REDUCING THE EMBODIED ENVIRONMENTAL IMPACT OF BUILDING STRUCTURES

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ABSTRACT

The building industry's unmistakable share in climate change ensured that many policies have been implemented to reduce its impact. However, most policies cover the operational energy and -emissions of buildings, and not their upfront embodied impacts. Fortunately, wood-based building products proved to be viable alternatives to more conventional materials such as concrete and steel since they have been attributed a lower environmental impact. Thus, they are often regarded as sustainable. However, the sustainability of wood is not absolute. This paper explores just how much more sustainable wood-based structures are compared to their conventional counterparts in terms of their embodied impact. It turns out that a sustainable building starts with compact city design which has a lower energy use per capita. This sustainable urbanism paradigm, in combination with timber building design, yields the lowest environmental impact. Moreover, technical innovation in timber engineering ensured that it is now able to compete with concrete and steel, and the added benefit of timbers versatility vouches for its use. In this paper, Life-cycle-assessment (LCA) is applied to a built case in Rotterdam which illustrates the environmental benefit of multi-storey timber building structures, even in the most unfavorable scenario for the timber variants.

KEYWORDS: *Life-cycle-assessment, Engineered timber, Sustainability, Built environment, Material efficiency*

I. INTRODUCTION

The building sector is responsible for 36% of global energy use and nearly 40% of energy-related CO_2 emissions (UNEP, 2018). Clearly, the built environment has a critical share in anthropogenic climate change. Fortunately, many policies are in place to mitigate the environmental impact. However, most policies focus on capping the operational energy of buildings rather than the embodied energy of building materials. Energy-efficient buildings will reduce energy use and carbon emissions in the long run. But, without a simultaneous focus on embodied energy and carbon, the savings that could be made now are lost. Reductions are needed now and not only in 30 years' time (Pomponi et al., 2018). The most effective strategy for mitigating embodied emissions is to intervene at the material level. Either by using less of the same material or by substituting with alternative materials (Pomponi et al., 2020). Biobased materials such as wood store carbon and proved to be viable alternatives for concrete and steel in terms of their structural application. It is often argued that wood deserves the grade of 'sustainable' more than others. But, as is argued by Hudert & Pfeiffer (2019), the sustainability of wood is not absolute. All-natural wood is hardly ever used in construction. Instead, engineered timber is used which usually relies on plastic adhesives and requires elaborate processing. And although wood is renewable, its availability is not absolute. The aggressive adoption of wood as a construction material raises practical questions about the capacity of forests (Pomponi et al., 2020). Therefore, we should use wood more considerately and efficiently as well. Moreover, global urbanization and demographic growth require 230 billion m^2 of new buildings to be built by 2060 (UNEP, 2018). Continuing to build with energy- and carbon-intensive materials could cause irreversible damage to our environment. How to make the right choice in the midst of many contradicting considerations?

This research aims to find out what it means to build materially efficient, in order to find out what sustainability actually entails. Repeatedly misusing the term will not ensure our continued existence (Zwerger, 2019). In order to do so, this research aims to answer the following question;

How can the structure of multistorey timber buildings be designed when taking material efficiency as a guiding principle?

This question will be answered through the following sub-questions;

- *What constitutes a multistorey timber building and why is it significant?*
- *Which parameters govern the structural design of multistorey timber buildings?*
- *How can material efficiency be quantified and by which criteria is it defined?*
- *Which structural design is more efficient in terms of material use?*

II. METHOD

2.1. General Method

The study comprises a two-phase research design where two strategies are combined in sequence. First, a qualitative literature study is conducted to highlight the significance of timber high rises and the considerations that occur during their design. The literature study aims to answer the first three sub-questions in order to set the framework for the case study. The case study, which comprises the second part of this research, is done through representation and simulation as described by Groat and Wang (2013). It starts with a digital, 3-dimensional representation of the Karel Doorman in Rotterdam. By applying different scenario inputs and generating various alternative representations we can start to speak of simulation (Groat and Wang, 2013). The case study comprises a single building but the method can be called a 'multiple case study'. Several variants of the same building are drafted and compared. The aim is to derive generalizations from the comparative differences. The case study method is described in more detail below.

2.2. Case study method

The aim of the case study is to find out how we can build materially efficient. By replacing the steel-timber hybrid structure of the Karel Doorman with several different materials, and by assessing the variants on the environmental impact, the final sub-question is answered. The boundary conditions of the study are the following: all variants are assessed through life-cycle modules A1-4, or cradle-to-site (See figure 2). In these modules, the largest impact can be made since cradle-to-site accounts for the largest share of environmental impact. This study deals with the vertical loading of the main structure and not the lateral stability. Thus, the concrete cores and steel bracing below the floors are excluded but taken into account qualitatively. The same goes for the transfer structure between the Karel Doorman and the Ter Meulen building. Fire-safety design is mentioned in the literature study but excluded from the case study.

The case study follows a linear structure and goes as follows: 1) All relevant drawings are collected. This includes structural drawings from Royal HaskoningDHV (2010) and architectural drawings from Ibelings van Tilburg Architecten (2010). 2) The drawings are studied and a 3D representation of the building is drafted using Building Information Modelling (BIM), Rhinoceros 7 specifically. 3) A representative fragment is chosen, being the column on grid intersection C1-3a plus two times half a grid size wide and one grid size deep. The fragment accounts for 3,51% of all floors and 2,42% of all beams and columns in the building. 4) The fragment is used to configure the structural calculation, for which the 'Handleiding Ontwerpen Draagconstructies' by Arends (2020) is used. 5) The base fragment is used as a benchmark and the Unity Check values are used to dimension the variants so that every fragment is loaded to the same capacity. The calculation yields the dimensions of the structural members of the variants. 6) These dimensions are then used to model all variants in Rhinoceros 7. The volume of used material is extracted and put into Excel. 7) Using the 3,51% and 2,42% as stated above, it is possible to calculate how much material would have been used in the entire building for each variant through extrapolation. 8) Using the Environmental Product Declarations (EPDs) it is possible to calculate the impact per building variant. 9) All materials need to be transported from the factory to the site. EcoTransIT, which is EN 16258 compliant, is used to calculate the corresponding impact. A scenario is chosen where concrete and steel are produced locally (Rotterdam and IJmuiden), deciduous wood products are produced in Germany, and coniferous wood products in Finland. 10) The final results are normalized whereby the functional unit is set to 'impact per m2 gross floor area (GFA)'.

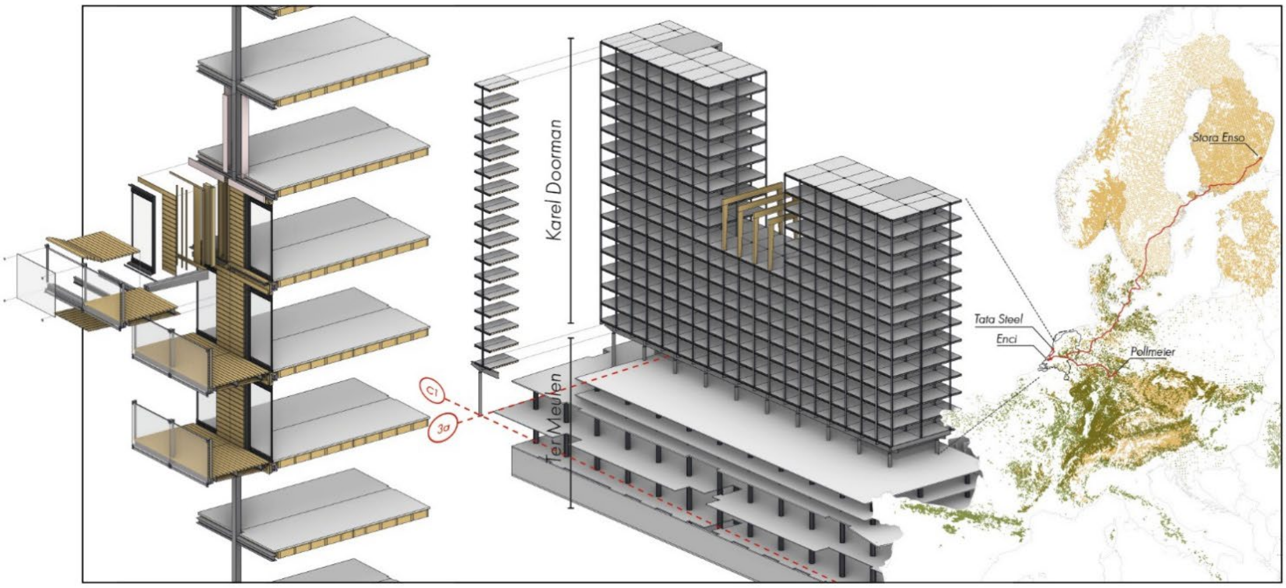

Figure 1. The Karel Doorman and its representative fragment (See also appendix B)

III. RESULTS

3.1. Significance of multi-storey timber buildings

According to Churkina et al., (2020), the following decades will be characterized by economic and demographic growth. The United Nations (2018) project 2.3 billion new urban dwellers by 2050. Consequently, we are facing huge housing and infrastructural challenges in addition to climate change. Moreover, growth and sustainability did not always correspond historically. But in order to solve this seeming paradox, urban planners propose sustainable schemes for development. The preferred paradigm is compact city planning which supposedly secures environmentally sound, economically viable, and socially beneficial development through dense, diverse, and mixed-use urbanism (Bibri, 2020). Compact cities have been attributed a lower energy use per capita (Resch et al., 2016).

In order to define 'multi-storey' in the context of sustainable urbanism it is important to find a link between the number of stories and environmental impact, if such a link exists. Because in theory, every building with more than one storey fits the definition of multi-storey. Resch et al., (2016) investigated how energy use relates to urban density and found that the optimal number of stories is somewhere between 7-27 stories. Reduction of heat exchange between a building and its environment would encourage building taller and wider, increasing overall density. Bohne et al., (2017) researched the link between building height and embodied greenhouse gas emissions and found that the optimal building height ranges between 10-20 stories. Moreover, it was found that using timber significantly reduces embodied emissions.

Wood is one of the few materials that actually sequester and store carbon during its lifetime. And although this process also happens in cementitious materials like concrete, the amount of carbon stored is but a fraction of the carbon emitted during manufacturing (Pomponi et al., 2020). Thus, using bio-based products such as timber is often regarded as the most sustainable solution in construction. However, as mentioned before, environmental impacts can only be mitigated if timber is used considerately as well because the production of engineered timber products requires energy and incurs emissions. Furthermore, the storage of carbon is one of woods' inherent qualities but it should not be misunderstood. The carbon stored in wood will ultimately be returned to the environment when the wood is disposed of either by incineration or natural degradation. If trees are felled and not replaced, timber construction is just an inefficient way to displace carbon in trees into carbon in timber structures (Pomponi et al., 2020).

3.2. Parameters governing design

The design of timber structures in Europe is governed by the European design standard Eurocode 5 (EN 1995-1-1: 2004). The Eurocode program was initiated to establish a set of harmonized technical rules for construction, and would ultimately replace all national rules (CEN, 2004). Structures are designed using Ultimate Limit State (ULS) and Serviceability Limit State (SLS) to maintain structural integrity and user comfort. Both are governed by the strength, stability, and stiffness of the structure. The strength of a beam or column is determined by the to be transferred forces and stresses compared to its material and cross-sectional properties. Stability is relevant for both ULS and SLS and usually manifests itself in deflection. Horizontal loads such as wind cause structures to deflect. Besides deflection, wind loads also cause structures to oscillate with a certain acceleration. This decreases user comfort and can be mitigated through structural stiffness. Furthermore, structures are designed by taking acoustic- and fire performance into account.

This brief description does not do the complexity of structural engineering justice, but it illustrates the key principles that govern design. However, the aforementioned parameters govern all structures and not just the timber ones. This is where the inherent properties of timber come into play.

The resurgence of wood-based products in construction stems from the need to make the sector more sustainable. Consequently, technical developments in timber engineering made sure timber can now compete with steel and concrete in its performance. For example, Cross Laminated Timber (CLT) and Laminated Veneer Lumber (LVL) are products that minimized the inhomogeneity and directional dependency (anisotropy) of the natural product. This allows for the accurate and predictable use of timber in construction (Kaufmann et al., 2018). Timber is also one of the lightest structural materials in terms of density. Combined with its strength, it can compete with steel which is incredibly strong but heavy. Its light weight reduces the size of the foundation and therefore material use in general. However, its relatively light weight can cause vibration which is why it is often combined with concrete. Steel-timber hybrids are also common to increase the stability and stiffness of timber structures. Quite recently, innovations in hardwoods are opening new dimensions in timber construction. Beech for example is much stronger than spruce. When processed, hardwoods do not only compete with steel in terms of strength but now also in slenderness. But what sets timber truly apart from any other material is its versatility (Kaufmann et al., 2018). Timber can also insulate, regulate humidity, and its aesthetic qualities can have measurable positive effects because of biophilia. And contrary to popular belief, timbers' combustible nature actually does not negatively affect fire safety when applied correctly. When wood burns, the charcoal produces a natural layer of insulation that prevents temperature rise in the material within which prevents a loss of strength (Herzog et al., 2004). This can be achieved by slightly over-dimensioning a structural member. Thus, the versatility of timber greatly enhances material efficiency in general because it can fulfill multiple roles at the same time.

