DESIGNING A SUSTAINABLE HIGH-RISE STRUCTURE

Research into the material environmental impact of the main load-bearing structure of the building for the European Patent Office

TU Delft zonneveld ingenieurs

E.C. Booms

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Preface

Dear reader,

Before you lies the master thesis “Designing a sustainable high-rise structure – Research into the material environmental impact of the main load-bearing structure of the building for the European Patent Office”. This thesis investigates the impact on the shadow price of the main load-bearing structure of a high-rise building when taking material environmental impact into account in the structural design by making use of the case study: the building for the European Patent Office in Rijswijk, The Netherlands. This master thesis is written in order to finalize the master Building Engineering with the specialisation Structural Design at the faculty of Civil Engineering at Delft University of Technology.

I would like to thank my graduation committee, Rob Nijsse, Karel Terwel, Henk Jonkers and Arnold Robbemont for their advice, support and feedback during my graduation process. My experience of our meetings is very pleasant and informative.

I am grateful to Harm Hoorn, managing director, for providing me the opportunity to carry out my research at Zonneveld Ingenieurs. I am thankful for the support I received from everyone at the company.
Elise van Westenbrugge-Bilardie provided me with a wealth of knowledge on sustainable structural design and Geert Ravenshorst shared his expertise in timber structures. I am very thankful for their time.

Last, but not least, my gratitude goes to my parents and my partner, for their ceaseless support and encouragement. My father’s wisdom, my mother’s patience, and my partner’s faith have all helped carry me through this rigorous process, which allowed me to successfully complete this thesis.

I hope you enjoy reading my report.

Elise Booms

Delft, August 2019

Summary

Sustainability is a hot topic. Most people relate sustainability to climate change. However, it encompasses more, for instance social aspects. The purpose of this thesis is to investigate the material environmental impact of a main load-bearing structure and if the shadow price can be decreased by optimising the main load-bearing structure. The following main question has been formulated: "*In which ways can the material environmental impact of the main load-bearing structure of a high-rise building be reduced?*".

For the material environmental impact, and therefore the shadow price, ten environmental impact categories have been considered, with global warming potential (climate change) being one of them. These environmental impact categories all have a certain shadow price per unit. These shadow prices represent the damage costs that would have to be made by the government in order to reach the environmental goals that have been set.
Each material and product has its own shadow price per kg. When it is determined how much of each material or product has been used in the main load-bearing structure, the total shadow price can be determined.

In this research the material environmental impact of the main load-bearing structure for the building for the European Patent Office has been determined and optimized. The originally designed main load-bearing structure for this building consists mainly of steel columns and beams, and Slimline floors. The total shadow price for the main load-bearing structure for this building is €1.119.378,11.
The optimisation has been done for a design lifespan of 50 years and for 200 years. Additionally, a higher live load that creates more flexibility for the 200-year scenario is examined. The original function for the building is "office" and the other considered function is "meeting".

As alternatives for the beams and columns, steel, concrete, and timber elements have been considered. Hollow core slabs and Lignatur floors were explored as alternatives for the Slimline floors.
For the columns, concrete has been determined to be the best option with the lowest shadow price and timber the worst. For the beams, however, concrete is the worst option and steel the best. This order of favourability is the same for a lifespan of 50 years as well as for a lifespan of 200 years and 200 years with a higher live load. This means that different materials will be used in the structure in order to reach a most optimum shadow price. Since this is not always desirable, an entire steel option, as well as an entire concrete and entire timber option have also been explored.
Besides, hollow core slab floor was deemed out to be the best option to reduce the shadow price. The Lignatur floor had an even higher shadow price than the original Slimline floor.

When designing for a longer lifespan, possible degradation mechanisms must be taken into account. Since the elements are located in an indoor environment, it is assumed that no degradation will occur for all three materials. The mechanical properties of steel and concrete elements will not decrease either. Concrete even becomes stronger when time progresses. However, the mechanical properties of timber may decrease with time. This has been taken into account by using a reduction factor, k_{mod}.

One of the requirements for the main load-bearing structure for the building for the European Patent Office is that it must be able to withstand fire for 120 minutes, in order for everybody to escape the building in a safe way. This is achieved by applying Promatect to the steel elements, enlarging the timber elements in such a way that after 120 minutes the remaining dimensions are sufficient to withstand the loads, and by enlarging the concrete cover for all concrete elements.

When implementing all measures and all new, optimized shadow prices, the following new total shadow prices have been found:

Table 1 New shadow prices for optimisation for 50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 697.968,33	62%	€ 0,174
Steel	€ 732.708,44	65%	€ 0,183
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 777.118,71	69%	€ 0,194

Table 2 New shadow prices for optimisation for 200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 700.727,86	63%	€ 0,044
Steel	€ 736.625,65	66%	€ 0,046
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 831.529,96	74%	€ 0,052

Table 3 New shadow prices for optimisation for 200 years with the function "meeting"

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 727.537,10	65%	€ 0,045
Steel	€ 766.547,82	68%	€ 0,048
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 871.076,64	78%	€ 0,054

It can be seen that the shadow prices for all optimized options are comparable, with a small difference leading to steel being marginally better than concrete, which in its turn is slightly better than timber. Besides, all new shadow prices are lower than the original shadow price.
It can be seen in the tables above that even though all shadow prices for the longer lifespan are higher than the shadow prices for a lifespan of 50 years, the shadow prices per m^2 per year are a lot lower. This means that prolonging the lifespan of a building is beneficial for decreasing the environmental impact the main load-bearing structure has.

In order to determine the sensitivity of the shadow prices for the order of preference of the materials, three scenarios have been examined; 25% higher shadow price for steel, 25% higher shadow price for concrete, and 25% higher shadow price for timber. These three scenarios show that concrete remains favourite for columns and steel for beams. With an increased shadow price for concrete or timber, steel remains to be the best option for choosing one material for the entire structure, even though the differences in shadow prices are small. When steel has an increased shadow price, this is not the case. Now concrete is the best and steel the worst option for a one-material structure. The difference between the shadow prices is also still small for this scenario.

It must, however, be taken into account that in the original structural design a second load path had also been designed and that this has not been considered in the optimisation. With this taken into account, the profiles and dimensions of the various elements will probably be bigger, leading to a higher shadow price, but the shadow prices are still expected to be lower than the original.

As additional information, the effect on the shadow prices when taking the benefits of recycling or reusing the materials after its life cycle into account has been examined. This results in a lower shadow price for the timber and steel elements, whereas concrete does not benefit from this. The new shadow prices are shown in the tables below. It can be seen that the order of best to worst option is now different than before. Steel still is the best option, timber follows with a slight difference, but concrete is now the worst option, with a bigger difference to the other two.

Table 4 New shadow prices for optimisation for 50 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 632.354,51	56%	€ 0,158
Steel	€ 632.354,51	56%	€ 0,158
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 656.457,54	59%	€ 0,164

Table 5 New shadow prices for optimisation for 200 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 634.249,65	57%	€ 0,040
Steel	€ 634.249,65	57%	€ 0,040
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 683.411,93	61%	€ 0,043

Table 6 New shadow prices for 200-year optimisation with the function "meeting" with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 648.735,76	58%	€ 0,041
Steel	€ 648.735,76	58%	€ 0,041
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 703.002,67	63%	€ 0,044

For reuse to be possible, the reuse potential of all three materials has been considered.
As far as is known, steel does not lose strength over time and as mentioned before, the steel elements are not likely to degrade. This means that the steel elements all have a high potential for reuse, whether it is after 50 years or after 200 years.
For the timber elements, however, it is quite different. As mentioned, the mechanical properties of timber can decrease with time. This leads to a lower maximum strength of the timber elements as time progresses. This, however, also means that the potential for reusing the timber elements is lower after 50 years and even more so after 200 years than for steel elements.
Concrete is mostly recycled instead of reused. The reason being that although concrete does not degrade, it is, however, a challenge to remove a concrete element from a structure without any damages. Therefore, it is easier to crush it and use as input for new concrete.

Abbreviations

ADP	Abiotic Depletion Potential
AP	Acidification Potential
EP	Eutrophication Potential
EPO	European Patent Office
FWAE	Fresh Water Aquatic Ecotoxicity
GWP	Global Warming Potential
HTP	Human Toxicity Potential
LCA	Life cycle assessment
MAE	Marine Aquatic Ecotoxicity
NIBE	The Dutch institute for building biology and ecology
ODP	Ozone Depletion Potential
PO	Photochemical Oxidation
TE	Terrestrial Ecotoxicity

Symbols

Symbol	Meaning	Unit
A	Area	[mm]
A_{ben}	Minimum required area	
F_t	Altered extreme value for the live load for the chosen lifespan	[kN/m^2]
F_{t0}	Extreme value for the live load for the original lifespan	[kN/m^2]
g	Weight	[kg]
G	Distributed load	[kg/m] [kg/m^2] [kg/m^3]
k_{mod}	Reduction factor for timber	[-]
L	Length	[m]
N	Normal force	[kN]
M	Bending moment	[kNm]
q	Distributed load	[kN/m]
q_d	Distributed load including load factors	
$q_{r.b.}$	Distributed dead load	
$q_{v.b.}$	Distributed live load	
t	Chosen lifespan	[years]
t_0	Original lifespan, usually 50 years	
u.c.	Unity check	[-]
ψ_0	Transient load factor for live load	[-]

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1. Introduction

1.1 Relevance

Sustainability is a hot topic, but what is it about? In the way most people talk about sustainability, it is mostly linked to climate change. Climate change has to do with the average temperature on earth rising due to an increase in greenhouse gasses in the earth's atmosphere. Greenhouse gasses are necessary for living on earth, since they partially keep the heat from the sun in the atmosphere. However, since the beginning of the industrial revolution in the 18th century, human activity, for example burning fossil fuels, has resulted in a rapid increase of these greenhouse gasses, with CO_2 as the most important one (Milieu Centraal, n.d.-b). Due to this increase in greenhouse gasses, the earth's temperature has risen by almost 1^{o}C. If nothing changes, the average temperature will only rise further, with negative effects on the living environment as a consequence (Milieu Centraal, n.d.-a).

Sustainability, however, encompasses more than just climate change. It includes environmental, economic, human, and socials aspects (CBS, n.d.). In this research the focus will be on environmental sustainability. In particular, on the environmental impact of materials used in the main load-bearing structure of high-rise buildings. Environmental impact encompasses various things, with global warming potential due to the emission of greenhouses gasses being one of them, but not the only one. Two examples of other categories are ozone depletion potential and human toxicity potential. In chapter 2.3 a short description is given of all environmental impact categories that will be considered.

It is not (yet) common practice for structural engineers to take environmental impact into account in their designs. But is it useful to do so? How much can be gained in terms of material environmental impact when this is taken into account in the structural design? This will be investigated in this thesis by means of a case study: the new built high-rise building for the European Patent Office in Rijswijk, The Netherlands. This is a sustainable building during use, but sustainability was not an important aspect in the structural design (De Wilde, 2018).

In the construction sector, a lot of raw materials are used. Worldwide the sector is responsible for 40% of all extracted raw materials. The extraction as well as the processing of the raw materials into building products cause environmental impact (MVO Nederland, 2015). About 60% of all the materials used in a building is in the load bearing structure (Peters, Alle gebouwen een 'constructierapport', n.d.). To lower the environmental impact of the construction sector, it might therefore be useful to optimize the load-bearing structure. In this research the optimisation will be limited to the main load-bearing structure.

It is laid down in the Dutch Building Regulations that the environmental impact of construction materials must be as low as possible. Examples of solutions to reduce the emission of greenhouse gasses are to use less material and use sustainable or recycled materials for construction (Bouwend Nederland, 2017). According to ir. Pim Peters and ir. Remko Wiltjer from IMd Raadgevende Ingenieurs, one way to design a sustainable structure is to prolong the lifespan of buildings (Peters & Wiltjer, Duurzaam construeren, 2009). Normally a building will be designed for a lifespan of 50 years. In order to see what it means for the environmental impact of the materials used for the main load-bearing structure to have a much longer lifespan, a lifespan of 200 years is also analysed.

1.2 European Patent Office

The European Patent Office (EPO) is one of the biggest international institutions in The Netherlands. It has a new built office in Rijswijk, The Netherlands. The building has been opened since June 2018 and consists of two parts, the high-rise building, which is the main building and is called “New Main”, and a lower part in which, among other things, the cafeteria is located. The lower part is called “New Hinge” (Croonwolter&dros, 2019). This paper will focus on the high-rise building.

It is a prestigious and integral building that has a lot of smart and sustainable innovations incorporated, including climate control, light, and energy savings. For example, the building uses a subsurface thermal energy storage system (Croonwolter&dros, 2019). Due to the implementation of these innovations, it has become a sustainable building during use (Wilde, 2018).

Figure 1 Impression of the EPO building (J.P. van Eesteren, n.d.)

EPO has chosen a striking design with special dimensions: 107 meters high, 156 meters long and 12,6 meters wide, making it a quite slender building in one direction, as can be seen in Figure 1. This building, designed by Atelier Jean Nouvel from Paris and Dam & Partners Architecten from Amsterdam, has 27 floors with a total floor area of 80.000 m^2 and creates more than 1.750 workplaces (Principle Properties, n.d.). Almost all the levels have a storey height of 3,6 m. The only exceptions are levels 1, 2, 14 and 27. They respectively have the following level heights: 5,4 m, 4,5 m, 6,3 m and 4,7 m.

However, EPO had considered whether it would be suitable to create such a big and modern office building in Rijswijk. To make sure that the building would stand out, but would not distort the surroundings, transparent and light materials were selected. This led to the final design of glass facades with a structure made primarily of steel. The transparency of the building can be seen in the impression given in Figure 2.

Besides, a pond was created to surround the building, giving the impression that it was being lifted up by the water. This can be seen in Figure 1 above. The entrance of the building is located below the water surface, which creates the effect of people going “through water” when entering the building (Croonwolter&dros, 2019).

Figure 2 Impression of the EPO building (J.P. van Eesteren, n.d.)

The building has a second skin façade, where planters are placed, as can be seen in Figure 3. The plants placed in them create a pleasant environment and contribute to the sound insulation. Because of that, the staff working in the building do not get disturbed by the nearby highway. The second skin also creates natural ventilation and provides a good regulatable temperature inside the office (Principle Properties, n.d.).

Figure 3 Planters in second skin façade (Copijn, n.d.)

All the important installations of the building can be found on the 14th floor. They are deliberately not placed on the roof in order to create a sky garden, as can be seen in Figure 4. The employees can relax or enjoy the views there, for instance during their break (Principle Properties, n.d.). In the figure presented below, it can also be seen that solar panels have been placed on top of the sky garden, which is also one of the measures to create a sustainable building during use.

Figure 4 Sky garden (Schut, 2018)

The load-bearing structure for this building has been designed by Zonneveld Ingenieurs in Rotterdam. They have made a design for a reference period of 50 years, in consequence class 3. This consequence class is used for when there are major catastrophes, such as a big loss of human lives, or large, negative effects for the environment if the building would collapse (Kennisportaal Constructieve Veiligheid, n.d.).
Besides, considering the size of the building and the number of people that are usually inside, it was important to design a second load path. With this second load path the building became robust enough to prevent progressive collapse, should one of the structural elements were to fail.

The main load-bearing structure of the building needs to be able to withstand fire for 120 minutes in order for everybody to escape the building in a safe way. For the steel structure to be able to achieve this time frame, fire resistant paint is applied.

The main load-bearing structure, as defined by NEN 6702, encompasses all structural elements from which failure will lead to the failure of other structural elements that are not situated in the immediate vicinity of the collapsed element (Bouwwereld, 2006). For this building, that means that the columns, beams, floors, and foundation are all part of the main load-bearing structure.
The stability frame of the building is not taken into account in this research, since this would be too time consuming and since research into environmental impact of various stability systems has already been conducted. Further information on the optimisation of stability systems can be found in the master thesis by G.J. Lankhorst (2018).

The plans for this office building were approved in September 2013. J.P. van Eesteren, Croon Elektrotechniek and Wolter & Dros, all three subsidiaries of the TBI holding, received the approval to start the building activities shortly after. These companies worked closely with the two architects of this building to make it a successful project.

Since most floors are very similar and most of the structure consists of steel, it was possible to use prefab elements, which resulted in shorter construction time. Besides, the construction site was relatively small, making prefab the most desirable option. The shorter construction time was another way the EPO ensured as little disturbance was made to its surroundings as possible. (Principle Properties, n.d.).

1.3 Research questions

In this thesis the following main question will be answered:

- *In which ways can the material environmental impact of the main load-bearing structure of a high-rise building be reduced?*

This will be done by answering the following key questions:

- *How can the material environmental impact and therefore the shadow price of a structure be determined?*
- *How can a main load-bearing structure be optimized in terms of material environmental impact?*
- *How big is the material environmental impact of the main load-bearing structure of the building for the European Patent Office?*
- *How big is the material environmental impact of an optimized structural design for the building for the European Patent Office for a design life span of 50 years?*
- *How big is the material environmental impact of an optimized structural design for the building for the European Patent Office for a design life span of 200 years?*
- *How big is the difference between the shadow price of the original and the optimized main load-bearing structure of the building for the European Patent Office?*

1.4 Approach

To answer the questions presented in the previous chapter, various methodologies have been used. These methods are described below.

Literature review & interviews

A literature review has been done in order to become familiar with material environmental impact and the shadow price of structures and construction materials. Life Cycle Assessment, shadow prices and the various environmental impact categories are topics that have been considered. Conversations with two experts in the field of sustainable structural design have been an addition to this review. Furthermore, the methods for optimising a main load-bearing structure for both 50 and 200 years have been critiqued to determine the main design issues that require consideration. For example, fire safety design or possible degradation mechanisms.

Gathering data

To determine the shadow price of the main load-bearing structure of the building for the European Patent Office that was designed by Zonneveld Ingenieurs, (hereafter "the original structural design"), the environmental impact of all the elements and materials used for the main load-bearing structure is analysed. This is carried out by collecting all the information on the materials used and creating a table that calculates what the shadow price of each material/product is, to give a final, total shadow price. The shadow price of the optimized structural design has been determined in the same way.

Optimising

The structural design for the building for the European Patent Office has been optimized for a reference period of 50 years as well as for 200 years. The optimisation for the main load-bearing structure has the purpose of achieving a shadow price as low as possible. The following assumptions are taken as starting points:

- The architectural design is as it is
- The structural requirements are the same as for the original designed structure, but the second load path will not be taken into account

With these starting points, a reasonable comparison can be made between the original designed and the optimized main load-bearing structure.

Analysing

A comparison in shadow prices of the original designed structure and the optimized structural design has been made to determine how much is gained in terms of material environmental impact with the optimized design. A reflection on the optimized designs is also performed to ascertain if all the functional aspects of the building are considered, and what the consequences of the various designs have on, for instance, the aesthetics of the building.

1.5 Report outline

The outline of this report is as follows: in chapter 2 the findings from the literature review concerning how to determine the environmental impact of materials and products are discussed. How to optimize the main load-bearing structure is presented in chapter 3. The material environmental impact of the original designed main load-bearing structure for the building for the European Patent Office is determined in chapter 4. The next, chapter 5, is about the optimized structural design that was designed with a shadow price that is as low as possible. After that, the conclusion follows in chapter 6, and the discussion and recommendations in chapter 7.

2. Material environmental impact and shadow price

In order to become familiar with the material environmental impact and the shadow price of a structure and construction materials, a literature review has been conducted. Conversations with ir. Elise van Westenbrugge-Bilardie from IMd Raadgevende Ingenieurs and dr. Henk Jonkers from Delft University of Technology have been additional to this review. This chapter describes the findings from the literature review and the conversations.

2.1 Life cycle assessment

Life cycle assessment (LCA) is a method to analyse the impact that a product has on the environment over its entire life cycle. A life cycle consists of all the steps that lead from raw materials to the manufactured product, including extraction of the materials, energy consumption, manufacturing, transportation, use, recycling, and final disposal or end of life. This life cycle has been divided into four parts: product stage (A1 to A3), construction process stage (A4 and A5), use stage (B1 to B5) and end of life stage (C1 to C4). A fifth stage, called benefits and loads (D), considers possible positive effects of the product after its life cycle. This positive effect can come from reusing or recycling the product. A complete overview of the different stages is shown in Figure 5.

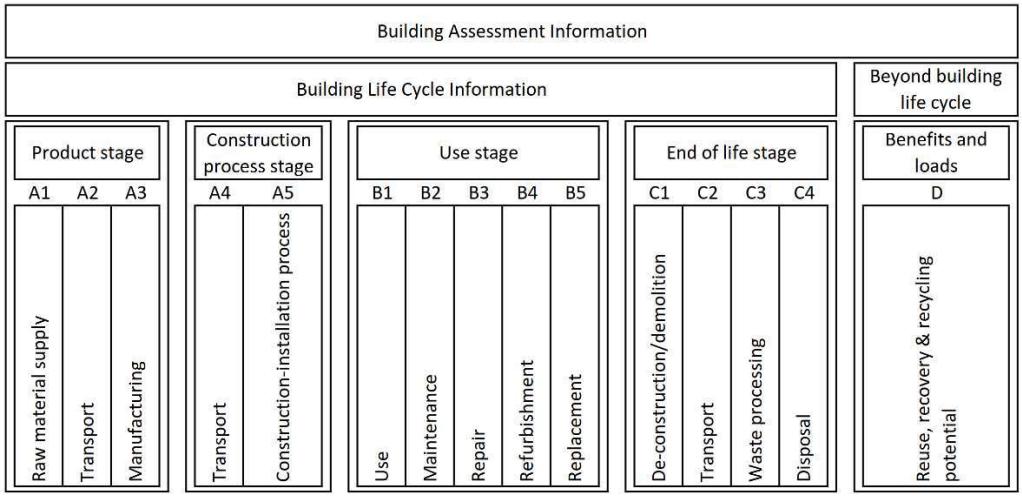

Figure 5 Stages of a life cycle

To determine the material environmental impact of the main load-bearing structure in this research, the main focus is on the product stage. The shadow price for the materials used in the main load-bearing structure is determined. Assumptions about the construction, use stage and end of life stage are made in order to give a full picture of the material environmental impact of the main load-bearing structure. The impact of category D, Benefits and Loads, is explored to provide additional understanding.

In order to perform an LCA calculation, several tools and software products have been introduced. Examples of Dutch tools are DuCo by IMd, GPR Gebouw, DGBC and the MRPI Free Tool (Lankhorst, 2018). When only looking at the material environmental impact, all these tools basically have the same function, which is to determine the shadow price of each material or product used and summate them. This leads to a total shadow price, which represents the material environmental impact of a building. In this project a table is used which functions similarly. The input for this table is the shadow prices per kg for each environmental impact category, the amount of each impact category per kg material used, and the amount of material used. This table can be seen in Appendix A. Sub-chapters 2.2 and 2.3 describe the shadow price and the environmental impact categories relatively.

2.2 Shadow price

According to the Dutch regulations, an LCA calculation must be submitted when applying for a building permit for new houses and offices bigger than 100 m^2 (Rijksdienst voor Ondernemend Nederland, n.d.). In the Netherlands, the results from the LCA calculations are expressed in a monetary value, the so-called "shadow price". The shadow price varies per environmental impact category. It represents the damage costs, per unit emission control, borne by the government as a result of direct environmental impacts. The Dutch shadow prices are established based on the country's environmental goals and are therefore only useable in The Netherlands.

The illustration below, Figure 6, shows how the shadow prices are established. Since the illustration comes from a Dutch source, translations of the terms are added in the figure. On the horizontal axis the emission of a certain impact category is given; on the left zero emission is allowed and when going to the right more emission is allowed. Linked to that, the damage costs per emission, and therefore the shadow price, is represented at the vertical axis. With 0 emission allowed, the costs are maximum. The more emission is allowed, the lower the costs are for the measures that need to be taken by the government (Bilardie, 2012).

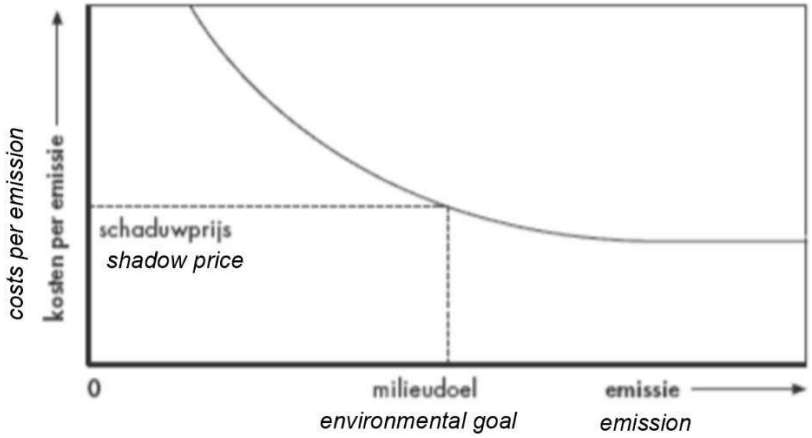

Figure 6 Determination of the shadow price (Bilardie, 2012)

As of the first of January 2018, the maximum allowed shadow price from the LCA calculations for new houses and offices bigger than 100 m^2 is 1,00 euro per m^2 gross floor area per year, which means that the maximum shadow price for a new building is related to the size and the reference period of that building (Rijksdienst voor Ondernemend Nederland, n.d.). The maximum allowed shadow price is meant to be lowered when time progresses. This implies that the Dutch government is pushing for better built constructions that have a lower environmental impact.

There are 10 environmental impact categories that must be taken into account in an LCA calculation according to the Dutch regulations (Rijksdienst voor Ondernemend Nederland, n.d.). They will be discussed in chapter 2.3. However, there are more categories. The Dutch Institute for Building Biology and Ecology, NIBE, takes more of these environmental categories into account, which inevitably leads to a higher shadow price. Here, the calculations of the shadow prices will be based on the information from the NIBE, but only the 10 impact categories required by the Dutch regulatory authority will be considered. In this way, it can also be seen how well a building performs in relation to the current requirements for the maximum shadow price.

2.3 Environmental impact categories

This section discusses the ten environmental impact categories, and their corresponding unit and shadow price per kilogram are presented. The source of the below given information is “Reader CIE4100 Materials and Ecological Engineering” by dr. H.M. Jonkers. A more detailed explanation of the impact categories can be found in the reader.

Abiotic depletion potential (ADP)
Abiotic depletion potential is an impact category that measures depletion of non-living (abiotic) resources, such as fossil fuels, minerals, clay and peat. It is dependent on the amount of resources and the extraction rate. This impact category is measured in antimony (Sb) equivalents. The environmental costs per kg equivalent is €0,16.

Global warming potential (GWP)
The Global Warming Potential is a way to measure to what extent a material contributes to global warming. The best known, but not the only, greenhouse gas that is emitted that contributes to global warming is CO_2. The other greenhouse gasses are converted into CO_2 equivalents and the shadow price per kg equivalent is €0,05.

Ozone depletion potential (ODP)
Ozone protects life on earth from ultraviolet radiation in the higher atmosphere. However, halogenated compounds, such as CFCs, enhance the decomposition of ozone. These compounds can for example be found in refrigerators and air conditioners. The unit for this impact category is kg CFC-11 equivalents and its shadow price is €30,00 per kg equivalent.

Human toxicity potential (HTP)
There are a lot of compounds that have a negative effect on human health. Although for a lot of them it is not known what their harmful concentrations are, limits have been set by governments. Below these limits it is believed that the concentrations are acceptable. HTP is measured in 1,4-dichlorobenzene (DB) equivalents and has a shadow price of €0,09 per kg equivalent.

Fresh water aquatic ecotoxicity (FWAE)
Just like for HTP, there are a lot of compounds that can have a negative effect on the living environment in fresh waters. The production of steel and cement is, for example, an activity that releases harmful compounds, like heavy metals. The unit of this environmental impact category is the same as for HTP, kg 1.4-DB equivalent, but the shadow price per kg equivalent is different, namely €0,03.

Marine aquatic ecotoxicity (MAE)
There are also compounds known that specifically have a negative effect on the marine environment. One compound group, the “persistent organic pollutants” (POPs), is known to be especially harmful for the marine environment, since they will hardly degrade and will accumulate in the food chain. The unit for MAE is also kg 1.4-DB equivalent and the environmental costs are €0,0001 per kg equivalent.

Terrestrial ecotoxicity (TE)
Terrestrial environment suffers from the same problem as marine environment. However, now instead of POPs, for example pesticides used for agriculture accumulates in the food chain. TE also has kg 1.4-DB equivalent as unit and its shadow price is €0,06 per kg equivalent.

Photochemical oxidation (PO)
Ozone, which is harmful in the lower atmosphere, is an example of a reactive photochemical compound. These compounds can have a negative effect on the living environment. As described in the before mentioned reader of dr. H.M. Jonkers: “Photochemical ozone . . . is formed due to photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx).” These compounds are for example emitted by the burning fossil fuels. The unit for PO is kg ethylene (C_2H_4) and per kg equivalent the environmental costs are €0,06.

Acidification potential (AP)
This environmental impact category deals with the depletion of calcium, magnesium and potassium, and its substitution by acidic elements, which are a result of air pollution. These acids will come down to the earth’s surface and will cause damage. AP is measured in SO_2 equivalents. The shadow price is €4,00 per kg equivalent.

Eutrophication potential (EP)
Nitrogen and phosphorous can usually be found in fertilizers for agriculture, but can also be found in the emission of fossil fuels. These two compounds usually limit the growth of water plants and algae. When the compounds reach these plants and algae, they will start to grow extensively, which may cause loss of other types of life. As mentioned in the reader by dr. H.M. Jonkers: “This process of excess nutrient loading in the environment is called 'eutrophication'.” EP is measured in phosphate (PO_4) equivalents. Its shadow price is €9,00 per kg equivalent.

With all units and shadow prices per kg of each environmental impact category summated, this gives the following information about the required 10 environmental impact categories:

Table 7 Summated information about the 10 environmental impact categories

Environmental impact category	Unit	Shadow price per kg
ADP	kg Sb eq	€ 0,16
GWP	kg CO_2 eq	€ 0,05
ODP	kg CFC-11 eq	€ 30,00
HTP	kg 1.4-DB eq	€ 0,09
FWAE	kg 1.4-DB eq	€ 0,03
MAE	kg 1.4-DB eq	€ 0,0001
TE	kg 1.4-DB eq	€ 0,06
PO	kg C_2H_4	€ 0,06
AP	kg SO_2 eq	€ 4,00
EP	kg PO_4 eq	€ 9,00

3. Optimizing the main load-bearing structure

In this chapter a description will be given on how the main load-bearing structure will be optimized and what needs to be considered when doing this.

3.1 Alternatives

In order to optimize the main load-bearing structure for a high-rise building in terms of shadow price, various alternative materials are examined for the various elements to determine their environmental impact. Since it is very time consuming to do this for all the elements, it is therefore more sensible to assess the elements with the most contribution to the total shadow price of the main load-bearing structure. As can be seen in chapter 5, the elements in the building for the European Patent Office with a big contribution are the steel columns and beams, and the floors in the storeys.

As alternatives for the columns and beams, steel profiles, and concrete and timber square or rectangular elements are analysed. The considered steel profiles are HEA, HEB, HEM, and squared hollow sections (hot rolled). Should the hollow sections prove to be insufficient, HD profiles will also be investigated. All steel profiles considered are in steel quality S460. The concrete and timber alternatives are determined with dimensions that are in multiples of 50 mm. The strength classes that are considered are C20/25, C30/37, C35/45, C55/67 for concrete and GL28h and D70 for timber.

For each considered element, the size and the type of loads on the element are determined. This is done by using the information from a SCIA model of the structure, created by Zonneveld Ingenieurs. For each original profile determination is made on the loads that are normative per floor, in order to optimise profiles as a group per level, instead of individually. This information provides the dimensions required for the different materials for each element. For this, the following computer programs are used: Technosoft Kolomwapening V6 for the concrete elements, and Technosoft Construct V6 for the timber elements. The steel elements are calculated manually.

This results in determining which materials, dimensions and profiles offer the lowest shadow price for all considered elements. This could possibly mean a mixture of all three materials to reach the most optimal structural design for the columns and beams. Since this is not always desirable, for instance for construction or aesthetic reasons, 4 options for the optimized structure will be determined; the best, an entire steel, an entire concrete, and an entire timber option.

Because of the big spans required for the floors (11,5 m) and the height of the building for the European Patent Office, many floor types are not possible as alternatives. The height makes it impractical to use in-situ concrete, since it will be difficult for the pumping machine to reach the top levels. Two floor types that are able to fulfil the requirements for this building are hollow core slabs and Lignatur floors. The first one is a concrete floor and the second is made of timber. Since it is less problematic to have a different material for the floor than for the rest of the structure and there is no steel option considered, the floors are considered differently. The floor type with the lowest shadow price is used to determine the total shadow price for all four options mentioned above.

3.2 Longer lifespan

As mentioned in chapter 1.1, the optimisation for the main load-bearing structure for the building for the European Patent Office is done for a lifespan of 50 years, as well as 200 years.
The characteristic values of the loads given in NEN-EN 1991 are mostly based on a lifespan of 50 years. When a different lifespan is used, the characteristic value of the live load must be altered. The characteristic value of the dead load remains the same, as well as the load factors. According to Prof.ir. A.C.W.M. Vrouwenvelder, as can be seen in Appendix B, this is the most common way in The Netherlands to increase the loads for a longer lifespan. Another approach that can achieve the same result is by increasing the load factors and keeping the live and dead loads the same. In this research, the first option, which is the most common way, is used. The following formula, given by NEN-EN 1990+A1+A1/C2:2011/NB:2011, will be used to alter the characteristic live load:

$$F_t = F_{t_0}\left\{1 + \frac{1-\psi_0}{9}\ln\left(\frac{t}{t_0}\right)\right\}$$

The meanings of the symbols are:

F_t	The altered extreme value for the live load for the chosen lifespan
F_{t0}	The extreme value for the live load for the original lifespan, usually 50 years
ψ_0	Transient load factor for live load, corresponding to the chosen function
t	The chosen lifespan
t_0	The original lifespan, usually 50 years

Besides increasing the loads on the structure, possible changes in the building must be taken into account. A longer lifespan means a bigger chance in desired changes. One way to make the building more flexible is by ensuring that the building can have a different function, other than the original one. To analyse this, a different function with a higher load is taken into account. The original function for this building is “office”, with a live load of 3,5 kN/m^2. The different function that is considered in this research is “meeting”, which has a prescribed live load of 5,0 kN/m^2.

Since the main load-bearing structure of the building for the European Patent Office is already very open, with mainly only columns and no load-bearing walls, it is quite easy to make changes in the floorplans in the future. Because of this, it is not necessary to make changes in the architectural design in order to make the building suitable for a life span of 200 years.

However, it might be possible that in the future people want to change the location of the elevators and stairs and/or make other openings in the floors. This is not very challenging accomplish, since the cores around the elevators is not part of the stability system. The Slimline floors, as well as the floors considered as alternatives, consist of plates in fixed, limited widths, which allow for easy (partial) removal. Creating so-called “trimming joints” helps to support the remaining parts to the subsequent plates. This trimming joint means that extra material will be used. However, it is assumed that the amount of material used for this is marginal, leading to little extra material environmental impact. Therefore, this is not taken into account in the calculation for the shadow prices.

When designing for a longer lifespan, possible degradation mechanisms for steel, concrete and timber must be taken into account.

For timber, degradation is dependent on the amount of oxygen, humidity and bacteria and/or fungi. In an indoor situation, as is the case for this main load-bearing structure, the circumstances are such that degradation does not occur. However, the mechanical properties of the timber can decrease as time progresses. In the calculations for the optimisations this will be taken into account by means of a reduction factor, k_{mod}. This factor takes load duration and humidity into account. The longer the load duration, i.e. the longer the lifespan of the structure, the lower the k_{mod} factor and the lower the design resistance of the timber. The following values are chosen for this factor; for a lifespan of 50 years k_{mod} = 0,80; for a lifespan of 200 years k_{mod} = 0,60.

Concrete hardens with time, although the speed of hardening slows down eventually. This means that a concrete structure will only become stronger with time. However, there are some possible degradation mechanisms for concrete structures. For instance, rotting concrete due to chloride attack, which can be seen in mainly older structures. This mainly occurs when there is a fault with the concrete mixture in the beginning. It is assumed that no problem occurred with the concrete mixture for this building, so this has not been taken into account.
To prevent possible corrosion of the steel reinforcement, the concrete cover must be bigger for a longer lifespan. The concrete cover for a lifespan of 50 years has been set at 30 mm and for 200 years at 40 mm.

With a steel structure, corrosion is a commonly known degradation mechanism. Corrosion occurs due to high humidity. However, since this structure is located in an indoor climate, the humidity is at such a level that corrosion does not occur. Besides, the steel is covered by fire resistant boards, as is discussed in the next chapter. These boards will additionally protect the profiles from corrosion.
The strength of steel remains constant over time and therefore no extra measures have to be taken into account for the steel elements for a longer lifespan.

3.3 Fire safety design

As mentioned in chapter 1.2, the main load-bearing structure must be able to withstand fire for 120 minutes. For the various materials there are various measures that are able to ensure that this timeframe is achieved. In this research, first the most optimal dimensions and profiles for all the considered elements are determined, as described in chapter 3.1, taking the various requirements, given in chapter 3.2, into account. The fire-resistant measures will then be added to these elements.

A few design measures for steel elements to create enough fire safety are to design the dimensions such that the profile can ensure it itself, paint it with special fire-resistant paint or apply special fire-resistant boards, such as Promatect. Creating self-sustaining steel elements usually means enlarging the profiles. Since the profiles must already be quite big due to the big loads on the elements, it is not a good idea to use this method. In this research is has been decided to use Promatect boards, even though painting is also a common measure, to cover up the steel elements and in that way ensure 120 minutes fire safety.

For timber elements, sufficient fire safety can be created by incorporating it into the design of the dimensions of the structure. Timber can also be covered by fire resistant boards, just like steel elements. In this report, it was chosen to use the first mentioned option.
According to the Eurocode the load factors become 1,0 in the event of fire. This means that the design loads become smaller than in normal situations and the minimum required dimensions will also be smaller. These minimum required dimensions for the timber are determined per element.

After that, the additionally needed dimensions are added. According to NEN-EN 1995-1-2, the burning rate of the chosen timber classes is 0,65 mm/minute, see Appendix C. With 120 minutes this means that 78 mm will be burned. It can be safely assumed that fire comes from all four sides, thus 78 mm must be added to the minimum dimensions on all four sides. The final dimensions of the timber elements are the maximum of either these minimum dimensions plus 78 mm added on all four sides, or the required dimensions in a normal situation.

Applying fire resistant boards is also an option for concrete structures. Other often used methods include using a spray mortar or ensuring a certain concrete cover. Here, the latter option is analysed. The minimum required concrete cover can be determined in two ways, according to NEN-EN 1992-1-2. Method A is used in this thesis. In Appendix D the calculation for the minimum required concrete cover can be found. Summated, this results in the following combinations of column width and concrete cover: 350/57 or 450/51. For the beams it is 200/65, 240/60, 300/55, or 500/50. For larger widths, the minimum concrete cover is taken as 50 mm.

4. Material environmental impact of the original main load-bearing structure

In this chapter the environmental impact of the main load-bearing structure for the building for the European Patent Office is determined, in the way that is described in chapter 3. As mentioned before, the structure for this building has been designed by Zonneveld Ingenieurs. The information on the used materials and products, which is used to determine the shadow price of the main load-bearing structure for this building, comes from their calculations and drawings.

4.1 Materials used in the main load-bearing structure

As mentioned in chapter 1.2, the main load-bearing structure of the building for the European Patent Office consists of columns, beams, floors and the foundation. In the basement, the columns and floors have been designed in concrete, in strength class C30/37; whereas in the storeys the columns and beams are all designed in steel. Concrete has a volumetric weight of 2.500 kg/m^3 and the volumetric weight of steel is 7.800 kg/m^3. Additionally, different floor types have been used in the original design in the storeys and for the foundation six types of piles have been used, all with concrete in strength class C35/45. These floor types are Slimline floors combined with Lewis floors and Comflor floors, prefabricated concrete floors, Comflor floors and hollow core slabs.

The basement floors are all solid, with a thickness of 300 mm. In total the floors have an area of 13.566,6 m^2, which produces a total weight of 10.174.950,38 kg. The columns in the basement, however, are not all the same. The drawings for the types of columns, and two tables of the calculations of the volume and weight of these columns can be seen in Appendix E. The total weight of all the columns in the basement is 379.646,75 kg.

The columns and beams in the storeys are also not all the same. In total 19 steel profiles for the columns and 28 profiles for the beams have been used in the original design. The columns and beams belonging to the façade have not been taken into account, since they are not part of the main load-bearing structure. The culmination of these profiles can be found in Appendix F. It can be seen that the columns have a total weight of 4.402.822,8 kg and for the beams it is 1.976.590,18 kg. The locations of all the beams and columns can be found in the floorplans, presented in Appendix L.

The Slimline floors consist of a “lower shell”, which is a concrete slab with a thickness of 70 mm in concrete quality C35/45, steel profiles on top of that, and an “upper shell”. Two steel profiles have been used in this building; IPE450 and IPE500. On top of the IPE450, a Lewis floor with a thickness of 70 mm is placed, while on top of the IPE500 Comflor 75 with a thickness of 250 mm is placed.

The Lewis floor consists of steel sheets, which weighs 5,8 kg/m^2, and mortar. With the thickness of 70 mm, 63 L/ m^2 is used. With a volumetric weight of 1,6 kg/L, this means that the mortar weighs 100,8 kg/m^2.
The Comflor 75 with a thickness of 250 mm also consists of steel sheets, but has concrete covering it, instead of mortar. The steel sheets for this floor type weighs 10 kg/m^2 and the concrete, in quality C20/25, weighs 531 kg/m^2.

The other Comflor floors consist of the same materials, but with different amounts and therefore different weights. Comflor 46 with a thickness of 115 mm has 9 kg/m^2 steel sheets and 239 kg/m^2 concrete. For Comflor 75 with a thickness of 125 mm it is 10 kg/m^2 and 231 kg/m^2. The steel sheets for the Comflor 75 with a thickness of 145 mm is the same as for the one with a thickness of 125 mm, but the weight of the concrete is bigger, namely 279 kg/m^2.

The prefabricated floors are all in concrete quality C55/67 and have a thickness of 150 and 250 mm. The hollow core slab floors have a thickness of 400 mm and are in concrete quality C45/55 and weigh 490 kg/m^2. On top of the slabs a compression zone in quality C30/37 with a thickness of 50/70 mm is placed.

A summation of all floor areas is presented below in Table 8.

Table 8 Total floor areas per floor type

Type	Area [m^2]
Slimline IPE450 + lewis d = 70	50.486,18
Slimline IPE500 + Comflor 75 d = 250	2.094,42
Prefabricated floor d = 150	924,38
Prefabricated floor d = 250	2.677,60
Comflor 46 d = 115	62,33
Comflor 75 d = 125	25,48
Comflor 75 d = 145	1.818,06
Comflor 75 d = 250	131,04
Hollow core slab d = 400; compression zone 50/70	1.904,76

With the above-given information, the following weights can be determined:

Table 9 Overview of weights of floors storeys

Floor type	Parts of floor type	Weight [kg]
Slimline IPE450 + Lewis d = 70	Lower shell	8.835.081,50
	IPE450	3.664.714,32
	Steel sheet	292.819,84
	Mortar	5.089.006,94
Slimline IPE500 + Comflor 75 d = 250	Lower shell	366.523,50
	IPE500	178.316,20
	Steel sheet	20.944,20
	Concrete	1.112.137,02
Prefabricated floors	Concrete	2.020.137,50
Comflor floors	Steel sheet	20.306,79
	Concrete	597.604,21
Hollow core slab d = 400; compression zone 50/70	Concrete slab	933.332,40
	Concrete compression zone	238.095,00

The six pile types that have been used are the following:

- Screwed tubular pile + grout injection, VSP-casing pile
- Screwed piles with lost tip + grout injection, VSP-pile
- Screwed tubular combined pile + grout injection, VSP-combined pile
- Screwed tubular pile (segments) + grout injection
- Screwed tubular pile + grout injection (the so-called “Waalpaal”)
- Auger pile

The piles have a total weight of 127.904.98,4 kg.

4.2 Environmental impact

In order to determine the environmental impact of the main load-bearing structure, it is important to know the shadow prices per kg material per material used. An overview of the shadow prices per kg of the materials mentioned in the previous chapter can be found in Table 10 below. These shadow prices have been determined by inserting the information of each material in the table that was explained in chapter 2.1, which can be seen in Appendix A. For concrete class C45/55, the average of the shadow prices for C35/45 and C55/67 is taken.

Table 10 Overview shadow prices per kg material

Material	Shadow price/kg
Concrete C20/25	€ 0,0073
Concrete C30/37	€ 0,0074
Concrete C35/45	€ 0,0075
Concrete C45/55	€ 0,0082
Concrete C55/67	€ 0,0090
Mortar	€ 0,0185
Steel	€ 0,0669
Steel sheets	€ 0,1757

With the weights mentioned in chapter 4.1 and the above-mentioned shadow prices per kg, the shadow prices for all elements belonging to the main load-bearing structure can be determined. The results can be found in Table 11. It can also be seen how much each part contributes to the total shadow price. Since the floors of the storeys consist of so many different parts, only their complete shadow price is given below.

Table 11 Overview of shadow prices original structure

What	Shadow price [€]	Percentage of total [%]
Basement		
Columns	€ 2.841,43	0,25%
Floors	€ 75.429,76	6,74%
Storeys		
Columns	€ 294.439,32	26,30%
Beams	€ 132.184,71	11,81%
Floors	€ 518.741,55	46,34%
Foundation	€ 95.741,33	8,55%
Total	€ 1.119.378,11	

The total shadow price of the main load-bearing structure, as can be seen above, is €1.119.378,11. As mentioned in chapter 2.2, the maximum allowed shadow price is 1,00 euro per m^2 gross floor area per year. Since the gross floor area is 80.000 m^2 and the lifespan of this structure is 50 years, it means that for the original main load-bearing structure for the building for the European Patent Office the shadow price per m^2 gross floor area per year is €0,28, being much lower than the set limit. However, it must be taken into account that the set limit is for all materials used in the building, not just the main load-bearing structure.

5. Optimized structural design

To determine how much the shadow price of the main load-bearing structure for the building for the European Patent Office could be lowered, the structure should be optimized. This optimisation is presented in this chapter.

As can be seen in chapter 4, the columns, beams and floors in the storeys are responsible for the majority of the total shadow price (84,45%) for the main load-bearing structure. These are the parts of the main load-bearing structure that are to be optimized.
Since it is too time consuming to do this for all columns, beams and types of floors, a decision is made to only examine the beams and columns with a minimum of 2% of the total weight of the beams and columns. Additionally, alternatives for the Slimline IPE450 + Lewis d = 70 have been examined, since this is the most common floor in this building. In Appendix F an overview of the weights per profile type for the columns and beams and the percentages of their contribution to the total weight can be found. When adhering to the 2% limit, this results in the following profiles for the beams and columns for which alternatives can be determined:

Beams:	- HD400x262	- HEA550	Columns:	- HD400x1086
	- HD400x551	- HEA600		- HD400x187
	- HE500AA	- HEB400		- HD400x262
	- HE550AA	- HEB450		- HD400x314
	- HE650AA	- HEB600		- HD400x421
	- HEA260	- HEB650		- HD400x463
	- HEA450			- HD400x744

In Table 10 a few shadow prices per kg are presented. For the optimisation, however, a few other materials also need to be considered. Their shadow prices per kg are:

Table 12 Overview shadow prices per kg material

Material	Shadow price/kg
Grout	€ 0,0185
Promatect	€ 0,0101
Reinforcing steel	€ 0,0833
Timber D70	€ 0,0696
Timber GL28h	€ 0,0595

5.1 Optimisation for 50 years

The elements with the above-mentioned profiles have been optimized, as described in chapter 3.1. An example of an optimized element is given in Appendix G. The example is for a column on level 9 that has HD400x262 as original profile. In this chapter summations of the results are presented. First the optimisations without the fire safety measures are be presented.

Table 13 Optimisation of the columns for 50 years without the fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 80.004,84	27%	€ 0,020
Steel	€ 114.655,32	39%	€ 0,029
Concrete	€ 80.004,84	27%	€ 0,020
Timber	€ 119.382,42	41%	€ 0,030

It can be seen that for the columns, concrete is the best choice and timber the worst. The percentages that compare the new shadow price to the original one are calculated with only the shadow prices of the columns, which is done by dividing the new shadow prices by the original shadow prices.
The timber option has a shadow price that is almost €40.000 higher than the concrete option, which means that the timber structure has a shadow price that is almost 1,5 times bigger than that of concrete. It can also be seen that the difference between the steel and timber option is quite small.

The concrete columns with the lowest shadow prices are all in concrete quality C55/67. This has to do with the fact that the columns are mostly only loaded by compressive normal forces and with a higher concrete quality, a higher maximum strength may be used. This leads to smaller dimensions being required. Because of this, even higher concrete classes have been considered.
In Appendix H a calculation with higher concrete classes for the same element used as example in Appendix G can be found. Due to the much higher shadow prices per kg for these higher concrete qualities and since the required dimensions are not that much smaller, these strength classes proved to have higher shadow prices. Therefore, they are not considered in the rest of the calculations.

For the beams, however, the relationship between the various materials is quite different. The percentages comparing the original and new shadow prices have been determined in the same way as for the columns. It can be seen that for the beams, steel is the best choice and concrete the worst, when only looking at the three options with the single materials used. The difference is a little higher than €60.000, which is about 3/4 of the shadow price for the steel option. There is a small difference between the best option and the steel option, which has to do with the fact that for a few beams, timber or concrete is the best option instead of steel.

Table 14 Optimisation of the beams for 50 years without the fire safety measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 79.812,97	60%	€ 0,020
Steel	€ 79.858,52	60%	€ 0,020
Concrete	€ 140.102,49	106%	€ 0,035
Timber	€ 103.691,97	78%	€ 0,026

When combining the optimisation for the beams and columns with the remaining part of the load-bearing structure, with the original floor the following is found.

Table 15 Optimisation for 50 years without the fire safety measures with the original floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 852.571,89	76%	€ 0,213
Steel	€ 887.267,92	79%	€ 0,222
Concrete	€ 912.861,41	82%	€ 0,228
Timber	€ 915.828,47	82%	€ 0,229

It can be seen that with the beams and columns combined, the difference between the four different options is relatively small, with the biggest difference in shadow prices between the best option and the timber option. The difference is a little over €63.000. This may seem high, but the shadow price of the timber option is only 7% higher than that of the best option. Compared to an entire steel or concrete structure, timber is comparable, which means that it does not really matter which material is chosen for the entire main load-bearing structure.

As mentioned before, for the optimisation, the second load path has not been taken into account. However, normally it should be studied. Taking a second load path into account would lead to bigger profiles and dimensions. Therefore, it is beneficial to remember that the new shadow prices for the optimisation could actually be higher. This means that for the best option, the reduction in shadow price would not be 24%, but possibly less than 20%.

As mentioned in chapter 3.1, hollow core slabs and Lignatur floors have been considered as alternatives for the Slimline floors. However, as can be seen in Appendix I, only the hollow core slab floor shows to have a lower shadow price than the original floor. Therefore, only the hollow core slab floor is considered further in this thesis.

When adding the optimisation for the hollow core slab floor, it can be seen that the reduction for the shadow price is a lot higher. The floor itself gives a reduction of 14%. The shadow price for the best option is now 38% lower than the original design. However, for this calculation, the second load path also should be added, which means less reduction. But, since the reduction is relatively significant, it will possibly still mean a significant reduction in shadow price.

