural solutions.

I started organising an International Conference on Structures and Architecture in 2010 which will have its 3rd edition in July 2016. We are proud to define it as the world's leading and largest global conference bridging the gap between both disciplines, structures and architecture. The contributions on creative and scientific aspects in the conception and construction of structures, on advanced technologies and on complex architectural and structural applications represent a fine blend of scientific, technical and practical

Universidade do Minho

Aalto University

innovations in both fields.

"Juuka in Ice" cannot be more aligned with that vision. I am privileged for the opportunity to participate in the project. I feel like a child who discovers what can be built by mixing only water with cellulose and waits for nature to do the rest.

This inspiring hands-on experience makes me remember the last sentences of a poem by António Gedeão entitled Philosopher's Stone:

They do not know, nor dream of,
that dreaming commands life.
That whenever a man dreams
the world leaps forth
like a colourful ball
into a child's little hands.
Prof. Paulo Cruz, University of Minho

Candela in Ice

50 civil engineering students of Ghent University in Belgium worked a full semester on the design of the Candela Pavilion in fibre reinforced Ice. The so-called "hypar" structure is inspired by the works of Felix Candela (1910-1997), a Spanish-Mexican architect famous for his thin-walled reinforced concrete shell structures. The design and construction are led by Prof. Jan Belis, Kenny Martens, Bert van Lancker and Bram Ronsse.

The first task of the students was the formfinding of the balloon, which was used to support the shell during its construction. This was done step by step by means of scale models and by computer simulations of the inflatable, until the right shape was found.

In the meantime, material tests were performed to determine the compressive strength and bending strength of the ice reinforced by cellulose fibres. Also the resistance of the textile for the balloon was tested in different directions, and experiments were performed to quantify the quality of the welded joints.

Then, the structural engineering was done. In particular, the minimum thickness of the ice was calculated to provide stability of the shell, also in case of heavy wind and snow. We would like to have a minimum wall thickness of five centimeters at the tops of the outer perimeter, and thicker parts in the valleys between the hypars.

The next step was the cutting and welding of the big balloon in a hall of the university. The membrane was delivered on rolls of about two meters wide, so many welds were needed. The curved parts were most difficult. Once the whole balloon was ready, a test inflation was organized at the faculty's campus in Ghent so the last leaks could be fixed. Then, everything was shipped by boat to Finland.

After two weeks of spraying with cellocrete on the inflatable, the freezing period was just long enough to create a good layer of structural ice. After removing the inflatable the result was excellent.

Candela Pavilion

UNIVERSITEIT GENT

SIOEN

Snow Track

The bridge and pavilions were part of a festival area named the ice paradise.
This area was in-between the quarry and stone center. At this ice paradise there was a snow path connection all the ice structures. This path was designed by 28 students of the Catholic University Leuven and named the snow-track. At the snow track there were 6 smaller ice structures named; the candela shell, the frozen forest, the chicken wire cave, the inflatable lamps, the frozen cardboard pavilion, the labyrinth of frozen ropes and the coffee cabin. The main viewpoint was from the coffee cabin into the enormous large and 70 meters deep quarry of the Tulikivi stone factory. This particular quarry was not anymore in use and gave us the opportunity to realize a 70 meter high frozen waterfall along the site of the quarry. In the evening the frozen waterfall was enlightened by colored lamps.

Finnish volunteers

From the last two projects we already knew some of the local residents in Juuka and surroundings. Real friendly and helpful people, willing to show their culture and habitat and truly interesting in the ice projects. This year it was great to meet so many new faces. Not only during the seven weeks building period, but also in the preparation weeks we had before. They learned us Ice-Hockey, Ice Fishing, riding a Finish sledge. We even got invited to eat typical finish reindeer. The cultural exchange went also the other way around. We learned them English, showed them the Dutch culture and invite them to our really good party's. They had never seen dress up parties like the Dutch Carnival.

Due to the all these kind of activities we build up a good relationship. And that was very useful for a project like this in an rather isolated place like Juuka. They helped us during the whole building period with all kind of things. The local residents have a lot of building skills from which we have learned a lot. Whereas, they copied our method to build a church out of ice.

It's hard to sum up all the names of the people that have helped us to reach our goals. Some of them left a little quote about how their experience was during this winter time.

And like one of the local volunteers told us. "You guys are not only build an ice bridge but surely also between two different cultures".

We can see without the help of all the local residents it would not have been such a great success.

A big thank you to all the people who have supported us.


MAAHANTUOJA
ROTATOR

Side projects and experience

In the beginning of the building period the temperature was far below zero. A perfect temperature to spray water. But before we could spray on the inflatable of the bridge, some additional work has to be done. However, we wanted to make use of the freezing temperature, so we started some little side projects.

The so called bubble Igloo was made in just 3 days. The pavilion came out really nice due to the blob like mould. The Pavilion was decorated with an real Tulikivi stove and reindeer hides. To give the Ice-track an icy start we build an ice tube entrance. To do so, we used an old balloon of one of the towers of the Sagrada Familia in Ice project. Instead of pulling it vertical, we laid it horizontal on the ground in front of the doors of the Tullikivi Stone Centre. Because of the small span it was possible to use only water and snow as building material. It was not only fun to do, but also a good way for the volunteers to practice with the building method and working conditions.

Jouni Hiltunen
It was interesting and nice to be a volunteer worker in Juuka Bridge in ice for everyone involved in the project mukana.Kiitos olleille.I hope so, that will be seen next year in a new project Nunnanlahti.
Greetings to all Jounilta.

Mr. Jari Nevalainen, Kuljetus Jari Nevalainen Ltd
It was interesting to have some different activities during winter time since normal building activities come a halt. Nice to work with such an eager group of students. Problems like language and culture arose but in the end it all was solved.

Mrs. Johanna Pajarinen, Kivikylän Herkku
Exciting and nice time. It was refreshing to work with and and for students. It was in a positive way a heavy work period (24/7) and when they left I was missing the group.

Mr. Aki and Seppo Kallinen, Pielisen Maanrakennus Ltd
We supported in many ways the basic work during the building process. It was exciting to cooperate in this international cultural environment.

Mr. Pentti Mansikkaviita, Expert
It was nice to see how happy and whole heartedly the students were working. The students are now more professional in making snow and snow constructions but due to changing weather conditions they will need more instruction time to react flexible to the weather changes. Although I worked most of my life everywhere in Europe, this was my first experience with reinforced snow and ice. With an unlimited budget you can make snow even in the desert.

Jan Graafmans, volunteer, Tujanranta Consultants
A big surprise that students from my Alma Mater, Eindhoven University of Technology, were coming to create world records in my retirement village, Juuka, Finland. With the pride of an alumnus, we tried to create and support an environment, where the creative plans could be realised. The total chaos and clash of culture, weather, technology, design, management, politics and nature caused a pandemonium of events and partial success. In spite of all, we did it. Waiting for your next challenge.

Tuula Ikonen-Graafmans, volunteer, Tujanranta Consultants
For over three years now, I together with numerous volunteers have been preparing and supporting students accommodation and arrangements for social life in Juuka. It has been fantastic to cooperate with students and creating a big international family. Good memories and welcome to Juuka also during the beautiful other seasons. It is always summertime here!


Tulikivi

Project team

On the 28th of December, the first students were ready to go to Finland and start building the Bridge in Ice. This group has changed during the seven weeks of building.

Students from all over the world, friends and family members came and went during the period of the project. They all had one goal: reach that world record and experience how it is to work in such tough working condition. Most of the volunteers were part of the building team but we had also a so called media-team, care-team and all round volunteers. But we all worked together, combined our tasks and learned from each other.

Even though we have done our best to get everyone on the picture (next page), there are still some missing of the more than 190 foreign and local volunteers.

It was amazing to see how many people put so much effort in this project.

"A once-in-a-lifetime-experience. Building impressive ice structures, surviving these inhuman temperatures, experience the typical Finnish culture, giving 95 people a place to sleep (when there's room for 60..), seeing the Northern Light, but above all, working day and night for creating such a successful project, with your new friends."

Veerle Jansen, volunteer coordinator

Side activities

Ice fishing & Snow scooters
The volunteers went ice fishing with the local people from Juuka many times. It was possible to do net fishing or ice fishing on the traditional way with a fishing rod. Many fish were caught and afterwards cleaned and eaten in Tulikivi Club. During ice fishing it was sometimes possible to ride on a snow scooter. With a speed of around 60 km/h builders were flying over the lake.

Factory tour Tulikivi
A tour was given by workers from Tulikivi trough the mine were the soap stones are extracted. In different groups a tour brought us to the mine and the saw factory. It was very impressive to see how the big stones are sawn into perfect smaller pieces by a computerized saw. It was very interesting to see the whole process form the mining up to the end products.

Husky tour at Koli
In Koli there was the possibility to participate in a Husky tour. Many volunteers and student wanted to participate in this tour. It was a great experience to do! After the husky tour, a visit was brought to Koli National Park. The best-known point in the park is at the 347m high top Ukko-Koli forming a vantage point over the Pielinen lake and forests in the east. Unfortunately, on many days during our stay the fog obstructed the view. Only a few students and volunteers were able to see the beautiful view, standing on top.

New Year's eve
On the last day of 2015, all the builders of the 'Bridge in Ice' went to the primary school of Nunnanlahti. A party was organized to celebrate new year's eve. At this party, for many of the builders their future was predicted by tin, there was a campfire where they could fry sausages and a big firework was provided by the people. It was striking that before 12 o'clock many citizens went home, this is because many people in Finland celebrate new year at home in the sauna. The building team went to Tulikiviklubi to celebrate de Dutch new year(1 hour later), and we have end the party in Hotelli Petra of course.