3.3. Material efficiency

Material efficiency entails the pursuit of strategies that lead to a substantial reduction in the production of energy-intensive materials whilst delivering human well-being. Achieving material efficiency is motivated by the need to reduce our energy demand, reduce our emissions and environmental impact, and secure resources (Allwood et al., 2013). Allwood et al. (2013) suggests, unless there exists a less CO_2-intensive substitute material, reducing emissions can be met by reducing the requirement for materials. This would mean the following: material efficiency can be attained by substituting conventional materials like steel and concrete with biobased materials and by using less of the same material either way, given the limited availability of any material. The environmental impact of any product or service can be quantified by using Life Cycle Assessment (LCA). In the building industry, EN 15804 and EN 15978 are the established standards to assess the environmental impact of building products and buildings (Gulck et al., 2022). Their international counterparts are ISO 14040 and ISO 14044. LCA's are phased into goal and scope definition, inventory analysis, life cycle impact assessment (LCIA), and interpretation. The inventory analysis lists all the relevant material inputs and their corresponding emissions. Converting the input and emissions into environmental impacts is done in the LCIA. LCIA comprises another four steps: 1) Classification, where all materials are sorted. 2) Characterization, where all materials are multiplied by a factor that represents their environmental impact. 3) Normalisation, where the quantified impact is compared to a certain reference value. 4) Weighting, where the impact categories are assigned a certain degree of importance. The results can generate a single score.

The life cycle of a building can be split into stages and modules as defined by EN 15804. The stages include production, construction, use, end of life, and sometimes benefits beyond the system boundary. According to LETI (2020), low operational energy, medium-scale residential buildings have a distribution of their whole-life carbon (embodied + operational carbon) as follows: 50% of their whole-life carbon is in the embodied carbon of modules A1-3. Another 4% can be attributed to the transport from factory to site. According to LETI (2020), 48% of the embodied carbon from modules A1-3 is in the superstructure of the building. Arguably, the most gain in terms of material efficiency can thus be achieved from Cradle (A1) to Site (A4) and in the superstructure of buildings. This, therefore, corresponds to the boundary conditions of the case study.

The embodied CO_2 equivalent emissions or Global Warming Potential (GWP) is often used as the main impact category in the LCA. The same goes for embodied energy (EE). Although significant, these two are not the only impact categories, however. LCA's also quantify other impacts on the environment such as Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP), and Water Use (WU) among others. The environmental performance of materials is reported in Environmental Product Declarations (EPDs). These are third-party verified, credible, and EN 15804 compliant.

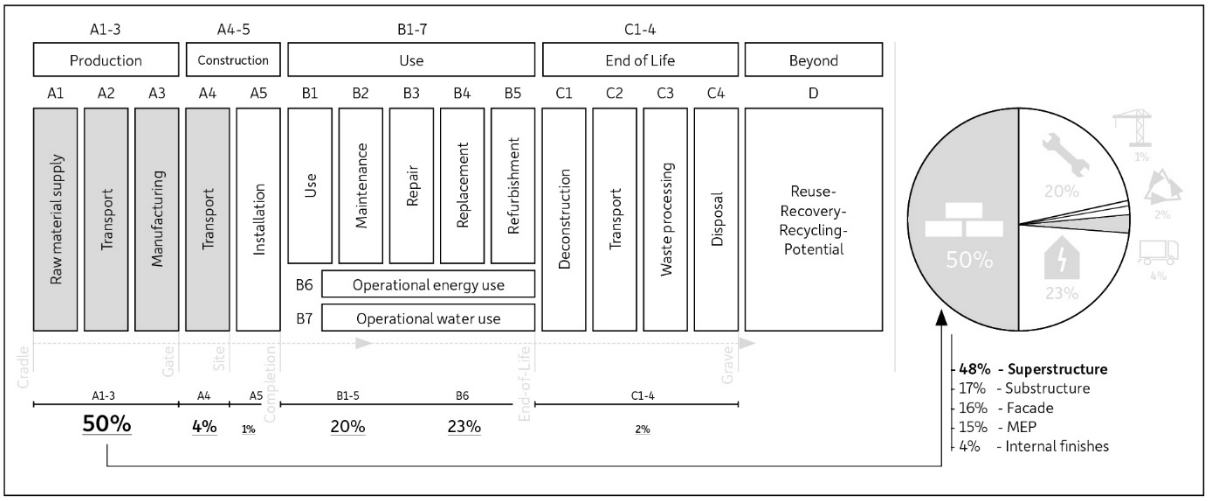

Figure 2. Life-Cycle modules, case-study scope marked in grey, adapted from LETI (2020) and IstructE (2020)

3.4. Case study

The case study deals with the embodied impact of structural variants of the Karel Doorman. This building was chosen because of its structural logic, because it was designed to be as light as possible, and because of the availability of technical drawings. The variants comprise several structural systems that vary from concrete, steel, timber, and hybrids. The matrix in Appendix A shows which combination of vertical and horizontal members forms a variant. Every structural variant is dimensioned to meet the same load criteria as the base fragment which corresponds with the actual building. LCA is applied to compare the environmental impact of each building variant. The first step is to calculate the impact of all variants through life cycle modules A1-3 by using the EPDs. The results are listed in Figure 3.

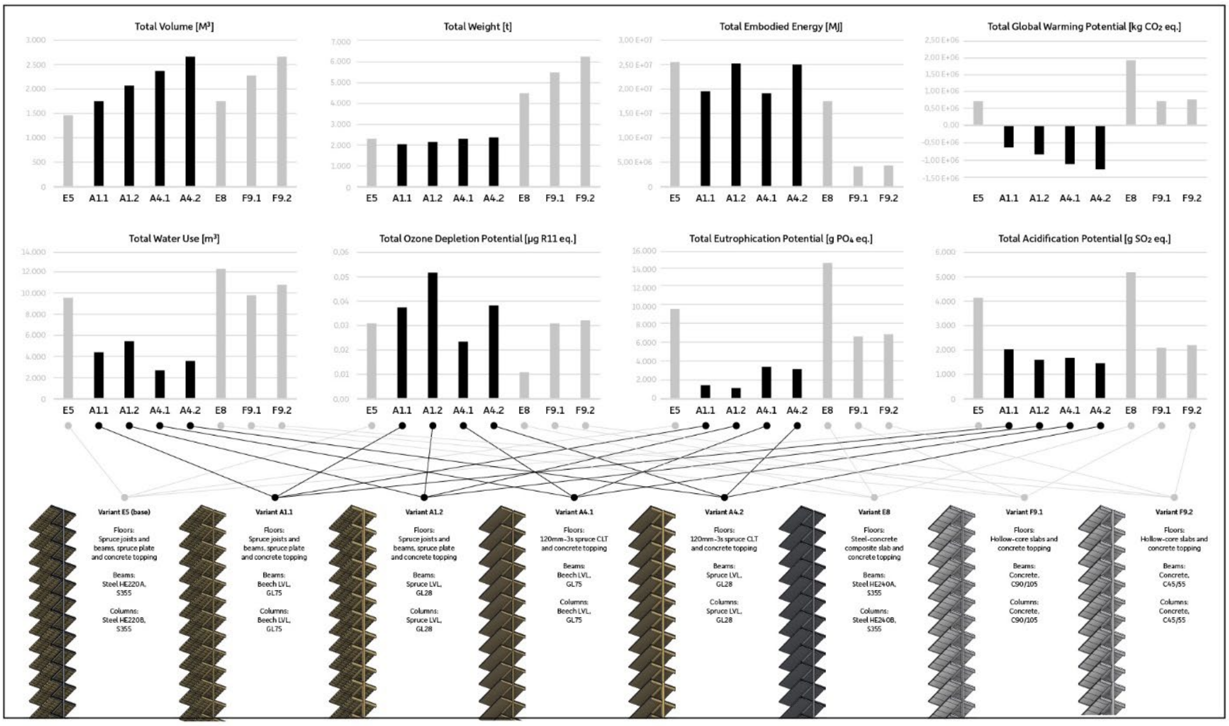

Figure 3. Environmental impact per building variant through module A1-3 (See also appendix C)

The second step is to calculate the environmental impact of the transportation of building materials, module A4. A scenario is chosen that is unfavorable for the timber variants. Softwoods have to be transported from Finland and hardwoods from Germany. This is to see if the timber variants are still the most favourable even if they have to be transported further. This scenario, although unfavorable, is not unusual given the geographical occurrence of these species. Input parameters for the calculation are: 1) Weight to be transported. 2) Starting location. 3) Destination. The calculation is done through EcoTransIT and the results are listed in figure 4. The environmental impact is expressed in different impact categories compared to modules A1-3 which makes it slightly more difficult to add up. Energy use, global warming potential, and sulfur-dioxide emissions do correspond between modules A1-4. Because the impact is related only to the weight and distance, the distribution of impact is the same across all impact categories. The graph below illustrates the ratio between the variants for every impact category, the timber variants are highlighted.

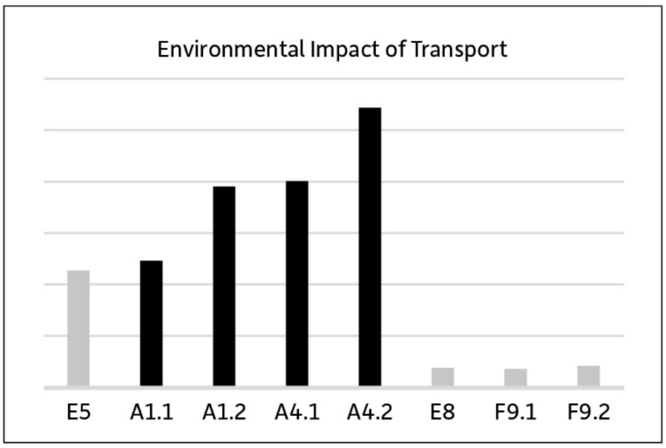

Figure 4. Environmental impact per variant due to transport (module A4)

The corresponding impact categories between A1-3 and A4 are summated to show a total environmental impact per building variant through modules A1-4. The results are normalized by dividing the cumulative impact by the functional unit, the Gross Floor Area (GFA) of the building. The results are listed in Figure 5.

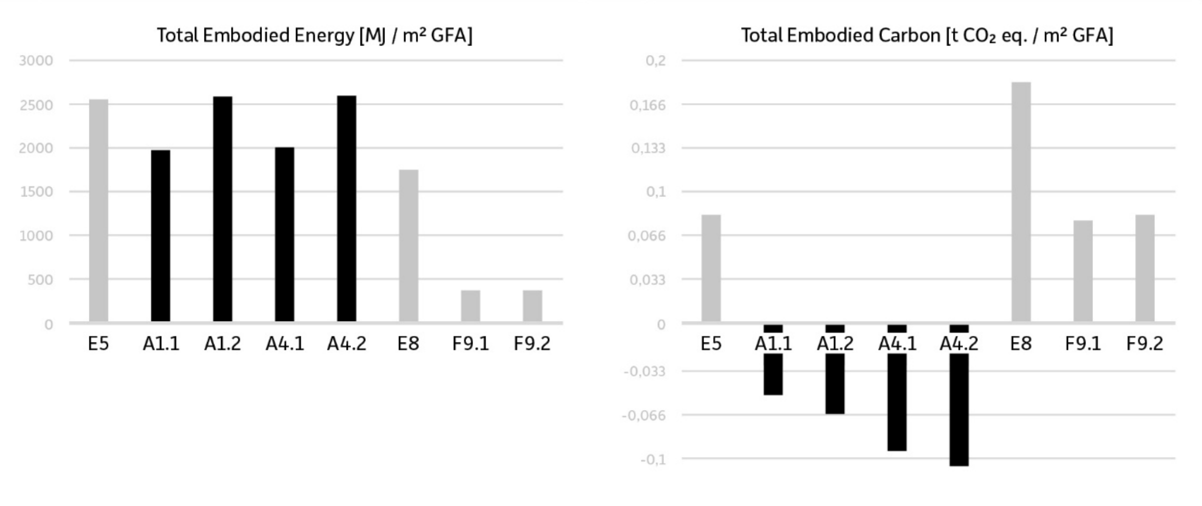

Figure 5. Total impact per variant from cradle-to-gate (module A1-4)

IV. CONCLUSION

4.1. Environmental impact

Compact city planning could provide a sustainable way forward for the challenges of demographic growth and increasing urbanization. Compact cities are attributed to lower energy use and multistorey timber buildings have lower embodied greenhouse gas emissions. The versatility of timber makes it an ideal building material and its structural capabilities can equal concrete and steel. Timbers' relatively low impact and greater efficiency have the potential to mitigate the large share the construction sector has in climate change. But how much more efficient is timber compared to more conventional structures?

