Furnishing the Terrassenhaus

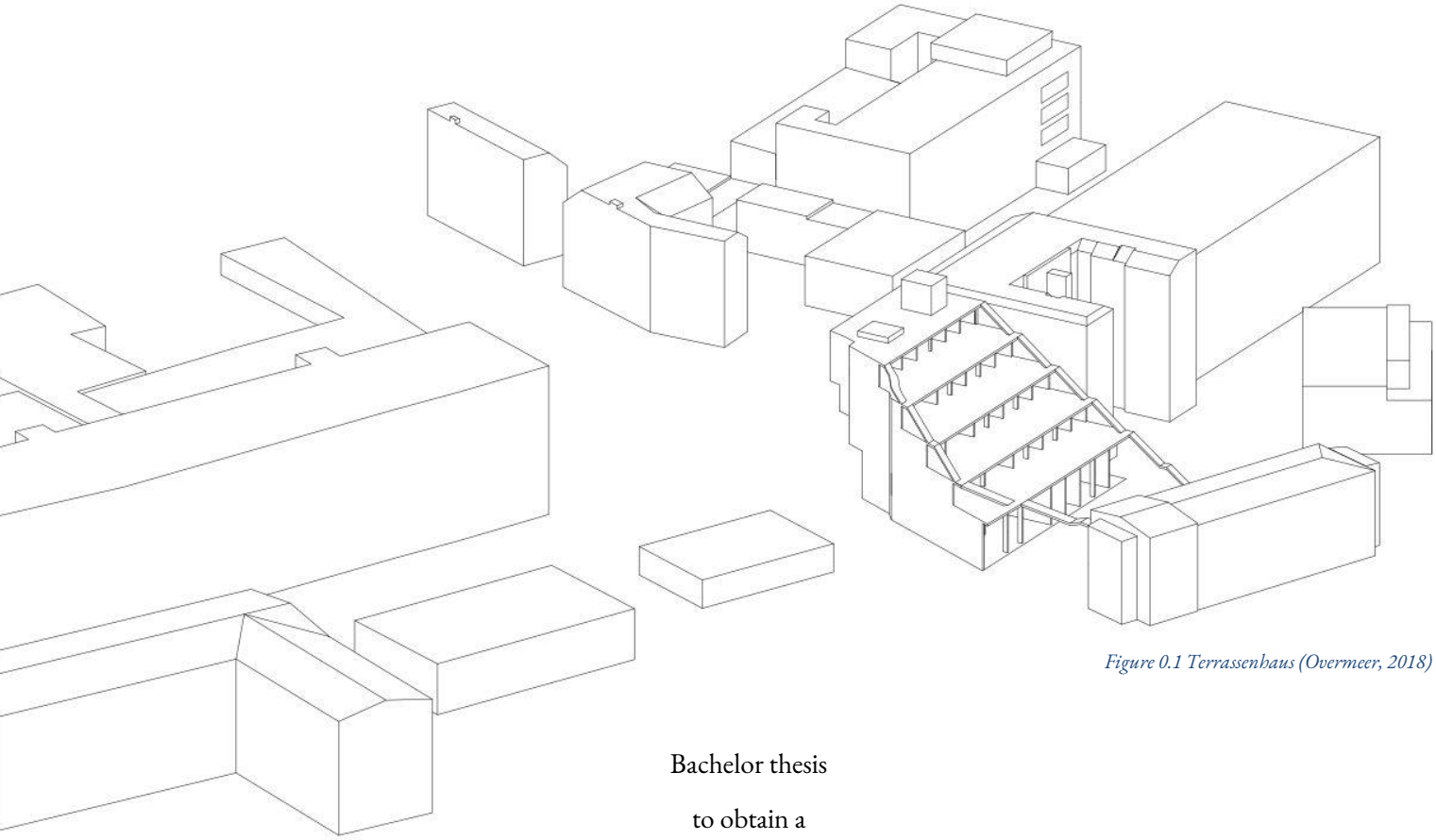

Figure 0.1 Terrassenhaus (Overmeer, 2018)

Bachelor thesis

to obtain a

Bachelor's degree in industrial design engineering.

For the university of Twente,

In association with Gebrüder Löhr GmbH

Submitted by

Mick Dorus Aaldering

Torstraße 70

10119 Berlin

28/05/2024

Title:	Furnishing the Terrassenhaus
Name:	Mick Dorus Aaldering
Student number:	S2144646
Course:	Industrial design engineering
Examination date:	05/06/2024
Client:	Gebrüder Löhr GmbH Bülowstraße 56 10783 Berlin, Germany
Assessment committee:	Julian Löhr Marten Toxopeus Janneke Massa Emile van der Heide

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Abstract:

Introduction

The lack of care taken with which tenant furnish their outdoor spaces is normally not noticed by the public, but with such a public and famous building like the Terrassenhaus in Berlin, this can cause the diminishing of value of the building, and it impedes the story the building tries to tell. To improve this, a more thought through outdoor furniture selection is needed. This bachelor thesis is carried out in cooperation with Loehr, a Berlin based furniture design company that also specializes in creative services. They initially have designed the interior of a part of the Terrassenhaus and have been aware of the outdoor furniture situation ever since.

Approach

First a comprehensive understanding of the Terrassenhaus was required. This was done by the review of relevant literature, visiting the building itself and interviewing an architect that works at the designing architecture firm. With this comprehensive understanding the first concepts could be ideated. These 4 concepts were developed further with the help from the analysis, and one was chosen to be developed further with simulations and a 1:1 technical model into a fully working prototype Figure 0.2. This prototype was then evaluated to confirm the fit with the Terrassenhaus.