Table 16 Optimisation for 50 years without the fire measures with the hollow core slab floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 697.822,31	62%	€ 0,174
Steel	€ 732.518,34	65%	€ 0,183
Concrete	€ 758.111,83	68%	€ 0,190
Timber	€ 761.078,89	68%	€ 0,190

When adding all the fire safety measures, the new shadow prices for the optimised structure increase slightly, but the increase is hardly mentionable. Only the beams and columns require the fire safety measures, since the hollow core slab itself already guarantees a fire safety of 120 minutes.

Table 17 Optimisation for 50 years with fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 697.968,33	62%	€ 0,174
Steel	€ 732.708,44	65%	€ 0,183
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 777.118,71	69%	€ 0,194

5.2 Optimisation for 200 years, same function

In order to optimize the elements for a lifespan of 200 years, it is important to determine how much the loads on the elements must be increased. This has been done with the formula presented in chapter 3.2. The original dead load is 4,75 kN/m^2 and the original live load is 3,50 kN/m^2. The transient load factor for the live load for the function “office” is 0,5. This information can be entered into the formula and gives the following result for the new live load:

$$F_t = F_{t_0}\left\{1 + \frac{1-\psi_0}{9}\ln\left(\frac{t}{t_0}\right)\right\} = 3{,}50 * \left\{1 + \frac{1-0{,}5}{9}\ln\left(\frac{200}{50}\right)\right\} = 3{,}50 * 1{,}077 = 3{,}77\ kN/m^2$$

To determine the increase in the design load in a column or beam, the design load for 50 years and 200 years are compared.
50 year: $q_d = 1{,}5 * q_{r.b.} + 1{,}65 * q_{v.b.} = 1{,}5 * 4{,}75 + 1{,}65 * 3{,}50 = 12{,}9\ kN/m^2$
200 years: $q_d = 1{,}5 * q_{r.b.} + 1{,}65 * q_{v.b.} = 1{,}5 * 4{,}75 + 1{,}65 * 3{,}77 = 13{,}34\ kN/m^2$
This means that the increase is 13,34/12,9 = 1,034, so 3,4%.

When using the increased loads, the lower k_{mod} factor for the timber elements, and the bigger concrete cover, the shadow prices become higher than for a lifespan of 50 years, but are still smaller than the original shadow price.

As can be seen below, for the steel and concrete columns, however, this increase in shadow prices is marginal. Due to the much longer lifespan and this very little increase in shadow prices, the shadow price per m^2 per year is much lower than for the optimisation for a lifespan of 50 years, by roughly 4 times. For the timber columns, the increase at about €30.000 in shadow price is more significant. This results in a shadow price that is about 25% higher than for the optimized structure for a lifespan of 50 years. However, for these timber columns, the shadow price per m^2 per year is 3,33 times lower than for the lifespan of 50 years, which is still significant.

Table 18 Optimisation of the columns for 200 years without the fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.189,20	28%	€ 0,005
Steel	€ 117.302,49	40%	€ 0,007
Concrete	€ 81.189,20	28%	€ 0,005
Timber	€ 149.616,24	51%	€ 0,009

For the beams, the increase in shadow price for the steel option is also marginal. For the concrete option, the increase is larger than for the columns, but at about 3%, the increase is still very small when compared to the concrete beams for the 50-year lifespan. For the steel and concrete option for a lifespan of 200 years, the shadow prices per m^2 per year are also about 4 times lower than for a lifespan of 50 years, just like for the columns. For the timber option, the new shadow price is, similar to the columns, about 25% higher than the shadow price for a lifespan of 50 years. The shadow price per m^2 per year for the timber option, however, is only 2,9 times lower than for a lifespan of 50 years, but it is still a significant decrease.

Table 19 Optimisation of the beams for 200 years without the fire safety measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.130,69	61%	€ 0,005
Steel	€ 81.130,69	61%	€ 0,005
Concrete	€ 144.660,48	109%	€ 0,009
Timber	€ 129.063,00	98%	€ 0,008

When the optimisation for the columns and beams are added to the remaining shadow prices of the original structure, the best, steel, and concrete options show little difference between the new shadow prices for a lifespan of 50 years and 200 years. These three options all have about 4 times lower shadow prices per m^2 per year when compared to the lifespan of 50 years.

The timber option, however, has an increased new shadow price of about 6%. The shadow price per m^2 per year is 3,75 times less, which is comparable to the other three options. As with the lifespan of 50 years, the difference between the shadow prices of the four options is not that significant, but now the difference between the best and the timber option is more substantial.

Table 20 Optimisation for 200 years without the fire safety measures with the original floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 855.073,97	76%	€ 0,053
Steel	€ 891.187,26	80%	€ 0,056
Concrete	€ 918.603,76	82%	€ 0,057
Timber	€ 971.433,32	87%	€ 0,061

Since the hollow core slab floor is the same for 50 years as for 200 years, it still reduces the new percentages of the shadow prices by 14% when comparing to the situation with the original floor. For a lifespan of 200 years, everything else is the same as for 50 years, as described in the previous chapter.

Table 21 Optimisation for 200 years without the fire safety measures with hollow core slab floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 700.324,39	63%	€ 0,044
Steel	€ 736.437,68	66%	€ 0,046
Concrete	€ 763.854,18	68%	€ 0,048
Timber	€ 816.683,74	73%	€ 0,051

When adding all the fire safety measures, the new shadow prices also marginally increase.

Table 22 Optimisation for 200 years with fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 700.727,86	63%	€ 0,044
Steel	€ 736.625,65	66%	€ 0,046
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 831.529,96	74%	€ 0,052

5.3 Optimisation for 200 years, meeting function

So far, the discussion has centred around the building being used as “office”. This chapter discusses how a change of function to “meeting” affects the loads on the columns and beams with a lifespan of 200 years, and therefore their shadow prices. The same method as in the previous chapter has been used. The dead load is 4,75 kN/m^2 and the live load for a lifespan of 50 years is 5,0 kN/m^2. The transient load factor for the live load for the function “meeting” is 0,4. This results in the following new live load:

$$F_t = F_{t_0}\{1 + \frac{1-\psi_0}{9}\ln\left(\frac{t}{t_0}\right)\} = 5{,}0 * \left\{1 + \frac{1-0{,}4}{9}\ln\left(\frac{200}{50}\right)\right\} = 3{,}50 * 1{,}092 = 5{,}46\ kN/m^2$$

Again, the design load for 50 years and 200 years is compared. However, the variable load for the lifespan of 50 years must be the original, 3,50 kN/m^2, to be able to determine the increase compared to the original loads.

50 year: $q_d = 1{,}5 * q_{r.b.} + 1{,}65 * q_{v.b.} = 1{,}5 * 4{,}75 + 1{,}65 * 3{,}50 = 12{,}9\ kN/m^2$
200 years: $q_d = 1{,}5 * q_{r.b.} + 1{,}65 * q_{v.b.} = 1{,}5 * 4{,}75 + 1{,}65 * 5{,}46 = 16{,}14\ kN/m^2$
This means that the increase is 16,14/12,9 = 1,251, or 25,1%, which is a more significant increase than is found in the previous chapter.

This bigger increase can clearly be seen in the new shadow prices for the optimisation for a lifespan of 200 years with the function “meeting”. The relationship between the four options for the columns and beams is still the same, with concrete being the best for the columns and steel being the best for the beams.

Compared to the optimisation for 50 years, the shadow price for the concrete columns is about 20% higher; and compared to 200 years with the same function it is a little over 18%. This clearly shows that the biggest increase in shadow price comes from the increase in loads and not from the bigger concrete cover.

In the “meeting” function, the steel option shows an increased shadow price of 22% and 20% respectively for a lifespan of 50 years and 200 years when compared to the “office” function. Even though the steel elements do not need extra measures for a longer lifespan and therefore all increases are due to the increased loads, the increase in shadow price is higher than for the concrete option. This has to do with the fact that the steel profiles have set dimensions, while for the concrete elements the dimensions can be altered to the minimum required.

The timber option, in comparison, has a more notable increase of 47% compared to the 50-year lifespan, and 17,5% to the 200-year lifespan. It is clear to see that the decrease in mechanical properties has a big impact on the shadow price for the timber option. It should be noted that the k_{mod} factor is the same for both optimisations for a lifespan of 200 years, thus proving that the 17,5% increase is due to the increased load.

All shadow prices per m^2 per year are still comparable to the ones for the optimisation for 200 years with the function “office” and are still a lot lower than for the optimisation for 50 years.

Table 23 200-year optimisation of the columns with function "meeting" without the fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 95.973,86	33%	€ 0,006
Steel	€ 140.862,49	48%	€ 0,009
Concrete	€ 95.973,86	33%	€ 0,006
Timber	€ 175.949,83	60%	€ 0,011

For the optimisation of the beams with a lifespan of 200 years with the function “meeting”, the same factors used in all the other comparisons hold true here. The only discrepancy is in the percentages. The use of steel in this function results in increased shadow prices of approximately 9,5% and 8% when compared to a 50 year and a 200-year lifespan with the “office” function, respectively. This increase is relatively more trivial than the one for the columns. This has to do with the fact that beams are mainly loaded by bending moments and the columns by compressive normal forces. Steel profiles are especially good at handling those bending moments, but have more problems with buckling due to the normal forces, thus bigger profiles must be chosen.

The increases for concrete are about 15% when comparing with 50 years and about 11,5% when comparing with 200 years with the function “office”. Lastly, timber has an increase in shadow price of about 39% and 11,5%.

Table 24 Beam optimisation for 200 years with function "meeting" without the fire measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 87.366,78	66%	€ 0,005
Steel	€ 87.490,06	66%	€ 0,005
Concrete	€ 161.546,90	122%	€ 0,010
Timber	€ 143.978,79	109%	€ 0,009

The increases in shadow prices can also be seen when the above-mentioned information is added to the remaining original shadow prices, with the original floor. However, the increase is much lower than when the columns and beams are considered separately. For the best option, the increase in shadow price is almost 3%, compared to the optimisation for 50 years and about 2,5% when compared to 200 years with the function “office”. Both for steel and concrete, it is approximately 4% and 3,5%, and for timber roughly 10,5% and 4%. Since the new shadow prices for 200 years with the function “meeting” are only marginally higher than for 50 years, all options have a lower shadow price per m^2 per year. Besides, the new shadow prices are still lower than the shadow price of the original main load-bearing structure. It must again, however, be taken into account that the shadow prices will be somewhat higher when taking the second load path into calculations.

Table 25 200-year optimisation, function "meeting" with the original floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 876.094,72	78%	€ 0,055
Steel	€ 921.106,63	82%	€ 0,058
Concrete	€ 950.274,84	85%	€ 0,059
Timber	€ 1.012.682,70	90%	€ 0,063

Adding the hollow core slab floor, reduces the percentages by 14%. This results in a significant decrease of the shadow price compared to the original design, even with taking the second load path into account.

Table 26 Optimisation for 200 years, "meeting" with the hollow core slab floor

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 721.345,14	64%	€ 0,045
Steel	€ 766.357,05	68%	€ 0,048
Concrete	€ 795.525,26	71%	€ 0,050
Timber	€ 857.933,12	77%	€ 0,054

When adding all the fire safety measures, the new shadow prices increase a marginally.

Table 27 Optimisation for 200 years with the function "meeting" with fire safety measures

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 727.537,10	65%	€ 0,045
Steel	€ 766.547,82	68%	€ 0,048
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 871.076,64	78%	€ 0,054

5.4 Category A4 to C and D from life cycle

As mentioned in chapter 2.1, assumptions are made about category A4 to C of the life cycle and the shadow prices for category D for the various materials are determined in order to create a full picture of the environmental impact of the optimized main load-bearing structure.

Category A4 to C include the construction process stage, use stage, and end of life stage of the materials. During the use stage there is probably no difference between the materials, since it can be assumed that in normal situations no maintenance, repair, or replacement is needed, as no degradation mechanisms are likely to occur in an indoor environment. The decrease of the mechanical properties of timber is the only thing likely to happen, but that has already been taken into account in the calculations by the k_{mod} factor.

There will, however, be a difference between the three considered materials during the construction process stage. This has to do with the weight of the various elements. The environmental impact due to transportation and the construction-installation process is lower for an element with a lower weight than for an element with a higher weight. As an example, for one column that has been optimized for a lifespan of 50 years, the steel option weighs 439,2 kg, while the concrete column weighs 562,5 kg and the timber option 575,64 kg. This means that the steel option has the lowest environmental impact in this life cycle category, followed by the concrete option and the timber option. However, the timber and concrete options are comparable.

For the end of life stage, transportation is again important. However, it is possible that during deconstruction, the elements are broken down into pieces small enough that allow for much easier transportation. Regardless, given that the total weight of an entire steel structure is less than that of an entire concrete or timber structure, transporting steel is much more efficient than transporting concrete or timber. This also results in a lower environmental impact for steel.

When implementing category D of the Life Cycle Analysis, the shadow prices of the steel and timber elements decrease. For the concrete elements, this is not the case since no positive effect for recycling or reusing the concrete has been taken into account in this category. The shadow prices per kg for category D for steel is €-0,0345 and for timber €-0,0300.

When comparing these shadow prices with the shadow prices for the product stage, it shows that the shadow price for the concrete option remains the same, while the steel option is decreased by about 48,5%, and the timber option by about 49,5%. This means that the relationships between the various options differ from the results presented in the previous chapters. The tables below present the final results of all optimisations with this category D taken into account. It can be seen that steel still is the best option, with a small benefit compared to timber. However, concrete has a relatively high shadow price, making it the worst option.

Table 28 New shadow prices for optimisation for 50 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 632.354,51	56%	€ 0,158
Steel	€ 632.354,51	56%	€ 0,158
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 656.457,54	59%	€ 0,164

Table 29 New shadow prices for optimisation for 200 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 634.249,65	57%	€ 0,040
Steel	€ 634.249,65	57%	€ 0,040
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 683.411,93	61%	€ 0,043

Table 30 New shadow prices for 200-year optimisation, function "meeting" with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 648.735,76	58%	€ 0,041
Steel	€ 648.735,76	58%	€ 0,041
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 703.002,67	63%	€ 0,044

For reuse to be possible, the reuse potential of all three materials have been considered. Their reuse potential is different from each other.
As far as is known, steel does not lose strength over time and as mentioned before, the steel elements are not likely to corrode, so it is not likely to degrade. This means that the steel elements all have a high potential for reuse, no matter if it is after 50 years or after 200 years.

For the timber elements, however, it is quite different. As mentioned, the mechanical properties of timber may decrease with time. This leads to less maximum strength of the timber elements as time progresses. In the calculations for this thesis this has also been taken into account, leading to bigger elements required for the lifespan of 200 years compared to 50 years. This, however, also means that the potential for reusing the timber elements is lower than for steel elements after 50 years and even more so after 200 years. An option could be to reuse the elements in buildings with lower loads than in the original building. However, this would mean that the elements would be bigger than normally required, which is not always desirable.

Concrete is usually recycled instead of reused. However, the material does not degrade, as mentioned before. Regardless, it would be challenging, if not impossible, to reuse concrete elements, since it is difficult to remove a concrete element from a structure without damaging the product. Therefore, it is easier to crush it and use as input for new concrete.

5.5 Sensitivity shadow prices

Since the shadow prices per kg are not definitive for the materials, it is important to see what it would mean if they would change. Therefore, three scenarios have been analysed, 25% increased shadow price for steel, for concrete and for timber. The results will be discussed below.
To make a fair comparison for the beams and columns, the shadow prices without fire safety measures have been determined. For the comparison with the total shadow prices, the fire-resistant measures have been included. The tables with the shadow prices are presented in Appendix J.

Higher shadow price steel
An increased shadow price for steel results in different orders for best to worst option.
For the columns, the best option remains to be concrete. However, now timber is a better option for a design lifespan of 50 years than steel. For a design life span of 200 years, both with function "office" and "meeting", the difference between the shadow prices for steel and timber have become very small. For the original function there is still a slight advantage for steel, whereas timber has a marginal benefit for the "meeting" function.
For the beams, however, steel remains to be the best option, no matter the lifespan. For a lifespan of 50 years, none the less, the difference between the shadow prices of steel and timber has become small.

With the increased shadow price for the steel beams and columns included in the calculation for the total shadow price, the steel option now is the worst, instead of the best option, when choosing one material. Besides, the difference between the shadow price for the steel option and the best and concrete option has increased. For a lifespan of 50 years, the difference with the timber option is also noticeable. For a lifespan of 200 years, however, steel and timber are comparable in terms of environmental impact.

Higher shadow price concrete
An increased shadow price for the concrete columns and beams does not have an impact on the order of best to worst option for those columns and beams. However, the difference in shadow prices for the columns does decrease and for the beams it increases. This results in concrete slightly becoming the worst option for a lifespan of 50 years, and becoming more comparable to timber, with a marginal advantage for concrete, for a lifespan of 200 years.

Higher shadow price timber
For the columns, nothing changes for the favourability in materials with an increased shadow price for timber. The difference with the other two materials just increases, which means that timber just becomes an even worse option. With a lifespan of 50 years, the order of best to worst option for the beams also remains the same. However, the difference to the steel option increases and to the concrete option decreases, making steel even more favourable. For the beams with a 200-year lifespan, concrete and timber exchange their favourability, in favour of concrete. Nevertheless, steel remains to be the best choice.
When the shadow prices of all elements are added together, the order of best to worst option does not change. Timber just becomes a more significantly worse option for a one-material structural design.

5.6 Comparison with other research

It is important to see how the results coming from this research compare to the results of other researches. In order to do this, the master thesis by G.J. Lankhorst (2018) will be used. In his report a comparison with literature is made. Overall, the conclusion of that comparison is that the results of his research are comparable to the results from the literature. Therefore, it is sufficient to only compare this research with his.
A comparison with a timber structure has not been found. Therefore, only steel and concrete will be analysed in this chapter. A remark on the results for the timber structures has been made in chapter 7.1.

The following things were found in the research of Lankhorst, among other things:

- Using only cradle-to-gate data for the LCA calculation, steel structures have a 6 to 35% higher environmental impact, compared to concrete structures
- Floors are responsible for a big part of the total environmental impact, in his research it was 32 to 73%
- Fire resistant materials only have a small contribution to the total environmental impact
- Of all the floor types analysed, the hollow core slab floors emerged to have the lowest environmental impact

Almost all these findings are similar to the findings in this research:

- The floors have the biggest contribution to the total shadow price, namely 53%
- The fire-resistant measures only marginally increase the shadow price of the main load-bearing structure
- The hollow core slab floor emerged to be the best option in this research

Even though the difference in shadow prices is marginal, this research showed that steel is more favourable than concrete in terms of environmental impact, unlike the research of Lankhorst.
The shadow prices per kilogram used in his research are comparable to the ones used in this research. However, for concrete he has used a volumetric weight of 2400 kg/m^3 and has added the shadow price of the reinforcement separately. In this research the volumetric weight of concrete has been assumed to be 2500 kg/m^3 and the shadow price for the reinforcement has also been added separately. This means that in this research a higher weight, and therefore a higher shadow price has been determined for the concrete elements.

Besides, in the research of Lankhorst not only columns, beams and floors, but also the stability of the building has been considered. It showed that in general the concrete stability measures result in a lower environmental impact than the steel stability measures. The only exceptions are outrigger structures for buildings with a height of 150 and 200 meters. With these stability measures not taken into account, the results for favourability can differ.
Both these aspects are probable explanations for the difference in preference between the research of Lankhorst and this research.

6. Conclusion

The originally designed main load-bearing structure for the building for the European Patent Office consists mainly of steel columns and beams, and Slimline floors. The total shadow price for the main load-bearing structure for this building is €1.119.378,11. As alternatives for the beams and columns, steel, concrete and timber elements are analysed. Hollow core slabs and Lignatur floors are considered as alternatives for the Slimline floors.

For the columns, concrete appears to be the best option and timber the worst. For the beams, however, concrete is the worst and steel the best option. This relationship in favourability is the same for a lifespan of 50 years as well as for a lifespan of 200 years. Besides, the hollow core slab floor emerges to be the best option to reduce the shadow price. The Lignatur floor has an even higher shadow price than the original Slimline floor.

Since it is not always desirable to have different materials in one structure, 4 options have been determined; the best option with not one particular material, an entire steel option, an entire concrete structure, and an entire timber structure. For all four options the hollow core slab floor has been used. This resulted in the following shadow prices:

Table 31 New shadow prices for optimisation for 50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 697.968,33	62%	€ 0,174
Steel	€ 732.708,44	65%	€ 0,183
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 777.118,71	69%	€ 0,194

Table 32 New shadow prices for optimisation for 200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 700.727,86	63%	€ 0,044
Steel	€ 736.625,65	66%	€ 0,046
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 831.529,96	74%	€ 0,052

Table 33 New shadow prices for optimisation for 200 years with the function "meeting"

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 727.537,10	65%	€ 0,045
Steel	€ 766.547,82	68%	€ 0,048
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 871.076,64	78%	€ 0,054

It can be seen that the shadow prices for all optimized options are comparable, with a small difference leading to steel being marginally better than concrete, which in its turn is slightly better than timber. Besides, all new shadow prices are lower than the original shadow price.

When looking at the shadow prices per m^2 per year, it can be seen that it is beneficial to use a longer lifespan. The reduction of this factor, when comparing a 200-year lifespan to one of 50 years, is 3,73 to 3,98 times for the function “office”. This is almost equal to the normal reduction due to the increased lifespan, which would be 4 times.
When doing the same comparison, but now with the function “meeting” for the 200-year lifespan, a similar reduction can be found. The reduction now is 3,59 to 3,87 times. The slightly smaller reduction has to do with the slightly bigger increase in shadow price due to the higher live load.

In order to determine the sensitivity of the shadow prices for the order of preference of the materials, three scenarios have been examined; 25% higher shadow price for steel, 25% higher shadow price for concrete, and 25% higher shadow price for timber. These three scenarios show that concrete remains favourite for columns and steel for beams. With an increased shadow price for concrete or timber, steel remains to be the best option for choosing one material for the entire structure, even though the differences in shadow prices are small. When steel has an increased shadow price, this is not the case. Now concrete is de best and steel the worst option for a one-material structure. The difference between the shadow prices is also still small for this scenario.

It must, however, be taken into account that in the original structural design a second load path had also been designed. This has not been considered in the optimisation. With this taken into account, the profiles and dimensions of the various elements would be bigger, leading to a higher shadow price, and therefore a smaller reduction is to be expected.

As additional information, there has been looked at the effect on the shadow prices when taking the benefits of recycling or reusing the materials after their life cycle into account. This results in a lower shadow price for the timber and steel elements, whereas concrete does not benefit from this. The shadow prices with this taken into account are presented below. It can be seen that the order of best to worst option is now different than before. Steel still is the best option, with timber being slightly worse, but concrete is now the worst option and the difference to the other two materials is more significant.

Table 34 New shadow prices for optimisation for 50 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 632.354,51	56%	€ 0,158
Steel	€ 632.354,51	56%	€ 0,158
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 656.457,54	59%	€ 0,164

Table 35 New shadow prices for optimisation for 200 years with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 634.249,65	57%	€ 0,040
Steel	€ 634.249,65	57%	€ 0,040
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 683.411,93	61%	€ 0,043

Table 36 New shadow prices for 200-year optimisation, function "meeting" with category D

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 648.735,76	58%	€ 0,041
Steel	€ 648.735,76	58%	€ 0,041
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 703.002,67	63%	€ 0,044

To summarise, in this research it has been found that the environmental impact of the main load-bearing structure of a high-rise building can be reduced by:

1. Prolonging the design lifespan of the building
   Even though a little more material is needed for the various elements of the main load-bearing structure, the environmental impact per year is much lower for a lifespan of 200 years than for a lifespan of 50 years. In order to gain this advantage, however, the longer lifespan must be guaranteed.

2. Designing with a higher live load
   In order to increase the chance of a longer lifespan for the building, it is wise to create flexibility concerning the function of the building. This can be achieved by using a higher live load than required for the original function. A higher live load will lead to a slightly higher shadow price, but it will still result in a lower shadow price per year, i.e. a lower environmental impact.

3. Choosing the best material for each application
   Even though the shadow prices of an entire steel, timber or concrete structure are quite similar, it can be seen that with the shadow prices coming from the NIBE database, using only the production stage of the life cycle, an entire steel structure or a combination of steel beams and concrete columns is the best option for a structure with a lifespan of 200 years. For a design lifespan of 50 years the difference in shadow prices is such small, that no preference can be determined.
   For floors with a big span and where no in-situ concrete can be used, hollow core slab floors proved to be the best choice.

7. Discussion and recommendations

7.1 Discussion

This research has not taken into consideration the effect different materials have on the dead load. For instance, as mentioned before, for one column that has been optimized for a lifespan of 50 years, the steel option weighs 439,2 kg, while the concrete column weighs 562,5 kg, and the timber option 575,64 kg. This means that the dead load would be lower for steel elements compared to concrete and timber elements. With this taken into account in the optimisations, it might be the case that the timber and concrete option emerge to have higher shadow prices, since the minimum required dimensions might be bigger. Besides, the self-weight of the elements also influences the foundation. The higher the loads, the higher the forces on the foundation. This means that the shadow price for the foundation will probably be higher for a concrete or timber structure than for a steel structure.

For all beams and columns in timber and concrete, the dimensions are determined to be in multiples of 50 mm, with the biggest difference in width and height being 100 mm. For the beams, in which bending moments are usually governing, it might be better to try different ratios in width and height. This could possibly reduce the shadow prices for the concrete and timber beams.

In this thesis the fire resistance of the elements has been designed after selecting the most favourable profiles and dimensions. The results of the most favourable steel profiles might be different when implementing the fire resistance from the start and selecting the profiles at the end. The required amount of Promatect varies with different profiles, which means that the shadow price of the best profile plus Promatect might be different from the best profile including Promatect. The results for the new shadow prices may also be different when using different fire-resistant measures than the ones that have been used in this research. However, the chosen measures are commonly used and as can be seen, their impact on the total shadow price is marginal.

The fire-resistant measures that have been applied in the original design have not been taken into account in the shadow price. This possibly means that the original shadow price may be higher. With the new shadow prices remaining as they are, a bigger reduction would be the result. However, as is shown in this report, the effect of the fire-resistant measures is marginal, which would probably mean that the above-mentioned effect will be relatively small.

It must be taken into consideration that the designed steel profiles in the original design all have similar, not too big dimensions. This creates a calm and open structure throughout the entire building. The optimized profiles and dimensions all have different dimensions, with some being relatively big, especially concrete and timber elements. This might be in contrast with the aesthetical desires for a building. Besides, incorporating relatively big elements may complicate the construction process, which would make these big elements undesirable.

It is generally considered that timber is a more sustainable material than steel and concrete. This research, however, shows that timber has a bigger environmental impact. This has to do with the fact that glued laminated timber has been used. When considering the same timber quality, but then massif instead of laminated, the shadow price per kg is now €0,0282 instead of €0,0595. This means that the shadow price reduces by 47%. With this new shadow price per kg for the timber elements, timber is the most favourable option for both the columns and beams. However, it would not be possible to use massif timber elements, due to the required dimensions of the elements. In The Netherlands, the normally used maximum dimensions of massif timber elements are 71x271 mm and 96x196 mm (width x height). These dimensions are not sufficient for most elements in this research. For low-rise buildings, however, this might be an option.

7.2 Recommendations

Since a façade of a building can have a big influence on the environmental impact of the total building and the building for the European Patent Office has a relatively large façade area, it could be interesting to do a same analysis as is done in this master thesis, only then for the façade, as it has different load types on the elements.

In this research, the focus has been on the main load-bearing structure, whereas the set limit for the maximum shadow price per m^2 per year is for all products and construction materials used in a building. In order to see how well a building performs regarding to this limit, it is therefore wise to determine the shadow price of the entire building. Besides, it would provide a good insight in how big the impact of the main load-bearing structure is for the total shadow price.

Even though the shadow price for the foundation has a relatively small impact on the total shadow price, it might be interesting to analyse how a foundation can have less environmental impact. In that way, more sustainable decisions can be made for all elements in a main load-bearing structure when designing one.

As for the elements optimised in this research, a few recommendations can be given. The case study has shown that for columns loaded by a relatively high compressive normal force, as is usually the case in high-rise buildings, concrete is the best option with the lowest shadow price. For the beams, with mainly bending moments as loads, steel is preferable. When it is desirable to design the beams and columns in the same material, steel would be a slightly better option. As for floors with a large span in high-rise buildings, hollow core slab floors have the lowest environmental impact.

These recommendations, however, only hold for the above-mentioned conditions.
With lower normal forces or with normal forces and bending moments combined, the preferred material for the columns might be different. For lower normal forces, timber will probably result in a lower shadow price, mainly due to the fact that massif elements would then be an option.

For the floors it is possible that other types would lead to lower shadow prices. For this to be possible, smaller spans and/or lower building heights are required. It is also possible to use different types of floors in one building, by using floors with lower shadow prices in the lower floors and hollow core slabs in the higher floors. With smaller spans the Lignatur will most likely be more efficient, which could possibly lead to a lower shadow price than for the hollow core slab floors.

When it is reasonable to believe that the materials used in the main load-bearing structure will be reused or recycled after their use in the building it is designed for, category D can be taken into account. For the columns and beams this would mean that steel is the option with the lowest shadow price. It must be kept in mind that these recommendations also only hold for the above-mentioned conditions.

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Calculations from Zonneveld Ingenieurs from which information is gathered:

- 3.X.X.XC-X-B3.60-K1 date: 03-11-2017
- 3.X.X.XC-X-B3.60-K2 date: 03-11-2017
- 3.X.X.XC-X-B3.60-V3 date: 03-11-2017
- 3.X.X.XC-X-B3.60-V6 date: 03-11-2017

Drawings from Zonneveld Ingenieurs from which information is gathered:

- 3.2.M.7C-21-B2.55-X-w-260 date: 01-09-2015
- 3.2.M.7C-21-B2.55-X-w-261 date: 29-09-2015
- 3.2.M.7C-21-B2.55-X-w-263 date: 02-10-2015
- 3.2.M.7C-21-B2.55-X-w-260 date: 01-09-2015
- 3.2.M.7C-21-B2.55-X-w-263 date: 02-10-2015
- 0.3.M.4C-PD-B1.10-01-b-220 date: 10-04-2015
- 0.3.M.4C-PD-B1.10-X-b-500 date: 21-10-2016
- 0.3.M.4C-PD-B1.10-X-b-501 date: 21-10-2016
- 0.3.M.4C-PD-B1.10-X-b-502 date: 21-10-2016
- 0.3.M.4C-PD-B1.10-X-b-503 date: 07-02-2017
- 0.3.M.4C-PD-B1.10-X-b-504 date: 08-11-2016

Appendices

A. Table used to determine the shadow prices

Table 37 Determining the shadow prices

Material/Product	Amount per impact category per kg materiaal/product										Shadowprice per kg material/product	Source
	ADP	GWP	ODP	HTP	FWAE	MAE	TE	PO	AP	EP		
	kg Sb eq	kg CO_2 eq	kg CFC-11 eq	kg 1.4-DB eq	kg 1.4-DB eq	kg 1.4-DB eq	kg 1.4-DB eq	kg C_2H_4	kg SO_2 eq	kg PO_4 eq		
	€ 0,16	€ 0,05	€ 30,00	€ 0,09	€ 0,03	€ 0,0001	€ 0,06	€ 0,06	€ 4,00	€ 9,00	€	
Concrete C20/25 CEM III	0,00027	0,09327	4,42E-09	0,01026	0,00217	3,57293	0,00018	7,40E-06	0,00022	0,00004	€ 0,0073	1
Concrete C30/37 CEM III	0,00028	0,09449	4,50E-09	0,01042	0,0022	3,62712	0,00018	7,53E-06	0,00023	0,00004	€ 0,0074	1
Concrete C35/45 CEM III	0,00028	0,09549	4,58E-09	0,01051	0,00219	3,63709	0,00018	7,62E-06	0,00023	0,00004	€ 0,0075	1
Concrete C55/67 CEM I - CEM III	0,00033	0,11803	5,19E-09	0,01193	0,00237	3,96361	0,00022	8,86E-06	0,00026	0,00005	€ 0,0090	1
Grout	0,00072	0,252	4,30E-09	0,0221	0,00052	3,67	0,00069	0,00006	0,00059	0,00011	€ 0,0185	2
Promatect	0,00088	0,113	1,59E-08	0,0296	0,00051	1,93	0,00019	0,00003	0,00029	0,00004	€ 0,0101	2
Reinfocing steel	0,00761	1,37	9,36E-09	0,0272	0,00128	3,95	0,00182	0,00047	0,00189	0,00033	€ 0,0833	2
Steel	0,00512	0,908	1,55E-08	0,0333	0,00302	6,34	0,00047	0,00033	0,00338	0,00037	€ 0,0669	2
Steel category D	-0,00272	-0,512	-3,72E-09	-0,00885	-0,00187	-1,78	-0,00014	-0,00018	-0,00151	-0,00015	€ -0,0345	2
Steel sheets	0,014	2,59	0,00	0,116	0,00292	13,30	0,001	0,00123	0,00663	0,0006	€ 0,1757	2
Timber D70	0,00387	0,533	6,60E-08	0,216	0,00599	30,10	0,0027	0,00036	0,0034	0,00066	€ 0,0696	2
Timber GL28h	0,00333	0,458	6,02E-08	0,197	0,00722	16,60	0,00178	0,00059	0,00288	0,00053	€ 0,0595	2
Timber categorie D	-0,00361	-0,443	-4,05E-08	-0,0392	-0,00115	-4,60	-0,00028	-0,00007	-0,00058	-0,00010	€ -0,0300	2

Source 1: Excel file: “National database environmental impacts incl FA-GWW-Steel BmS_Eng.xls”, made by R. Scholtes, date 8 April 2010
Source 2: NIBE database “Environmental Profiles”, date 26 April 2019

The following types of materials from NIBE has been used:

Grout	188 – Grout
Promatect	21 – Gypsum, Rogypsum
Reinforcing steel	257 – Steel, Reinforcement [VWN]
Steel	137 – Steel, Heavy Construction Products (beams, columns)
Steel category D	WNL1008D – Steel Heavy Construction Products – BmS (MRPI) – D
Steel sheets	140 – Steel, Medium Construction Products (lintels, road barriers)
Timber D70	420 – African hardwood, dried (12 – 16%), rough sawn, from sustainable managed forest [VVNH]
Timber GL28h	29 – Wood, soft, laminated, from sustainable managed forest (460 kg/m^3)
Timber category D	WNL0017D – Wood, contamined (i.a. painted, preserved) – D

B. E-mail contact with Prof.ir. A.C.W.M. Vrouwenvelder

From: Elise Booms [mailto:elisebooms@hotmail.com]
Sent: woensdag 12 juni 2019 16:11
To: Ton Vrouwenvelder - CITG
Subject: Veiligheidsfactoren constructie 200 jaar

Beste meneer Vrouwenvelder,

Voor mijn afstudeerproject kijk ik naar een constructie met een ontwerp levensduur van 50 en 200 jaar. De constructieonderdelen waar ik naar kijk staan in een binnen situatie en hebben daardoor niet tot nauwelijks te maken met materiaalaantasting.

Voor de constructie met een ontwerp levensduur van 200 jaar neem ik onderstaande mee om een hogere veranderlijke belasting te bepalen. Ik ben er echter op geattendeerd door mijn begeleiders dat ik daarnaast ook andere veiligheidsfactoren moet toepassen, zowel aan de belasting- als aan de materiaalkant. Voor dit laatste hebben ze me naar u doorverwezen. Mijn vraag aan u is dan ook of u documentatie en/of formules heeft waar ik naar kan kijken om deze veiligheidsfactoren te bepalen, zodat ik op de juiste manier de dimensies voor de constructie kan bepalen.

(2) Karakteristieke waarden van de veranderlijke belastingen voor gebouwen in NEN-EN 1991 zijn in het algemeen gebaseerd op een ontwerplevensduur van 50 jaar. Indien ontwerplevensduren afwijkend van de ontwerplevensduur van 50 jaar zijn gebruikt, mogen de extreme waarden van gelijkmatig verdeelde belastingen zijn aangepast. In een aantal gevallen zijn daarvoor regels opgenomen in de desbetreffende normbladen in de reeks NEN-EN 1991, zoals voor:

— sneeuwbelasting in bijlage D NEN-EN 1991-1-3+C1;

— windbelasting in opmerking 4 van 4.2 NEN-EN 1991-1-4+A1+C2;

— thermische belastingen in bijlage A.2 NEN-EN 1991-1-5+C1.

Indien NEN-EN 1991 geen regels geeft, zoals bij vloerbelasting, mag zijn uitgegaan van:

$$F_t = F_{t_0}\left(1 + \frac{1-\psi_0}{9}\ln\left(\frac{t}{t_0}\right)\right)$$

waarin:

F_t is de aangepaste extreme waarde van de veranderlijke gelijkmatig verdeelde belasting bij de referentieperiode die hoort bij de gekozen ontwerplevensduur;

F_{t_0} is de extreme waarde van de veranderlijke gelijkmatig verdeelde belasting bij de basisreferentieperiode;

OPMERKING Het gaat hier om de basisreferentieperiode die hoort bij de ontwerplevensduur van een nieuwbouwplan (meestal 50 jaar).

ψ_0 is de ψ_0-factorwaarde [1)] te ontlenen aan tabel NB.2 – A1.1 respectievelijk NB.9 – A2.1;

t is de referentieperiode die hoort bij de gekozen ontwerplevensduur;

t_0 is de basisreferentieperiode.

OPMERKING Het gaat hier om de basisreferentieperiode die hoort bij de ontwerplevensduur van een nieuwbouwplan (meestal 50 jaar).

Ik hoor graag van u.

Met vriendelijke groet,
Elise Booms

Vrouwenvelder, A.C.W.M. (Ton) <ton.vrouwenvelder
@tno.nl>
Ma 24-6-2019 12:09
U; Ton Vrouwenvelder - CITG

Beste Mevr Booms

Volgens de Nationale Bijlage bij Eurocode EN 1990 moet voor elke constructie in gevolgklasse CC 2 een betrouwbaarheidsindex van 3,8 voor de geplande levensduur worden aangehouden. De geplande levensduur mag daarbij niet lager worden gekozen dan 15 jaar, maar dat is voor u niet van belang.

In de methode van de partiele factoren is dat in Nederland uitgewerkt door de karakteristieke belastingen van variabele belastingen te verhogen bij een langere beoogde levensduur; de partiele factoren blijven gelijk.

Uiteraard kan men hetzelfde bereiken door de karakteristieke belastingen gelijk te houden en de factoren aan te passen. Een uitwerking die beide doet is mij niet bekend.
Mogelijk is men in de war met een eventuele aanpassing van de doelbetrouwbaarheid in gevel van een CC3 - constructie. Hier hoort volgens de theorie een aanpassing bij van alle factoren. In de praktijk van de Eurocode heeft men ervoor gekozen de aanpassing van de materiaalfactoren te verwerken in de aanpassing van de belastingfactoren.

In de hoop dat dit u helpt.

A Vrouwenvelder

C. Burning rate timber

From NEN-EN 1995-1-2:2005 en:

$$d_{char,0} = \beta_0 \, t \qquad (3.1)$$

where:

$d_{char,0}$ is the design charring depth for one-dimensional charring;

β_0 is the one-dimensional design charring rate under standard fire exposure;

t is the time of fire exposure.

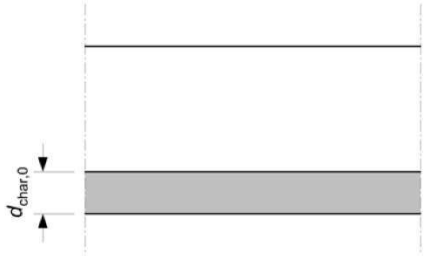


Figure 3.1 — One-dimensional charring of wide cross section (fire exposure on one side)

Table 3.1 – Design charring rates β_0 and β_n of timber, LVL, wood panelling and wood-based panels

	β_0 mm/min	β_n mm/min
a) Softwood and beech		
Glued laminated timber with a characteristic density of ≥ 290 kg/m^3	0,65	0,7
Solid timber with a characteristic density of ≥ 290 kg/m^3	0,65	0,8
b) Hardwood		
Solid or glued laminated hardwood with a characteristic density of 290 kg/m^3	0,65	0,7
Solid or glued laminated hardwood with a characteristic density of ≥ 450 kg/m^3	0,50	0,55
c) LVL		
with a characteristic density of ≥ 480 kg/m^3	0,65	0,7
d) Panels		
Wood panelling	0,9[a]	–
Plywood	1,0[a]	–
Wood-based panels other than plywood	0,9[a]	–
[a] The values apply to a characteristic density of 450 kg/m^3 and a panel thickness of 20 mm; see 3.4.2(9) for other thicknesses and densities.		

The timber that is used in this research is glued laminated timber, softwood or beech, with a volumetric weight of more than 290 kg/m^3. This means that the burning rate of the timber is 0,65 mm/min.

D. Minimum required concrete cover fire

Columns

From NEN-EN 1992-1-2:2005 en:

There are two methods for determining the minimum concrete cover, method A and B. In this report method A has been used.

Table 5.2a: Minimum column dimensions and axis distances for columns with rectangular or circular section

Standard fire resistance	Minimum dimensions (mm) Column width b_{min}/axis distance a of the main bars			
	Column exposed on more than one side			Exposed on one side
	$\mu_{fi} = 0.2$	$\mu_{fi} = 0.5$	$\mu_{fi} = 0.7$	$\mu_{fi} = 0.7$
1	2	3	4	5
R 30	200/25	200/25	200/32 300/27	155/25
R 60	200/25	200/36 300/31	250/46 350/40	155/25
R 90	200/31 300/25	300/45 400/38	350/53 450/40**	155/25
R 120	250/40 350/35	350/45** 450/40**	350/57** 450/51**	175/35
R 180	350/45**	350/63**	450/70**	230/55
R 240	350/61**	450/75**	-	295/70

** Minimum 8 bars

For prestressed columns the increase of axis distance according to 4.2.2. (4) should be noted.

For this report: R120

μ = design load in the fire situation / design load at normal temperature conditions

This results in: μ = 0,640 for 50 years

μ = 0,660 for 200 years

μ = 0,792 for 200 years with function “meeting”

It was chosen to use the values belonging to μ = 0,7.

Beams

Table 5.5: Minimum dimensions and axis distances for simply supported beams made with reinforced and prestressed concrete

Standard fire resistance	Minimum dimensions (mm)						
	Possible combinations of a and b_{min} where a is the average axis distance and b_{min} is the width of beam				Web thickness b_w		
					Class WA	Class WB	Class WC
1	2	3	4	5	6	7	8
R 30	b_{min}= 80 a = 25	120 20	160 15*	200 15*	80	80	80
R 60	b_{min}= 120 a = 40	160 35	200 30	300 25	100	80	100
R 90	b_{min}= 150 a = 55	200 45	300 40	400 35	110	100	100
R 120	b_{min}= 200 a = 65	240 60	300 55	500 50	130	120	120
R 180	b_{min}= 240 a = 80	300 70	400 65	600 60	150	150	140
R 240	b_{min}= 280 a = 90	350 80	500 75	700 70	170	170	160
a_{sd} = a + 10mm (see note below)							

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

a_{sd} is the axis distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of b_{min} greater than that given in Column 4 no increase of a_{sd} is required.

* Normally the cover required by EN 1992-1-1 will control.

R120 must be used. For dimensions bigger than 500 mm, a minimum concrete cover of 50 mm has been taken into account.

