

Title

Three arches for a roof – case-study of a multi-disciplinary design process

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Abstract

In this article, the design process for the remarkable curved roof for a sports hall in Genk (BE) is traced. The research is based on files from the archives of both the architect and the structural engineer and aims to develop specific knowledge on multidisciplinary design processes in building design.

The project was granted to the partnership of young architects and a renowned office for structural engineering. The new building is roofed with three oversized arches, proposed as a shell structure in concrete in the competition, but executed as a steel truss system. The goal of this article is to make observations specifically on the collaborative design process between the architect and the engineer, in the specific context of a design competition. It is observed how the final structure got its form, how design decisions were made and how the collaboration defined the project.

Close observations are made on six key moments in this design process. For these pivotal points sketches, documents and communication, are discussed in detail. In the end three general observations are made on the case study.

Key words

Arches, design process, multidisciplinary design, genetic criticism, case study, structure in architecture.

Statements and declarations

The authors have no relevant financial or non-financial interests to disclose.

The authors have no competing interests to declare that are relevant to the content of this article.

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

The authors have no financial or proprietary interests in any material discussed in this article.

1 INTRODUCTION

In this article the design process for the remarkable curved roof for a sports hall in Genk (BE) is traced. The design results from a layered design process, in which both the architect and the structural engineers were thoroughly engaged.

In the field of design studies, a lot of research has been done on the nature of design. The broad scope, the high level of abstraction of these theories and the fact that research is mostly based on oral sources and experiments, does however not allow to get detailed insight in the course of (multidisciplinary) design processes in building design. It hinders to take the temporal aspect into account, which is necessary for example to understand the shifting positions of team members and the evolving value of statements throughout the process. These handicaps can be overcome by the bottom-up approach of case studies.

The goal is to make observations specifically on the collaborative design process between the architect and the engineer, in the specific context of a design competition. It is observed how the final structure got its form, how design decisions were made and how the collaboration defined the project.

The design process is scrutinized based on files from the archives of both the architect and the structural engineer - further referred to as the engineer. Documents such as sketches, calculation models, presentations and mail conversation are organized in temporal sequence, in order to chronologically reconstruct the design process. Close observations are made on six key moments in this design process. They are pivotal moments to observe the roles of and the collaboration between the architect and the engineer. For these pivotal points sketches, documents and communication is discussed in detail.

The method used, is loosely based on the methodological concepts of genetic criticism. In this scholarly field in literature, manuscripts are used to study works of literature.

From both archives, documents of resp. 439 pages and 766 pages from before and after the competition are composed. The selection served as the critical corpus for this research and is what distinguishes this set of documents from the archive. It is a crucial step in genetic criticism, in which a selection is made with a specific focus on the roof of the building and with the research questions on the collaborative design process in mind.

The project scrutinized in this case study originates from an Open Call competition. Open Call competitions are one of the instruments the Flemish Governmental Architect installs. It is a selection procedure in two phases: a competition for five candidates, selected out of interested participants, followed by a negotiation phase. The project is granted to prepare for public tendering, only after which a contractor gets involved.

The competition to extend the sports hall in Genk was part of Open Call 18, launched in the summer of 2009. The competition brief was to extend an existing sports complex, known for its swimming pool with a hypar roof. This building was designed by Isia Isgour and André Paduart in the seventies. It is one of the most prominent examples of a thin shell structure in Belgium.

PATS BOEM ... VLINDERSLAG!

Met een rigoureuze geste verstarde architect Isia Isgour de sierlijke beweging waarbij de zwemmer moeizaam door het water glijdt door beide armen synchroon vooruit te zwaaien. In één trek heft de atleet het hoofd boven water om naar lucht te happen.

Vanaf de lager gelegen oostzijde is de indrukwekkende betonnen dakconstructie het meest zichtbaar. De betonnen vleugels steken expressief boven de pint uit. De verticaliteit van de 3 schoorstenen in combinatie met de horizontaliteit van het raam zorgt voor evenwicht en dynamiek.

Hoe kunnen wij deze uitgekende compositie bewaren?

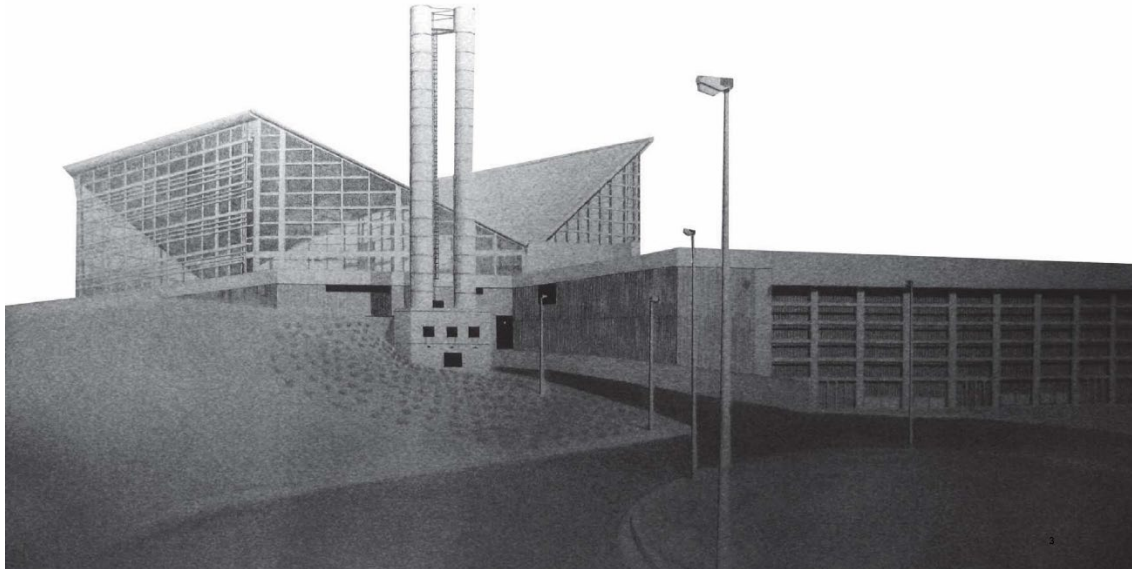


Figure 1 Swimming pool with hypar roof by Isia Isgour and André Paduart. Page 3 of competition booklet

The case study focuses on the proposal of a design team consisting of the young 'Bel Architects' and the renowned office for structural engineering 'Ney & Partners'. In their motivation they wrote '(...) Due to the combination of young design talent and experienced competence, we guarantee a fresh and at the same time feasible concept' [1]. The selection report more or less copied the statement. A general remark in italics as well states 'Good engineers / Architectural design starting from constructive principles' [2].

The specific 'design identity' of both offices are important for the specific course of this design process. In a text published in 2006 on the practice of Ney & Partners, the following can be read: ' (...) the task of the engineer, Ney maintains, is 'not free of obligations'... (...) the engineer, who always looks for what is called the 'structural optimum' (...) The structural optimum not only provides us with the most economical solution, but also the right solution. (...) In clear terms, the quest for the 'structural optimum' often results in the design of forms that make sure that only purely tensile or compressive forces occur in the material and that bending moments and other parasitic material stresses are avoided as much as possible.' [3] This aspiration, to always look for the structural optimum, will prove to be crucial in the specific course of the process.

In an interview with Bel Architects the question is asked who of the two partners 'thinks' the most in a constructive way, since one of the associates has worked for Samyn, a known 'architect-engineer' in Belgium. They answer that their taste for construction is one of the important things they have in common and agree that the 'structural aspect' is not something that can be separated from architectural design. [4] This interest in structures and structure in architecture, probably made the architects receptive for the engineers arguments and facilitated a design process in which both the architect and the engineer can operate as equivalent design partners.

The team decided to go against the competition brief and proposed not to extend the existing building, but to build a separate sports hall. They argued that it would be impossible not to harm the existing building by attaching a large extension to it, nor to give architectural value to these new sports facilities. The new building has a rectangular plan of 60 by 81m and is covered in longitudinal direction by three oversized arches, proposed as a shell structure in concrete in the competition. Although the team had already decided on the architectural form and the structural concept during the competition phase, afterwards the roof evolved from prominent and visible concrete vaults to a concealed steel truss system.



Figure 2 The finished building. Picture by Tim Van De Velde

In what follows, a short overview of the six pivotal points in this case study is made.

A ‘proper’ relation to the existing building, access of natural light in the sports hall and an integrated solution for the structure, techniques, acoustics,... are main concerns from the beginning of the project. The first pivotal point is when these aspirations materialize in the architectural project with three large arches. This happens during a meeting, only one week before the competition deadline. With the arches, the concept of ‘the ideal shape’ is introduced. Both agree to look for ‘the ideal shape’ of the roof. In doing so this becomes a mutual design objective. Such a concept however allows for different interpretations. In semiotics, the concept of a ‘floating signifier’ exists. These are signifiers without a specific signified, which means that they can mean different things to different people. [5, 6] The collaborators have to look for a compatible understanding of the concept in the context of this specific project. To get to a final design, both have to argue and negotiate on the shared definition of what this shape will be. ‘The ideal shape’ will evolve to a central concept in the collaborative design process.

The second focus is on the competition bundle, published at the end of May 2010. It can be seen that the presentation is made with a specific rhetoric for the competition. The decisive tone of the statements imply that the design is already in an advanced stadium, for which the proposal is as well appreciated in the jury report. The archival documents however prove that the design was still in a premature stage, as can be expected from a competition proposal. These premature statements, and specifically the emphasis on concrete and a shell structure, do have consequences throughout the design process. Corrections on these statements have to be made later, which at a certain point introduces tension in the relation between the architect and the engineer.

The first study report by the engineers can be seen as the start of the second phase of the design process, after the competition. The first version is published in February 2011. This report tries to nuance exactly the statements made during the competition. It mainly focuses on ‘the ideal shape’ of the cross section of the arches and opens the options for several construction method and materials, including concrete, steel and masonry. The focus on the cross section specifically keeps these options open. This angle and the conclusion that an ‘ideal shape’ - a shape in which bending moments are minimized - has to be looked for, orients the further course of the process.

The fourth pivot is the definition of the cross section of the arches, a decision made on June 22nd. After a long process in which the common ground for the ideal shape was sought for, during which both the architects and the engineers tried to fit the boundary conditions of the others into their priorities, the engineers reaffirmed that the arches should in their opinion be ‘optimal’ shapes, thus catenaries. They use classical arguments such as the economy of materials, but it is clear that this pursue as well had to do with the

identity and the specific design preferences of the engineers. Structurally, the arches are secondary. The arches span the sports hall in the longitudinal direction, which primarily makes them beams. The catenary shapes are obtained by recalibrating another boundary condition: the client agrees to reduce the free height of the sports fields in the corners of the sports hall.

The fifth pivotal point is the end of the preliminary design phase only a week later, and bundles two occurrences. First is the response of a contractor that questioned the feasibility of cast-in-place concrete shells, the execution method the engineers asked them to evaluate. Second is the response of the client on an image that showed prominent ribs in acoustic material on inside the arches. Both occurrences urge the team to recalibrate their priorities and the relative importance of the design priorities. The focus is reoriented toward an integrated design proposal with prefabricated concrete elements. In the scope of this article the focus is mainly on the first occurrence, since the discussion between the architect and the engineer illustrates their relative position at this point. In this case the architects take the lead by stating that an increase in budget is not an option, and by seriously questioning the input from the contractor.

The last pivotal point is at the end of September, when the engineers (firmly) propose to shift the structural system from prefabricated concrete shells to a steel truss system. This results in another discussion. In this case the engineers rather take the lead and persuade the architects that a steel solution is best fit for this project.

The part of the design process after the design competition was used before in a paper [7]. In section 2.3 of this paper a general, visual overview is given of how the roof structure evolved after the competition from a concrete shell structure towards a simple, steel truss system. The case was used as an example to make some comments on the proposed chapter on ‘conceptual design’ in fib Model Code 2010 [8], a publication that serves as a basis to develop future codes for the design of concrete structures. It is argued that ‘conceptual’ design is not a phase before the ‘detailed’ design in the workflow of the engineer, as is proposed in this design code. The design process is linear nor predictable. The paper argues that both ‘types’ of design acts always co-exist to a certain degree in the work of the engineer. Acknowledging that both cooperating partners go through an equivalent kind of creative design process, is an important premise to compare and to find the common ground on these points where they develop the design together.