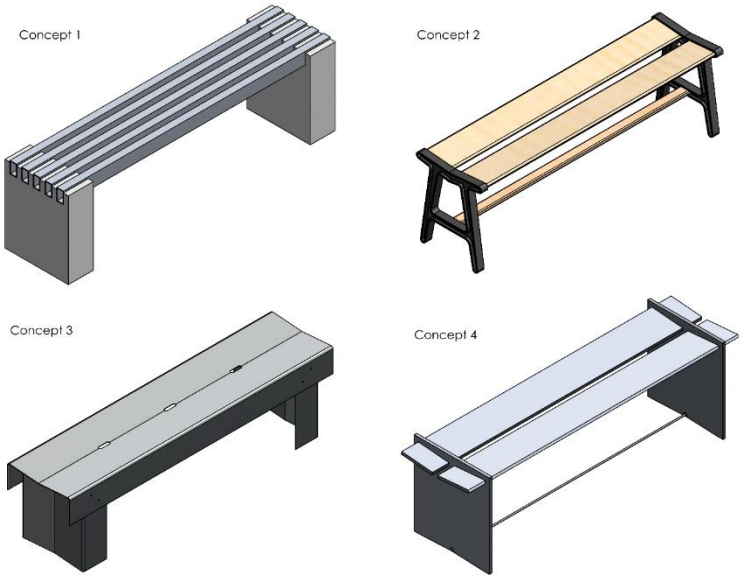


Figure 0.1 The four developed concepts (own work)

Result

The end result is a raw aluminium bench (concept 4 in *Figure 0.1*) that embodies the design ethos (the value system with which something is designed) and narrative (story the building tries to tell) of the Terrassenhaus.

Following the design ethos means that the bench is designed with only pragmatic, non-aesthetic choices made, this is seen in its simple construction and its lack of any ornamentation. The following of the narrative results in a bench that is extremely sturdy, easily changeable for a different scenario it needs to perform in. This changeability is due to its construction that fully relies on friction between the horizontal and vertical plates and the tension from the bottom cable. When the tension is removed, the parts are easily slid away from each other. This makes reusing the vertical plates for a smaller bench or even a stool extremely easy and makes adding other (yet to be developed) components easy.

This design is the basis for the further development of a set of furniture pieces that will transform the Terrassenhaus. This transformation hopes to achieve better coherence within the building and improvement of the clarity of the story the building is trying to tell.

Conclusion & recommendations

It was concluded in the evaluation that the designed bench fits well with the Terrassenhaus. Further development would include bringing the design all the way to production (which includes producing a second prototype that is waterjet cut and finding producers for all processes) and development of additional parts like soft seating additions, several sizes of backrests, side tables, umbrella holders or plant potholders. Additionally, the further furnishment of the Terrassenhaus would start from this basis of design, which further would include tables and more lounge oriented furniture.

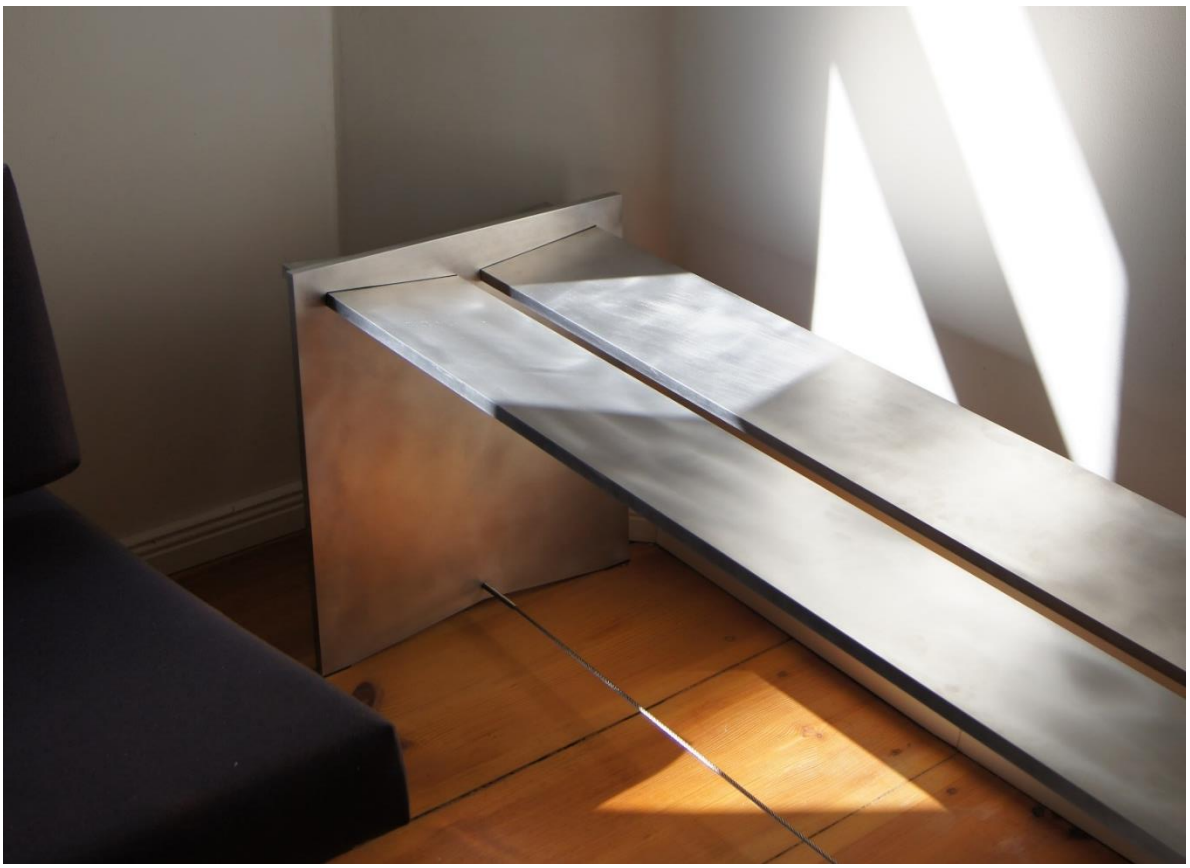


Figure 0.2 Final design proposal (own work)

1 Introduction

In this thesis, the basis for an outdoor furniture solution for the Terrassenhaus in Berlin will be conceived. The Terrassenhaus is a famous architectural building in Berlin, designed by Brandlhuber architekten, (currently known as BPLUS). In this building, the interior one of the offices is designed by Loehr, which is the hosting institution for the thesis.

Loehr is a small furniture design company from Berlin that also frequently takes on full interior design projects. In their conversations with the tenants of the Terrassenhaus, it came to light that the outdoor space of the building is not satisfactory utilised yet. And is now furnished with a mixed range of styles and types of furnishment. This is likely caused by tenants having different ideas on how to furnish the outdoor space and not putting in the effort to create a cohesive space across all terraces or even across one terrace. This is a big loss because the outdoor space of the Terrassenhaus has much to offer for both private and public use.