E. Types of columns in basement

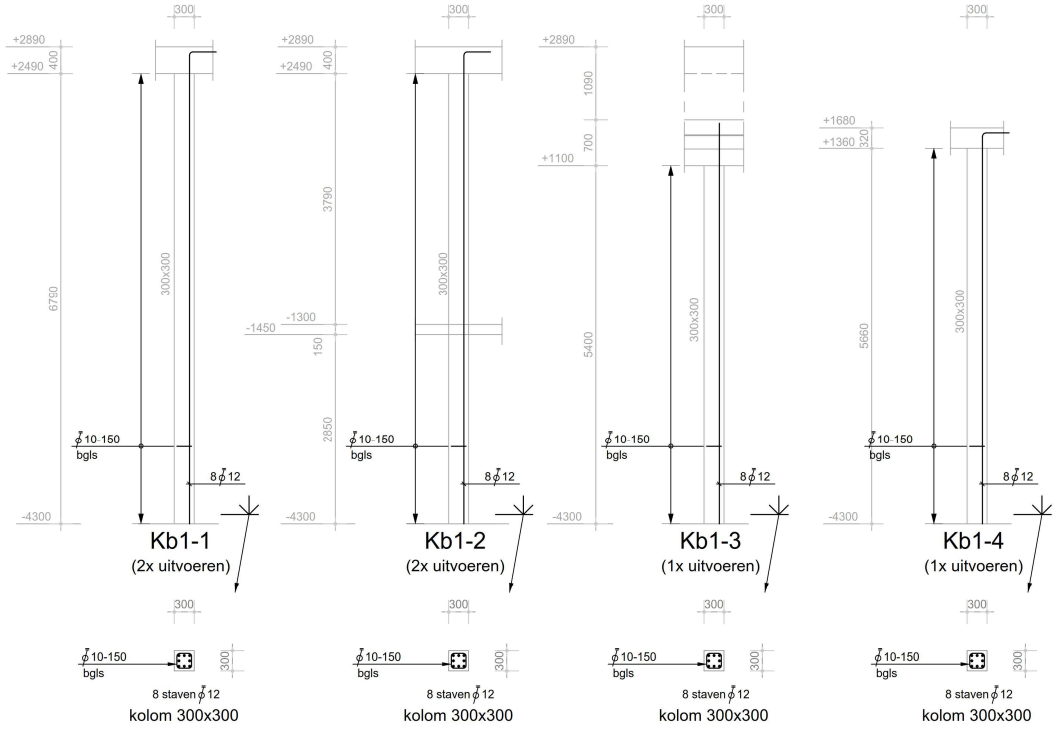


Figure 7 Columns type KB1-1 to Kb1-4

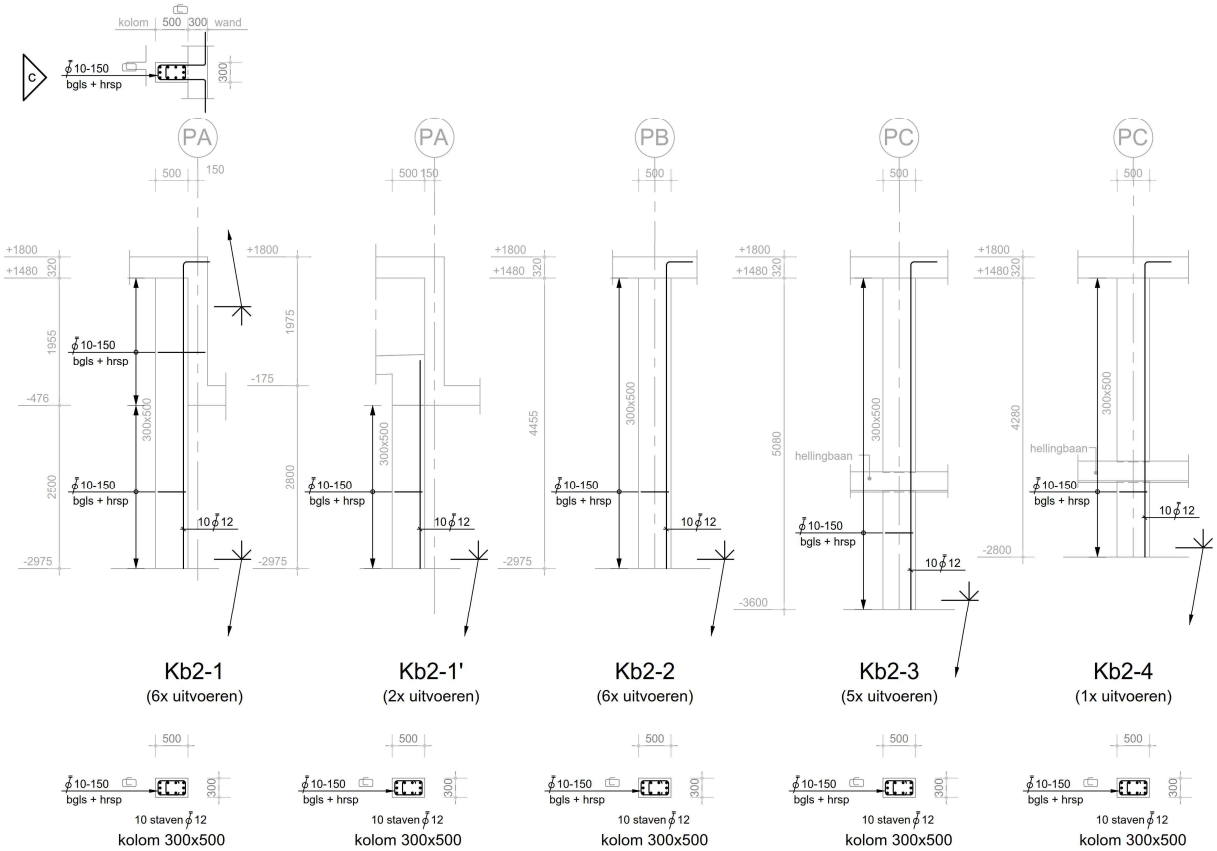


Figure 8 Column type Kb2-1 to Kb2-4

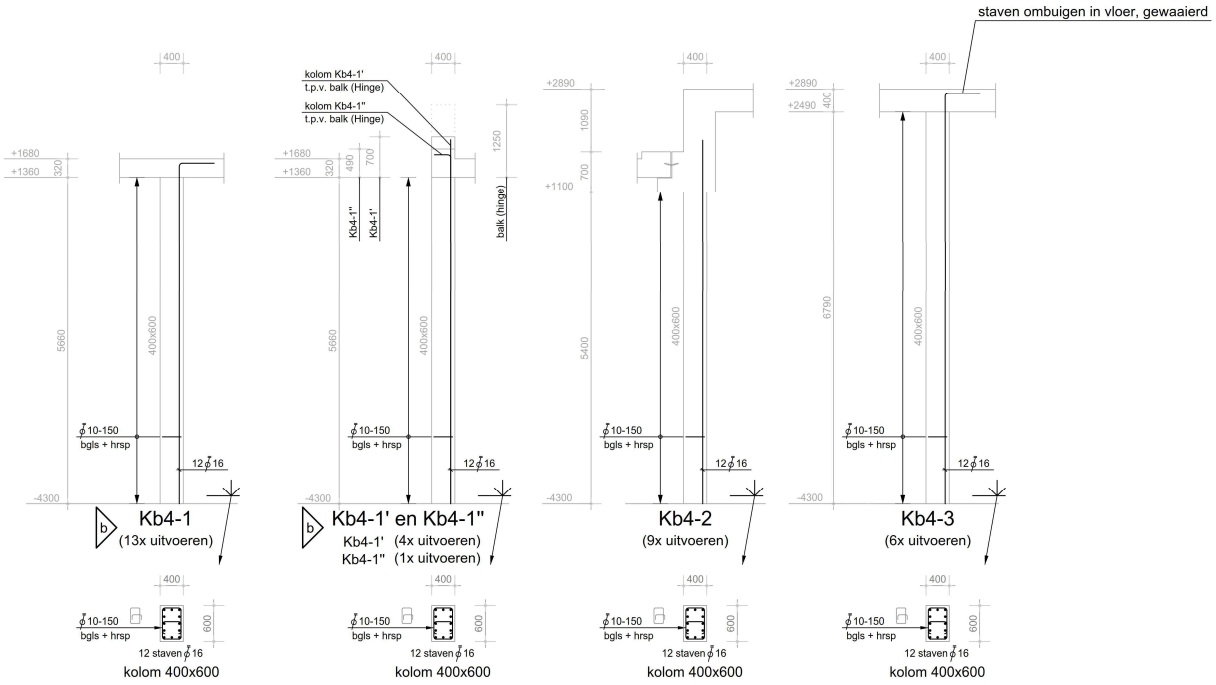


Figure 9 Columns type Kb4-1 to Kb4-3

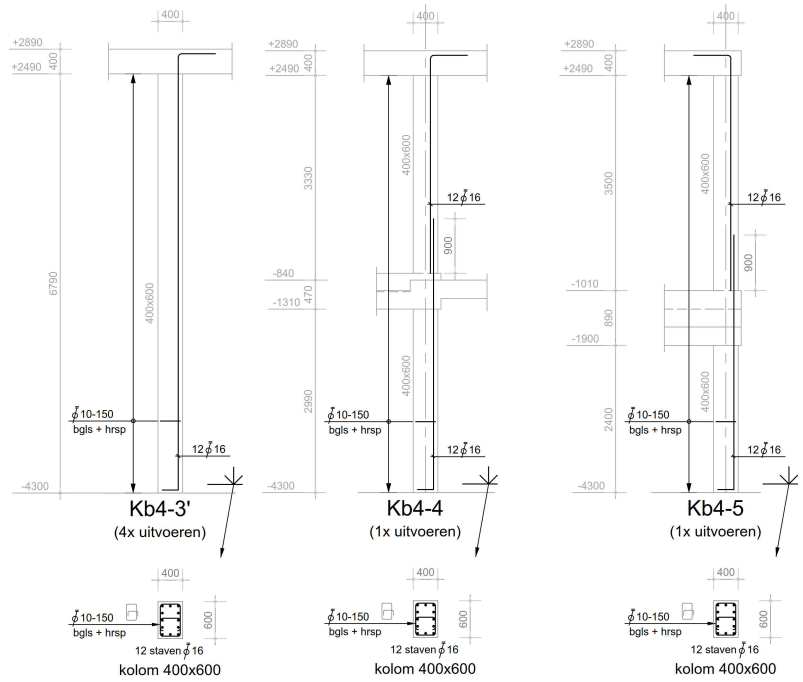


Figure 10 Column type Kb4-3' to Kb4-5

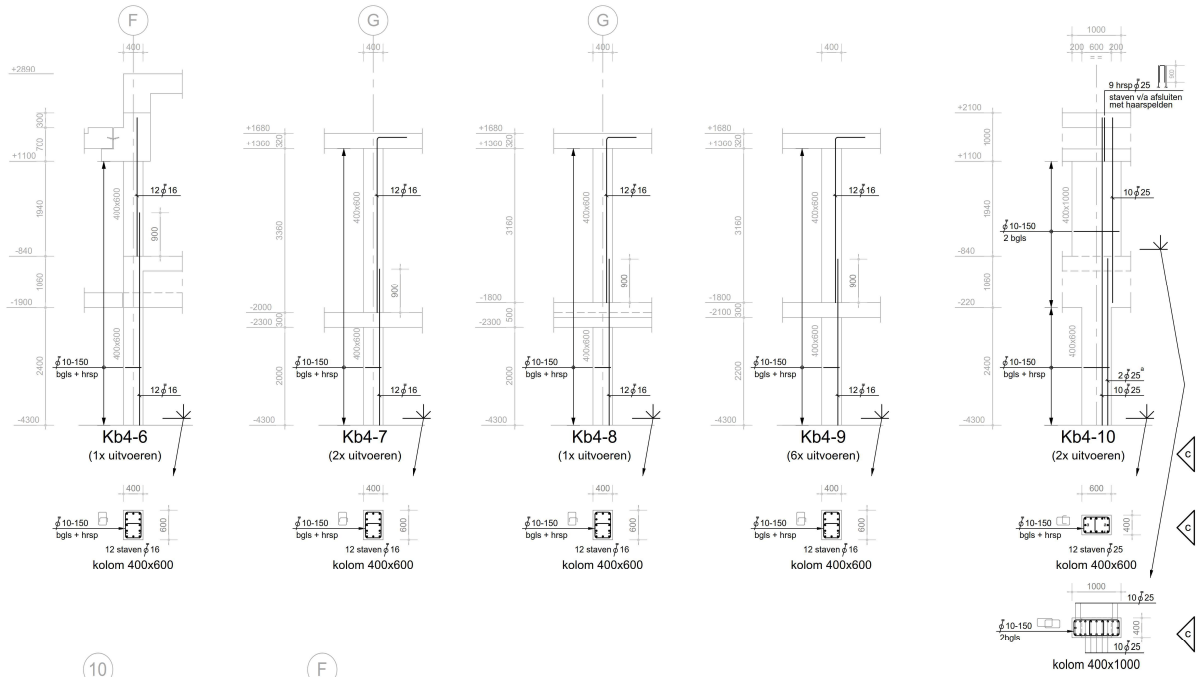


Figure 11 Columns type Kb4-6 to Kb4-10

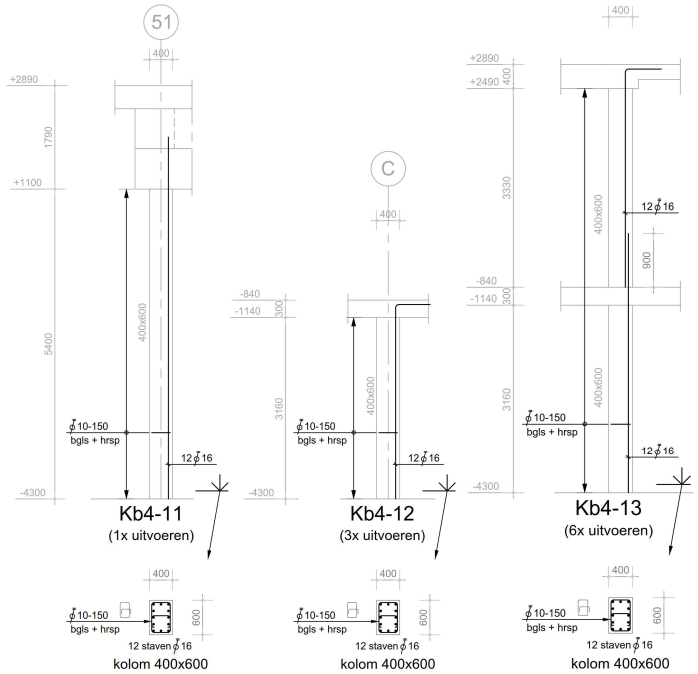


Figure 12 Columns type Kb4-11 to Kb4-13

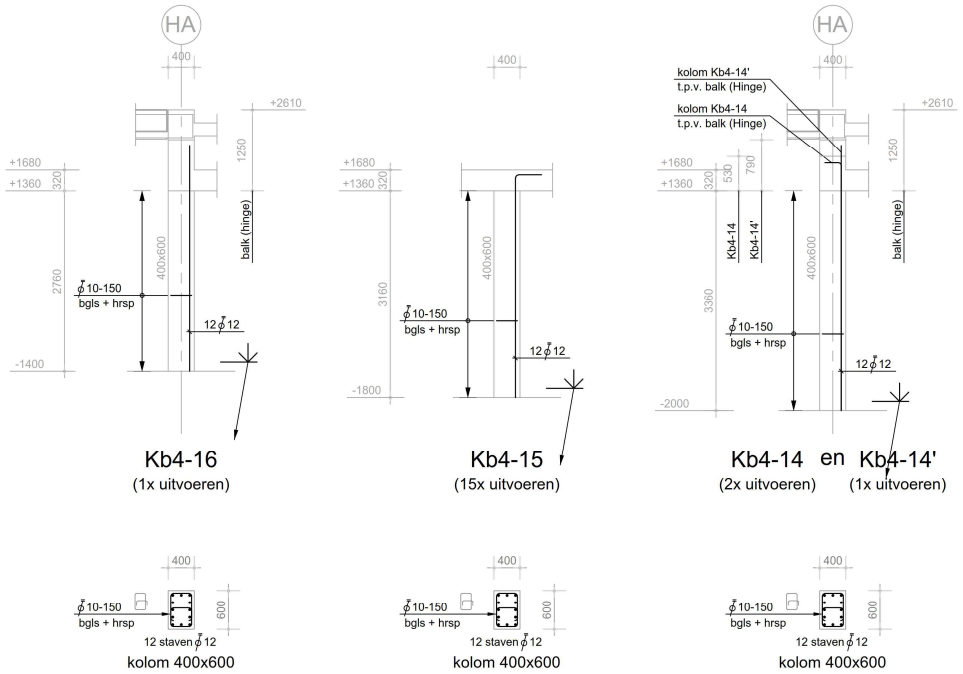


Figure 13 Column type Kb4-14 to Kb4-16

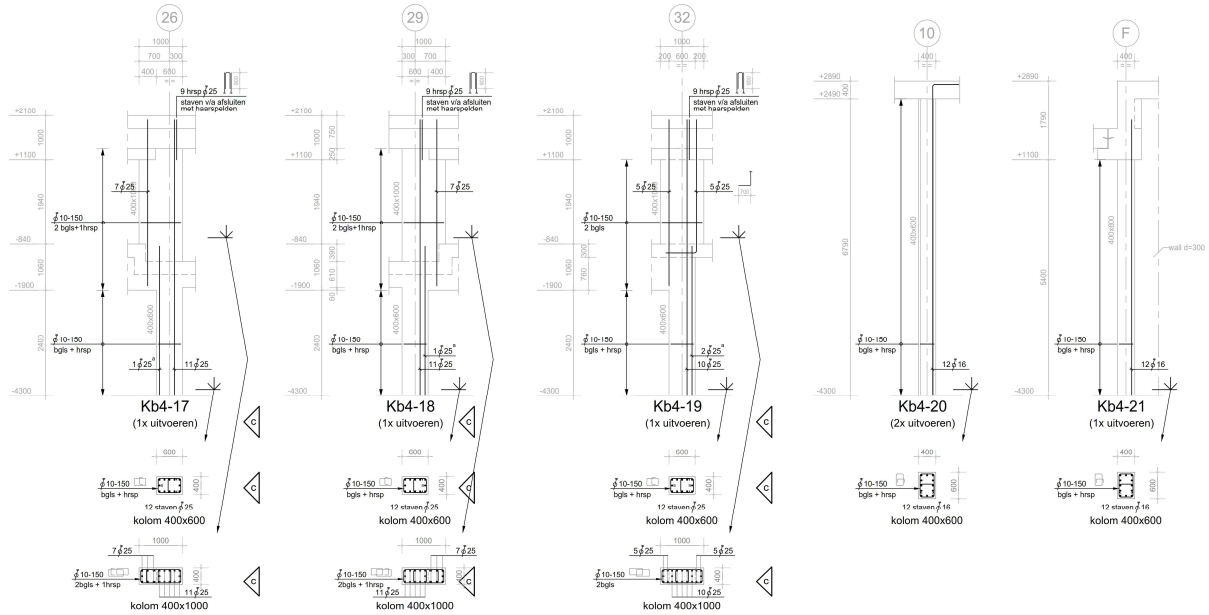


Figure 14 Columns type Kb4-17 to Kb4-21

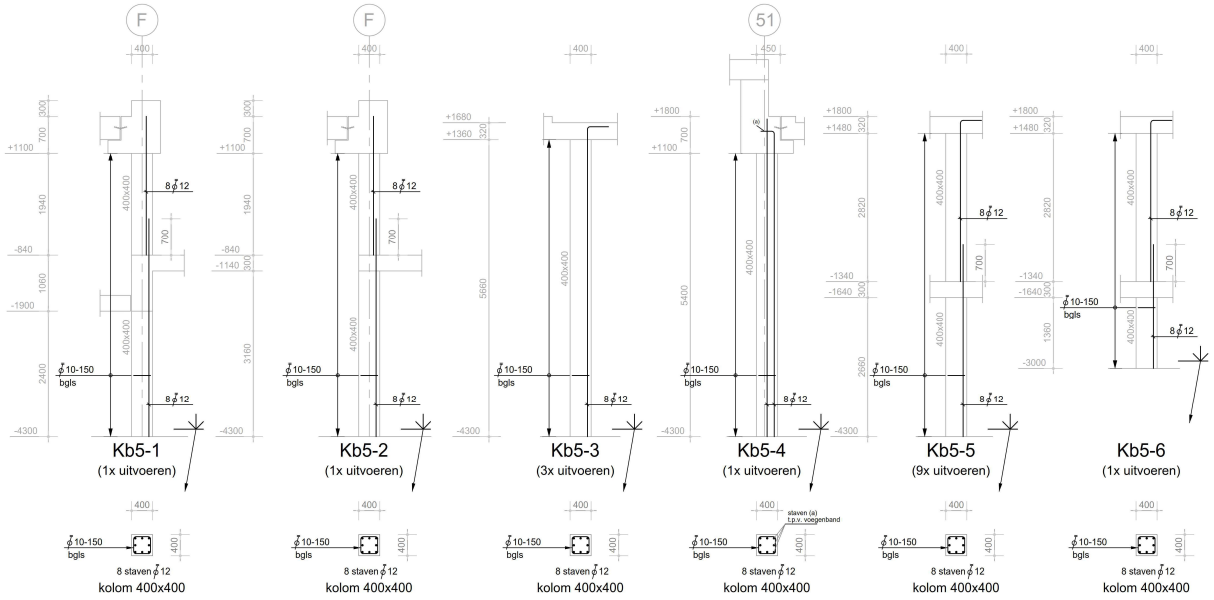


Figure 15 Column type Kb5-1 to Kb5-6

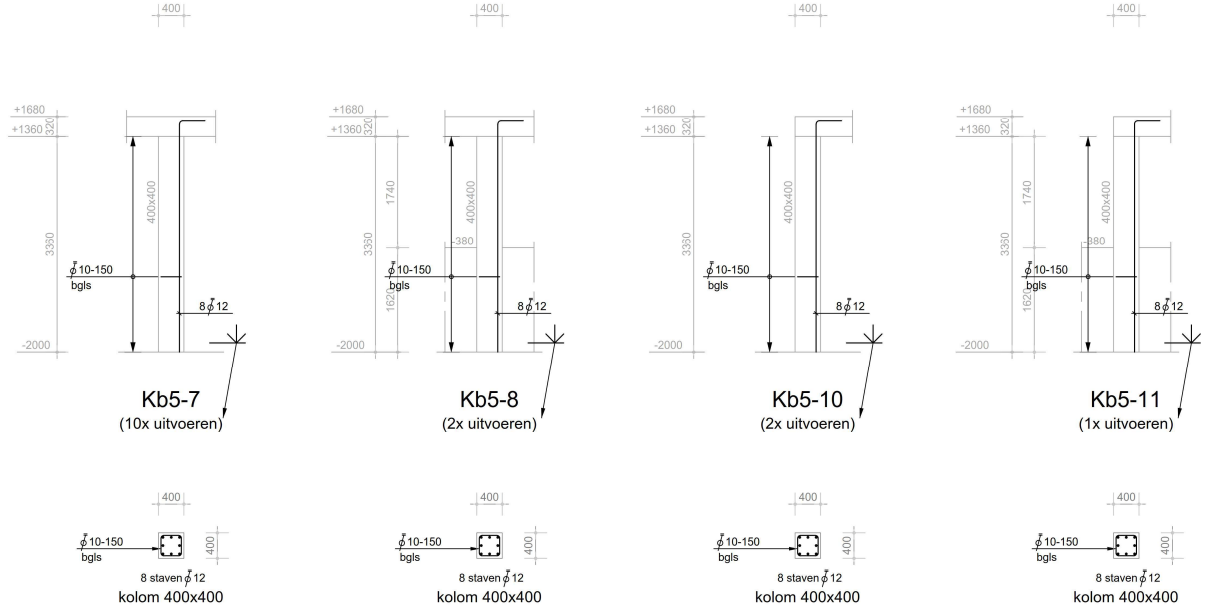


Figure 16 Column type Kb5-7, Kb5-8, Kb5-10 and Kb5-11

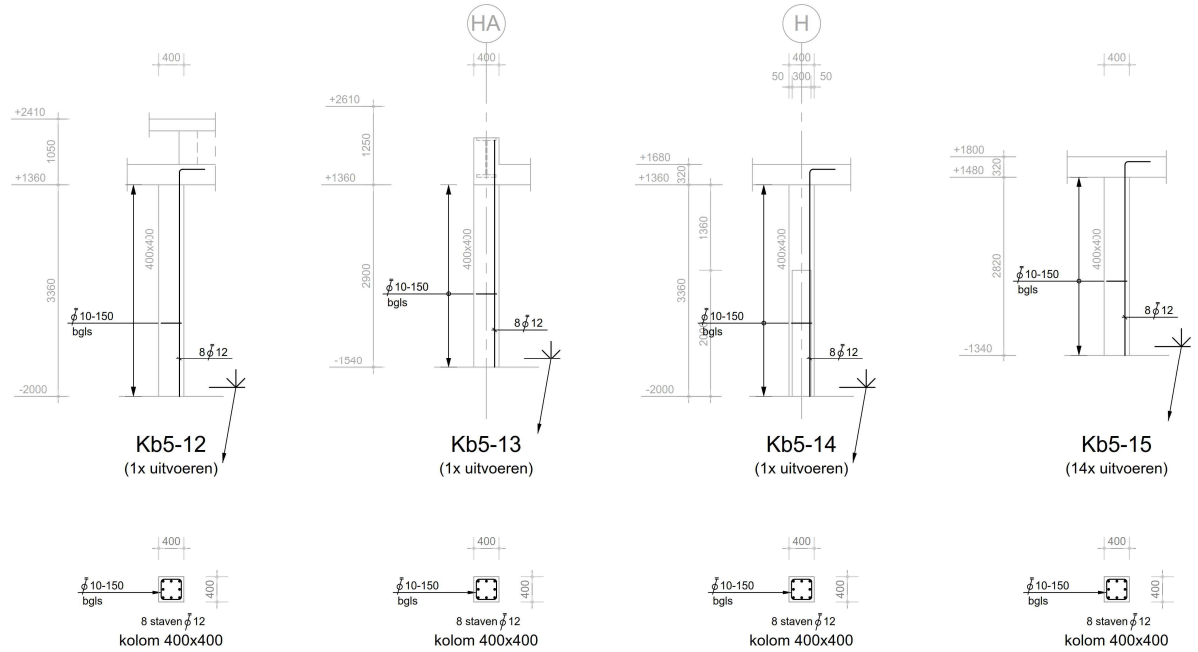


Figure 17 Column type Kb5-12 to Kb5-15

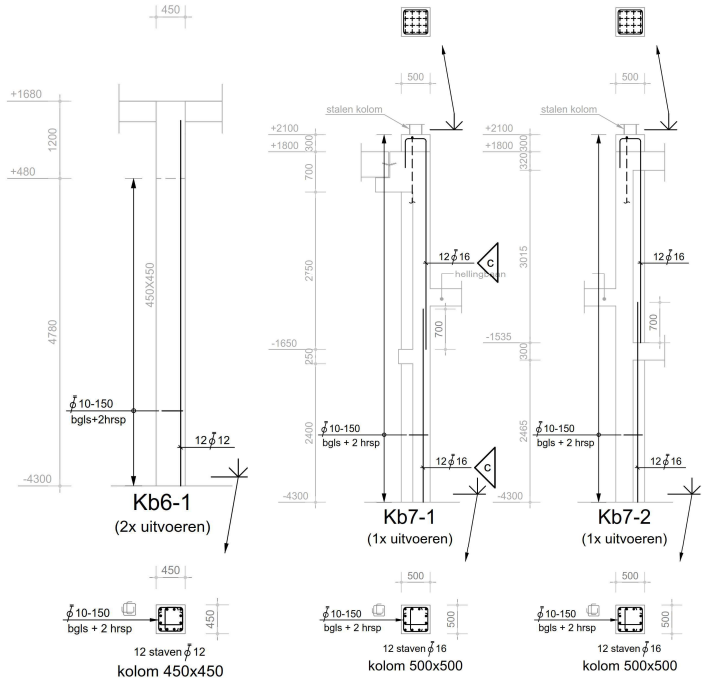


Figure 18 Column type Kb6-1, Kb7-1 and Kb7-2

Table 38 Overview columns basement level -1

Amount	Type	Length x width [mm]	Height [m]	Volume [m^3]	Weight [kg] (volume*amount*2500)
2	Kb1-1	300x300	6,8	0,612	3060
2	Kb1-2	300x300	6,8	0,612	3060
1	Kb1-3	300x300	5,4	0,486	1215
1	Kb1-4	300x300	5,66	0,5094	1273,5
6	Kb2-1	300x500	4,46	0,669	10035
2	Kb2-1’	300x500	2,8	0,42	2100
6	Kb2-2	300x500	4,46	0,669	10035
5	Kb2-3	300x500	5,08	0,762	9525
1	Kb2-4	300x500	4,28	0,642	1605
13	Kb4-1	400x600	5,66	1,3584	44148
4	Kb4-1'	400x600	5,66	1,3584	13584
1	Kb4-1''	400x600	5,66	1,3584	3396
9	Kb4-2	400x600	5,4	1,296	29160
6	Kb4-3	400x600	6,8	1,632	24480
4	Kb4-3’	400x600	6,8	1,632	16320
1	Kb4-4	400x600	6,8	1,632	4080
1	Kb4-5	400x600	6,8	1,632	4080
1	Kb4-6	400x600	5,4	1,296	3240
2	Kb4-7	400x600	5,66	1,3584	6792
1	Kb4-8	400x600	5,66	1,3584	3396
6	Kb4-9	400x600	5,66	1,3584	20376
2	Kb4-10	400x600	5,4	1,296	6480
1	Kb4-11	400x600	5,4	1,296	3240
3	Kb4-12	400x600	3,16	0,7584	5688
6	Kb4-13	400x600	6,8	1,632	24480
1	Kb4-17	400x600	5,4	1,296	3240
1	Kb4-18	400x600	5,4	1,296	3240
1	Kb4-19	400x600	5,4	1,296	3240
2	Kb4-20	400x600	6,8	1,632	8160
1	Kb4-21	400x600	5,4	1,296	3240
1	Kb5-1	400x400	5,4	0,864	2160
1	Kb5-2	400x400	5,4	0,864	2160
3	Kb5-3	400x400	5,66	0,9056	6792
1	Kb5-4	400x400	5,4	0,864	2160
9	Kb5-5	400x400	5,78	0,9248	20808
1	Kb5-6	400x400	4,48	0,7168	1792
2	Kb6-1	450x450	5,66	1,14615	5730,75
1	Kb7-1	500x500	5,4	1,35	3375
1	Kb7-2	500x500	5,78	1,445	3612,5
113					**324558,75**

Table 39 Overview columns basement level 0

Amount	Type	Length x width [mm]	Height [m]	Volume [m^3]	Weight [kg] (volume*amount*2500)
2	Kb4-14	400x600	3,36	0,8064	4032
1	Kb4-14'	400x600	3,36	0,8064	2016
4	Kb4-15	400x600	3,16	0,7584	7584
1	Kb4-16	400x600	2,76	0,6624	1656
10	Kb5-7	400x400	3,36	0,5376	13440
2	Kb5-8	400x400	3,36	0,5376	2688
2	Kb5-10	400x400	3,36	0,5376	2688
1	Kb5-11	400x400	3,36	0,5376	1344
1	Kb5-12	400x400	3,36	0,5376	1344
1	Kb5-13	400x400	2,9	0,464	1160
1	Kb5-14	400x400	3,36	0,5376	1344
14	Kb5-15	400x400	2,82	0,4512	15792
40					**55088**

F. Beams and columns in original design

Table 40 Overview profiles beams

Overview profiles beams	G [kg/m]	L [m]	g [kg]	% g
HD400x262	262	288	75456	3,82%
HD400x382	382	102,6	39193,2	1,98%
HD400x509	509	36	18324	0,93%
HD400x551	551	224,4	123644,4	6,26%
HE450AA	99,7	224,3	22362,71	1,13%
HE500AA	107	2814	301098	15,23%
HE550AA	120	3095,4	371448	18,79%
HE650AA	138	1017	140346	7,10%
HEA120	19,9	400	7960	0,40%
HEA200	42,3	164,9	6975,27	0,35%
HEA240	60,3	167,8	10118,34	0,51%
HEA260	68,2	624	42556,8	2,15%
HEA280	76,4	3,2	244,48	0,01%
HEA360	112	122,5	13720	0,69%
HEA400	125	286	35750	1,81%
HEA450	140	802,4	112336	5,68%
HEA550	166	590	97940	4,95%
HEA550 (S460)	166	23,6	3917,6	0,20%
HEA600	178	533,4	94945,2	4,80%
HEA650	190	840,8	159752	8,08%
HEB300	117	24	2808	0,14%
HEB400	155	264	40920	2,07%
HEB450	171	501,9	85824,9	4,34%
HEB600	212	281,4	59656,8	3,02%
HEB650	225	299,8	67455	3,41%
HEM450	263	86,4	22723,2	1,15%
HEM700	301	23,6	7103,6	0,36%
K160x80x10	33,7	356,4	12010,68	0,61%
Total			1976590,18	

Table 41 Overview profiles columns

Overview profiles columns	G [kg/m]	L [m]	g [kg]	% g
200x200x10	58,8	10,8	635,04	0,01%
HD260x68.2	68,2	59,4	4051,08	0,09%
HD400x1086	1086	2788,2	3027985,2	68,77%
HD400x187	187	902,9	168842,3	3,83%
HD400x262	262	423	110826	2,52%
HD400x287	287	19,8	5682,6	0,13%
HD400x314	314	428,4	134517,6	3,06%
HD400x421	421	570,6	240222,6	5,46%
HD400x463	463	1062	491706	11,17%
HD400x592	592	61,2	36230,4	0,82%
HD400x634	634	108	68472	1,56%
HD400x744	744	126,9	94413,6	2,14%
HEA100	16,7	193	3223,1	0,07%
HEB140	24,7	75,2	1857,44	0,04%
HEB360	142	14,1	2002,2	0,05%
K120x120x8	27,6	196,6	5426,16	0,12%
K200x200x10	58,8	41,1	2416,68	0,05%
K250x250x10	74,5	25,2	1877,4	0,04%
K300x300x10	90,2	27	2435,4	0,06%
Total			4402822,8	

G. Example calculation

Column HD400x262 at level 9
Determinant force: N = -9355 kN (compression)
L = 3,6 m

HD400x262: A = 33460 mm^2; G = 262 kg/m; Shadow price/kg = €0,0669
$A_{ben} = N*10^3/\sigma = 9355*10^3/460 = 20336,96\ mm^2$
u.c. = A_{ben}/A = 20336,96/33460 = 0,61
Check for flexural buckling: $u.c._y$ = 0,63 $u.c._z$ = 0,66
g = G*L = 262*3,6 = 943,2 kg
Shadow price = shadow price/kg*g = 0,0669*943,2 = €63,10

Best optimisation: concrete 500x550 (C55/67) with reinforcement 4ø16+12ø12;
shadow price = €27,22
The shadow price of the optimized column is 43,14% of the shadow price of the original column.

Optimisation in steel:
Best option: K350x350x16; shadow price = €39,98

Flexural buckling in z direction is governing, so only this unity check will be presented below. A_{ben} stays the same for all steel profiles, so will not be determined again per profile.

HEA650: A = 24164 mm^2; G = 190 kg/m; Shadow price/kg = €0,0669
u.c. = A_{ben}/A = 20336,96/24146 = 0,842
Check for flexural buckling: u.c. = 0,97
g = G*L = 190*3,6 = 684 kg
Shadow price = shadow price/kg*g = 0,0669*684 = €45,76

HEB500: A = 23864 mm^2; G = 187 kg/m; Shadow price/kg = €0,0669
u.c. = A_{ben}/A = 20336,96/23864 = 0,852
Check for flexural buckling: u.c. = 0,97
g = G*L = 187*3,6 = 673,2 kg
Shadow price = shadow price/kg*g = 0,0669*673,2 = €45,04

HEM300: A = 30308 mm^2; G = 238 kg/m; Shadow price/kg = €0,0669
u.c. = A_{ben}/A = 20336,96/30308 = 0,671
Check for flexural buckling: u.c. = 0,78
g = G*L = 238*3,6 = 856,8 kg
Shadow price = shadow price/kg*g = 0,0669*856,8 = €57,32

K350x350x16: A = 21101 mm^2; G = 166 kg/m; Shadow price/kg = €0,0669
u.c. = A_{ben}/A = 20336,96/21101 = 0,964
Check for flexural buckling: u.c. = 0,99
g = G*L = 166*3,6 = 597,6 kg
Shadow price = shadow price/kg*g = 0,0669*597,6 = €39,98

Optimisation in concrete:
Best option: 500x550 (C55/67) with reinforcement 4ø16+12ø12; shadow price = €27,22

850x850 (C20/25): A = 722500 mm^2; G = 1806,25 kg/m; Shadow price/kg = €0,0073
$A_{ben} = N*10^3/\sigma = 9355*10^3/13,33 = 701625\ mm^2$
u.c. = $A_{ben}/A = 701625/722500 = 0,971$
g = G*L = 1806,25*3,6 = 6502,5 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0073*6502,5] + [0,0833*60,65] = €52,57

700x700 (C30/37): A = 490000 mm^2; G = 1225 kg/m; Shadow price/kg = €0,0074
$A_{ben} = N*10^3/\sigma = 9355*10^3/20 = 467750\ mm^2$
u.c. = $A_{ben}/A = 467750/490000 = 0,955$
g = G*L = 1225*3,6 = 4410 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0074*4410] + [0,0833*60,65] = €37,74

650x650 (C35/45): A = 422500 mm^2; G = 1056,25 kg/m; Shadow price/kg = €0,0075
$A_{ben} = N*10^3/\sigma = 9355*10^3/23,33 = 400929\ mm^2$
u.c. = $A_{ben}/A = 400929/422500 = 0,949$
g = G*L = 1056,25*3,6 = 3802,5 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0075*3802,5] + [0,0833*60,65] = €33,51

500x550 (C55/67): A = 275000 mm^2; G = 687,5 kg/m; Shadow price/kg = €0,0090
$A_{ben} = N*10^3/\sigma = 9355*10^3/36,67 = 255136\ mm^2$
u.c. = $A_{ben}/A = 255136/275000 = 0,928$
g = G*L = 687,5*3,6 = 2475 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0090*2475] + [0,0833*60,65] = €27,22

Optimisation in timber:
Best option: 700x700 (GL28h); shadow price = €43,02

700x700 (GL28h): A = 490000 mm^2; G = 200,9 kg/m; Shadow price/kg = €0,0595
$A_{ben} = N*10^3/\sigma = 9355*10^3/19,5 = 479744\ mm^2$
u.c. = A_{ben}/A = 479744/490000 = 0,979
g = G*L = 200,9*3,6 = 723,24 kg
Shadow price = shadow price/kg*g = 0,0595*723,24 = €43,02

450x500 (D70): A = 225000 mm^2; G = 202,5 kg/m; Shadow price/kg = €0,0696
$A_{ben} = N*10^3/\sigma = 9355*10^3/42 = 222738\ mm^2$
u.c. = A_{ben}/A = 222738/225000 = 0,990
g = G*L = 202,5*3,6 = 729 kg
Shadow price = shadow price/kg*g = 0,0696*729 = €50,74

H. Calculation with higher concrete classes

High strength concrete (C90/105) and ultra-high strength concrete (compressive strength after 28 days = 188 MPa) are considered. Since the concrete classes in the excel file mentioned in Appendix A only go up to C70/85, the shadow prices are determined by means of the composition of the concrete. The composition for C90/105 has been determined by dr. ir. M. Ottele from Delft University of Technology. For the concrete with a strength of 188 MPa the source is (Fehling, Schmidt, & Stürwald, 2008)

It was chosen to get a first impression of the shadow prices before determining it in detail. Because it did not prove to be beneficial to use these types of concrete, the shadow prices have not been determined in detail.
The determination of the shadow prices per kilogram materials, just like in Appendix A, can be found at the end of this appendix.

C90/105

For this concrete class, not all transportation distances were known. It was chosen to use one distance for the sand and steel fibres, which originate from Denmark and Norway. This distance is 1200 km, which is approximately the distance from Oslo by ship.

Table 42 Determining shadow price per m³ for C90/105

Material	G [kg/m³]	Shadow price/kg	Shadow price/m³
0,1-1,5 mm sand from Denmark	284	€ 0,0014	€ 0,38
2-4 mm sand from Norway	1260	€ 0,0014	€ 1,70
Microsilica	427	€ 0,0005	€ 0,19
Cement CEM-I 52,5R	445	€ 0,0722	€ 32,13
Water	142	€ 0,00004	€ 0,01
Steel fibres 0,4x12,5 mm from Denmark	75	€ 0,1929	€ 14,47
Transportation from Oslo (1200 km) per kg goods		€ 0,00996	
0,1-1,5 mm sand			€ 2,83
2-4 mm sand			€ 12,55
Steel fibres			€ 0,75
Total			**€ 65,01**

Since the volumetric weight of concrete is 2500 kg/m³, the shadow price per kg is €65,01/2500 = €0,026.

188 MPa

The transportation distance has been kept the same for the sand that will be used in this concrete class.

Table 43 Determining shadow price per m³ for 188 MPa

Material	G [kg/m³]	Shadow price/kg	Shadow price/m³
Quartz sand	975	€ 0,0014	€ 1,32
Quartz flour	207	€ 0,0014	€ 0,28
Microsilica	135	€ 0,0005	€ 0,06
Cement CEM-I 52,5R	832	€ 0,0722	€ 60,07
Water	166	€ 0,00004	€ 0,01
Superplasticizer I	35	€ 0,0889	€ 3,11
Transportation from Oslo (1200 km) per kg goods		€ 0,00996	
Quartz sand			€ 9,71
Quarts flour			€ 2,06
Total			**€ 76,62**

The shadow price per kg is €76,62/2500 = €0,0306.

Calculation with higher concrete classes

C90/105
400x400 (C90/105): A = 160000 mm^2; G = 400 kg/m; Shadow price/kg = €0,0260
$A_{ben} = N*10^3/\sigma = 9355*10^3/60,0 = 155917\ mm^2$
u.c. = $A_{ben}/A = 155917/160000 = 0,974$
g = G*L = 400*3,6 = 1440 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0260*1440] + [0,0833*60,65] = €42.49

188 MPa
350x350 (C188): A = 122500 mm^2; G = 306,25 kg/m; Shadow price/kg = €0,0306
$A_{ben} = N*10^3/\sigma = 9355*10^3/125,33 = 74640,96\ mm^2$
u.c. = $A_{ben}/A = 74640,96/90000 = 0,829$
g = G*L = 306,25*3,6 = 1102,5 kg
Reinforcement: 4ø16+12ø12; A = 2160; G = 16,848 kg/m Shadow price/kg = €0,0833
A_{ben} = 2151,7 mm^2; u.c. = $A_{ben}/A = 2151,7/2160 = 0,996$
g = G*L = 16,848*3,6 = 60,65 kg
Shadow price = $[\text{shadow price/kg*g}]_{concrete} + [\text{shadow price/kg*g}]_{reinforcement}$
= [0,0306*1102,5] + [0,0833*60,65] = €38,79

It must be kept in mind that these determined shadow prices per kg material are not complete, since, for instance, the transportation of the cement and the impact of the process have not been taken into account. With this taken into account, the shadow prices per kg would be higher. Regardless, the shadow prices for the columns are still higher than for the columns in lower concrete qualities, as can be seen in Appendix G.

Table with determination shadow prices

Table 44 Determining the shadow prices

Material/Product	Amount of impact categories per kg materiaal/product										Shadowprice per kg material/product	Source
	ADP	GWP	ODP	HTP	FWAE	MAE	TE	PO	AP	EP		
	kg Sb eq	kg CO_2 eq	kg CFC-11 eq	kg 1.4-DB eq	kg 1.4-DB eq	kg 1.4-DB eq	kg 1.4-DB eq	kg C_2H_4	kg SO_2 eq	kg PO_4 eq	€	
	€ 0,16	€ 0,05	€ 30,00	€ 0,09	€ 0,03	€ 0,0001	€ 0,06	€ 0,06	€ 4,00	€ 9,00		
Sand 0,1-1,5 mm	7,40E-05	0,0106	1,85E-09	0,00363	5,22E-05	0,179	8,61E-06	7,4021E-06	7,69E-05	1,72E-05	€ 0,0014	2
Sand 2-4 mm	7,40E-05	0,0106	1,85E-09	0,00363	5,22E-05	0,179	8,61E-06	7,4021E-06	7,69E-05	1,72E-05	€ 0,0014	2
Microsilica	3,77E-05	0,0049	4,87E-10	8,99E-04	1,62E-05	0,0651	1,75E-05	2,17E-06	1,89E-05	4,28E-06	€ 0,0005	2
Cement CEMI 52,5R	0,00201	1,12	9,61E-09	0,0551	0,00157	8,25	0,00176	0,00012	0,00156	0,00041	€ 0,0722	2
Water	2,63E-06	3,69E-04	3,49E-11	0,00012	2,48E-06	0,00931	4,01E-06	2,07E-07	1,90E-06	2,49E-07	€ 0,00004	2
Steel fibres 0,4x12,5 mm	0,014	1,9	9,00E-08	0,61	0,028	62	0,029	0,0013	0,0061	0,00083	€ 0,1929	1
Quartz sand	7,40E-05	0,0106	1,85E-09	0,00363	5,22E-05	0,179	8,61E-06	7,4021E-06	7,69E-05	1,72E-05	€ 0,0014	2
Quartz flour	7,40E-05	0,0106	1,85E-09	0,00363	5,22E-05	0,179	8,61E-06	7,4021E-06	7,69E-05	1,72E-05	€ 0,0014	2
Superplasticizer I	0,00808	0,724	9,60E-08	0,0744	0,0294	9,1	0,00034	0,00141	0,00967	0,00046	€ 0,0889	2
Transport per ship	0,00017	0,025	2,90E-09	0,018	0,00033	2,2	6,00E-05	2,90E-05	0,00055	0,00033	€ 0,0083	3

The above-mentioned shadow price per kilogram for transport per ship is per tkm (tonne kilometre). Since the distance used in this project is 1200 km, the shadow price has been multiplied by 1,2: 0,0083*1,2 = 0,00996.

Source 1: Excel file: “National database environmental impacts incl FA-GWW-Steel BmS_Eng.xls”, made by R. Scholtes, date 8 April 2010
Source 2: NIBE database “Environmental Profiles”, date 26 April 2019
Source 3: Excel file: “CUR groenbeton dataset”, made by H. Jonkers, date 8 December 2017

The following types of materials from NIBE has been used:

Sand	253 – Sand, sieve [NVLB]
Microsilica	339 – Silica fume
Cement CEMI 52,5R	173 – CEM-I 52,5 R (NL)
Water	290 – Water – Tap water
Superplasticizer	180 – Superplasticisers, 30-45% active content

I. Calculations floors

Hollow core slab floor

The specifications for a hollow core slab floor with a thickness of 320 mm, in Dutch, are:

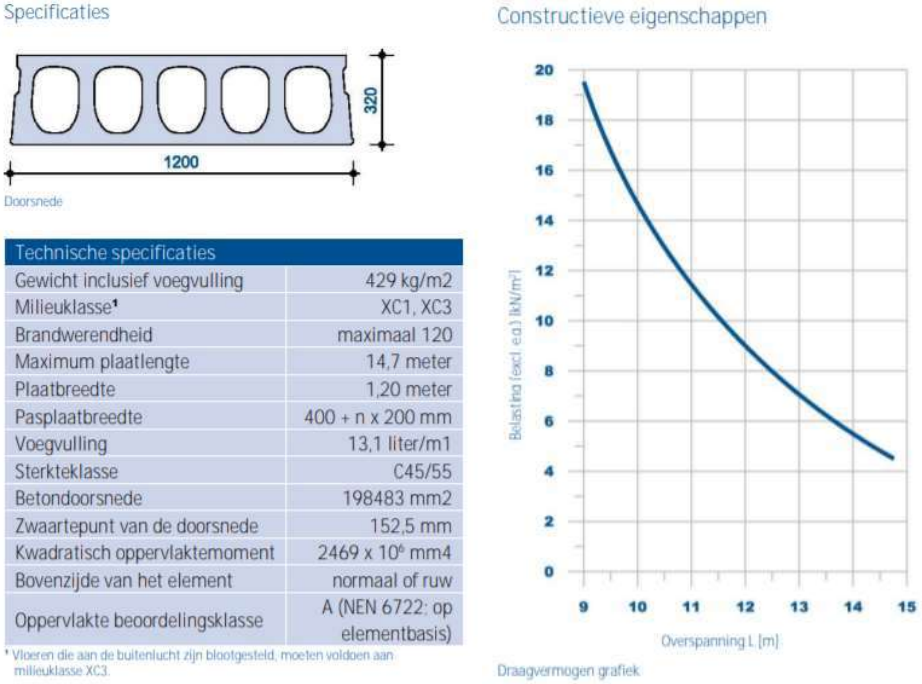


Figure 19 Specifications of hollow core slab

With a span of 11,5 m, the maximum load on the floor (excluding self-weight) is 10 kN/m^2. This is sufficient for the design loads for a lifespan of 50 years, as well as for 200 years.
As can be seen, the fire resistance is already 120 minutes. Therefore, no further measures had to be taken into account.

The total area of the Slimline floor for which the hollow core slab floor has been designed as alternative is 50.486,18 m^2. A hollow core slab floor consists of the slabs, with reinforcement in them, and a compression layer with reinforcement.
The amount of reinforcement inside the slabs has been determined with the website of VBI: https://www.vbi-techniek.nl/Product_Selector/Vloeren_selector#/ For this building, the required area of reinforcement is 617 mm^2/m^2, which is 4,8126 kg/m^2. The compression layer, with a thickness of 5 cm, has a self-weight of 125 kg/m^2.Lastly, the reinforcement in the compression layer weighs 1,021 kg/m^2.
This all results in the following shadow price for the hollow core slab floors:

Table 45 Shadow price hollow core slab floor

Material	G [kg/m^2]	g [kg]	Shadow price/kg	Shadow price
Hollow core slab floor (C45/55)	429	21658571,2	€ 0,0082	€ 177.600,28
Reinforcement in slabs	4,81	242969,8	€ 0,0833	€ 20.231,33
Compression layer (C30/37)	125	6310772,5	€ 0,0074	€ 46.783,53
Reinforcement in compression layer	1,021	51547,3	€ 0,0833	€ 4.292,18
Total				**€ 248.907,32**

With the shadow prices of the remaining floor that gives a total of €363.991,98. The original shadow price of the floors is €571.882,47, which means that the hollow core slab floors reduce the shadow price of the floors with 36%.

Lignatur floor

For the Lignatur floor, the following thicknesses with corresponding maximum loads are possible: (AG, 2014)

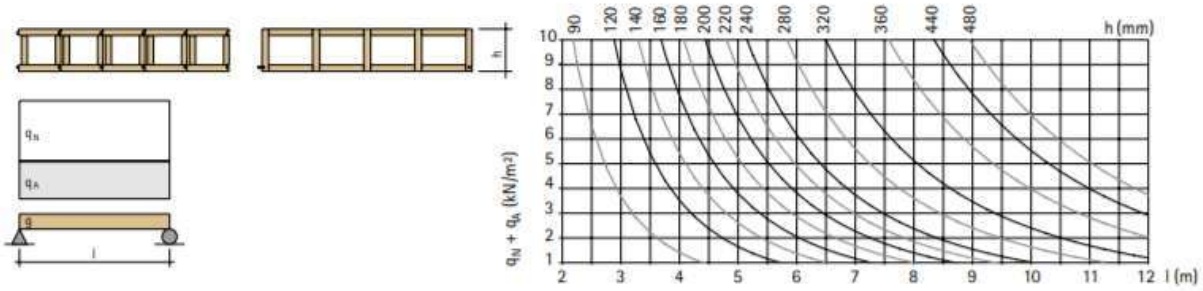


Figure 20 Specifications Lignatur floor

With a span of 11,5 m, the only option that fulfils the requirements for the loads, is a thickness of 480 mm. The floors have a self-weight of 200 to 600 kg/m^2. Considering that the biggest thickness has been chosen, the self-weight of 600 kg/m^2 has been used. The area for this floor type is the same as for the hollow core slabs, 50486,18 m^2, resulting in 30291708 kg. It is not known which type of timber is used for Lignatur floors, but it is known that it is laminated. Therefore, GL28h, with €0,0595/kg, will be considered. Thus, the shadow price for Lignatur floors is €1.802.095,48, which is 319% of the original shadow price.

This floor type does not have a fire resistance of 120 minutes from itself. Therefore, measures still have to be applied. However, since the shadow price is already higher than for the original floor type, this has not been done.

J. Tables with increased shadow prices

For the columns and beams, the shadow prices without fire safety measures are presented. This has been done to make a fair comparison with the normal shadow prices possible. For the total shadow prices the fire measures and the hollow core slab floors have been included.

Higher shadow price steel

Columns

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 80.004,84	27%	€ 0,020
Steel	€ 143.319,15	49%	€ 0,036
Concrete	€ 80.004,84	27%	€ 0,020
Timber	€ 119.382,42	41%	€ 0,030

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.189,20	28%	€ 0,005
Steel	€ 146.628,11	50%	€ 0,009
Concrete	€ 81.189,20	28%	€ 0,005
Timber	€ 149.616,24	51%	€ 0,009

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 95.973,86	33%	€ 0,006
Steel	€ 176.078,11	60%	€ 0,011
Concrete	€ 95.973,86	33%	€ 0,006
Timber	€ 175.949,83	60%	€ 0,011

200 years, meeting

Beams

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 99.823,15	76%	€ 0,025
Steel	€ 99.823,15	76%	€ 0,025
Concrete	€ 140.102,49	106%	€ 0,035
Timber	€ 103.691,97	78%	€ 0,026

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 101.413,36	77%	€ 0,006
Steel	€ 101.413,36	77%	€ 0,006
Concrete	€ 144.660,48	109%	€ 0,009
Timber	€ 129.063,00	98%	€ 0,008

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 109.208,48	83%	€ 0,007
Steel	€ 109.362,58	83%	€ 0,007
Concrete	€ 161.546,90	122%	€ 0,010
Timber	€ 143.978,79	109%	€ 0,009

200 years, meeting

Total

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 742.913,86	66%	€ 0,186
Steel	€ 842.170,00	75%	€ 0,211
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 777.118,71	69%	€ 0,194

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 746.388,67	67%	€ 0,047
Steel	€ 848.291,31	76%	€ 0,053
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 831.529,96	74%	€ 0,052

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 776.776,78	69%	€ 0,049
Steel	€ 895.043,82	80%	€ 0,056
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 871.076,64	78%	€ 0,054

200 years, meeting

Higher shadow price concrete

Columns

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 100.006,05	34%	€ 0,025
Steel	€ 114.655,32	39%	€ 0,029
Concrete	€ 100.006,05	34%	€ 0,025
Timber	€ 119.382,42	41%	€ 0,030

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 101.486,50	34%	€ 0,006
Steel	€ 117.302,49	40%	€ 0,007
Concrete	€ 101.486,50	34%	€ 0,006
Timber	€ 149.616,24	51%	€ 0,009

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 119.967,33	41%	€ 0,007
Steel	€ 140.862,49	48%	€ 0,009
Concrete	€ 119.967,33	41%	€ 0,007
Timber	€ 175.949,83	60%	€ 0,011

200 years meeting

Beams

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 79.858,52	60%	€ 0,020
Steel	€ 79.858,52	60%	€ 0,020
Concrete	€ 175.128,11	132%	€ 0,044
Timber	€ 103.691,97	78%	€ 0,026

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.130,69	61%	€ 0,005
Steel	€ 81.130,69	61%	€ 0,005
Concrete	€ 180.825,60	137%	€ 0,011
Timber	€ 129.063,00	98%	€ 0,008

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 87.366,78	66%	€ 0,005
Steel	€ 87.490,06	66%	€ 0,005
Concrete	€ 201.933,63	153%	€ 0,013
Timber	€ 143.978,79	109%	€ 0,009

200 years meeting

Total

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 717.969,54	64%	€ 0,179
Steel	€ 732.708,44	65%	€ 0,183
Concrete	€ 814.315,65	73%	€ 0,204
Timber	€ 777.118,71	69%	€ 0,194

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 721.101,24	64%	€ 0,045
Steel	€ 736.625,65	66%	€ 0,046
Concrete	€ 822.021,75	73%	€ 0,051
Timber	€ 831.529,96	74%	€ 0,052

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 753.021,21	67%	€ 0,047
Steel	€ 766.547,82	68%	€ 0,048
Concrete	€ 870.589,14	78%	€ 0,054
Timber	€ 871.076,64	78%	€ 0,054

200 years meeting

Higher shadow price timber

Columns

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 80.004,84	27%	€ 0,020
Steel	€ 114.655,32	39%	€ 0,029
Concrete	€ 80.004,84	27%	€ 0,020
Timber	€ 149.228,03	51%	€ 0,037

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.189,20	28%	€ 0,005
Steel	€ 117.302,49	40%	€ 0,007
Concrete	€ 81.189,20	28%	€ 0,005
Timber	€ 187.020,30	64%	€ 0,012

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 95.973,86	33%	€ 0,006
Steel	€ 140.862,49	48%	€ 0,009
Concrete	€ 95.973,86	33%	€ 0,006
Timber	€ 219.937,29	75%	€ 0,014

200 years meeting

Beams

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 79.858,52	60%	€ 0,020
Steel	€ 79.858,52	60%	€ 0,020
Concrete	€ 140.102,49	106%	€ 0,035
Timber	€ 129.614,96	98%	€ 0,032

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 81.130,69	61%	€ 0,005
Steel	€ 81.130,69	61%	€ 0,005
Concrete	€ 144.660,48	109%	€ 0,009
Timber	€ 161.328,75	122%	€ 0,010

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 87.366,78	66%	€ 0,005
Steel	€ 87.490,06	66%	€ 0,005
Concrete	€ 161.546,90	122%	€ 0,010
Timber	€ 179.973,49	136%	€ 0,011

200 years meeting

Total

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 697.968,33	62%	€ 0,174
Steel	€ 732.708,44	65%	€ 0,183
Concrete	€ 759.053,42	68%	€ 0,190
Timber	€ 836.897,26	75%	€ 0,209

50 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 700.727,86	63%	€ 0,044
Steel	€ 736.625,65	66%	€ 0,046
Concrete	€ 765.218,30	68%	€ 0,048
Timber	€ 904.911,33	81%	€ 0,057

200 years

Option	New shadow price	Percentage of original shadow price	Shadow price per m^2 per year
Best	€ 727.537,10	65%	€ 0,045
Steel	€ 766.547,82	68%	€ 0,048
Concrete	€ 804.072,21	72%	€ 0,050
Timber	€ 954.344,68	85%	€ 0,060

200 years meeting

K. All optimized elements

Below the optimized elements are presented. In the tables per box the information is given about the profiles or dimensions and the corresponding shadow price for that element. Underneath the shadow price, the percentage compared to the original shadow price of the element is presented. The information given below is for the situation without fire safety measures.