It goes without saying that this elaborate discussion on the process is still a large simplification of the complete process and that selections were made to obtain the goal of this article: make observations on the collaboration between the architect and the engineer. Other specialists such as an acoustic engineer, engineers for special techniques were involved as well. They of course had a certain impact as well, but are not specifically observed in this study.

The language used in the process was Dutch. Translations have been made by the author.

2 SIX PIVOTAL POINTS

2.1 *A building ‘Such as the one of Isgour’*

Bel architects were asked during an interview what their starting point was for the ‘three shells’.[4] Their first idea was to make the extension underground, with a roof out of glass bricks. This would be located in front of the existing building and serve as a square. After a conversation with Laurent Ney it however became clear this would have tricky consequences. (...) So they asked themselves, why would we organise the program underground, why wouldn’t we make a building *such as the one of Isgour*? The building raised from the ground, floor by floor. First it was still a rectangular box, but this missed something. The architects state that the new sports hall owes its shape to the existing building.

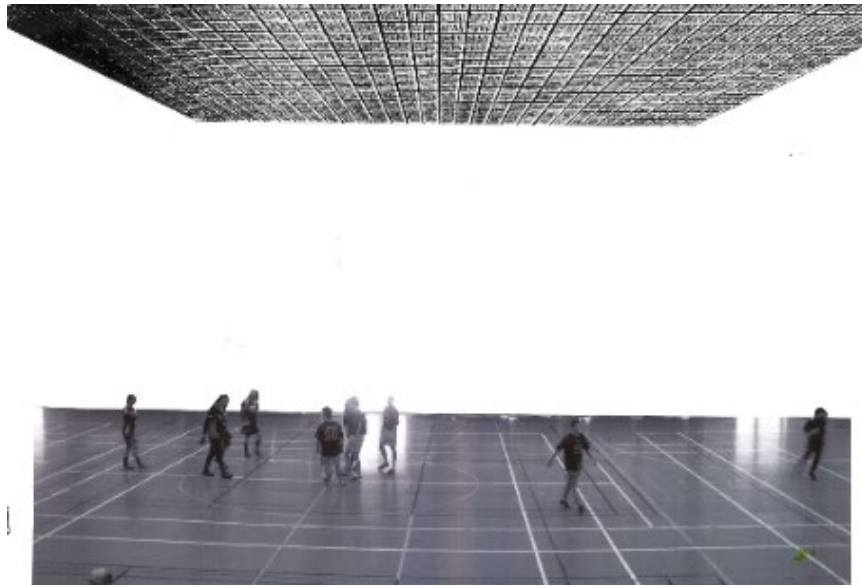


Figure 3 Early collage of a sports hall with a glass brick roof. - archive Bel Architects, April-May 2010

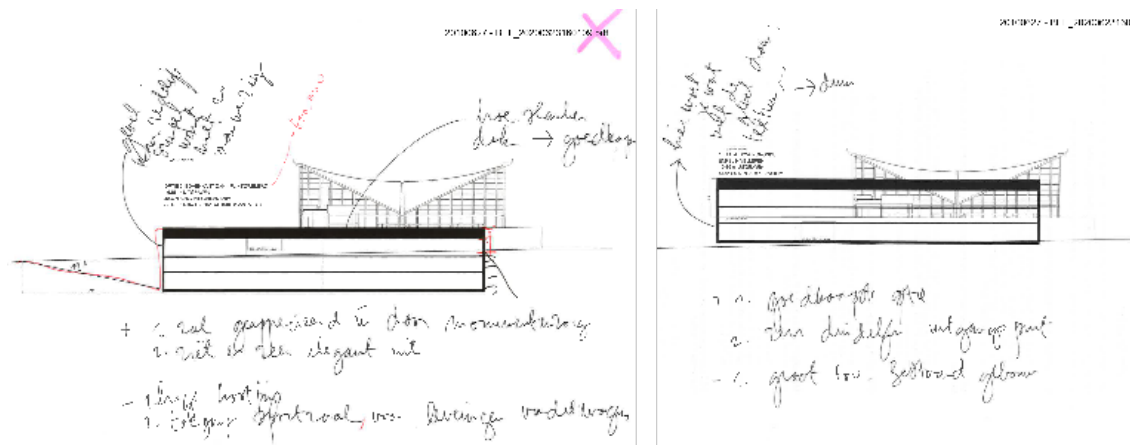


Figure 4 Sketches with assessment of the level of the building in relation to Paduart & Isgour's Hypar roofed building. - Archive Bel Architects, April-May 2010

In the competition brief [9] as well as in the briefings [10], the importance and the value of the existing building of Isgour and Paduart is strongly emphasized. Numerous documents were collected by the architects on the buildings of René Paduart and on thin shell structures (in Belgium). Marks on the elaborate report by the Flanders heritage Agency indicate for example the roof consisting of a concatenation of five thin hypar roof elements in concrete, organized in such a way that they are no subject to bending forces. The relation to the existing building is an important focus of the design, very early in the process. The question of how to materialize this relation, however asks for extensive design labour. Sketches in *Figure 5* are illustrative to this.

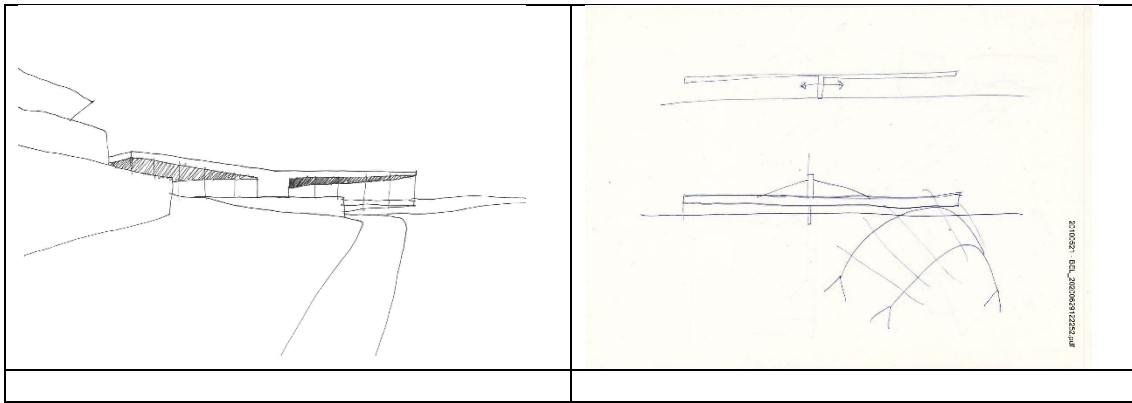


Figure 5 Ideas for a building 'such as the one of Isgour.' - archive Bel Architects, between 21/05/2010 and 11/06/2010

Another important aspect, already present in the idea to use glass bricks for the roof, is the goal to get diffuse, natural daylight into the sports hall. At this point, Ney & Partners did some first dimensioning for a grid of steel beams to span the sports hall. It is attempted to *integrate* this access of natural light with the acoustic solutions, thermal isolation, the structure and other aspects of the design, for which as well numerous sketches are made. (Figure 6)

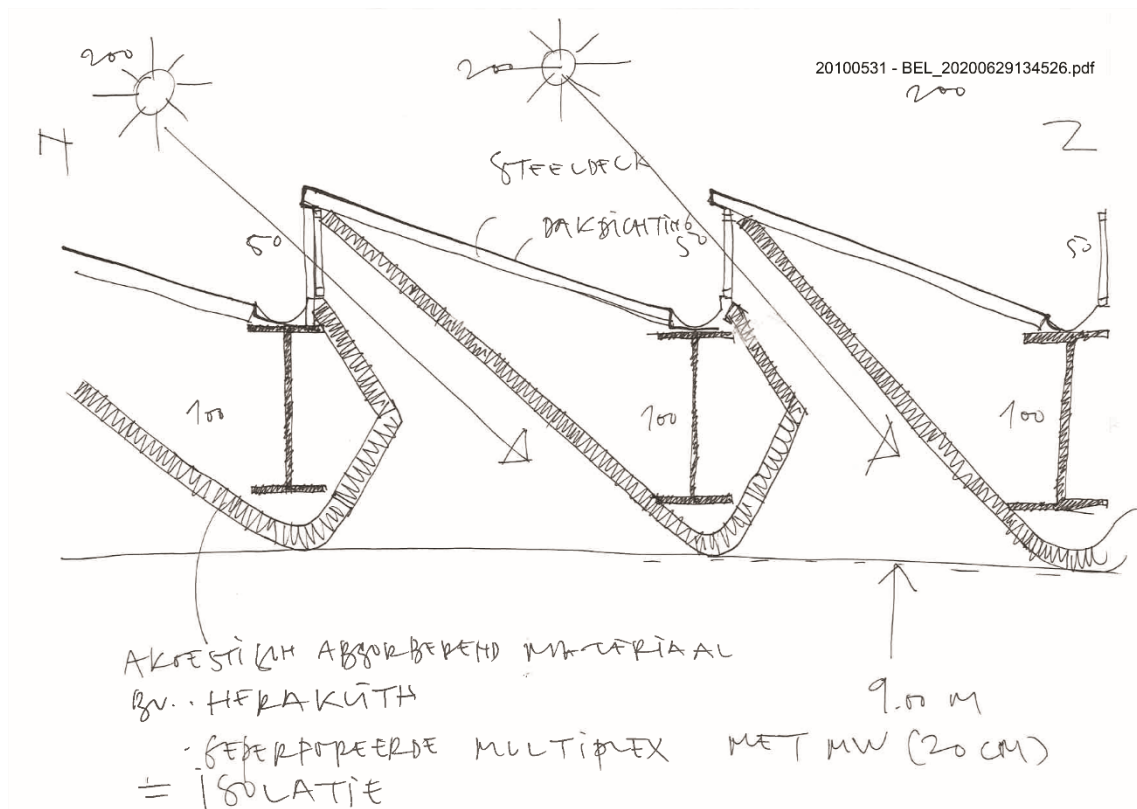


Figure 6 Design sketch in which access of natural light is integrated with the acoustic solutions, thermal insulation, the structure and other aspects of the design. - archive Bel Architects, between 21/05/2010 and 11/06/2010.

The idea to make a building with three prominent arches is validated in a meeting between the architects and the structural engineers, only eight days before the competition deadline. The idea has grown in a very short time in the architect's office, two days earlier they send a three page summary of six possible roof sheds, in which the arches cannot be seen yet. [11].

The arches strongly remind of the design for the museum of modern art in Warsaw¹ by Christian Kerez. Copies of pages on this project in an issue of El Croquis [13], as well as a page titled 'Kerez' with sketches

¹ The design was never executed, but has only been discarded in 2012, two years after this competition. [12]

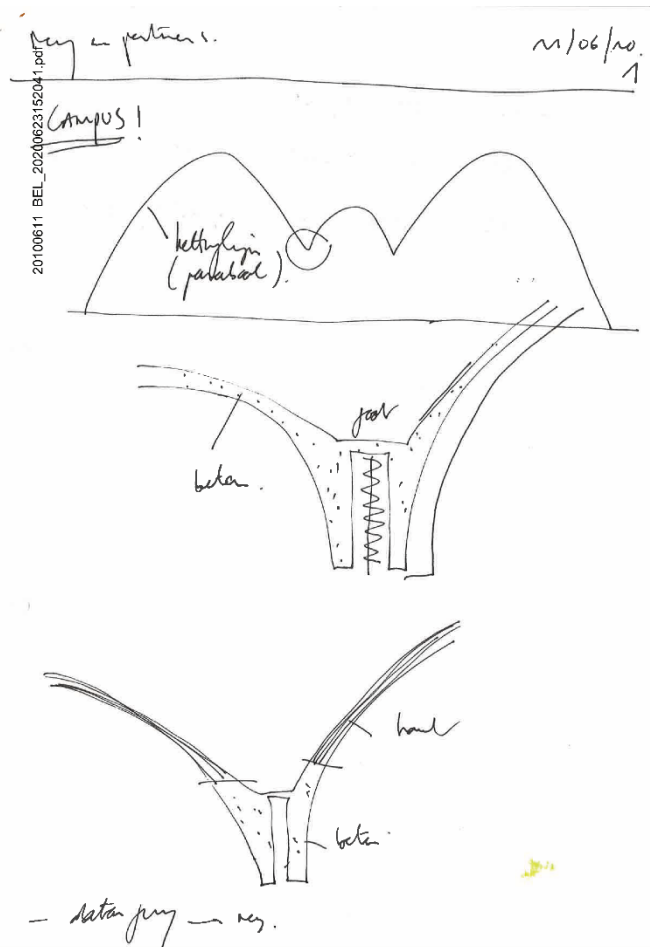


Figure 8 Meeting notes by Bel from a meeting with Ney & Partners - Archive Bel, 11/06/2010

The meeting notes (Figure 8) are concise, but do clearly summarize the design intentions. In the cross section on top, two key words are written; 'funicular line (parabola)'. Already at this meeting Ney & partners has mentioned their desiderata for the shape of the arches. The sketches below illustrate both the idea to integrate techniques, and the idea to make concrete longitudinal beams, on top of which the arches can for example be executed in wood. In first instance, a monolithic structure was not necessarily assumed.