As per usual, it is difficult to give an unequivocal and straightforward answer to the question. Material efficiency is not just about using the least amount of material volumetrically but entails the pursuit of a lower environmental impact. However, the environmental impact is expressed through multiple impact categories. So in order to give an absolute answer, the categories should be weighted. But, weighting depends on a value judgement that is made based on policy- scientific or monetary targets. The risk is that weighting factors are chosen to reflect what one wants to see. ISO 14040 and 14044 also specify that weighting should be excluded from comparisons disclosed to the public because the average consumer does not understand the implications of a single score (Meijer, 2014). Nevertheless, several significant statements can be made:

- The timber variants (A1.1 – A4.2) are more efficient in every impact category except for EE and ODP.
- Transportation causes the EE for the timber variants to further rise by approximately 8-11%. Transportation of the timber variants however does not undo their advantage in terms of GWP, they are still much more efficient than the other variants, even in the most unfavorable scenario.
- GWP and EE of transport for base-variant E5 are 10% and 4% respectively, which is comparable to the results that LETI (2020) found.
- Steel, whilst having the lowest volume, has the highest environmental impact across nearly every impact category.

- Generally, SO_2 emissions from life cycle modules A1-3 are marginal compared to similar emissions in module A4.
- The Karel Doorman (E5) was designed to be as light as possible. The timber variants however are almost as light, with variants A1.1 and A1.2 even being lighter. They also have a lower impact in general.
- Manufacturing of engineered timber is more energy intensive than the production of concrete but this can be mitigated by using renewable energy. Production of concrete incurs emissions regardless of the use of renewable energy because of chemical processes.
- Arguably, the most materially efficient way to build is by using hardwoods in the superstructure. Less material is needed but it still stores relatively high amounts of carbon. Sourcing them locally would reduce the impact of transportation and its energy-intensive production could be done using renewables. Sustainable forestry is paramount, however.

4.2. Generalizability

Although the case study dealt with the Karel Doorman specifically, the findings can be generalized. Assessing the embodied impact of the structure of a building through life cycle modules A1-4 probably yields the largest mitigation of embodied impact for any building. This is because the largest share by far corresponds with these modules. The environmental benefits of applying timber compared to steel or concrete are significant, even if the timber has to be transported from further away. And the versatility, which is more difficult to quantify, also vouches for the use of timber. Assessing the comparative differences between variants can be, and already is, applied globally. Comparative LCA is progressively being applied in the design phase.

4.3. Reflection and further research

Generally speaking, LCAs are much more complex than the study carried out here. The applied boundary conditions allowed for this LCA to be executed in a short timeframe. Usually, boundary conditions are much broader than modules A1-4 and encompass the whole building. Furthermore, the probabilistic nature of LCA is not included in this research and the outcomes are single-point estimates. In reality, estimations of embodied impact vary and this case study did not account for the likelihood and variability of any given value. In other words, uncertainty is not included in the study. The author is aware of this and therefore chose not to point out a single variant as the 'absolute best' or most efficient solution because a deterministic assessment has many associated uncertainties (Mendoza Beltran et al., 2018).

LCAs are becoming more standard practice and the body of knowledge on LCA is growing rapidly (Pomponi et al., 2018). But for LCAs to function properly, the EPDs for construction materials are indispensable. Drafting the EPDs takes time, and so does the third-party verification. Thus, the credibility of LCAs depends on the availability of EPDs. To assess innovative products, such as beech LVL, their EPDs are needed. Unfortunately, this was unavailable at the time of the research. The EPD of beech LVL used in the study was approximated by using so-called extrapolation between species, as described by Golsteijn (2014). Thus, the author stresses the importance of elaborate EPD databases so that innovative products can be assessed as soon as they are relevant.

Finally, it should be noted that a structural design is not only dependent on vertical loading but also on fire-safety and lateral stability among others. And environmental impacts depend largely on the building's lifetime for example. Neither was included in the case study. Nevertheless, the study gives insight into the environmental impact of building structures and illustrates how these can be mitigated.

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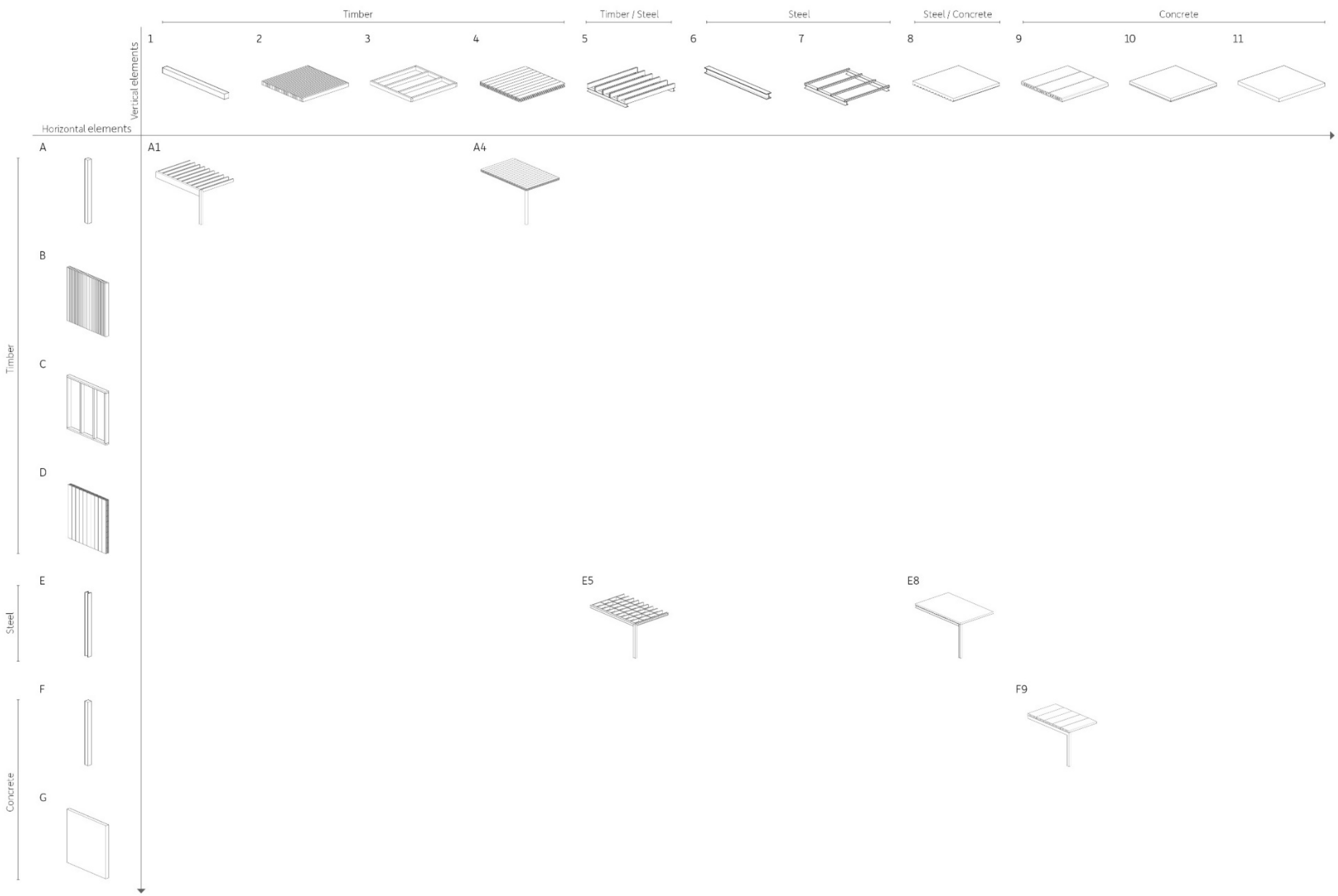
APPENDIX A


Timber
Timber / Steel
Steel
Steel / Concrete
Concrete
Vertical elements
1
2
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11
Horizontal elements
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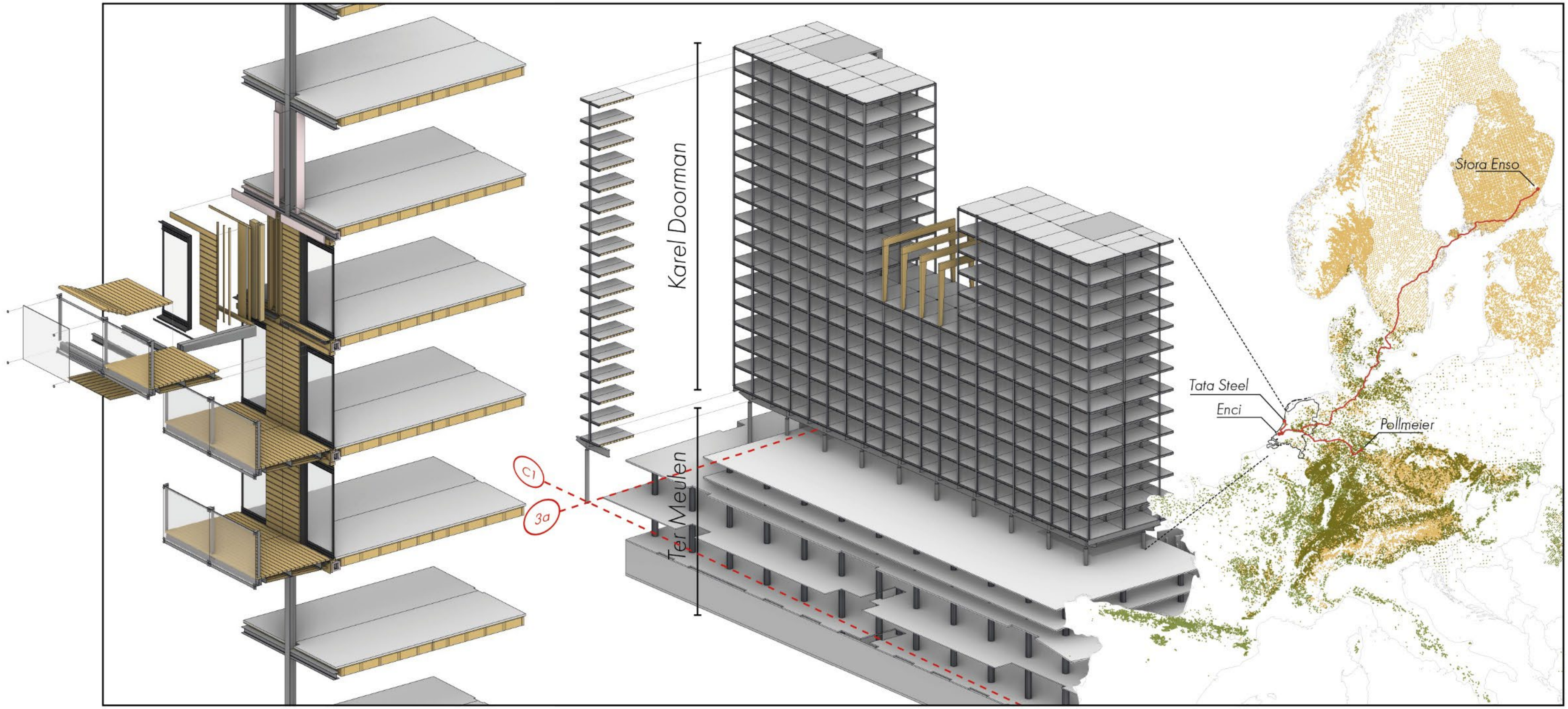
APPENDIX B



Karel Doorman
Ter Meulen
C1
3a
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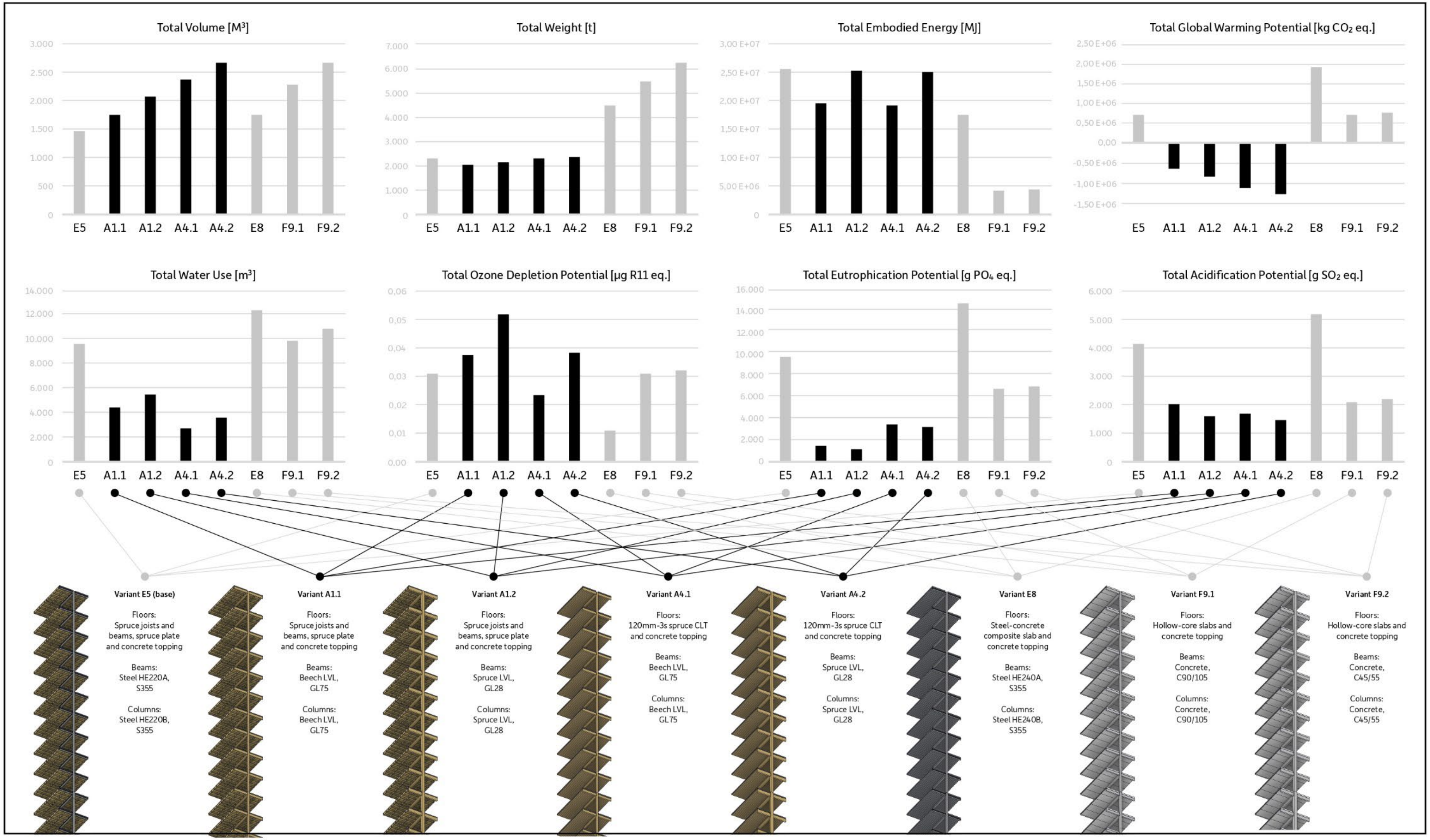
APPENDIX C