Columns

Profiles and dimensions

HD400x187 (L13&21) € 45,04 N = 7750 kN			
	Steel	**Concrete**	**Timber**
50 years	K300x300x16 € 33,96 75%	450x500 (C55/67) 4ø16+12ø12 € 23,19 51%	650x700 (GL28h) € 39,95 89%
200 years	K400x400x12,5 € 36,37 81%	450x500 (C55/67) 4ø16+12ø12 € 23,19 51%	800x800 (GL28h) € 56,19 125%
200 years meeting	K400x400x16 € 46,00 102%	500x550 (C55/67) 4ø16+16ø12 € 28,28 63%	850x900 (GL28h) € 67,17 149%

HD400x187 (L14) € 78,81 N = 6736 kN			
	Steel	**Concrete**	**Timber**
50 years	K350x350x12,5 € 55,21 70%	450x450 (C55/67) 8ø16 € 35,15 45%	600x650 (GL28h) € 59,92 76%
200 years	K400x400x12,5 € 63,64 81%	450x450 (C55/67) 8ø16 € 35,15 45%	750x750 (GL28h) € 86,43 110%
200 years meeting	K400x400x16 € 80,50 102%	500x500 (C55/67) 4ø16+12ø12 € 44,11 56%	800x850 (GL28h) € 104,48 133%

HD400x187 (L15) € 45,04 N = 6278 kN			
	Steel	**Concrete**	**Timber**
50 years	K400x400x10 € 29,38 65%	400x450 (C55/67) 8ø16 € 18,27 41%	600x600 (GL28h) € 31,61 70%
200 years	K400x400x10 € 29,38 65%	400x450 (C55/67) 8ø16 € 18,27 41%	700x700 (GL28h) € 43,02 96%
200 years meeting	K400x400x12,5 € 36,37 81%	450x500 (C55/67) 4ø16+12ø12 € 23,19 51%	750x800 (GL28h) € 52,68 117%

HD400x187 (L17)	€ 45,04	N = 5391 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x10 € 25,53 57%	400x400 (C55/67) 4ø16+4ø12 € 15,84 35%	550x550 (GL28h) € 26,56 59%
200 years	K350x350x10 € 25,53 57%	400x400 (C55/67) 8ø16 € 16,66 37%	650x650 (GL28h) € 37,10 82%
200 years meeting	K400x400x10 € 29,38 65%	450x450 (C55/67) 8ø16 € 20,09 45%	700x750 (GL28h) € 46,09 102%

HD400x187 (L19&20)	€ 45,04	N = 8216 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x12,5 € 36,37 81%	500x500 (C55/67) 4ø16+12ø12 € 25,21 56%	650x700 (GL28h) € 39,95 89%
200 years	K400x400x12,5 € 36,37 81%	500x500 (C55/67) 4ø16+12ø12 € 25,21 56%	800x800 (GL28h) € 56,19 125%
200 years meeting	K400x400x16 € 46,00 102%	550x550 (C55/67) 12ø16 € 30,03 67%	900x900 (GL28h) € 71,12 158%

HD400x187 (L22)	€ 45,04	N = 6827 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x10 € 29,38 65%	450x450 (C55/67) 8ø16 € 20,09 45%	600x650 (GL28h) € 34,24 76%
200 years	K350x350x12,5 € 31,55 70%	450x450 (C55/67) 4ø16+8ø12 € 20,32 45%	750x750 (GL28h) € 49,39 110%
200 years meeting	K400x400x12,5 € 36,37 81%	500x500 (C55/67) 4ø16+12ø12 € 25,21 56%	800x850 (GL28h) € 59,70 133%

HD400x187 (L23)	€ 45,04	N = 5849 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x10 € 25,53 57%	400x450 (C55/67) 8ø16 € 18,27 41%	550x600 (GL28h) € 28,97 64%
200 years	K300x300x12,5 € 26,97 60%	400x450 (C55/67) 8ø16 € 18,27 41%	650x700 (GL28h) € 39,95 89%
200 years meeting	K350x350x12,5 € 31,55 70%	450x450 (C55/67) 4ø16+8ø12 € 20,32 45%	750x750 (GL28h) € 49,39 110%

HD400x187 (L24)	€ 45,04	N = 4926 kN	
	Steel	**Concrete**	**Timber**
50 years	K300x300x10 € 21,72 48%	350x400 (C55/67) 4ø16+4ø12 € 14,22 32%	500x550 (GL28h) € 24,14 54%
200 years	HEA340 € 25,29 56%	350x400 (C55/67) 4ø16+4ø12 € 14,22 32%	600x650 (GL28h) € 34,24 76%
200 years meeting	K300x300x12,5 € 26,97 60%	400x450 (C55/67) 8ø16 € 18,27 41%	700x700 (GL28h) € 43,02 96%

HD400x187 (L25)	€ 45,04	N = 3979 kN	
	Steel	**Concrete**	**Timber**
50 years	K300x300x8 € 17,53 39%	350x350 (C55/67) 4ø16+4ø12 € 12,81 28%	450x500 (GL28h) € 19,75 44%
200 years	K350x350x8 € 20,57 46%	350x350 (C55/67) 4ø16+4ø12 € 12,81 28%	550x600 (GL28h) € 28,97 64%
200 years meeting	K300x300x10 € 21,72 48%	350x400 (C55/67) 4ø16+4ø12 € 14,22 32%	600x650 (GL28h) € 34,24 76%

HD400x187 (L26&27)	€ 45,04	N = 3112 kN	
	Steel	**Concrete**	**Timber**
50 years	K250x250x8 € 14,52 32%	300x300 (C55/67) 4ø16 € 9,14 20%	400x450 (GL28h) € 15,80 35%
200 years	K250x250x8 € 14,52 32%	300x300 (C55/67) 4ø16 € 9,14 20%	500x500 (GL28h) € 21,95 49%
200 years meeting	K300x300x8 € 17,53 39%	350x350 (C55/67) 4ø16+4ø12 € 12,81 28%	550x550 (GL28h) € 26,56 59%

HD400x262 m (L2)	€ 78,87	N = 12273 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 70,75 90%	600x600 (C55/67) 4ø16+20ø12 € 45,23 57%	850x850 (GL28h) € 79,29 101%
200 years	K400x400x20 € 70,75 90%	600x600 (C55/67) 4ø16+20ø12 € 45,23 57%	950x1000 (GL28h) € 104,26 132%
200 years meeting	HD400x314 € 94,53 120%	650x650 (C55/67) 4ø16+28ø12 € 54,18 69%	1050x1100 (GL28h) € 126,76 161%

HD400x262 (L3&4)	€ 63,10	N = 11824 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 90%	550x600 (C55/67) 4ø16+20ø12 € 33,77 54%	800x850 (GL28h) € 59,70 95%
200 years	K400x400x20 € 56,60 90%	600x600 (C55/67) 4ø16+20ø12 € 36,19 57%	950x1000 (GL28h) € 83,41 132%
200 years meeting	HD400x287 € 69,12 110%	650x650 (C55/67) 4ø16+24ø12 € 42,28 67%	1050x1050 (GL28h) € 96,80 153%

HD400x262 (L5&6)	€ 63,10	N = 11019 kN	
	Steel	**Concrete**	**Timber**
50 years	HEA800 € 53,95 85%	550x550 (C55/67) 4ø16+16ø12 € 30,50 48%	800x800 (GL28h) € 56,19 89%
200 years	K400x400x20 € 56,60 90%	550x600 (C55/67) 4ø16+20ø12 € 33,77 54%	950x950 (GL28h) € 79,24 126%
200 years meeting	HD400x262 € 63,10 100%	600x650 (C55/67) 16ø16 € 38,96 62%	1000x1050 (GL28h) € 92,19 146%

HD400x262 (L14)	€ 110,42	N = 10650 kN	
	Steel	**Concrete**	**Timber**
50 years	HEA800 € 99,04 90%	550x550 (C55/67) 4ø16+16ø12 € 53,37 48%	800x800 (GL28h) € 98,34 89%
200 years	K400x400x20 € 99,04 90%	550x600 (C55/67) 4ø16+16ø12 € 57,25 52%	900x950 (GL28h) € 131,37 119%
200 years meeting	HD400x347 € 146,25 132%	600x650 (C55/67) 16ø16 € 68,18 62%	1000x1050 (GL28h) € 161,33 146%

HD400x262 (L7, 8, 13, 15)	€ 63,10	N = 10202 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x16 € 46,00 73%	550x550 (C55/67) 4ø16+16ø12 € 30,50 48%	750x800 (GL28h) € 52,68 83%
200 years	K400x400x16 € 46,00 73%	550x550 (C55/67) 4ø16+16ø12 € 30,50 48%	900x900 (GL28h) € 71,12 113%
200 years meeting	K400x400x20 € 56,60 90%	600x600 (C55/67) 4ø16+20ø12 € 36,19 57%	1000x1000 (GL28h) € 87,80 139%

HD400x262 (L9&10)	€ 63,10	N = 9355 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x16 € 39,98 63%	500x550 (C55/67) 4ø16+12ø12 € 27,22 43%	700x750 (GL28h) € 46,09 73%
200 years	K400x400x16 € 46,00 73%	500x550 (C55/67) 12ø16 € 27,81 44%	850x900 (GL28h) € 67,17 106%
200 years meeting	K400x400x20 € 56,60 90%	550x600 (C55/67) 4ø16+20ø12 € 33,77 54%	950x950 (GL28h) € 79,24 126%

HD400x262 (L11, 12, 17)	€ 63,10	N = 8539 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x12,5 € 36,37 58%	500x500 (C55/67) 4ø16+12ø12 € 25,21 40%	700x700 (GL28h) € 43,02 68%
200 years	K350x350x16 € 39,98 63%	500x500 (C55/67) 4ø16+12ø12 € 25,21 40%	800x850 (GL28h) € 59,70 95%
200 years meeting	K400x400x16 € 46,00 73%	550x550 (C55/67) 4ø16+16ø12 € 30,50 48%	900x900 (GL28h) € 71,12 113%

HD400x314 m (L5&6)	€ 75,62	N = 15180 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x287 € 69,12 91%	650x650 (C55/67) 4ø16+24ø12 € 42,28 56%	900x950 (GL28h) € 75,07 99%
200 years	HD400x314 € 75,62 100%	650x700 (C55/67) 4ø16+28ø12 € 45,96 61%	1050x1100 (GL28h) € 101,41 134%
200 years meeting	HD400x382 € 92,00 122%	700x750 (C55/67) 4ø16+32ø12 € 52,66 70%	1200x1200 (GL28h) € 126,43 167%

HD400x314 (L7&8)	€ 75,62	N = 13924 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x262 € 63,10 83%	650x650 (C55/67) 16ø16 € 38,96 52%	900x900 (GL28h) € 71,12 94%
200 years	HD400x287 € 63,10 83%	650x650 (C55/67) 4ø16+24ø12 € 42,28 56%	1050x1050 (GL28h) € 96,80 128%
200 years meeting	HD400x347 € 83,57 111%	700x700 (C55/67) 4ø16+32ø12 € 49,84 66%	1150x1150 (GL28h) € 116,11 154%

HD400x314 (L9, 10, 13)	€ 75,62	N = 12677 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 75%	600x600 (C55/67) 4ø16+20ø12 € 36,19 48%	850x850 (GL28h) € 63,44 84%
200 years	K400x400x20 € 56,60 75%	600x600 (C55/67) 4ø16+20ø12 € 36,19 48%	1000x1000 (GL28h) € 87,80 116%
200 years meeting	HD400x314 € 75,62 100%	650x700 (C55/67) 4ø16+28ø12 € 45,96 61%	1100x1100 (GL28h) € 106,24 140%

HD400x314 (L11)	€ 75,62	N = 10993 kN	
	Steel	**Concrete**	**Timber**
50 years	HEA800 € 53,95 71%	550x550 (C55/67) 4ø16+16ø12 € 30,50 40%	800x800 (GL28h) € 56,19 74%
200 years	HEB650 € 54,19 72%	550x600 (C55/67) 4ø16+20ø12 € 33,77 45%	950x950 (GL28h) € 79,24 105%
200 years meeting	HD400x262 € 63,10 83%	600x650 (C55/67) 16ø16 € 38,96 52%	1000x1050 (GL28h) € 92,19 122%

HD400x314 (L12)	€ 75,62	N = 11479 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 75%	550x600 (C55/67) 4ø16+20ø12 € 33,77 45%	800x800 (GL28h) € 56,19 74%
200 years	K400x400x20 € 56,60 75%	550x600 (C55/67) 4ø16+20ø12 € 33,77 45%	950x950 (GL28h) € 79,24 105%
200 years meeting	HEM600 € 68,64 91%	650x650 (C55/67) 4ø16+24ø12 € 42,28 56%	1050x1050 (GL28h) € 96,80 128%

HD400x314 (L16)	€ 75,62	N = 8528 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x12,5 € 36,37 48%	500x500 (C55/67) 4ø16+12ø12 € 25,21 33%	700x700 (GL28h) € 43,02 57%
200 years	HEA600 € 42,87 57%	500x500 (C55/67) 4ø16+12ø12 € 25,21 33%	800x850 (GL28h) € 59,70 79%
200 years meeting	HEM300 € 45,52 60%	550x550 (C55/67) 4ø16+16ø12 € 30,50 40%	900x900 (GL28h) € 71,12 94%

HD400x314 (L18)	€ 75,62	N = 7436 kN	
	Steel	**Concrete**	**Timber**
50 years	K300x300x16 € 33,96 45%	500x500 (C55/67) 4ø16+12ø12 € 25,21 33%	650x650 (GL28h) € 37,10 49%
200 years	K250x250x20 € 33,96 45%	500x500 (C55/67) 4ø16+12ø12 € 25,21 33%	750x800 (GL28h) € 52,68 70%
200 years meeting	K350x350x16 € 39,98 53%	550x550 (C55/67) 4ø16+12ø12 € 29,44 39%	850x850 (GL28h) € 63,44 84%

HD400x421 m (L2)	€ 126,74	N = 19960 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x421 € 126,74 100%	750x750 (C55/67) 24ø16 € 70,79 56%	1050x1100 (GL28h) € 126,76 100%
200 years	HD400x421 € 126,74 100%	750x800 (C55/67) 24ø16 € 74,57 59%	1250x1250 (GL28h) € 171,48 135%
200 years meeting	HD400x509 € 153,23 121%	850x850 (C55/67) 4ø16+44ø12 € 89,69 71%	1350x1400 (GL28h) € 207,43 164%

HD400x421 (L1)	€ 152,09	N = 12744 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 84,89 56%	600x600 (C55/67) 4ø16+20ø12 € 54,28 36%	850x850 (GL28h) € 95,15 63%
200 years	HD400x287 € 103,68 68%	600x650 (C55/67) 4ø16+20ø12 € 57,91 38%	1000x1000 (GL28h) € 131,70 87%
200 years meeting	HD400x347 € 125,35 82%	650x700 (C55/67) 4ø16+28ø12 € 68,94 45%	1100x1100 (GL28h) € 159,36 105%

HD400x421 (L12)	€ 101,39	N = 12755 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 56%	600x600 (C55/67) 4ø16+20ø12 € 36,19 36%	850x850 (GL28h) € 63,44 63%
200 years	K400x400x20 € 56,60 56%	600x650 (C55/67) 4ø16+20ø12 € 38,61 38%	1000x1000 (GL28h) € 87,80 87%
200 years meeting	HD400x314 € 75,62 75%	650x700 (C55/67) 4ø16+28ø12 € 45,96 45%	1100x1100 (GL28h) € 106,24 105%

HD400x421 (L3)	€ 101,39	N = 18837 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x382 € 92,00 91%	700x750 (C55/67) 4ø16+32ø12 € 52,66 52%	1000x1050 (GL28h) € 92,19 91%
200 years	HD400x382 € 92,00 91%	750x750 (C55/67) 24ø16 € 56,63 56%	1200x1200 (GL28h) € 126,43 125%
200 years meeting	HD400x463 € 111,51 110%	800x850 (C55/67) 28ø16 € 67,98 67%	1300x1350 (GL28h) € 154,09 152%

HD400x421 (L4)	€ 101,39	N = 18176 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 83,57 82%	700x750 (C55/67) 4ø16+32ø12 € 52,66 52%	1000x1050 (GL28h) € 92,19 91%
200 years	HD400x382 € 92,00 91%	700x750 (C55/67) 4ø16+32ø12 € 52,66 52%	1200x1200 (GL28h) € 126,43 125%
200 years meeting	HD400x463 € 111,51 110%	800x800 (C55/67) 4ø16+40ø12 € 64,05 63%	1300x1300 (GL28h) € 148,38 146%

HD400x421 (L5)	€ 101,39	N = 17507 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 83,57 82%	700x700 (C55/67) 4ø16+32ø12 € 49,84 49%	1000x1000 (GL28h) € 87,80 87%
200 years	HD400x347 € 83,57 82%	700x750 (C55/67) 4ø16+32ø12 € 52,66 52%	1150x1200 (GL28h) € 121,16 120%
200 years meeting	HD400x421 € 101,39 100%	750x800 (C55/67) 4ø16+36ø12 € 59,76 59%	1250x1300 (GL28h) € 142,67 141%

HD400x421 (L6)	€ 101,39	N = 16840 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 83,57 82%	700x700 (C55/67) 4ø16+28ø12 € 48,78 48%	950x1000 (GL28h) € 83,41 82%
200 years	HD400x347 € 83,57 82%	700x700 (C55/67) 20ø16 € 48,90 48%	1150x1150 (GL28h) € 116,11 115%
200 years meeting	HD400x421 € 101,39 100%	750x800 (C55/67) 4ø16+36ø12 € 59,76 59%	1250x1250 (GL28h) € 137,19 135%

HD400x421 (L7)	€ 101,39	N = 16155 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x314 € 75,62 75%	650x700 (C55/67) 4ø16+28ø12 € 45,96 45%	950x950 (GL28h) € 79,24 78%
200 years	HD400x314 € 75,62 75%	700x700 (C55/67) 4ø16+28ø12 € 48,78 48%	1100x1150 (GL28h) € 111,07 110%
200 years meeting	HD400x382 € 92,00 91%	750x750 (C55/67) 24ø16 € 56,63 56%	1200x1250 (GL28h) € 131,70 130%

HD400x421 (L8)	€ 101,39	N = 15486 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x314 € 75,62 75%	650x700 (C55/67) 4ø16+28ø12 € 45,96 45%	950x950 (GL28h) € 79,24 78%
200 years	HD400x314 € 75,62 75%	650x700 (C55/67) 4ø16+28ø12 € 45,96 45%	1100x1100 (GL28h) € 106,24 105%
200 years meeting	HD400x382 € 92,00 91%	750x750 (C55/67) 24ø16 € 56,63 56%	1200x1200 (GL28h) € 126,43 125%

HD400x421 (L9)	€ 101,39	N = 14802 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x287 € 69,12 68%	650x650 (C55/67) 4ø16+24ø12 € 42,28 42%	900x950 (GL28h) € 75,07 74%
200 years	HD400x287 € 69,12 68%	650x650 (C55/67) 4ø16+28ø12 € 43,34 43%	1050x1100 (GL28h) € 101,41 100%
200 years meeting	HD400x347 € 83,57 82%	700x750 (C55/67) 4ø16+32ø12 € 52,66 52%	1150x1200 (GL28h) € 121,16 120%

HD400x421 (L10)	€ 101,39	N = 14127 kN	
	Steel	**Concrete**	**Timber**
50 years	HEM550 € 66,95 66%	600x650 (C55/67) 4ø16+24ø12 € 39,66 39%	900x900 (GL28h) € 71,12 70%
200 years	HEM600 € 68,64 68%	650x650 (C55/67) 4ø16+24ø12 € 42,28 42%	1050x1050 (GL28h) € 96,80 95%
200 years meeting	HD400x347 € 83,57 82%	700x700 (C55/67) 4ø16+32ø12 € 49,84 49%	1150x1150 (GL28h) € 116,11 115%

HD400x421 (L11)	€ 101,39	N = 13436 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x262 € 63,10 62%	600x650 (C55/67) 16ø16 € 38,96 38%	850x900 (GL28h) € 67,17 66%
200 years	HD400x262 € 63,10 62%	600x650 (C55/67) 16ø16 € 38,96 38%	1000x1050 (GL28h) € 92,19 91%
200 years meeting	HD400x347 € 83,57 82%	700x700 (C55/67) 4ø16+28ø12 € 48,78 48%	1100x1150 (GL28h) € 111,07 110%

HD400x421 (L13&16)	€ 101,39	N = 9250 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x16 € 39,98 39%	500x550 (C55/67) 4ø16+12ø12 € 27,22 27%	700x750 (GL28h) € 46,09 45%
200 years	HEB500 € 45,04 44%	500x550 (C55/67) 12ø16 € 27,81 27%	850x850 (GL28h) € 63,44 63%
200 years meeting	K400x400x20 € 56,60 56%	550x600 (C55/67) 4ø16+20ø12 € 33,77 33%	900x950 (GL28h) € 75,07 74%

HD400x421 (L14)	€ 177,43	N = 6818 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x12,5 € 55,21 31%	450x450 (C55/67) 8ø16 € 35,15 20%	600x650 (GL28h) € 59,92 34%
200 years	K400x400x12,5 € 63,64 36%	450x450 (C55/67) 4ø16+8ø12 € 35,56 20%	700x750 (GL28h) € 80,67 45%
200 years meeting	K400x400x16 € 80,50 45%	500x500 (C55/67) 4ø16+12ø12 € 44,11 25%	800x800 (GL28h) € 98,34 55%

HD400x421 (L15)	€ 101,39	N = 6050 kN	
	Steel	**Concrete**	**Timber**
50 years	K300x300x12,5 € 26,97 27%	400x450 (C55/67) 8ø16 € 18,27 18%	600x600 (GL28h) € 31,61 31%
200 years	K250x250x16 € 27,70 27%	400x450 (C55/67) 8ø16 € 18,27 18%	700x700 (GL28h) € 43,02 42%
200 years meeting	K300x300x16 € 33,96 33%	450x500 (C55/67) 4ø16+12ø12 € 23,19 23%	750x750 (GL28h) € 49,39 49%

HD400x421 (L17)	€ 101,39	N = 5576 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x10 € 25,53 25%	400x400 (C55/67) 8ø16 € 16,66 16%	550x600 (GL28h) € 28,97 29%
200 years	K350x350x10 € 25,53 25%	400x400 (C55/67) 8ø16 € 16,66 16%	650x700 (GL28h) € 39,95 39%
200 years meeting	K350x350x12,5 € 31,55 31%	450x450 (C55/67) 8ø16 € 20,09 20%	700x750 (GL28h) € 46,09 45%

HD400x421 (L18)	€ 101,39	N = 7850 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x12,5 € 36,37 36%	450x500 (C55/67) 4ø16+12ø12 € 23,19 23%	650x700 (GL28h) € 39,95 39%
200 years	K400x400x12,5 € 36,37 36%	450x500 (C55/67) 4ø16+12ø12 € 23,19 23%	750x800 (GL28h) € 52,68 52%
200 years meeting	K400x400x16 € 46,00 45%	500x550 (C55/67) 12ø16 € 27,81 27%	850x850 (GL28h) € 63,44 63%

HD400x463 (L3)	€ 111,51	N = 15754 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x314 € 75,62 68%	650x700 (C55/67) 4ø16+28ø12 € 45,96 41%	950x950 (GL28h) € 79,24 71%
200 years	HD400x314 € 75,62 68%	650x700 (C55/67) 4ø16+28ø12 € 45,96 41%	1100x1100 (GL28h) € 106,24 95%
200 years meeting	HD400x382 € 92,00 83%	750x750 (C55/67) 4ø16+36ø12 € 56,74 51%	1200x1250 (GL28h) € 131,70 118%

HD400x463 (L4)	€ 111,51	N = 12694 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 51%	600x600 (C55/67) 4ø16+20ø12 € 36,19 32%	850x850 (GL28h) € 63,44 57%
200 years	K400x400x20 € 56,60 51%	600x600 (C55/67) 4ø16+20ø12 € 36,19 32%	1000x1000 (GL28h) € 87,80 79%
200 years meeting	HD400x314 € 75,62 68%	650x700 (C55/67) 4ø16+28ø12 € 45,96 41%	1100x1100 (GL28h) € 106,24 95%

HD400x463 (L5&6)	€ 111,51	N = 8792 kN	
	Steel	**Concrete**	**Timber**
50 years	K350x350x16 € 39,98 36%	500x500 (C55/67) 4ø16+12ø12 € 25,21 23%	700x700 (GL28h) € 43,02 39%
200 years	K350x350x16 € 39,98 36%	500x500 (C55/67) 4ø16+12ø12 € 25,21 23%	800x850 (GL28h) € 59,70 54%
200 years meeting	K400x400x16 € 46,00 41%	550x550 (C55/67) 4ø16+16ø12 € 30,50 27%	900x900 (GL28h) € 71,12 64%

HD400x463 (L7)	€ 111,51	N = 8238 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x12,5 € 36,37 33%	450x500 (C55/67) 4ø16+12ø12 € 23,19 21%	700x700 (GL28h) € 43,02 39%
200 years	K400x400x12,5 € 36,37 33%	500x500 (C55/67) 4ø16+12ø12 € 25,21 23%	800x800 (GL28h) € 56,19 50%
200 years meeting	K400x400x16 € 46,00 41%	550x550 (C55/67) 12ø16 € 30,03 27%	850x900 (GL28h) € 67,17 60%

HD400x463 (L8-10)	€ 111,51	N = 6797 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x10 € 29,38 26%	450x450 (C55/67) 8ø16 € 20,09 18%	600x650 (GL28h) € 34,24 31%
200 years	K400x400x10 € 29,38 26%	450x450 (C55/67) 4ø16+8ø12 € 20,32 18%	700x750 (GL28h) € 46,09 41%
200 years meeting	K400x400x12,5 € 36,37 33%	500x500 (C55/67) 4ø16+12ø12 € 25,21 23%	800x800 (GL28h) € 56,19 50%

HD400x463 (L11)	€ 111,51	N = 5759 kN	
	Steel	**Concrete**	**Timber**
50 years	K220x220x16 € 24,08 22%	400x400 (C55/67) 8ø16 € 16,66 15%	550x600 (GL28h) € 28,97 26%
200 years	K350x350x10 € 25,53 23%	400x450 (C55/67) 8ø16 € 18,27 16%	650x700 (GL28h) € 39,95 36%
200 years meeting	K350x350x12,5 € 31,55 28%	450x450 (C55/67) 4ø16+8ø12 € 20,32 18%	750x750 (GL28h) € 49,39 44%

HD400x463 (L12&13)	€ 111,51	N = 9961 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x16 € 46,00 41%	500x550 (C55/67) 12ø16 € 27,81 25%	750x750 (GL28h) € 49,39 44%
200 years	K400x400x16 € 46,00 41%	550x550 (C55/67) 12ø16 € 30,03 27%	850x900 (GL28h) € 67,17 60%
200 years meeting	K400x400x20 € 56,60 51%	600x600 (C55/67) 4ø16+20ø12 € 36,19 32%	950x950 (GL28h) € 79,24 71%

HD400x463 (L14)	€ 195,14	N = 5467 kN	
	Steel	**Concrete**	**Timber**
50 years	K220x220x16 € 42,15 22%	400x400 (C55/67) 8ø16 € 29,15 15%	550x550 (GL28h) € 46,48 24%
200 years	K220x220x16 € 42,15 22%	400x400 (C55/67) 8ø16 € 29,15 15%	650x650 (GL28h) € 64,92 33%
200 years meeting	K350x350x12,5 € 55,21 28%	450x450 (C55/67) 8ø16 € 35,15 18%	700x750 (GL28h) € 80,67 41%

HD400x463 (L17&24)	€ 111,51	N = 5460 kN	
	Steel	**Concrete**	**Timber**
50 years	K220x220x16 € 24,08 22%	400x400 (C55/67) 8ø16 € 16,66 15%	550x550 (GL28h) € 26,56 24%
200 years	K220x220x16 € 24,08 22%	400x400 (C55/67) 8ø16 € 16,66 15%	650x650 (GL28h) € 37,10 33%
200 years meeting	K350x350x12,5 € 31,55 28%	450x450 (C55/67) 8ø16 € 20,09 18%	700x750 (GL28h) € 46,09 41%

HD400x463 (L15, 18, 20)	€ 111,51	N = 4809 kN	
	Steel	**Concrete**	**Timber**
50 years	K260x260x11 € 20,47 18%	350x400 (C55/67) 4ø16+4ø12 € 14,22 13%	500x550 (GL28h) € 24,14 22%
200 years	K250x250x12,5 € 22,13 20%	350x400 (C55/67) 4ø16+4ø12 € 14,22 13%	600x600 (GL28h) € 31,61 28%
200 years meeting	K350x350x10 € 25,53 23%	400x450 (C55/67) 8ø16 € 18,27 16%	650x700 (GL28h) € 39,95 36%

HD400x463 (L16)	€ 111,51	N = 3506 kN	
	Steel	**Concrete**	**Timber**
50 years	K250x250x10 € 17,94 16%	300x350 (C55/67) 4ø16+4ø12 € 11,40 10%	450x450 (GL28h) € 17,78 16%
200 years	K250x250x10 € 17,94 16%	300x350 (C55/67) 4ø16+4ø12 € 11,40 10%	500x550 (GL28h) € 24,14 22%
200 years meeting	K260x260x11 € 20,47 18%	350x350 (C55/67) 4ø16+4ø12 € 12,81 11%	550x600 (GL28h) € 28,97 26%

HD400x463 (L19&22)	€ 111,51	N = 3186 kN	
	Steel	**Concrete**	**Timber**
50 years	K180x180x12,5 € 15,51 14%	300x300 (C55/67) 4ø16 € 9,14 8%	400x450 (GL28h) € 15,80 14%
200 years	K250x250x8 € 14,52 13%	300x300 (C55/67) 4ø16 € 9,14 8%	500x500 (GL28h) € 21,95 20%
200 years meeting	K250x250x10 € 17,94 16%	350x350 (C55/67) 4ø16+4ø12 € 12,81 11%	550x550 (GL28h) € 26,56 24%

HD400x463 (L21&26)	€ 111,51	N = 4071 kN	
	Steel	**Concrete**	**Timber**
50 years	K200x200x12,5 € 17,41 16%	350x350 (C55/67) 4ø16+4ø12 € 12,81 11%	450x500 (GL28h) € 19,75 18%
200 years	K220x220x12,5 € 19,29 17%	350x350 (C55/67) 4ø16+4ø12 € 12,81 11%	550x600 (GL28h) € 28,97 26%
200 years meeting	K220x220x16 € 24,08 22%	350x400 (C55/67) 4ø16+4ø12 € 14,22 13%	600x650 (GL28h) € 34,24 31%

HD400x463 (L23)	€ 111,51	N = 6288 kN	
	Steel	**Concrete**	**Timber**
50 years	K250x250x16 € 27,70 25%	400x450 (C55/67) 8ø16 € 18,27 16%	600x600 (GL28h) € 31,61 28%
200 years	K400x400x10 € 29,38 26%	400x450 (C55/67) 8ø16 € 18,27 16%	700x700 (GL28h) € 43,02 39%
200 years meeting	K400x400x12,5 € 36,37 33%	450x500 (C55/67) 4ø16+12ø12 € 23,19 21%	750x800 (GL28h) € 52,68 47%

HD400x463 (L25)	€ 111,51	N = 2792 kN	
	Steel	**Concrete**	**Timber**
50 years	K260x260x7,1 € 13,49 12%	300x300 (C55/67) 4ø16 € 9,14 8%	400x400 (GL28h) € 14,05 13%
200 years	K260x260x7,1 € 13,49 12%	300x300 (C55/67) 4ø16 € 9,14 8%	450x500 (GL28h) € 19,75 18%
200 years meeting	K300x300x8 € 17,53 16%	300x350 (C55/67) 4ø16 € 10,35 9%	500x550 (GL28h) € 24,14 22%

HD400x744 (L1)	€ 268,77	N = 21097 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x463 € 167,26 62%	750x800 (C55/67) 4ø16+36ø12 € 89,65 33%	1100x1100 (GL28h) € 159,36 59%
200 years	HD400x463 € 167,26 62%	750x800 (C55/67) 4ø16+40ø12 € 91,23 34%	1250x1300 (GL28h) € 214,01 80%
200 years meeting	HD400x551 € 199,05 74%	850x850 (C55/67) 4ø16+48ø12 € 109,22 41%	1400x1400 (GL28h) € 258,13 96%

HD400x744 (L2)	€ 223,98	N = 16040 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 104,46 47%	650x700 (C55/67) 4ø16+28ø12 € 57,45 26%	950x950 (GL28h) € 99,05 44%
200 years	HD400x347 € 104,46 47%	650x700 (C55/67) 4ø16+28ø12 € 57,45 26%	1100x1150 (GL28h) € 138,83 62%
200 years meeting	HD400x421 € 126,74 57%	750x750 (C55/67) 24ø16 € 70,79 32%	1200x1250 (GL28h) € 164,62 73%

HD400x744 (L3)	€ 179,18	N = 15013 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x287 € 69,12 39%	650x650 (C55/67) 4ø16+24ø12 € 42,28 24%	900x950 (GL28h) € 75,07 42%
200 years	HD400x314 € 75,62 42%	650x700 (C55/67) 4ø16+28ø12 € 45,96 26%	1050x1100 (GL28h) € 101,41 57%
200 years meeting	HD400x382 € 92,00 51%	700x750 (C55/67) 4ø16+32ø12 € 52,66 29%	1150x1200 (GL28h) € 121,16 68%

HD400x744 (L4)	€ 179,18	N = 14049 kN	
	Steel	**Concrete**	**Timber**
50 years	HEM550 € 66,95 37%	600x650 (C55/67) 4ø16+24ø12 € 39,66 22%	900x900 (GL28h) € 71,12 40%
200 years	HEM600 € 68,64 38%	650x650 (C55/67) 4ø16+24ø12 € 42,28 24%	1050x1050 (GL28h) € 96,80 54%
200 years meeting	HD400x347 € 83,57 47%	700x700 (C55/67) 4ø16+32ø12 € 49,84 28%	1150x1150 (GL28h) € 116,11 65%

HD400x1086 (L1)	€ 392,32	N = 25362 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x551 € 199,05 51%	900x900 (C55/67) 4ø16+48ø12 € 119,80 31%	1200x1200 (GL28h) € 189,65 48%
200 years	HD400x551 € 199,05 51%	950x950 (C55/67) 4ø16+48ø12 € 130,98 33%	1350x1400 (GL28h) € 248,91 63%
200 years meeting	HD400x677 € 244,57 62%	1000x1000 (C55/67) 4ø16+60ø12 € 147,53 38%	1500x1500 (GL28h) € 296,32 76%

HD400x1086 (L2)	€ 326,93	N = 23555,5 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x551 € 165,87 51%	900x900 (C55/67) 28ø16 € 98,08 30%	1150x1150 (GL28h) € 145,14 44%
200 years	HD400x551 € 165,87 51%	900x900 (C55/67) 28ø16 € 98,08 30%	1300x1350 (GL28h) € 192,61 59%
200 years meeting	HD400x677 € 203,81 62%	1000x1000 (C55/67) 4ø16+56ø12 € 121,62 37%	1450x1450 (GL28h) € 230,75 71%

HD400x1086 (L3)	€ 261,55	N = 22974 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x551 € 132,70 51%	900x900 (C55/67) 4ø16+40ø12 € 77,75 30%	1150x1150 (GL28h) € 145,14 55%
200 years	HD400x551 € 132,70 51%	900x900 (C55/67) 4ø16+40ø12 € 77,75 30%	1300x1350 (GL28h) € 154,09 59%
200 years meeting	HD400x677 € 163,05 62%	1000x1000 (C55/67) 4ø16+52ø12 € 96,24 37%	1450x1450 (GL28h) € 184,60 71%

HD400x1086 (L4)	€ 261,55	N = 22598,5 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x421 € 101,39 39%	800x800 (C55/67) 4ø16+40ø12 € 64,05 24%	1100x1150 (GL28h) € 111,07 42%
200 years	HD400x463 € 111,51 43%	800x800 (C55/67) 28ø16 € 64,76 25%	1300x1300 (GL28h) € 148,38 57%
200 years meeting	HD400x551 € 132,70 51%	900x900 (C55/67) 4ø16+52ø12 € 80,92 31%	1400x1450 (GL28h) € 178,23 68%

HD400x1086 (L5)	€ 261,55	N = 21123 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x421 € 101,39 39%	750x800 (C55/67) 4ø16+36ø12 € 59,76 23%	1100x1150 (GL28h) € 111,07 42%
200 years	HD400x421 € 101,39 39%	800x800 (C55/67) 4ø16+40ø12 € 60,82 23%	1250x1250 (GL28h) € 137,19 52%
200 years meeting	HD400x509 € 122,58 47%	850x900 (C55/67) 4ø16+48ø12 € 76,24 29%	1350x1400 (GL28h) € 165,94 63%

HD400x1086 (L6)	€ 261,55	N = 20747,5 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x421 € 101,39 39%	750x800 (C55/67) 4ø16+36ø12 € 59,76 23%	1050x1100 (GL28h) € 101,41 39%
200 years	HD400x421 € 101,39 39%	750x800 (C55/67) 4ø16+40ø12 € 60,82 23%	1250x1250 (GL28h) € 137,19 52%
200 years meeting	HD400x509 € 122,58 47%	850x850 (C55/67) 4ø16+48ø12 € 72,81 28%	1350x1400 (GL28h) € 165,94 63%

HD400x1086 (L7)	€ 261,55	N = 20345 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x382 € 92,00 35%	750x750 (C55/67) 4ø16+36ø12 € 56,74 22%	1050x1100 (GL28h) € 101,41 39%
200 years	HD400x421 € 101,39 39%	750x800 (C55/67) 4ø16+36ø12 € 59,76 23%	1250x1250 (GL28h) € 137,19 52%
200 years meeting	HD400x509 € 122,58 47%	850x850 (C55/67) 4ø16+48ø12 € 72,81 28%	1350x1350 (GL28h) € 160,01 61%

HD400x1086 (L8)	€ 261,55	N = 18404 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 83,57 32%	700x750 (C55/67) 4ø16+32ø12 € 52,66 20%	1000x1050 (GL28h) € 92,19 35%
200 years	HD400x382 € 92,00 35%	700x750 (C55/67) 4ø16+32ø12 € 52,66 20%	1150x1200 (GL28h) € 121,16 46%
200 years meeting	HD400x463 € 111,51 43%	800x800 (C55/67) 4ø16+40ø12 € 64,05 24%	1300x1300 (GL28h) € 148,38 57%

HD400x1086 (L9&10)	€ 261,55	N = 17999 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x347 € 83,57 32%	700x750 (C55/67) 4ø16+32ø12 € 52,66 20%	1000x1000 (GL28h) € 87,80 34%
200 years	HD400x382 € 92,00 35%	700x750 (C55/67) 4ø16+32ø12 € 52,66 20%	1150x1200 (GL28h) € 121,16 46%
200 years meeting	HD400x421 € 101,39 39%	800x800 (C55/67) 4ø16+40ø12 € 64,05 24%	1250x1300 (GL28h) € 142,67 55%

HD400x1086 (L11&12)	€ 261,55	N = 15470 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x314 € 75,62 29%	650x700 (C55/67) 4ø16+28ø12 € 45,96 18%	950x950 (GL28h) € 79,24 30%
200 years	HD400x314 € 75,62 29%	650x700 (C55/67) 4ø16+28ø12 € 45,96 18%	1050x1100 (GL28h) € 101,41 39%
200 years meeting	HD400x382 € 92,00 35%	750x750 (C55/67) 4ø16+36ø12 € 56,74 22%	1150x1200 (GL28h) € 121,16 46%

HD400x1086 (L13)	€ 261,55	N = 14677,5 kN	
	Steel	**Concrete**	**Timber**
50 years	HD400x287 € 69,12 26%	650x650 (C55/67) 4ø16+24ø12 € 42,28 16%	900x950 (GL28h) € 75,07 29%
200 years	HD400x287 € 69,12 26%	650x650 (C55/67) 4ø16+24ø12 € 42,28 16%	1050x1050 (GL28h) € 96,80 37%
200 years meeting	HD400x347 € 83,57 32%	700x750 (C55/67) 4ø16+32ø12 € 52,66 20%	1150x1150 (GL28h) € 116,11 44%

HD400x1086 (L14)	€ 457,71	N = 12296 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 99,04 22%	600x600 (C55/67) 4ø16+20ø12 € 63,33 14%	900x950 (GL28h) € 104,48 23%
200 years	K400x400x20 € 99,04 22%	600x600 (C55/67) 4ø16+20ø12 € 63,33 14%	1000x1000 (GL28h) € 153,65 34%
200 years meeting	HD400x382 € 161,00 35%	650x700 (C55/67) 4ø16+28ø12 € 80,43 18%	1050x1100 (GL28h) € 177,46 39%

HD400x1086 (L15)	€ 261,55	N = 11848 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 56,60 22%	550x600 (C55/67) 4ø16+20ø12 € 33,77 13%	800x850 (GL28h) € 59,70 23%
200 years	K400x400x20 € 56,60 22%	600x600 (C55/67) 4ø16+20ø12 € 36,19 14%	950x1000 (GL28h) € 83,41 32%
200 years meeting	HD400x287 € 69,12 26%	650x650 (C55/67) 4ø16+24ø12 € 42,28 16%	1050x1050 (GL28h) € 96,80 37%

HD400x1086 (L16)	€ 261,55	N = 9762 kN	
	Steel	**Concrete**	**Timber**
50 years	K400x400x16 € 46,00 18%	500x550 (C55/67) 12ø16 € 27,81 11%	750x750 (GL28h) € 49,39 19%
200 years	K400x400x16 € 46,00 18%	550x550 (C55/67) 12ø16 € 30,03 11%	850x900 (GL28h) € 67,17 26%
200 years meeting	K400x400x20 € 56,60 22%	600x600 (C55/67) 4ø16+20ø12 € 36,19 14%	950x1000 (GL28h) € 83,41 32%

HD400x1086 (L17)	€ 261,55	N = 9352 kN	
	Steel	**Concrete**	**Timber**
50 years	HEB500 € 45,04 17%	500x550 (C55/67) 4ø16+12ø12 € 27,22 10%	700x750 (GL28h) € 46,09 18%
200 years	K400x400x16 € 46,00 18%	500x550 (C55/67) 12ø16 € 27,81 11%	850x900 (GL28h) € 67,17 26%
200 years meeting	K400x400x20 € 56,60 22%	550x600 (C55/67) 4ø16+20ø12 € 33,77 13%	950x950 (GL28h) € 79,24 30%

HD400x1086 (L18)	€ 261,55	N = 8970 kN	
	Steel	**Concrete**	**Timber**
50 years	HEA600 € 42,87 16%	500x500 (C55/67) 4ø16+12ø12 € 25,21 10%	700x750 (GL28h) € 46,09 18%
200 years	HEB500 € 45,04 17%	500x550 (C55/67) 4ø16+12ø12 € 27,22 10%	850x850 (GL28h) € 63,44 24%
200 years meeting	HEB650 € 54,19 21%	550x600 (C55/67) 4ø16+16ø12 € 32,71 13%	900x950 (GL28h) € 75,07 29%

HD400x1086 (L19)	€ 261,55	N = 7007 kN	
	Steel	**Concrete**	**Timber**
50 years	HEA450 € 33,72 13%	450x450 (C55/67) 4ø16+8ø12 € 20,32 8%	600x650 (GL28h) € 34,24 13%
200 years	K400x400x12,5 € 36,37 14%	450x450 (C55/67) 4ø16+8ø12 € 20,32 8%	750x750 (GL28h) € 49,39 19%
200 years meeting	HEB450 € 41,18 16%	500x500 (C55/67) 4ø16+12ø12 € 25,21 10%	800x850 (GL28h) € 59,70 23%

<u>New shadow price best and concrete option 50 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €80.004,84 (=27%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
13	3	3,6	2019,6	€ 135,06	51	€ 68,88
14	3	6,3	3534,3	€ 236,36	45	€ 106,36
15	3	3,6	2019,6	€ 135,06	41	€ 55,38
17	3	3,6	2019,6	€ 135,06	35	€ 47,27
19	25	3,6	16830	€ 1.125,51	56	€ 630,28
20	25	3,6	16830	€ 1.125,51	56	€ 630,28
21	25	3,6	16830	€ 1.125,51	51	€ 574,01
22	25	3,6	16830	€ 1.125,51	45	€ 506,48
23	25	3,6	16830	€ 1.125,51	41	€ 461,46
24	25	3,6	16830	€ 1.125,51	32	€ 360,16
25	25	3,6	16830	€ 1.125,51	28	€ 315,14
26	25	3,6	16830	€ 1.125,51	20	€ 225,10
27	28	4,7	24609,2	€ 1.645,74	20	€ 329,15
Totaal			168842,3	€ 11.291,35		**€ 4.309,96**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	57	€	134,83
3	3	3,6	2829,6	€ 189,23	54	€	102,18
4	3	3,6	2829,6	€ 189,23	54	€	102,18
5	3	3,6	2829,6	€ 189,23	48	€	90,83
6	3	3,6	2829,6	€ 189,23	48	€	90,83
7	3	3,6	2829,6	€ 189,23	48	€	90,83
8	3	3,6	2829,6	€ 189,23	48	€	90,83
9	3	3,6	2829,6	€ 189,23	43	€	81,37
10	3	3,6	2829,6	€ 189,23	43	€	81,37
11	3	3,6	2829,6	€ 189,23	40	€	75,69
12	3	3,6	2829,6	€ 189,23	40	€	75,69
13	10	3,6	9432	€ 630,77	48	€	302,77
14	17	6,3	28060,2	€ 1.876,53	48	€	900,73
15	19	3,6	17920,8	€ 1.198,46	48	€	575,26
16	3	3,6	2829,6	€ 189,23	48	€	90,83
17	19	3,6	17920,8	€ 1.198,46	40	€	479,38
18	3	3,6	2829,6	€ 189,23	48	€	90,83
Totaal			110826	€ 7.411,50		**€**	**3.456,44**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	56	€	423,34
6	12	3,6	13564,8	€ 907,15	56	€	508,00
7	10	3,6	11304	€ 755,96	52	€	393,10
8	12	3,6	13564,8	€ 907,15	52	€	471,72
9	10	3,6	11304	€ 755,96	48	€	362,86
10	12	3,6	13564,8	€ 907,15	48	€	435,43
11	10	3,6	11304	€ 755,96	40	€	302,38
12	12	3,6	13564,8	€ 907,15	45	€	408,22
13	7	3,6	7912,8	€ 529,17	48	€	254,00
16	12	3,6	13564,8	€ 907,15	33	€	299,36
18	12	3,6	13564,8	€ 907,15	33	€	299,36
Totaal			134517,6	€ 8.995,88		**€**	**4.157,76**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	33	€	1.507,28
2	3	4,5	10044	€ 671,69	26	€	174,64
3	3	3,6	8035,2	€ 537,35	24	€	128,97
4	3	3,6	8035,2	€ 537,35	22	€	118,22
Totaal			94413,6	€ 6.313,92		**€**	**1.929,10**

HD400x421							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	3	5,4	6820,2	€	456,10	36	€ 164,20
2	19	4,5	35995,5	€	2.407,20	56	€ 1.348,03
3	19	3,6	28796,4	€	1.925,76	52	€ 1.001,40
4	19	3,6	28796,4	€	1.925,76	52	€ 1.001,40
5	9	3,6	13640,4	€	912,20	49	€ 446,98
6	7	3,6	10609,2	€	709,49	48	€ 340,56
7	9	3,6	13640,4	€	912,20	45	€ 410,49
8	7	3,6	10609,2	€	709,49	45	€ 319,27
9	9	3,6	13640,4	€	912,20	42	€ 383,13
10	7	3,6	10609,2	€	709,49	39	€ 276,70
11	9	3,6	13640,4	€	912,20	38	€ 346,64
12	7	3,6	10609,2	€	709,49	36	€ 255,42
13	3	3,6	4546,8	€	304,07	27	€ 82,10
14	3	6,3	7956,9	€	532,12	20	€ 106,42
15	3	3,6	4546,8	€	304,07	18	€ 54,73
16	7	3,6	10609,2	€	709,49	27	€ 191,56
17	3	3,6	4546,8	€	304,07	16	€ 48,65
18	7	3,6	10609,2	€	709,49	23	€ 163,18
Totaal			240222,6	€	16.064,92		**€ 6.940,85**

HD400x463							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
3	10	3,6	16668	€	1.114,67	41	€ 457,02
4	12	3,6	20001,6	€	1.337,61	32	€ 428,04
5	12	3,6	20001,6	€	1.337,61	23	€ 307,65
6	12	3,6	20001,6	€	1.337,61	23	€ 307,65
7	12	3,6	20001,6	€	1.337,61	21	€ 280,90
8	12	3,6	20001,6	€	1.337,61	18	€ 240,77
9	12	3,6	20001,6	€	1.337,61	18	€ 240,77
10	12	3,6	20001,6	€	1.337,61	18	€ 240,77
11	12	3,6	20001,6	€	1.337,61	15	€ 200,64
12	12	3,6	20001,6	€	1.337,61	25	€ 334,40
13	12	3,6	20001,6	€	1.337,61	25	€ 334,40
14	12	6,3	35002,8	€	2.340,82	15	€ 351,12
15	12	3,6	20001,6	€	1.337,61	13	€ 173,89
16	12	3,6	20001,6	€	1.337,61	10	€ 133,76
17	12	3,6	20001,6	€	1.337,61	15	€ 200,64
18	12	3,6	20001,6	€	1.337,61	13	€ 173,89
19	12	3,6	20001,6	€	1.337,61	8	€ 107,01
20	12	3,6	20001,6	€	1.337,61	13	€ 173,89
21	12	3,6	20001,6	€	1.337,61	11	€ 147,14
22	12	3,6	20001,6	€	1.337,61	8	€ 107,01
23	12	3,6	20001,6	€	1.337,61	16	€ 214,02
24	12	3,6	20001,6	€	1.337,61	15	€ 200,64
25	12	3,6	20001,6	€	1.337,61	8	€ 107,01
26	12	3,6	20001,6	€	1.337,61	11	€ 147,14
Totaal			491706	€	32.882,90		**€ 5.610,16**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	31	€	3.768,87
2	28	4,5	136836	€ 9.150,92	30	€	2.745,28
3	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
4	28	3,6	109468,8	€ 7.320,74	24	€	1.756,98
5	28	3,6	109468,8	€ 7.320,74	23	€	1.683,77
6	28	3,6	109468,8	€ 7.320,74	23	€	1.683,77
7	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
8	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
9	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
10	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
11	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
12	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
13	28	3,6	109468,8	€ 7.320,74	16	€	1.171,32
14	28	6,3	191570,4	€ 12.811,29	14	€	1.793,58
15	28	3,6	109468,8	€ 7.320,74	13	€	951,70
16	28	3,6	109468,8	€ 7.320,74	11	€	805,28
17	28	3,6	109468,8	€ 7.320,74	10	€	732,07
18	28	3,6	109468,8	€ 7.320,74	10	€	732,07
19	28	3,6	109468,8	€ 7.320,74	8	€	585,66
20	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
21	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
22	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
23	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
24	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
25	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
26	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
Totaal			3027985	€ 202.496,88		**€**	**44.618,60**