After the meeting, a collaborator at Ney & Partners prepares a drawing in which 'the optimised shape for the arch' is indicated in red [14]. (Figure 9, top section). In an internal message is noted that a thickness of 20 cm is assumed, which 'looks slender but should be possible' and that it probably is best to use the same shape for the three arches to cope with the thrust. This first message is integrally forwarded to the architect by Ney's project engineer, reaffirming the statements the colleague made by adding that it is theoretical, but correct. 'In attachment as well 'the ideal shape' in red. With ideal only pressure forces is meant.' [15] In this way, the concept of 'the ideal shape is introduced.

The architects reply that the proposed shape looks good, and that they indeed should look for an ideal shape. [16] They however add several other constraints for the shape of the section (see Figure 1 Figure 9). They comment on the decreased width of the arch in the middle, which should stay related to the sports field below, and on the increased height, which makes it different from the height of Isgour's. They continue with 'the optimisation of the shell thickness'. The architects estimated the volume of concrete on 970m³ (for the cost estimation), which allows for a thickness of 12cm. They add that 'if the shell thickness would evolve to 15cm, this would be fine'.

Later the architects inform the collaborating acoustic and energetic engineers that they chose, together with Ney & Partners, for a shell structure.[17] They send three sections in attachment. (Figure 9 below) The black outline has both structurally and formally their preference, but multiplies the ideal volume – the rectangular one- by a factor of 1.4 à 1.6. It is interesting to note that in this drawing, the proposed line by Ney & Partners is not taken into account.

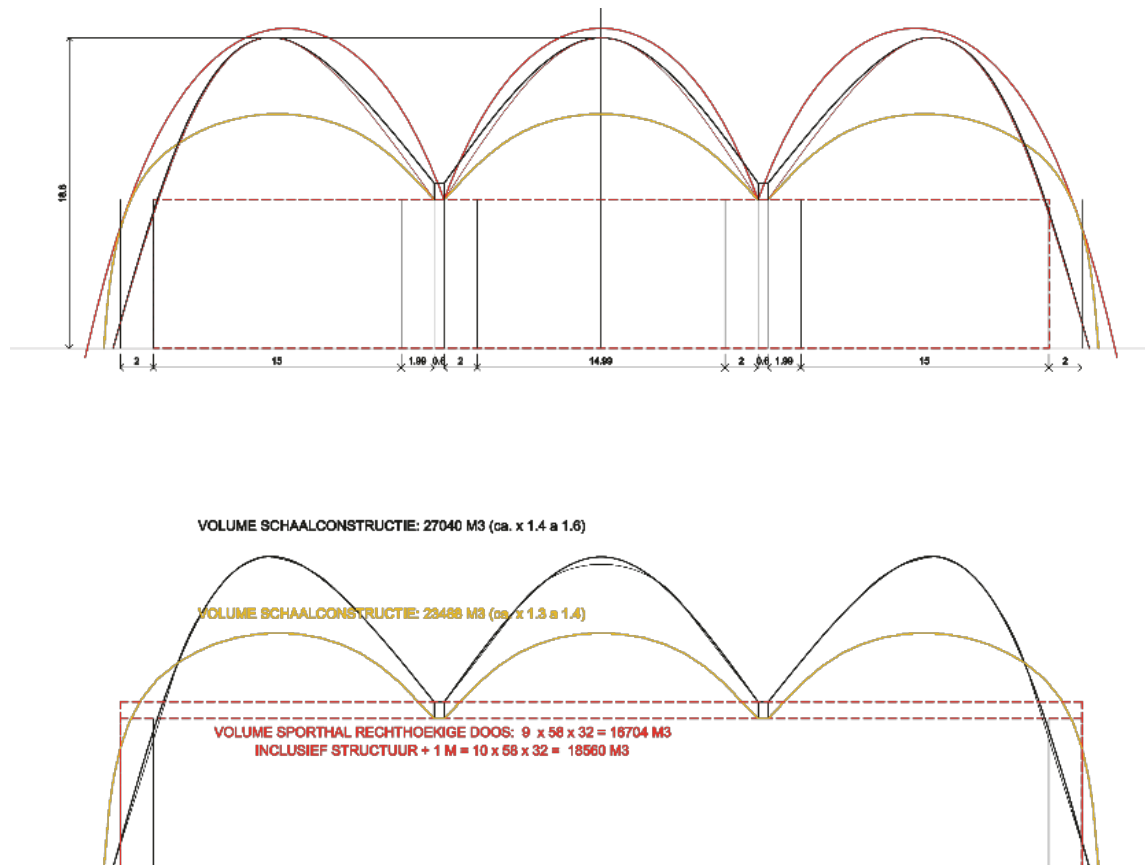


Figure 9 Top section: top red line indicates 'the optimized shape' for the arches, proposed by Ney & Partners. Section below: Three options for comparison proposed by Bel. - Archive Ney & Partners 11/06/2010

In this first phase, the design goals for the sports hall, a building that can relate to the existing building and the admission of natural daylight, concretised in a design with three prominent arches.

The aim to make the arches catenaries is a clear, formal design input from the engineers, motivated by their concept of an *ideal shape*. The architect and the engineer agree on the ideal shape as design objective, but have a nuanced different understanding of what an ideal shape entails. For the engineers this refers to the idea of the optimal use of material, an important concept in their practice, as is discussed in the introduction. The architects agree on the option with the highest arches (see Figure 9 below), but keep their own variant, which meets the boundary conditions they have set. This shape is close to the *optimal shape* Ney & Partners propose, but the deviation has a crucial impact on internal forces in the shells.

2.2 The most complete project. A tactical approach.

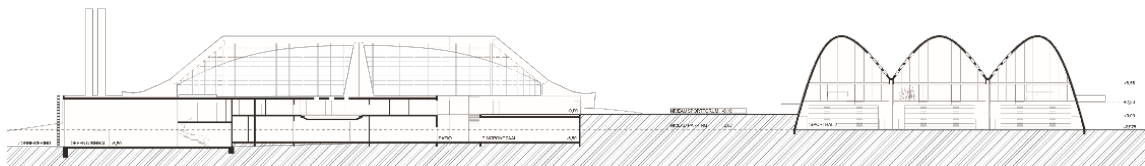


Figure 10 Section in competition bundle, presented in relation to the existing building

The competition bundle is finalized at the end of June 2010, counts 75 pages and is divided into six chapters. The first chapter elaborates on 'Masterplan sports village' and mainly argues for the proposal of a separate building. The second chapter is titled 'Phase 1: The ideal sports hall', followed by 'Phase two: renovation', which focuses on some interventions in the existing building. These are followed by chapters elaborating on cost estimation, cost management and a chapter on 'principles of sustainability'. [18]

The second chapter starts with a text on the new sports hall. This is surprisingly concrete. It for example states that the surface of the building will be 80,8m by 59,4m or that the colour of the sports floor will be

azure blue in rubber PU-finishing. A shell structure in concrete is proposed, which is further emphasized with specific full page illustrations (Figure 11).



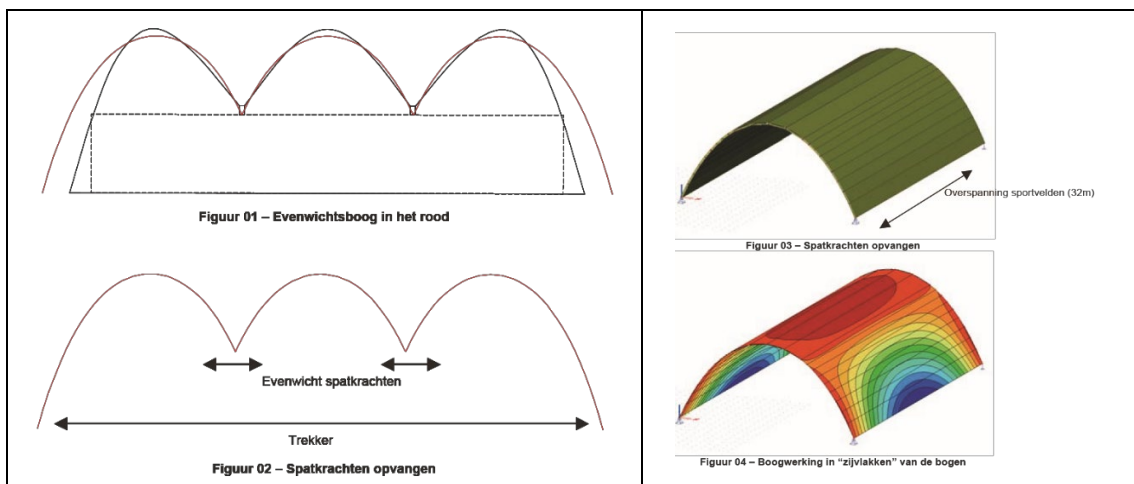
Figure 11 Full page illustrations in competition bundle. ‘White concrete’ on the left, ‘shell structure’ on the right. The subtext (left) is on the perforations in the roof

A significant part of this chapter is devoted to technical specifications. Three pages, provided by Ney & Partners [19], are specifically on the structure. Similar notes were included on acoustics³, HVAC-installation, lightning and fire prevention.

In the pages on the structure, the equilibrium shape, the structural principle of the arch ‘in three dimensions’, the execution methods and even foundations are discussed. In the first part: ‘For a given height and width, determined by the plan organization, architecture, access of natural light, acoustics etcetera, we looked for the most ideal arch shape. This ideal arch form is the equilibrium shape, in which the arch only works in compression.’ This is immediately nuanced: ‘Slight bending as a result of asymmetrical mobile loads, such as wind, snow and maintenance are unavoidable and relatively small. The search for this equilibrium shape is an iterative process because it depends on the thickness, which in turn depends on the shape...’ [18].

Further, the issue of thrust inherent to arches is described and the thickness is discussed. ‘At this stage, the goal is a shell with a constant thickness of 20 cm. At a later stage, this thickness will have to be optimized, taking design criteria such as buckling stability, reinforcement concentrations etcetera into account. This optimization process will in any case result in a shell of variable thickness.’

The following subchapter explains that the shells can not only be observed in section, since bending action in longitudinal direction as well occurs. In the chapter on execution, two possible execution methods are evaluated – cast-in-place or with prefabricated wide slab elements.



³ The part on acoustics states: ‘To achieve good room acoustics, we first look at the geometry of the hall. The volume does not have a standard beam shape, but is conceived as a curved shell structure. This limits the number of flat, even walls and thus the risk of bothersome echoes.’

Figure 12 Illustration in competition bundle in the chapter 'structure'. Left: illustrations on equilibrium shape. (internal discussion on shape can be seen here) Right: illustrations under 'arches in three dimensions'

Four illustrations (Figure 12) are included. The one left on top shows two arched lines. The black one corresponds with the outline drawn by the architects in the other documents. The red line is the 'equilibrium arch' as proposed by Ney & Partners. The picture thus shows explicitly that the exact section is not found yet, which is opposed to the reassured statements made in the text. The two coloured images illustrate that the shells as well have to span in longitudinal direction. The image below is a drawing generated in final element software. A trained eye understands how this depicts bending action, although the result probably shows vertical deformations in the shell⁴.

The team is the only one selected for the negotiation phase. A set of questions is formulated, mainly aiming for clarifications. The architects prepare an elaborate additional booklet in which each question is answered. [21] It starts by stating that the answers will only be final during the process and that their answers have to be understood as intentions and possibilities.