Break the Week-Party's
clearly, building the Bridge in Ice and the other ice project had our priority, but to get extra commitment from the volunteers we wanted to organize some extra events. Therefore, we had a weekly theme party's on Saturday were , all the volunteers and the local citizens were invited to. Furthermore, on Wednesday evenings, we had our Break the Week campfire party. It was a spontaneous action of our Media-team. It was a nice moment to get to know the new people who had just arrived.

Media team

Students from the SintLucas College, a creative vocational secondary school in Eindhoven and Boxtel, were involved in the 'Bridge in Ice' project this year. The media team reporting on the project consisted of a number of students from the Audiovisual Production and Photography courses. One student from the Media and Events Management course was involved in promoting and organising events for the project. Liselotte de Haan and Stan van Breemen tell us about their experiences.

Try-out

Liselotte de Haan, a third-year Media and Events Management student: 'I was asked to take on a new project set up by the TU/e and use it for my internship. This was the first cooperation between SintLucas and the TU/e; a try-out in other words. So it was all quite exciting, as you can imagine!'

Flexibility required

As part of her internship, she contributed ideas for promoting the project, updating social media and preparing events for the seven weeks in Finland. 'Working as the sole 'event manager' for this project was extremely challenging. Even so, I learned so much during those five months that I wouldn't have it any other way. The most important thing I learned is that you have to be flexible when you are involved in a project like this. After four months of preparation in the Netherlands, you more or less assume that everything will run smoothly. But I still had a few really tough challenges to overcome. In the face of adversity, you have to think of solutions on the spot. For example, when the equipment wouldn't work because it was so cold. So being able to handle stress came in useful!' says Liselotte.

Extreme temperature differences

The members of the media team also had to demonstrate their flexibility and ability to improvise. Stan van Breemen, a fourth-year student studying Audiovisual Production: 'Obviously, we had to overcome quite a few problems. For example, temperatures of 38 degrees below zero. Challenging conditions for us and our equipment. Both our hair and the camera shutter froze solid. The huge temperature difference between the environment indoors and outdoors mainly affected the equipment though. When we came back to our warm office after half an hour of filming, moisture started to condense on the camera. Resulting in water in the camera and lenses. Fortunately, all the equipment survived. After all, we are not used to working in these extreme conditions so you simply have to make do. Improvise in other words.'

Fantastic experience

Both students see their participation in the 'Bridge in Ice' project as an unforgettable experience. Liselotte tells us that 'in addition to the days spent working, there was enough time to enjoy all the authentic Finnish activities. Ranging from riding snow scooters and dog sledding with huskies to seeing the Northern Lights.' Stan comments that 'being thrown in at the deep end is the best way to learn. This project stands head and shoulders above all the other projects I have participated in via SintLucas. We would all like to thank the TU/e and SintLucas for this fantastic experience.'

Media and press

During the project we had a lot of media attention. It already started in the beginning of April when we launched our idea of building an ice bridge. In almost all the Dutch newspapers and several television programs, like 'Een Vandaag', 'WNL' and 'Hart van Nederland' we were mentioned. Even the news was picked up outside our borders.

During the building process, our so called media-team supported us by making all the photos and videos. Because of the growing media attention they also did the communication with the press and organized interview meetings, took care of our Facebook page, and all other social media items.

There were several journalist on location. One local newspaper from Holland 'Eindhovens Dagblad' send a journalist for one week and followed us on the building site and during our free time. But also big international TV stations and newspapers like Discovery Channel andStory House Productions were interested in our plans. And even the popular internet page VICE had two articles about the project.

Several blogs were updated every week. One of them by Cobouw, a newspaper for the Dutch building industry. They posted a weekly story about the project, so people who were interested could follow it from there. The project was also really popular in Finland. Several television stations came to Juuka to report something about it in the news. And the local newspapers published weekly updates.

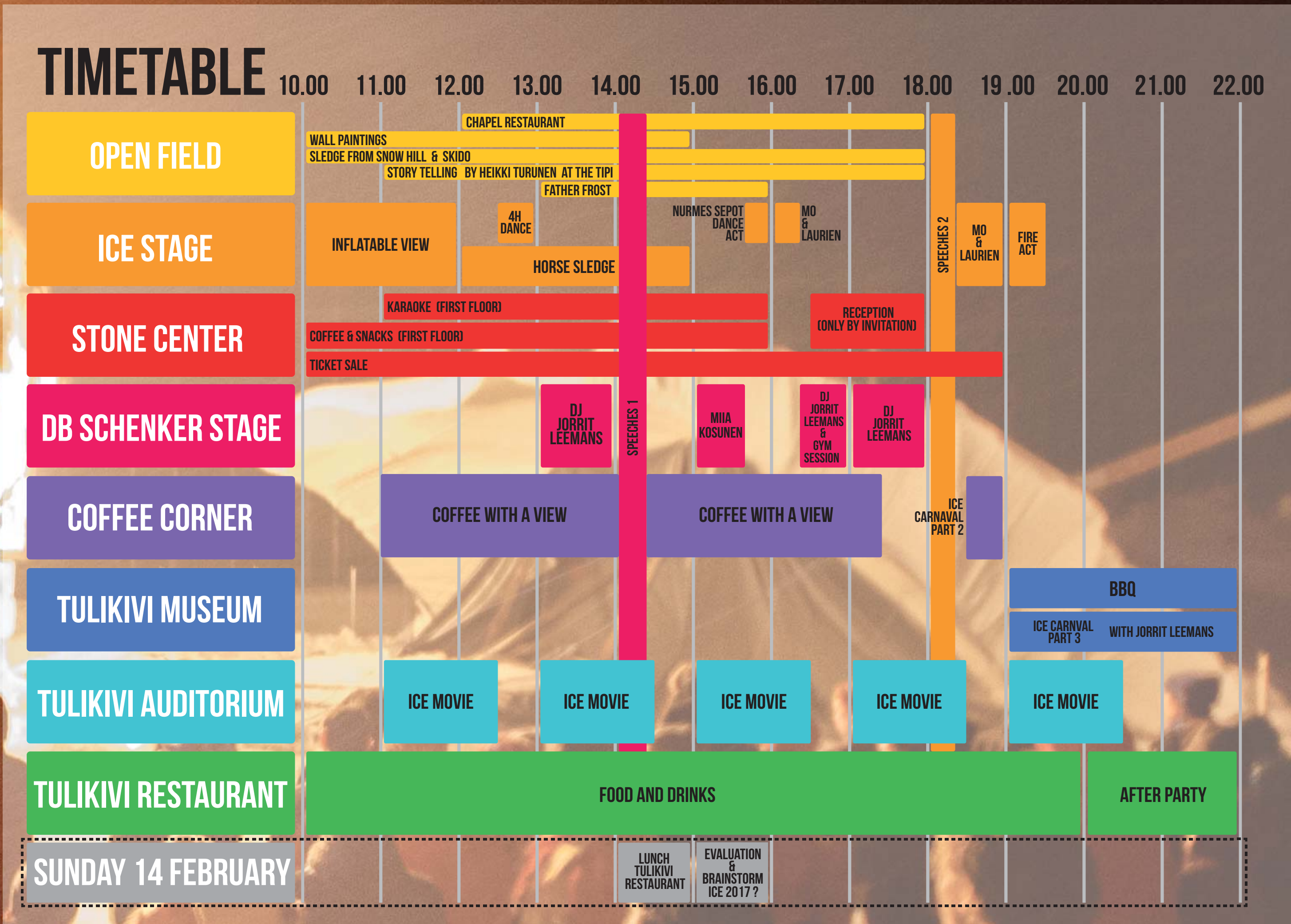
In the end, the media attention went so fast that the newspapers in Holland were earlier aware of the collapse of the bridge than our own volunteers.

On this page you see a collage of the articles that were published around the world.

It was a total new but great experience we had with all the media attention.

Opening

On Saturday February 13th 2016, The grand opening of The Bridge in Ice had started.
Unfortunately without a Bridge, Candela Pavilion and a beautiful ice track. But that was no reason to skip the openings ceremony. Everyone had worked so hard the last seven weeks and we wanted to celebrate that.
The opening was like a festival, different stages and all kind of things to do. There were tracks for children to play, slide and drive on little snowmobiles. The exposition and gift shops about the project were opened inside the Tulikivi Stone Centre and it was possible to buy some typical Finnish food. After the reception, the opening day was traditionally ended in Hotelli Petra and the adventure of building the Bridge in Ice came to an end. Despite the terrible weather we all had a great day and night.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OPEN FIELD
CHAPEL RESTAURANT
WALL PAINTINGS
SLEDGE FROM SNOW HILL & SKIDO
STORY TELLING BY HEIKKI TURUNEN AT THE TIPI
FATHER FROST
ICE STAGE
INFLATABLE VIEW
4H DANCE
HORSE SLEDGE
NURMES SEPOT DANCE ACT
MO & LAURIEN
SPEECHES 2
MO & LAURIEN
FIRE ACT
STONE CENTER
KARAOKE (FIRST FLOOR)
COFFEE & SNACKS (FIRST FLOOR)
TICKET SALE
RECEPTION (ONLY BY INVITATION)
DB SCHENKER STAGE
DJ JORRIT LEEMANS
SPEECHES 1
MIIA KOSUNEN
DJ JORRIT LEEMANS & GYM SESSION
DJ JORRIT LEEMANS
COFFEE CORNER
COFFEE WITH A VIEW
COFFEE WITH A VIEW
ICE CARNAVAL PART 2
TULIKIVI MUSEUM
BBQ
ICE CARNVAL PART 3
WITH JORRIT LEEMANS
TULIKIVI AUDITORIUM
ICE MOVIE
ICE MOVIE
ICE MOVIE
ICE MOVIE
ICE MOVIE
TULIKIVI RESTAURANT
FOOD AND DRINKS
AFTER PARTY
SUNDAY 14 FEBRUARY
LUNCH TULIKIVI RESTAURANT
EVALUATION & BRAINSTORM ICE 2017 ?