<u>New shadow price best and concrete option 200 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €81.189,20 (=28%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	51	€	68,88
14	3	6,3	3534,3	€ 236,36	45	€	106,36
15	3	3,6	2019,6	€ 135,06	41	€	55,38
17	3	3,6	2019,6	€ 135,06	37	€	49,97
19	25	3,6	16830	€ 1.125,51	56	€	630,28
20	25	3,6	16830	€ 1.125,51	56	€	630,28
21	25	3,6	16830	€ 1.125,51	51	€	574,01
22	25	3,6	16830	€ 1.125,51	45	€	506,48
23	25	3,6	16830	€ 1.125,51	41	€	461,46
24	25	3,6	16830	€ 1.125,51	32	€	360,16
25	25	3,6	16830	€ 1.125,51	28	€	315,14
26	25	3,6	16830	€ 1.125,51	20	€	225,10
27	28	4,7	24609,2	€ 1.645,74	20	€	329,15
Totaal			168842,3	€ 11.291,35		**€**	**4.312,66**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	57	€	134,83
3	3	3,6	2829,6	€ 189,23	57	€	107,86
4	3	3,6	2829,6	€ 189,23	57	€	107,86
5	3	3,6	2829,6	€ 189,23	54	€	102,18
6	3	3,6	2829,6	€ 189,23	54	€	102,18
7	3	3,6	2829,6	€ 189,23	48	€	90,83
8	3	3,6	2829,6	€ 189,23	48	€	90,83
9	3	3,6	2829,6	€ 189,23	44	€	83,26
10	3	3,6	2829,6	€ 189,23	44	€	83,26
11	3	3,6	2829,6	€ 189,23	40	€	75,69
12	3	3,6	2829,6	€ 189,23	40	€	75,69
13	10	3,6	9432	€ 630,77	48	€	302,77
14	17	6,3	28060,2	€ 1.876,53	52	€	975,80
15	19	3,6	17920,8	€ 1.198,46	48	€	575,26
16	3	3,6	2829,6	€ 189,23	48	€	90,83
17	19	3,6	17920,8	€ 1.198,46	40	€	479,38
18	3	3,6	2829,6	€ 189,23	48	€	90,83
Totaal			110826	€ 7.411,50		**€**	**3.569,35**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	61	€	461,13
6	12	3,6	13564,8	€ 907,15	61	€	553,36
7	10	3,6	11304	€ 755,96	56	€	423,34
8	12	3,6	13564,8	€ 907,15	56	€	508,00
9	10	3,6	11304	€ 755,96	48	€	362,86
10	12	3,6	13564,8	€ 907,15	48	€	435,43
11	10	3,6	11304	€ 755,96	45	€	340,18
12	12	3,6	13564,8	€ 907,15	45	€	408,22
13	7	3,6	7912,8	€ 529,17	48	€	254,00
16	12	3,6	13564,8	€ 907,15	33	€	299,36
18	12	3,6	13564,8	€ 907,15	33	€	299,36
Totaal			134517,6	€ 8.995,88		**€**	**4.345,24**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	34	€	1.552,96
2	3	4,5	10044	€ 671,69	26	€	174,64
3	3	3,6	8035,2	€ 537,35	26	€	139,71
4	3	3,6	8035,2	€ 537,35	24	€	128,97
Totaal			94413,6	€ 6.313,92		**€**	**1.996,27**

HD400x421							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	3	5,4	6820,2	€ 456,10	38	€	173,32
2	19	4,5	35995,5	€ 2.407,20	59	€	1.420,25
3	19	3,6	28796,4	€ 1.925,76	56	€	1.078,43
4	19	3,6	28796,4	€ 1.925,76	52	€	1.001,40
5	9	3,6	13640,4	€ 912,20	52	€	474,35
6	7	3,6	10609,2	€ 709,49	48	€	340,56
7	9	3,6	13640,4	€ 912,20	48	€	437,86
8	7	3,6	10609,2	€ 709,49	45	€	319,27
9	9	3,6	13640,4	€ 912,20	43	€	392,25
10	7	3,6	10609,2	€ 709,49	42	€	297,99
11	9	3,6	13640,4	€ 912,20	38	€	346,64
12	7	3,6	10609,2	€ 709,49	38	€	269,61
13	3	3,6	4546,8	€ 304,07	27	€	82,10
14	3	6,3	7956,9	€ 532,12	20	€	106,42
15	3	3,6	4546,8	€ 304,07	18	€	54,73
16	7	3,6	10609,2	€ 709,49	27	€	191,56
17	3	3,6	4546,8	€ 304,07	16	€	48,65
18	7	3,6	10609,2	€ 709,49	23	€	163,18
Totaal			240222,6	€ 16.064,92		**€**	**7.198,55**

HD400x463							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
3	10	3,6	16668	€ 1.114,67	41	€	457,02
4	12	3,6	20001,6	€ 1.337,61	32	€	428,04
5	12	3,6	20001,6	€ 1.337,61	23	€	307,65
6	12	3,6	20001,6	€ 1.337,61	23	€	307,65
7	12	3,6	20001,6	€ 1.337,61	23	€	307,65
8	12	3,6	20001,6	€ 1.337,61	18	€	240,77
9	12	3,6	20001,6	€ 1.337,61	18	€	240,77
10	12	3,6	20001,6	€ 1.337,61	18	€	240,77
11	12	3,6	20001,6	€ 1.337,61	16	€	214,02
12	12	3,6	20001,6	€ 1.337,61	27	€	361,15
13	12	3,6	20001,6	€ 1.337,61	27	€	361,15
14	12	6,3	35002,8	€ 2.340,82	15	€	351,12
15	12	3,6	20001,6	€ 1.337,61	13	€	173,89
16	12	3,6	20001,6	€ 1.337,61	10	€	133,76
17	12	3,6	20001,6	€ 1.337,61	15	€	200,64
18	12	3,6	20001,6	€ 1.337,61	13	€	173,89
19	12	3,6	20001,6	€ 1.337,61	8	€	107,01
20	12	3,6	20001,6	€ 1.337,61	13	€	173,89
21	12	3,6	20001,6	€ 1.337,61	11	€	147,14
22	12	3,6	20001,6	€ 1.337,61	8	€	107,01
23	12	3,6	20001,6	€ 1.337,61	16	€	214,02
24	12	3,6	20001,6	€ 1.337,61	15	€	200,64
25	12	3,6	20001,6	€ 1.337,61	8	€	107,01
26	12	3,6	20001,6	€ 1.337,61	11	€	147,14
Totaal			491706	€ 32.882,90		**€**	**5.703,79**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	33	€	4.012,03
2	28	4,5	136836	€ 9.150,92	30	€	2.745,28
3	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
4	28	3,6	109468,8	€ 7.320,74	25	€	1.830,18
5	28	3,6	109468,8	€ 7.320,74	23	€	1.683,77
6	28	3,6	109468,8	€ 7.320,74	23	€	1.683,77
7	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
8	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
9	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
10	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
11	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
12	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
13	28	3,6	109468,8	€ 7.320,74	16	€	1.171,32
14	28	6,3	191570,4	€ 12.811,29	14	€	1.793,58
15	28	3,6	109468,8	€ 7.320,74	14	€	1.024,90
16	28	3,6	109468,8	€ 7.320,74	11	€	805,28
17	28	3,6	109468,8	€ 7.320,74	11	€	805,28
18	28	3,6	109468,8	€ 7.320,74	10	€	732,07
19	28	3,6	109468,8	€ 7.320,74	8	€	585,66
20	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
21	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
22	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
23	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
24	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
25	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
26	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
Totaal			3027985	€ 202.496,88		**€**	**45.081,38**

<u>New shadow price best and concrete option 200 years “meeting”</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €95.973,86 (=33%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	63	€	85,09
14	3	6,3	3534,3	€ 236,36	56	€	132,36
15	3	3,6	2019,6	€ 135,06	51	€	68,88
17	3	3,6	2019,6	€ 135,06	45	€	60,78
19	25	3,6	16830	€ 1.125,51	67	€	754,09
20	25	3,6	16830	€ 1.125,51	67	€	754,09
21	25	3,6	16830	€ 1.125,51	63	€	709,07
22	25	3,6	16830	€ 1.125,51	56	€	630,28
23	25	3,6	16830	€ 1.125,51	45	€	506,48
24	25	3,6	16830	€ 1.125,51	41	€	461,46
25	25	3,6	16830	€ 1.125,51	32	€	360,16
26	25	3,6	16830	€ 1.125,51	28	€	315,14
27	28	4,7	24609,2	€ 1.645,74	28	€	460,81
Totaal			168842,3	€ 11.291,35		**€**	**5.298,69**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	69	€	163,21
3	3	3,6	2829,6	€ 189,23	67	€	126,78
4	3	3,6	2829,6	€ 189,23	67	€	126,78
5	3	3,6	2829,6	€ 189,23	62	€	117,32
6	3	3,6	2829,6	€ 189,23	62	€	117,32
7	3	3,6	2829,6	€ 189,23	57	€	107,86
8	3	3,6	2829,6	€ 189,23	57	€	107,86
9	3	3,6	2829,6	€ 189,23	54	€	102,18
10	3	3,6	2829,6	€ 189,23	54	€	102,18
11	3	3,6	2829,6	€ 189,23	48	€	90,83
12	3	3,6	2829,6	€ 189,23	48	€	90,83
13	10	3,6	9432	€ 630,77	57	€	359,54
14	17	6,3	28060,2	€ 1.876,53	62	€	1.163,45
15	19	3,6	17920,8	€ 1.198,46	57	€	683,12
16	3	3,6	2829,6	€ 189,23	54	€	102,18
17	19	3,6	17920,8	€ 1.198,46	48	€	575,26
18	3	3,6	2829,6	€ 189,23	54	€	102,18
Totaal			110826	€ 7.411,50		**€**	**4.238,91**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	70	€	529,17
6	12	3,6	13564,8	€ 907,15	70	€	635,00
7	10	3,6	11304	€ 755,96	66	€	498,93
8	12	3,6	13564,8	€ 907,15	66	€	598,72
9	10	3,6	11304	€ 755,96	61	€	461,13
10	12	3,6	13564,8	€ 907,15	61	€	553,36
11	10	3,6	11304	€ 755,96	52	€	393,10
12	12	3,6	13564,8	€ 907,15	56	€	508,00
13	7	3,6	7912,8	€ 529,17	61	€	322,79
16	12	3,6	13564,8	€ 907,15	40	€	362,86
18	12	3,6	13564,8	€ 907,15	39	€	353,79
Totaal			134517,6	€ 8.995,88		**€**	**5.216,86**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	41	€	1.872,68
2	3	4,5	10044	€ 671,69	32	€	214,94
3	3	3,6	8035,2	€ 537,35	29	€	155,83
4	3	3,6	8035,2	€ 537,35	28	€	150,46
Totaal			94413,6	€ 6.313,92		**€**	**2.393,92**

HD400x421							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	3	5,4	6820,2	€ 456,10	45	€	205,25
2	19	4,5	35995,5	€ 2.407,20	71	€	1.709,11
3	19	3,6	28796,4	€ 1.925,76	67	€	1.290,26
4	19	3,6	28796,4	€ 1.925,76	63	€	1.213,23
5	9	3,6	13640,4	€ 912,20	59	€	538,20
6	7	3,6	10609,2	€ 709,49	59	€	418,60
7	9	3,6	13640,4	€ 912,20	56	€	510,83
8	7	3,6	10609,2	€ 709,49	56	€	397,32
9	9	3,6	13640,4	€ 912,20	52	€	474,35
10	7	3,6	10609,2	€ 709,49	49	€	347,65
11	9	3,6	13640,4	€ 912,20	48	€	437,86
12	7	3,6	10609,2	€ 709,49	45	€	319,27
13	3	3,6	4546,8	€ 304,07	33	€	100,34
14	3	6,3	7956,9	€ 532,12	25	€	133,03
15	3	3,6	4546,8	€ 304,07	23	€	69,94
16	7	3,6	10609,2	€ 709,49	33	€	234,13
17	3	3,6	4546,8	€ 304,07	20	€	60,81
18	7	3,6	10609,2	€ 709,49	27	€	191,56
Totaal			240222,6	€ 16.064,92		**€**	**8.651,74**

HD400x463							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
3	10	3,6	16668	€ 1.114,67	51	€	568,48
4	12	3,6	20001,6	€ 1.337,61	41	€	548,42
5	12	3,6	20001,6	€ 1.337,61	27	€	361,15
6	12	3,6	20001,6	€ 1.337,61	27	€	361,15
7	12	3,6	20001,6	€ 1.337,61	27	€	361,15
8	12	3,6	20001,6	€ 1.337,61	23	€	307,65
9	12	3,6	20001,6	€ 1.337,61	23	€	307,65
10	12	3,6	20001,6	€ 1.337,61	23	€	307,65
11	12	3,6	20001,6	€ 1.337,61	18	€	240,77
12	12	3,6	20001,6	€ 1.337,61	32	€	428,04
13	12	3,6	20001,6	€ 1.337,61	32	€	428,04
14	12	6,3	35002,8	€ 2.340,82	18	€	421,35
15	12	3,6	20001,6	€ 1.337,61	16	€	214,02
16	12	3,6	20001,6	€ 1.337,61	11	€	147,14
17	12	3,6	20001,6	€ 1.337,61	18	€	240,77
18	12	3,6	20001,6	€ 1.337,61	16	€	214,02
19	12	3,6	20001,6	€ 1.337,61	11	€	147,14
20	12	3,6	20001,6	€ 1.337,61	16	€	214,02
21	12	3,6	20001,6	€ 1.337,61	13	€	173,89
22	12	3,6	20001,6	€ 1.337,61	11	€	147,14
23	12	3,6	20001,6	€ 1.337,61	21	€	280,90
24	12	3,6	20001,6	€ 1.337,61	18	€	240,77
25	12	3,6	20001,6	€ 1.337,61	9	€	120,38
26	12	3,6	20001,6	€ 1.337,61	13	€	173,89
Totaal			491706	€ 32.882,90		**€**	**6.955,57**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	38	€	4.619,91
2	28	4,5	136836	€ 9.150,92	37	€	3.385,84
3	28	3,6	109468,8	€ 7.320,74	37	€	2.708,67
4	28	3,6	109468,8	€ 7.320,74	31	€	2.269,43
5	28	3,6	109468,8	€ 7.320,74	29	€	2.123,01
6	28	3,6	109468,8	€ 7.320,74	28	€	2.049,81
7	28	3,6	109468,8	€ 7.320,74	28	€	2.049,81
8	28	3,6	109468,8	€ 7.320,74	24	€	1.756,98
9	28	3,6	109468,8	€ 7.320,74	24	€	1.756,98
10	28	3,6	109468,8	€ 7.320,74	24	€	1.756,98
11	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
12	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
13	28	3,6	109468,8	€ 7.320,74	20	€	1.464,15
14	28	6,3	191570,4	€ 12.811,29	18	€	2.306,03
15	28	3,6	109468,8	€ 7.320,74	16	€	1.171,32
16	28	3,6	109468,8	€ 7.320,74	14	€	1.024,90
17	28	3,6	109468,8	€ 7.320,74	13	€	951,70
18	28	3,6	109468,8	€ 7.320,74	13	€	951,70
19	28	3,6	109468,8	€ 7.320,74	10	€	732,07
20	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
21	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
22	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
23	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
24	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
25	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
26	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
Totaal			3027985	€ 202.496,88		**€**	**54.236,22**

<u>New shadow price steel option 50 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €114.655,32 (=39%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	75	€	101,30
14	3	6,3	3534,3	€ 236,36	70	€	165,45
15	3	3,6	2019,6	€ 135,06	65	€	87,79
17	3	3,6	2019,6	€ 135,06	57	€	76,98
19	25	3,6	16830	€ 1.125,51	81	€	911,66
20	25	3,6	16830	€ 1.125,51	81	€	911,66
21	25	3,6	16830	€ 1.125,51	75	€	844,13
22	25	3,6	16830	€ 1.125,51	65	€	731,58
23	25	3,6	16830	€ 1.125,51	57	€	641,54
24	25	3,6	16830	€ 1.125,51	48	€	540,24
25	25	3,6	16830	€ 1.125,51	39	€	438,95
26	25	3,6	16830	€ 1.125,51	32	€	360,16
27	28	4,7	24609,2	€ 1.645,74	32	€	526,64
Totaal			168842,3	€ 11.291,35		**€**	**6.338,09**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	90	€	212,88
3	3	3,6	2829,6	€ 189,23	90	€	170,31
4	3	3,6	2829,6	€ 189,23	90	€	170,31
5	3	3,6	2829,6	€ 189,23	85	€	160,85
6	3	3,6	2829,6	€ 189,23	85	€	160,85
7	3	3,6	2829,6	€ 189,23	73	€	138,14
8	3	3,6	2829,6	€ 189,23	73	€	138,14
9	3	3,6	2829,6	€ 189,23	63	€	119,21
10	3	3,6	2829,6	€ 189,23	63	€	119,21
11	3	3,6	2829,6	€ 189,23	58	€	109,75
12	3	3,6	2829,6	€ 189,23	58	€	109,75
13	10	3,6	9432	€ 630,77	73	€	460,46
14	17	6,3	28060,2	€ 1.876,53	90	€	1.688,88
15	19	3,6	17920,8	€ 1.198,46	73	€	874,87
16	3	3,6	2829,6	€ 189,23	73	€	138,14
17	19	3,6	17920,8	€ 1.198,46	58	€	695,10
18	3	3,6	2829,6	€ 189,23	73	€	138,14
Totaal			110826	€ 7.411,50		**€**	**5.604,99**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	91	€	687,92
6	12	3,6	13564,8	€ 907,15	91	€	825,50
7	10	3,6	11304	€ 755,96	83	€	627,44
8	12	3,6	13564,8	€ 907,15	83	€	752,93
9	10	3,6	11304	€ 755,96	75	€	566,97
10	12	3,6	13564,8	€ 907,15	75	€	680,36
11	10	3,6	11304	€ 755,96	71	€	536,73
12	12	3,6	13564,8	€ 907,15	75	€	680,36
13	7	3,6	7912,8	€ 529,17	75	€	396,88
16	12	3,6	13564,8	€ 907,15	48	€	435,43
18	12	3,6	13564,8	€ 907,15	45	€	408,22
Totaal			134517,6	€ 8.995,88		**€**	**6.598,74**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	62	€	2.831,86
2	3	4,5	10044	€ 671,69	47	€	315,70
3	3	3,6	8035,2	€ 537,35	39	€	209,57
4	3	3,6	8035,2	€ 537,35	37	€	198,82
Totaal			94413,6	€ 6.313,92		**€**	**3.555,95**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
1	3	5,4	6820,2	€ 456,10	56	€	255,42
2	19	4,5	35995,5	€ 2.407,20	100	€	2.407,20
3	19	3,6	28796,4	€ 1.925,76	91	€	1.752,44
4	19	3,6	28796,4	€ 1.925,76	82	€	1.579,13
5	9	3,6	13640,4	€ 912,20	82	€	748,01
6	7	3,6	10609,2	€ 709,49	82	€	581,78
7	9	3,6	13640,4	€ 912,20	75	€	684,15
8	7	3,6	10609,2	€ 709,49	75	€	532,12
9	9	3,6	13640,4	€ 912,20	68	€	620,30
10	7	3,6	10609,2	€ 709,49	66	€	468,26
11	9	3,6	13640,4	€ 912,20	62	€	565,57
12	7	3,6	10609,2	€ 709,49	56	€	397,32
13	3	3,6	4546,8	€ 304,07	39	€	118,59
14	3	6,3	7956,9	€ 532,12	31	€	164,96
15	3	3,6	4546,8	€ 304,07	27	€	82,10
16	7	3,6	10609,2	€ 709,49	39	€	276,70
17	3	3,6	4546,8	€ 304,07	25	€	76,02
18	7	3,6	10609,2	€ 709,49	36	€	255,42
Totaal			240222,6	€ 16.064,92		**€**	**11.565,47**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
3	10	3,6	16668	€ 1.114,67	68	€	757,98
4	12	3,6	20001,6	€ 1.337,61	51	€	682,18
5	12	3,6	20001,6	€ 1.337,61	36	€	481,54
6	12	3,6	20001,6	€ 1.337,61	36	€	481,54
7	12	3,6	20001,6	€ 1.337,61	33	€	441,41
8	12	3,6	20001,6	€ 1.337,61	26	€	347,78
9	12	3,6	20001,6	€ 1.337,61	26	€	347,78
10	12	3,6	20001,6	€ 1.337,61	26	€	347,78
11	12	3,6	20001,6	€ 1.337,61	22	€	294,27
12	12	3,6	20001,6	€ 1.337,61	41	€	548,42
13	12	3,6	20001,6	€ 1.337,61	41	€	548,42
14	12	6,3	35002,8	€ 2.340,82	22	€	514,98
15	12	3,6	20001,6	€ 1.337,61	18	€	240,77
16	12	3,6	20001,6	€ 1.337,61	16	€	214,02
17	12	3,6	20001,6	€ 1.337,61	22	€	294,27
18	12	3,6	20001,6	€ 1.337,61	18	€	240,77
19	12	3,6	20001,6	€ 1.337,61	14	€	187,27
20	12	3,6	20001,6	€ 1.337,61	18	€	240,77
21	12	3,6	20001,6	€ 1.337,61	16	€	214,02
22	12	3,6	20001,6	€ 1.337,61	14	€	187,27
23	12	3,6	20001,6	€ 1.337,61	25	€	334,40
24	12	3,6	20001,6	€ 1.337,61	22	€	294,27
25	12	3,6	20001,6	€ 1.337,61	12	€	160,51
26	12	3,6	20001,6	€ 1.337,61	16	€	214,02
Totaal			491706	€ 32.882,90		**€**	**8.616,43**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	51	€	6.200,40
2	28	4,5	136836	€ 9.150,92	51	€	4.666,97
3	28	3,6	109468,8	€ 7.320,74	51	€	3.733,58
4	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
5	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
6	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
7	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
8	28	3,6	109468,8	€ 7.320,74	32	€	2.342,64
9	28	3,6	109468,8	€ 7.320,74	32	€	2.342,64
10	28	3,6	109468,8	€ 7.320,74	32	€	2.342,64
11	28	3,6	109468,8	€ 7.320,74	29	€	2.123,01
12	28	3,6	109468,8	€ 7.320,74	29	€	2.123,01
13	28	3,6	109468,8	€ 7.320,74	26	€	1.903,39
14	28	6,3	191570,4	€ 12.811,29	22	€	2.818,48
15	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
16	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
17	28	3,6	109468,8	€ 7.320,74	17	€	1.244,53
18	28	3,6	109468,8	€ 7.320,74	16	€	1.171,32
19	28	3,6	109468,8	€ 7.320,74	13	€	951,70
20	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
21	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
22	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
23	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
24	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
25	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
26	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
Totaal			3027985	€ 202.496,88		**€**	**63.393,68**

<u>New shadow price steel option 200 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €117.302,49 (=40%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	81	€	109,40
14	3	6,3	3534,3	€ 236,36	81	€	191,45
15	3	3,6	2019,6	€ 135,06	65	€	87,79
17	3	3,6	2019,6	€ 135,06	57	€	76,98
19	25	3,6	16830	€ 1.125,51	81	€	911,66
20	25	3,6	16830	€ 1.125,51	81	€	911,66
21	25	3,6	16830	€ 1.125,51	81	€	911,66
22	25	3,6	16830	€ 1.125,51	70	€	787,86
23	25	3,6	16830	€ 1.125,51	60	€	675,30
24	25	3,6	16830	€ 1.125,51	56	€	630,28
25	25	3,6	16830	€ 1.125,51	46	€	517,73
26	25	3,6	16830	€ 1.125,51	32	€	360,16
27	28	4,7	24609,2	€ 1.645,74	32	€	526,64
Totaal			168842,3	€ 11.291,35		**€**	**6.698,59**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	90	€	212,88
3	3	3,6	2829,6	€ 189,23	90	€	170,31
4	3	3,6	2829,6	€ 189,23	90	€	170,31
5	3	3,6	2829,6	€ 189,23	90	€	170,31
6	3	3,6	2829,6	€ 189,23	90	€	170,31
7	3	3,6	2829,6	€ 189,23	73	€	138,14
8	3	3,6	2829,6	€ 189,23	73	€	138,14
9	3	3,6	2829,6	€ 189,23	73	€	138,14
10	3	3,6	2829,6	€ 189,23	73	€	138,14
11	3	3,6	2829,6	€ 189,23	63	€	119,21
12	3	3,6	2829,6	€ 189,23	63	€	119,21
13	10	3,6	9432	€ 630,77	73	€	460,46
14	17	6,3	28060,2	€ 1.876,53	90	€	1.688,88
15	19	3,6	17920,8	€ 1.198,46	73	€	874,87
16	3	3,6	2829,6	€ 189,23	73	€	138,14
17	19	3,6	17920,8	€ 1.198,46	63	€	755,03
18	3	3,6	2829,6	€ 189,23	73	€	138,14
Totaal			110826	€ 7.411,50		**€**	**5.740,60**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	100	€	755,96
6	12	3,6	13564,8	€ 907,15	100	€	907,15
7	10	3,6	11304	€ 755,96	83	€	627,44
8	12	3,6	13564,8	€ 907,15	83	€	752,93
9	10	3,6	11304	€ 755,96	75	€	566,97
10	12	3,6	13564,8	€ 907,15	75	€	680,36
11	10	3,6	11304	€ 755,96	72	€	544,29
12	12	3,6	13564,8	€ 907,15	75	€	680,36
13	7	3,6	7912,8	€ 529,17	75	€	396,88
16	12	3,6	13564,8	€ 907,15	57	€	517,07
18	12	3,6	13564,8	€ 907,15	45	€	408,22
Totaal			134517,6	€ 8.995,88		**€**	**6.837,63**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	62	€	2.831,86
2	3	4,5	10044	€ 671,69	47	€	315,70
3	3	3,6	8035,2	€ 537,35	42	€	225,69
4	3	3,6	8035,2	€ 537,35	38	€	204,19
Totaal			94413,6	€ 6.313,92		**€**	**3.577,44**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original		%	Shadow price
1	3	5,4	6820,2	€	456,10	68	€ 310,15
2	19	4,5	35995,5	€	2.407,20	100	€ 2.407,20
3	19	3,6	28796,4	€	1.925,76	91	€ 1.752,44
4	19	3,6	28796,4	€	1.925,76	91	€ 1.752,44
5	9	3,6	13640,4	€	912,20	82	€ 748,01
6	7	3,6	10609,2	€	709,49	82	€ 581,78
7	9	3,6	13640,4	€	912,20	75	€ 684,15
8	7	3,6	10609,2	€	709,49	75	€ 532,12
9	9	3,6	13640,4	€	912,20	68	€ 620,30
10	7	3,6	10609,2	€	709,49	68	€ 482,45
11	9	3,6	13640,4	€	912,20	62	€ 565,57
12	7	3,6	10609,2	€	709,49	56	€ 397,32
13	3	3,6	4546,8	€	304,07	44	€ 133,79
14	3	6,3	7956,9	€	532,12	36	€ 191,56
15	3	3,6	4546,8	€	304,07	27	€ 82,10
16	7	3,6	10609,2	€	709,49	44	€ 312,18
17	3	3,6	4546,8	€	304,07	25	€ 76,02
18	7	3,6	10609,2	€	709,49	36	€ 255,42
Totaal			240222,6	€	16.064,92		**€ 11.885,00**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original		%	Shadow price
3	10	3,6	16668	€	1.114,67	68	€ 757,98
4	12	3,6	20001,6	€	1.337,61	51	€ 682,18
5	12	3,6	20001,6	€	1.337,61	36	€ 481,54
6	12	3,6	20001,6	€	1.337,61	36	€ 481,54
7	12	3,6	20001,6	€	1.337,61	33	€ 441,41
8	12	3,6	20001,6	€	1.337,61	26	€ 347,78
9	12	3,6	20001,6	€	1.337,61	26	€ 347,78
10	12	3,6	20001,6	€	1.337,61	26	€ 347,78
11	12	3,6	20001,6	€	1.337,61	23	€ 307,65
12	12	3,6	20001,6	€	1.337,61	41	€ 548,42
13	12	3,6	20001,6	€	1.337,61	41	€ 548,42
14	12	6,3	35002,8	€	2.340,82	22	€ 514,98
15	12	3,6	20001,6	€	1.337,61	20	€ 267,52
16	12	3,6	20001,6	€	1.337,61	16	€ 214,02
17	12	3,6	20001,6	€	1.337,61	22	€ 294,27
18	12	3,6	20001,6	€	1.337,61	20	€ 267,52
19	12	3,6	20001,6	€	1.337,61	13	€ 173,89
20	12	3,6	20001,6	€	1.337,61	20	€ 267,52
21	12	3,6	20001,6	€	1.337,61	17	€ 227,39
22	12	3,6	20001,6	€	1.337,61	13	€ 173,89
23	12	3,6	20001,6	€	1.337,61	26	€ 347,78
24	12	3,6	20001,6	€	1.337,61	22	€ 294,27
25	12	3,6	20001,6	€	1.337,61	12	€ 160,51
26	12	3,6	20001,6	€	1.337,61	17	€ 227,39
Totaal			491706	€	32.882,90		**€ 8.723,44**

HD400x1086						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
1	31	5,4	181796,4	€ 12.157,66	51	€ 6.200,40
2	28	4,5	136836	€ 9.150,92	51	€ 4.666,97
3	28	3,6	109468,8	€ 7.320,74	51	€ 3.733,58
4	28	3,6	109468,8	€ 7.320,74	43	€ 3.147,92
5	28	3,6	109468,8	€ 7.320,74	39	€ 2.855,09
6	28	3,6	109468,8	€ 7.320,74	39	€ 2.855,09
7	28	3,6	109468,8	€ 7.320,74	39	€ 2.855,09
8	28	3,6	109468,8	€ 7.320,74	35	€ 2.562,26
9	28	3,6	109468,8	€ 7.320,74	35	€ 2.562,26
10	28	3,6	109468,8	€ 7.320,74	35	€ 2.562,26
11	28	3,6	109468,8	€ 7.320,74	29	€ 2.123,01
12	28	3,6	109468,8	€ 7.320,74	29	€ 2.123,01
13	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
14	28	6,3	191570,4	€ 12.811,29	22	€ 2.818,48
15	28	3,6	109468,8	€ 7.320,74	22	€ 1.610,56
16	28	3,6	109468,8	€ 7.320,74	18	€ 1.317,73
17	28	3,6	109468,8	€ 7.320,74	18	€ 1.317,73
18	28	3,6	109468,8	€ 7.320,74	17	€ 1.244,53
19	28	3,6	109468,8	€ 7.320,74	14	€ 1.024,90
20	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
21	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
22	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
23	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
24	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
25	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
26	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
Totaal			3027985	€ 202.496,88		**€ 64.857,83**

<u>New shadow price steel option 200 years “meeting”</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €140.862,49 (=48%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
13	3	3,6	2019,6	€ 135,06	102	€ 137,76
14	3	6,3	3534,3	€ 236,36	102	€ 241,08
15	3	3,6	2019,6	€ 135,06	81	€ 109,40
17	3	3,6	2019,6	€ 135,06	65	€ 87,79
19	25	3,6	16830	€ 1.125,51	102	€ 1.148,02
20	25	3,6	16830	€ 1.125,51	102	€ 1.148,02
21	25	3,6	16830	€ 1.125,51	102	€ 1.148,02
22	25	3,6	16830	€ 1.125,51	81	€ 911,66
23	25	3,6	16830	€ 1.125,51	70	€ 787,86
24	25	3,6	16830	€ 1.125,51	60	€ 675,30
25	25	3,6	16830	€ 1.125,51	48	€ 540,24
26	25	3,6	16830	€ 1.125,51	39	€ 438,95
27	28	4,7	24609,2	€ 1.645,74	39	€ 641,84
Totaal			168842,3	€ 11.291,35		**€ 8.015,95**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	120	€	283,84
3	3	3,6	2829,6	€ 189,23	110	€	208,15
4	3	3,6	2829,6	€ 189,23	110	€	208,15
5	3	3,6	2829,6	€ 189,23	100	€	189,23
6	3	3,6	2829,6	€ 189,23	100	€	189,23
7	3	3,6	2829,6	€ 189,23	90	€	170,31
8	3	3,6	2829,6	€ 189,23	90	€	170,31
9	3	3,6	2829,6	€ 189,23	90	€	170,31
10	3	3,6	2829,6	€ 189,23	90	€	170,31
11	3	3,6	2829,6	€ 189,23	73	€	138,14
12	3	3,6	2829,6	€ 189,23	73	€	138,14
13	10	3,6	9432	€ 630,77	90	€	567,69
14	17	6,3	28060,2	€ 1.876,53	132	€	2.477,02
15	19	3,6	17920,8	€ 1.198,46	90	€	1.078,61
16	3	3,6	2829,6	€ 189,23	73	€	138,14
17	19	3,6	17920,8	€ 1.198,46	73	€	874,87
18	3	3,6	2829,6	€ 189,23	73	€	138,14
Totaal			110826	€ 7.411,50		**€**	**7.310,58**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	122	€	922,27
6	12	3,6	13564,8	€ 907,15	122	€	1.106,72
7	10	3,6	11304	€ 755,96	111	€	839,11
8	12	3,6	13564,8	€ 907,15	111	€	1.006,93
9	10	3,6	11304	€ 755,96	100	€	755,96
10	12	3,6	13564,8	€ 907,15	100	€	907,15
11	10	3,6	11304	€ 755,96	83	€	627,44
12	12	3,6	13564,8	€ 907,15	91	€	825,50
13	7	3,6	7912,8	€ 529,17	100	€	529,17
16	12	3,6	13564,8	€ 907,15	60	€	544,29
18	12	3,6	13564,8	€ 907,15	53	€	480,79
Totaal			134517,6	€ 8.995,88		**€**	**8.545,33**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	74	€	3.379,96
2	3	4,5	10044	€ 671,69	57	€	382,87
3	3	3,6	8035,2	€ 537,35	51	€	274,05
4	3	3,6	8035,2	€ 537,35	47	€	252,56
Totaal			94413,6	€ 6.313,92		**€**	**4.289,44**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
1	3	5,4	6820,2	€ 456,10	82	€	374,00
2	19	4,5	35995,5	€ 2.407,20	121	€	2.912,72
3	19	3,6	28796,4	€ 1.925,76	110	€	2.118,34
4	19	3,6	28796,4	€ 1.925,76	110	€	2.118,34
5	9	3,6	13640,4	€ 912,20	100	€	912,20
6	7	3,6	10609,2	€ 709,49	100	€	709,49
7	9	3,6	13640,4	€ 912,20	91	€	830,11
8	7	3,6	10609,2	€ 709,49	91	€	645,64
9	9	3,6	13640,4	€ 912,20	82	€	748,01
10	7	3,6	10609,2	€ 709,49	82	€	581,78
11	9	3,6	13640,4	€ 912,20	82	€	748,01
12	7	3,6	10609,2	€ 709,49	75	€	532,12
13	3	3,6	4546,8	€ 304,07	56	€	170,28
14	3	6,3	7956,9	€ 532,12	45	€	239,45
15	3	3,6	4546,8	€ 304,07	33	€	100,34
16	7	3,6	10609,2	€ 709,49	56	€	397,32
17	3	3,6	4546,8	€ 304,07	31	€	94,26
18	7	3,6	10609,2	€ 709,49	45	€	319,27
Totaal			240222,6	€ 16.064,92		**€**	**14.551,67**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
3	10	3,6	16668	€ 1.114,67	83	€	925,18
4	12	3,6	20001,6	€ 1.337,61	68	€	909,57
5	12	3,6	20001,6	€ 1.337,61	41	€	548,42
6	12	3,6	20001,6	€ 1.337,61	41	€	548,42
7	12	3,6	20001,6	€ 1.337,61	41	€	548,42
8	12	3,6	20001,6	€ 1.337,61	33	€	441,41
9	12	3,6	20001,6	€ 1.337,61	33	€	441,41
10	12	3,6	20001,6	€ 1.337,61	33	€	441,41
11	12	3,6	20001,6	€ 1.337,61	28	€	374,53
12	12	3,6	20001,6	€ 1.337,61	51	€	682,18
13	12	3,6	20001,6	€ 1.337,61	51	€	682,18
14	12	6,3	35002,8	€ 2.340,82	28	€	655,43
15	12	3,6	20001,6	€ 1.337,61	23	€	307,65
16	12	3,6	20001,6	€ 1.337,61	18	€	240,77
17	12	3,6	20001,6	€ 1.337,61	28	€	374,53
18	12	3,6	20001,6	€ 1.337,61	23	€	307,65
19	12	3,6	20001,6	€ 1.337,61	16	€	214,02
20	12	3,6	20001,6	€ 1.337,61	23	€	307,65
21	12	3,6	20001,6	€ 1.337,61	22	€	294,27
22	12	3,6	20001,6	€ 1.337,61	16	€	214,02
23	12	3,6	20001,6	€ 1.337,61	33	€	441,41
24	12	3,6	20001,6	€ 1.337,61	28	€	374,53
25	12	3,6	20001,6	€ 1.337,61	16	€	214,02
26	12	3,6	20001,6	€ 1.337,61	22	€	294,27
Totaal			491706	€ 32.882,90		**€**	**10.783,36**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	62	€	7.537,75
2	28	4,5	136836	€ 9.150,92	62	€	5.673,57
3	28	3,6	109468,8	€ 7.320,74	62	€	4.538,86
4	28	3,6	109468,8	€ 7.320,74	51	€	3.733,58
5	28	3,6	109468,8	€ 7.320,74	47	€	3.440,75
6	28	3,6	109468,8	€ 7.320,74	47	€	3.440,75
7	28	3,6	109468,8	€ 7.320,74	47	€	3.440,75
8	28	3,6	109468,8	€ 7.320,74	43	€	3.147,92
9	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
10	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
11	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
12	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
13	28	3,6	109468,8	€ 7.320,74	32	€	2.342,64
14	28	6,3	191570,4	€ 12.811,29	35	€	4.483,95
15	28	3,6	109468,8	€ 7.320,74	26	€	1.903,39
16	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
17	28	3,6	109468,8	€ 7.320,74	22	€	1.610,56
18	28	3,6	109468,8	€ 7.320,74	21	€	1.537,36
19	28	3,6	109468,8	€ 7.320,74	16	€	1.171,32
20	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
21	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
22	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
23	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
24	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
25	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
26	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
Totaal			3027985	€ 202.496,88		**€**	**78.384,20**

<u>New shadow price timber option 50 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €119.382,42 (=41%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	89	€	120,20
14	3	6,3	3534,3	€ 236,36	76	€	179,63
15	3	3,6	2019,6	€ 135,06	70	€	94,54
17	3	3,6	2019,6	€ 135,06	59	€	79,69
19	25	3,6	16830	€ 1.125,51	89	€	1.001,70
20	25	3,6	16830	€ 1.125,51	89	€	1.001,70
21	25	3,6	16830	€ 1.125,51	89	€	1.001,70
22	25	3,6	16830	€ 1.125,51	76	€	855,39
23	25	3,6	16830	€ 1.125,51	64	€	720,33
24	25	3,6	16830	€ 1.125,51	54	€	607,77
25	25	3,6	16830	€ 1.125,51	44	€	495,22
26	25	3,6	16830	€ 1.125,51	35	€	393,93
27	28	4,7	24609,2	€ 1.645,74	35	€	576,01
Totaal			168842,3	€ 11.291,35		**€**	**7.127,82**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	101	€	238,90
3	3	3,6	2829,6	€ 189,23	95	€	179,77
4	3	3,6	2829,6	€ 189,23	95	€	179,77
5	3	3,6	2829,6	€ 189,23	89	€	168,41
6	3	3,6	2829,6	€ 189,23	89	€	168,41
7	3	3,6	2829,6	€ 189,23	83	€	157,06
8	3	3,6	2829,6	€ 189,23	83	€	157,06
9	3	3,6	2829,6	€ 189,23	73	€	138,14
10	3	3,6	2829,6	€ 189,23	73	€	138,14
11	3	3,6	2829,6	€ 189,23	68	€	128,68
12	3	3,6	2829,6	€ 189,23	68	€	128,68
13	10	3,6	9432	€ 630,77	83	€	523,54
14	17	6,3	28060,2	€ 1.876,53	89	€	1.670,11
15	19	3,6	17920,8	€ 1.198,46	83	€	994,72
16	3	3,6	2829,6	€ 189,23	73	€	138,14
17	19	3,6	17920,8	€ 1.198,46	68	€	814,95
18	3	3,6	2829,6	€ 189,23	73	€	138,14
Totaal			110826	€ 7.411,50		**€**	**6.062,61**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	99	€	748,40
6	12	3,6	13564,8	€ 907,15	99	€	898,08
7	10	3,6	11304	€ 755,96	94	€	710,60
8	12	3,6	13564,8	€ 907,15	94	€	852,72
9	10	3,6	11304	€ 755,96	84	€	635,00
10	12	3,6	13564,8	€ 907,15	84	€	762,00
11	10	3,6	11304	€ 755,96	74	€	559,41
12	12	3,6	13564,8	€ 907,15	74	€	671,29
13	7	3,6	7912,8	€ 529,17	84	€	444,50
16	12	3,6	13564,8	€ 907,15	57	€	517,07
18	12	3,6	13564,8	€ 907,15	49	€	444,50
Totaal			134517,6	€ 8.995,88		**€**	**7.243,57**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	59	€	2.694,84
2	3	4,5	10044	€ 671,69	44	€	295,55
3	3	3,6	8035,2	€ 537,35	42	€	225,69
4	3	3,6	8035,2	€ 537,35	40	€	214,94
Totaal			94413,6	€ 6.313,92		**€**	**3.431,01**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
1	3	5,4	6820,2	€ 456,10	63	€	287,34
2	19	4,5	35995,5	€ 2.407,20	100	€	2.407,20
3	19	3,6	28796,4	€ 1.925,76	91	€	1.752,44
4	19	3,6	28796,4	€ 1.925,76	91	€	1.752,44
5	9	3,6	13640,4	€ 912,20	87	€	793,62
6	7	3,6	10609,2	€ 709,49	82	€	581,78
7	9	3,6	13640,4	€ 912,20	78	€	711,52
8	7	3,6	10609,2	€ 709,49	78	€	553,40
9	9	3,6	13640,4	€ 912,20	74	€	675,03
10	7	3,6	10609,2	€ 709,49	70	€	496,64
11	9	3,6	13640,4	€ 912,20	66	€	602,05
12	7	3,6	10609,2	€ 709,49	63	€	446,98
13	3	3,6	4546,8	€ 304,07	45	€	136,83
14	3	6,3	7956,9	€ 532,12	34	€	180,92
15	3	3,6	4546,8	€ 304,07	31	€	94,26
16	7	3,6	10609,2	€ 709,49	45	€	319,27
17	3	3,6	4546,8	€ 304,07	29	€	88,18
18	7	3,6	10609,2	€ 709,49	39	€	276,70
Totaal			240222,6	€ 16.064,92		**€**	**12.156,63**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
3	10	3,6	16668	€ 1.114,67	71	€	791,42
4	12	3,6	20001,6	€ 1.337,61	57	€	762,44
5	12	3,6	20001,6	€ 1.337,61	39	€	521,67
6	12	3,6	20001,6	€ 1.337,61	39	€	521,67
7	12	3,6	20001,6	€ 1.337,61	39	€	521,67
8	12	3,6	20001,6	€ 1.337,61	31	€	414,66
9	12	3,6	20001,6	€ 1.337,61	31	€	414,66
10	12	3,6	20001,6	€ 1.337,61	31	€	414,66
11	12	3,6	20001,6	€ 1.337,61	26	€	347,78
12	12	3,6	20001,6	€ 1.337,61	44	€	588,55
13	12	3,6	20001,6	€ 1.337,61	44	€	588,55
14	12	6,3	35002,8	€ 2.340,82	24	€	561,80
15	12	3,6	20001,6	€ 1.337,61	22	€	294,27
16	12	3,6	20001,6	€ 1.337,61	16	€	214,02
17	12	3,6	20001,6	€ 1.337,61	24	€	321,03
18	12	3,6	20001,6	€ 1.337,61	22	€	294,27
19	12	3,6	20001,6	€ 1.337,61	14	€	187,27
20	12	3,6	20001,6	€ 1.337,61	22	€	294,27
21	12	3,6	20001,6	€ 1.337,61	18	€	240,77
22	12	3,6	20001,6	€ 1.337,61	14	€	187,27
23	12	3,6	20001,6	€ 1.337,61	28	€	374,53
24	12	3,6	20001,6	€ 1.337,61	24	€	321,03
25	12	3,6	20001,6	€ 1.337,61	13	€	173,89
26	12	3,6	20001,6	€ 1.337,61	18	€	240,77
Totaal			491706	€ 32.882,90		**€**	**9.592,89**

HD400x1086							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	31	5,4	181796,4	€ 12.157,66	48	€	5.835,68
2	28	4,5	136836	€ 9.150,92	44	€	4.026,41
3	28	3,6	109468,8	€ 7.320,74	55	€	4.026,41
4	28	3,6	109468,8	€ 7.320,74	42	€	3.074,71
5	28	3,6	109468,8	€ 7.320,74	42	€	3.074,71
6	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
7	28	3,6	109468,8	€ 7.320,74	39	€	2.855,09
8	28	3,6	109468,8	€ 7.320,74	35	€	2.562,26
9	28	3,6	109468,8	€ 7.320,74	34	€	2.489,05
10	28	3,6	109468,8	€ 7.320,74	34	€	2.489,05
11	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
12	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
13	28	3,6	109468,8	€ 7.320,74	29	€	2.123,01
14	28	6,3	191570,4	€ 12.811,29	23	€	2.946,60
15	28	3,6	109468,8	€ 7.320,74	23	€	1.683,77
16	28	3,6	109468,8	€ 7.320,74	19	€	1.390,94
17	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
18	28	3,6	109468,8	€ 7.320,74	18	€	1.317,73
19	28	3,6	109468,8	€ 7.320,74	13	€	951,70
20	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
21	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
22	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
23	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
24	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
25	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
26	28	3,6	109468,8	€ 7.320,74	30	€	2.196,22
Totaal			3027985	€ 202.496,88		**€**	**64.785,93**

<u>New shadow price timber option 200 years</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €149.616,24 (=51%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
13	3	3,6	2019,6	€ 135,06	125	€	168,83
14	3	6,3	3534,3	€ 236,36	110	€	259,99
15	3	3,6	2019,6	€ 135,06	96	€	129,66
17	3	3,6	2019,6	€ 135,06	82	€	110,75
19	25	3,6	16830	€ 1.125,51	125	€	1.406,89
20	25	3,6	16830	€ 1.125,51	125	€	1.406,89
21	25	3,6	16830	€ 1.125,51	125	€	1.406,89
22	25	3,6	16830	€ 1.125,51	110	€	1.238,06
23	25	3,6	16830	€ 1.125,51	89	€	1.001,70
24	25	3,6	16830	€ 1.125,51	76	€	855,39
25	25	3,6	16830	€ 1.125,51	64	€	720,33
26	25	3,6	16830	€ 1.125,51	49	€	551,50
27	28	4,7	24609,2	€ 1.645,74	49	€	806,41
Totaal			168842,3	€ 11.291,35		**€**	**10.063,27**

HD400x262							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	3	4,5	3537	€ 236,54	132	€	312,23
3	3	3,6	2829,6	€ 189,23	132	€	249,78
4	3	3,6	2829,6	€ 189,23	132	€	249,78
5	3	3,6	2829,6	€ 189,23	126	€	238,43
6	3	3,6	2829,6	€ 189,23	126	€	238,43
7	3	3,6	2829,6	€ 189,23	113	€	213,83
8	3	3,6	2829,6	€ 189,23	113	€	213,83
9	3	3,6	2829,6	€ 189,23	106	€	200,58
10	3	3,6	2829,6	€ 189,23	106	€	200,58
11	3	3,6	2829,6	€ 189,23	95	€	179,77
12	3	3,6	2829,6	€ 189,23	95	€	179,77
13	10	3,6	9432	€ 630,77	113	€	712,77
14	17	6,3	28060,2	€ 1.876,53	119	€	2.233,07
15	19	3,6	17920,8	€ 1.198,46	113	€	1.354,25
16	3	3,6	2829,6	€ 189,23	95	€	179,77
17	19	3,6	17920,8	€ 1.198,46	95	€	1.138,53
18	3	3,6	2829,6	€ 189,23	95	€	179,77
Totaal			110826	€ 7.411,50		**€**	**8.275,18**

HD400x314							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
5	10	3,6	11304	€ 755,96	134	€	1.012,98
6	12	3,6	13564,8	€ 907,15	134	€	1.215,58
7	10	3,6	11304	€ 755,96	128	€	967,62
8	12	3,6	13564,8	€ 907,15	128	€	1.161,15
9	10	3,6	11304	€ 755,96	116	€	876,91
10	12	3,6	13564,8	€ 907,15	116	€	1.052,29
11	10	3,6	11304	€ 755,96	105	€	793,75
12	12	3,6	13564,8	€ 907,15	105	€	952,51
13	7	3,6	7912,8	€ 529,17	116	€	613,84
16	12	3,6	13564,8	€ 907,15	79	€	716,65
18	12	3,6	13564,8	€ 907,15	70	€	635,00
Totaal			134517,6	€ 8.995,88		**€**	**9.998,28**

HD400x744							
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	17	5,4	68299,2	€ 4.567,52	80	€	3.654,01
2	3	4,5	10044	€ 671,69	62	€	416,45
3	3	3,6	8035,2	€ 537,35	57	€	306,29
4	3	3,6	8035,2	€ 537,35	54	€	290,17
Totaal			94413,6	€ 6.313,92		**€**	**4.666,93**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
1	3	5,4	6820,2	€ 456,10	87	€	396,81
2	19	4,5	35995,5	€ 2.407,20	135	€	3.249,72
3	19	3,6	28796,4	€ 1.925,76	125	€	2.407,20
4	19	3,6	28796,4	€ 1.925,76	125	€	2.407,20
5	9	3,6	13640,4	€ 912,20	120	€	1.094,64
6	7	3,6	10609,2	€ 709,49	115	€	815,92
7	9	3,6	13640,4	€ 912,20	110	€	1.003,42
8	7	3,6	10609,2	€ 709,49	105	€	744,97
9	9	3,6	13640,4	€ 912,20	100	€	912,20
10	7	3,6	10609,2	€ 709,49	95	€	674,02
11	9	3,6	13640,4	€ 912,20	91	€	830,11
12	7	3,6	10609,2	€ 709,49	87	€	617,26
13	3	3,6	4546,8	€ 304,07	63	€	191,56
14	3	6,3	7956,9	€ 532,12	45	€	239,45
15	3	3,6	4546,8	€ 304,07	42	€	127,71
16	7	3,6	10609,2	€ 709,49	63	€	446,98
17	3	3,6	4546,8	€ 304,07	39	€	118,59
18	7	3,6	10609,2	€ 709,49	52	€	368,94
Totaal			240222,6	€ 16.064,92		**€**	**16.646,70**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
3	10	3,6	16668	€ 1.114,67	95	€	1.058,94
4	12	3,6	20001,6	€ 1.337,61	79	€	1.056,71
5	12	3,6	20001,6	€ 1.337,61	54	€	722,31
6	12	3,6	20001,6	€ 1.337,61	54	€	722,31
7	12	3,6	20001,6	€ 1.337,61	50	€	668,80
8	12	3,6	20001,6	€ 1.337,61	41	€	548,42
9	12	3,6	20001,6	€ 1.337,61	41	€	548,42
10	12	3,6	20001,6	€ 1.337,61	41	€	548,42
11	12	3,6	20001,6	€ 1.337,61	36	€	481,54
12	12	3,6	20001,6	€ 1.337,61	60	€	802,57
13	12	3,6	20001,6	€ 1.337,61	60	€	802,57
14	12	6,3	35002,8	€ 2.340,82	33	€	772,47
15	12	3,6	20001,6	€ 1.337,61	28	€	374,53
16	12	3,6	20001,6	€ 1.337,61	22	€	294,27
17	12	3,6	20001,6	€ 1.337,61	33	€	441,41
18	12	3,6	20001,6	€ 1.337,61	28	€	374,53
19	12	3,6	20001,6	€ 1.337,61	20	€	267,52
20	12	3,6	20001,6	€ 1.337,61	28	€	374,53
21	12	3,6	20001,6	€ 1.337,61	26	€	347,78
22	12	3,6	20001,6	€ 1.337,61	20	€	267,52
23	12	3,6	20001,6	€ 1.337,61	39	€	521,67
24	12	3,6	20001,6	€ 1.337,61	33	€	441,41
25	12	3,6	20001,6	€ 1.337,61	18	€	240,77
26	12	3,6	20001,6	€ 1.337,61	26	€	347,78
Totaal			491706	€ 32.882,90		**€**	**13.027,20**

HD400x1086						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
1	31	5,4	181796,4	€ 12.157,66	63	€ 7.659,32
2	28	4,5	136836	€ 9.150,92	59	€ 5.399,05
3	28	3,6	109468,8	€ 7.320,74	59	€ 4.319,24
4	28	3,6	109468,8	€ 7.320,74	57	€ 4.172,82
5	28	3,6	109468,8	€ 7.320,74	52	€ 3.806,78
6	28	3,6	109468,8	€ 7.320,74	52	€ 3.806,78
7	28	3,6	109468,8	€ 7.320,74	52	€ 3.806,78
8	28	3,6	109468,8	€ 7.320,74	46	€ 3.367,54
9	28	3,6	109468,8	€ 7.320,74	46	€ 3.367,54
10	28	3,6	109468,8	€ 7.320,74	46	€ 3.367,54
11	28	3,6	109468,8	€ 7.320,74	39	€ 2.855,09
12	28	3,6	109468,8	€ 7.320,74	39	€ 2.855,09
13	28	3,6	109468,8	€ 7.320,74	37	€ 2.708,67
14	28	6,3	191570,4	€ 12.811,29	34	€ 4.355,84
15	28	3,6	109468,8	€ 7.320,74	32	€ 2.342,64
16	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
17	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
18	28	3,6	109468,8	€ 7.320,74	24	€ 1.756,98
19	28	3,6	109468,8	€ 7.320,74	19	€ 1.390,94
20	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
21	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
22	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
23	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
24	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
25	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
26	28	3,6	109468,8	€ 7.320,74	25	€ 1.830,18
Totaal			3027985	€ 202.496,88		**€ 77.956,73**

<u>New shadow price timber option 200 years “meeting”</u>
Original shadow price of columns: €294.439,32
New shadow price of columns: €175.949,83 (=60%)
These shadow prices are including the shadow prices of the columns that have not been optimized.