How money can be saved is included, since cost estimations exceeded the initial budget with 27% [18, 22]. A message by Ney & Partners, sent during the negotiation phase, informs that 'Laurent launched the idea to make the arches in masonry, *à la manière de* Eladio Dieste.' Although the project leader is sceptic, he mentions that according to Laurent Ney this should be cheaper.[23] Bel architects answer that they are great fans of Dieste's work. They add that in any case they should answer the questions of the negotiation phase with an overview of possibilities for the structure, to illustrate that a lot of research will be necessary and that a part of the solution for the budget *can* be found here [24]. The engineers propose to 'at least include something such as: concerning the shell construction far more research has to be done. A possible solution can be found in the execution with reinforced masonry (cf. Eladio Dieste). Possibly a lot can be saved there.' [25].

In the booklet this question is answered by suggesting possible savings can be made in the roof structure by optimizing the amount of material and/or the execution method. 'Margin in thickness of the concrete shell: max 20cm, min 14cm. (...) The exact amount is difficult to determine without offers from contractors.' [21] On the optimization of execution method is noted that more research is necessary, but that options are legio: cast-in-place concrete shells, concrete shells with concrete prefabricated elements, a concrete structure with infill masonry, a steel structure with a hybrid steel plate concrete floor system, wood,... [21]

The answers are sufficient. The team is granted the project. The final report of selection concludes: '(The proposal) is the most complete project and makes a daring conclusion by building it in another place. It is in line with the initial campus model by Isgour. (...) The collaboration of a driven architect and a good engineer makes the project exceptional, in the same way exactly this combination made the existing complex extraordinary.' [20]

One can ask her-/himself why in a competition proposal so much energy is spent on the technical aspects of the proposal. For professionals in the specific domains, it is obvious how general these descriptions often are. The archives as well prove that it is impossible for the team to already have made such thorough studies on the design.

The approach however proved to be very effective. The proposal did not only convince with the idea to make a separate building, it is as well praised as the most complete project in the jury report. This is why the input of the engineers in a competition proposal, should as well be read in the light of the rhetoric used to try to win a competition. A proposal that looks well studied and detailed is convincing and reassuring

⁴ One question during the jury is on the structural aspects, which seems to indicate that the coloured scheme (Figure 12) was indeed misunderstood: 'The diagram showing the arc action in the "side planes" of the arches shows that the forces transmitted are minimal in the centre of these "side planes". Does this allow to save material here, so that the arch transfers its forces at four points?'

The written answer in the jury report ([20]) is vague: 'You will always need the tirant between the arcs. In other words: the beam will always be there. The hollow beam in which the partition wall hangs actually acts as a tirant. This construction works in the three directions. (note: in the competition design partition walls to subdivide the sports halls were proposed. The rails were integrated in the longitudinal beams in between the arches).

for a client. It is interesting to note that the team stands united in this tactical approach⁵. As shown, the engineers as well make specific statements on the used material, the execution methods etcetera.

Whereas the team wants to keep the structural principle and material open for research, the proposal clearly aims for a shell structure, made in concrete.

It is agreed that is safe to recalibrate these statements during the negotiation phase by remarking that it would be good to list several possibilities for the structure. They however as well bluff on the possible savings in the budget, as can be understood from the archive and mail conversation, no thorough study has been (or could be) done (in this phase) to evaluate the cost. It has to be noted that already here is mentioned that a contractor should be contacted to get a specific price estimation.

2.3 *The design choice to keep options open*

How the design developed after the competition till tender is generally illustrated in section 2.3 of [7]. The general evolution thus will only be sketched very shortly again in this text.

In February of 2011 the engineers publish a first version of study report 1 [26]. Its purpose is to set the different design parameters for the shell structure. The report is largely explanatory on structural principles and consequences. It has three chapters: shape, material and execution method. Most attention is given to the study of the shape of the section.

Again is defined what an ideal shape means for the engineers. ‘This is *the equilibrium shape*, in which no moments will occur. It minimizes the use of material. (...) This form is confirmed by the results from the calculation model.’ Six coloured diagrams are included to illustrate.⁶ (Figure 13)

⁵ Another example of this tactical approach is in the use of references: The competition bundle shows one reference: the Fronton Recoletos in Madrid by Zuazo Egaldo and Eduardo Torroja. [18] This is remarkable, since they were well aware of the design of Christian Kerez. In the interview with Bel Architects [4] the architects are complimented with the fact that they share their sources of inspiration, specifically referring to the Fronton Recoletos in this competition bundle. The architects answer that they never show all their references, because it would be contra-productive to put all your cards on the table. They add that this reference was chosen to show that in ‘those years’ not only beautiful shells were made, but as well that it is possible to get beautiful natural light inside with them, which is very convincing. This at least illustrates the architects to be well aware of what to say, and what not to say during the competition phase.

⁶ From left to right and from top to bottom, results are shown for: normal forces in the direction of the curvature and in longitudinal direction, moments in longitudinal direction, moments in the direction of the curvature, torsional moments and deformations in vertical direction. In none of these diagrams the boundary conditions are identifiable, nor is it clear what loads are used.

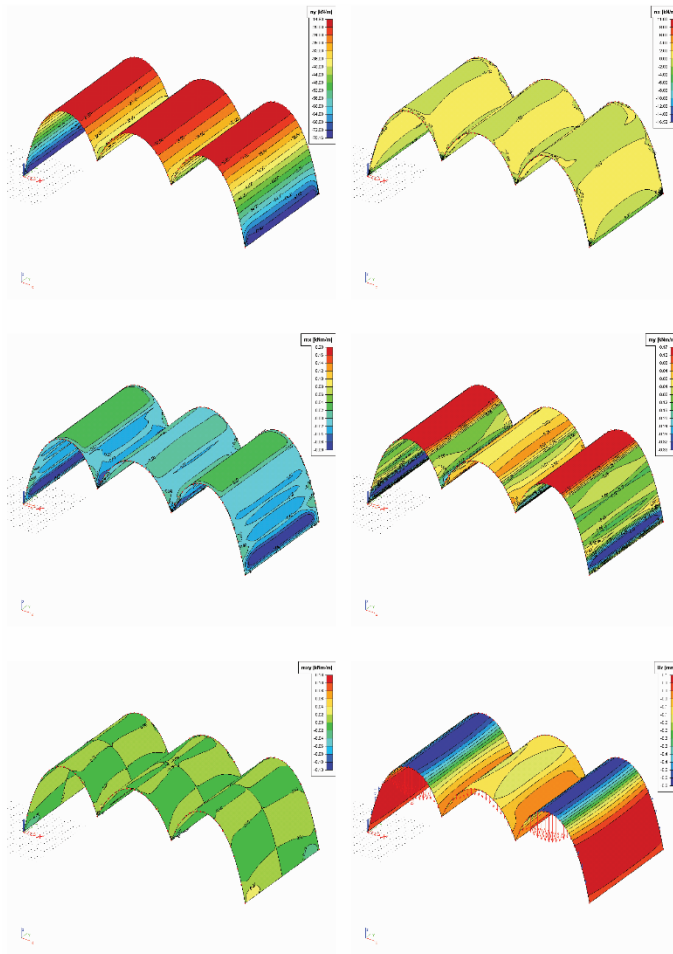


Figure 13 Comparison in final element method of the moments produced in the arches, in the direction of the arch section. – study report 1 by Ney & Partners, 29/03/2011

Apart from the first and the last, the values on the scales indicate that the internal forces are negligible, so indeed no moments occur. These diagrams indeed prove the statements made. No result however resembles the image shown in the competition bundle (Figure 12). To get results like the ones shown here, the valleys in the middle have to be linearly supported. This cancels the beam action in longitudinal direction. The calculation model is a large simplification of the actual structural behaviour of the design. As was discussed in the competition design, the longitudinal direction is structurally very important. When this action is taken into account, the statement that *no* moments occur in the shell is inaccurate.

This however does not change the fact that indeed less moments will occur, than when the shape of the arches would be random. This is illustrated in Figure 14. **Fout! Verwijzingsbron niet gevonden..** In the left image, the arches are separately supported with line supports. This result matches the result shown in the study report. In the middle and left image, only the corners of the intermediate valleys are supported. The arches in the middle have the optimal section Ney & Partners is looking for. On the right, the exact same calculation is made for the section shape as drawn in the competitions bundle. (Figure 10, Figure 9 below). It is clear that the moments in the shells in this direction are indeed optimized with an equilibrium shape.

The engineers isolate a certain structural principle that is on the table for discussion and advocate for their preferences, making use of simplified calculation models.

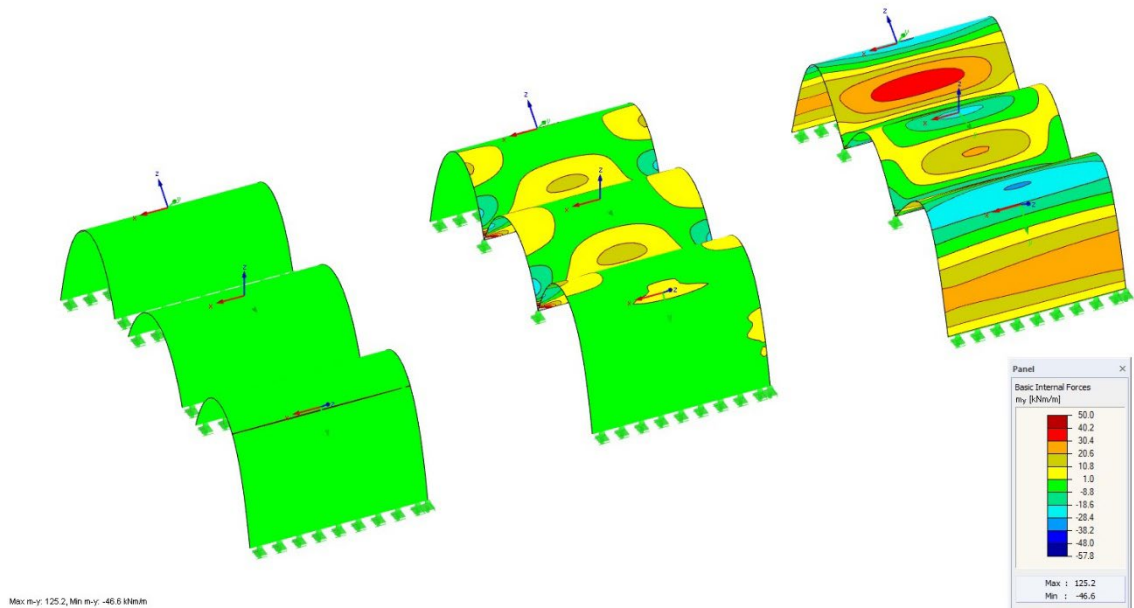


Figure 14 Comparison in final element method of the moments produced in the arches, in the direction of the arch section. Image generated by the author of this article.

Left image: arches are separately supported with line supports. This result matches the result shown in the study report. Middle and right image: only the corners of the intermediate valleys are supported, which is closer to reality. Middle: optimal section Ney & Partners is looking for. Right: same calculation for the section shape as drawn by the architect in the competition booklet. Moments do occur in the ‘optimized’ section (middle), but far less than in the ‘free form’ section (right)

In the estimation for the proposed thickness of the shell, it becomes clear that the option in masonry was still taken into account. The report elaborates on the equilibrium shape being influenced by variable loads. It is proposed to look for the equilibrium shape under permanent loading. An idea to cope with this, is to look for a thickness that circumscribes the envelope of all equilibrium shapes, which results in a minimal thickness of 25cm for the central arch. It is noted that for an execution in concrete, this thickness is not necessary, since bending moments can easily be taken as well. To equilibrate the thrust of the intermediate shell, it is estimated that the outer bows need a thickness of 32cm⁷. Note that the thickness of 25cm has a purely geometric motivation, and is not informed by material tensions or (buckling)stability. It as well originates from the logic of masonry, since this is the only material that has limited capacity to cope with bending moments.

In the chapter on execution methods, a table with eight options is added in the second version of the report [27]. The options all have a specific construction type (shell, vault, skeleton) – see Figure 15 - and material (concrete, masonry, steel).

⁷ ‘The concatenation of different bows, with similar spans and supports on different heights, results in variable thrusts. This imbalance will have to be compensated in the intermediate supports, or transferred by the outer shells to the outer supports. Another idea is to increase the load on the outer bows. Because of this, their thrust increases, until they compensate the intermediate thrust.’ ([26]) The thickness of 32cm for the outer aches linearly follows from the ratio of thrusts of the different arches and the proposed thickness of 25cm to meet the equilibrium shape for all load combinations in the inner arch.