Figure 1.1 High view Terrassenhaus (Ghinițoiu, 2020)

The incoherent furnishment muddies the story or narrative the building tries to tell and thus, diminishing the value and effectiveness of the building. In average buildings, this is not a big enough problem to warrant such a radical redesign of the furniture plan, but in the case of the Terrassenhaus, a famous and public architectural building with a strong philosophical narrative, this incoherence brings a real diminishing of its value.

This is where the thesis comes in, and the plan to design a fitting outdoor furniture piece is born. This piece can start to tie together the levels of Terraces and make the furniture of the Terrassenhaus more in line with its image. Further furniture pieces might be needed to complete this task, such as tables, chairs, lounge chairs and side tables. The design of these other pieces falls out of the scope of the thesis due to time constraints.

The final design proposal is seen as the starting point for this transformation. The eventual goal of this transformation would be to create a set of constant companions for the building, that remain there throughout the changing of tenants and improves the coherence and value in the Terrassenhaus.

2 Approach

To design something for a specific context, deep and accurate knowledge of that context is needed. Therefore, the first step is the analysis of the Terrassenhaus and how the building was designed and how the building is used. From that analysis, a needed typology is defined within the design requirements.
This typology is found by looking at what would have the biggest impact on the Terrassenhaus to start the transformation. With these design requirements, the concept generation phase is guided, the design requirements are only guiding, and not strictly followed in this stage. This approach leaves more room for expansion of ideas and facilitates a broader ideation phase. Out of this phase several concepts are pursued in the concept development phase, exploring their validity and possibility. From these concepts, one is chosen through a weighted point system to be taken all the way to the detailing phase. This is where the smaller details of the design are developed, and structural analysis is done by way of simulation and technical models. The final product will be a 1:1 prototype that is representative of the final design proposal and the starting point for the possible future transformation of the Terrassenhaus' outdoor space. To check its validity as a viable furniture option for the Terrassenhaus, it is evaluated against the design requirements and is subjected to several surveys to validate the fit with the Terrassenhaus.

2.1 Main question

What would a fitting outdoor furniture solution look like for the Terrassenhaus?

2.2 Sub questions

1. What materials are prominent in the Terrassenhaus?
2. What form ideas are prominent in the Terrassenhaus?
3. What is the design ethos of the Terrassenhaus?
4. What is the narrative of the Terrassenhaus?
5. How is the outdoor space of the Terrassenhaus used currently?
6. What outdoor furniture typology is most used at the Terrassenhaus?
7. What measurements fit the needed typology?
8. What other characteristics fit the needed typology?

Narrative is the goal the architect has tried to achieve/ the story the architect tried to tell.
Design ethos is the way the architect tries to achieve this goal.

3 Analysis

3.1 Approach

In this chapter the steps of the analysis are explained, this will result in a report on the most relevant parts of the Terrassenhaus. With this the following sub question will be answered.

1. *Material* What materials are prominent in the Terrassenhaus?
2. *Form* What form ideas are prominent in the Terrassenhaus?
3. *Ethos* What is the design ethos of the Terrassenhaus?
4. *Narrative* What is the narrative of the Terrassenhaus?
5. *Use* How is the outdoor space of the Terrassenhaus used?
6. *Typology* What outdoor furniture typology is most used at the Terrassenhaus?

The first three sub questions are answered by the analysis of the building itself and sub question 4 and 5 are answered by the analysis of the users.
Between these two parts of the analysis, a focus is put on the building itself, this is due to the fact that ideally, the furniture will accompany the building for a long time, in which tenants will most likely change, and with that their opinions. This all results in more extensive research conducted into all the design aspects of the building, and that only some observational research is done for the use of the outdoor space.

3.1.1 Goal

The goal of the analysis is to get a comprehensive understanding of the Terrassenhaus and how it's used. This includes the construction and aesthetics of the building, the design ethos and what guided the architects in their decisions. This way not only the materials and form of the building can be designed for, but also the deeper reasoning behind them.

3.1.2 Literature

There are three main sources of literature used for understanding the Terrassenhaus,
The Brandlhuber edition of El Croquis, ARCH+ feature 78 about the Terrassenhaus, and an article in BAUWELT on the Terrassenhaus.
El Croquis is chosen because it puts the Terrassenhaus next to the other buildings Brandlhuber has designed in the past, putting it in context within his oeuvre. This helps understanding his style of architecture.
ARCH+ is chosen because it is an excellent source behind the philosophy of the building since it is an interview Arno Brandlhuber about the Terrassenhaus and its cultural and ethical significance.
BAUWELT is chosen because it resembled a good source of facts and basic concepts of the building, as well as some deeper information of the actual choices made.

3.1.3 Field study

Secondly a field study is performed, this entails going to the Terrassenhaus and making pictures, drawings, and notes of what was seen there to understand the construction, materiality, and form of the building deeper. Next to this the existing furniture in all outdoor areas is looked at and counted. This gives a clear representation of the type and amount of furniture that is used in these areas, thus the furniture that would be needed at this time.

3.1.4 Interview

The interview with Jonas Janke took place on 28th of February 2024 at his office in Berlin Lichtenberg. Jonas Janke is a partner at BPLUS (formally known as Brandlhuber+ architekten), the firm that has design the Terrassenhaus. He is an experienced architect and, although he hasn't worked personally on the Terrassenhaus, has deep knowledge of the design ethos and narrative of the Terrassenhaus. The interview was recorded and transcribed and is to be found in appendix 1.

The conclusion to this interview, and the analysis in total is the report on the Terrassenhaus, which will serve as a basis for future choices to be made and as a general design directive.

3.2 Report on the Terrassenhaus

3.2.1 Intro

The Terrassenhaus, also sometimes known as LoBe block, is a newly (2018) completed building in north-west of Berlin. The Terrassenhaus is designed by Brandlhuber+, the architecture office run by Arno Brandlhuber, one of Germany's most influential and famous architects. This essay will try to capture the essence of the Terrassenhaus, and with that answer some of the sub-questions.

3.2.2 Narrative

Here sub question 4. Narrative is answered.