HD400x187						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
13	3	3,6	2019,6	€ 135,06	149	€ 201,24
14	3	6,3	3534,3	€ 236,36	133	€ 314,35
15	3	3,6	2019,6	€ 135,06	117	€ 158,02
17	3	3,6	2019,6	€ 135,06	102	€ 137,76
19	25	3,6	16830	€ 1.125,51	158	€ 1.778,30
20	25	3,6	16830	€ 1.125,51	158	€ 1.778,30
21	25	3,6	16830	€ 1.125,51	149	€ 1.677,01
22	25	3,6	16830	€ 1.125,51	133	€ 1.496,93
23	25	3,6	16830	€ 1.125,51	110	€ 1.238,06
24	25	3,6	16830	€ 1.125,51	96	€ 1.080,49
25	25	3,6	16830	€ 1.125,51	76	€ 855,39
26	25	3,6	16830	€ 1.125,51	59	€ 664,05
27	28	4,7	24609,2	€ 1.645,74	59	€ 970,99
Totaal			168842,3	€ 11.291,35		**€ 12.350,89**

HD400x262						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	3	4,5	3537	€ 236,54	161	€ 380,83
3	3	3,6	2829,6	€ 189,23	153	€ 289,52
4	3	3,6	2829,6	€ 189,23	153	€ 289,52
5	3	3,6	2829,6	€ 189,23	146	€ 276,28
6	3	3,6	2829,6	€ 189,23	146	€ 276,28
7	3	3,6	2829,6	€ 189,23	139	€ 263,03
8	3	3,6	2829,6	€ 189,23	139	€ 263,03
9	3	3,6	2829,6	€ 189,23	126	€ 238,43
10	3	3,6	2829,6	€ 189,23	126	€ 238,43
11	3	3,6	2829,6	€ 189,23	113	€ 213,83
12	3	3,6	2829,6	€ 189,23	113	€ 213,83
13	10	3,6	9432	€ 630,77	139	€ 876,76
14	17	6,3	28060,2	€ 1.876,53	146	€ 2.739,73
15	19	3,6	17920,8	€ 1.198,46	139	€ 1.665,85
16	3	3,6	2829,6	€ 189,23	113	€ 213,83
17	19	3,6	17920,8	€ 1.198,46	113	€ 1.354,25
18	3	3,6	2829,6	€ 189,23	113	€ 213,83
Totaal			110826	€ 7.411,50		**€ 10.007,26**

HD400x314						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
5	10	3,6	11304	€ 755,96	167	€ 1.262,45
6	12	3,6	13564,8	€ 907,15	167	€ 1.514,94
7	10	3,6	11304	€ 755,96	154	€ 1.164,17
8	12	3,6	13564,8	€ 907,15	154	€ 1.397,01
9	10	3,6	11304	€ 755,96	140	€ 1.058,34
10	12	3,6	13564,8	€ 907,15	140	€ 1.270,01
11	10	3,6	11304	€ 755,96	122	€ 922,27
12	12	3,6	13564,8	€ 907,15	128	€ 1.161,15
13	7	3,6	7912,8	€ 529,17	140	€ 740,84
16	12	3,6	13564,8	€ 907,15	94	€ 852,72
18	12	3,6	13564,8	€ 907,15	84	€ 762,00
Totaal			134517,6	€ 8.995,88		**€ 12.105,89**

HD400x744						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
1	17	5,4	68299,2	€ 4.567,52	96	€ 4.384,82
2	3	4,5	10044	€ 671,69	73	€ 490,34
3	3	3,6	8035,2	€ 537,35	68	€ 365,40
4	3	3,6	8035,2	€ 537,35	65	€ 349,28
Totaal			94413,6	€ 6.313,92		**€ 5.589,84**

HD400x421							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
1	3	5,4	6820,2	€ 456,10	105	€	478,91
2	19	4,5	35995,5	€ 2.407,20	164	€	3.947,81
3	19	3,6	28796,4	€ 1.925,76	152	€	2.927,16
4	19	3,6	28796,4	€ 1.925,76	146	€	2.811,61
5	9	3,6	13640,4	€ 912,20	141	€	1.286,21
6	7	3,6	10609,2	€ 709,49	135	€	957,81
7	9	3,6	13640,4	€ 912,20	130	€	1.185,86
8	7	3,6	10609,2	€ 709,49	125	€	886,86
9	9	3,6	13640,4	€ 912,20	120	€	1.094,64
10	7	3,6	10609,2	€ 709,49	115	€	815,92
11	9	3,6	13640,4	€ 912,20	110	€	1.003,42
12	7	3,6	10609,2	€ 709,49	105	€	744,97
13	3	3,6	4546,8	€ 304,07	74	€	225,01
14	3	6,3	7956,9	€ 532,12	55	€	292,67
15	3	3,6	4546,8	€ 304,07	49	€	148,99
16	7	3,6	10609,2	€ 709,49	74	€	525,02
17	3	3,6	4546,8	€ 304,07	45	€	136,83
18	7	3,6	10609,2	€ 709,49	63	€	446,98
Totaal			240222,6	€ 16.064,92		**€**	**19.916,70**

HD400x463							
Level	Amount	Length	g [kg]	Shadow price original	%	Shadow price	
3	10	3,6	16668	€ 1.114,67	118	€	1.315,32
4	12	3,6	20001,6	€ 1.337,61	95	€	1.270,73
5	12	3,6	20001,6	€ 1.337,61	64	€	856,07
6	12	3,6	20001,6	€ 1.337,61	64	€	856,07
7	12	3,6	20001,6	€ 1.337,61	60	€	802,57
8	12	3,6	20001,6	€ 1.337,61	50	€	668,80
9	12	3,6	20001,6	€ 1.337,61	50	€	668,80
10	12	3,6	20001,6	€ 1.337,61	50	€	668,80
11	12	3,6	20001,6	€ 1.337,61	44	€	588,55
12	12	3,6	20001,6	€ 1.337,61	71	€	949,70
13	12	3,6	20001,6	€ 1.337,61	71	€	949,70
14	12	6,3	35002,8	€ 2.340,82	41	€	959,73
15	12	3,6	20001,6	€ 1.337,61	36	€	481,54
16	12	3,6	20001,6	€ 1.337,61	26	€	347,78
17	12	3,6	20001,6	€ 1.337,61	41	€	548,42
18	12	3,6	20001,6	€ 1.337,61	36	€	481,54
19	12	3,6	20001,6	€ 1.337,61	24	€	321,03
20	12	3,6	20001,6	€ 1.337,61	36	€	481,54
21	12	3,6	20001,6	€ 1.337,61	31	€	414,66
22	12	3,6	20001,6	€ 1.337,61	24	€	321,03
23	12	3,6	20001,6	€ 1.337,61	47	€	628,68
24	12	3,6	20001,6	€ 1.337,61	41	€	548,42
25	12	3,6	20001,6	€ 1.337,61	22	€	294,27
26	12	3,6	20001,6	€ 1.337,61	31	€	414,66
Totaal			491706	€ 32.882,90		**€**	**15.838,41**

HD400x1086						
Level	**Amount**	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
1	31	5,4	181796,4	€ 12.157,66	76	€ 9.239,82
2	28	4,5	136836	€ 9.150,92	71	€ 6.497,16
3	28	3,6	109468,8	€ 7.320,74	71	€ 5.197,73
4	28	3,6	109468,8	€ 7.320,74	68	€ 4.978,10
5	28	3,6	109468,8	€ 7.320,74	63	€ 4.612,07
6	28	3,6	109468,8	€ 7.320,74	63	€ 4.612,07
7	28	3,6	109468,8	€ 7.320,74	61	€ 4.465,65
8	28	3,6	109468,8	€ 7.320,74	57	€ 4.172,82
9	28	3,6	109468,8	€ 7.320,74	55	€ 4.026,41
10	28	3,6	109468,8	€ 7.320,74	55	€ 4.026,41
11	28	3,6	109468,8	€ 7.320,74	46	€ 3.367,54
12	28	3,6	109468,8	€ 7.320,74	46	€ 3.367,54
13	28	3,6	109468,8	€ 7.320,74	44	€ 3.221,13
14	28	6,3	191570,4	€ 12.811,29	39	€ 4.996,40
15	28	3,6	109468,8	€ 7.320,74	37	€ 2.708,67
16	28	3,6	109468,8	€ 7.320,74	32	€ 2.342,64
17	28	3,6	109468,8	€ 7.320,74	30	€ 2.196,22
18	28	3,6	109468,8	€ 7.320,74	29	€ 2.123,01
19	28	3,6	109468,8	€ 7.320,74	23	€ 1.683,77
20	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
21	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
22	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
23	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
24	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
25	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
26	28	3,6	109468,8	€ 7.320,74	26	€ 1.903,39
Totaal			3027985	€ 202.496,88		**€ 91.158,89**

Beams

Profiles and dimensions

HD400x262 (L1,7,23)	€ 52,58	N = 82 kN (tension)	My = 32 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA100 € 3,35 6%	200x250 (C35/45) 4ø16 € 4,37 8%	200x250 (GL28h) € 3,66 7%
200 years	HEA120 € 3,99 8%	200x250 (C35/45) 4ø16 € 4,37 8%	200x300 (GL28h) € 4,39 8%
200 years meeting	HEA120 € 3,99 8%	250x250 (C55/67) 4ø16 € 5,77 11%	200x300 (GL28h) € 4,39 8%

HD400x262 (L2)	€ 57,84	N = 1769 kN (tension)	My = 56 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA160 € 6,71 12%	950x1000 (C35/45) 4ø16+12ø12 € 63,30 109%	400x450 (GL28h) € 14,49 25%
200 years	HEB140 € 7,44 13%	900x900 (C55/67) 4ø16+8ø12 € 63,52 110%	450x500 (GL28h) € 18,11 31%
200 years meeting	K200x200x6,3 € 8,39 15%	1000x1000 (C55/67) 4ø16+12ø12 € 78,53 136%	500x550 (GL28h) € 22,13 38%

HD400x262 (L5)	€ 57,84	N = 1450 kN (tension)	My = 56 kNm
	Steel	**Concrete**	**Timber**
50 years	K140x140x6,3 € 5,76 10%	800x800 (C55/67) 8ø16 € 50,74 88%	400x400 (GL28h) € 12,88 22%
200 years	K140x140x6,3 € 5,76 10%	800x850 (C35/45) 4ø16+8ø12 € 53,68 93%	450x450 (GL28h) € 16,30 28%
200 years meeting	HEB140 € 7,44 13%	900x900 (C55/67) 4ø16+8ø12 € 63,52 110%	450x500 (GL28h) € 18,11 31%

HD400x262 (L9)	€ 52,58	N = 154 kN (tension)	
	Steel	**Concrete**	**Timber**
50 years	K60x60x4 € 1,38 3%	250x300 (C55/67) 4ø12 € 5,92 11%	100x150 (GL28h) € 1,10 2%
200 years	K60x60x4 € 1,38 3%	250x300 (C55/67) 4ø12 € 5,92 11%	150x150 (GL28h) € 1,65 3%
200 years meeting	K60x60x4 € 1,38 3%	300x350 (C35/45) 4ø12 € 6,78 13%	150x200 (GL28h) € 2,19 4%

HD400x262 (L11)	€ 57,84	N = 927 kN (tension)	My = 56 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA140 € 5,45 9%	650x650 (C55/67) 4ø16+4ø12 € 33,92 59%	350x350 (GL28h) € 9,86 17%
200 years	HEA140 € 5,45 9%	650x650 (C55/67) 4ø16+4ø12 € 33,92 59%	350x400 (GL28h) € 11,27 19%
200 years meeting	HEA140 € 5,45 9%	700x750 (C55/67) 4ø16+12ø12 € 41,49 72%	400x400 (GL28h) € 12,88 22%

HD400x262 (L14)	€ 57,84	N = 730 kN (tension)	My = 57 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA140 € 5,45 9%	600x650 (C35/45) 4ø16 € 25,81 45%	350x350 (GL28h) € 9,86 17%
200 years	HEA140 € 5,45 9%	600x600 (C55/67) 4ø16 € 28,33 49%	350x400 (GL28h) € 11,27 19%
200 years meeting	K150x150x6,3 € 6,20 11%	700x700 (C35/45) 4ø16+4ø12 € 32,95 57%	400x400 (GL28h) € 12,88 22%

HD400x262 (L19)	€ 35,05	N = 394 kN (tension)	
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 3,76 11%	450x500 (C35/45) 4ø16 € 9,47 27%	300x350 (GL28h) € 5,12 15%
200 years	K150x150x6,3 € 3,76 11%	450x500 (C35/45) 4ø16 € 9,47 27%	300x400 (GL28h) € 5,85 17%
200 years meeting	HEA160 € 4,07 12%	500x550 (C55/67) 4ø16 € 11,34 32%	350x400 (GL28h) € 6,83 19%

HD400x262 (L21)	€ 35,05	My = 111 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA180 € 4,75 14%	300x350 (C30/37) 4ø16+12ø12 € 6,70 19%	300x350 (GL28h) € 5,12 15%
200 years	HEA180 € 4,75 14%	300x350 (C30/37) 4ø16+12ø12 € 6,70 19%	350x450 (GL28h) € 7,68 22%
200 years meeting	K220x220x6,3 € 5,61 16%	300x350 (C35/45) 4ø16+16ø12 € 7,32 21%	400x450 (GL28h) € 8,78 25%

HD400x262 (L25)	€ 35,05	N = 150 kN (tension)	My = 71 kNm
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 3,76 11%	300x350 (C30/37) 4ø16 € 4,94 14%	300x300 (GL28h) € 4,39 13%
200 years	K150x150x6,3 € 3,76 11%	250x300 (C55/67) 4ø16+4ø12 € 4,99 14%	300x350 (GL28h) € 5,12 15%
200 years meeting	HEA160 € 4,07 12%	300x350 (C35/45) 4ø16+4ø12 € 5,56 16%	300x400 (GL28h) € 5,85 17%

HD400x262 (L27)	€ 52,58	N = 393 kN	My = 71 kNm
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 5,64 11%	250x300 (C30/37) 4ø16+4ø12 € 6,62 13%	300x350 (GL28h) € 7,68 15%
200 years	K150x150x6,3 € 5,64 11%	250x300 (C30/37) 4ø16+4ø12 € 6,62 13%	300x400 (GL28h) € 8,78 17%
200 years meeting	HEA160 € 6,10 12%	300x300 (C30/37) 8ø16 € 8,14 15%	350x400 (GL28h) € 10,24 19%

HD400x551 (L2)	€ 154,82	N = 4516 kN (tension)	11060 kN (compr.)
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 66,03 43%	1550x1550 (C35/45) 4ø16+36ø12 € 202,12 131%	800x800 (GL28h) € 65,56 42%
200 years	K400x400x20 € 66,03 43%	1550x1600 (C35/45) 4ø16+40ø12 € 209,44 135%	1000x1000 (GL28h) € 102,43 66%
200 years meeting	HD400x287 € 80,64 52%	1550x1600 (C55/67) 4ø16+40ø12 € 247,79 160%	1100x1100 (GL28h) € 123,94 80%

HD400x551 (L3)	€ 154,82	N = 6232 kN (tension)	12982 kN (compr.)
	Steel	**Concrete**	**Timber**
50 years	K400x400x20 € 66,03 43%	1650x1700 (C55/67) 28ø16 € 279,19 180%	850x900 (GL28h) € 78,36 51%
200 years	HD400x262 € 73,62 48%	1850x1850 (C55/67) 4ø16+56ø12 € 288,45 186%	1050x1100 (GL28h) € 118,31 76%
200 years meeting	HD400x347 € 97,50 63%	1850x1850 (C55/67) 4ø16+56ø12 € 341,37 220%	1200x1200 (GL28h) € 147,50 95%

HE650AA (L2&16-18)	€ 83,09	My = 879 kNm	
	Steel	**Concrete**	**Timber**
50 years	K400x400x10 € 73,45 88%	750x750 (C20/25) 4ø16+48ø12 € 128,89 155%	650x700 (GL28h) € 99,87 120%
200 years	HEA400 € 75,26 91%	800x800 (C20/25) 4ø16+48ø12 € 141,64 170%	700x800 (GL28h) € 122,92 148%
200 years meeting	HE650AA € 83,09 100%	850x850 (C20/25) 4ø16+56ø12 € 160,49 193%	750x850 (GL28h) € 139,93 168%

HE650AA(L3,4,10,13)	€ 83,09	My = 750 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 76%	700x700 (C20/25) 4ø16+44ø12 € 114,33 138%	600x650 (GL28h) € 85,60 103%
200 years	HEA360 € 67,43 81%	750x750 (C30/37) 4ø16+40ø12 € 124,94 150%	650x750 (GL28h) € 107,01 129%
200 years meeting	HEA400 € 75,26 91%	800x800 (C20/25) 4ø16+48ø12 € 141,64 170%	700x800 (GL28h) € 122,92 148%

HE650AA (L6&8)	€ 83,09	My = 680 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 76%	650x700 (C20/25) 4ø16+40ø12 € 105,93 127%	550x650 (GL28h) € 78,47 94%
200 years	HEA340 € 63,22 76%	700x700 (C30/37) 4ø16+40ø12 € 112,85 136%	650x700 (GL28h) € 99,87 120%
200 years meeting	HEA360 € 67,43 81%	750x750 (C20/25) 4ø16+48ø12 € 128,89 155%	700x750 (GL28h) € 115,24 139%

HE650AA (L12&19)	€ 83,09	My = 812 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA360 € 67,43 81%	700x750 (C20/25) 4ø16+44ø12 € 120,09 145%	600x700 (GL28h) € 92,19 111%
200 years	HEA360 € 67,43 81%	700x750 (C35/45) 4ø16+44ø12 € 122,18 147%	700x750 (GL28h) € 115,24 139%
200 years meeting	HEA400 € 75,26 91%	800x800 (C30/37) 4ø16+52ø12 € 145,80 175%	750x800 (GL28h) € 131,70 159%

HE650AA (L15)	€ 83,09	My = 1130 kNm	
	Steel	**Concrete**	**Timber**
50 years	HE650AA € 83,09 100%	800x850 (C35/45) 4ø16+52ø12 € 153,57 185%	700x750 (GL28h) € 115,24 139%
200 years	HE650AA € 83,09 100%	850x850 (C30/37) 4ø16+56ø12 € 162,20 195%	750x850 (GL28h) € 139,93 168%
200 years meeting	HE650AA € 83,09 100%	900x950 (C30/37) 4ø16+60ø12 € 186,94 225%	800x900 (GL28h) € 158,04 190%

HE650AA (L20)	€ 83,09	My = 1383 kNm	
	Steel	**Concrete**	**Timber**
50 years	HE650AA € 83,09 100%	900x950 (C20/25) 4ø16+60ø12 € 184,91 223%	750x800 (GL28h) € 131,70 159%
200 years	HE650AA € 83,09 100%	900x950 (C35/45) 4ø16+60ø12 € 188,33 227%	800x900 (GL28h) € 158,04 190%
200 years meeting	HE650AA € 83,09 100%	1000x1050 (C20/25) 4ø16+68ø12 € 222,26 267%	850x950 (GL28h) € 177,25 213%

HE650AA (L21)	€ 28,62	My = 952 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA400 € 25,92 91%	750x800 (C30/37) 4ø16+48ø12 € 47,01 164%	700x700 (GL28h) € 37,05 129%
200 years	HEA400 € 25,92 91%	800x800 (C20/25) 4ø16+52ø12 € 49,70 174%	700x800 (GL28h) € 42,34 148%
200 years meeting	HE650AA € 28,62 100%	850x850 (C30/37) 4ø16+56ø12 € 55,87 195%	750x850 (GL28h) € 48,20 168%

HE650AA (L22)	€ 28,62	Nd = 3080 (tension)	My = 977 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA400 € 25,92 91%	1150x1200 (C55/67) 4ø16+28ø12 € 103,79 363%	750x850 (GL28h) € 48,20 168%
200 years	HEA400 € 25,92 91%	1300x1300 (C35/45) 4ø16+28ø12 € 106,03 370%	850x950 (GL28h) € 61,05 213%
200 years meeting	HE650AA € 28,62 100%	1300x1300 (C55/67) 4ø16+32ø12 € 126,23 441%	950x1000 (GL28h) € 71,82 251%

HE650AA (L23&24)	€ 83,09	My = 752 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 76%	650x750 (C20/25) 4ø16+40ø12 € 111,28 134%	600x650 (GL28h) € 85,60 103%
200 years	HEA360 € 67,43 81%	700x750 (C20/25) 28ø16 € 119,22 143%	650x750 (GL28h) € 107,01 129%
200 years meeting	HEA400 € 75,26 91%	750x800 (C30/37) 4ø16+48ø12 € 136,48 164%	700x800 (GL28h) € 122,92 148%

HEA450 (L2-25)	€ 105,83	My = 115 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA180 € 26,84 25%	300x350 (C30/37) 4ø16+12ø12 € 37,84 36%	300x350 (GL28h) € 28,94 27%
200 years	HEA180 € 26,84 25%	300x350 (C30/37) 4ø16+12ø12 € 37,84 36%	350x450 (GL28h) € 43,41 41%
200 years meeting	K220x220x6,3 € 31,67 30%	350x400 (C30/37) 4ø16+12ø12 € 45,17 43%	400x450 (GL28h) € 49,61 47%

HEA450 (L26)	€ 105,83	My = 210 kNm	
	Steel	**Concrete**	**Timber**
50 years	K250x250x6,3 € 36,21 34%	400x400 (C35/45) 4ø16+20ø12 € 56,32 53%	350x450 (GL28h) € 43,41 41%
200 years	HEA220 € 38,18 36%	400x500 (C20/25) 12ø16 € 58,99 56%	450x500 (GL28h) € 62,01 59%
200 years meeting	K260x260x7,1 € 42,33 40%	450x500 (C30/37) 4ø16+20ø12 € 69,61 66%	450x550 (GL28h) € 68,21 64%

HEA550 (L2-13&15-25)	€ 125,49	My = 1114 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA450 € 105,83 84%	800x850 (C30/37) 4ø16+52ø12 € 191,43 153%	700x750 (GL28h) € 144,69 115%
200 years	HEA450 € 105,83 84%	850x850 (C20/25) 4ø16+56ø12 € 201,50 161%	800x900 (GL28h) € 198,43 158%
200 years meeting	HEA500 € 117,17 93%	650x750 (C35/45) 4ø16+80ø12 € 175,33 140%	850x950 (GL28h) € 222,54 177%

HEA550 (L14)	€ 125,49	My = 1489 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 117,17 93%	950x950 (C20/25) 4ø16+64ø12 € 245,29 195%	750x850 (GL28h) € 175,69 140%
200 years	HEA500 € 117,17 93%	950x1000 (C20/25) 4ø16+64ø12 € 255,10 203%	900x950 (GL28h) € 235,63 188%
200 years meeting	HEA550 € 125,49 100%	1050x1050 (C30/37) 44ø16 € 295,80 236%	950x1050 (GL28h) € 274,90 219%

HEA550 (L26)	€ 125,49	My = 1940 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA550 € 125,49 100%	1050x1100 (C20/25) 4ø16+72ø12 € 304,06 242%	850x900 (GL28h) € 210,83 168%
200 years	HEA600 € 134,56 107%	1100x1100 (C20/25) 4ø16+76ø12 € 318,73 254%	950x1050 (GL28h) € 274,90 219%
200 years meeting	HEA650 € 143,63 114%	1200x1200 (C20/25) 4ø16+84ø12 € 372,84 297%	1050x1100 (GL28h) € 318,31 254%

HEA600 (L2&26)	€ 107,17	My = 2143 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA600 € 107,17 100%	1100x1150 (C20/25) 4ø16+76ø12 € 262,90 245%	850x950 (GL28h) € 177,25 165%
200 years	HEA650 € 114,40 107%	1150x1150 (C20/25) 4ø16+80ø12 € 274,99 257%	1000x1100 (GL28h) € 241,45 225%
200 years meeting	HEA700 € 122,83 115%	1250x1250 (C20/25) 4ø16+88ø12 € 319,74 298%	1050x1150 (GL28h) € 265,04 247%

HEA600 (L3)	€ 107,17	N = 410 kN (tension)	My = 816 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA360 € 67,43 63%	700x700 (C30/37) 28ø16 € 114,63 107%	650x700 (GL28h) € 99,87 93%
200 years	HEA360 € 67,43 63%	700x750 (C35/45) 4ø16+40ø12 € 119,54 112%	700x800 (GL28h) € 122,92 115%
200 years meeting	HEA400 € 75,26 70%	750x800 (C20/25) 4ø16+48ø12 € 135,06 126%	750x850 (GL28h) € 139,93 131%

HEA650 (L2)	€ 114,40	N = 1703 kN (tension)	My = 994 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA400 € 75,26 66%	1000x1000 (C30/37) 4ø16+64ø12 € 213,77 187%	700x800 (GL28h) € 122,92 107%
200 years	HEA400 € 75,26 66%	1000x1050 (C30/37) 4ø16+64ø12 € 222,11 194%	750x850 (GL28h) € 139,93 122%
200 years meeting	HEA450 € 84,29 74%	1100x1150 (C20/25) 4ø16+76ø12 € 262,90 230%	800x900 (GL28h) € 158,04 138%

HEA650 (L3)	€ 152,53	My = 1410 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 124,43 82%	900x950 (C20/25) 4ø16+60ø12 € 246,55 162%	750x800 (GL28h) € 175,60 115%
200 years	HEA500 € 124,43 82%	950x950 (C20/25) 4ø16+64ø12 € 260,49 171%	850x950 (GL28h) € 236,33 155%
200 years meeting	HEA550 € 133,26 87%	1000x1050 (C30/37) 4ø16+68ø12 € 299,67 196%	950x1000 (GL28h) € 278,03 182%

HEA650 (L5,7,9)	€ 114,40	N = 666 kN (tension)	My = 703 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 55%	700x700 (C30/37) 4ø16+40ø12 € 112,85 99%	600x700 (GL28h) € 92,19 81%
200 years	HEA340 € 63,22 55%	700x700 (C30/37) 28ø16 € 114,63 100%	700x750 (GL28h) € 115,24 101%
200 years meeting	K400x400x10 € 73,45 64%	750x750 (C30/37) 4ø16+48ø12 € 130,23 114%	750x800 (GL28h) € 131,70 115%

HEA650 (L11)	€ 114,40	N = 2215 kN (tension)	My = 737 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 55%	1000x1000 (C55/67) 4ø16+24ø12 € 222,11 194%	650x750 (GL28h) € 107,01 94%
200 years	HEA340 € 63,22 55%	1100x1150 (C35/45) 16ø16 € 231,85 203%	700x800 (GL28h) € 122,92 107%
200 years meeting	HEA400 € 75,26 66%	1200x1250 (C35/45) 4ø16+24ø12 € 273,18 239%	750x850 (GL28h) € 139,93 122%

HEA650 (L27)	€ 114,40	N = 347 kN (tension)	My = 3267 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA800 € 134,87 118%	1300x1300 (C30/37) 4ø16+96ø12 € 350,00 306%	1000x1100 (GL28h) € 241,45 211%
200 years	HEA800 € 134,87 118%	1350x1350 (C20/25) 4ø16+96ø12 € 356,68 312%	1150x1250 (GL28h) € 315,53 276%
200 years meeting	HEA900 € 151,73 133%	1450x1450 (C30/37) 4ø16+104ø12 € 424,09 371%	1250x1350 (GL28h) € 370,40 324%

HEB450 (L14)	€ 36,61	N = 77 kN (tension)	My = 73 kNm
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 6,02 16%	250x300 (C30/37) 8ø16 € 7,79 21%	300x300 (GL28h) € 7,02 19%
200 years	K160x160x6,3 € 6,44 18%	300x300 (C30/37) 8ø16 € 8,68 24%	300x400 (GL28h) € 9,37 26%
200 years meeting	HEA160 € 6,51 18%	300x350 (C30/37) 8ø16 € 9,57 26%	300x400 (GL28h) € 9,37 26%

HEB450 (L27)	€ 70,93	My = 864 kNm	
	Steel	**Concrete**	**Timber**
50 years	K400x400x10 € 50,60 71%	750x750 (C20/25) 4ø16+48ø12 € 88,79 125%	600x700 (GL28h) € 63,51 90%
200 years	K400x400x10 € 50,60 71%	750x750 (C30/37) 4ø16+48ø12 € 89,71 126%	750x800 (GL28h) € 90,73 128%
200 years meeting	HEA450 € 58,07 82%	800x850 (C20/25) 4ø16+52ø12 € 103,92 147%	800x850 (GL28h) € 102,82 145%

HEB450 (L28)	€ 41,18	N = 381 kN	My = 1326 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 37,33 91%	850x850 (C30/37) 4ø16+56ø12 € 64,88 158%	750x800 (GL28h) € 52,68 128%
200 years	HEA500 € 37,33 91%	850x900 (C30/37) 4ø16+56ø12 € 67,72 164%	850x950 (GL28h) € 70,90 172%
200 years meeting	HEA550 € 39,98 97%	950x950 (C30/37) 4ø16+64ø12 € 79,00 192%	900x1000 (GL28h) € 79,02 192%

HEB600 (L14)	€ 127,64	My = 1610 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 93,32 73%	950x1000 (C30/37) 40ø16 € 205,46 161%	750x850 (GL28h) € 139,93 110%
200 years	HEA550 € 99,95 78%	1000x1000 (C30/37) 4ø16+68ø12 € 216,41 170%	900x1000 (GL28h) € 197,55 155%
200 years meeting	HEA600 € 107,17 84%	1100x1100 (C20/25) 4ø16+76ø12 € 253,85 199%	950x1050 (GL28h) € 218,95 172%

HEB650 (L14)	€ 135,47	N = 2528 kN (tension)	My = 1485 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 93,32 69%	1150x1200 (C35/45) 4ø16+48ø12 € 268,82 198%	850x900 (GL28h) € 167,92 124%
200 years	HEA500 € 93,32 69%	1050x1100 (C55/67) 4ø16+52ø12 € 271,84 201%	900x950 (GL28h) € 187,67 139%
200 years meeting	HEA550 € 99,95 74%	1300x1300 (C35/45) 4ø16+56ø12 € 326,32 241%	950x1050 (GL28h) € 218,95 162%

HEB650 (L3)	€ 135,47	N = 800 kN (tension)	My = 1146 kNm
	Steel	**Concrete**	**Timber**
50 years	HEA450 € 84,29 62%	850x850 (C20/25) 4ø16+56ø12 € 160,49 118%	700x800 (GL28h) € 122,92 91%
200 years	HEA450 € 84,29 62%	850x850 (C30/37) 4ø16+56ø12 € 162,20 120%	800x900 (GL28h) € 158,04 117%
200 years meeting	HEA500 € 93,32 69%	900x950 (C35/45) 4ø16+60ø12 € 188,33 139%	850x950 (GL28h) € 177,25 131%

HEB650 (L25)	€ 135,47	N = 4422 kN	My = 1096 kNm
	Steel	**Concrete**	**Timber**
50 years	K400x400x16 € 115,00 85%	700x750 (C35/45) 4ø16+40ø12 € 119,54 88%	800x900 (GL28h) € 158,04 117%
200 years	K400x400x16 € 115,00 85%	750x750 (C35/45) 4ø16+40ø12 € 125,86 93%	850x950 (GL28h) € 177,25 131%
200 years meeting	K400x400x20 € 141,49 104%	750x800 (C35/45) 4ø16+48ø12 € 137,46 101%	900x1000 (GL28h) € 197,55 146%

HEB650 (L26)	€ 135,47	My = 1462 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA500 € 93,32 69%	950x950 (C20/25) 4ø16+64ø12 € 195,37 144%	750x850 (GL28h) € 139,93 103%
200 years	HEA500 € 93,32 69%	950x950 (C35/45) 4ø16+64ø12 € 198,97 147%	900x950 (GL28h) € 187,67 139%
200 years meeting	HEA550 € 99,95 74%	1050x1050 (C30/37) 44ø16 € 235,59 174%	950x1000 (GL28h) € 208,52 154%

HEB650 (L27)	€ 135,47	My = 1847 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA550 € 99,95 74%	1050x1050 (C20/25) 44ø16 € 232,98 172%	850x900 (GL28h) € 167,92 124%
200 years	HEA600 € 107,17 79%	1050x1100 (C20/25) 4ø16+72ø12 € 242,17 179%	950x1050 (GL28h) € 218,95 162%
200 years meeting	HEA650 € 114,40 84%	1150x1200 (C20/25) 4ø16+80ø12 € 284,45 210%	1000x1100 (GL28h) € 241,45 178%

HEB400 (L28)	€ 93,32	My = 687 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA340 € 63,22 68%	650x700 (C20/25) 4ø16+40ø12 € 105,93 114%	550x650 (GL28h) € 78,47 84%
200 years	HEA340 € 63,22 68%	650x700 (C35/45) 4ø16+40ø12 € 107,75 115%	700x750 (GL28h) € 115,24 123%
200 years meeting	K400x400x10 € 73,45 79%	750x750 (C20/25) 4ø16+48ø12 € 128,89 138%	700x800 (GL28h) € 122,92 132%

HEA260 (L3)	€ 15,06	N = 247 kN (tension)	My = 19 kNm
	Steel	**Concrete**	**Timber**
50 years	K100x100x4 € 2,63 17%	350x400 (C35/45) 4ø12 € 9,61 64%	200x250 (GL28h) € 4,02 27%
200 years	K100x100x4 € 2,63 17%	350x400 (C35/45) 4ø12 € 9,61 64%	200x300 (GL28h) € 4,83 32%
200 years meeting	K100x100x5 € 3,25 22%	350x400 (C55/67) 4ø12 € 11,32 75%	250x300 (GL28h) € 6,04 40%

HEA260 (L4)	€ 13,69	Mz = 68 kNm	
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 5,64 41%	250x300 (C30/37) 8ø16 € 7,30 53%	300x300 (GL28h) € 6,58 48%
200 years	K150x150x6,3 € 5,64 41%	250x300 (C30/37) 8ø16 € 7,30 53%	300x350 (GL28h) € 7,68 56%
200 years meeting	K180x180x6,3 € 6,82 50%	300x350 (C30/37) 8ø16 € 8,97 66%	300x400 (GL28h) € 8,78 64%

HEA260 (L6,10,12,17)	€ 13,69	N = 161 kN (tension)	My = 13 kNm
	Steel	**Concrete**	**Timber**
50 years	K90x90x4 € 2,15 16%	250x300 (C55/67) 4ø12 € 5,92 43%	200x200 (GL28h) € 2,93 21%
200 years	K90x90x4 € 2,15 16%	250x300 (C55/67) 4ø12 € 5,92 43%	200x250 (GL28h) € 3,66 27%
200 years meeting	K90x90x4 € 2,15 16%	300x300 (C55/67) 4ø12 € 6,93 51%	200x250 (GL28h) € 3,66 27%

HEA260 (L8)	€ 18,25	N = 1111 kN (tension)	My = 71 kNm
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 7,52 41%	700x700 (C55/67) 4ø16+4ø12 € 47,16 258%	350x400 (GL28h) € 13,66 75%
200 years	K150x150x6,3 € 7,52 41%	700x750 (C55/67) 4ø16+4ø12 € 50,29 276%	400x450 (GL28h) € 17,56 96%
200 years meeting	HEA160 € 8,13 45%	850x900 (C35/45) 8ø16 € 61,44 337%	450x500 (GL28h) € 21,95 120%

HEA260 (L13)	€ 13,69	N = 75 kN (tension)	My = 24 kNm
	Steel	**Concrete**	**Timber**
50 years	K100x100x5 € 2,95 22%	200x200 (C35/45) 4ø16 € 3,81 28%	200x250 (GL28h) € 3,66 27%
200 years	K100x100x5 € 2,95 22%	200x200 (C55/67) 4ø16 € 4,25 31%	200x300 (GL28h) € 4,39 32%
200 years meeting	HEA100 € 3,35 24%	200x250 (C35/45) 4ø16 € 4,37 32%	250x300 (GL28h) € 5,49 40%

HEA260 (L15,16,22)	€ 9,12	N = 490 kN (tension)	My = 71 kNm
	Steel	**Concrete**	**Timber**
50 years	K150x150x6,3 € 3,76 41%	450x500 (C55/67) 4ø16 € 11,12 122%	300x350 (GL28h) € 5,12 56%
200 years	K150x150x6,3 € 3,76 41%	450x500 (C55/67) 4ø16 € 11,12 122%	350x400 (GL28h) € 6,83 75%
200 years meeting	HEA160 € 4,07 45%	500x550 (C55/67) 4ø16 € 13,36 146%	350x450 (GL28h) € 7,68 84%

HEA260 (L18)	€ 13,69	My = 111 kNm	
	Steel	**Concrete**	**Timber**
50 years	HEA180 € 7,12 52%	300x350 (C30/37) 4ø16+12ø12 € 10,05 73%	300x350 (GL28h) € 7,68 56%
200 years	HEA180 € 7,12 52%	350x400 (C20/25) 4ø16+8ø12 € 11,00 80%	350x450 (GL28h) € 11,52 84%
200 years meeting	K220x220x6,3 € 8,41 61%	350x400 (C30/37) 4ø16+12ø12 € 11,99 88%	400x450 (GL28h) € 13,17 96%

<u>New shadow price best and steel option 50 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €79.812,97 (=60%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262						
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
1	24	6288	€ 420,51	6	€	25,23
2	24	6288	€ 420,51	12	€	50,46
5	24	6288	€ 420,51	10	€	42,05
7	24	6288	€ 420,51	6	€	25,23
9	24	6288	€ 420,51	2	€	8,41
11	24	6288	€ 420,51	9	€	37,85
14	24	6288	€ 420,51	9	€	37,85
19	24	6288	€ 420,51	11	€	46,26
21	24	6288	€ 420,51	14	€	58,87
23	24	6288	€ 420,51	6	€	25,23
25	24	6288	€ 420,51	11	€	46,26
27	24	6288	€ 420,51	11	€	46,26
Totaal		75456	€ 5.046,13		**€**	**449,95**

HD400x551						
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	112,2	61822,2	€ 4.134,37	42	€	1.736,43
3	112,2	61822,2	€ 4.134,37	43	€	1.777,78
Totaal		123644,4	€ 8.268,73		**€**	**3.514,21**

HE650AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	95,4	13165,2	€	880,42	88	€	774,77
3	49,6	6844,8	€	457,75	76	€	347,89
4	54,5	7521	€	502,97	76	€	382,26
6	54,5	7521	€	502,97	76	€	382,26
8	54,5	7521	€	502,97	76	€	382,26
10	54,5	7521	€	502,97	76	€	382,26
12	54,5	7521	€	502,97	81	€	407,40
13	54,5	7521	€	502,97	76	€	382,26
15	54,5	7521	€	502,97	100	€	502,97
16	54,5	7521	€	502,97	88	€	442,61
17	54,5	7521	€	502,97	88	€	442,61
18	54,5	7521	€	502,97	88	€	442,61
19	54,5	7521	€	502,97	81	€	407,40
20	54,5	7521	€	502,97	100	€	502,97
21	54,5	7521	€	502,97	91	€	457,70
22	54,5	7521	€	502,97	91	€	457,70
23	54,5	7521	€	502,97	76	€	382,26
24	54,5	7521	€	502,97	76	€	382,26
Totaal		140346	€	9.385,66		**€**	**7.862,43**

HEA450							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	23,6	3304	€	220,96	25	€	55,24
3	23,6	3304	€	220,96	25	€	55,24
4	23,6	3304	€	220,96	25	€	55,24
5	23,6	3304	€	220,96	25	€	55,24
6	23,6	3304	€	220,96	25	€	55,24
7	23,6	3304	€	220,96	25	€	55,24
8	23,6	3304	€	220,96	25	€	55,24
9	23,6	3304	€	220,96	25	€	55,24
10	23,6	3304	€	220,96	25	€	55,24
11	23,6	3304	€	220,96	25	€	55,24
12	23,6	3304	€	220,96	25	€	55,24
13	23,6	3304	€	220,96	25	€	55,24
15	23,6	3304	€	220,96	25	€	55,24
16	23,6	3304	€	220,96	25	€	55,24
17	23,6	3304	€	220,96	25	€	55,24
18	23,6	3304	€	220,96	25	€	55,24
19	23,6	3304	€	220,96	25	€	55,24
20	23,6	3304	€	220,96	25	€	55,24
21	23,6	3304	€	220,96	25	€	55,24
22	23,6	3304	€	220,96	25	€	55,24
23	23,6	3304	€	220,96	25	€	55,24
24	23,6	3304	€	220,96	25	€	55,24
25	23,6	3304	€	220,96	25	€	55,24
26	259,6	36344	€	2.430,51	34	€	826,37
Totaal		112336	€	7.512,48		**€**	**2.096,87**

HEA550					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3917,6	€ 261,99	84	€ 220,07
3	23,6	3917,6	€ 261,99	84	€ 220,07
4	23,6	3917,6	€ 261,99	84	€ 220,07
5	23,6	3917,6	€ 261,99	84	€ 220,07
6	23,6	3917,6	€ 261,99	84	€ 220,07
7	23,6	3917,6	€ 261,99	84	€ 220,07
8	23,6	3917,6	€ 261,99	84	€ 220,07
9	23,6	3917,6	€ 261,99	84	€ 220,07
10	23,6	3917,6	€ 261,99	84	€ 220,07
11	23,6	3917,6	€ 261,99	84	€ 220,07
12	23,6	3917,6	€ 261,99	84	€ 220,07
13	23,6	3917,6	€ 261,99	84	€ 220,07
14	23,6	3917,6	€ 261,99	93	€ 243,65
15	23,6	3917,6	€ 261,99	84	€ 220,07
16	23,6	3917,6	€ 261,99	84	€ 220,07
17	23,6	3917,6	€ 261,99	84	€ 220,07
18	23,6	3917,6	€ 261,99	84	€ 220,07
19	23,6	3917,6	€ 261,99	84	€ 220,07
20	23,6	3917,6	€ 261,99	84	€ 220,07
21	23,6	3917,6	€ 261,99	84	€ 220,07
22	23,6	3917,6	€ 261,99	84	€ 220,07
23	23,6	3917,6	€ 261,99	84	€ 220,07
24	23,6	3917,6	€ 261,99	84	€ 220,07
25	23,6	3917,6	€ 261,99	84	€ 220,07
26	23,6	3917,6	€ 261,99	100	€ 261,99
Totaal		97940	€ 6.549,75		**€ 5.567,29**

HEA600					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	126	22428	€ 1.499,88	100	€ 1.499,88
3	126	22428	€ 1.499,88	63	€ 944,92
26	281,4	50089,2	€ 3.349,72	100	€ 3.349,72
Totaal		94945,2	€ 6.349,47		**€ 5.794,52**

HEA650					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	186	35340	€ 2.363,37	66	€ 1.559,82
3	150	28500	€ 1.905,94	82	€ 1.562,87
5	54,5	10355	€ 692,49	55	€ 380,87
7	54,5	10355	€ 692,49	55	€ 380,87
9	54,5	10355	€ 692,49	55	€ 380,87
11	54,5	10355	€ 692,49	55	€ 380,87
27	286,8	54492	€ 3.644,16	118	€ 4.300,11
Totaal		159752	€ 10.683,43		**€ 8.946,28**

HEB450							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
14	12,4	2120,4	€	141,80	16	€	22,69
27	27,6	4719,6	€	315,62	71	€	224,09
28	273,1	46700,1	€	3.123,07	91	€	2.842,00
Totaal		53540,1	€	3.580,50		**€**	**3.088,78**

HEB600							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
14	281,4	59656,8	€	3.989,56	73	€	2.912,38
Totaal		59656,8	€	3.989,56		**€**	**2.912,38**

HEB650							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
3	12,4	2790	€	186,58	62	€	115,68
14	27,6	6210	€	415,29	69	€	286,55
25	273,1	61447,5	€	4.109,31	85	€	3.492,91
26	274,1	61672,5	€	4.124,36	69	€	2.845,81
27	275,1	61897,5	€	4.139,40	74	€	3.063,16
Totaal		194017,5	€	12.974,94		**€**	**9.804,11**

HEB400							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
28	273,1	42330,5	€	2.830,86	68	€	1.924,98
Totaal		42330,5	€	2.830,86		**€**	**1.924,98**

HEA260							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
3	24	1636,8	€	109,46	17	€	18,61
4	24	1636,8	€	109,46	41	€	44,88
6	24	1636,8	€	109,46	16	€	17,51
8	24	1636,8	€	109,46	41	€	44,88
10	24	1636,8	€	109,46	16	€	17,51
12	24	1636,8	€	109,46	16	€	17,51
13	24	1636,8	€	109,46	22	€	24,08
15	24	1636,8	€	109,46	41	€	44,88
16	24	1636,8	€	109,46	41	€	44,88
17	24	1636,8	€	109,46	16	€	17,51
18	24	1636,8	€	109,46	52	€	56,92
20	24	1636,8	€	109,46	84	€	91,95
22	24	1636,8	€	109,46	41	€	44,88
24	24	1636,8	€	109,46	84	€	91,95
26	24	1636,8	€	109,46	84	€	91,95
28	264	18004,8	€	1.204,07	84	€	1.011,42
Totaal		42556,8	€	2.845,99		**€**	**1.681,32**

HE500AA							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	16	€	322,18
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	16	€	322,18
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.376,30**

HE550AA							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	16	€	361,32
15	281,4	33768	€	2.258,24	16	€	361,32
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.203,78**

<u>New shadow price best and steel option 200 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €81.130,69 (=61%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
1	24	6288	€	420,51	8	€	33,64
2	24	6288	€	420,51	13	€	54,67
5	24	6288	€	420,51	10	€	42,05
7	24	6288	€	420,51	8	€	33,64
9	24	6288	€	420,51	3	€	12,62
11	24	6288	€	420,51	9	€	37,85
14	24	6288	€	420,51	9	€	37,85
19	24	6288	€	420,51	11	€	46,26
21	24	6288	€	420,51	14	€	58,87
23	24	6288	€	420,51	8	€	33,64
25	24	6288	€	420,51	11	€	46,26
27	24	6288	€	420,51	11	€	46,26
Totaal		75456	€	5.046,13		**€**	**483,59**

HD400x551						
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	112,2	61822,2	€ 4.134,37	43	€	1.777,78
3	112,2	61822,2	€ 4.134,37	48	€	1.984,50
Totaal		123644,4	€ 8.268,73		**€**	**3.762,27**

HE650AA						
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**	
2	95,4	13165,2	€ 880,42	91	€	801,19
3	49,6	6844,8	€ 457,75	81	€	370,77
4	54,5	7521	€ 502,97	81	€	407,40
6	54,5	7521	€ 502,97	76	€	382,26
8	54,5	7521	€ 502,97	76	€	382,26
10	54,5	7521	€ 502,97	81	€	407,40
12	54,5	7521	€ 502,97	81	€	407,40
13	54,5	7521	€ 502,97	81	€	407,40
15	54,5	7521	€ 502,97	100	€	502,97
16	54,5	7521	€ 502,97	91	€	457,70
17	54,5	7521	€ 502,97	91	€	457,70
18	54,5	7521	€ 502,97	91	€	457,70
19	54,5	7521	€ 502,97	81	€	407,40
20	54,5	7521	€ 502,97	100	€	502,97
21	54,5	7521	€ 502,97	91	€	457,70
22	54,5	7521	€ 502,97	91	€	457,70
23	54,5	7521	€ 502,97	81	€	407,40
24	54,5	7521	€ 502,97	81	€	407,40
Totaal		140346	€ 9.385,66		**€**	**8.082,74**

HEA450					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	23,6	3304	€ 220,96	25	€ 55,24
3	23,6	3304	€ 220,96	25	€ 55,24
4	23,6	3304	€ 220,96	25	€ 55,24
5	23,6	3304	€ 220,96	25	€ 55,24
6	23,6	3304	€ 220,96	25	€ 55,24
7	23,6	3304	€ 220,96	25	€ 55,24
8	23,6	3304	€ 220,96	25	€ 55,24
9	23,6	3304	€ 220,96	25	€ 55,24
10	23,6	3304	€ 220,96	25	€ 55,24
11	23,6	3304	€ 220,96	25	€ 55,24
12	23,6	3304	€ 220,96	25	€ 55,24
13	23,6	3304	€ 220,96	25	€ 55,24
15	23,6	3304	€ 220,96	25	€ 55,24
16	23,6	3304	€ 220,96	25	€ 55,24
17	23,6	3304	€ 220,96	25	€ 55,24
18	23,6	3304	€ 220,96	25	€ 55,24
19	23,6	3304	€ 220,96	25	€ 55,24
20	23,6	3304	€ 220,96	25	€ 55,24
21	23,6	3304	€ 220,96	25	€ 55,24
22	23,6	3304	€ 220,96	25	€ 55,24
23	23,6	3304	€ 220,96	25	€ 55,24
24	23,6	3304	€ 220,96	25	€ 55,24
25	23,6	3304	€ 220,96	25	€ 55,24
26	259,6	36344	€ 2.430,51	36	€ 874,98
Totaal		112336	€ 7.512,48		**€ 2.145,48**

HEA550						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	23,6	3917,6	€ 261,99	84	€	220,07
3	23,6	3917,6	€ 261,99	84	€	220,07
4	23,6	3917,6	€ 261,99	84	€	220,07
5	23,6	3917,6	€ 261,99	84	€	220,07
6	23,6	3917,6	€ 261,99	84	€	220,07
7	23,6	3917,6	€ 261,99	84	€	220,07
8	23,6	3917,6	€ 261,99	84	€	220,07
9	23,6	3917,6	€ 261,99	84	€	220,07
10	23,6	3917,6	€ 261,99	84	€	220,07
11	23,6	3917,6	€ 261,99	84	€	220,07
12	23,6	3917,6	€ 261,99	84	€	220,07
13	23,6	3917,6	€ 261,99	84	€	220,07
14	23,6	3917,6	€ 261,99	93	€	243,65
15	23,6	3917,6	€ 261,99	84	€	220,07
16	23,6	3917,6	€ 261,99	84	€	220,07
17	23,6	3917,6	€ 261,99	84	€	220,07
18	23,6	3917,6	€ 261,99	84	€	220,07
19	23,6	3917,6	€ 261,99	84	€	220,07
20	23,6	3917,6	€ 261,99	84	€	220,07
21	23,6	3917,6	€ 261,99	84	€	220,07
22	23,6	3917,6	€ 261,99	84	€	220,07
23	23,6	3917,6	€ 261,99	84	€	220,07
24	23,6	3917,6	€ 261,99	84	€	220,07
25	23,6	3917,6	€ 261,99	84	€	220,07
26	23,6	3917,6	€ 261,99	107	€	280,33
Totaal		97940	€ 6.549,75		**€**	**5.585,63**