Further research and new plans

This is a proposal for the design and construct of the highest shell structure in ice by the Structural Ice Association. We invite universities, schools and volunteers to participate in this international project.

After our projects in Juuka, Finland, we intend to continue our ice research with a large project in a more stable and cold climate. In Harbin, in the Northeast of China, an annual ice festival takes place. It is the largest ice festival in the world where huge ice towers of solid blocks of ice are built. This would be an excellent location for our research. Therefore we have contacted Harbin Institute of Technology (H.I.T).

Professor Yue Wu and Phd student Qingpeng Li of the School of Civil Engineering at H.I.T. supports our initiative. The university invited Arno Pronk to give a summer course of two weeks on ice structures in July 2016. During this visit the project in the winter of 2017/2018 described below can be discussed and arranged.

For the design proposal for the Harbin Ice Festival the following aspects have been taken into account:

- International cooperation
- Showcase for research on reinforced ice
- Shell structures instead of solid ice
- Inspired on traditional Chinese towers
- Inspired on European design tradition and culture
- Ability to compete with the enormous structures of the Harbin Ice Festival
- Short construction period
- Safety
- Maximum exposure
- "Solid" structure with low risk for failure

The design consists of a 30-meter high vertical tube with six entrances. The design is a modern version of a traditional Chinese tower and also refers to a flamenco dress. To enter the centre of the tower the audience has to climb one of the six staircases made of transparent solid ice blocks. The ice blocks in the staircases are illuminated similarly to most of the solid ice structures in the ice festival (see Fig. 4). In the evening an uplighter at the bottom of the tower will illuminate the sky.

The shell of the structure will be constructed by cellulose-reinforced ice. The composite will be sprayed on an inflatable. The inflatable will be removed after finishing the ice shell.

The aim of this project is to gain more knowledge about the creep behavior of ice and ice composites and the engineering and construction of thin-shell ice structures. Besides the structure will be a new record for highest shell structure in ice. It is our goal to realize the Flamenco Ice Project by an international team consisting of professors, researchers and students from universities all over the world.

You are invited to join us. For more information, please visit our website:
www.structuralice.com

"After months of preparations and seven weeks of working on the building site, we unfortunately lost the battle against the weather.
The calculated warmer periods came exactly at the wrong time.
At the 8th of February at 4.00 AM during a guard shift, the middle part of the bridge came down due to the melting process of the previous days.
Of course we are disappointed, especially because we are convinced that the Bridge in Ice would have been standing on its own.
We would like to thank everyone who contributed to our incredible graduation project Da Vinci's Bridge in Ice. We enjoyed all the cooperation's and experiences, together we've done an incredible job and worked on an unforgettable project."
Roel and Thijs

Colophon

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This magazine is made to show the incredible time we had during constructing Da Vinci's Bridge in Ice and all other ice projects in Juuka, 2016.

We would like to thank every contributor for their effort.

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Eindhoven, June 2016


DB SCHENKER

11.1 Properties of the membrane

SCANTARP

VINYPLAN 6813
ВИНИПЛАН 6813

Pohjakangas/ Grundväv/ Base fabric Trägerstoff/ Основа		1100 dtex polyester 1100 дтекс Полиэстер
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Repimislujuus/ Rivhållfasthet/ Tear strength/ Weiterreissfestigkeit Прочность на разрыв	DIN 53363	300/300 N
Vetolujuus/ Draghållfasthet Tensile strength/ Reissfestigkeit Прочность на растяжение	EN ISO 1421 DIN 53354	2400/2300 N/5 cm
Tartunta/ Vidhäftning/ Adhesion Haftung/ Адгезия	IVK 3.13	100 N/5 cm
Lämmön-/pakkasenkesto Temperaturbeständighet Temperature resistance Temperaturbeständigkeit Температурный режим использования	SFS-EN 1876-1	+ 70 °C - -35 °C
Palosuojaus/Brandskydd/ Flame retardancy/Schwerentflammbarkeit/ Огнеустойчивость		---

Ilmoitetut arvot ovat tuotannon keskiarvoja. De angivna värdena är genomsnittsvärden från produktion. Technical data shown are average values from production. Die angegebenen technischen Daten sind Durchschnittswerte der Produktion. Все вышеуказанные технические данные являются средними показателями производства.

Kaikki materiaalimme ovat UV- ja homesuojattuja. Alla våra materialer är UV- och mögelskyddade. All our materials are UV, mildew and rot resistant. Alle unsere Materialien sind beständig gegen UV-Strahlen und Schimmel. Все материалы имеют ультрафиолетовую и грибковую устойчивость.

Pidätämme oikeuden muuttaa tietoja tarvittaessa ilman etukäteisilmoitusta. Vi förbehåller oss rätten att ändra uppgifterna utan förhandsinformation. We reserve the right to change the specification without prior notice. The technical data is offered without liability. Änderungen auf den neuesten technischen Stand vorbehalten. Die Angaben sollen ohne Rechtsverbindlichkeit informieren. По мере необходимости за нами остаётся право на изменения (спецификатно-технических) показателей без предварительной информации.
25.08.05

Oy Scantarp Ab
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Puh. (017) 288 1188
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Kotipaikka Kuopio
Y-tunnus 2017560-9
www.scantarp.fi

Domicile Kuopio
VAT no: FI20175609

11.2 Properties of the rope

Polypropyleen - 3 strengs - oranje

Opmaak: kunststof haspel of tros

Touw gemaakt van Polypropyleen is uitermate geschikt voor algemene toepassingen.
<u>Kenmerken:</u>
drijvend, matige rek, redelijk slijtbestendig en een goede prijs/kwaliteit verhouding.

Bestelnr.	dia / MM	MBL/ kg	Opmaak	Barcodenr.
2503010003010/08	3	350	hs à 100 m	8712437001476
2503010004010/08	4	400	hs à 100 m	8712437705145
2503020004010/08	4	400	hs à 200 m	8712437705343
2503022004010/08	4	400	hs à 220 m	8712437253011
2503010005010/08	5	450	hs à 100 m	8712437705152
2503020005010/08	5	450	hs à 200 m	8712437705350
2503022005010/08	5	450	hs à 220 m	8712437253035
2503010006010/08	6	550	hs à 100 m	8712437705169
2503020006010/08	6	550	hs à 200 m	8712437705367
2503020006010/03	6	680	tros à 200 m	8712437257255
2503022006010/08	6	550	hs à 220 m	8712437001377
2503010008010/08	8	960	hs à 100 m	8712437705183
2503020008010/08	8	960	hs à 200 m	8712437705381
2503020008010/03	8	1200	tros à 200 m	8712437257248
2503022008010/08	8	960	hs à 220 m	8712437001384
2503010010010/08	10	1425	hs à 100 m	8712437705206
2503020010010/08	10	1425	hs à 200 m	8712437705404
2503020010010/03	10	1800	tros à 200 m	8712437257217
2503022010010/08	10	1425	hs à 220 m	8712437001391
2503010012010/08	12	2030	hs à 100 m	8712437705220
2503022012010/08	12	2030	hs à 220 m	8712437001520
2503010014010/08	14	2790	hs à 100 m	8712437705237
2503022014010/03	14	2790	tros à 220 m	8712437705565
2503010016010/08	16	3500	hs à 100 m	8712437280208
2503022016010/03	16	3500	tros à 220 m	8712437705572
2503010018010/03	18	4450	hs à 100 m	8712437255497
2503022018010/03	18	4450	tros à 220 m	8712437253400
2503010020010/03	20	5370	hs à 100 m	8712437252533
2503022020010/03	20	5370	tros à 220 m	8712437253448
2503022022010/03	22	6500	tros à 220 m	8712437253509
2503022024010/03	24	7600	tros à 220 m	8712437253547

ook leverbaar in andere lengtes en diameters

11.3 Properties of the main steel cables

CASAR

Zert.-Nr. QS-126 HH

CASAR Drahtseilwerk Saar GmbH · Postfach 187 · D-66454 Kirkel

Kunde/Customer/Client

TEREX-DEMAG GMBH & CO. KG
WERK WALLERSCHEID

POSTFACH 1552
66465 ZWEIBRÜCKEN
DEUTSCHLAND

Abnahmeprüfzeugnis nach DIN EN 10204 3.1
Certificates on material tests / Certificats des essais de materiaux

Ihre Bestellung Nr.: / Your order No. / Commande No.: 7000000689 WERK 0020 — vom: / of / du: 04.08.06

Unsere Komm. Nr.: / Our Comm. No. / Notre référence No.: DE06004416 — vom: / of / du: 04.08.06

Unsere Rechnung Nr.: / Our invoice No. / Notre facture No.: 2007300697 — vom: / of / du: 30.01.07

Länge: / Length / Longueur: 1 X 260.00 M

Seilnenndurchmesser: / Ø nominal of wire rope / du câble: 21.00 MM

Konstruktion: / Construction: CASAR STARLIFT
ATTEST-NR.: 1166/2006
MARK. POS.00010 ID.NR. 149 100 12
DREHUNGSFREI NON-ROTATING ANTIGIRATOIRE