Figure 3.1 picture front of Terrassenhaus (own work)

The narrative of the building, (the conceptual and philosophical story it tries to tell) is one of an “intelligent ruin”, a term coined by bOb van Reeth, (van Reeth, 2013, 39). An intelligent ruin is a building that takes the unknown future into account and is robust enough to still be valuable in that far away future. In practice this often means having a building that leaves room for interpretation of the user. This results in a hard shell of a building that can be interpreted by the user to fit the needs of the time. Following this narrative creates some basic requirements for the building. These include an extremely durable construction and a flexible, changeable, interior, in the case of Terrassenhaus this is done by having no load bearing walls, so the interior can become one big room, or several smaller rooms. Next to this durability of construction, there also needs to be a durability of aesthetics, so that the building does not diminish in value over time. This is mainly down to the choice of material and will be discussed later. Everything starts with this narrative, and the goal is to translate this almost philosophical idea, into a building.

3.2.3 Design ethos

Here sub question 3. Ethos is answered.

Analysing the design ethos explores why certain choices were made. To explain the route (that is made up out of those choices) towards its goal (the narrative). This is so this can be emulated during the design of the furniture piece.

The design ethos of the Terrassenhaus has one basic but important rule, everything is done out of practical and pragmatic need. Nothing is added purely for aesthetic reasons. In Jonas' words,

"There is never a decision how can we make it more beautiful or how can we make it more appealing somehow. If the concept is somehow fitting and if it's somehow bringing value to the concept and how can we do it. This is always the question: is this somehow bringing benefits for the concept. But not does this look cooler or would it be nicer in red or blue or this is not a question at all." From the interview with Jonas, *Appendix 1 line 107-109.*

Another aspect of the ethos is minimizing the effort it takes to create the design. This does not mean minimalism but is more aimed at letting the existing rules and constraints of the typology and its context dictate do much of the designing. "*Maybe not minimizing but fulfilling the things that we try out with the least effort. Not over complicated somehow because of any conceptual or any aesthetic thoughts." Appendix 1 line 103-104.*

3.2.4 Form

Here sub question 2. Form is answered.

A giant stepped structure, creating an overhang, which serves as a transitional space from public to private, and terrasses, that creates semi-private space for the tenants. (Thein, 2018, 49-57)

To achieve the flexibility of an "intelligent ruin" the construction is one of pillars and slabs and the utilities, bathrooms and elevators are in two central columns. This construction technique makes it possible that none of the dividing walls

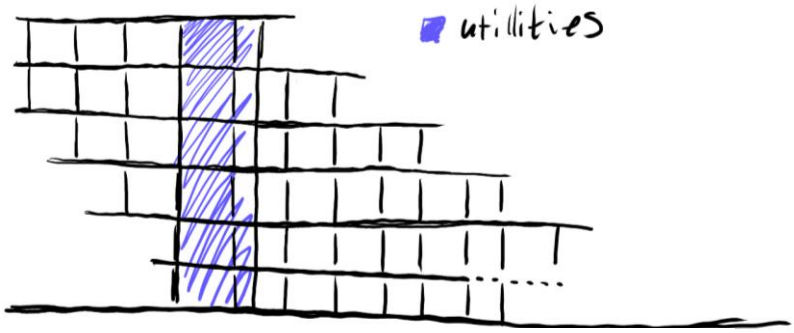


Figure 3.2 Utilities Terrassenhaus (own work)

are load bearing, thus can be removed, or changed in the future.

There seem to be no decorations or additions that are purely aesthetic. And even a lot of normally necessary additions like rain drainage pipes and inside stairs are removed (by slanting the terrasses 2% and using the elevators indoors and designating the outside stairs as fire stairs). This gives the building a distinctly un-ornamental appearance. This also helps in creating a long-lasting structure because it cuts down on future maintenance and repairs. You cannot repair or replace something that you don't have. Solving the puzzle of what a building needs to do (practically and legislationally), in the most straight forward way. The volume is the maximum number of cubic meters allowed on the site, and the outer wall is following the border of the plot exactly, hence the angled steps on the side of the building. (Thein, 2018, 49-59) This way, the shape and size of terraces is dictated by the given building legislation, maximizing their size while also maximizing the use of the land. Again, here the design ethos is seen throughout the choices.

The radical following of the given legislation or rules is seen everywhere in the (concept) of the building and is an integral part of Brandlhubers style of architecture. Many elements of this idea are also seen in other buildings from Brandlhuber, for instance Brunnenstraße 9, here they bring the fire escape stairs outside, and use these as main entrance points and outside area for the building. (Márquez Cecilia & Levene, 2018, 114)

The shape of the building is one of hard corners, heavy, closed shapes, and homogeneous construct ion. Construction details like bolts and brackets are not hidden but are simply not there.

Figure 3.3 Brunnenstrasse 9 (BPLUS architekten, 2010)

3.2.5 Materials

Here sub question 1. Materials is answered.

The most prominent material that is used is concrete, it is used in its construction, outside facade, floors, ceilings, and some walls.

Other materials used are plywood for some wall sections, glass with anodized aluminium frames. Galvanized steel railings outside and grey/ silver fabric curtains outside.

Just like the form, the material choice comes from the underlying narrative, to achieve such a construction

Figure 3.4 Pictures Terrassenhaus (Overmeer, 2018)

as previously explained, a material like concrete is needed. This provides the load baring capacities to achieve these flexible inner spaces without the need for loadbearing walls.

Concrete also allows the building to last extremely long because it is very weather resistant and loses little of its structural properties.

Next to strength that is retained, long lasting aesthetics are maybe as important. If the building looks rundown, and the cost of restoration is too high, a building might get torn down. This would go against creating a "intelligent ruin". Which in the case of the Terrassenhaus means relying on the intrinsic value of the material itself, not so much a coating or a façade cladding, which often have a shorter aesthetic lifetime.

This will bring the material choice towards a more raw and materialistic side, this is seen with the raw concrete, the raw aluminium and the galvanized railings. This aesthetic benefits from the

Figure 3.5 Stairs Terrassenhaus (own work)

historical and cultural heritage of German materialistic art. Which is traceable back to the late German contemporary artist Joseph Beuys and his followers.

"In Brandlhubers work, materials generally appear as they are, without any cladding or finish. As in the work of Beuys and his followers –in contrast to American minimal or conceptual art – the material always has a social, cultural, and psychological meaning and feeling." (Márquez Cecilia & Levene, 2018, 15)

Although the choice of material is a pragmatic one, the cultural value is not lost on the architect.