HEA600						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	126	22428	€ 1.499,88	107	€	1.604,87
3	126	22428	€ 1.499,88	63	€	944,92
26	281,4	50089,2	€ 3.349,72	107	€	3.584,20
Totaal		94945,2	€ 6.349,47		**€**	**6.133,99**

HEA650						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	186	35340	€ 2.363,37	66	€	1.559,82
3	150	28500	€ 1.905,94	82	€	1.562,87
5	54,5	10355	€ 692,49	55	€	380,87
7	54,5	10355	€ 692,49	55	€	380,87
9	54,5	10355	€ 692,49	55	€	380,87
11	54,5	10355	€ 692,49	55	€	380,87
27	286,8	54492	€ 3.644,16	118	€	4.300,11
Totaal		159752	€ 10.683,43		**€**	**8.946,28**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	18	€ 25,52
27	27,6	4719,6	€	315,62	71	€ 224,09
28	273,1	46700,1	€	3.123,07	91	€ 2.842,00
Totaal		53540,1	€	3.580,50		**€ 3.091,62**

HEB600						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	281,4	59656,8	€	3.989,56	78	€ 3.111,85
Totaal		59656,8	€	3.989,56		**€ 3.111,85**

HEB650						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	12,4	2790	€	186,58	62	€ 115,68
14	27,6	6210	€	415,29	69	€ 286,55
25	273,1	61447,5	€	4.109,31	85	€ 3.492,91
26	274,1	61672,5	€	4.124,36	69	€ 2.845,81
27	275,1	61897,5	€	4.139,40	79	€ 3.270,13
Totaal		194017,5	€	12.974,94		**€ 10.011,08**

HEB400						
Level	Length	g [kg]	Shadow price original		%	Shadow price
28	273,1	42330,5	€	2.830,86	68	€ 1.924,98
Totaal		42330,5	€	2.830,86		**€ 1.924,98**

HEA260						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	24	1636,8	€	109,46	17	€ 18,61
4	24	1636,8	€	109,46	41	€ 44,88
6	24	1636,8	€	109,46	16	€ 17,51
8	24	1636,8	€	109,46	41	€ 44,88
10	24	1636,8	€	109,46	16	€ 17,51
12	24	1636,8	€	109,46	16	€ 17,51
13	24	1636,8	€	109,46	22	€ 24,08
15	24	1636,8	€	109,46	41	€ 44,88
16	24	1636,8	€	109,46	41	€ 44,88
17	24	1636,8	€	109,46	16	€ 17,51
18	24	1636,8	€	109,46	52	€ 56,92
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	41	€ 44,88
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 1.681,32**

HE500AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
4	281,4	30109,8	€ 2.013,60	17	€ 342,31
6	281,4	30109,8	€ 2.013,60	41	€ 825,57
8	281,4	30109,8	€ 2.013,60	16	€ 322,18
10	281,4	30109,8	€ 2.013,60	41	€ 825,57
12	281,4	30109,8	€ 2.013,60	16	€ 322,18
16	281,4	30109,8	€ 2.013,60	16	€ 322,18
18	281,4	30109,8	€ 2.013,60	22	€ 442,99
20	281,4	30109,8	€ 2.013,60	41	€ 825,57
22	281,4	30109,8	€ 2.013,60	41	€ 825,57
24	281,4	30109,8	€ 2.013,60	16	€ 322,18
Totaal		301098	€ 20.135,97		**€ 5.376,30**

HE550AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
5	281,4	33768	€ 2.258,24	17	€ 383,90
7	281,4	33768	€ 2.258,24	41	€ 925,88
9	281,4	33768	€ 2.258,24	16	€ 361,32
11	281,4	33768	€ 2.258,24	41	€ 925,88
13	281,4	33768	€ 2.258,24	16	€ 361,32
15	281,4	33768	€ 2.258,24	16	€ 361,32
17	281,4	33768	€ 2.258,24	22	€ 496,81
19	281,4	33768	€ 2.258,24	41	€ 925,88
21	281,4	33768	€ 2.258,24	41	€ 925,88
23	281,4	33768	€ 2.258,24	16	€ 361,32
25	281,4	33768	€ 2.258,24	52	€ 1.174,28
Totaal		371448	€ 24.840,63		**€ 7.203,78**

<u>New shadow price best and steel option 200 years “meeting”</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €87.366,78 (=66%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262					
Level	Length	g [kg]	Shadow price original	%	Shadow price
1	24	6288	€ 420,51	8	€ 33,64
2	24	6288	€ 420,51	15	€ 63,08
5	24	6288	€ 420,51	13	€ 54,67
7	24	6288	€ 420,51	8	€ 33,64
9	24	6288	€ 420,51	3	€ 12,62
11	24	6288	€ 420,51	9	€ 37,85
14	24	6288	€ 420,51	11	€ 46,26
19	24	6288	€ 420,51	12	€ 50,46
21	24	6288	€ 420,51	16	€ 67,28
23	24	6288	€ 420,51	8	€ 33,64
25	24	6288	€ 420,51	12	€ 50,46
27	24	6288	€ 420,51	12	€ 50,46
Totaal		75456	€ 5.046,13		**€ 534,05**

HD400x551					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	112,2	61822,2	€ 4.134,37	52	€ 2.149,87
3	112,2	61822,2	€ 4.134,37	63	€ 2.604,65
Totaal		123644,4	€ 8.268,73		**€ 4.754,52**

HE650AA					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	95,4	13165,2	€ 880,42	100	€ 880,42
3	49,6	6844,8	€ 457,75	91	€ 416,55
4	54,5	7521	€ 502,97	91	€ 457,70
6	54,5	7521	€ 502,97	81	€ 407,40
8	54,5	7521	€ 502,97	81	€ 407,40
10	54,5	7521	€ 502,97	91	€ 457,70
12	54,5	7521	€ 502,97	91	€ 457,70
13	54,5	7521	€ 502,97	91	€ 457,70
15	54,5	7521	€ 502,97	100	€ 502,97
16	54,5	7521	€ 502,97	100	€ 502,97
17	54,5	7521	€ 502,97	100	€ 502,97
18	54,5	7521	€ 502,97	100	€ 502,97
19	54,5	7521	€ 502,97	91	€ 457,70
20	54,5	7521	€ 502,97	100	€ 502,97
21	54,5	7521	€ 502,97	100	€ 502,97
22	54,5	7521	€ 502,97	100	€ 502,97
23	54,5	7521	€ 502,97	91	€ 457,70
24	54,5	7521	€ 502,97	91	€ 457,70
Totaal		140346	€ 9.385,66		**€ 8.836,46**

HEA450					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3304	€ 220,96	30	€ 66,29
3	23,6	3304	€ 220,96	30	€ 66,29
4	23,6	3304	€ 220,96	30	€ 66,29
5	23,6	3304	€ 220,96	30	€ 66,29
6	23,6	3304	€ 220,96	30	€ 66,29
7	23,6	3304	€ 220,96	30	€ 66,29
8	23,6	3304	€ 220,96	30	€ 66,29
9	23,6	3304	€ 220,96	30	€ 66,29
10	23,6	3304	€ 220,96	30	€ 66,29
11	23,6	3304	€ 220,96	30	€ 66,29
12	23,6	3304	€ 220,96	30	€ 66,29
13	23,6	3304	€ 220,96	30	€ 66,29
15	23,6	3304	€ 220,96	30	€ 66,29
16	23,6	3304	€ 220,96	30	€ 66,29
17	23,6	3304	€ 220,96	30	€ 66,29
18	23,6	3304	€ 220,96	30	€ 66,29
19	23,6	3304	€ 220,96	30	€ 66,29
20	23,6	3304	€ 220,96	30	€ 66,29
21	23,6	3304	€ 220,96	30	€ 66,29
22	23,6	3304	€ 220,96	30	€ 66,29
23	23,6	3304	€ 220,96	30	€ 66,29
24	23,6	3304	€ 220,96	30	€ 66,29
25	23,6	3304	€ 220,96	30	€ 66,29
26	259,6	36344	€ 2.430,51	40	€ 972,20
Totaal		112336	€ 7.512,48		**€ 2.496,80**

HEA550					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3917,6	€ 261,99	93	€ 243,65
3	23,6	3917,6	€ 261,99	93	€ 243,65
4	23,6	3917,6	€ 261,99	93	€ 243,65
5	23,6	3917,6	€ 261,99	93	€ 243,65
6	23,6	3917,6	€ 261,99	93	€ 243,65
7	23,6	3917,6	€ 261,99	93	€ 243,65
8	23,6	3917,6	€ 261,99	93	€ 243,65
9	23,6	3917,6	€ 261,99	93	€ 243,65
10	23,6	3917,6	€ 261,99	93	€ 243,65
11	23,6	3917,6	€ 261,99	93	€ 243,65
12	23,6	3917,6	€ 261,99	93	€ 243,65
13	23,6	3917,6	€ 261,99	93	€ 243,65
14	23,6	3917,6	€ 261,99	100	€ 261,99
15	23,6	3917,6	€ 261,99	93	€ 243,65
16	23,6	3917,6	€ 261,99	93	€ 243,65
17	23,6	3917,6	€ 261,99	93	€ 243,65
18	23,6	3917,6	€ 261,99	93	€ 243,65
19	23,6	3917,6	€ 261,99	93	€ 243,65
20	23,6	3917,6	€ 261,99	93	€ 243,65
21	23,6	3917,6	€ 261,99	93	€ 243,65
22	23,6	3917,6	€ 261,99	93	€ 243,65
23	23,6	3917,6	€ 261,99	93	€ 243,65
24	23,6	3917,6	€ 261,99	93	€ 243,65
25	23,6	3917,6	€ 261,99	93	€ 243,65
26	23,6	3917,6	€ 261,99	114	€ 298,67
Totaal		97940	€ 6.549,75		**€ 6.164,62**

HEA600					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	126	22428	€ 1.499,88	115	€ 1.724,86
3	126	22428	€ 1.499,88	70	€ 1.049,91
26	281,4	50089,2	€ 3.349,72	115	€ 3.852,18
Totaal		94945,2	€ 6.349,47		**€ 6.626,95**

HEA650					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	186	35340	€ 2.363,37	74	€ 1.748,89
3	150	28500	€ 1.905,94	87	€ 1.658,17
5	54,5	10355	€ 692,49	64	€ 443,19
7	54,5	10355	€ 692,49	64	€ 443,19
9	54,5	10355	€ 692,49	64	€ 443,19
11	54,5	10355	€ 692,49	66	€ 457,04
27	286,8	54492	€ 3.644,16	133	€ 4.846,73
Totaal		159752	€ 10.683,43		**€ 10.040,42**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	18	€ 25,52
27	27,6	4719,6	€	315,62	82	€ 258,81
28	273,1	46700,1	€	3.123,07	97	€ 3.029,38
Totaal		53540,1	€	3.580,50		€ 3.313,72

HEB600						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
14	281,4	59656,8	€	3.989,56	84	€ 3.351,23
Totaal		59656,8	€	3.989,56		**€ 3.351,23**

HEB650						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	12,4	2790	€	186,58	69	€ 128,74
14	27,6	6210	€	415,29	74	€ 307,32
25	273,1	61447,5	€	4.109,31	101	€ 4.150,40
26	274,1	61672,5	€	4.124,36	74	€ 3.052,02
27	275,1	61897,5	€	4.139,40	84	€ 3.477,10
Totaal		194017,5	€	12.974,94		**€ 11.115,58**

HEB400						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
28	273,1	42330,5	€	2.830,86	79	€ 2.236,38
Totaal		42330,5	€	2.830,86		**€ 2.236,38**

HEA260						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	24	1636,8	€	109,46	22	€ 24,08
4	24	1636,8	€	109,46	50	€ 54,73
6	24	1636,8	€	109,46	16	€ 17,51
8	24	1636,8	€	109,46	45	€ 49,26
10	24	1636,8	€	109,46	16	€ 17,51
12	24	1636,8	€	109,46	16	€ 17,51
13	24	1636,8	€	109,46	24	€ 26,27
15	24	1636,8	€	109,46	45	€ 49,26
16	24	1636,8	€	109,46	45	€ 49,26
17	24	1636,8	€	109,46	16	€ 17,51
18	24	1636,8	€	109,46	61	€ 66,77
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	45	€ 49,26
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 1.726,20**

HE500AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	16	€	322,18
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	16	€	322,18
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.376,30**

HE550AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	16	€	361,32
15	281,4	33768	€	2.258,24	16	€	361,32
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.203,78**

<u>New shadow price concrete option 50 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €140.102,49 (=106%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
1	24	6288	€	420,51	8	€	33,64
2	24	6288	€	420,51	109	€	458,36
5	24	6288	€	420,51	88	€	370,05
7	24	6288	€	420,51	8	€	33,64
9	24	6288	€	420,51	11	€	46,26
11	24	6288	€	420,51	59	€	248,10
14	24	6288	€	420,51	45	€	189,23
19	24	6288	€	420,51	27	€	113,54
21	24	6288	€	420,51	19	€	79,90
23	24	6288	€	420,51	8	€	33,64
25	24	6288	€	420,51	14	€	58,87
27	24	6288	€	420,51	13	€	54,67
Totaal		75456	€	5.046,13		**€**	**1.719,89**

HD400x551					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	112,2	61822,2	€ 4.134,37	131	€ 5.416,02
3	112,2	61822,2	€ 4.134,37	180	€ 7.441,86
Totaal		123644,4	€ 8.268,73		**€ 12.857,88**

HE650AA					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	95,4	13165,2	€ 880,42	155	€ 1.364,66
3	49,6	6844,8	€ 457,75	138	€ 631,69
4	54,5	7521	€ 502,97	138	€ 694,10
6	54,5	7521	€ 502,97	127	€ 638,77
8	54,5	7521	€ 502,97	127	€ 638,77
10	54,5	7521	€ 502,97	138	€ 694,10
12	54,5	7521	€ 502,97	145	€ 729,30
13	54,5	7521	€ 502,97	138	€ 694,10
15	54,5	7521	€ 502,97	185	€ 930,49
16	54,5	7521	€ 502,97	155	€ 779,60
17	54,5	7521	€ 502,97	155	€ 779,60
18	54,5	7521	€ 502,97	155	€ 779,60
19	54,5	7521	€ 502,97	145	€ 729,30
20	54,5	7521	€ 502,97	223	€ 1.121,62
21	54,5	7521	€ 502,97	164	€ 824,87
22	54,5	7521	€ 502,97	363	€ 1.825,77
23	54,5	7521	€ 502,97	134	€ 673,98
24	54,5	7521	€ 502,97	134	€ 673,98
Totaal		140346	€ 9.385,66		**€ 15.204,28**

HEA450					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	23,6	3304	€ 220,96	36	€ 79,54
3	23,6	3304	€ 220,96	36	€ 79,54
4	23,6	3304	€ 220,96	36	€ 79,54
5	23,6	3304	€ 220,96	36	€ 79,54
6	23,6	3304	€ 220,96	36	€ 79,54
7	23,6	3304	€ 220,96	36	€ 79,54
8	23,6	3304	€ 220,96	36	€ 79,54
9	23,6	3304	€ 220,96	36	€ 79,54
10	23,6	3304	€ 220,96	36	€ 79,54
11	23,6	3304	€ 220,96	36	€ 79,54
12	23,6	3304	€ 220,96	36	€ 79,54
13	23,6	3304	€ 220,96	36	€ 79,54
15	23,6	3304	€ 220,96	36	€ 79,54
16	23,6	3304	€ 220,96	36	€ 79,54
17	23,6	3304	€ 220,96	36	€ 79,54
18	23,6	3304	€ 220,96	36	€ 79,54
19	23,6	3304	€ 220,96	36	€ 79,54
20	23,6	3304	€ 220,96	36	€ 79,54
21	23,6	3304	€ 220,96	36	€ 79,54
22	23,6	3304	€ 220,96	36	€ 79,54
23	23,6	3304	€ 220,96	36	€ 79,54
24	23,6	3304	€ 220,96	36	€ 79,54
25	23,6	3304	€ 220,96	36	€ 79,54
26	259,6	36344	€ 2.430,51	53	€ 1.288,17
Totaal		112336	€ 7.512,48		**€ 3.117,68**

HEA550					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3917,6	€ 261,99	153	€ 400,84
3	23,6	3917,6	€ 261,99	153	€ 400,84
4	23,6	3917,6	€ 261,99	153	€ 400,84
5	23,6	3917,6	€ 261,99	153	€ 400,84
6	23,6	3917,6	€ 261,99	153	€ 400,84
7	23,6	3917,6	€ 261,99	153	€ 400,84
8	23,6	3917,6	€ 261,99	153	€ 400,84
9	23,6	3917,6	€ 261,99	153	€ 400,84
10	23,6	3917,6	€ 261,99	153	€ 400,84
11	23,6	3917,6	€ 261,99	153	€ 400,84
12	23,6	3917,6	€ 261,99	153	€ 400,84
13	23,6	3917,6	€ 261,99	153	€ 400,84
14	23,6	3917,6	€ 261,99	195	€ 510,88
15	23,6	3917,6	€ 261,99	153	€ 400,84
16	23,6	3917,6	€ 261,99	153	€ 400,84
17	23,6	3917,6	€ 261,99	153	€ 400,84
18	23,6	3917,6	€ 261,99	153	€ 400,84
19	23,6	3917,6	€ 261,99	153	€ 400,84
20	23,6	3917,6	€ 261,99	153	€ 400,84
21	23,6	3917,6	€ 261,99	153	€ 400,84
22	23,6	3917,6	€ 261,99	153	€ 400,84
23	23,6	3917,6	€ 261,99	153	€ 400,84
24	23,6	3917,6	€ 261,99	153	€ 400,84
25	23,6	3917,6	€ 261,99	153	€ 400,84
26	23,6	3917,6	€ 261,99	242	€ 634,02
Totaal		97940	€ 6.549,75		**€ 10.364,32**

HEA600					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	126	22428	€ 1.499,88	245	€ 3.674,69
3	126	22428	€ 1.499,88	107	€ 1.604,87
26	281,4	50089,2	€ 3.349,72	245	€ 8.206,82
Totaal		94945,2	€ 6.349,47		**€ 13.486,38**

HEA650					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	186	35340	€ 2.363,37	187	€ 4.419,50
3	150	28500	€ 1.905,94	162	€ 3.087,62
5	54,5	10355	€ 692,49	99	€ 685,57
7	54,5	10355	€ 692,49	99	€ 685,57
9	54,5	10355	€ 692,49	99	€ 685,57
11	54,5	10355	€ 692,49	194	€ 1.343,43
27	286,8	54492	€ 3.644,16	306	€ 11.151,13
Totaal		159752	€ 10.683,43		**€ 22.058,38**

HEB450						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
14	12,4	2120,4	€	141,80	21	€ 29,78
27	27,6	4719,6	€	315,62	125	€ 394,53
28	273,1	46700,1	€	3.123,07	158	€ 4.934,46
Totaal		53540,1	€	3.580,50		**€ 5.358,77**

HEB600						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
14	281,4	59656,8	€	3.989,56	161	€ 6.423,18
Totaal		59656,8	€	3.989,56		**€ 6.423,18**

HEB650						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
3	12,4	2790	€	186,58	118	€ 220,17
14	27,6	6210	€	415,29	198	€ 822,28
25	273,1	61447,5	€	4.109,31	88	€ 3.616,19
26	274,1	61672,5	€	4.124,36	144	€ 5.939,07
27	275,1	61897,5	€	4.139,40	172	€ 7.119,77
Totaal		194017,5	€	12.974,94		**€ 17.717,49**

HEB400						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
28	273,1	42330,5	€	2.830,86	114	€ 3.227,18
Totaal		42330,5	€	2.830,86		**€ 3.227,18**

HEA260						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
3	24	1636,8	€	109,46	64	€ 70,06
4	24	1636,8	€	109,46	53	€ 58,01
6	24	1636,8	€	109,46	43	€ 47,07
8	24	1636,8	€	109,46	258	€ 282,41
10	24	1636,8	€	109,46	43	€ 47,07
12	24	1636,8	€	109,46	43	€ 47,07
13	24	1636,8	€	109,46	28	€ 30,65
15	24	1636,8	€	109,46	122	€ 133,54
16	24	1636,8	€	109,46	122	€ 133,54
17	24	1636,8	€	109,46	43	€ 47,07
18	24	1636,8	€	109,46	73	€ 79,91
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	122	€ 133,54
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 2.397,20**

HE500AA							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	16	€	322,18
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	16	€	322,18
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.376,30**

HE550AA							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	16	€	361,32
15	281,4	33768	€	2.258,24	16	€	361,32
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.203,78**

<u>New shadow price concrete option 200 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €144.660,48 (=109%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**	
1	24	6288	€	420,51	8	€	33,64
2	24	6288	€	420,51	110	€	462,56
5	24	6288	€	420,51	93	€	391,08
7	24	6288	€	420,51	8	€	33,64
9	24	6288	€	420,51	11	€	46,26
11	24	6288	€	420,51	59	€	248,10
14	24	6288	€	420,51	49	€	206,05
19	24	6288	€	420,51	27	€	113,54
21	24	6288	€	420,51	19	€	79,90
23	24	6288	€	420,51	8	€	33,64
25	24	6288	€	420,51	14	€	58,87
27	24	6288	€	420,51	13	€	54,67
Totaal		75456	€	5.046,13		**€**	**1.761,94**

HD400x551					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	112,2	61822,2	€ 4.134,37	135	€ 5.581,40
3	112,2	61822,2	€ 4.134,37	186	€ 7.689,92
Totaal		123644,4	€ 8.268,73		**€ 13.271,32**

HE650AA					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	95,4	13165,2	€ 880,42	170	€ 1.496,72
3	49,6	6844,8	€ 457,75	150	€ 686,62
4	54,5	7521	€ 502,97	150	€ 754,45
6	54,5	7521	€ 502,97	136	€ 684,04
8	54,5	7521	€ 502,97	136	€ 684,04
10	54,5	7521	€ 502,97	150	€ 754,45
12	54,5	7521	€ 502,97	147	€ 739,36
13	54,5	7521	€ 502,97	150	€ 754,45
15	54,5	7521	€ 502,97	195	€ 980,79
16	54,5	7521	€ 502,97	170	€ 855,05
17	54,5	7521	€ 502,97	170	€ 855,05
18	54,5	7521	€ 502,97	170	€ 855,05
19	54,5	7521	€ 502,97	147	€ 739,36
20	54,5	7521	€ 502,97	227	€ 1.141,74
21	54,5	7521	€ 502,97	174	€ 875,16
22	54,5	7521	€ 502,97	370	€ 1.860,98
23	54,5	7521	€ 502,97	143	€ 719,24
24	54,5	7521	€ 502,97	143	€ 719,24
Totaal		140346	€ 9.385,66		**€ 16.155,79**

HEA450					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3304	€ 220,96	36	€ 79,54
3	23,6	3304	€ 220,96	36	€ 79,54
4	23,6	3304	€ 220,96	36	€ 79,54
5	23,6	3304	€ 220,96	36	€ 79,54
6	23,6	3304	€ 220,96	36	€ 79,54
7	23,6	3304	€ 220,96	36	€ 79,54
8	23,6	3304	€ 220,96	36	€ 79,54
9	23,6	3304	€ 220,96	36	€ 79,54
10	23,6	3304	€ 220,96	36	€ 79,54
11	23,6	3304	€ 220,96	36	€ 79,54
12	23,6	3304	€ 220,96	36	€ 79,54
13	23,6	3304	€ 220,96	36	€ 79,54
15	23,6	3304	€ 220,96	36	€ 79,54
16	23,6	3304	€ 220,96	36	€ 79,54
17	23,6	3304	€ 220,96	36	€ 79,54
18	23,6	3304	€ 220,96	36	€ 79,54
19	23,6	3304	€ 220,96	36	€ 79,54
20	23,6	3304	€ 220,96	36	€ 79,54
21	23,6	3304	€ 220,96	36	€ 79,54
22	23,6	3304	€ 220,96	36	€ 79,54
23	23,6	3304	€ 220,96	36	€ 79,54
24	23,6	3304	€ 220,96	36	€ 79,54
25	23,6	3304	€ 220,96	36	€ 79,54
26	259,6	36344	€ 2.430,51	56	€ 1.361,09
Totaal		112336	€ 7.512,48		**€ 3.190,60**

HEA550							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	23,6	3917,6	€	261,99	161	€	421,80
3	23,6	3917,6	€	261,99	161	€	421,80
4	23,6	3917,6	€	261,99	161	€	421,80
5	23,6	3917,6	€	261,99	161	€	421,80
6	23,6	3917,6	€	261,99	161	€	421,80
7	23,6	3917,6	€	261,99	161	€	421,80
8	23,6	3917,6	€	261,99	161	€	421,80
9	23,6	3917,6	€	261,99	161	€	421,80
10	23,6	3917,6	€	261,99	161	€	421,80
11	23,6	3917,6	€	261,99	161	€	421,80
12	23,6	3917,6	€	261,99	161	€	421,80
13	23,6	3917,6	€	261,99	161	€	421,80
14	23,6	3917,6	€	261,99	203	€	531,84
15	23,6	3917,6	€	261,99	161	€	421,80
16	23,6	3917,6	€	261,99	161	€	421,80
17	23,6	3917,6	€	261,99	161	€	421,80
18	23,6	3917,6	€	261,99	161	€	421,80
19	23,6	3917,6	€	261,99	161	€	421,80
20	23,6	3917,6	€	261,99	161	€	421,80
21	23,6	3917,6	€	261,99	161	€	421,80
22	23,6	3917,6	€	261,99	161	€	421,80
23	23,6	3917,6	€	261,99	161	€	421,80
24	23,6	3917,6	€	261,99	161	€	421,80
25	23,6	3917,6	€	261,99	161	€	421,80
26	23,6	3917,6	€	261,99	254	€	665,45
Totaal		97940	€	6.549,75		**€**	**10.898,78**

HEA600							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	126	22428	€	1.499,88	257	€	3.854,68
3	126	22428	€	1.499,88	112	€	1.679,86
26	281,4	50089,2	€	3.349,72	257	€	8.608,78
Totaal		94945,2	€	6.349,47		**€**	**14.143,32**

HEA650							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	186	35340	€	2.363,37	194	€	4.584,93
3	150	28500	€	1.905,94	171	€	3.259,16
5	54,5	10355	€	692,49	100	€	692,49
7	54,5	10355	€	692,49	100	€	692,49
9	54,5	10355	€	692,49	100	€	692,49
11	54,5	10355	€	692,49	203	€	1.405,76
27	286,8	54492	€	3.644,16	312	€	11.369,78
Totaal		159752	€	10.683,43		**€**	**22.697,10**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	24	€ 34,03
27	27,6	4719,6	€	315,62	126	€ 397,69
28	273,1	46700,1	€	3.123,07	164	€ 5.121,84
Totaal		53540,1	€	3.580,50		**€ 5.553,56**

HEB600						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	281,4	59656,8	€	3.989,56	170	€ 6.782,24
Totaal		59656,8	€	3.989,56		**€ 6.782,24**

HEB650						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	12,4	2790	€	186,58	120	€ 223,90
14	27,6	6210	€	415,29	201	€ 834,74
25	273,1	61447,5	€	4.109,31	93	€ 3.821,66
26	274,1	61672,5	€	4.124,36	147	€ 6.062,80
27	275,1	61897,5	€	4.139,40	179	€ 7.409,53
Totaal		194017,5	€	12.974,94		**€ 18.352,63**

HEB400						
Level	Length	g [kg]	Shadow price original		%	Shadow price
28	273,1	42330,5	€	2.830,86	115	€ 3.255,49
Totaal		42330,5	€	2.830,86		**€ 3.255,49**

HEA260						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	24	1636,8	€	109,46	64	€ 70,06
4	24	1636,8	€	109,46	53	€ 58,01
6	24	1636,8	€	109,46	43	€ 47,07
8	24	1636,8	€	109,46	276	€ 302,11
10	24	1636,8	€	109,46	43	€ 47,07
12	24	1636,8	€	109,46	43	€ 47,07
13	24	1636,8	€	109,46	31	€ 33,93
15	24	1636,8	€	109,46	122	€ 133,54
16	24	1636,8	€	109,46	122	€ 133,54
17	24	1636,8	€	109,46	43	€ 47,07
18	24	1636,8	€	109,46	80	€ 87,57
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	122	€ 133,54
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 2.427,85**

HE500AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	16	€	322,18
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	16	€	322,18
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.376,30**

HE550AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	16	€	361,32
15	281,4	33768	€	2.258,24	16	€	361,32
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.203,78**

<u>New shadow price concrete option 200 years “meeting”</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €161.546,90 (=122%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
1	24	6288	€	420,51	11	€	46,26
2	24	6288	€	420,51	136	€	571,89
5	24	6288	€	420,51	110	€	462,56
7	24	6288	€	420,51	11	€	46,26
9	24	6288	€	420,51	13	€	54,67
11	24	6288	€	420,51	72	€	302,77
14	24	6288	€	420,51	57	€	239,69
19	24	6288	€	420,51	32	€	134,56
21	24	6288	€	420,51	21	€	88,31
23	24	6288	€	420,51	11	€	46,26
25	24	6288	€	420,51	16	€	67,28
27	24	6288	€	420,51	15	€	63,08
Totaal		75456	€	5.046,13		**€**	**2.123,58**

HD400x551					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	112,2	61822,2	€ 4.134,37	160	€ 6.614,99
3	112,2	61822,2	€ 4.134,37	220	€ 9.095,61
Totaal		123644,4	€ 8.268,73		**€ 15.710,60**

HE650AA					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	95,4	13165,2	€ 880,42	193	€ 1.699,22
3	49,6	6844,8	€ 457,75	170	€ 778,17
4	54,5	7521	€ 502,97	170	€ 855,05
6	54,5	7521	€ 502,97	155	€ 779,60
8	54,5	7521	€ 502,97	155	€ 779,60
10	54,5	7521	€ 502,97	170	€ 855,05
12	54,5	7521	€ 502,97	175	€ 880,19
13	54,5	7521	€ 502,97	170	€ 855,05
15	54,5	7521	€ 502,97	225	€ 1.131,68
16	54,5	7521	€ 502,97	193	€ 970,73
17	54,5	7521	€ 502,97	193	€ 970,73
18	54,5	7521	€ 502,97	193	€ 970,73
19	54,5	7521	€ 502,97	175	€ 880,19
20	54,5	7521	€ 502,97	267	€ 1.342,92
21	54,5	7521	€ 502,97	195	€ 980,79
22	54,5	7521	€ 502,97	441	€ 2.218,09
23	54,5	7521	€ 502,97	164	€ 824,87
24	54,5	7521	€ 502,97	164	€ 824,87
Totaal		140346	€ 9.385,66		**€ 18.597,51**

HEA450					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3304	€ 220,96	43	€ 95,01
3	23,6	3304	€ 220,96	43	€ 95,01
4	23,6	3304	€ 220,96	43	€ 95,01
5	23,6	3304	€ 220,96	43	€ 95,01
6	23,6	3304	€ 220,96	43	€ 95,01
7	23,6	3304	€ 220,96	43	€ 95,01
8	23,6	3304	€ 220,96	43	€ 95,01
9	23,6	3304	€ 220,96	43	€ 95,01
10	23,6	3304	€ 220,96	43	€ 95,01
11	23,6	3304	€ 220,96	43	€ 95,01
12	23,6	3304	€ 220,96	43	€ 95,01
13	23,6	3304	€ 220,96	43	€ 95,01
15	23,6	3304	€ 220,96	43	€ 95,01
16	23,6	3304	€ 220,96	43	€ 95,01
17	23,6	3304	€ 220,96	43	€ 95,01
18	23,6	3304	€ 220,96	43	€ 95,01
19	23,6	3304	€ 220,96	43	€ 95,01
20	23,6	3304	€ 220,96	43	€ 95,01
21	23,6	3304	€ 220,96	43	€ 95,01
22	23,6	3304	€ 220,96	43	€ 95,01
23	23,6	3304	€ 220,96	43	€ 95,01
24	23,6	3304	€ 220,96	43	€ 95,01
25	23,6	3304	€ 220,96	43	€ 95,01
26	259,6	36344	€ 2.430,51	66	€ 1.604,14
Totaal		112336	€ 7.512,48		**€ 3.789,39**

HEA550						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	23,6	3917,6	€ 261,99	140	€	366,79
3	23,6	3917,6	€ 261,99	140	€	366,79
4	23,6	3917,6	€ 261,99	140	€	366,79
5	23,6	3917,6	€ 261,99	140	€	366,79
6	23,6	3917,6	€ 261,99	140	€	366,79
7	23,6	3917,6	€ 261,99	140	€	366,79
8	23,6	3917,6	€ 261,99	140	€	366,79
9	23,6	3917,6	€ 261,99	140	€	366,79
10	23,6	3917,6	€ 261,99	140	€	366,79
11	23,6	3917,6	€ 261,99	140	€	366,79
12	23,6	3917,6	€ 261,99	140	€	366,79
13	23,6	3917,6	€ 261,99	140	€	366,79
14	23,6	3917,6	€ 261,99	236	€	618,30
15	23,6	3917,6	€ 261,99	140	€	366,79
16	23,6	3917,6	€ 261,99	140	€	366,79
17	23,6	3917,6	€ 261,99	140	€	366,79
18	23,6	3917,6	€ 261,99	140	€	366,79
19	23,6	3917,6	€ 261,99	140	€	366,79
20	23,6	3917,6	€ 261,99	140	€	366,79
21	23,6	3917,6	€ 261,99	140	€	366,79
22	23,6	3917,6	€ 261,99	140	€	366,79
23	23,6	3917,6	€ 261,99	140	€	366,79
24	23,6	3917,6	€ 261,99	140	€	366,79
25	23,6	3917,6	€ 261,99	140	€	366,79
26	23,6	3917,6	€ 261,99	297	€	778,11
Totaal		97940	€ 6.549,75		**€**	**9.832,48**

HEA600						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	126	22428	€ 1.499,88	298	€	4.469,63
3	126	22428	€ 1.499,88	126	€	1.889,84
26	281,4	50089,2	€ 3.349,72	298	€	9.982,17
Totaal		94945,2	€ 6.349,47		**€**	**16.341,64**

HEA650						
Level	Length	g [kg]	Shadow price original	%	Shadow price	
2	186	35340	€ 2.363,37	230	€	5.435,74
3	150	28500	€ 1.905,94	196	€	3.735,64
5	54,5	10355	€ 692,49	114	€	789,44
7	54,5	10355	€ 692,49	114	€	789,44
9	54,5	10355	€ 692,49	114	€	789,44
11	54,5	10355	€ 692,49	239	€	1.655,06
27	286,8	54492	€ 3.644,16	371	€	13.519,83
Totaal		159752	€ 10.683,43		**€**	**26.714,60**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	26	€ 36,87
27	27,6	4719,6	€	315,62	147	€ 463,97
28	273,1	46700,1	€	3.123,07	192	€ 5.996,30
Totaal		53540,1	€	3.580,50		**€ 6.497,14**

HEB600						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
14	281,4	59656,8	€	3.989,56	199	€ 7.939,22
Totaal		59656,8	€	3.989,56		**€ 7.939,22**

HEB650						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	12,4	2790	€	186,58	139	€ 259,35
14	27,6	6210	€	415,29	241	€ 1.000,86
25	273,1	61447,5	€	4.109,31	101	€ 4.150,40
26	274,1	61672,5	€	4.124,36	174	€ 7.176,38
27	275,1	61897,5	€	4.139,40	210	€ 8.692,75
Totaal		194017,5	€	12.974,94		**€ 21.279,74**

HEB400						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
28	273,1	42330,5	€	2.830,86	138	€ 3.906,58
Totaal		42330,5	€	2.830,86		**€ 3.906,58**

HEA260						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	24	1636,8	€	109,46	75	€ 82,10
4	24	1636,8	€	109,46	66	€ 72,24
6	24	1636,8	€	109,46	51	€ 55,83
8	24	1636,8	€	109,46	337	€ 368,88
10	24	1636,8	€	109,46	51	€ 55,83
12	24	1636,8	€	109,46	51	€ 55,83
13	24	1636,8	€	109,46	32	€ 35,03
15	24	1636,8	€	109,46	146	€ 159,81
16	24	1636,8	€	109,46	146	€ 159,81
17	24	1636,8	€	109,46	51	€ 55,83
18	24	1636,8	€	109,46	88	€ 96,33
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	146	€ 159,81
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 2.644,58**

HE500AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	16	€	322,18
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	16	€	322,18
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.376,30**

HE550AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	16	€	361,32
15	281,4	33768	€	2.258,24	16	€	361,32
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.203,78**

<u>New shadow price timber option 50 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €103.691,97 (=78%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
1	24	6288	€	420,51	7	€	29,44
2	24	6288	€	420,51	25	€	105,13
5	24	6288	€	420,51	22	€	92,51
7	24	6288	€	420,51	7	€	29,44
9	24	6288	€	420,51	2	€	8,41
11	24	6288	€	420,51	17	€	71,49
14	24	6288	€	420,51	17	€	71,49
19	24	6288	€	420,51	15	€	63,08
21	24	6288	€	420,51	15	€	63,08
23	24	6288	€	420,51	7	€	29,44
25	24	6288	€	420,51	13	€	54,67
27	24	6288	€	420,51	15	€	63,08
Totaal		75456	€	5.046,13		**€**	**681,23**

HD400x551						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
2	112,2	61822,2	€	4.134,37	42	€ 1.736,43
3	112,2	61822,2	€	4.134,37	51	€ 2.108,53
Totaal		123644,4	€	8.268,73		**€ 3.844,96**

HE650AA						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
2	95,4	13165,2	€	880,42	120	€ 1.056,51
3	49,6	6844,8	€	457,75	103	€ 471,48
4	54,5	7521	€	502,97	103	€ 518,06
6	54,5	7521	€	502,97	94	€ 472,79
8	54,5	7521	€	502,97	94	€ 472,79
10	54,5	7521	€	502,97	103	€ 518,06
12	54,5	7521	€	502,97	111	€ 558,29
13	54,5	7521	€	502,97	103	€ 518,06
15	54,5	7521	€	502,97	139	€ 699,13
16	54,5	7521	€	502,97	120	€ 603,56
17	54,5	7521	€	502,97	120	€ 603,56
18	54,5	7521	€	502,97	120	€ 603,56
19	54,5	7521	€	502,97	111	€ 558,29
20	54,5	7521	€	502,97	159	€ 799,72
21	54,5	7521	€	502,97	129	€ 648,83
22	54,5	7521	€	502,97	168	€ 844,99
23	54,5	7521	€	502,97	103	€ 518,06
24	54,5	7521	€	502,97	103	€ 518,06
Totaal		140346	€	9.385,66		**€ 10.983,78**

HEA450					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3304	€ 220,96	27	€ 59,66
3	23,6	3304	€ 220,96	27	€ 59,66
4	23,6	3304	€ 220,96	27	€ 59,66
5	23,6	3304	€ 220,96	27	€ 59,66
6	23,6	3304	€ 220,96	27	€ 59,66
7	23,6	3304	€ 220,96	27	€ 59,66
8	23,6	3304	€ 220,96	27	€ 59,66
9	23,6	3304	€ 220,96	27	€ 59,66
10	23,6	3304	€ 220,96	27	€ 59,66
11	23,6	3304	€ 220,96	27	€ 59,66
12	23,6	3304	€ 220,96	27	€ 59,66
13	23,6	3304	€ 220,96	27	€ 59,66
15	23,6	3304	€ 220,96	27	€ 59,66
16	23,6	3304	€ 220,96	27	€ 59,66
17	23,6	3304	€ 220,96	27	€ 59,66
18	23,6	3304	€ 220,96	27	€ 59,66
19	23,6	3304	€ 220,96	27	€ 59,66
20	23,6	3304	€ 220,96	27	€ 59,66
21	23,6	3304	€ 220,96	27	€ 59,66
22	23,6	3304	€ 220,96	27	€ 59,66
23	23,6	3304	€ 220,96	27	€ 59,66
24	23,6	3304	€ 220,96	27	€ 59,66
25	23,6	3304	€ 220,96	27	€ 59,66
26	259,6	36344	€ 2.430,51	41	€ 996,51
Totaal		112336	€ 7.512,48		**€ 2.368,64**

HEA550					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3917,6	€ 261,99	115	€ 301,29
3	23,6	3917,6	€ 261,99	115	€ 301,29
4	23,6	3917,6	€ 261,99	115	€ 301,29
5	23,6	3917,6	€ 261,99	115	€ 301,29
6	23,6	3917,6	€ 261,99	115	€ 301,29
7	23,6	3917,6	€ 261,99	115	€ 301,29
8	23,6	3917,6	€ 261,99	115	€ 301,29
9	23,6	3917,6	€ 261,99	115	€ 301,29
10	23,6	3917,6	€ 261,99	115	€ 301,29
11	23,6	3917,6	€ 261,99	115	€ 301,29
12	23,6	3917,6	€ 261,99	115	€ 301,29
13	23,6	3917,6	€ 261,99	115	€ 301,29
14	23,6	3917,6	€ 261,99	140	€ 366,79
15	23,6	3917,6	€ 261,99	115	€ 301,29
16	23,6	3917,6	€ 261,99	115	€ 301,29
17	23,6	3917,6	€ 261,99	115	€ 301,29
18	23,6	3917,6	€ 261,99	115	€ 301,29
19	23,6	3917,6	€ 261,99	115	€ 301,29
20	23,6	3917,6	€ 261,99	115	€ 301,29
21	23,6	3917,6	€ 261,99	115	€ 301,29
22	23,6	3917,6	€ 261,99	115	€ 301,29
23	23,6	3917,6	€ 261,99	115	€ 301,29
24	23,6	3917,6	€ 261,99	115	€ 301,29
25	23,6	3917,6	€ 261,99	115	€ 301,29
26	23,6	3917,6	€ 261,99	168	€ 440,14
Totaal		97940	€ 6.549,75		**€ 7.736,56**

HEA600					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	126	22428	€ 1.499,88	165	€ 2.474,79
3	126	22428	€ 1.499,88	93	€ 1.394,88
26	281,4	50089,2	€ 3.349,72	165	€ 5.527,04
Totaal		94945,2	€ 6.349,47		**€ 9.396,72**

HEA650					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	186	35340	€ 2.363,37	107	€ 2.528,80
3	150	28500	€ 1.905,94	115	€ 2.191,83
5	54,5	10355	€ 692,49	81	€ 560,92
7	54,5	10355	€ 692,49	81	€ 560,92
9	54,5	10355	€ 692,49	81	€ 560,92
11	54,5	10355	€ 692,49	94	€ 650,94
27	286,8	54492	€ 3.644,16	211	€ 7.689,18
Totaal		159752	€ 10.683,43		**€ 14.743,51**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	19	€ 26,94
27	27,6	4719,6	€	315,62	90	€ 284,06
28	273,1	46700,1	€	3.123,07	128	€ 3.997,54
Totaal		53540,1	€	3.580,50		**€ 4.308,54**

HEB600						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	281,4	59656,8	€	3.989,56	110	€ 4.388,51
Totaal		59656,8	€	3.989,56		**€ 4.388,51**

HEB650						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	12,4	2790	€	186,58	91	€ 169,79
14	27,6	6210	€	415,29	124	€ 514,97
25	273,1	61447,5	€	4.109,31	117	€ 4.807,89
26	274,1	61672,5	€	4.124,36	103	€ 4.248,09
27	275,1	61897,5	€	4.139,40	124	€ 5.132,86
Totaal		194017,5	€	12.974,94		**€ 14.873,59**

HEB400						
Level	Length	g [kg]	Shadow price original		%	Shadow price
28	273,1	42330,5	€	2.830,86	84	€ 2.377,92
Totaal		42330,5	€	2.830,86		**€ 2.377,92**

HEA260						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	24	1636,8	€	109,46	27	€ 29,55
4	24	1636,8	€	109,46	48	€ 52,54
6	24	1636,8	€	109,46	21	€ 22,99
8	24	1636,8	€	109,46	75	€ 82,10
10	24	1636,8	€	109,46	21	€ 22,99
12	24	1636,8	€	109,46	21	€ 22,99
13	24	1636,8	€	109,46	27	€ 29,55
15	24	1636,8	€	109,46	56	€ 61,30
16	24	1636,8	€	109,46	56	€ 61,30
17	24	1636,8	€	109,46	21	€ 22,99
18	24	1636,8	€	109,46	56	€ 61,30
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	56	€ 61,30
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 1.818,15**

HE500AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
4	281,4	30109,8	€ 2.013,60	17	€ 342,31
6	281,4	30109,8	€ 2.013,60	41	€ 825,57
8	281,4	30109,8	€ 2.013,60	16	€ 322,18
10	281,4	30109,8	€ 2.013,60	41	€ 825,57
12	281,4	30109,8	€ 2.013,60	16	€ 322,18
16	281,4	30109,8	€ 2.013,60	16	€ 322,18
18	281,4	30109,8	€ 2.013,60	22	€ 442,99
20	281,4	30109,8	€ 2.013,60	41	€ 825,57
22	281,4	30109,8	€ 2.013,60	41	€ 825,57
24	281,4	30109,8	€ 2.013,60	16	€ 322,18
Totaal		301098	€ 20.135,97		**€ 5.376,30**

HE550AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
5	281,4	33768	€ 2.258,24	17	€ 383,90
7	281,4	33768	€ 2.258,24	41	€ 925,88
9	281,4	33768	€ 2.258,24	16	€ 361,32
11	281,4	33768	€ 2.258,24	41	€ 925,88
13	281,4	33768	€ 2.258,24	16	€ 361,32
15	281,4	33768	€ 2.258,24	16	€ 361,32
17	281,4	33768	€ 2.258,24	22	€ 496,81
19	281,4	33768	€ 2.258,24	41	€ 925,88
21	281,4	33768	€ 2.258,24	41	€ 925,88
23	281,4	33768	€ 2.258,24	16	€ 361,32
25	281,4	33768	€ 2.258,24	52	€ 1.174,28
Totaal		371448	€ 24.840,63		**€ 7.203,78**

<u>New shadow price timber option 200 years</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €129.063,00 (=98%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262					
Level	Length	g [kg]	Shadow price original	%	Shadow price
1	24	6288	€ 420,51	8	€ 33,64
2	24	6288	€ 420,51	31	€ 130,36
5	24	6288	€ 420,51	28	€ 117,74
7	24	6288	€ 420,51	8	€ 33,64
9	24	6288	€ 420,51	3	€ 12,62
11	24	6288	€ 420,51	19	€ 79,90
14	24	6288	€ 420,51	19	€ 79,90
19	24	6288	€ 420,51	17	€ 71,49
21	24	6288	€ 420,51	22	€ 92,51
23	24	6288	€ 420,51	8	€ 33,64
25	24	6288	€ 420,51	15	€ 63,08
27	24	6288	€ 420,51	17	€ 71,49
Totaal		75456	€ 5.046,13		**€ 820,00**

HD400x551						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
2	112,2	61822,2	€	4.134,37	66	€ 2.728,68
3	112,2	61822,2	€	4.134,37	76	€ 3.142,12
Totaal		123644,4	€	8.268,73		**€ 5.870,80**

HE650AA						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
2	95,4	13165,2	€	880,42	148	€ 1.303,03
3	49,6	6844,8	€	457,75	129	€ 590,49
4	54,5	7521	€	502,97	129	€ 648,83
6	54,5	7521	€	502,97	120	€ 603,56
8	54,5	7521	€	502,97	120	€ 603,56
10	54,5	7521	€	502,97	129	€ 648,83
12	54,5	7521	€	502,97	139	€ 699,13
13	54,5	7521	€	502,97	129	€ 648,83
15	54,5	7521	€	502,97	168	€ 844,99
16	54,5	7521	€	502,97	148	€ 744,39
17	54,5	7521	€	502,97	148	€ 744,39
18	54,5	7521	€	502,97	148	€ 744,39
19	54,5	7521	€	502,97	139	€ 699,13
20	54,5	7521	€	502,97	190	€ 955,64
21	54,5	7521	€	502,97	148	€ 744,39
22	54,5	7521	€	502,97	213	€ 1.071,32
23	54,5	7521	€	502,97	129	€ 648,83
24	54,5	7521	€	502,97	129	€ 648,83
Totaal		140346	€	9.385,66		**€ 13.592,55**

HEA450					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3304	€ 220,96	41	€ 90,59
3	23,6	3304	€ 220,96	41	€ 90,59
4	23,6	3304	€ 220,96	41	€ 90,59
5	23,6	3304	€ 220,96	41	€ 90,59
6	23,6	3304	€ 220,96	41	€ 90,59
7	23,6	3304	€ 220,96	41	€ 90,59
8	23,6	3304	€ 220,96	41	€ 90,59
9	23,6	3304	€ 220,96	41	€ 90,59
10	23,6	3304	€ 220,96	41	€ 90,59
11	23,6	3304	€ 220,96	41	€ 90,59
12	23,6	3304	€ 220,96	41	€ 90,59
13	23,6	3304	€ 220,96	41	€ 90,59
15	23,6	3304	€ 220,96	41	€ 90,59
16	23,6	3304	€ 220,96	41	€ 90,59
17	23,6	3304	€ 220,96	41	€ 90,59
18	23,6	3304	€ 220,96	41	€ 90,59
19	23,6	3304	€ 220,96	41	€ 90,59
20	23,6	3304	€ 220,96	41	€ 90,59
21	23,6	3304	€ 220,96	41	€ 90,59
22	23,6	3304	€ 220,96	41	€ 90,59
23	23,6	3304	€ 220,96	41	€ 90,59
24	23,6	3304	€ 220,96	41	€ 90,59
25	23,6	3304	€ 220,96	41	€ 90,59
26	259,6	36344	€ 2.430,51	59	€ 1.434,00
Totaal		112336	€ 7.512,48		**€ 3.517,61**

HEA550							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	23,6	3917,6	€	261,99	158	€	413,94
3	23,6	3917,6	€	261,99	158	€	413,94
4	23,6	3917,6	€	261,99	158	€	413,94
5	23,6	3917,6	€	261,99	158	€	413,94
6	23,6	3917,6	€	261,99	158	€	413,94
7	23,6	3917,6	€	261,99	158	€	413,94
8	23,6	3917,6	€	261,99	158	€	413,94
9	23,6	3917,6	€	261,99	158	€	413,94
10	23,6	3917,6	€	261,99	158	€	413,94
11	23,6	3917,6	€	261,99	158	€	413,94
12	23,6	3917,6	€	261,99	158	€	413,94
13	23,6	3917,6	€	261,99	158	€	413,94
14	23,6	3917,6	€	261,99	188	€	492,54
15	23,6	3917,6	€	261,99	158	€	413,94
16	23,6	3917,6	€	261,99	158	€	413,94
17	23,6	3917,6	€	261,99	158	€	413,94
18	23,6	3917,6	€	261,99	158	€	413,94
19	23,6	3917,6	€	261,99	158	€	413,94
20	23,6	3917,6	€	261,99	158	€	413,94
21	23,6	3917,6	€	261,99	158	€	413,94
22	23,6	3917,6	€	261,99	158	€	413,94
23	23,6	3917,6	€	261,99	158	€	413,94
24	23,6	3917,6	€	261,99	158	€	413,94
25	23,6	3917,6	€	261,99	158	€	413,94
26	23,6	3917,6	€	261,99	219	€	573,76
Totaal		97940	€	6.549,75		**€**	**10.587,02**

HEA600							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	126	22428	€	1.499,88	225	€	3.374,72
3	126	22428	€	1.499,88	115	€	1.724,86
26	281,4	50089,2	€	3.349,72	225	€	7.536,87
Totaal		94945,2	€	6.349,47		**€**	**12.636,45**

HEA650							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
2	186	35340	€	2.363,37	122	€	2.883,31
3	150	28500	€	1.905,94	155	€	2.954,21
5	54,5	10355	€	692,49	101	€	699,42
7	54,5	10355	€	692,49	101	€	699,42
9	54,5	10355	€	692,49	101	€	699,42
11	54,5	10355	€	692,49	107	€	740,97
27	286,8	54492	€	3.644,16	276	€	10.057,88
Totaal		159752	€	10.683,43		**€**	**18.734,61**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	26	€ 36,87
27	27,6	4719,6	€	315,62	128	€ 404,00
28	273,1	46700,1	€	3.123,07	172	€ 5.371,69
Totaal		53540,1	€	3.580,50		**€ 5.812,56**

HEB600						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	281,4	59656,8	€	3.989,56	155	€ 6.183,81
Totaal		59656,8	€	3.989,56		**€ 6.183,61**

HEB650						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	12,4	2790	€	186,58	117	€ 218,30
14	27,6	6210	€	415,29	139	€ 577,26
25	273,1	61447,5	€	4.109,31	131	€ 5.383,19
26	274,1	61672,5	€	4.124,36	139	€ 5.732,85
27	275,1	61897,5	€	4.139,40	162	€ 6.705,83
Totaal		194017,5	€	12.974,94		**€ 18.617,44**

HEB400						
Level	Length	g [kg]	Shadow price original		%	Shadow price
28	273,1	42330,5	€	2.830,86	123	€ 3.481,95
Totaal		42330,5	€	2.830,86		**€ 3.481,95**

HEA260						
Level	Length	g [kg]	Shadow price original		%	Shadow price
3	24	1636,8	€	109,46	32	€ 35,03
4	24	1636,8	€	109,46	56	€ 61,30
6	24	1636,8	€	109,46	27	€ 29,55
8	24	1636,8	€	109,46	96	€ 105,08
10	24	1636,8	€	109,46	27	€ 29,55
12	24	1636,8	€	109,46	27	€ 29,55
13	24	1636,8	€	109,46	32	€ 35,03
15	24	1636,8	€	109,46	75	€ 82,10
16	24	1636,8	€	109,46	75	€ 82,10
17	24	1636,8	€	109,46	27	€ 29,55
18	24	1636,8	€	109,46	84	€ 91,95
20	24	1636,8	€	109,46	75	€ 82,10
22	24	1636,8	€	109,46	75	€ 82,10
24	24	1636,8	€	109,46	75	€ 82,10
26	24	1636,8	€	109,46	75	€ 82,10
28	264	18004,8	€	1.204,07	75	€ 903,05
Totaal		42556,8	€	2.845,99		**€ 1.842,23**

HE500AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
4	281,4	30109,8	€	2.013,60	17	€	342,31
6	281,4	30109,8	€	2.013,60	41	€	825,57
8	281,4	30109,8	€	2.013,60	30	€	604,08
10	281,4	30109,8	€	2.013,60	41	€	825,57
12	281,4	30109,8	€	2.013,60	30	€	604,08
16	281,4	30109,8	€	2.013,60	16	€	322,18
18	281,4	30109,8	€	2.013,60	22	€	442,99
20	281,4	30109,8	€	2.013,60	41	€	825,57
22	281,4	30109,8	€	2.013,60	41	€	825,57
24	281,4	30109,8	€	2.013,60	16	€	322,18
Totaal		301098	€	20.135,97		**€**	**5.940,11**

HE550AA							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
5	281,4	33768	€	2.258,24	17	€	383,90
7	281,4	33768	€	2.258,24	41	€	925,88
9	281,4	33768	€	2.258,24	16	€	361,32
11	281,4	33768	€	2.258,24	41	€	925,88
13	281,4	33768	€	2.258,24	30	€	677,47
15	281,4	33768	€	2.258,24	30	€	677,47
17	281,4	33768	€	2.258,24	22	€	496,81
19	281,4	33768	€	2.258,24	41	€	925,88
21	281,4	33768	€	2.258,24	41	€	925,88
23	281,4	33768	€	2.258,24	16	€	361,32
25	281,4	33768	€	2.258,24	52	€	1.174,28
Totaal		371448	€	24.840,63		**€**	**7.836,09**

<u>New shadow price timber option 200 years “meeting”</u>
Original shadow price of beams: €132.184,71
New shadow price of beams: €143.978,79 (=109%)
These shadow prices are including the shadow prices of the beams that have not been optimized.