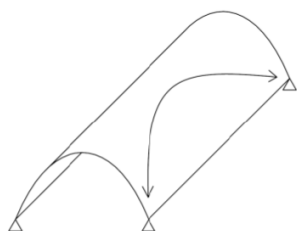


Fig.: optie 1 (schaal)

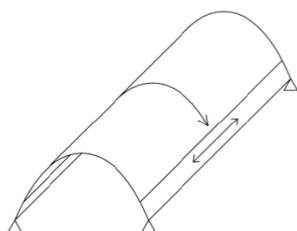


Fig.: optie 2 (gewelf)

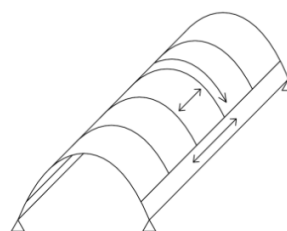


Fig.: optie 3 (skelet)

Figure 15 Three principles for the construction types in longitudinal direction. 'option 1 (shell), option 2 (vault), option 3 (skeleton) – study report 1 by Ney & Partners, 29/03/2011

optie A	- schaal - beton			
optie B	- schaal - beton			
optie C	- gewelf - beton			
optie D	- gewelf - beton			
optie E	- skelet - beton			
optie F	- gewelf - metselwerk			
optie G	- skelet - staal			
optie H	- skelet - staal			

Fig.: Overzichtstabel mogelijke uitvoeringswijzen (principeperspectief, dwarsnede, langssnede)

Figure 16 Overview of possible construction methods – study report 1 by Ney & Partners, 29/03/2011

All options are discussed and a comparison in cost/ square meter is given. Option A is set as the 'reference option'. Options B, C, E, G and H are estimated to result in savings of up to 20%. Options G and H are possible executions in steel. These are estimated to be 10% cheaper than the shells in concrete (option A).

An 'important remark' is added: 'The comparison has to be understood in the preliminary phase the project is in. Besides, several other related cost like the weight of foundations is not included. Again is noted that the best way to compare prices properly, is to ask contractors to make an offer. Though for this, the design studies of the team are not elaborate enough yet.'

It is concluded that from a structural point of view, option 'C'(concrete with large prefabricated elements) is preferred. The option is the most economic, leaves different execution options open, appearance is controllable and execution time can be kept short. The solutions in steel (options G, H) are mentioned as well as valuable and 'to be researched', since they give the same advantages, though for a slightly higher price. These options however are not scrutinized further in detail at this stage of the design.

This first study report is concluded with: 'In addition to the structural requirements, architectural, acoustic and economic factors play a role in the choice of the desired solution. The 'optimum' shape is the one that can combine all these requirements.' [26]

Although this study report discusses several technical aspects, it is more an extension of the competition bundle, in the sense that crucial aspects, the construction method and the related material, are still very open. The choice to focus on the optimal cross section, which allows to keep all options open, determines the course and the outcome of the design. Structurally, the 'ideal shape' is only crucial in the case of masonry or smaller prefabricated concrete elements, in which connections should be preserved from (too large) bending moments. Based on the observations made in the report, it could have equally been concluded that a solution in steel or concrete would allow for a wider variety of cross sections, such as the one proposed in the competition. Steel and concrete can easily cope with bending moments.

2.4 Catenary trump

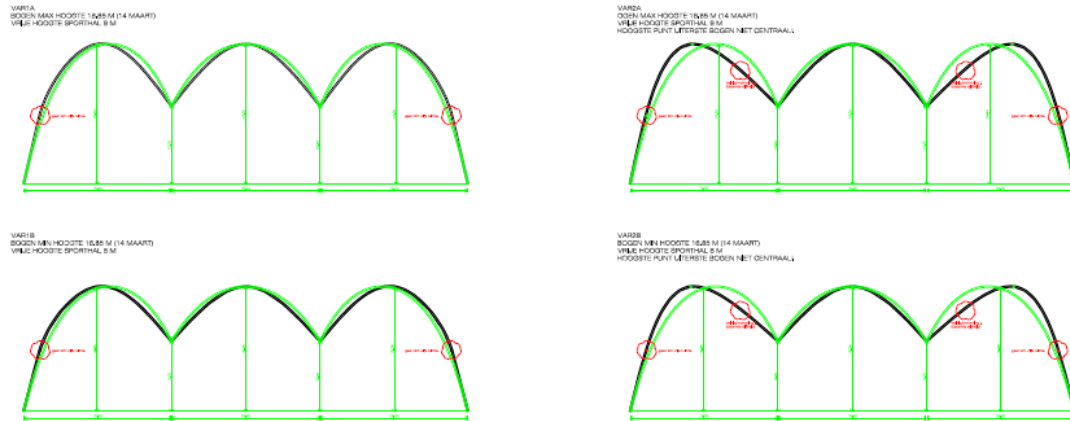
In the months following, the search for the ideal cross section is a main focus for both the architect and the engineer. The archive contains a large amount of sketches, copies and communication on the arch shapes, all with small, nuanced differences. (Figure 17, Figure 19). The architects try to find shapes that (in their perception) are close to the catenaries proposed by Ney & Partners, and the engineers make calculations to estimate the consequences of the deviations proposed by the architects. (Figure 18)

This discussion on the margin to deviate from the ideal shape as proposed by Ney, culminates around the half of June, the moment on which a second study report to accompany the end of the preliminary design phase is prepared.

'As Laurent stresses, the shape of the cross section is *not free to choose* in the case of a shell construction (an optimal shape in which materials work optimally.) (...) We therefore recommend choosing a shape as close as possible to the optimal shape.' [28] The engineers add three options (Figure 20), of which only the third one is valid for the architects. They have several remarks and propose to fix 5 points for the outline should meet [29]. These fixed points indicate: The width of the building (this point must not move too much outward, since it enlarges the footprint and thus the cost), the width at gallery level (at this point, the idea is still to make a passerelle at the edge of the building), the free height of 9m (a free height of 9m was prescribed for the sports fields. In previous proposals often a small kink is introduced, which enlarges internal moments in the wall significantly⁸). Two other fixed points are the height of the ridge (which should correspond to the height of Isgour's building) and the height of the longitudinal beams in the armpits of the arches.

The engineers answer with a 'family of catenaries' (Figure 21). These take the free height of 9 metres into account, since this seems the most stringent condition to them [29]. To find a common ground, at last the boundary conditions are re-evaluated. Two days later, the client approves a small reduction of the free height on the sports fields. (Figure 22) [30]. The final shape is agreed upon with a very small adjustment by Ney & partners, to allow for a certain width of the longitudinal beams in the middle [31].

⁸. see also no.11 in fig 2. of [7]



MOGELIJK PARABOLISCHE
VORM TE BENADEREN

MOOISTE VARIANT (BOGEN ELEGANTER)
GEEN PARABOOL: METSELWERK ONMOGELIJK?

Figure 17 Reaction by Ney & Partners on the proposed shapes of the architect. Attachment in mail 14/03/2011 [32]

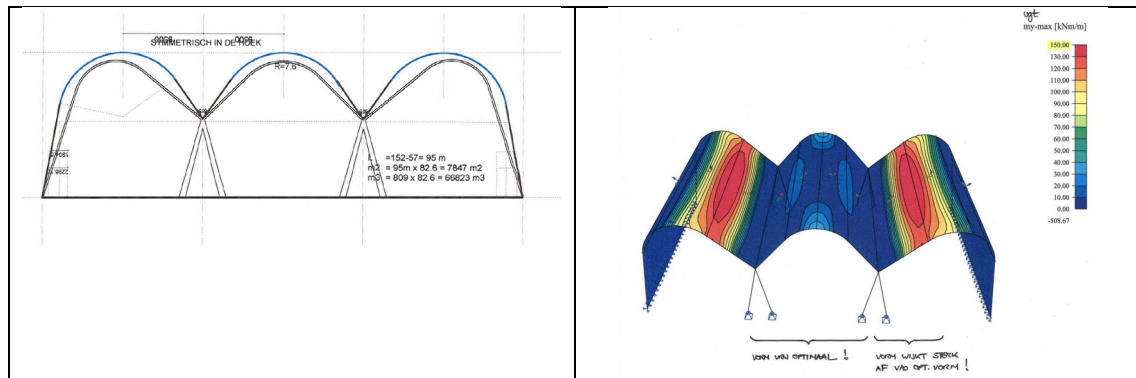


Figure 18 Studies on the shapes of the arches as proposed by Bel architects - Ney & Partners, 6/06/2011

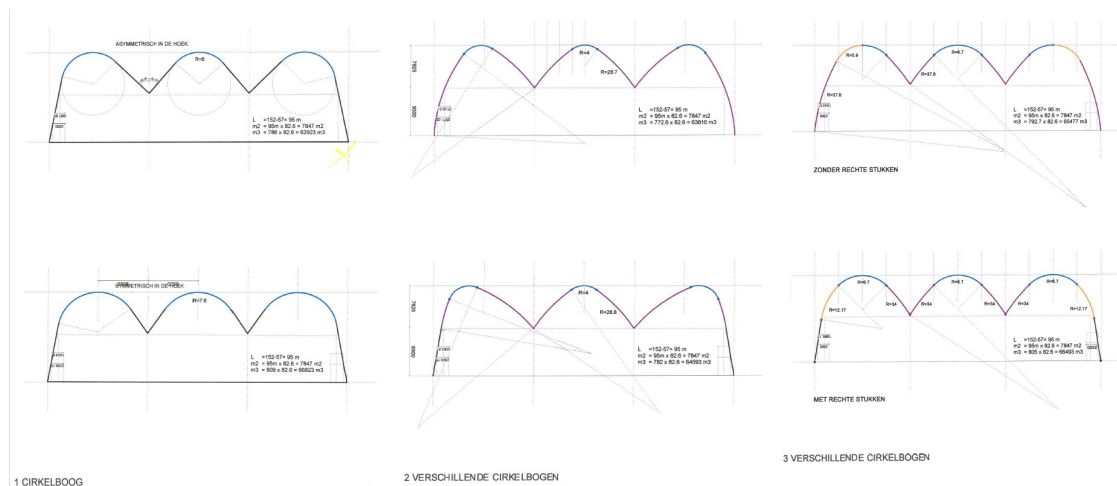
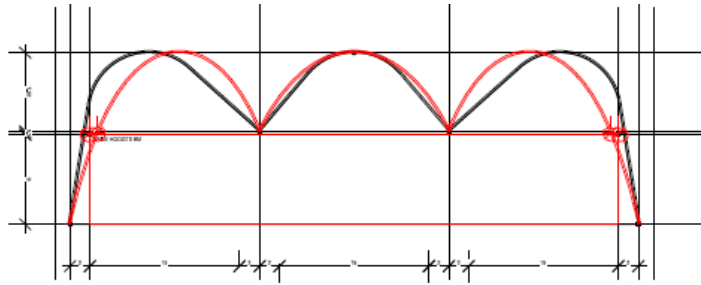
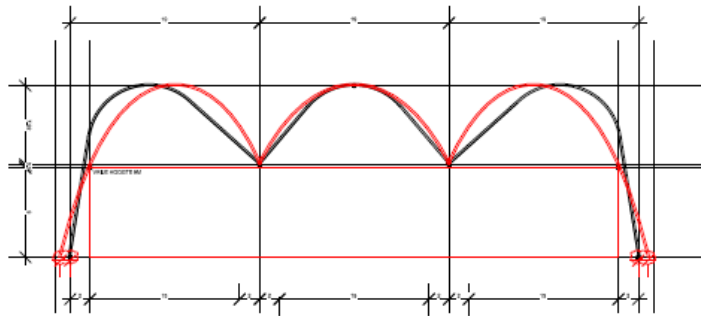


Figure 19 Different arch shapes composed out of circular arcs - Bel architects, June 2011

- VARIANT 1
- + evenwichtsvorm
 - drie gelijke overspanningen
 - vrije hoogte op de randen < 9m



- VARIANT 2
- + evenwichtsvorm
 - vrije hoogte overal gerespecteerd
 - grotere grondoppervlakte



- VARIANT 3
- + evenwichtsvorm
 - drie gelijke overspanningen
 - vrije hoogte overal gerespecteerd
 - knik elst extra maatregelen:
 - ofwel een horizontale rib
 - ofwel trekkers net boven vrije hoogte
 - ofwel verticale verstijvers op schuine wand