Note that, this relying on pragmatism to guide the design choices, also means that if the underlying narrative would point towards a wood construction (or if the German legislation for fire safety would allow this), the building would have been built from wood. Therefore, the material is a means to an end. It should first and foremost enable the designer to follow the narrative that was set from the beginning of the design process.

Figure 3.6 Photo Terrassenhaus (TIMPAU)

3.2.6 Use

Here sub questions 5. Use and 6. Typology are answered.

The building is meant for a heterogeneous group of people, both accommodating living and commercial spaces in one building. (Ngo et al., 2018, 11)

The shape of the building creates two types of outdoor areas, a transitional space between public and private in the front, and the semi-private, semi-public terraces at the back. This mixed-use space blurs the boundary between private and public space (Márquez Cecilia & Levene, 2018, 199)

Although in reality there was some fighting back from this, with some terrasses having a small rope added

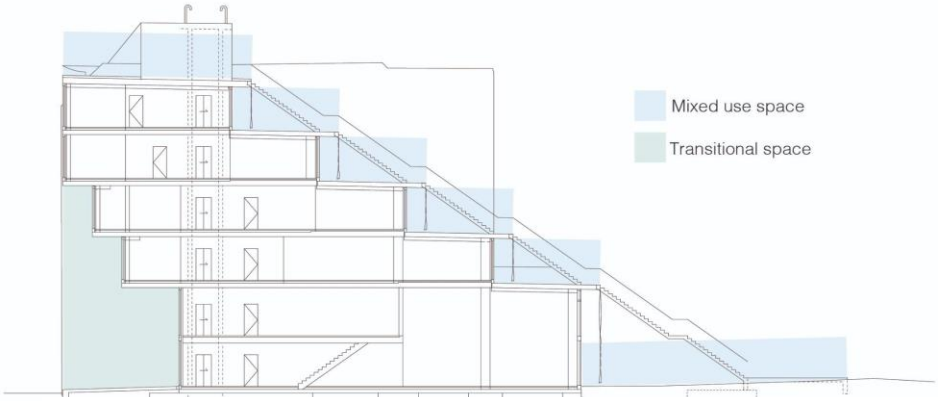


Figure 3.7 Outdoor space designation Terrassenhaus ((Thein, 2018) with supplements from the author)

by the tenants in the hope to define this boundary more clearly. For the stairs are public space, but the Terraces are more meant for private use.

The current use of the building is mainly commercial, with only the top, and smallest layer being used for a single residence. This is reflected in the furniture, which is more based around group sitting seen in the high number of benches. This is logical when looking at the users of the building, which are mostly studio offices and a single yoga studio, these people will use the outdoor space for team lunches or work sessions with good weather. The focus on the terraces lies therefore more on a practical outdoor space, rather than a recreational space. In total, there are 27 benches, 20 sitting chairs, 8 lounge chairs, 1 lounge couch and 4 stools. If counted per seating placement (3 persons per bench, 2 per lounge couch) the divide is seen in *Table* 3.1.

Bench	81
Chair	20
Lounge chair	8
Stool	4
Lounge couch	2

Table 3.1 Seating options at Terrassenhaus

3.2.7 Conclusion

The narrative of the Terrassenhaus is to create a heterogeneous building that also sticks to the theme of an "intelligent ruin". This is a narrative that requires flexibility in its use and longevity of its materials.
Next to this, the design ethos is solely based in pragmatic choices. Nothing is done for aesthetic purposes only. Everything serves a function, and the functionality is achieved with as little effort as possible.
The form is one of no ornamentation, with sharp edges and overhanging features.
The material is the rawest version of the material that is best suited for the intended job.
The outdoor space is mainly used for group seating like team lunches or events, with these activities they mostly using benches, as seen from the high number of benches without backrests used on the tables at the Terrassenhaus. These are not meant for long sitting sessions but more practical in their use (due to being able to step over the bench to sit in between two people.). To have the greatest impact on the Terrassenhaus on this first step of the total transformation, the bench is the chosen typology for the thesis.

3.3 Defining the problem further

Visual coherence is important when trying to convey a story or narrative with a design. If parts of this design are not in line with the rest, visually or otherwise, the message can be muddied and unclear, and this diminishes the whole purpose of an architecturally significant building like the Terrassenhaus. At the Terrassenhaus this visual coherence has seemingly not been considered when furnishing the outside of the Terrassenhaus. This is deduced from looking at the current furnishings of the Terrassenhaus, many of which either don't follow the same design ethos as the building or don't match with each other visually. For example, in *Figure 3.8* you can see two different typologies of single seating, with two completely different styles and two completely different relationships with the building. The green chair in the back has a contrasting form and material, and the concrete stools copie the form and the material from the Terrassenhaus. Both designs can be considered to follow parts of the design ethos of the Terrassenhaus, being of simple construction with no ornamentation or additions. The concrete stools can be considered following the narrative, being of a nearly indestructible material, but it is lacking the accounting for the future of the narrative. Thus, individually fitting the building fine, but as a whole, this does not fit together. Another example would be *Figure 3.9*, where there is some matching of furniture style in both the lounge couch and the chairs, but they are incoherent with the Terrassenhaus itself. Having ornamental additions like an extra swooped seating surface on the lounge couch or the thin stringy backrests of the chairs. These are purely aesthetic choices, thus going against the design ethos of the Terrassenhaus. The narrative is also not followed, using painted metal that can and will be damaged over time, leaving the underlying metal to rust and decay.

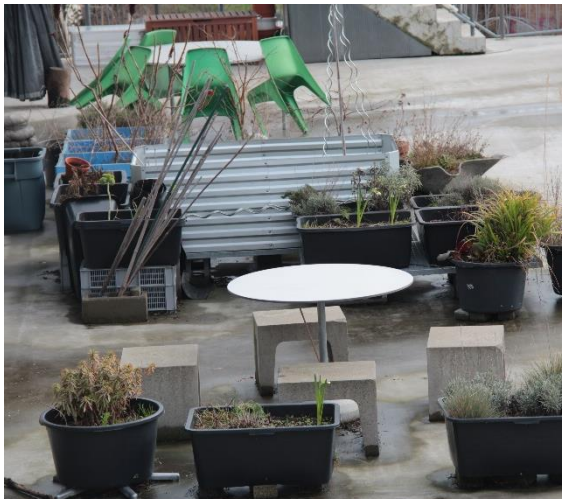


Figure 3.8 Example incoherence Terrassenhaus (own work)

Figure 3.9 Example incoherence Terrassenhaus (own work)

4 Design requirements

In this chapter the design requirements are set up. These are used as guidelines for the designing phase and are the values that are measured against in the result phase. These design requirements aim to answer the following sub-questions;

6. What measurements fit the needed typology?
7. What other characteristics fit the needed typology?

The final measurements are concluded in Table 4.1 at the end of this chapter.