HD400x262							
Level	Length	g [kg]	Shadow price original		%	Shadow price	
1	24	6288	€	420,51	8	€	33,64
2	24	6288	€	420,51	38	€	159,79
5	24	6288	€	420,51	31	€	130,36
7	24	6288	€	420,51	8	€	33,64
9	24	6288	€	420,51	4	€	16,82
11	24	6288	€	420,51	22	€	92,51
14	24	6288	€	420,51	22	€	92,51
19	24	6288	€	420,51	19	€	79,90
21	24	6288	€	420,51	25	€	105,13
23	24	6288	€	420,51	8	€	33,64
25	24	6288	€	420,51	17	€	71,49
27	24	6288	€	420,51	19	€	79,90
Totaal		75456	€	5.046,13		**€**	**929,33**

HD400x551					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	112,2	61822,2	€ 4.134,37	80	€ 3.307,49
3	112,2	61822,2	€ 4.134,37	95	€ 3.927,65
Totaal		123644,4	€ 8.268,73		**€ 7.235,14**

HE650AA					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	95,4	13165,2	€ 880,42	168	€ 1.479,11
3	49,6	6844,8	€ 457,75	148	€ 677,47
4	54,5	7521	€ 502,97	148	€ 744,39
6	54,5	7521	€ 502,97	139	€ 699,13
8	54,5	7521	€ 502,97	139	€ 699,13
10	54,5	7521	€ 502,97	148	€ 744,39
12	54,5	7521	€ 502,97	159	€ 799,72
13	54,5	7521	€ 502,97	148	€ 744,39
15	54,5	7521	€ 502,97	190	€ 955,64
16	54,5	7521	€ 502,97	168	€ 844,99
17	54,5	7521	€ 502,97	168	€ 844,99
18	54,5	7521	€ 502,97	168	€ 844,99
19	54,5	7521	€ 502,97	159	€ 799,72
20	54,5	7521	€ 502,97	213	€ 1.071,32
21	54,5	7521	€ 502,97	168	€ 844,99
22	54,5	7521	€ 502,97	251	€ 1.262,45
23	54,5	7521	€ 502,97	148	€ 744,39
24	54,5	7521	€ 502,97	148	€ 744,39
Totaal		140346	€ 9.385,66		**€ 15.545,58**

HEA450					
Level	**Length**	**g [kg]**	**Shadow price original**	**%**	**Shadow price**
2	23,6	3304	€ 220,96	47	€ 103,85
3	23,6	3304	€ 220,96	47	€ 103,85
4	23,6	3304	€ 220,96	47	€ 103,85
5	23,6	3304	€ 220,96	47	€ 103,85
6	23,6	3304	€ 220,96	47	€ 103,85
7	23,6	3304	€ 220,96	47	€ 103,85
8	23,6	3304	€ 220,96	47	€ 103,85
9	23,6	3304	€ 220,96	47	€ 103,85
10	23,6	3304	€ 220,96	47	€ 103,85
11	23,6	3304	€ 220,96	47	€ 103,85
12	23,6	3304	€ 220,96	47	€ 103,85
13	23,6	3304	€ 220,96	47	€ 103,85
15	23,6	3304	€ 220,96	47	€ 103,85
16	23,6	3304	€ 220,96	47	€ 103,85
17	23,6	3304	€ 220,96	47	€ 103,85
18	23,6	3304	€ 220,96	47	€ 103,85
19	23,6	3304	€ 220,96	47	€ 103,85
20	23,6	3304	€ 220,96	47	€ 103,85
21	23,6	3304	€ 220,96	47	€ 103,85
22	23,6	3304	€ 220,96	47	€ 103,85
23	23,6	3304	€ 220,96	47	€ 103,85
24	23,6	3304	€ 220,96	47	€ 103,85
25	23,6	3304	€ 220,96	47	€ 103,85
26	259,6	36344	€ 2.430,51	64	€ 1.555,53
Totaal		112336	€ 7.512,48		**€ 3.944,05**

HEA550					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	23,6	3917,6	€ 261,99	177	€ 463,72
3	23,6	3917,6	€ 261,99	177	€ 463,72
4	23,6	3917,6	€ 261,99	177	€ 463,72
5	23,6	3917,6	€ 261,99	177	€ 463,72
6	23,6	3917,6	€ 261,99	177	€ 463,72
7	23,6	3917,6	€ 261,99	177	€ 463,72
8	23,6	3917,6	€ 261,99	177	€ 463,72
9	23,6	3917,6	€ 261,99	177	€ 463,72
10	23,6	3917,6	€ 261,99	177	€ 463,72
11	23,6	3917,6	€ 261,99	177	€ 463,72
12	23,6	3917,6	€ 261,99	177	€ 463,72
13	23,6	3917,6	€ 261,99	177	€ 463,72
14	23,6	3917,6	€ 261,99	219	€ 573,76
15	23,6	3917,6	€ 261,99	177	€ 463,72
16	23,6	3917,6	€ 261,99	177	€ 463,72
17	23,6	3917,6	€ 261,99	177	€ 463,72
18	23,6	3917,6	€ 261,99	177	€ 463,72
19	23,6	3917,6	€ 261,99	177	€ 463,72
20	23,6	3917,6	€ 261,99	177	€ 463,72
21	23,6	3917,6	€ 261,99	177	€ 463,72
22	23,6	3917,6	€ 261,99	177	€ 463,72
23	23,6	3917,6	€ 261,99	177	€ 463,72
24	23,6	3917,6	€ 261,99	177	€ 463,72
25	23,6	3917,6	€ 261,99	177	€ 463,72
26	23,6	3917,6	€ 261,99	254	€ 665,45
Totaal		97940	€ 6.549,75		**€ 11.904,82**

HEA600					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	126	22428	€ 1.499,88	247	€ 3.704,69
3	126	22428	€ 1.499,88	131	€ 1.964,84
26	281,4	50089,2	€ 3.349,72	247	€ 8.273,81
Totaal		94945,2	€ 6.349,47		**€ 13.943,34**

HEA650					
Level	Length	g [kg]	Shadow price original	%	Shadow price
2	186	35340	€ 2.363,37	138	€ 3.261,45
3	150	28500	€ 1.905,94	182	€ 3.468,81
5	54,5	10355	€ 692,49	115	€ 796,37
7	54,5	10355	€ 692,49	115	€ 796,37
9	54,5	10355	€ 692,49	115	€ 796,37
11	54,5	10355	€ 692,49	122	€ 844,84
27	286,8	54492	€ 3.644,16	324	€ 11.807,08
Totaal		159752	€ 10.683,43		**€ 21.771,27**

HEB450						
Level	Length	g [kg]	Shadow price original		%	Shadow price
14	12,4	2120,4	€	141,80	26	€ 36,87
27	27,6	4719,6	€	315,62	145	€ 457,65
28	273,1	46700,1	€	3.123,07	192	€ 5.996,30
Totaal		53540,1	€	3.580,50		**€ 6.490,83**

HEB600						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
14	281,4	59656,8	€	3.989,56	172	€ 6.862,04
Totaal		59656,8	€	3.989,56		**€ 6.862,04**

HEB650						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	12,4	2790	€	186,58	131	€ 244,42
14	27,6	6210	€	415,29	162	€ 672,78
25	273,1	61447,5	€	4.109,31	146	€ 5.999,59
26	274,1	61672,5	€	4.124,36	154	€ 6.351,51
27	275,1	61897,5	€	4.139,40	178	€ 7.368,14
Totaal		194017,5	€	12.974,94		**€ 20.636,44**

HEB400						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
28	273,1	42330,5	€	2.830,86	132	€ 3.736,73
Totaal		42330,5	€	2.830,86		**€ 3.736,73**

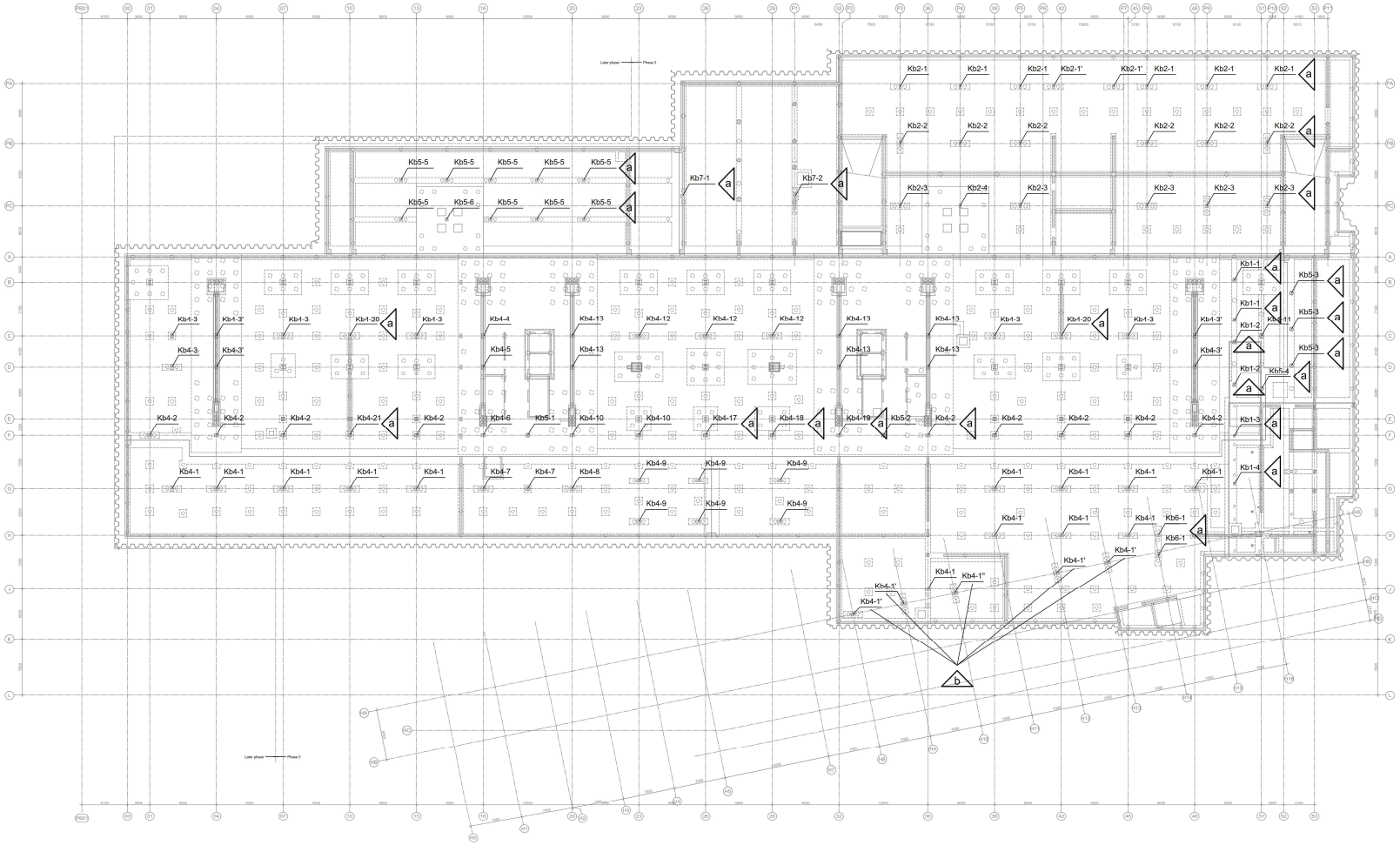
HEA260						
Level	**Length**	**g [kg]**	**Shadow price original**		**%**	**Shadow price**
3	24	1636,8	€	109,46	40	€ 43,78
4	24	1636,8	€	109,46	64	€ 70,06
6	24	1636,8	€	109,46	27	€ 29,55
8	24	1636,8	€	109,46	120	€ 131,35
10	24	1636,8	€	109,46	27	€ 29,55
12	24	1636,8	€	109,46	27	€ 29,55
13	24	1636,8	€	109,46	40	€ 43,78
15	24	1636,8	€	109,46	84	€ 91,95
16	24	1636,8	€	109,46	84	€ 91,95
17	24	1636,8	€	109,46	27	€ 29,55
18	24	1636,8	€	109,46	96	€ 105,08
20	24	1636,8	€	109,46	84	€ 91,95
22	24	1636,8	€	109,46	84	€ 91,95
24	24	1636,8	€	109,46	84	€ 91,95
26	24	1636,8	€	109,46	84	€ 91,95
28	264	18004,8	€	1.204,07	84	€ 1.011,42
Totaal		42556,8	€	2.845,99		**€ 2.075,38**

HE500AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
4	281,4	30109,8	€ 2.013,60	17	€ 342,31
6	281,4	30109,8	€ 2.013,60	41	€ 825,57
8	281,4	30109,8	€ 2.013,60	32	€ 644,35
10	281,4	30109,8	€ 2.013,60	41	€ 825,57
12	281,4	30109,8	€ 2.013,60	32	€ 644,35
16	281,4	30109,8	€ 2.013,60	32	€ 644,35
18	281,4	30109,8	€ 2.013,60	22	€ 442,99
20	281,4	30109,8	€ 2.013,60	41	€ 825,57
22	281,4	30109,8	€ 2.013,60	41	€ 825,57
24	281,4	30109,8	€ 2.013,60	32	€ 644,35
Totaal		301098	€ 20.135,97		**€ 6.665,00**

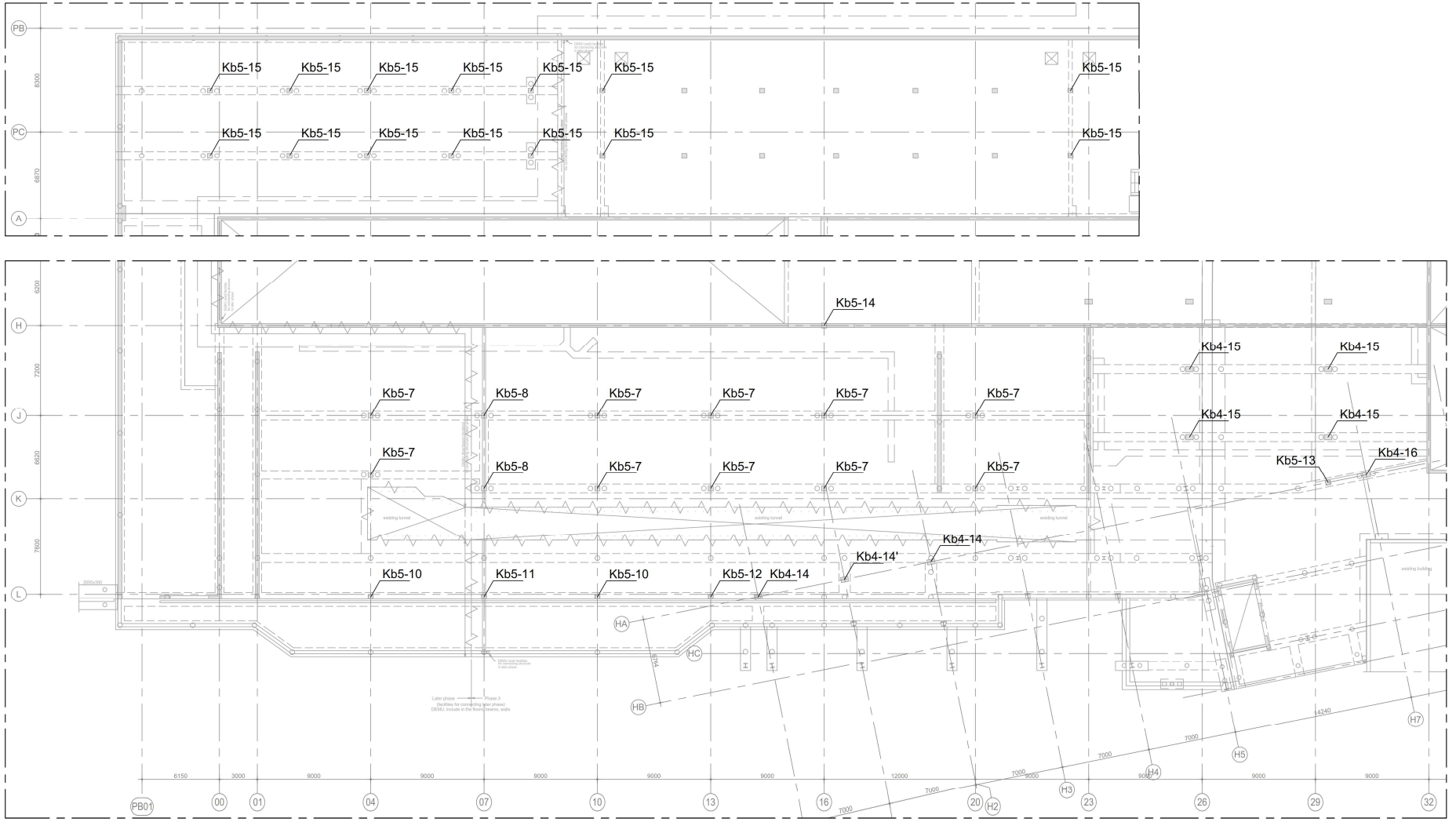
HE550AA					
Level	Length	g [kg]	Shadow price original	%	Shadow price
5	281,4	33768	€ 2.258,24	17	€ 383,90
7	281,4	33768	€ 2.258,24	41	€ 925,88
9	281,4	33768	€ 2.258,24	32	€ 722,64
11	281,4	33768	€ 2.258,24	41	€ 925,88
13	281,4	33768	€ 2.258,24	32	€ 722,64
15	281,4	33768	€ 2.258,24	32	€ 722,64
17	281,4	33768	€ 2.258,24	22	€ 496,81
19	281,4	33768	€ 2.258,24	41	€ 925,88
21	281,4	33768	€ 2.258,24	41	€ 925,88
23	281,4	33768	€ 2.258,24	32	€ 722,64
25	281,4	33768	€ 2.258,24	52	€ 1.174,28
Totaal		371448	€ 24.840,63		**€ 8.649,06**

L. Floorplans

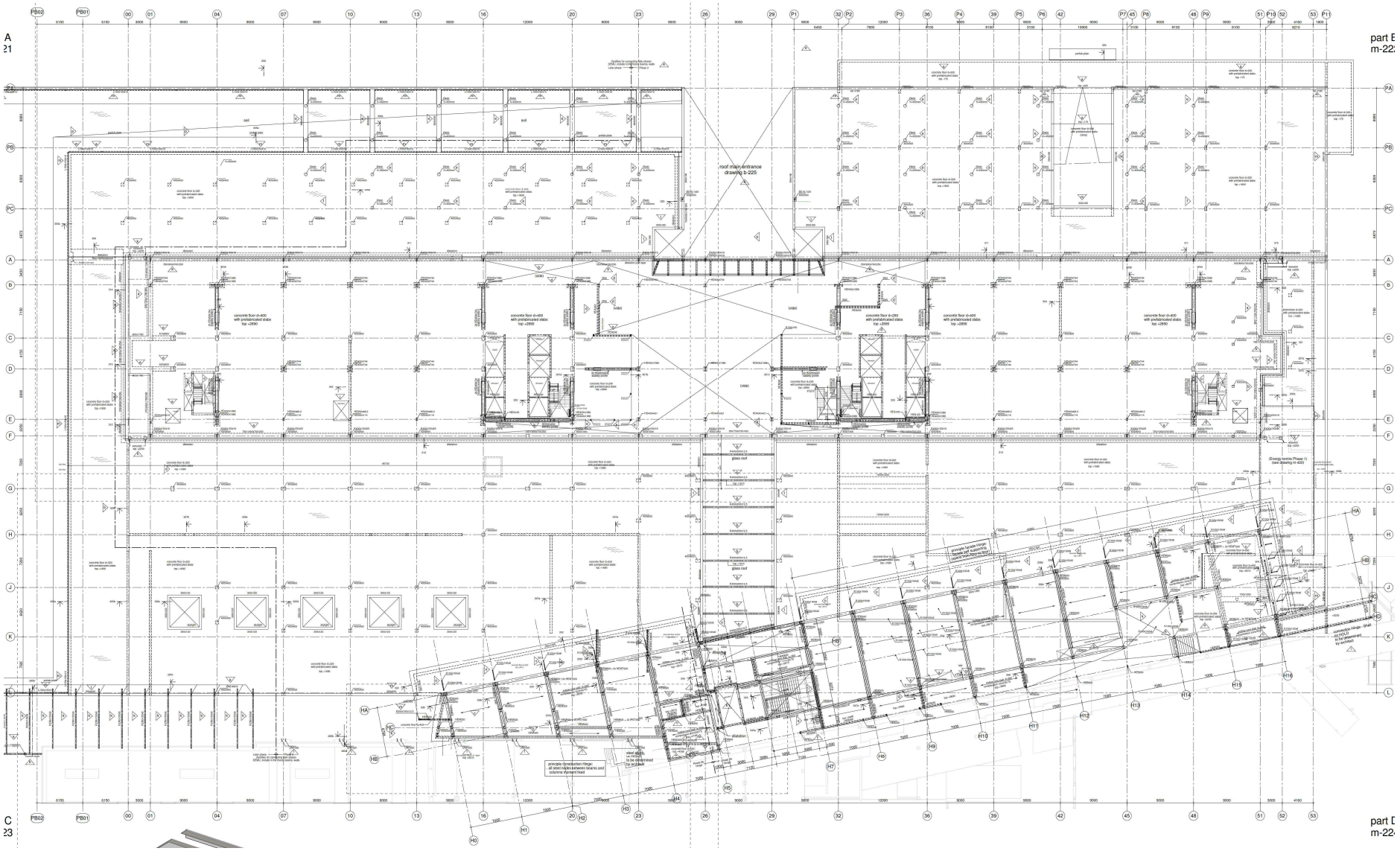
Below all floorplans of the building for the European Patent Office are given. The enlarged versions of these floorplans are presented in a separate document, called “Floorplans of the European Patent Office in Rijswijk, The Netherlands”.



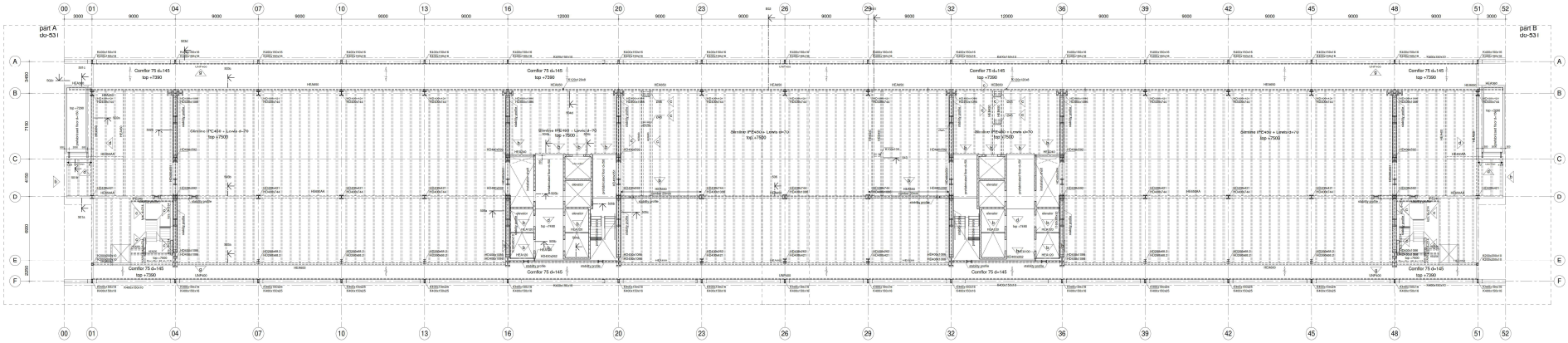
Level -1


Kb5-15
Kb5-14
Kb5-7
Kb5-8
Kb5-10
Kb5-11
Kb5-12
Kb4-14
Kb4-14'
Kb4-15
Kb4-16
Kb5-13
PB
PC
A
H
J
K
L
HA
HB
HC
PB01
00
01
04
07
10
13
16
20
23
26
29
32
H2
H3
H4
H5
H7

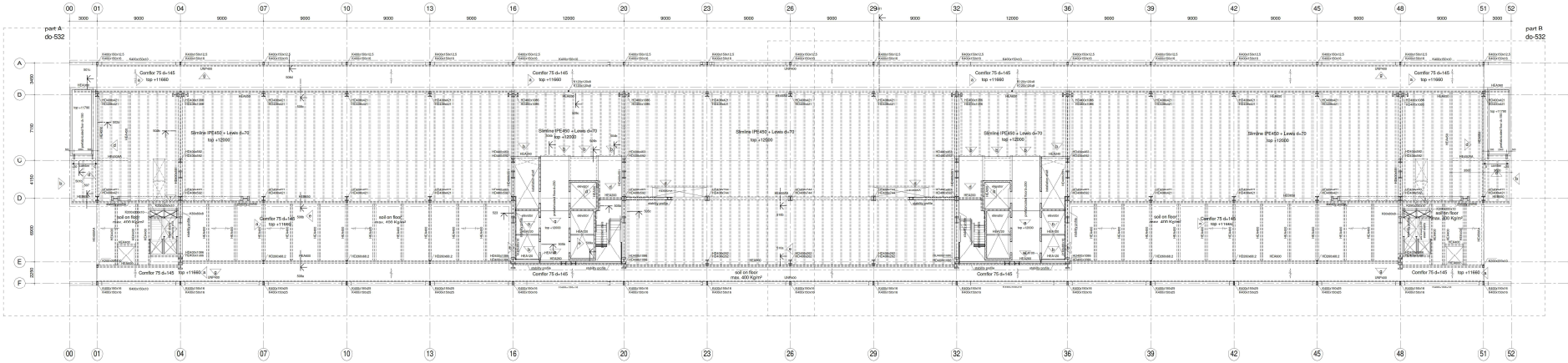
Level 0


roof main entrance
drawing b-225
principle tensile member
principle construction hinge:
all steel nodes between bearing and
columns stronger fixed

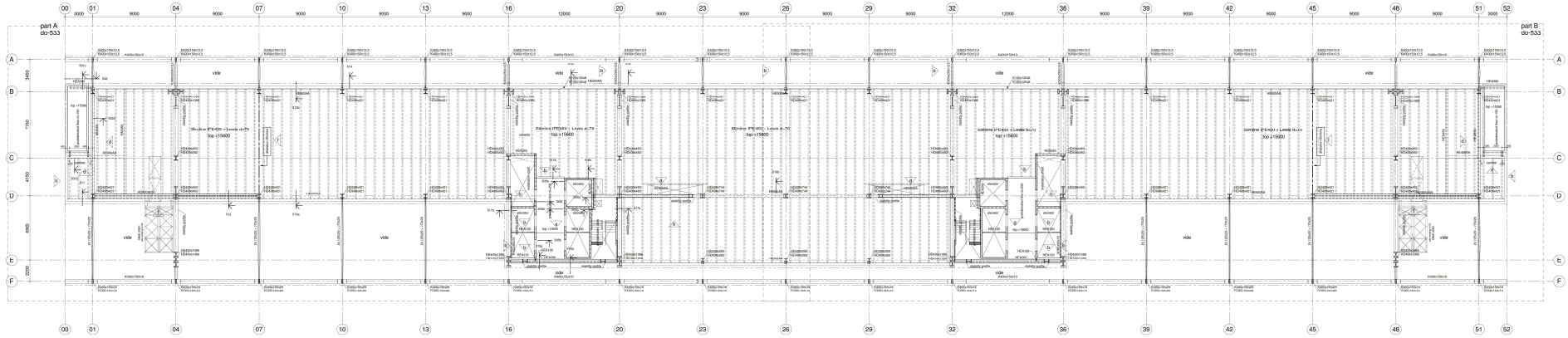
Level 1



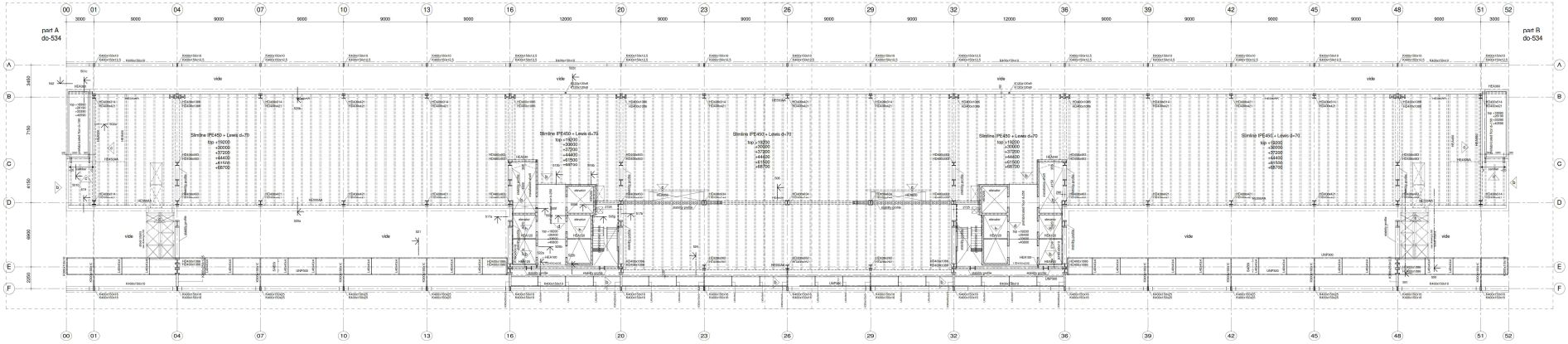
Level 2



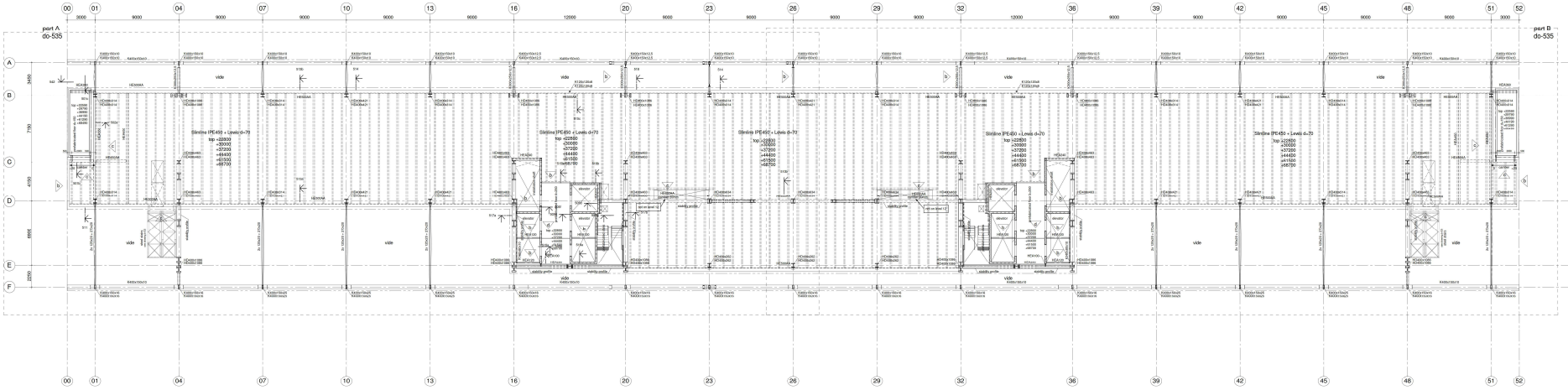
Level 3



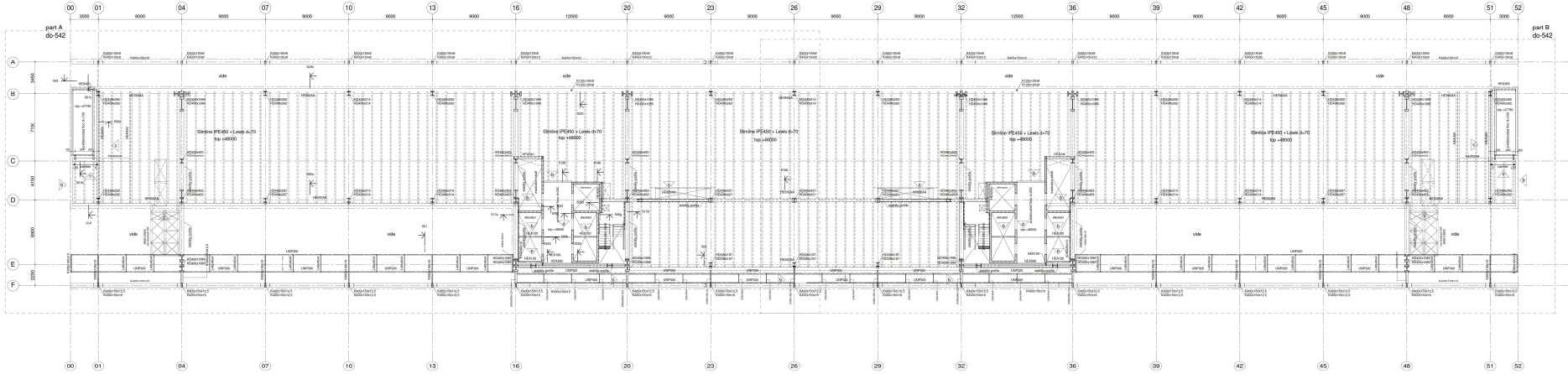
Level 4



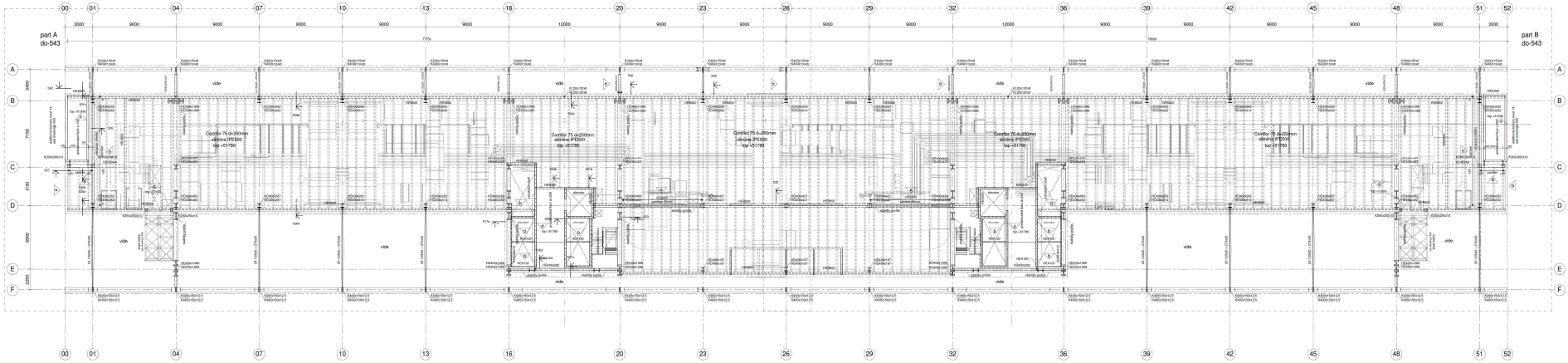
Level 5, 7, 9 and 11



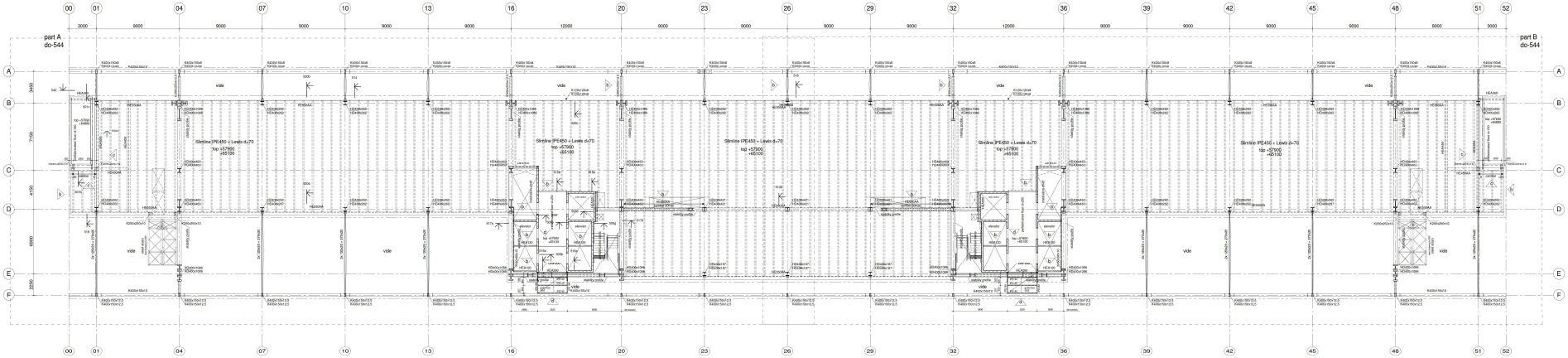
Level 6, 8, 10, 12, 16 and 18



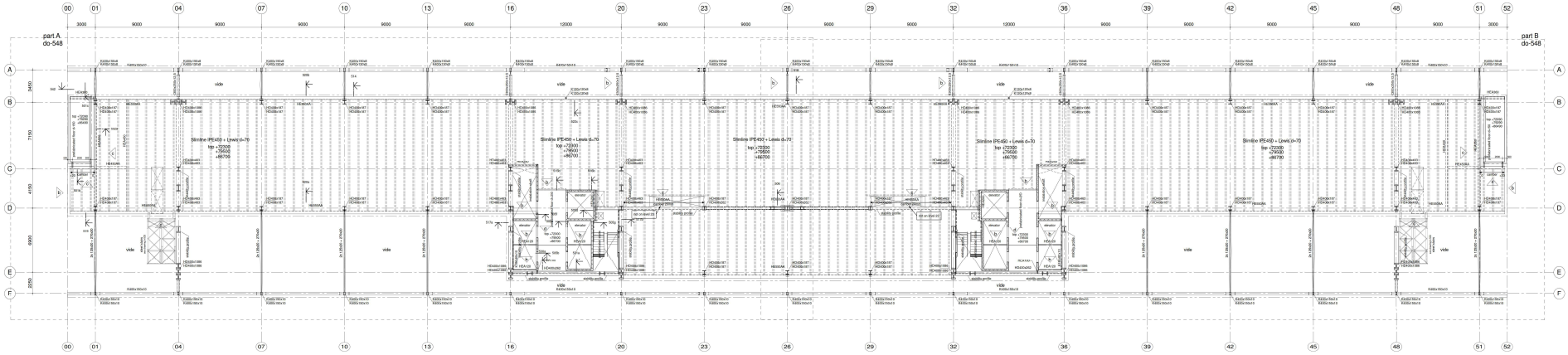
Level 13



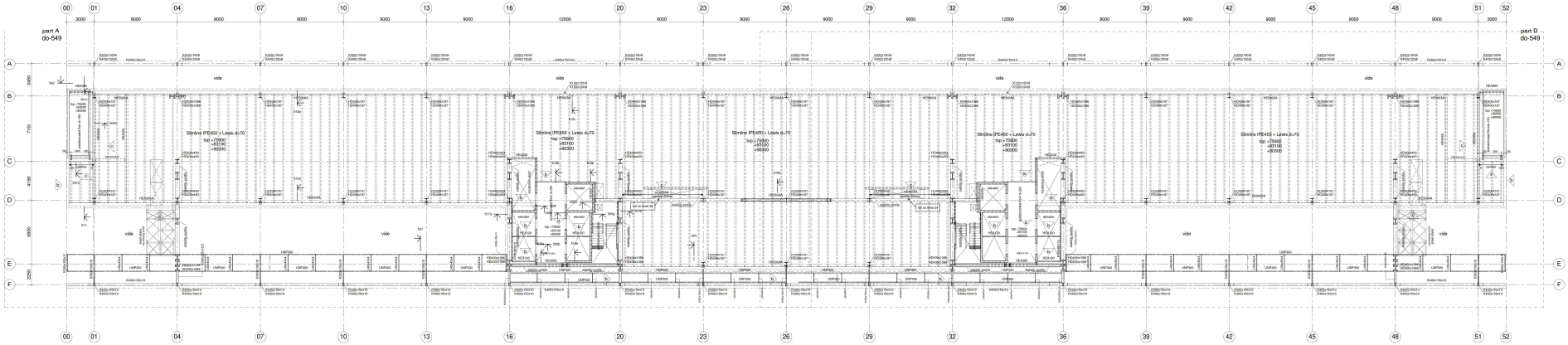
Level 14



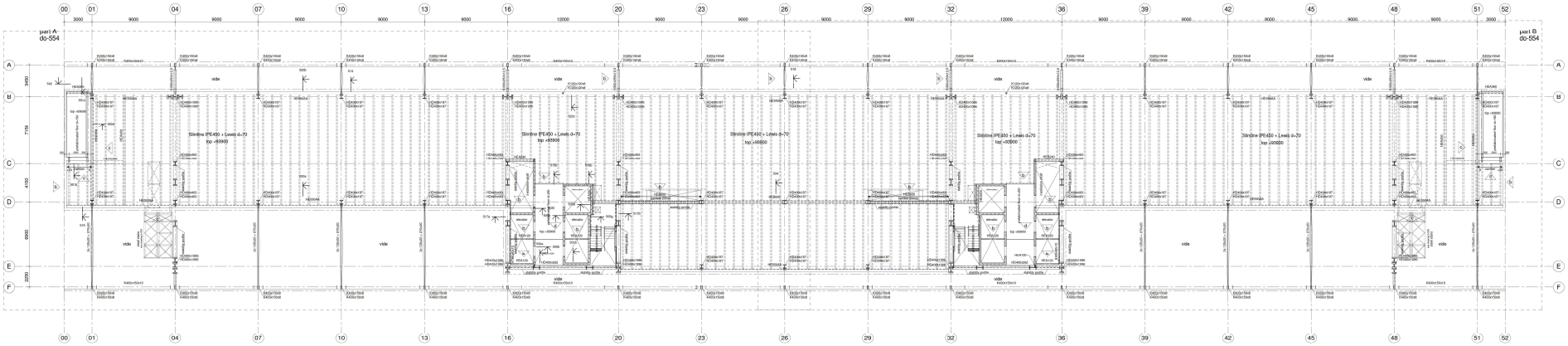
Level 15 and 17



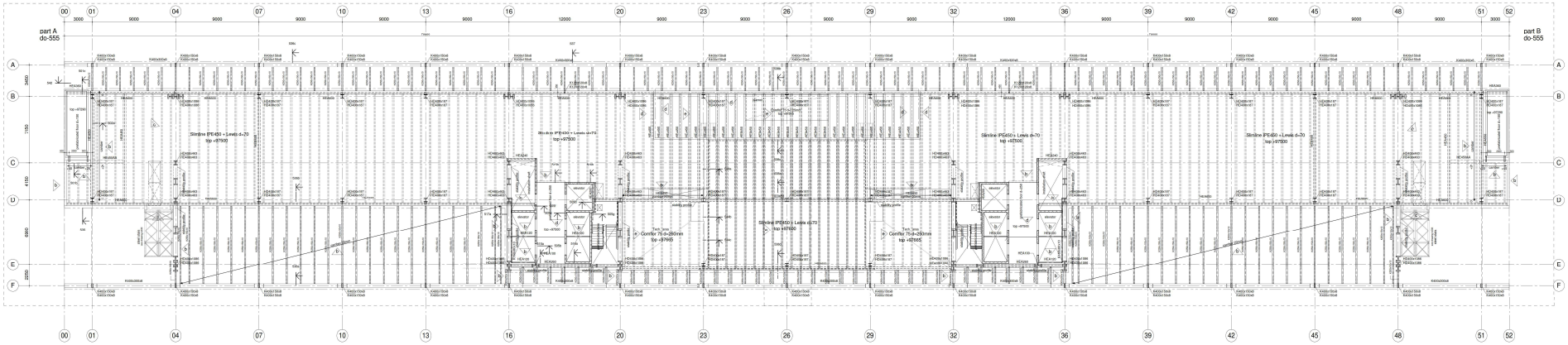
Level 19, 21 and 23



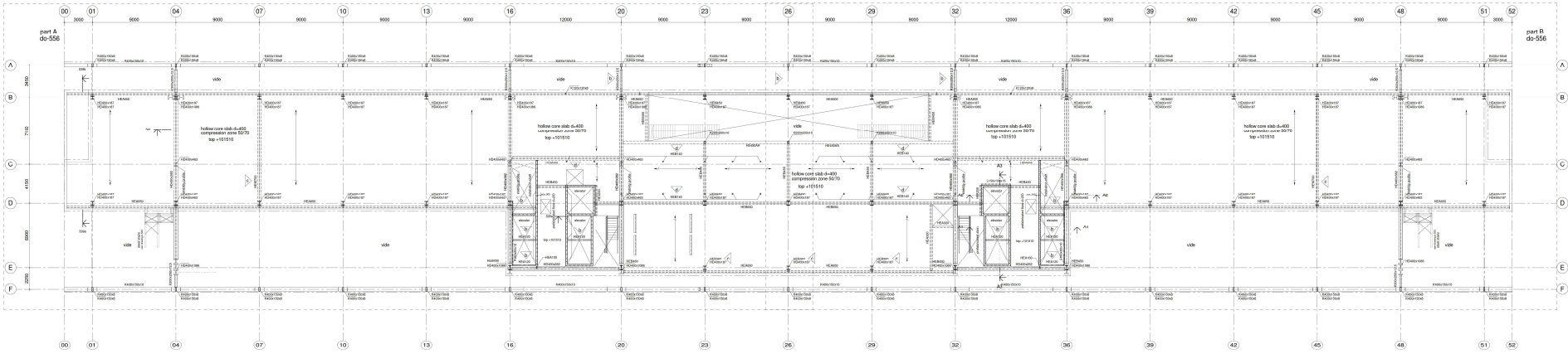
Level 20, 22 and 24



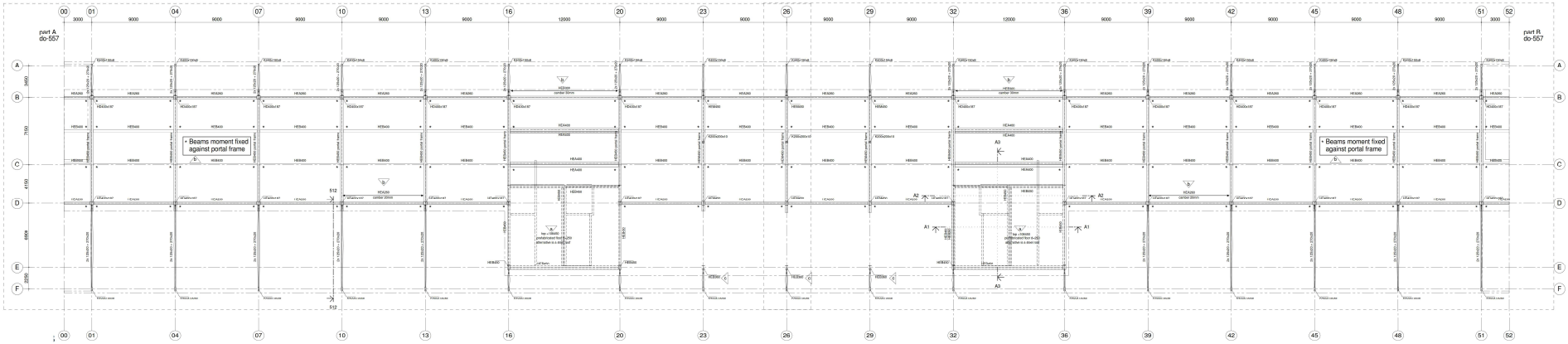
Level 25



Level 26



Level 27



Level 28