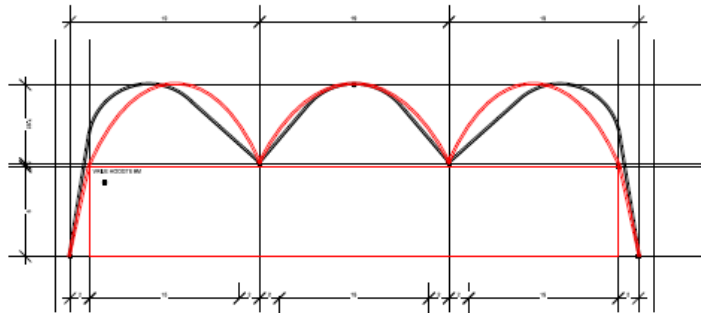


Figure 20 Three options – Ney & Partners, attachment in mail 13/06/2011

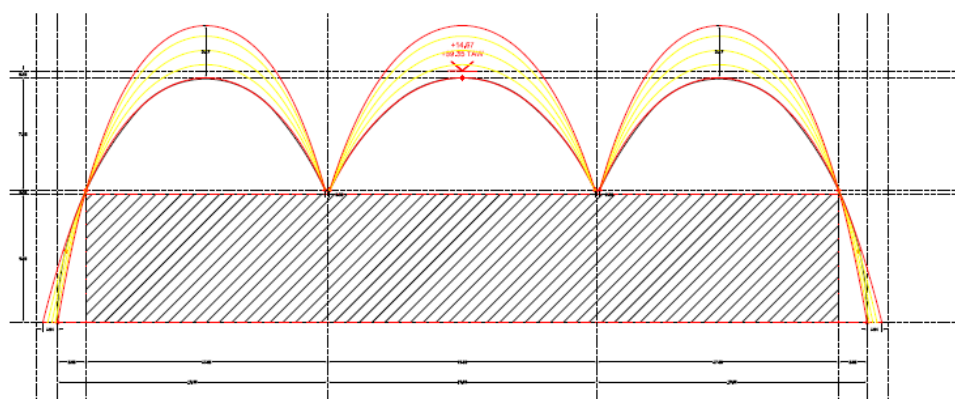


Figure 21 Family of catenaries – Nev & Partners, 20/06/2011

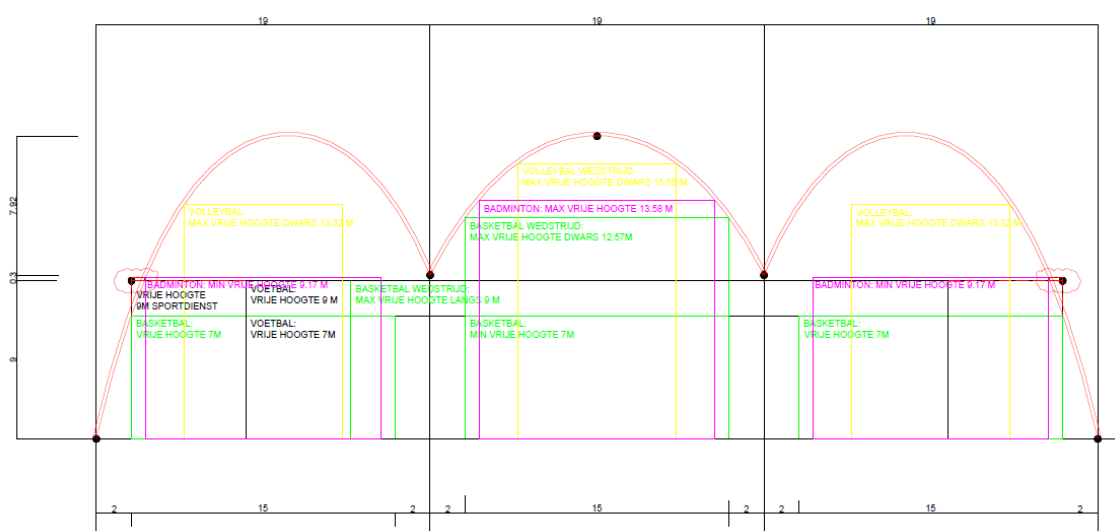


Figure 22 Final cross section, with rigid points to take in account. – Ney & Partners, 22/06/2011

The shape for the cross section is settled, and with this an important step seems to have been taken in the design process. The shape meets both the requirements of the architect, thus one that fulfills all the boundary conditions, and of the engineers, that looked for a shape that allows for an optimal use of material. This discussion has so far been a purely theoretical one, since no concrete material has been coupled to the execution yet. For the architects the ideal shape rather is one that fits all the boundary conditions. These boundary conditions can be pragmatic, such as the maximal surface of the building to limit the cost. Even so they can be the result of a chosen design priority, such as the reference they want to make to the existing building in the restriction of the height. For the engineers the ideal shape is strongly related to the ‘optimal’ use of the material. This is not a purely pragmatic objective. Calculation methods do allow to accurately estimate internal forces in all shapes one can think of.

2.5 Integrated design & reality check. Shifts in design rationale.

So far the evolution of the shape of the cross sections has been discussed elaborately, but this is of course only one concern in the design for the roof (as is the roof only a part of the design story for the whole building.) In the meantime several other aspects are tackled, such as the study of how to allow daylight to enter into the building or the possibilities to cope with the thrust. (Figure 23⁹).

⁹ This is an alternative to what was proposed in the first study report. See footnote **Fout! Bladwijzer niet gedefinieerd..**

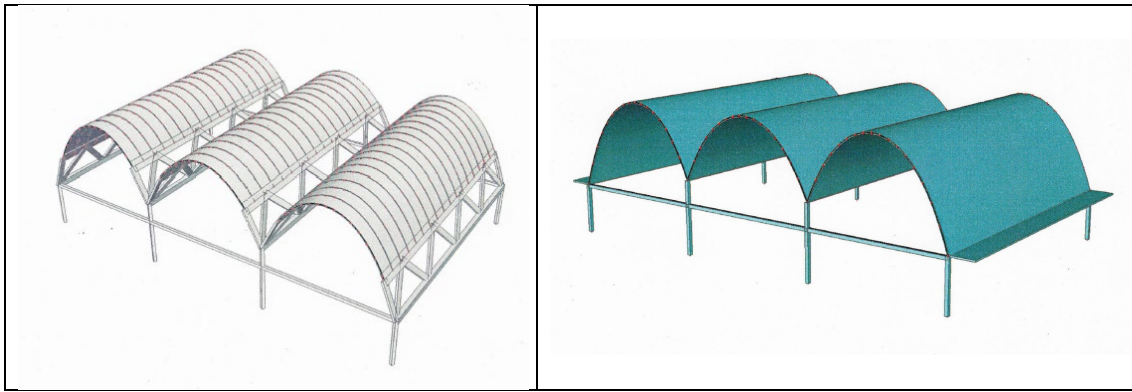


Figure 23 Left: structural solution to allow daylight to enter in the valleys of the arches. - Ney & Partners, 21/04/2011. Right: structural solution to cope with thrust by integrating horizontal beams or canopies at the rear of the building. - Ney & Partners, 31/03/2011

In the scope of this article, three occasions are highlighted to sketch the further evolutions. The first one is the price estimation that was finally received from the contractor, who was consulted weeks before by Ney & Partners. The answer comes right before the deadline of the preliminary design phase, around the same moment as the final decision for the shape of the cross section.

In a first reply to the engineers, the contractor asked ‘why concrete, and not a solution in steel? Will the design stay in concrete or can we switch to steel? An execution with prefabricated elements will practically very difficult.’ [33] The engineers answer: ‘Concrete is a logical choice if the shape is as close as possible to the optimal shape since the concrete then works optimally, and the shell can be kept fairly thin. In addition, there is a preference for concrete from an energetic point of view (thermal mass) and an acoustic point of view. Therefore, the shell will remain in concrete in the first place. However, if you expect that it can be cheaper in steel, we will have to reconsider that option.’ [34]

The contractor’s final response for a cast-in-place concrete shell results in a cost estimation 20% higher than what was estimated before. The engineers immediately communicate this to the architects, stating that if this exceeding of the budget is not feasible, the concept of the shell might have to be completely reconsidered, for example by looking for a solution in steel. [35]

The architects reply that (another) budget increase is not possible and argue for this in 6 bullet points. [36]. They state that there already has been too much discussion on the budget and that this conclusion based on one price estimation might be premature. They as well refer to the first study report, in which a prefabricated option would be 20% cheaper and add that the client will ask on what estimations these prices were based. The fifth point states that ‘the question of how these shells can be made out of concrete, within the budget, might be a question that asks for more research by the engineers’. Several references¹⁰ are added to advocate for the feasibility of shells in concrete in Belgium. At last they come back to the proposed larger thickness of the outer shells to cope with the trust, asking of this for sure is the most logical solution. (see footnote **Fout! Bladwijzer niet gedefinieerd.**).

A few hours later the engineers reply by stressing again that it is very hard to make a price estimation for this project due to its specificity, and that the price of the shell will stay a point of discussion until the day the prices of the public tender are received. [37] They add that when they analyse the proposed price further in detail, they assume some posts might be cheaper, which results in a price estimation similar to their current one. They propose not to communicate the contractor’s answer to the client and to organize a meeting the next week, where Laurent Ney as well would participate. The agenda for this meeting is the assessment of a cast-in-place and a prefabricated solution in concrete, of which the last option is chosen.

Several observations can be made. This mail conversation is a clear point of conflict. In this phase the architect has taken the lead, clearly showing their dissatisfaction. They firmly state that a raise in budget cannot be asked of the client. In their arguments references are used of existing roofs with arches, pointing that something similar should be possible to design. These structures however date from another era or have a completely different structural system. They urge the engineers to put more ‘design’ effort in the project

¹⁰ Hangars in Antwerp by André paduart, for which especially a reusable formwork system would have been developed. A hall in the city of Mons (BE), fully prefabricated by René Greisch. And the Nekkerhall in Mechelen (BE). Both are fully prefabricated, and rood the hall with one arch, not a concatenation of arches.

to find a solution in concrete and repeat the cost estimation made in the first study report. The reservations made by the engineers at that point do not seem to be taken into account.

The engineers react defensive but understanding, stating that this cost estimation might be tweaked and by organizing a team meeting, with the presence of Laurent Ney. Another noticeable aspect is that the execution in concrete seems to have become a basic assumption. This can be seen in the assessment that is made in the meeting between a cast-in place concrete shell or a prefabricated concrete shell, in the set of references the architects use to advocate for the feasibility of concrete shells and in the urge of the engineers to the contractor to prepare a price for a solution in concrete. The arguments of the engineers - advantages for acoustics and fire protection - are valid but equally easily argued against¹¹.

The second occasion is one of the responses of the client to the presentation that was given to conclude the preliminary design phase. The front image shows a model on which several ribs are added on the shells, indicating lamellas in acoustic material¹². (Figure 24)

The formal reaction of the client indicates that the proposed solution has a radical impact on the spatial perception. The client regrets that the calm simplicity of the shells as proposed in the competition phase, in which various issues were solved simultaneously (stability, light, acoustics etc.), is lost and asks to look for another solution to solve the acoustics of the sports hall.[38]



Figure 24 Front image of bundle to present the preliminary design phase. - Bel Architects, 5/07/2021

¹¹ A sports hall is not a club in the midst of a living area, the mass of the concrete facilitates noise not to be transferred to the outside, but has few advantage for the internal acoustic quality. Fire protection of steel is more labour-intensive than for concrete, but is standard practice.

¹² In the previous paper on this case-study was indicated that the purpose of these ribs was unclear. Further research however brought clarification.

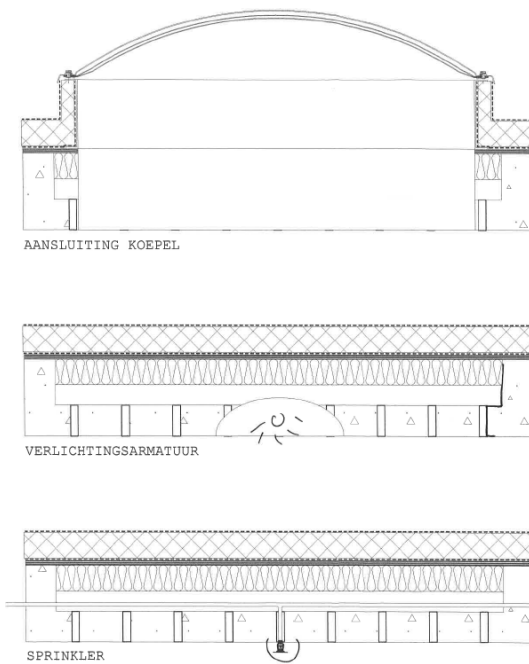


Figure 25 Proposal for prefabricated elements in which techniques, acoustics and ridges for stiffness are integrated – Bel Architects, 8/8/2011.