Einlage: / Core / Nature de l'âme:

Nennzugfestigkeit: / Tensile strength / Résistance des fils: 1960 N/MM2

Rechn. Bruchkraft: / Calc. aggr. breaking load: / Charge de rupture calculée: 444.30 KN

Wirkliche Bruchkraft: / Actual breaking load: / Charge de rupture obtenue: 345.00 KN

Tragende Drähte in den Außenlitzen: / Number of load bearing wires in the outer strands: / Nombre de fils porteurs des torons extérieurs: 112

Haspel-Nr.: / Reel-No.: / Bobine-No.: 559

Datum / Date / Date: 31.01.07

Schlagart / Kind of lay / mode du câblage:
GLEICHSCHLAG RECHTS
LANGS RIGHT HAND/LANG A DROITE

Oberfläche der Drähte / Surface / Revêtement de surface:
BLANK/UNGALVANIZED/ACIER CLAIR

Mindestbruchkraft: / Minimum breaking load: / Charge de rupture effective: 339.20 KN

Längengewicht: / Weight per unit length: / Poids par unité de longueur: 204.00 kg/% m

Außendrahtdurchmesser: / Outer wire diameter: / Diamètre des fils extérieurs:

Hersteller / Manufacturer / Producteur
(Signature)

CASAR

Dieses Schreiben wurde elektronisch erstellt und ist ...
QUALITAETSSICHERUNG/H. RAUBER

11.4 Properties of the anchors

In practice

Test location

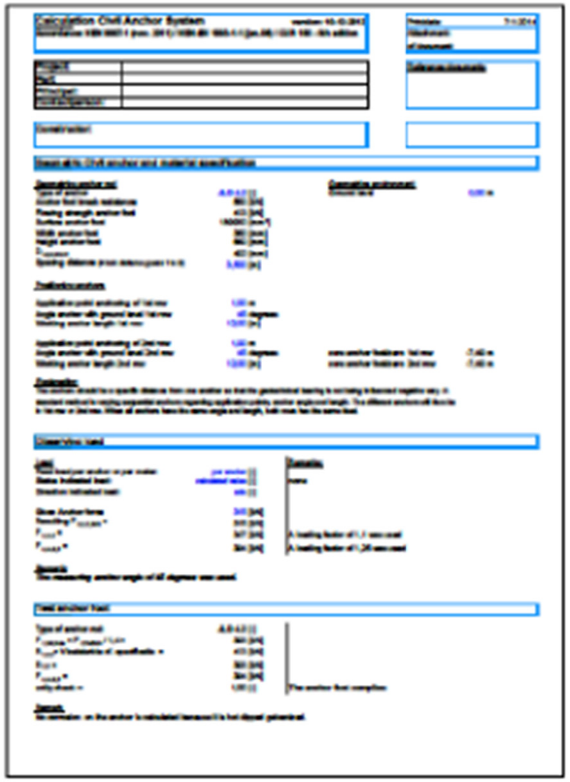
If there is insufficient earth mechanical data available, an inspection test can be made on location for the correct anchoring type before the commencement of activities. This is to confirm the loading capacity of the anchor in the prevailing sub-soil.

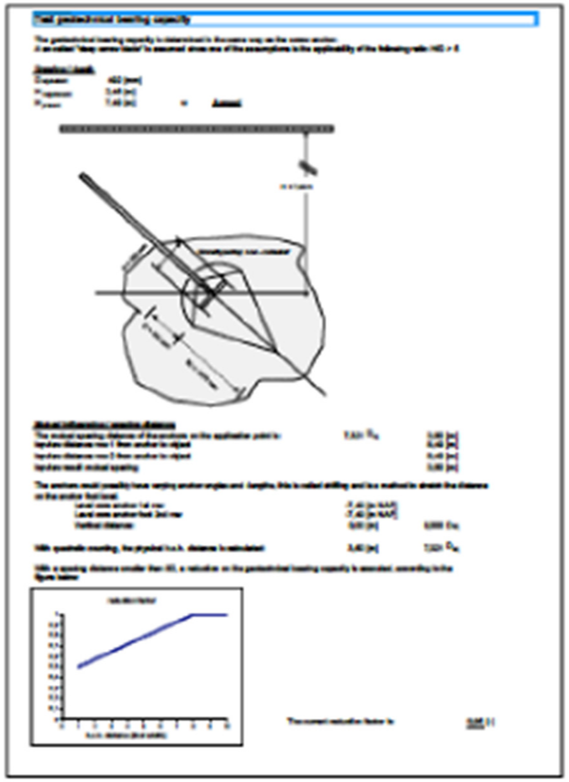
Calculation

The JLD-anchors are designed to satisfy the nationally applicable norms. For the Netherlands, the eurocode 7 is applicable.

Ultimate load

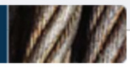
JLD 1.0	Ultimate load	16 kN
JLD 1.2	Ultimate load	40 kN
JLD 1.4	Ultimate load	120 kN
JLD 2.2	Ultimate load	220 kN
JLD 2.4	Ultimate load	220 kN
JLD 2.8	Ultimate load	220 kN
JLD 4.2	Ultimate load	550 kN
JLD 4.4	Ultimate load	550 kN

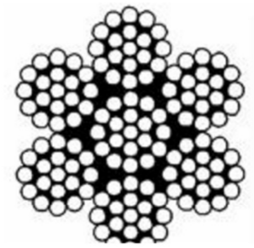




11.5 Properties of the stability cables

7x19





Verzinkte staalkern 7x19

Afwerking: Verzinkt
Constructie: 7x19
Treksterkte: 1770N/mm2 - 180 kgf/mm2
Slagwijze: Kruisslag rechts
Gebr.fact.: 5
Toepassing: Tuien, universeel

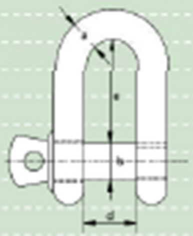
Eigenschappen tabel

	diameter	min breek		gewicht per 100 mtr
		1770 N/mm2		
	mm	kg	kN	kg
10301402	3	588	5,77	3,43
10401402	4	1050	10,3	6,1
10501402	5	1630	16	9,53
10601402	6	2360	23,1	13,7
10701402	7	3200	31,4	18,7
10801402	8	4180	41	24,4

11.6 Properties of the d-shackles

MENNENS
staalkabel-, hijs- en heftechniek

G-3151



Yellow Pin Shackles

dee shackles with screw collar pin

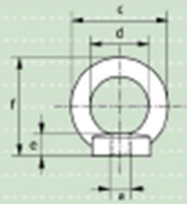
- **Material** : bow and pin high tensile steel, Grade 6
- **Standard** : generally to US Fed. Spec. RR-C-271
- **Finish** : hot dipped galvanized
- **Note** : import quality

working load limit	diameter bow	diameter pin	diameter eye	width inside	length inside	weight each
	a	b	c	d	e	
t	mm	mm	mm	mm	mm	kg
0.33	5	6	12	9.5	19	0.03
0.5	6	8	16	12	22	0.05
0.75	8	10	19	13.5	26	0.08
1	10	11	23	17	32	0.13
1.5	11	13	27	19	37	0.2
2	13	16	30	20	41	0.27
3.25	16	19	38	27	51	0.57
4.75	19	22	46	32	60	1.19
6.5	22	25	53	36	71	1.43
8.5	25	28	61	43	81	2.16
9.5	28	32	68	46	90	3.06
12	32	35	76	51	100	4.11
13.5	35	38	84	57	111	5.28
17	38	42	92	60	122	7.24
25	45	50	106	73	146	12.14