Total Volume [M³]
Total Weight [t]
Total Embodied Energy [MJ]
Total Global Warming Potential [kg CO₂ eq.]
Total Water Use [m³]
Total Ozone Depletion Potential [µg R11 eq.]
Total Eutrophication Potential [g PO₄ eq.]
Total Acidification Potential [g SO₂ eq.]
E5 A1.1 A1.2 A4.1 A4.2 E8 F9.1 F9.2
Variant E5 (base)
Floors: Spruce joists and beams, spruce plate and concrete topping
Beams: Steel HE220A, S355
Columns: Steel HE220B, S355
Variant A1.1
Floors: Spruce joists and beams, spruce plate and concrete topping
Beams: Beech LVL, GL75
Columns: Beech LVL, GL75
Variant A1.2
Floors: Spruce joists and beams, spruce plate and concrete topping
Beams: Spruce LVL, GL28
Columns: Spruce LVL, GL28
Variant A4.1
Floors: 120mm-3s spruce CLT and concrete topping
Beams: Beech LVL, GL75
Columns: Beech LVL, GL75
Variant A4.2
Floors: 120mm-3s spruce CLT and concrete topping
Beams: Spruce LVL, GL28
Columns: Spruce LVL, GL28
Variant E8
Floors: Steel-concrete composite slab and concrete topping
Beams: Steel HE240A, S355
Columns: Steel HE240B, S355
Variant F9.1
Floors: Hollow-core slabs and concrete topping
Beams: Concrete, C90/105
Columns: Concrete, C90/105
Variant F9.2
Floors: Hollow-core slabs and concrete topping
Beams: Concrete, C45/55
Columns: Concrete, C45/55

APPENDIX D: CALCULATIONS

Variant E5, Houten vloer, Stalen ligger, Stalen kolom

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	430	2,8	Abc

Bron: [x], [y] en [z]

Dimensioneren vloer
Materiaal: **Hout**

Opbouw:				
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
18mm	Vuren plaat	450kg/m3	7,74kg/m2	0,0774 kN/m2
225mm	Gelam. Houten balklaag	430kg/m3	26,06kg/m2	0,261 kN/m2
	Plafond en Installatie		60kg/m2	0,6 kN/m2
			+	**2,2584** kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**2,26**

Eigenschappen ligger

ligger [mm]	b ligger [m]	dichtheid [kg/]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
210	220	X	0,515	5,15E+05	5,41E+08	S355	355 N/mm2	210000

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Staal** Profiel: **HE220A** Sterkteklasse: **355** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	2,26	=	**8,9609**			
q_{eg}						=	**0,515** +			
								9,4759		**6,93875**

Blijvende belasting = G: **9,4759**
Partiële factor = γ_G: 1,2
= *11,3711*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **21,77921** kN/m

M_d = 1/8 x q_{ugt} x l2 **102,968** kNm
1,03E+08 Nmm

Spanning in Ligger: σ = M_d / W **199,938** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger

ligger [mm]	b ligger [m]	dichtheid [kg/]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
171	180	X	0,362	2,94E+05	2,51E+08	S355	355 N/mm2	210000

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Staal** Profiel: **HE180A** Sterkteklasse: **355** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,362** +			
								10,2745		**0**

Blijvende belasting = G: **10,2745**
Partiële factor = γ_G: 1,2
= *12,3294*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **12,3294** kN/m

M_d = 1/8 x q_{ugt} x l2 **24,22916** kNm
2,42E+07 Nmm

Spanning in Ligger: σ = M_d / W **82,412** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A

h kolom	b kolom	dichtheid	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
200	200	X	0,625	2,00E+05	2,00E+07	S355	355 N/mm2	210000
				(Zwak)	(Zwak)			

Dimensioneren Kolom A
Materiaal: **Staal** Profiel: **HE200B** Sterkteklasse: **355** Oppervlak doorsnede: **7808** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,515	=	**1,583625**						
Kolom gew.	q_k	3,05	x			0,625	=	**1,90625** +						
									39,98398					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,515	=	**1,583625**						
Kolom gew.	q_k	3,05	x			0,625	=	**1,90625** +	31,04464					
Aant. vloer.	n	9	x						**279,4018**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,362	=	**1,43533**						
Aant. vloer.	n	9	x						**12,91797**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **477,71**
Partiële factor = γ_G: 1,2
= *573,252*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1195,84** kN
= *1195844* N

Spanning in Kolom: Totale belasting UGT + Facade = **1498,17** kN
= *1498175* N
σ = **191,8769** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom

h kolom	b kolom	dichtheid	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
220	220	X	0,728	2,58E+05	2,84E+07	S355	355 N/mm2	210000
				(Zwak)	(Zwak)			

Dimensioneren Kolom B
Materiaal: **Staal** Profiel: **HE220B** Sterkteklasse: **355** Oppervlak doorsnede: **9104** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,515	=	**1,583625**						
Kolom gew.	q_k	3,05	x			0,625	=	**1,90625** +						
									39,98398					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,515	=	**1,583625**						
Kolom gew.	q_k	3,05	x			0,625	=	**1,90625** +	31,04464					
Aant. vloer.	n	9	x						**279,4018**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,515	=	**1,583625**						
Kolom gew.	q_k	3,05	x			0,728	=	**2,2204** +	31,35879					
Aant. vloer.	n	6	x						**188,1528**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,362	=	**1,43533**						
Aant. vloer.	n	15	x						**21,52995**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **771,4122**
Partiële factor = γ_G: 1,2
= *925,695*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **2205,41** kN
= *2205415* N

Spanning in Kolom: Totale belasting UGT + Facade = **2689,14** kN
= *2689145* N
σ = **295,3806** N/mm2

U.C. = σ / S **0,83**

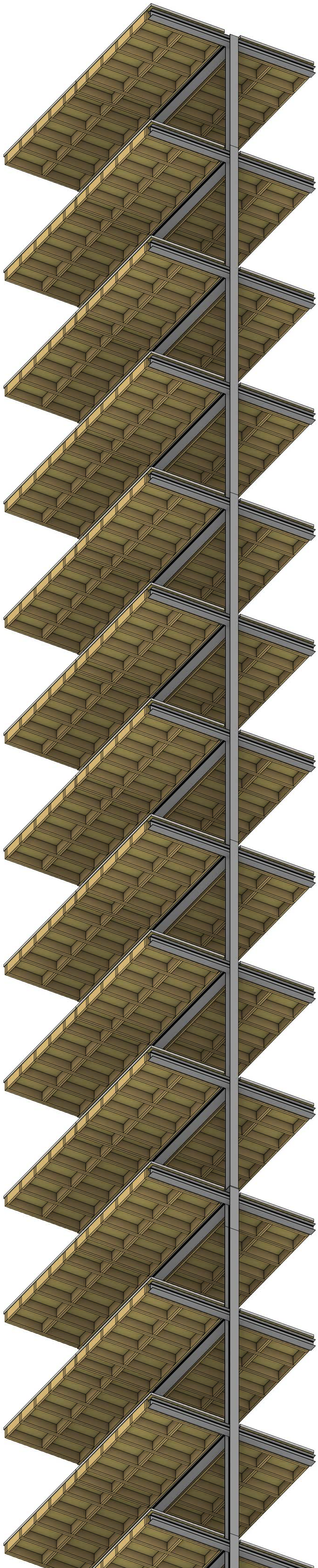
Knik Kolom

$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr} = 6{,}33E+06 \text{ N}$$

(1) U.C.= **0,42**
(5) U.C.= **2,12**
n= 2,36

l= 3050
E= 210000
I_z= 2,84E+07
n2= 9,8696

Boven= 5,89E+13
Onder= 9302500



Variant E5 (base)

Floors:
Spruce joists and beams, spruce plate and concrete topping

Beams:
Steel HE220A, S355

Columns:
Steel HE220B, S355

Variant A1.1, Houten vloer, Houten ligger, Houten kolom (Deciduous)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	430	2,8	Abc

Bron: [x], [y] en [z]

Dimensioneren vloer
Materiaal: **Hout**

Opbouw:				
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
18mm	Vuren plaat	450kg/m3	7,74kg/m2	0,0774 kN/m2
225mm	Gelam. Houten balklaag	430kg/m3	26,06kg/m2	0,261 kN/m2
	Plafond en Installatie		60kg/m2	0,6 kN/m2
			+	**2,2584** kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**2,26**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	380	100	800	0,304	2,41E+06	4,57E+08	GL75	75 N/mm2	16800

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Hout** Profiel: **380x100** Sterkteklasse: **75** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	2,26	=	**8,9609**			
q_{eg}						=	**0,304** +			
								9,2649		**6,93875**

Blijvende belasting = G: **9,2649**
Partiële factor = γ_G: 1,2
= *11,1179*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **21,52601** kN/m

M_d = 1/8 x q_{ugt} x l2 **101,7709** kNm
1,02E+08 Nmm

Spanning in Ligger: σ = M_d / W **42,287** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	290	100	800	0,232	1,40E+06	2,03E+08	GL75	75 N/mm2	16800

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Hout** Profiel: **290x100** Sterkteklasse: **75** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,232** +			
								10,1445		**0**

Blijvende belasting = G: **10,1445**
Partiële factor = γ_G: 1,2
= *12,1734*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **12,1734** kN/m

M_d = 1/8 x q_{ugt} x l2 **23,9226** kNm
2,39E+07 Nmm

Spanning in Ligger: σ = M_d / W **17,067** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	190	190	800	0,2888	1,14E+06	1,09E+08	GL75	75 N/mm2	16800

Dimensioneren Kolom A
Materiaal: **Hout** Profiel: **190x190** Sterkteklasse: **75** Oppervlak doorsnede: **36100** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,304	=	**0,9348**						
Kolom gew.	q_k	3,05	x			0,2888	=	**0,88084** +						
									38,30974					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,304	=	**0,9348**						
Kolom gew.	q_k	3,05	x			0,2888	=	**0,88084** +	29,37041					
Aant. vloer.	n	9	x						**264,3337**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,232	=	**0,91988**						
Aant. vloer.	n	9	x						**8,27892**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **456,3286**
Partiële factor = γ_G: 1,2
= *547,594*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1170,19** kN
= *1170186* N

Spanning in Kolom: Totale belasting UGT + Facade = **1472,52** kN
= *1472517* N
σ = **40,78995** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	206	206	800	0,339488	1,46E+06	1,50E+08	GL75	75 N/mm2	16800

Dimensioneren Kolom B
Materiaal: **Hout** Profiel: **206x206** Sterkteklasse: **75** Oppervlak doorsnede: **42436** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,304	=	**0,9348**						
Kolom gew.	q_k	3,05	x			0,2888	=	**0,88084** +						
									38,30974					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,304	=	**0,9348**						
Kolom gew.	q_k	3,05	x			0,2888	=	**0,88084** +	29,37041					
Aant. vloer.	n	9	x						**264,3337**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,26	=	**27,55477**						
Eig. gew.	q_{eg}	3,075	x			0,304	=	**0,9348**						
Kolom gew.	q_k	3,05	x			0,339488	=	**1,035438** +	29,52501					
Aant. vloer.	n	6	x						**177,15**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,232	=	**0,91988**						
Aant. vloer.	n	15	x						**13,7982**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **735,9354**
Partiële factor = γ_G: 1,2
= *883,122*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **2162,84** kN
= *2162843* N

Spanning in Kolom: Totale belasting UGT + Facade = **2646,57** kN
= *2646573* N
σ = **62,36622** N/mm2