These two occasions both result in the team looking for prefabricated elements in which indeed lighting, thermal insulation and acoustics are integrated. (Figure 25) Acoustics had not been a priority in the design process before, probably because the preliminary studies in the competition phase stated that the shape of the hall did not have to be disadvantageous for the space acoustics.¹³[39]

This leads to the third occasion. On the 22nd of August Ney & Partners start scrutinizing perforations to enable acoustic material to be placed behind the structure. The ratio of the openings should be between 50% and 70%. They realize that this implies very large openings. This large that it implies a truss system rather than a shell structure.[40] (Figure 26)

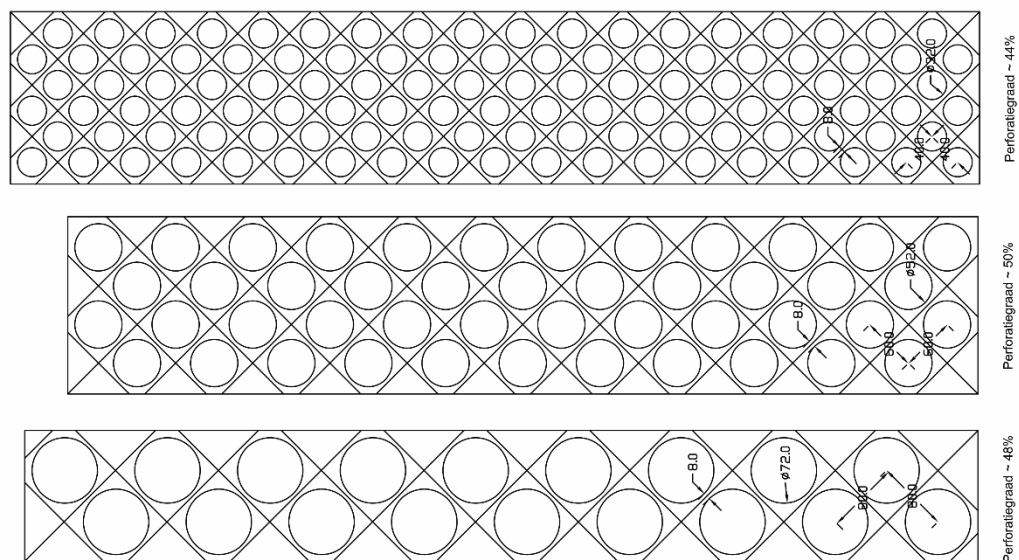


Figure 26 Surface of openings between 50% and 70% of the surface. Ney & Partners – 22/08/2011

¹³ See footnote 3.

2.6 The ideal shape: a three hinged arch and a steel truss system

The engineers start looking for perforated prefabricated elements, in which at first the material nor the cross section is questioned again. Such tests are shown in Figure 27.

On the 19th of September, Laurent Ney has a phone call with Bel Architects, as can be seen on the notes in the archive of the latter. The note 'steel = realistic' is framed. This leads to the final mail discussion that will be highlighted in this article. The architects send a long e-mail after their 'short conversation' with Laurent Ney. [41]

They do understand that steel can be a beautiful solution, if the resulting impression is related to the one proposed in the competition. A long list of elaborate questions follows, ranging from the exact amount of savings this steel structure will entail ('up until now it has always been said that a steel structure would be the most economical. We are thus interested in the exact margin on the budget'), how flashover for fire safety will be solved, what build-up will be proposed for the roof structure etcetera. The engineer reacts rather reserved, answering to several questions by questioning what is expected of the structural engineers or by stating that these questions are not for them to be solved.¹⁴ [42]

Following these answers, the architects conclude that it will be better 'to continue the path they have been taking since the competition. A building with a shell structure in concrete: cast-in-place or prefabricated. Based on the vagueness of your answers, it seems impossible to justify this proposal to the client. To us, it seems the task of the engineer to make a feasible proposition that matches the image proposed in the competition, within the cost estimation proposed by you'. [43].

Laurent Ney replies internally to his colleagues, with the question to verify: 'I thought I was clear before. A solution in concrete with the acoustic requirements as they are now is, in my opinion, just nonsense. (...) The architectural quality of your design is in the SPACE. I think it is a pity to endanger the design with such an inefficient choice of material. I thus formally advise against continuing the design with a concrete solution. The risk in terms of budget is too large. Thank you to take this remark in account.' [44]

It is not clear whether this message was actually sent. The next day during a meeting the structure in steel is validated.

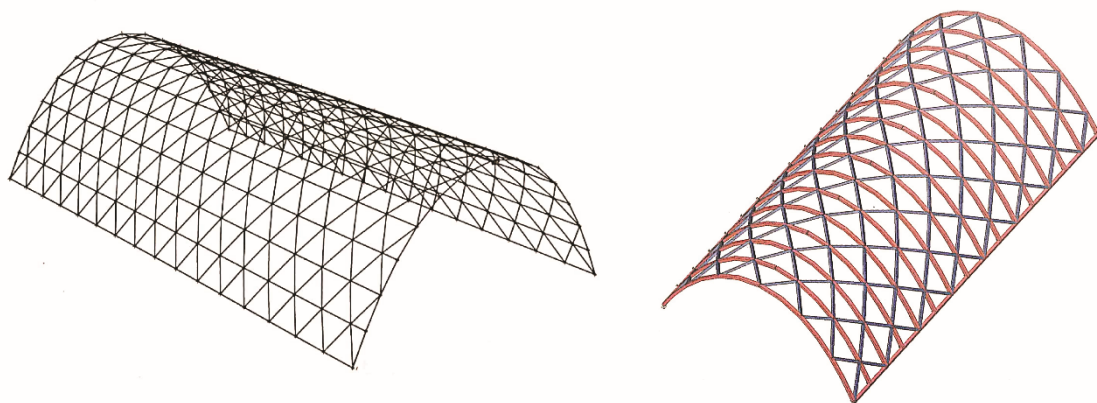


Figure 27 Stages in the development of the (concrete) truss system. Left: triangular net with horizontal lines (24/08/2011, Ney & Partners). Right: triangular net with verticals. (09/09/2011, Ney & Partners)

The decision to change the structural system initiates a last recalibration in the definition of what the ideal shape means. The clarity and simplicity of the final structure in longitudinal direction only gradually grew into the design of the steel structure.

The idea to make consecutive vertical three hinged arches emerged around the time of the shift in structural system. (Figure 28) A three hinged arch has two advantages: 'All of its forces and stresses can be completely and precisely determined by hand calculation methods.(...) Another advantage is that they are more forgiving in the sense that, for example, the vertical settlement of one support will not occasion supplemental

¹⁴ The staunch attitude of the engineers might as well be informed by the price estimation they received from a contractor specialized in prefabricated concrete. Of several options, only the most basic one would be feasible within the current budget. This answer arrived in the architects mailbox between Laurent's phone call and the architects list of questions. They however forward it to the engineers, just asking them to check how the estimation relates to the budget for the roof structure. ([41])

stresses in the arch segments.’[45] This again fits the goal of the engineers to make optimal use of material. It is not necessary to make these three hinge arches today, as mainstream advanced calculation methods can cope with highly indeterminate systems and the ratio of the height over the span of the truss results in a very rigid system¹⁵.

In the final structure 4 steel trusses are integrated in the valleys of the arches. The length of the building is divided in three parts: two trusses span 32,5 meters, with a smaller one that spans of 17,5 metres in between. The diagonal ends of the trusses are less optimal from a structural perspective. The structure made place for technical shafts integrated in the columns. Due to the very low self-weight of such a system, thrust is of a less decisive order than in case of concrete. The trusses are as well are oriented in the extension of the arches, which is why they can help deviate the thrust to the supports.

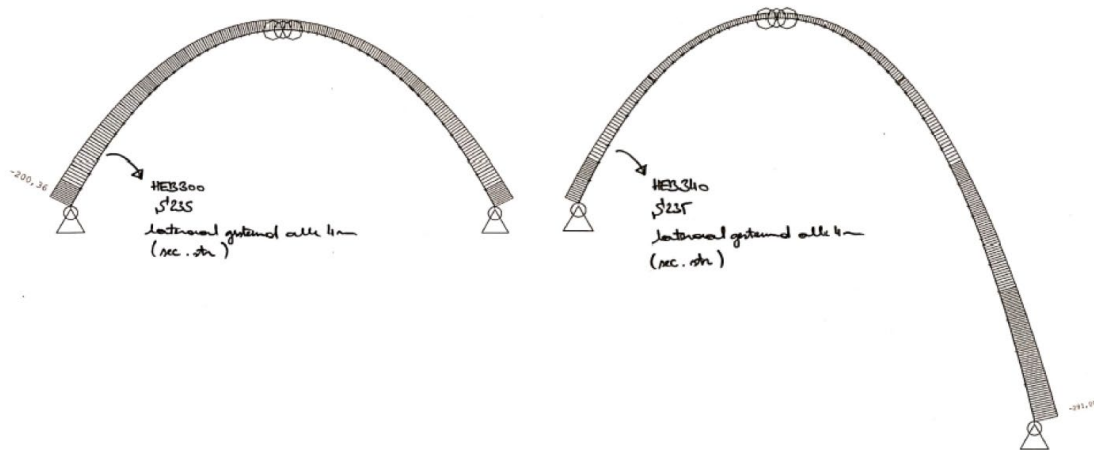


Figure 28 First calculations for three hinged arches - Ney & partners – 19/09/2011.

In the early design phases, the height of the arches, the concrete as material and the shell as a structural system seemed to be the necessary aspects to let the new building converse with the existing one. Although technically this is not the nature of the final roof structure, it is exactly through the formal evocation of a shell roof that the aimed for relation with the existing building is obtained. This evocation is made through the catenary shapes or the arches. Examples can be found in the title of an article on the project ‘steel roof in conversation with existing roof shells’ [47], or in the question of an interviewer for the origin of the ‘three shells’ [4].

¹⁵ For the large spans the height over span ratio 1/8,125 (4m over 32,5metres). In first rules for steel trusses for roofs a ratio of 1/10-15 is used. ([46])

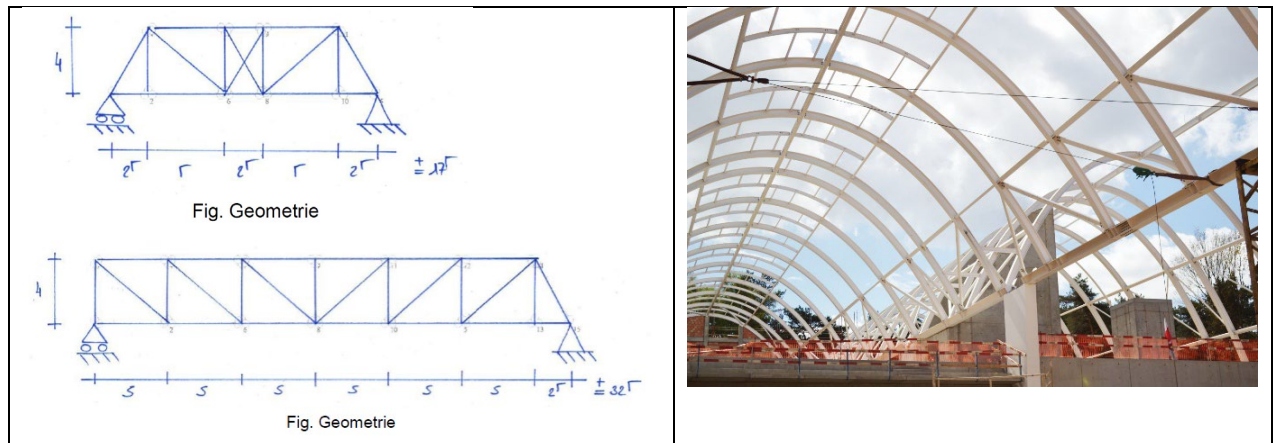


Figure 29 Left: sketches of the final trusses in longitudinal direction. Right: picture of the executed structure.