11.7 Properties of the eye nuts

MENNENS
staalkabel-, hijs- en heftechniek

S-8142
E-8142



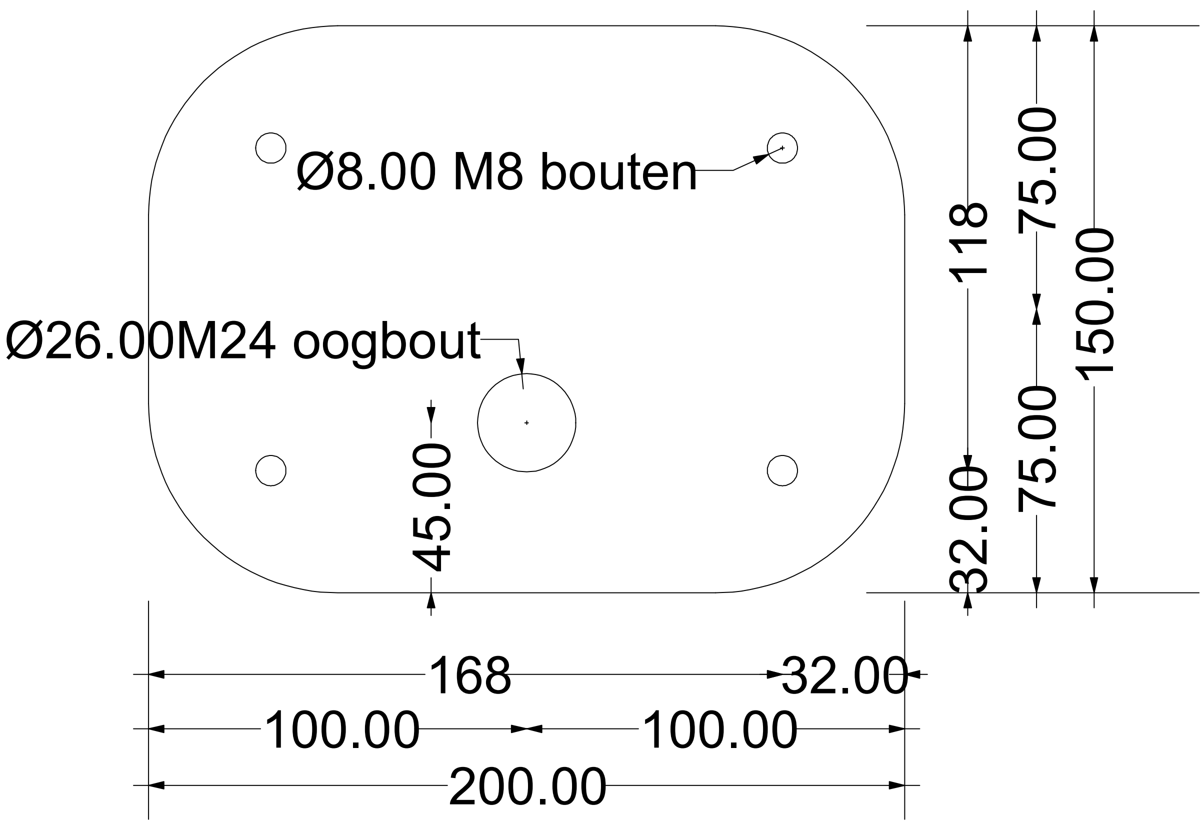
Green Pin® eye nuts

generally to DIN 582

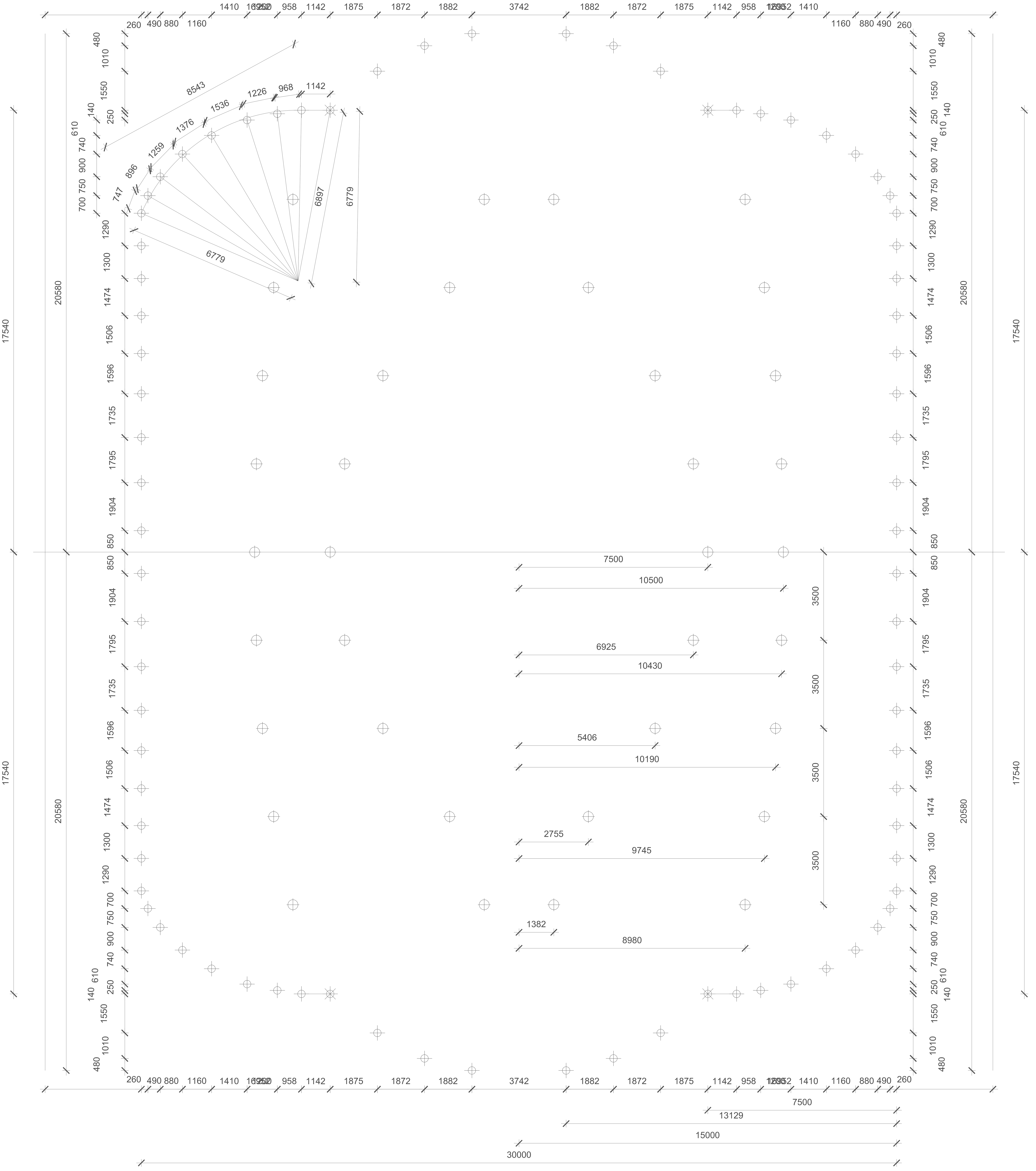
- **Material** : carbon steel, C15
- **Safety factor** : MBL equals 6 x WLL
- **Standard** : generally to DIN 582
- **Finish** : self coloured
  electro-galvanized
- **Certification** : at no extra charges this product can be supplied with a works certificate and/or EC Declaration of Conformity. Test certificates can be supplied upon request

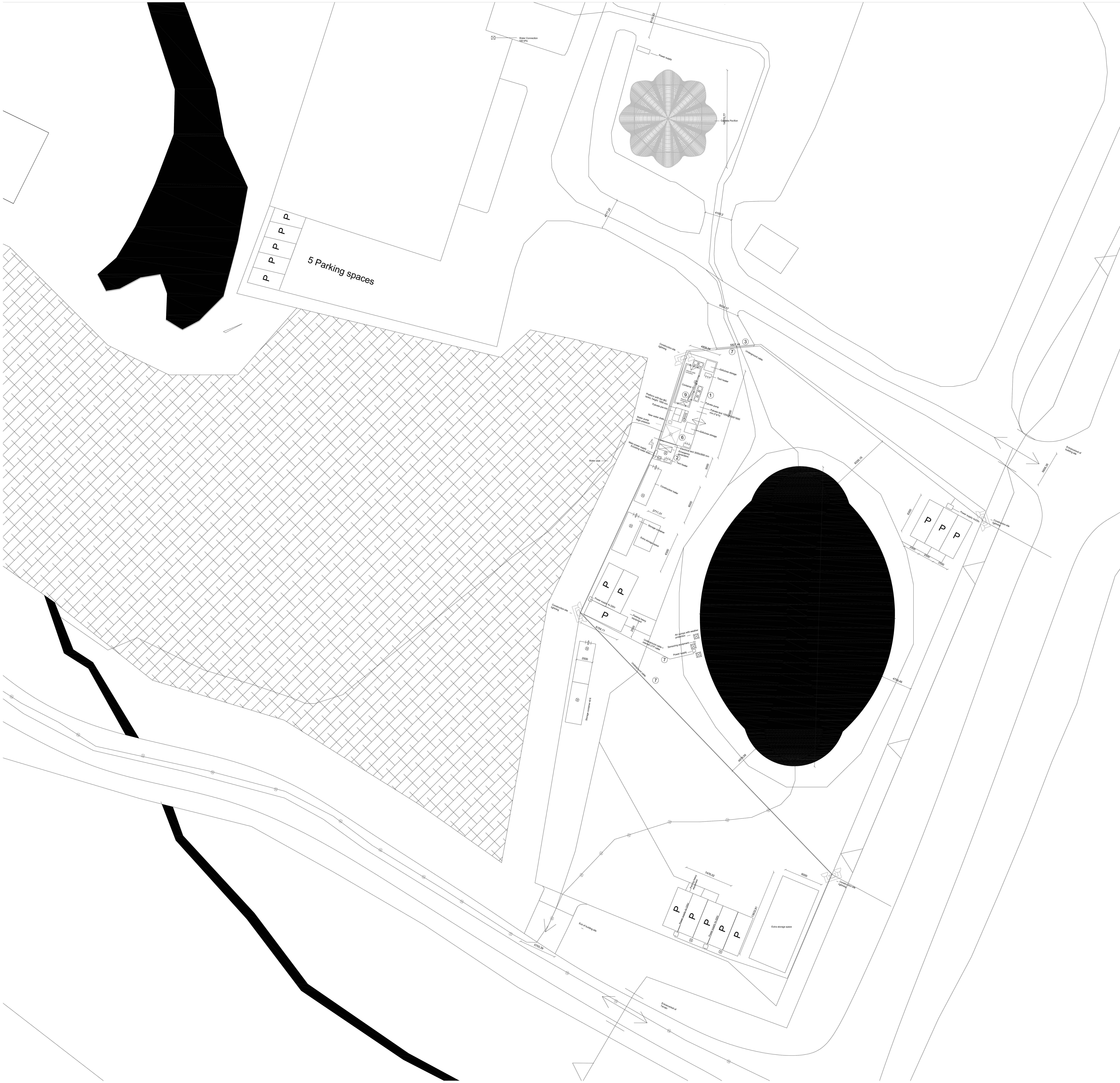
working load limit	diameter thread	diameter base	diameter eye outside	diameter eye inside	thickness base	height	weight per 100 pcs
	a	b	c	d	e	f	
t	mm	mm	mm	mm	mm	mm	kg
0.07	M 6 x 1.00	20	36	20	8.5	36	4.2
0.14	M 8 x 1.25	20	36	20	8.5	36	5.2
0.23	M 10 x 1.50	25	45	25	10	45	9.4
0.34	M 12 x 1.75	30	54	30	11	53	16
0.49	M 14 x 2.00	35	63	35	13	60	22
0.7	M 16 x 2.00	35	63	35	13	62	24
0.9	M 18 x 2.50	40	72	40	16	71	36
1.2	M 20 x 2.50	40	72	40	16	71	35.2
1.5	M 22 x 2.50	45	81	45	18	80	58.6
1.8	M 24 x 3.00	50	90	50	20	90	70.6
2.5	M 27 x 3.00	50	90	50	20	90	102
3.2	M 30 x 3.50	65	108	60	25	109	132
4.3	M 33 x 3.50	65	108	60	25	110	170
4.6	M 36 x 4.00	75	126	70	30	128	208
6.1	M 39 x 4.00	75	126	70	30	130	260
7	M 42 x 4.50	85	144	80	35	147	311
8	M 45 x 4.50	85	144	80	35	150	407
8.6	M 48 x 5.00	100	166	90	40	168	502
8.6	M 52 x 5.00	110	184	100	45	187	830
11.5	M 56 x 5.50	110	184	100	45	187	669
16	M 64 x 6.00	120	206	110	50	208	930
21	M 72 x 6.00	150	260	140	60	260	1500