U.C. = σ / S **0,83**

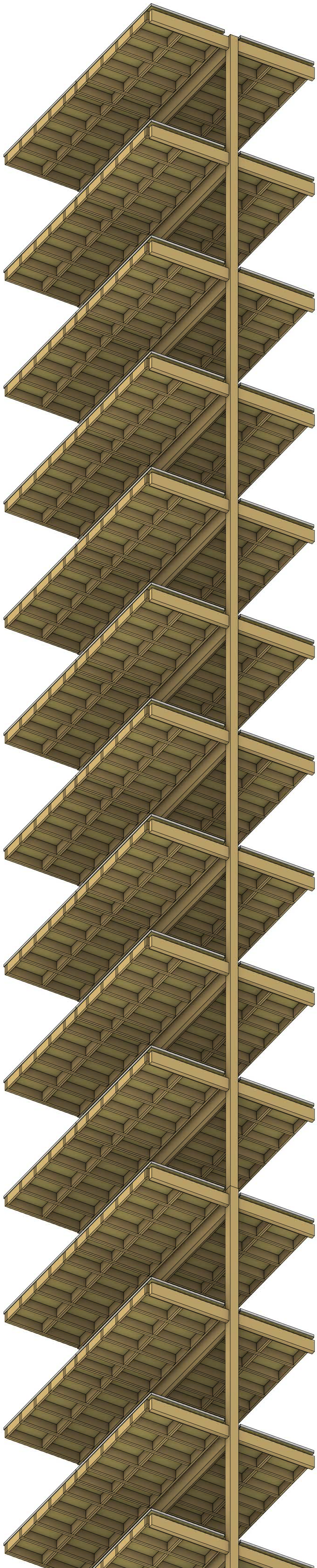
Knik Kolom

$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr}$ = 3,34E+07 N

(1) U.C.= **0,08**
(5) U.C.= **0,40**
n= 12,63

l= 3050
E= 210000
I_z= 1,50E+08
n2= 9,8696

Boven= 3,1E+14
Onder= 9302500



Variant A1.1

Floors:
Spruce joists and beams, spruce plate and concrete topping

Beams:
Beech LVL, GL75

Columns:
Beech LVL, GL75

Variant A1.2, Houten vloer, Houten ligger, Houten kolom (Coniferous)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	430	2,8	Abc

Bron: [x], [y] en [z]

Dimensioneren vloer
Materiaal: **Hout**

Opbouw:				
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
18mm	Vuren plaat	450kg/m3	7,74kg/m2	0,0774 kN/m2
225mm	Gelam. Houten balklaag	430kg/m3	26,06kg/m2	0,261 kN/m2
	Plafond en Installatie		60kg/m2	0,6 kN/m2
			+	**2,2584** kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**2,26**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	500	155	430	0,33325	6,46E+06	1,61E+09	GL28	28 N/mm2	12600

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Hout** Profiel: **500x155** Sterkteklasse: **28** Lengte: **6,150**

	Lengte [m]	Breedte [m]	Last [kN/m2]	Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	3,965	1,75			6,93875	
q_{rb}	1	3,965	2,26	8,9609			
q_{eg}				0,33325 +			
					9,29415		6,93875

Blijvende belasting = G: 9,29415 — Partiële factor = γ_G: 1,2 — = 11,153
Verander. belasting = Q: 6,93875 — Partiële factor = γ_Q: 1,5 — = 10,4081

q_{ugt} — Totale belasting UGT = γ_G x G + γ_Q x Q = F_d 21,56111 kN/m

M_d = 1/8 x q_{ugt} x l2 — 101,9369 kNm; 1,02E+08 Nmm

Spanning in Ligger: σ = M_d / W — 15,784 N/mm2

U.C. = σ / S — **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	400	140	430	0,2408	3,73E+06	7,47E+08	GL28	28 N/mm2	12600

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Hout** Profiel: **400x140** Sterkteklasse: **28** Lengte: **3,965**

	Lengte [m]	Breedte [m]	Last [kN/m2]	Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	3,965	2,5	9,9125			
q_{eg}				0,2408 +			
					10,1533		0

Blijvende belasting = G: 10,1533 — Partiële factor = γ_G: 1,2 — = 12,184
Verander. belasting = Q: 0 — Partiële factor = γ_Q: 1,5 — = 0

q_{ugt} — Totale belasting UGT = γ_G x G + γ_Q x Q = F_d 12,18396 kN/m

M_d = 1/8 x q_{ugt} x l2 — 23,94335 kNm; 2,39E+07 Nmm

Spanning in Ligger: σ = M_d / W — 6,413 N/mm2

U.C. = σ / S — **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	312	312	430	0,418579	5,06E+06	7,90E+08	GL28	28 N/mm2	12600

Dimensioneren Kolom A
Materiaal: **Hout** Profiel: **312x312** Sterkteklasse: **28** Oppervlak doorsnede: **97344** mm2

		Lengte [m]	Breedte [m]	Last [kN/m2]	Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]	Fact. [Y]	Verand. belast. [kN]
Dak									
Opgel. bel.	q_{ob}	3,075	3,965	1			12,19238	0	0
Rust. bel.	q_{rb}	3,075	3,956	3	36,4941				
Eig. gew.	q_{eg}	3,075		0,33325	1,024744				
Kolom gew.	q_k	3,05		0,418579	1,276667 +				
						38,79551			
Vloeren									
Opgel. bel.	q_{ob}	3,075	3,965	1,75			21,33666	1	21,33666
Rust. bel.	q_{rb}	3,075	3,965	2,26	27,55477				
Eig. gew.	q_{eg}	3,075		0,33325	1,024744				
Kolom gew.	q_k	3,05		0,418579	1,276667 +				
						29,85618			
Aant. vloer.	n	9				268,7056			192,0299
Loggia									
Opgel. bel.	q_{ob}	2,5	3,965	2,5			24,78125	1	24,78125
Rust. bel.	q_{rb}	2,5	3,965	1,5	14,86875				
Eig. gew.	q_{eg}	2,5		0,515	1,2875 +				
						16,15625			
Aant. vloer.	n	9				145,4063			223,0313
Sec. liggers									
Eig. gew.	q_{eg}	3,965		0,2408	0,954772				
Aant. vloer.	n	9				8,592948			
Facade									
Eig. gew.	q_{eg}	30,5	3,965	2,5		302,3313			

Totaal [kN]
Blijvende belasting = G: 461,5003 — Partiële factor = γ_G: 1,2 — = 553,8
Verander. belasting = Q: 415,0612 — Partiële factor = γ_Q: 1,5 — = 622,592

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d 1176,39 kN = 1176392 N

Spanning in Kolom: Totale belasting UGT + Facade = 1478,72 kN = 1478723 N; σ = 15,1907 N/mm2

U.C. = σ / S — **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	338	338	430	0,491249	6,44E+06	1,09E+09	GL28	28 N/mm2	12600

Dimensioneren Kolom B
Materiaal: **Hout** Profiel: **338x338** Sterkteklasse: **28** Oppervlak doorsnede: **114244** mm2

		Lengte [m]	Breedte [m]	Last [kN/m2]	Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]	Fact. [Y]	Verand. belast. [kN]
Dak									
Opgel. bel.	q_{ob}	3,075	3,965	1			12,19238	0	0
Rust. bel.	q_{rb}	3,075	3,956	3	36,4941				
Eig. gew.	q_{eg}	3,075		0,33325	1,024744				
Kolom gew.	q_k	3,05		0,418579	1,276667 +				
						38,79551			
Vloeren A									
Opgel. bel.	q_{ob}	3,075	3,965	1,75			21,33666	1	21,33666
Rust. bel.	q_{rb}	3,075	3,965	2,26	27,55477				
Eig. gew.	q_{eg}	3,075		0,33325	1,024744				
Kolom gew.	q_k	3,05		0,418579	1,276667 +				
						29,85618			
Aant. vloer.	n	9				268,7056			192,0299
Vloeren B									
Opgel. bel.	q_{ob}	3,075	3,965	3,956			48,23304	1	48,23304
Rust. bel.	q_{rb}	3,075	3,965	2,26	27,55477				
Eig. gew.	q_{eg}	3,075		0,33325	1,024744				
Kolom gew.	q_k	3,05		0,491249	1,49831 +				
						30,07782			
Aant. vloer.	n	6				180,4669			289,3982
Loggia									
Opgel. bel.	q_{ob}	2,5	3,965	2,5			24,78125	1	24,78125
Rust. bel.	q_{rb}	2,5	3,965	1,5	14,86875				
Eig. gew.	q_{eg}	2,5		0,515	1,2875 +				
						16,15625			
Aant. vloer.	n	15				242,3438			371,7188
Sec. liggers									
Eig. gew.	q_{eg}	3,965		0,2408	0,954772				
Aant. vloer.	n	15				14,32158			
Facade									
Eig. gew.	q_{eg}	48,8	3,965	2,5		483,73			

Totaal [kN]
Blijvende belasting = G: 744,6334 — Partiële factor = γ_G: 1,2 — = 893,56
Verander. belasting = Q: 853,1469 — Partiële factor = γ_Q: 1,5 — = 1279,72

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d 2173,28 kN = 2173280 N

Spanning in Kolom: Totale belasting UGT + Facade = 2657,01 kN = 2657010 N; σ = 23,25733 N/mm2

U.C. = σ / S — **0,83**

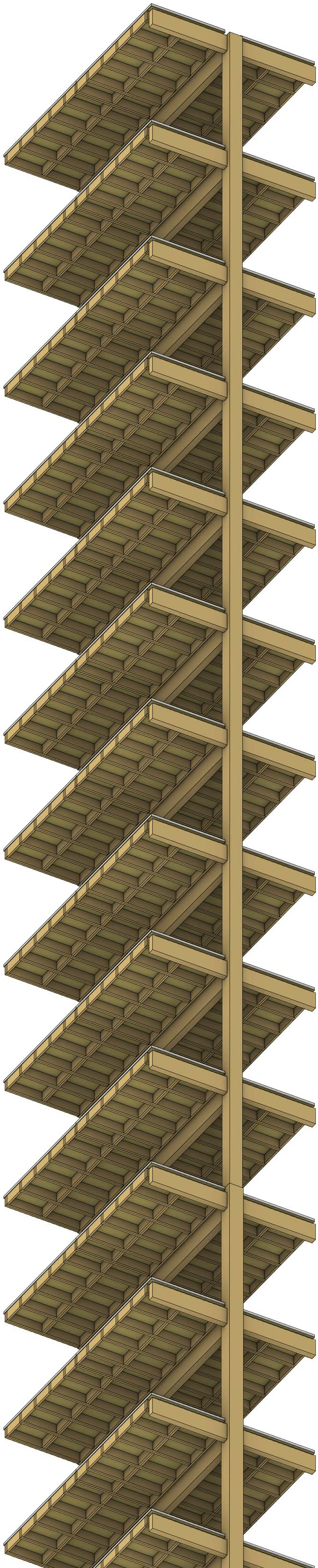
Knik Kolom

$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2_{cr}} = 2{,}42E+08\ N$$

(1) U.C.= 0,01
(5) U.C.= 0,05
n= 91,20

l= 3050
E= 210000
I_z= 1,09E+09
n2= 9,8696

Boven= 2,3E+15
Onder= 9302500



Variant A1.2

Floors:
Spruce joists and beams, spruce plate and concrete topping

Beams:
Spruce LVL, GL28

Columns:
Spruce LVL, GL28

Variant A4.1, CLT vloer, Houten ligger, Houten kolom (Deciduous)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	X	X	Martinsons

Bron: [1]

Dimensioneren vloer
Materiaal: **Hout (CLT)**

Opbouw:				
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
120-3s 120mm	CLT		48kg/m2	0,48
	Plafond en Installatie		60kg/m2	0,6 kN/m2
			+	**2,4** kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{rb}	3,965	1,75	X	**2,4**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	388	100	800	0,3104	2,51E+06	4,87E+08	GL75	75 N/mm2	16800

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Hout** Profiel: **388x100** Sterkteklasse: **75** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	2,4	=	**9,516**			
q_{eg}						=	**0,3104** +			
								9,8264		**6,93875**

Blijvende belasting = G: **9,8264**
Partiële factor = Y_G: 1,2
= *11,7917*

Verander. belasting = Q: **6,93875**
Partiële factor = Y_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = Y_G x G + Y_Q x Q = F_d **22,19981** kN/m

M_d = 1/8 x q_{ugt} x l2 **104,9565** kNm
1,05E+08 Nmm

Spanning in Ligger: σ = M_d / W **41,831** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	290	100	800	0,232	1,40E+06	2,03E+08	GL75	75 N/mm2	16800

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Hout** Profiel: **290x100** Sterkteklasse: **75** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,232** +			
								10,1445		**0**

Blijvende belasting = G: **10,1445**
Partiële factor = Y_G: 1,2
= *12,1734*

Verander. belasting = Q: **0**
Partiële factor = Y_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = Y_G x G + Y_Q x Q = F_d **12,1734** kN/m

M_d = 1/8 x q_{ugt} x l2 **23,9226** kNm
2,39E+07 Nmm

Spanning in Ligger: σ = M_d / W **17,067** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	192	192	800	0,294912	1,18E+06	1,13E+08	GL75	75 N/mm2	16800