In this second discussion, the roles are the other way around. Ney informs the architects by telephone on their insight to make the structure in steel and they answer the long list of questions in a concise manner. It is interesting to note that in these questions some rather inaccurate statements are made. The architects for example say that ‘throughout the process, steel has always been said to be the cheapest solution’ of that ‘they are working with concrete since the competition’. As well interesting to note is that again Laurent Ney takes the lead on a pivotal point in the design process, although he never makes a decision but only ‘advises’ the architects to make certain choices¹⁶. This was as well the case when he urged for a catenary shape for the cross section. The final argument for a steel structure is made by (re)defining the essence of the design. This is not in the nature of the structure, but in the generated space. Here again however the ‘efficient’ use of materials is mentioned by the engineers.

The answer of the architects is exemplary for the general image the architects have on the work of the engineer. ‘To us, it seems the task of the engineer to make a feasible proposition that matches the image proposed in the competition, within the cost estimation proposed by you.’ What is ‘feasible’ has no clear definition and is something that has to be scrutinized as well throughout the process for each specific project. It is interesting to explicitly read again that this would be the realm of the engineers. Of course the engineers managed the cost estimation for the roof structure and so it is fair that the architects point their responsibility. On the other hand it can be seen in the early stages of the process, that the engineers as well do support the architects in their bold proposition, at a point where the budget is as well deliberately stretched for the sake of the idea and that they do make reservations on these estimations.

It is specific to this research to highlight such common discussions between collaborators. It however has to be stressed that these discussions are common (or even vital) to collaborations, as well as mutual understanding. That the shift to a steel structure in the end was supported by the architects, can be understood from: ‘At first, barrel vaults were planned, but in coordination with the engineer, it was decided to use vaults that follow the more efficient catenary line. Even after the design phase, stability plays an important role. “We received a telephone call from Laurent Ney to say that the roof could not be realised in concrete, but in steel,” say Jeroen Beerten and Tom Louwette of Bel architects, “thanks to this change, we can meet the strict fire and acoustic requirements. A concrete roof would become unnecessarily complex, due to the difficult integration of more and more techniques and the in-situ implementation of concrete.” [49]

¹⁶ In the beforementioned text on Ney& Partners:[3] (...) all the firm’s projects bear his own personal signature. Laurent Ney is an author in the original sense of the word. In another article it is explained that this is especially true for bridges. Their work is often less visible when they collaborate with architects on building projects. “This is our role”, Ney says. ‘We are specialists in structure’.[48] Although their hand is clearly visible in the final project, it can be seen in how design proposals are formulated, that their supportive position is maintained.

3 GENERAL OBSERVATIONS

In this article, the design process for the roof of a sports hall is illustrated. Several observations on how design decisions are made, how collaborators use their own tools in negotiations and on how statements evolve during the collaboration, are made at the end of each of the six discussed pivotal points.

To conclude, three more general observations on the collaboration and the research are formulated.

In a collaborative design process, and even more in designs where the engineer is explicitly involved in the conceptual design phase, a mutual design rationale has to be found. The first phases of the design are about the quest for these storylines. The exact definition of this mutual rationale is subject to the further process. The concept of the ‘ideal shape’ emerges in the first phase of the design and both the architect and the engineer agree that this should be one of the design rationales for the project. Due to the different epistemological conditions the architect and the engineer operate from, but as well because they have their own identities in the design process, the team members have different priorities for the concept of an *ideal shape*. Looking at the concept of ‘the ideal shape’ as a floating signifier in this design process, facilitated to evaluate how the collaborative design process between the architect and the engineer evolved, how decisions were made, how conflict and mutual understanding are key in a such a collaboration.

The attitude to keep looking for the optimal shape illustrates the engagement the engineers as well as the architects have towards the design. In the vision of Laurent Ney [3] the optimal shape as a true shape is already discussed. In this case this ambition seems to be emphasized by the relation to the neighbouring shell structure.

‘Often, the engineer is the watchdog of architecture, watching over buildability and affordability. Sometimes, however, a more intensive interaction develops, a reflection on stability in the genesis of the project so that structure and architecture become one.’ [49] In this case the involvement of the office for structural engineering proved to be guiding and crucial for the final outcome of the design. An engagement towards design implies an understanding and an ability to cope with the uncertainties of a design process, especially in the first phases of a design.

The projective rather than decisive character of the first phases of the design imply a premature nature of statements. This is own to the early phases of a design process, in which a competition is inevitably situated. It seems to be generally misunderstood that the engineer’s work, often considered as more scientific and thus ‘objective’, could escape this reality of the early design phase. The implementation in reality is far more complex than the basic structural laws the engineer has in his toolbox. The reality of this misconception is used in design competitions. The team’s selection is motivated with the participation of an experienced engineer that guarantees a feasible concept and the competition bundle is laced with several technical notes. But it as well introduces tensions and misunderstanding in the further collaboration. Acknowledging this reality would allow to bypass this misconception and might fertilize even more fruitful collaborations. When engaged towards design, both cooperating partners go through an equivalent kind of creative design process. Finality of the statements made are largely related to the stage in which the design is, and this applies for the engineers as much as it does for architects.

At last, the research method proves to be very effective to scrutinize the design process in a profound manner and deepens the course of events sketched in discourse. Several cited interviews prove that they are illustrative for the general course of the design process, but as well that they are large simplifications of the actual course of events. This research exposes the messy reality of a design process, of which progressive insight is an inevitable aspect and in which conflict and mutual understanding are key.

In the realms of engineering, this understanding of fluid and uncontrollable nature of the course of a process and how engineers can engage in a creative design process, is an underexposed aspect in the understanding of what the work entails. At the same time, the full consequences of engineers engaging in (early) design in collaborations neither seems to be widely understood. Although all particular on their own, such case studies are exemplary for the actual courses of complex design processes. Such references can be very helpful for (young) designers, both architects and engineers, to better understand the complex reality in which they daily operate.

ACKNOWLEDGEMENTS

The authors wish to express gratitude to Bel Architects and Ney & Partners to grant full access to their archives of the project, to make this case-study possible.

REFERENCES

1. Team Vlaams Bouwmeester (2009) SELECTIE bij de Open Oproep tot kandidatuurstelling 18 | 2009, projectgebonden selectie m.b.t. het project 13: Volledige studieopdracht voor de renovatie en uitbreiding van het Stedelijk Sportcentrum te Genk. Voorstelling van de 10 geselecteerde kandidaten, Brussel, Team Vlaams Bouwmeester - Vlaamse Overheid.
2. Team Vlaams Bouwmeester (2010) Selectiebeslissing bij de Open Oproep tot kandidatuurstelling 18 | 2009, de projectgebonden selectie m.b.t. het project 13: Volledige studieopdracht voor de renovatie en uitbreiding van het Stedelijk Sportcentrum te Genk, Brussel, Team Vlaams Bouwmeester - Vlaamse Overheid.
3. Strauven I (2006) Laurent Ney's authorship. In: V. Brunetta and V. Patteeuw Book ed Laurent Ney's authorship. Antwerp, VAI.
4. De Kooning E, Van Gerrewey C, Eggermont B (2012) BEL Architecten in gesprek. In: Book ed BEL Architecten in gesprek. Gent WZW Editions & Productions.
5. Buchanan I (2010) floating signifier. ed., Oxford University Press.
6. Chandler D, Munday R (2020) empty signifier In 559 Oxford University Press: Retrieved October 8 2021, from <https://www.oxfordreference.com/view/10.1093/acref/9780198841838.001.0001/acref-9780198841838-e-862>
7. Devriese T, Van Den Driessche M, Belis J (2021). From exposed concrete vaults to concealed steel trusses: conceptual design as a creative design act rather than a phase. Conceptual Design of Structures 2021, international fib symposium. Solothurn. <https://doi.org/10.35789/fib.proc.0055.2021.CDSymp.P015>
8. New Model Code fib special activity group (2012) Model Code 2010 Final Draft - volume 2, Lausanne, International Federation for Structural Concrete.
9. Stad Genk (2009) Renovatie en uitbreiding sporthal stedelijk sportcentrum. Projectdefinitie., Genk, Stad Genk.
10. Dienst Ruimtelijke Ordening Genk (2010) Open oproep 1813: stedelijk sportcentrum te Genk - 1e briefing, Genk, Stad Genk.
11. Bel architects (2010) E-mail communication 09/06/2010 to Ney & Partners, Daidalos
12. Szczelina M (2012) Christian Kerez bids farewell to Warsaw. domus.
13. Marquez Cecilia F, Levene R (2009) Museum of modern art, Warsaw. In: Book ed Museum of modern art, Warsaw. Madrid, El Croquis.
14. Ney & Partners (2010) E-mail communication (internal) 11/06/2010 to project leader Ney & Partners,
15. Ney & Partners (2010) E-mail communication 11/06/2010 to Bel architects,
16. Bel architects (2010) E-mail communication 12/06/2010 to project leader Ney & Partners,
17. Bel architects (2010) E-mail communication 13/06/2010 to project leader Ney & Partners, Daidalos
18. Beerten J, Louwette T, Ney L (2010) OO1813 B Ontwerp voor de volledige studieopdracht voor de uitbreiding van het stedelijk sportcentrum te Genk (competition bundle), Antwerpen & Brussel, Bel Architects, Ney & Partners.
19. Ney & Partners (2010) Conceptnota.doc (19/06/2010). ed. Brussels, Ney & Partners.
20. Team Vlaams Bouwmeester, Stad Genk (2010) Gunningsverslag bij de Open Oproep tot kandidatuurstelling 18 | 2009, de projectgebonden selectie m.b.t. het project 13: Volledige studieopdracht voor de renovatie en uitbreiding van het Stedelijk Sportcentrum te Genk, Genk, Stad Genk.
21. tv BEL! – Ney & Partners n.v. (2010) Nota bijkomende vragen: Ontwerp voor de volledige studieopdracht voor de uitbreiding van het stedelijk sportcentrum te Genk, Antwerpen & Brussel, Bel Architects, Ney & Partners.

22. Dienst Ruimtelijke Ordening Genk (2010) Open oproep 1813: stedelijk sporcentrum te Genk - 2e briefing, Genk, Stad Genk.
23. Ney & Partners (2010) E-mail communication 14/07/2010 to Bel architects,
24. Bel architects (2010) E-mail communication 14/07/2010 to Ney & Partners,
25. Ney & Partners (2010) E-mail communication 19/08/2010 to Bel architects,
26. Ney & Partners (2011) Studierapport 01
27. Ney & Partners (2011) Studierapport 01A.
28. Ney & Partners (2011) E-mail communication 13/06/2011 to Bel architects,
29. Ney & Partners (2011) E-mail communication 20/06/2011 to Bel architects,
30. Bel architects (2011) E-mail communication 22/06/2011 to project leader Ney & Partners,
31. Ney & Partners (2011) E-mail communication 22/06/2011 to Bel architects,
32. Ney & Partners (2011) E-mail communication 14/03/2011 to Bel architects,
33. Contractor (2011) E-mail communication 10/06/2011 to project leader Ney & Partners,
34. Ney & Partners (2011) E-mail communication 14/06/2011 to Contractor,
35. Ney & Partners (2011) E-mail communication 30/06/2011 to Bel architects,
36. Bel architects (2011) E-mail communication 30/06/2011 to project leader Ney & Partners,
37. Ney & Partners (2011) E-mail communication 30/06/2011 (2) to Bel architects,
38. City of Genk (2011) E-mail communication 01/08/2011 to Bel architects,
39. Daidalos (2010) E-mail communication 14/06/2010 to Bel architects,
40. Ney & Partners (2011) E-mail communication 22/08/2011 to Bel architects,
41. Bel architects (2011) E-mail communication 20/09/2011 to Ney & Partners,
42. Ney & Partners (2011) E-mail communication 22/09/2011 to Bel architects,
43. Bel architects (2011) E-mail communication 22/09/2011 to team Ney & Partners,
44. Laurent Ney (2011) E-mail communication (internal) 22/09/2011 to Ney & Partners,
45. Sandaker B N a, Eggen A P a, Cruvellier M a (2019) The structural basis of architecture, New York : Routledge.
46. te Bovelt A (2004) Bouwmethodiek. In: K. Hofkens Book ed Bouwmethodiek. Utrecht/Zutphen, ThiemeMeulenhoff. 196
47. Vander Beken J, Cornelis R (2016) Stalen dak in dialoog met bestaande schaaldak. InfoSteel, 46, 62-64.
48. Sels G (2019) Tegen een brug zegt hij nooit 'Ney'. DS2 De Standaard, 2-3.
49. Vandewalle J (2015) Ney & Partners Maatwerk. A+, 252, 58-61.