4.1 Approach

The design requirements are set up with five possible parts.

Requirement

These rules need to be followed in the final design proposal, often posing a substantial problem if not achieved.

Wish

These rules are nice additions to the design, and should be followed, if possible, but it does not pose a substantial problem if not followed.

Bonus

These rules can be added if it does not take away from the design without it.

Justification

Here the reasoning behind the requirements or wish is explained, if no justification is given, it was deemed self-explanatory or outside of the scope of the thesis.

Quantification

Here exact measurements are given where deemed appropriate, if no quantification is given, this is deemed outside of the scope of the thesis.

4.2 Design requirements.

Typology

I. **Requirement:** The design proposal should resemble a bench that is used with a table.
Justification: This is the most used piece of furniture at the Terrassenhaus thus will have the most impact on cohesion of the Terrassenhaus. 3.2.7

II. **Requirement**: The design proposal should have limited or no backrests.
Bonus: The design proposal should have removable or movable backrests to make both getting out easier and add comfort.
Justification: This makes it possible to leave the bench with minimal effort when the bench is filled. This weights up to the added ergonomic benefit of having a backrest because the intended use is not one of long extended use periods. 3.2.7 Use

Size measurements

III. **Requirement**: The design proposal should be comfortable for 90% of the German population.
Justification: The amount of inclusivity (from P_5 to P_{95}), is chosen in this case. ISO 26800 explains:

"In ergonomics, the variation within the target population is commonly accounted for by using the 5th and/or 95th percentiles of important design characteristics (e.g. body size, visual abilities, literacy), with the intention of accommodating at least 90% of the target population. In some circumstances, a different percentile range is used. For example, in many safety-related applications, the 1st and 99th percentiles are used." (International Organization for Standardization, 2011)

This application is not safety related so the 5^{th} and 95^{th} percentiles are enough.

Quantification:

There are three basic measurements that need to be considered when looking at sizing. Figure 4.1

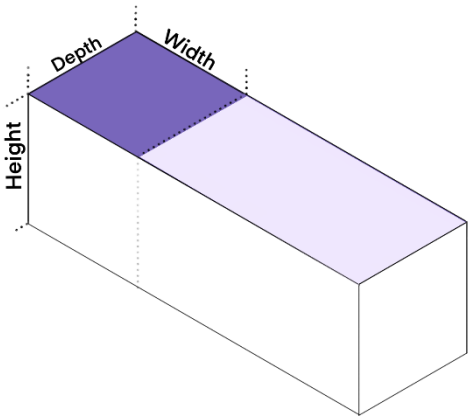


Figure 4.1 Seating measurements diagram (own work)

Hight of seating surface.

Depth of seating surface.

Width of seating surface.

Next to this there are other additions to these measurements that could improve comfortability, like a flexible or concave seating surface. These additions are not considered in the design requirements due to lack of specific need of good ergonomics with this typology, a backrest less bench is not meant as an ergonomic specific seating but one that handles multiple people easily. Added comfort is appreciated but not a focus point.

Hight of seating surface.

The ideal seating hight is determined by the popliteal (back of the knee) hight of user and the thickness of their shoe soles. Since both these factors can vary immensely between users, the maximum at both ends is calculated (short woman with thin shoes and tall man with thick shoes) and the middle point is taken. There is no special importance being put on either taller or shorter users, because both users would be uncomfortable if the seating would be either too low or too high for them.

this all concludes in the following. 375mm+20mm ((F_5) lowest popliteal hight, + thin sole) + 490mm+35mm (M95 highest popliteal hight, + high sole) / 2 = 460 mm

All German anthropometric data for the seating hight calculations are taken from DIN CEN ISO/TR 7250-2:2013-08 (Deutsches Institut für Normung, 2013) through (Vitesco Technologies, 2014) see, *Figure A. 1 Anthropometric data* and all shoe thickness measurements are taken from (Eger, Bonnema, Lutters, & van der Voort, 2013).

Depth of seating surface.

Only a minimum seat depth is looked at, this is because a deep seat, given that there is no reliance on a backrest for ergonomics, is not less comfortable. A shallow seating surface is very uncomfortable, even unusable. Therefore, the minimum seat depth is 304mm. This is taken from a study from the International Journal of ergonomics (Feizhou, 2001). In this study the seating surface has no accompanying backrest, and the subjects are seated at a table.

Width of seating surface.

The total amount of seating width depends on the amount of people the bench is meant for, this is not something that can be defined given the need for different sizes of tables, the bench therefore will be for anywhere around two to four people, if possible, with different versions with differing lengths to accommodate different size tables. We can however allocate a certain amount of seating room per person. To little seating room will be uncomfortable, but there is no such thing as too much room in this case. Thus, the width is taken from the widest possible scenario. Which in this case is the 95th percentile men with thick clothes on. 525mm (M_{95} shoulder width) + 80mm (thick winter coat) = 605 mm

There is some allowance on the outside seated users, their arms can hang over the edge of the seating surface on the outside. This makes these seating areas smaller by 525 mm(M_{95} elbow width) – 420 mm(M_{95} hip width) / 2 = 52.5mm

This makes a two-person bench a minimum of 552.5 mm+552.5=1105 mm and a three person bench a minimum of 552.5 mm+605 mm+552.5 mm=1710 mm.

It is noted that this methodology does not account for all seating and body positions thus cannot guarantee that some people might take up more space than estimated.

All German anthropometric data for the seating width calculations are taken from DIN CEN ISO/TR 7250-2:2013-08 (Deutsches Institut für Normung, 2013) through (Vitesco Technologies, 2014) see, Figure A. 1 Anthropometric data and all clothing thickness measurements are taken from (Eger, Bonnema, Lutters, & van der Voort, 2013).