Dimensioneren Kolom A
Materiaal: **Hout** Profiel: **192x192** Sterkteklasse: **75** Oppervlak doorsnede: **36864** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,3104	=	**0,95448**						
Kolom gew.	q_k	3,05	x			0,294912	=	**0,899482** +						
									38,34806					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,3104	=	**0,95448**						
Kolom gew.	q_k	3,05	x			0,294912	=	**0,899482** +						
									31,11566					
Aant. vloer.	n	9	x						**280,041**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +						
									16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,232	=	**0,91988**						
Aant. vloer.	n	9	x						**8,27892**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **472,0742**
Partiële factor = Y_G: 1,2
= *566,489*

Verander. belasting = Q: **415,0612**
Partiële factor = Y_Q: 1,5
= *622,592*

Totale belasting UGT = Y_G x G + Y_Q x Q = F_d **1189,08** kN
= *1189081* N

Spanning in Kolom: Totale belasting UGT + Facade = **1491,41** kN
= *1491412* N
σ = **40,45714** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	208	208	800	0,346112	1,50E+06	1,56E+08	GL75	75 N/mm2	16800

Dimensioneren Kolom B
Materiaal: **Hout** Profiel: **208x208** Sterkteklasse: **75** Oppervlak doorsnede: **43264** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,3104	=	**0,95448**						
Kolom gew.	q_k	3,05	x			0,294912	=	**0,899482** +						
									38,34806					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,3104	=	**0,95448**						
Kolom gew.	q_k	3,05	x			0,294912	=	**0,899482** +						
									31,11566					
Aant. vloer.	n	9	x						**280,041**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,3104	=	**0,95448**						
Kolom gew.	q_k	3,05	x			0,346112	=	**1,055642** +						
									31,27182					
Aant. vloer.	n	6	x						**187,6309**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +						
									16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,232	=	**0,91988**						
Aant. vloer.	n	15	x						**13,7982**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **762,1619**
Partiële factor = Y_G: 1,2
= *914,594*

Verander. belasting = Q: **853,1469**
Partiële factor = Y_Q: 1,5
= *1279,72*

Totale belasting UGT = Y_G x G + Y_Q x Q = F_d **2194,31** kN
= *2194315* N

Spanning in Kolom: Totale belasting UGT + Facade = **2678,04** kN
= *2678045* N
σ = **61,90007** N/mm2

U.C. = σ / S **0,83**

Knik Kolom

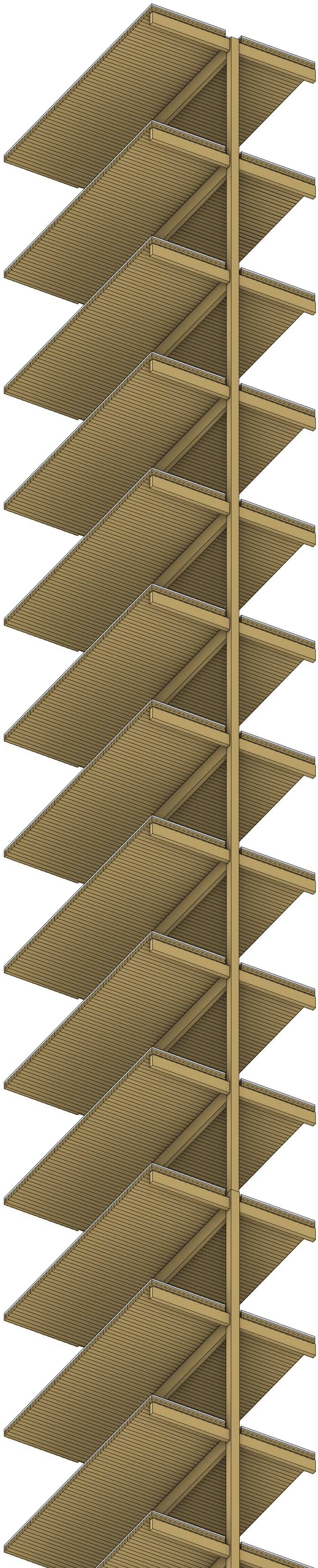
$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr} = 3{,}48E{+}07 \text{ N}$$

(1) U.C.= **0,08**
(5) U.C.= **0,39**
n= 12,98

l= *3050*
E= *210000*
I_z= *1,56E+08*
n2= *9,8696*

Boven= *3,2E+14*
Onder= *9302500*

[1] http://solidtimber.nl/wp-content/uploads/2019/09/Overspanningstabel-CLT-2017-04-28.pdf

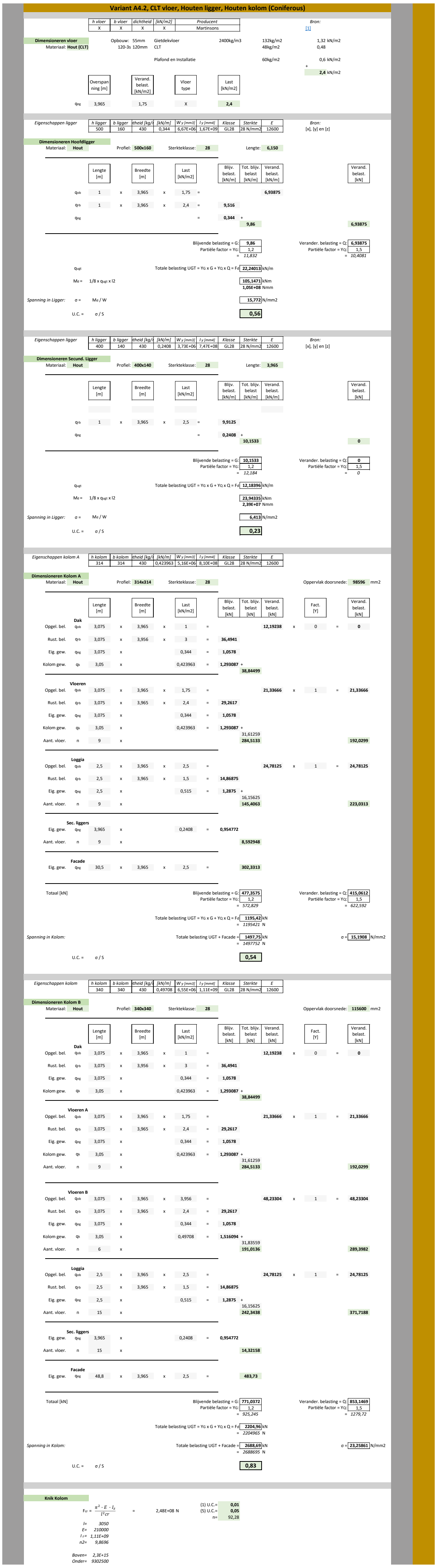


Variant A4.1

Floors:
120mm-3s spruce CLT and concrete topping

Beams:
Beech LVL, GL75

Columns:
Beech LVL, GL75



Variant A4.2, CLT vloer, Houten ligger, Houten kolom (Coniferous)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	X	X	Martinsons

Bron: [1]

Dimensioneren vloer
Materiaal: **Hout (CLT)**

Opbouw:	55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
120-3s	120mm	CLT		48kg/m2	0,48
		Plafond en Installatie		60kg/m2	0,6 kN/m2 +
					2,4 kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**2,4**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W y [mm3]	I y [mm4]	Klasse	Sterkte	E
	500	160	430	0,344	6,67E+06	1,67E+09	GL28	28 N/mm2	12600

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Hout** Profiel: **500x160** Sterkteklasse: **28** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	2,4	=	**9,516**			
q_{eg}						=	**0,344** +			
								9,86		**6,93875**

Blijvende belasting = G: **9,86**
Partiële factor = γ_G: 1,2
= *11,832*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **22,24013** kN/m

M_d = 1/8 x q_{ugt} x l2 **105,1471** kNm
1,05E+08 Nmm

Spanning in Ligger: σ = M_d / W **15,772** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W y [mm3]	I y [mm4]	Klasse	Sterkte	E
	400	140	430	0,2408	3,73E+06	7,47E+08	GL28	28 N/mm2	12600

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Hout** Profiel: **400x140** Sterkteklasse: **28** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,2408** +			
								10,1533		**0**

Blijvende belasting = G: **10,1533**
Partiële factor = γ_G: 1,2
= *12,184*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **12,18396** kN/m

M_d = 1/8 x q_{ugt} x l2 **23,94335** kNm
2,39E+07 Nmm

Spanning in Ligger: σ = M_d / W **6,413** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W y [mm3]	I y [mm4]	Klasse	Sterkte	E
	314	314	430	0,423963	5,16E+06	8,10E+08	GL28	28 N/mm2	12600

Dimensioneren Kolom A
Materiaal: **Hout** Profiel: **314x314** Sterkteklasse: **28** Oppervlak doorsnede: **98596** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,344	=	**1,0578**						
Kolom gew.	q_k	3,05	x			0,423963	=	**1,293087** +	**38,84499**					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,344	=	**1,0578**						
Kolom gew.	q_k	3,05	x			0,423963	=	**1,293087** +	31,61259					
Aant. vloer.	n	9	x						**284,5133**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,2408	=	**0,954772**						
Aant. vloer.	n	9	x						**8,592948**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **477,3575**
Partiële factor = γ_G: 1,2
= *572,829*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1195,42** kN
= *1195421* N

Spanning in Kolom: Totale belasting UGT + Facade = **1497,75** kN
= *1497752* N
σ = **15,1908** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W y [mm3]	I y [mm4]	Klasse	Sterkte	E
	340	340	430	0,49708	6,55E+06	1,11E+09	GL28	28 N/mm2	12600

Dimensioneren Kolom B
Materiaal: **Hout** Profiel: **340x340** Sterkteklasse: **28** Oppervlak doorsnede: **115600** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,344	=	**1,0578**						
Kolom gew.	q_k	3,05	x			0,423963	=	**1,293087** +	**38,84499**					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,344	=	**1,0578**						
Kolom gew.	q_k	3,05	x			0,423963	=	**1,293087** +	31,61259					
Aant. vloer.	n	9	x						**284,5133**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	2,4	=	**29,2617**						
Eig. gew.	q_{eg}	3,075	x			0,344	=	**1,0578**						
Kolom gew.	q_k	3,05	x			0,49708	=	**1,516094** +	31,83559					
Aant. vloer.	n	6	x						**191,0136**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,2408	=	**0,954772**						
Aant. vloer.	n	15	x						**14,32158**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **771,0372**
Partiële factor = γ_G: 1,2
= *925,245*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **2204,96** kN
= *2204965* N

Spanning in Kolom: Totale belasting UGT + Facade = **2688,69** kN
= *2688695* N
σ = **23,25861** N/mm2

U.C. = σ / S **0,83**

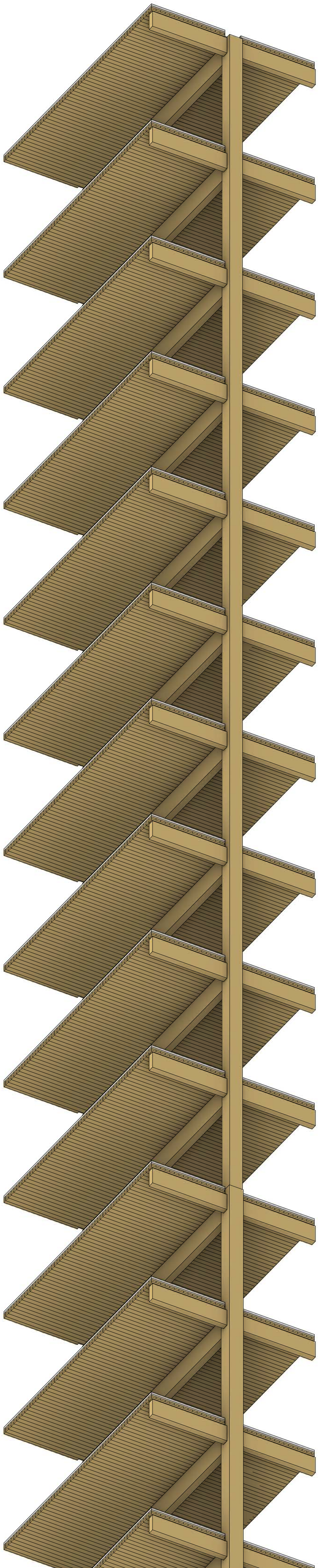
Knik Kolom

$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr}$ = 2,48E+08 N

(1) U.C.= **0,01**
(5) U.C.= **0,05**
n= 92,28

l= 3050
E= 210000
I_z= 1,11E+09
n2= 9,8696

Boven= 2,3E+15
Onder= 9302500



Variant A4.2

Floors:
120mm-3s spruce CLT and concrete topping

Beams:
Spruce LVL, GL28

Columns:
Spruce LVL, GL28

Variant E8, Staalplaatbetonvloer, Stalen ligger, Stalen kolom

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	X	2,7	ComFlor E60

Bron: [1]

Dimensioneren vloer
Materiaal: **Staal/Beton**

Opbouw:					
	55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
	120mm	ComFlor E60			2,7 kN/m2
		Plafond en Installatie		60kg/m2	0,6 kN/m2
				+	**4,62** kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**4,62**

Eigenschappen ligger

ligger [mm]	b ligger [mm]	dichtheid [kg/m]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
230	240	X	0,615	6,75E+05	7,76E+08	S355	355 N/mm2	210000