Detail anchor plates



Anchor plan


8543
1536
1226
968
1142
1376
1259
896
747
6779
6897
6779
7500
10500
6925
10430
5406
10190
2755
9745
1382
8980
3500
20580
17540
7500
13129
15000
30000



Every category has been indicated in layers.
Action list (indication in drawing):

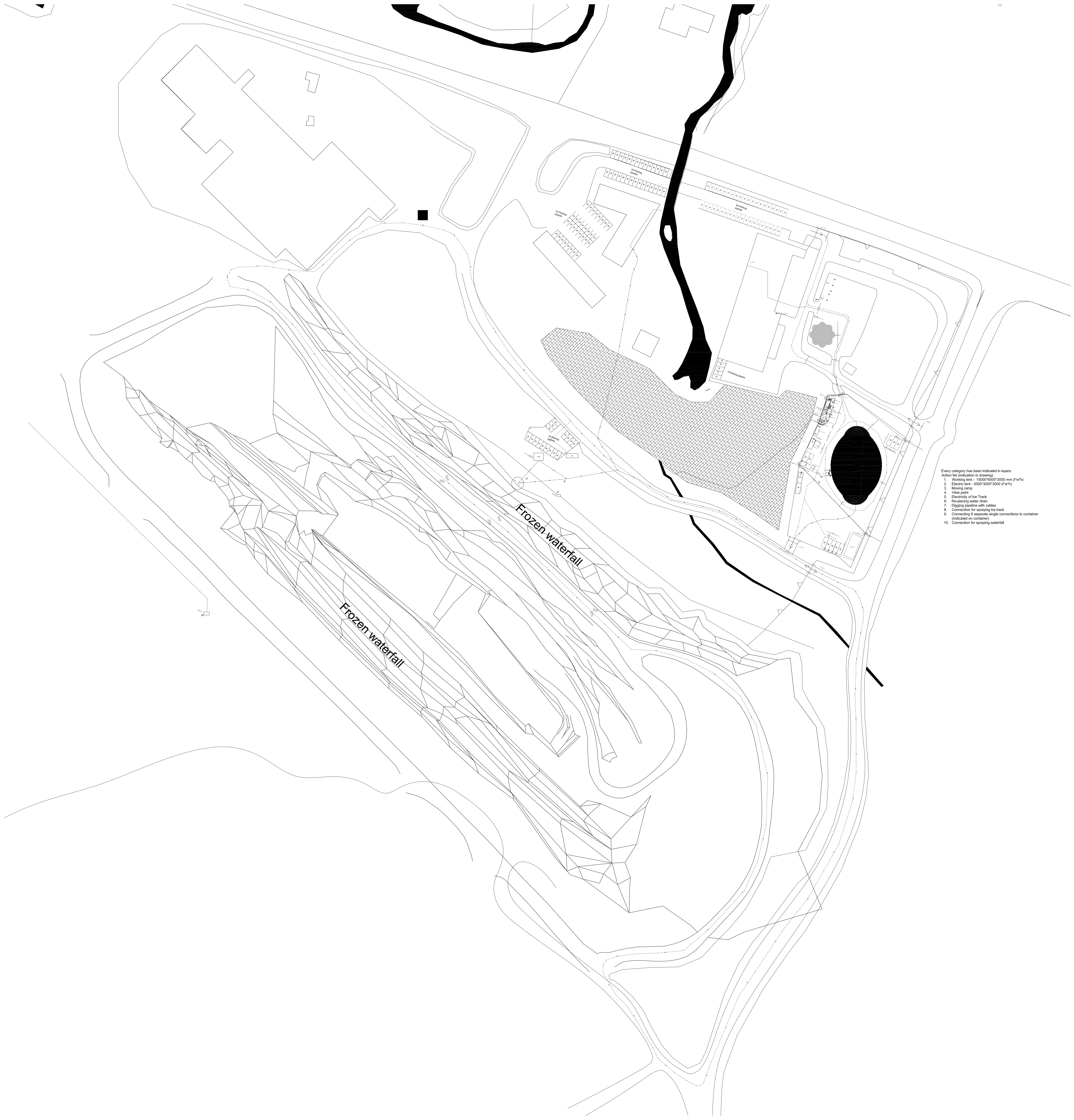
1. Working tent - 15000*6000*3000 mm (l*w*h)
2. Electric tent - 3000*3000*3000 (l*w*h)
3. Moving ramp
4. View point
5. Electricity of Ice Track
6. Re-placing water drain
7. Digging pipeline with cables
8. Connection for spraying ice track
9. Connecting 9 separate single connections to container (indicated on container)
10. Connection for spraying waterfall

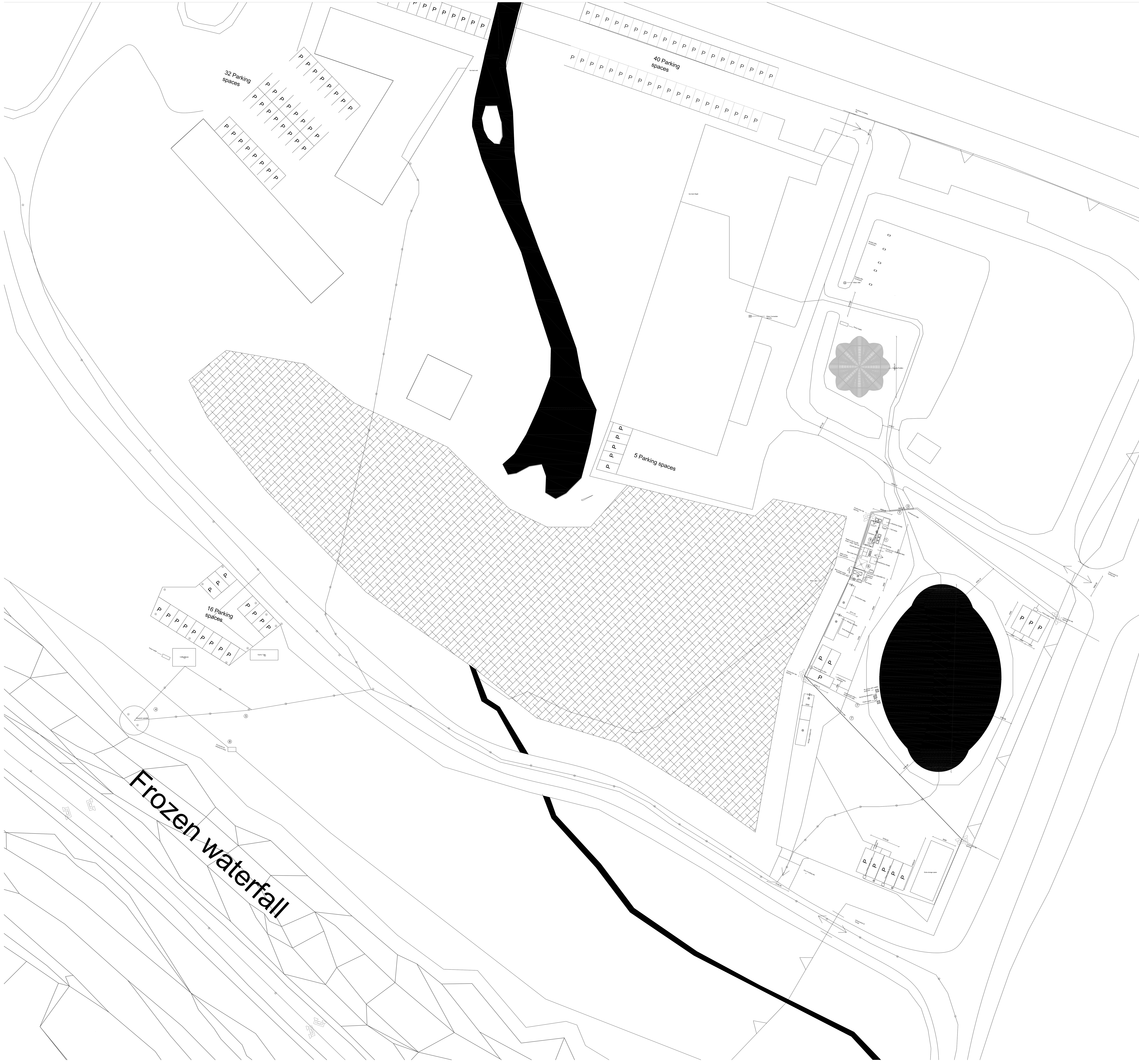
Building site Bridge in Ice
Scale: 1:200
3-11-2015