Strength

IV. **Requirement**: The design proposal should not flex excessively or deform permanently during all expected use scenarios.

Justification: Excessive bending can cause deformation; this can shorten the lifespan of the product dramatically.

Quantification: The M95 weight of a European is 100kg (Deutsches Institut für Normung, 2013) through (Vitesco Technologies, 2014), this becomes about 1KN per person On top of this a 150% safety margin is added. 1.5KN per person.

This is what the bench needs to resist vertically without permanent deformation or excessive bending. Permanent deformation occurs when the yield strength is exceeded. Excessive bending is judged to be anything more than 25mm at maximum loading. But less bending is better. With exceptions for when bending is part of the design, for instance to create more comfort.

On top of this, some horizontal loads need to be considered, the users will not sit completely still after all. This is an estimated 200N per direction, per person.

Weather resistance

V. **Requirement**: The design proposal should not corrode in a way that limits the life of the product.

Wish: The design proposal should not corrode in a way that diminishes the aesthetics of the product.

Justification: The design proposal may be outside for all weather conditions. Retaining structural integrity and aesthetic value is important for the lifespan of the design proposal. This is not only always an important point in any design, but with the given narrative and its focus on longevity, *3.2.2*, this point becomes even more important.

Quantification:

The weather resistance of a product comes down to several factors, divided into two groups. *Material factors* and *structural factors.*

Material factors:

i. All build materials should be resistant to corrosion to rot or be coated with a corrosion or rot resistant layer.

ii. If a material is coated, repeated use of the product should not damage the coating.

iii. Exposure to sunlight should not damage any of the materials. Also, discolouration due to UV should be avoided.

Structural factors:

iv. The chance for standing water should be minimized, at points where rainwater can collect, corrosion or rot occurs faster. This can also cause discoloration or algae buildup. This can be done by slanting major surfaces of at least 2% or with holes or slits on the horizontal surfaces. The effective ness of these, should be tested before the final design proposal.

Practical

VI. **Requirement**: The design proposal should be movable by two people.

Wish: The design proposal should be movable by a single person.

Justification: This is important because a design should always try to minimize the force required to use it, and since moving furniture is often part of its use, the weight should be limited. In this case there is no specific need for extra mobile furniture, thus the maximum weight is set on a realistic level that still leaves plenty of room for flexibility in its design.

Quantification:

"The maximum force to be exerted acceptably through arms/hands is around 200N for 95% of men and 80% of woman. This acceptable maximum force will exponentially decrease as frequency and duration increases." (Eger, Bonnema, Lutters, & van der Voort, 2013, p. 121) As the moving will occur infrequently and will be aided by leg and back muscles so although 200N is a good starting point, a margin of 25% can be added onto this. This will translate to about 25 kg per person maximum.

VII. **Requirement**: The design proposal should use feet.

Justification: This is to ensure a steady stance on uneven surfaces.

Quantification: The use of feet means that the design proposal touches the floor at least three separate contact points.

Aesthetics

VIII. **Requirement**: The design proposal should fit the Terrassenhaus.

Justification: To combat the problems outlined in 3.3 with the current furniture selection, the design proposal should be fitting with the Terrassenhaus. This makes sure that the narrative of the

building stays clear and unmuddied by incohesive (both with each other and with the building) furnishment.

Quantification:

The fitting of a design to its context is a fundamentally objective task. One thing can be said though. It is not simply a question of copying the context to the design, as seen by the many theories on harmonizing colours or interior design, contrast can be an important part of a harmonious composition. (Donahue, 2024).

Rather the focus of the question “does it fit” will be laid around the design ethos and narrative of the design matching up with that of the Terrassenhaus. Matching narratives will make de design part of the narrative of the building, strengthening it, and the matching design ethos will help in getting the approach to this narrative right. The narrative and the design ethos of the Terrassenhaus this can be found in *3.2.2* and *3.2.3* respectively.

Production

IX. **Requirement**: The design proposal should be producible by Loehr

Justification: For the design proposal to be a viable product, it needs to be produced. This mean that a contractor of Loehr would produce them. And although they have many contractors, some things they don’t have easy access to, for instance injection moulding or casting of metal. This could only be viable for a larger production run. Which is not the case.

Quantification: There are 27 outdoor benches at the Terrassenhaus, saying that about 1\3 of those would be initially replaced, this leaves an initial production run of 9 benches. This is the amount that should be producible at Loehr contractors.

Repairability

X. **Wish**: The design proposal should have parts that are repairable or replaceable.

Justification: As a product is used, some parts may become damaged, this should not mean that the whole product should be replaced or thrown out. Ideally the most likely parts to be damaged should be easiest to be replaced. This elongates the possible lifespan of the product.

Quantification: The bench should be made from separate parts that are joined together in a way that is reversable, for instance with bolts. To be replaced parts should be easily reproducible.

4.3 Data sheet design requirements.

These are the measurements summarized from *4.2 Design requirements.*

They answer sub question 6. *What measurements fit the needed typology?*

#	Description	Quantification	Justification
III	Minimal depth for the seating surface	304mm	(Feizhou, 2001)
	Height for the seating surface	460 mm	375mm+20mm (F_5 popliteal hight + thin sole) + 490mm+35mm (M_{95} popliteal hight + high sole) / 2 = 460 mm
	Minimal width for the seating surface per person.	605 mm per person in the middle 552.5 mm per person on the edge	525mm (elbow width M_{95}) + 80mm (thick winter coat) = 605 mm
V	Vertical load	1500 N per intended person, spread evenly on the sitting surface.	100KG is M_{95} + 150% safety
	Horizontal load.	200N per person, per axis.	
	Deformation at max load	Maximum 25mm Wish 10mm	
VI	Maximum weight.	Maximum: 50 kg Wish :25 kg	Maximum 250N exertion per person

Table 4.1 Data sheet technical requirements

5 Concept Generation

The design process is broken down into three steps:

Concept generation

Concept development

Concept detailing

In this chapter, the road to the answer to the main question, *What would a fitting outdoor furniture solution look like for the Terrassenhaus?* will is started.

In this phase the main form finding is done. The end result of this phase is concluded into four basic concepts.

This phase is stylistically guided by the COP/CON matrix.

This matrix is used to explore the relationship between the furniture and the building. Because in making furniture and a building match it is not always best to copy the features of the building. Contrasting form or materials therefore should also be explored.