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Staal** Profiel: **HE240A** Sterkteklasse: **355** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	4,62	=	**18,3183**			
q_{eg}						=	**0,615** +			
								18,9333		**6,93875**

Blijvende belasting = G: **18,9333**
Partiële factor = γ_G: 1,2
= *22,72*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **33,12809** kN/m

M_d = 1/8 x q_{ugt} x l2 **156,6234** kNm
1,57E+08 Nmm

Spanning in Ligger: σ = M_d / W **232,035** N/mm2

U.C. = σ / S **0,65**

Eigenschappen ligger

ligger [mm]	b ligger [mm]	dichtheid [kg/m]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
171	180	X	0,362	2,94E+05	2,51E+08	S355	355 N/mm2	210000

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Staal** Profiel: **HE180A** Sterkteklasse: **355** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,362** +			
								10,2745		**0**

Blijvende belasting = G: **10,2745**
Partiële factor = γ_G: 1,2
= *12,3294*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **12,3294** kN/m

M_d = 1/8 x q_{ugt} x l2 **24,22916** kNm
2,42E+07 Nmm

Spanning in Ligger: σ = M_d / W **82,412** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A

h kolom	b kolom	dichtheid	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
220	220	X	0,728	2,58E+05 (Zwak)	2,84E+07 (Zwak)	S355	355 N/mm2	210000

Dimensioneren Kolom A
Materiaal: **Staal** Profiel: **HE220B** Sterkteklasse: **355** Oppervlak doorsnede: **9104** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,615	=	**1,891125**						
Kolom gew.	q_k	3,05	x			0,728	=	**2,2204** +						
									40,60563					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,62	=	**56,32877**						
Eig. gew.	q_{eg}	3,075	x			0,615	=	**1,891125**						
Kolom gew.	q_k	3,05	x			0,728	=	**2,2204** +	60,4403					
Aant. vloer.	n	9	x						**543,9627**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,362	=	**1,43533**						
Aant. vloer.	n	9	x						**12,91797**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **742,8925**
Partiële factor = γ_G: 1,2
= *891,471*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1514,06** kN
= *1514063* N

Spanning in Kolom: Totale belasting UGT + Facade = **1816,39** kN
= *1816394* N
σ = **199,516** N/mm2

U.C. = σ / S **0,56**

Eigenschappen kolom

h kolom	b kolom	dichtheid	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
240	240	X	0,848	3,27E+05 (Zwak)	3,92E+07 (Zwak)	S355	355 N/mm2	210000

Dimensioneren Kolom B
Materiaal: **Staal** Profiel: **HE240B** Sterkteklasse: **355** Oppervlak doorsnede: **10599** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			0,615	=	**1,891125**						
Kolom gew.	q_k	3,05	x			0,728	=	**2,2204** +						
									40,60563					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,62	=	**56,32877**						
Eig. gew.	q_{eg}	3,075	x			0,615	=	**1,891125**						
Kolom gew.	q_k	3,05	x			0,728	=	**2,2204** +	60,4403					
Aant. vloer.	n	9	x						**543,9627**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,62	=	**56,32877**						
Eig. gew.	q_{eg}	3,075	x			0,615	=	**1,891125**						
Kolom gew.	q_k	3,05	x			0,848	=	**2,5864** +	60,8063					
Aant. vloer.	n	6	x						**364,8378**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,362	=	**1,43533**						
Aant. vloer.	n	15	x						**21,52995**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **1213,28**
Partiële factor = γ_G: 1,2
= *1455,94*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **2735,66** kN
= *2735656* N

Spanning in Kolom: Totale belasting UGT + Facade = **3219,39** kN
= *3219386* N
σ = **303,7443** N/mm2

U.C. = σ / S **0,86**

Knik Kolom

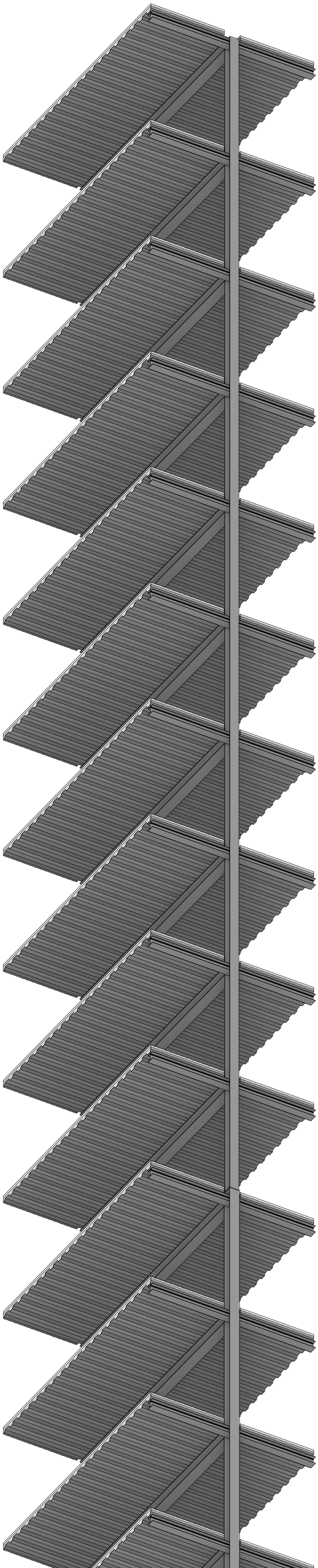
$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr} = 8{,}74E{+}06 \text{ N}$$

(1) U.C.= **0,37**
(5) U.C.= **1,84**
n= 2,71

l= 3050
E= 210000
I_z= 3,92E+07
n2= 9,8696

Boven= 8,1E+13
Onder= 9302500

[1] https://www.dutchengineering.nl/media/vk_1198/files/ComFlorE60.pdf



Variant E8

Floors:
Steel-concrete composite slab and concrete topping

Beams:
Steel HE240A, S355

Columns:
Steel HE240B, S355

Variant F9.1, Kanaalplaatvloer, Betonnen ligger, Betonnen kolom (C90/105)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	X	X	VBI Kanaalplaatvloer

Bron: [1]

Dimensioneren vloer
Materiaal: **Beton**

Opbouw:					
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32	kN/m2
150mm	Kanaalplaatvloer		268kg/m2	2,68	kN/m2
	Plafond en Installatie		60kg/m2	0,6	kN/m2
				+	
				4,6	kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**4,6**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	500	115	2400	1,38	4,79E+06	1,20E+09	C90/105	60 N/mm2	44000

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Beton** Profiel: **500x115** Sterkteklasse: **60** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	4,6	=	**18,239**			
q_{eg}						=	**1,38**	+		
								19,619		**6,93875**

Blijvende belasting = G: **19,619**
Partiële factor = γ_G: 1,2
= *23,5428*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **33,95093** kN/m

M_d = 1/8 x q_{ugt} x l2 **160,5136** kNm
1,61E+08 Nmm

Spanning in Ligger: σ = M_d / W **33,498** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	300	125	2400	0,9	1,88E+06	2,81E+08	C90/105	60 N/mm2	44000

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Beton** Profiel: **300x125** Sterkteklasse: **60** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**0,9**	+		
								10,8125		**0**

Blijvende belasting = G: **10,8125**
Partiële factor = γ_G: 1,2
= *12,975*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **12,975** kN/m

M_d = 1/8 x q_{ugt} x l2 **25,49786** kNm
2,55E+07 Nmm

Spanning in Ligger: σ = M_d / W **13,599** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	242	242	2400	1,405536	2,36E+06	2,86E+08	C90/105	60 N/mm2	44000

Dimensioneren Kolom A
Materiaal: **Beton** Profiel: **242x242** Sterkteklasse: **60** Oppervlak doorsnede: **58564** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			1,38	=	**4,2435**						
Kolom gew.	q_k	3,05	x			1,405536	=	**4,286885**	+					
									45,02448					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			1,38	=	**4,2435**						
Kolom gew.	q_k	3,05	x			1,405536	=	**4,286885**	+					
									64,61531					
Aant. vloer.	n	9	x						**581,5378**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875**	+					
									16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,9	=	**3,5685**						
Aant. vloer.	n	9	x						**32,1165**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **804,085**
Partiële factor = γ_G: 1,2
= *964,902*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1587,49** kN
= *1587494* N

Spanning in Kolom: Totale belasting UGT + Facade = **1889,83** kN
= *1889825* N
σ = **32,2694** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	259	259	2400	1,609944	2,90E+06	3,75E+08	C90/105	60 N/mm2	44000

Dimensioneren Kolom B
Materiaal: **Beton** Profiel: **259x259** Sterkteklasse: **60** Oppervlak doorsnede: **67081** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			1,38	=	**4,2435**						
Kolom gew.	q_k	3,05	x			1,405536	=	**4,286885**	+					
									45,02448					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			1,38	=	**4,2435**						
Kolom gew.	q_k	3,05	x			1,405536	=	**4,286885**	+					
									64,61531					
Aant. vloer.	n	9	x						**581,5378**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			1,38	=	**4,2435**						
Kolom gew.	q_k	3,05	x			1,609944	=	**4,910329**	+					
									65,23875					
Aant. vloer.	n	6	x						**391,4325**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875**	+					
									16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			0,9	=	**3,5685**						
Aant. vloer.	n	15	x						**53,5275**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **1313,866**
Partiële factor = γ_G: 1,2
= *1576,64*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **2856,36** kN
= *2856360* N

Spanning in Kolom: Totale belasting UGT + Facade = **3340,09** kN
= *3340090* N
σ = **49,79189** N/mm2

U.C. = σ / S **0,83**

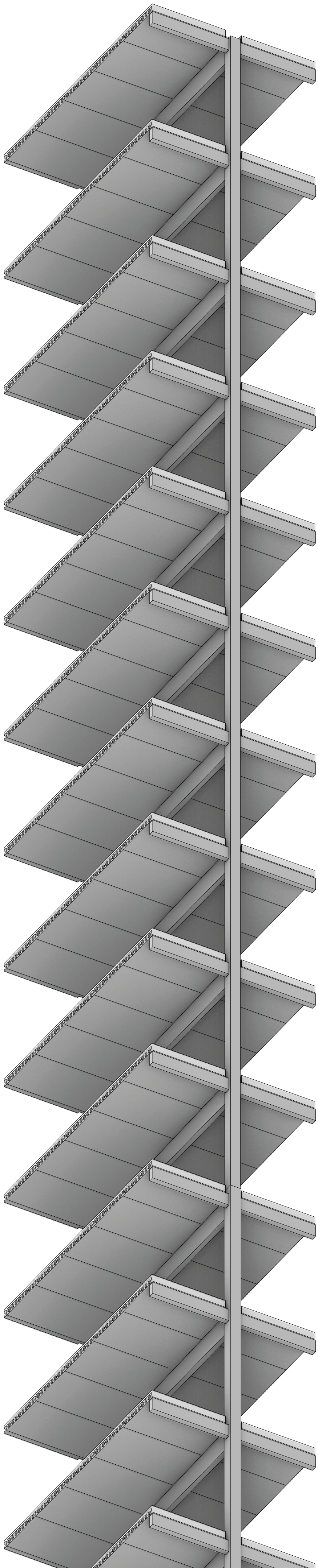
Knik Kolom

$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr} = 8{,}35E+07 \text{ N}$$

(1) U.C.= **0,04**
(5) U.C.= **0,20**
n= 25,01

l= 3050
E= 210000
I_z= 3,75E+08
n2= 9,8696

Boven= 7,8E+14
Onder= 9302500



Variant F9.1

Floors:
Hollow-core slabs and concrete topping

Beams:
Concrete,
C90/105

Columns:
Concrete,
C90/105

Variant F9.2, Kanaalplaatvloer, Betonnen ligger, Betonnen kolom (C45/55)

h vloer	b vloer	dichtheid	[kN/m2]	Producent
X	X	X	X	VBI Kanaalplaatvloer

Bron: [1]

Dimensioneren vloer
Materiaal: **Beton**

Opbouw:				
55mm	Gietdekvloer	2400kg/m3	132kg/m2	1,32 kN/m2
150mm	Kanaalplaatvloer		268kg/m2	2,68 kN/m2
	Plafond en Installatie		60kg/m2	0,6 kN/m2 +
				4,6 kN/m2

	Overspanning [m]	Verand. belast. [kN/m2]	Vloer type	Last [kN/m2]
q_{eg}	3,965	1,75	X	**4,6**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	545	200	2400	2,616	9,90E+06	2,70E+09	C45/55	30 N/mm2	36000

Bron: [x], [y] en [z]

Dimensioneren Hoofdligger
Materiaal: **Beton** Profiel: **545x200** Sterkteklasse: **30** Lengte: **6,150**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{ob}	1	x	3,965	x	1,75	=			**6,93875**	
q_{rb}	1	x	3,965	x	4,6	=	**18,239**			
q_{eg}						=	**2,616** +			
								20,855		**6,93875**

Blijvende belasting = G: **20,855**
Partiële factor = γ_G: 1,2
= *25,026*

Verander. belasting = Q: **6,93875**
Partiële factor = γ_Q: 1,5
= *10,4081*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **35,43413** kN/m