Every category has been indicated in layers.
Action list (indication in drawing):

1. Working tent - 15000*6000*3000 mm (l*w*h)
2. Electric tent - 3000*3000*3000 (l*w*h)
3. Moving ramp
4. View point
5. Electricity of Ice Track
6. Re-placing water drain
7. Digging pipeline with cables
8. Connection for spraying ice track
9. Connecting 9 separate single connections to container (indicated on container)
10. Connection for spraying waterfall

Building site Fences
Scale: -
3-11-2015


Frozen waterfall
Frozen waterfall
Every category has been indicated in layers.
Action list (indication in drawing):
1. Working tent - 15000*6000*3000 mm (l*w*h)
2. Electric tent - 3000*3000*3000 (l*w*h)
3. Moving ramp
4. View point
5. Electricity of Ice Track
6. Re-placing water drain
7. Digging pipeline with cables
8. Connection for spraying ice track
9. Connecting 9 separate single connections to container (indicated on container)
10. Connection for spraying waterfall



Every category has been indicated in layers.
Action list (indication in drawing):

1. Working tent - 15000*6000*3000 mm (l*w*h)
2. Electric tent - 3000*3000*3000 (l*w*h)
3. Moving ramp
4. View point
5. Electricity of Ice Track
6. Re-placing water drain
7. Digging pipeline with cables
8. Connection for spraying ice track
9. Connecting 9 separate single connections to container (indicated on container)
10. Connection for spraying waterfall

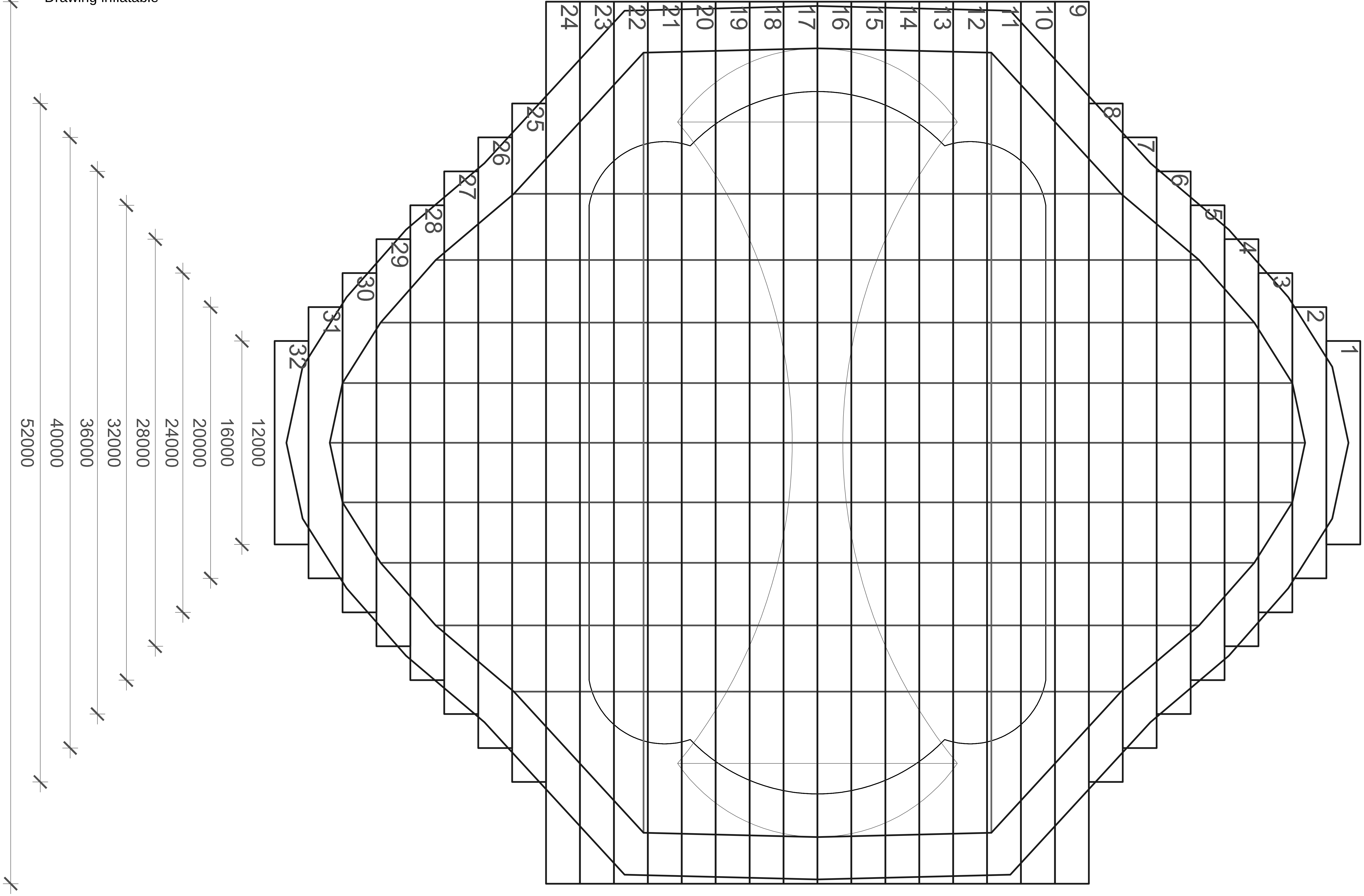
Building site Snowtrack
Scale: -
3-11-2015

Every category has been indicated in layers.

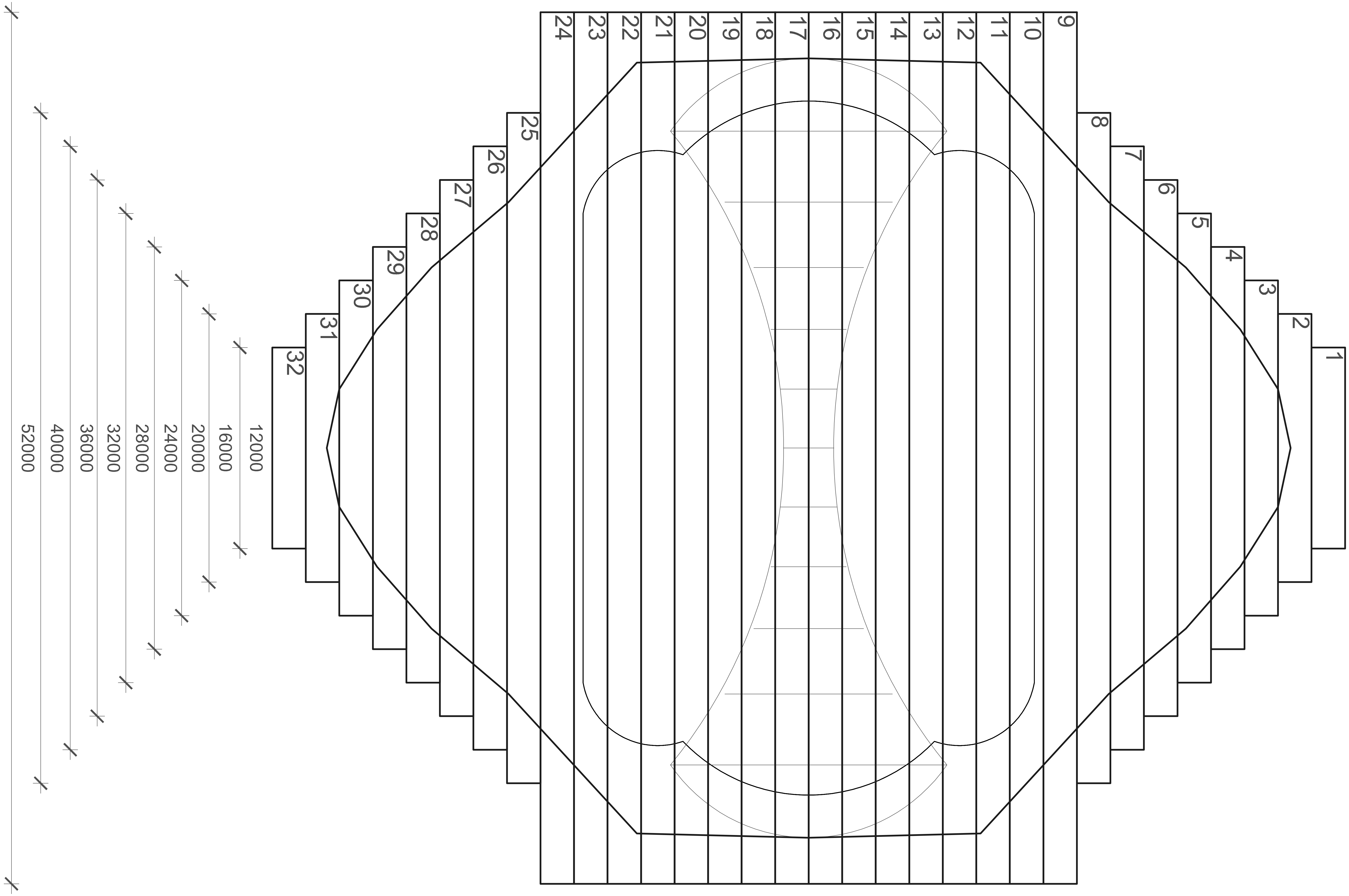
Action list (indication in drawing):