M_d = 1/8 x q_{ugt} x l2 **167,5259** kNm
1,68E+08 Nmm

Spanning in Ligger: σ = M_d / W **16,920** N/mm2

U.C. = σ / S **0,56**

Eigenschappen ligger	h ligger	b ligger	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	400	145	2400	1,392	3,87E+06	7,73E+08	C45/55	30 N/mm2	36000

Bron: [x], [y] en [z]

Dimensioneren Secund. Ligger
Materiaal: **Beton** Profiel: **400x145** Sterkteklasse: **30** Lengte: **3,965**

	Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN/m]	Tot. blijv. belast [kN/m]	Verand. belast. [kN/m]	Verand. belast. [kN]
q_{rb}	1	x	3,965	x	2,5	=	**9,9125**			
q_{eg}						=	**1,392** +			
								11,3045		**0**

Blijvende belasting = G: **11,3045**
Partiële factor = γ_G: 1,2
= *13,5654*

Verander. belasting = Q: **0**
Partiële factor = γ_Q: 1,5
= *0*

q_{ugt} Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **13,5654** kN/m

M_d = 1/8 x q_{ugt} x l2 **26,65809** kNm
2,67E+07 Nmm

Spanning in Ligger: σ = M_d / W **6,894** N/mm2

U.C. = σ / S **0,23**

Eigenschappen kolom A	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	352	352	2400	2,973696	7,27E+06	1,28E+09	C45/55	30 N/mm2	36000

Dimensioneren Kolom A
Materiaal: **Beton** Profiel: **352x352** Sterkteklasse: **30** Oppervlak doorsnede: **123904** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			2,616	=	**8,0442**						
Kolom gew.	q_k	3,05	x			2,973696	=	**9,069773** +						
									53,60807					
Vloeren														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			2,616	=	**8,0442**						
Kolom gew.	q_k	3,05	x			2,973696	=	**9,069773** +	73,1989					
Aant. vloer.	n	9	x						**658,7901**					**192,0299**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	9	x						**145,4063**					**223,0313**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			1,392	=	**5,51928**						
Aant. vloer.	n	9	x						**49,67352**					
Facade														
Eig. gew.	q_{eg}	30,5	x	3,965	x	2,5	=		**302,3313**					

Totaal [kN]

Blijvende belasting = G: **907,4779**
Partiële factor = γ_G: 1,2
= *1088,97*

Verander. belasting = Q: **415,0612**
Partiële factor = γ_Q: 1,5
= *622,592*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **1711,57** kN
= *1711565* N

Spanning in Kolom: Totale belasting UGT + Facade = **2013,90** kN
= *2013896* N

σ = **16,25368** N/mm2

U.C. = σ / S **0,54**

Eigenschappen kolom	h kolom	b kolom	dichtheid [kg/m3]	[kN/m]	W_y [mm3]	I_y [mm4]	Klasse	Sterkte	E
	377	377	2400	3,411096	8,93E+06	1,68E+09	C45/55	30 N/mm2	36000

Dimensioneren Kolom B
Materiaal: **Beton** Profiel: **377x377** Sterkteklasse: **30** Oppervlak doorsnede: **142129** mm2

		Lengte [m]		Breedte [m]		Last [kN/m2]		Blijv. belast. [kN]	Tot. blijv. belast [kN]	Verand. belast. [kN]		Fact. [Y]		Verand. belast. [kN]
Dak														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1	=			**12,19238**	x	0	=	**0**
Rust. bel.	q_{rb}	3,075	x	3,956	x	3	=	**36,4941**						
Eig. gew.	q_{eg}	3,075	x			2,616	=	**8,0442**						
Kolom gew.	q_k	3,05	x			2,973696	=	**9,069773** +						
									53,60807					
Vloeren A														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	1,75	=			**21,33666**	x	1	=	**21,33666**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			2,616	=	**8,0442**						
Kolom gew.	q_k	3,05	x			2,973696	=	**9,069773** +	73,1989					
Aant. vloer.	n	9	x						**658,7901**					**192,0299**
Vloeren B														
Opgel. bel.	q_{ob}	3,075	x	3,965	x	3,956	=			**48,23304**	x	1	=	**48,23304**
Rust. bel.	q_{rb}	3,075	x	3,965	x	4,6	=	**56,08493**						
Eig. gew.	q_{eg}	3,075	x			2,616	=	**8,0442**						
Kolom gew.	q_k	3,05	x			3,411096	=	**10,40384** +	74,53297					
Aant. vloer.	n	6	x						**447,1978**					**289,3982**
Loggia														
Opgel. bel.	q_{ob}	2,5	x	3,965	x	2,5	=			**24,78125**	x	1	=	**24,78125**
Rust. bel.	q_{rb}	2,5	x	3,965	x	1,5	=	**14,86875**						
Eig. gew.	q_{eg}	2,5	x			0,515	=	**1,2875** +	16,15625					
Aant. vloer.	n	15	x						**242,3438**					**371,7188**
Sec. liggers														
Eig. gew.	q_{eg}	3,965	x			1,392	=	**5,51928**						
Aant. vloer.	n	15	x						**82,7892**					
Facade														
Eig. gew.	q_{eg}	48,8	x	3,965	x	2,5	=		**483,73**					

Totaal [kN]

Blijvende belasting = G: **1484,729**
Partiële factor = γ_G: 1,2
= *1781,67*

Verander. belasting = Q: **853,1469**
Partiële factor = γ_Q: 1,5
= *1279,72*

Totale belasting UGT = γ_G x G + γ_Q x Q = F_d **3061,39** kN
= *3061395* N

Spanning in Kolom: Totale belasting UGT + Facade = **3545,12** kN
= *3545125* N

σ = **24,94301** N/mm2

U.C. = σ / S **0,83**

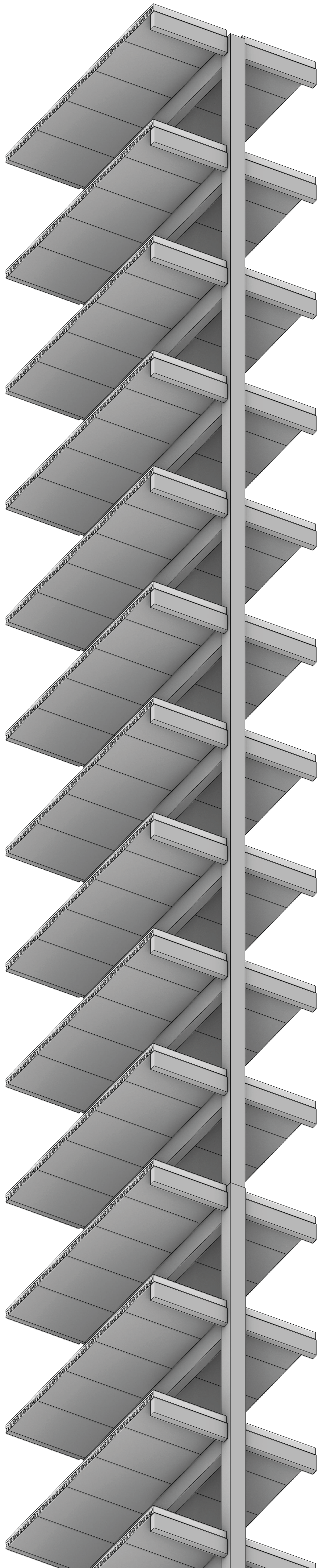
Knik Kolom

$$F_{cr} = \frac{\pi^2 \cdot E \cdot I_z}{l^2 cr} = 3{,}75E+08 \text{ N}$$

(1) U.C.= **0,01**
(5) U.C.= **0,05**
n= 105,80

l= *3050*
E= *210000*
I_z= *1,68E+09*
n2= *9,8696*

Boven= *3,5E+15*
Onder= *9302500*

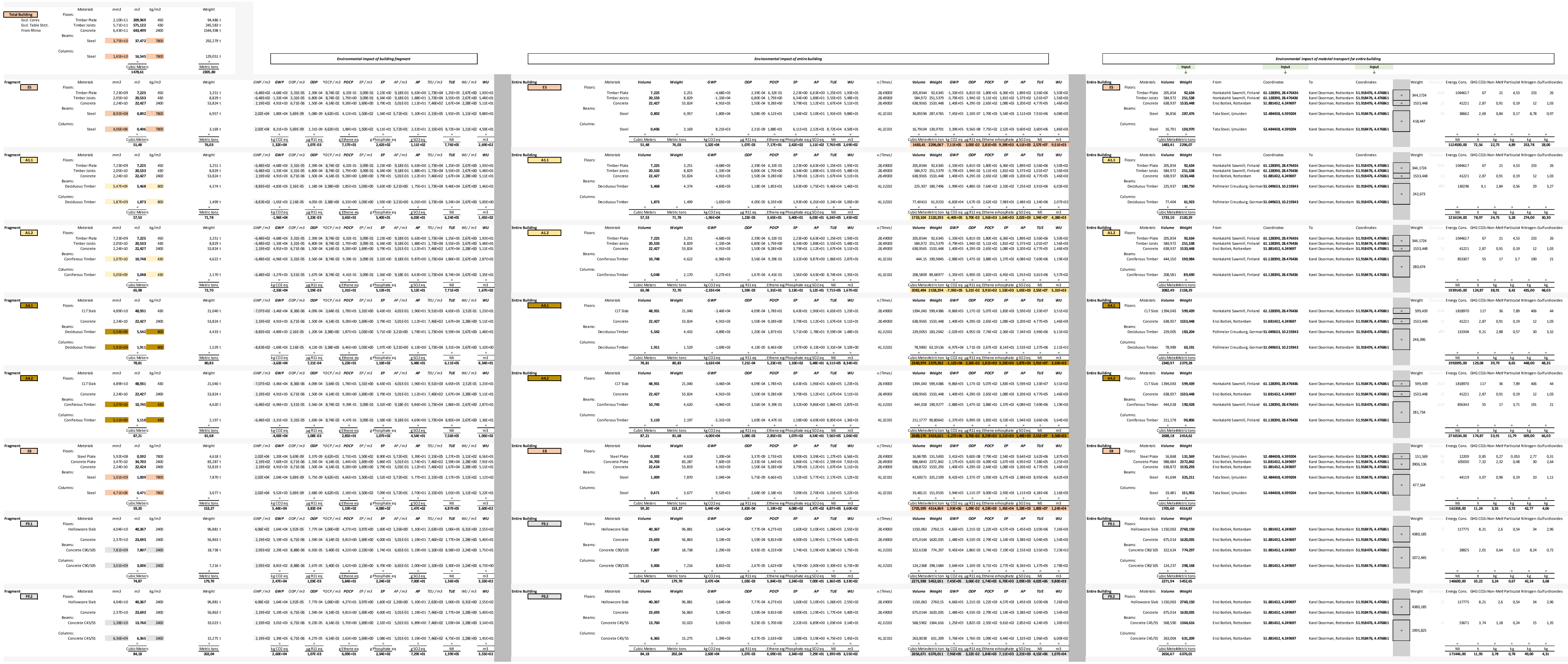


Variant F9.2

Floors:
Hollow-core slabs and concrete topping

Beams:
Concrete,
C45/55

Columns:
Concrete,
C45/55



	Volume	Weight	GWP	ODP	POCP	EP	AP	TUE	WU
E5	1483,41	2296,067	7,11E+05	3,05E-02	2,81E+03	9,39E+03	4,11E+03	2,57E+07	9,51E+03
A1.1	1733,104	2120,293	-6,40E+05	3,70E-02	1,36E+03	1,64E+03	2,02E+03	1,94E+07	4,38E+03
A1.2	2082,494	2158,294	-7,95E+05	5,21E-02	3,91E+02	1,53E+03	1,65E+03	2,55E+07	5,31E+03
A4.1	2340,974	2379,282	-1,12E+06	2,26E-02	1,81E+03	3,23E+03	1,87E+03	1,91E+07	2,63E+03
A4.2	2688,176	2414,621	-1,27E+06	3,76E-02	8,29E+02	3,11E+03	1,48E+03	2,51E+07	3,56E+03
E8	1705,599	4514,869	1,93E+06	1,09E-02	4,28E+03	1,45E+04	5,28E+03	1,80E+07	1,24E+04
F9.1	2271,938	5452,651	7,45E+05	3,06E-02	1,74E+03	6,70E+03	2,09E+03	4,02E+06	9,80E+03
F9.2	2656,671	6376,011	7,96E+05	3,22E-02	1,84E+03	7,11E+03	2,21E+03	4,15E+06	1,07E+04
			kg	µg	g	g	g	MJ	m3

Environmental Impact entire building variants

	Energy Cons.	GHG CO2e	thane Hydr	iculate ma	Nitrogen oxides	Sulfurdioxides
E5	1124500,00	72,56	22,75	4,89	253,78	28,00
A1.1	1216134,00	78,97	24,75	5,28	274,00	30,30
A1.2	1939145,00	124,87	38,91	8,42	435,00	48,03
A4.1	1992095,00	129,08	39,79	8,65	448,00	48,35
A4.2	2716534,00	174,87	53,91	11,79	609,00	66,03
E8	161358,00	11,24	3,55	0,72	42,77	4,06
F9.1	146600,00	10,22	3,24	0,67	42,24	3,68
F9.2	171446,00	11,95	3,78	0,78	49,00	4,31
	MJ	t	kg	kg	kg	kg

Envionmental impact transportation entire building variants