1. Working tent - 15000*6000*3000 mm (l*w*h)
2. Electric tent - 3000*3000*3000 (l*w*h)
3. Moving ramp
4. View point
5. Electricity of Ice Track
6. Re-placing water drain
7. Digging pipeline with cables
8. Connection for spraying ice track
9. Connecting 9 separate single connections to container (indicated on container)
10. Connection for spraying waterfall

Drawing inflatable



Drawing inflatable



Rope lengths

C0/D0	
m	
4,00	
6,15	1
8,30	1
12,30	
49,20	

C1/D1
m
4,00
5,73
7,72
10,33
14,33
57,31

C2/D2
m
4,00
6,08
8,33
10,69
13,61
15,92
18,27
20,38
22,71
23,95
27,95
111,78

C3/D3
m
4,00
6,61
8,68
11,41
13,80
16,33
18,93
21,66
25,66
102,66

C4/D4
m
4,00
7,27
9,36
11,86
14,44
17,13
19,49
23,49
93,96

C5/D5
m
4,00
7,71
9,78
12,39
15,10
17,26
21,26
85,03

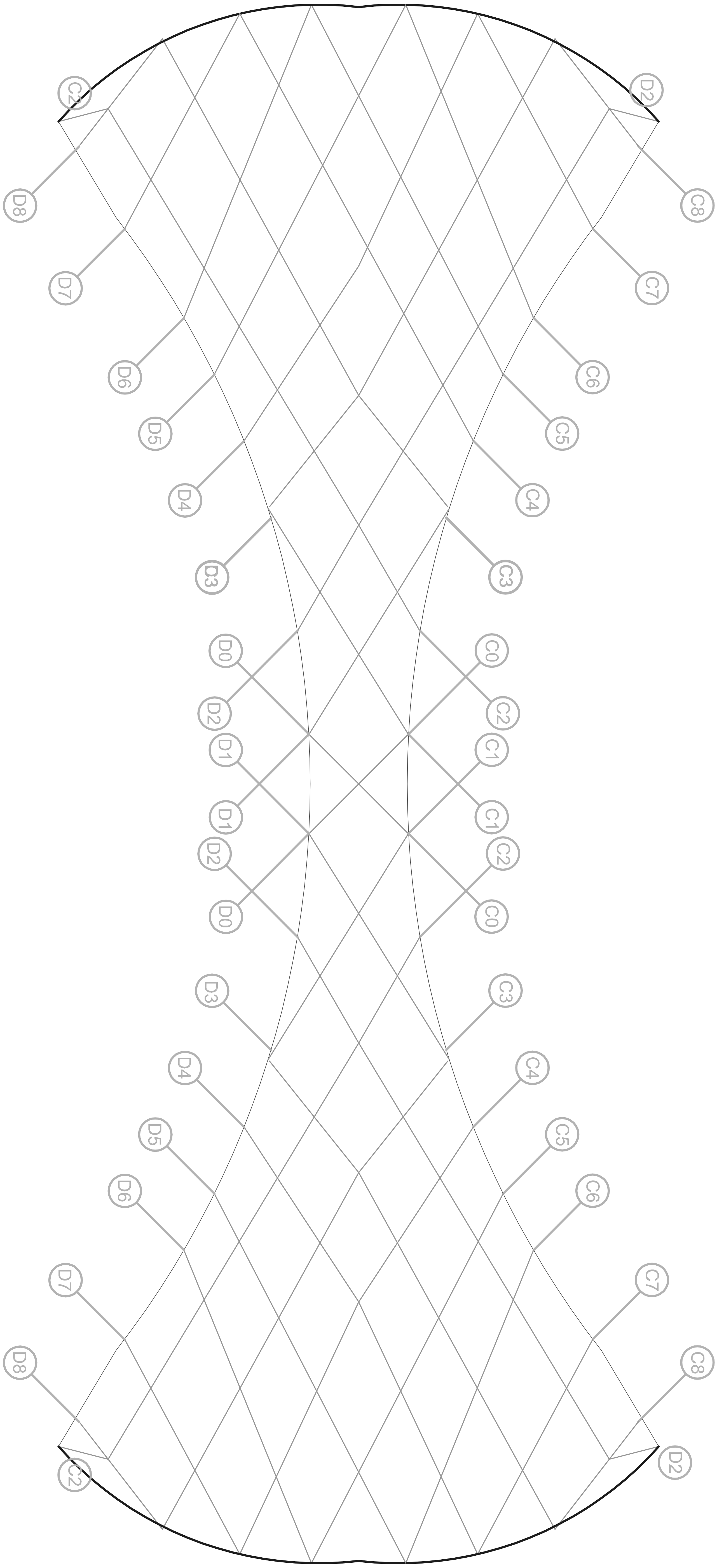
C6/D6
m
4,00
7,19
9,22
11,66
13,70
17,70
70,80

C7/D7
m
4,00
6,68
8,60
11,00
15,00
60,01

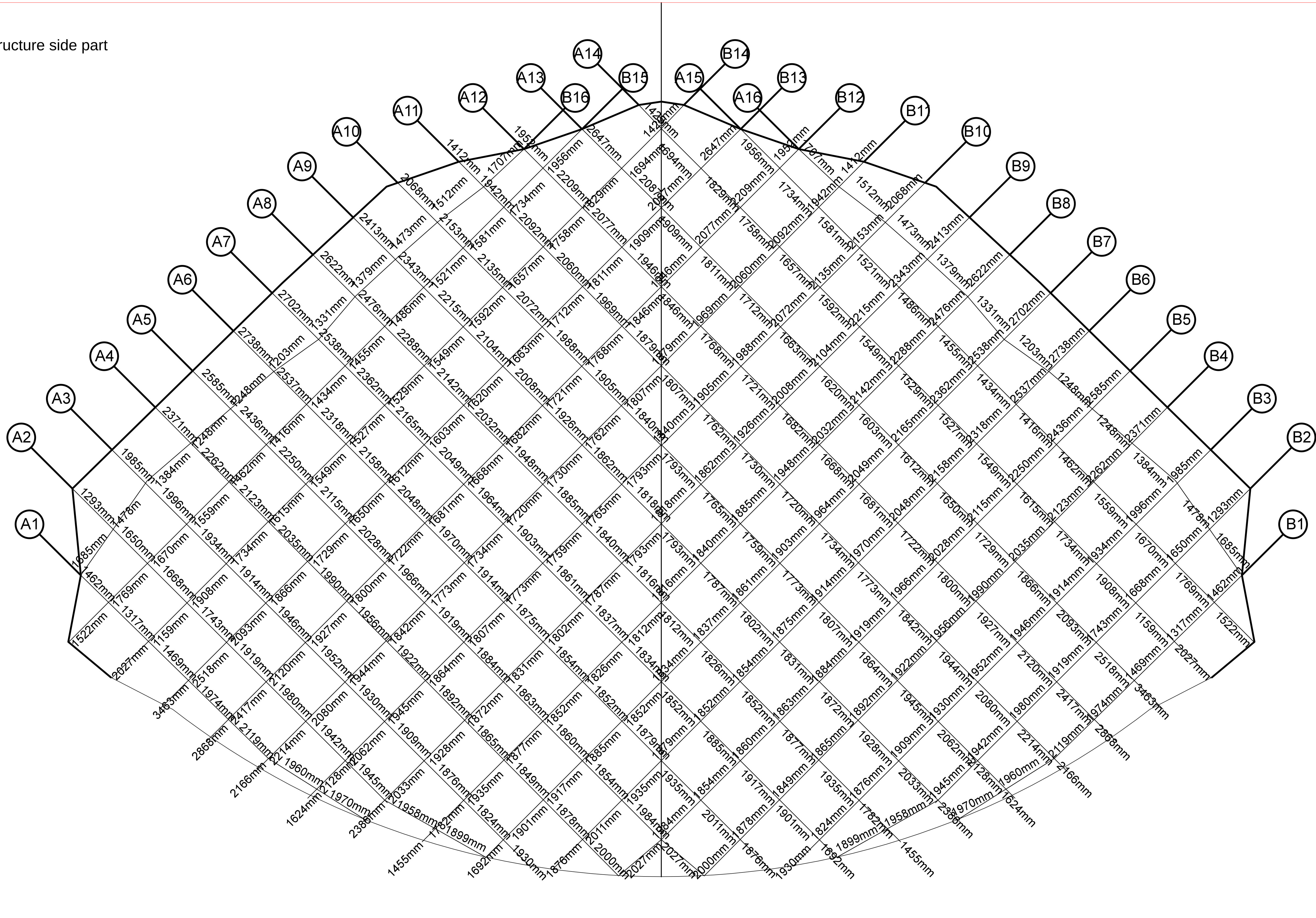
C8/D8

m
4,00
5,79
7,63
11,63
46,52

Rope structure mid part



Rope structure side part



Deflation of the inflatable 10-13 February:

- Placing fences on the bridge(needs to hold 100kg side force). Requires: boom lift
    - Drilling holes on the top of the bridge
    - Placing poles
    - Placing net structure between poles
    - Spraying cellulose
    - Fence will be one with the bridge
- Measuring thickness ice: checking if the Ice structure is thick enough(top minimal of 600m)
- Disconnect stability cable with eye-nuts.
- Disconnect the Eye-nuts with main cable.
- Bring down columns
- Carefully bring down the pressure in the inflatable.

- Cleaning building site
- Death load Test
- Reconstruct the slope
- Spreading gravel over the bridge.
- Final Test