This matrix guides this process and makes sure that no combinations are overlooked.

	Contrasting material	Copy material
Contrasting form	CONF CONM	CONF COPM
Copy form:	COPF CONM	COPF COPM

Table 5.1 COP/CON matrix

Each part gets a collage with suiting furniture and materials, this helps with visualising these sections of the matrix. From there separate ideation stages are performed. Which will all yield a single concept to develop in later chapters.

It should be reiterated that this matrix is solely used for concept generation, to enhance the spread of ideas, but is not later used for concept development or detailing. Here the narrative and design ethos take precedence over the matrix because of this is more closely related to fitting with the Terrassenhaus. All the spots of the matrix could fit the Terrassenhaus equally well, since contrast or copy can both be work at fitting with the building. The outcome of this concept generations stage does not say anything about what combination in the matrix is best suited to fit a design to its context.

5.1 COPF COPM

Figure 5.1 Copy form Copy material collage, (1-4 own work, 5 (Frama, 2011), 6 (wonderewoonwereld, sd), 7 (islandliving, 2020), 8 (Martlewood, 2020))

As established in chapter 3.2 the shape of the Terrassenhaus is dominated by heavy shapes, uniform materials, and straight forward construction techniques. This lends itself well to concrete structures, which often have a single material and a single production technique. Other materials used are galvanised steel, aluminium, and plywood, which are all unpainted and are only coated (in the case of galvanisation or anodization) to protect it from the elements.

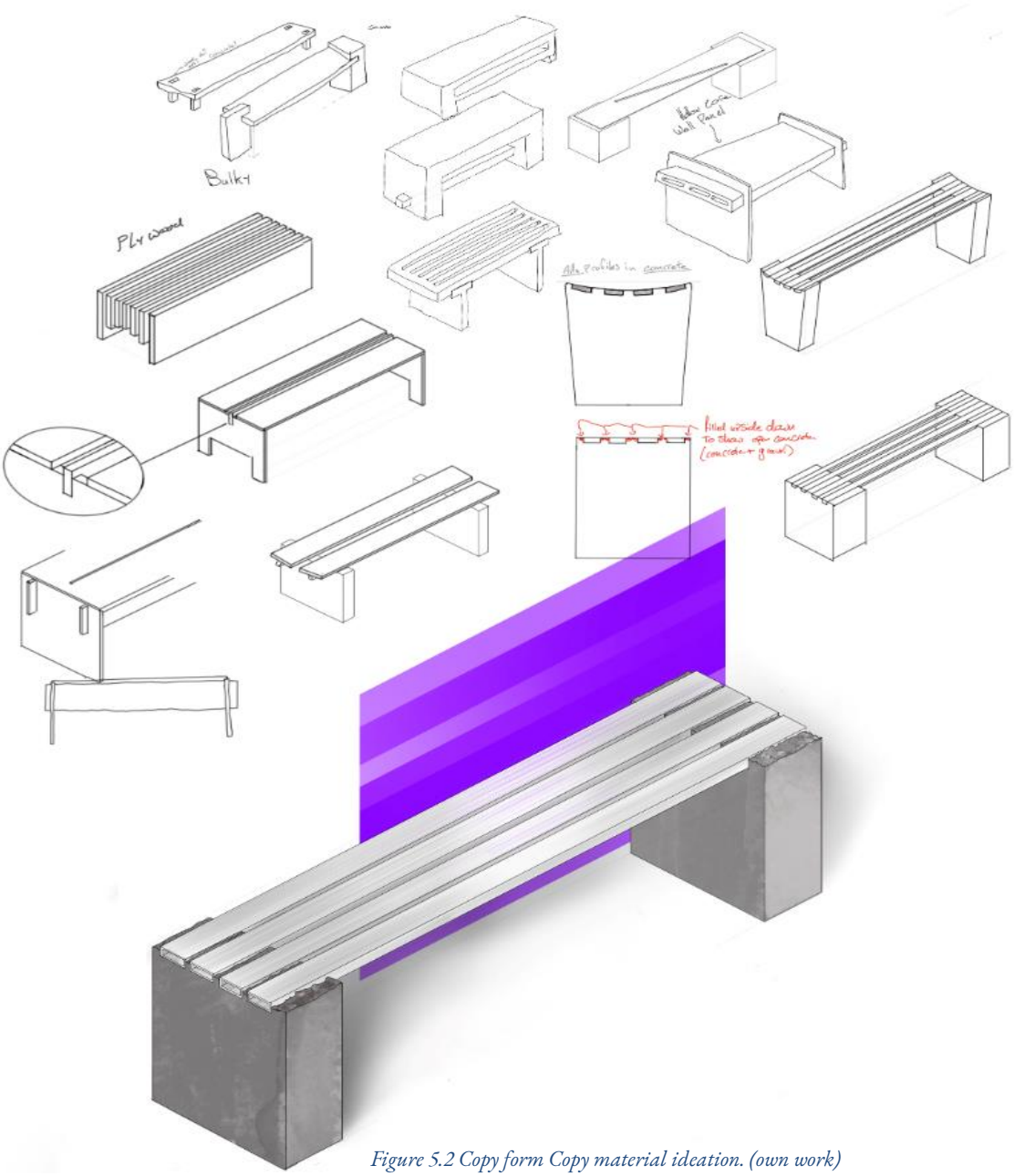


Figure 5.2 Copy form Copy material ideation. (own work)

Concept 1 has focussed on the strengths of the available material in this part of the COPCON matrix. Concrete is strong in compression, and aluminium tubing is strong in bending forces. This is combined by another natural strength of one of the materials, the possibility of pouring concrete to shape to moulds. Using the aluminium extrusions in the mould the concrete shapes to the aluminium, and if done imperfectly, still imprints this building technique upon the user with its unfinished top surface. The main points to look at in further development are the weight of the bench and use of different shaped extrusions. The weight of the bench might be a problem, as calculating this bench comes up to about 120 KG, which is much above the maximum of 50KG, *Table 4.1 Data sheet technical requirements*.

5.2 CONF CONM

Figure 5.3 Contrasting form contrasting material collage. (1, 7 own work). 2 (modular railing, 2018), 3 (Hendriksen, 2023), 4 (mirrorinox, 2012), 5 (Grcic, Hut-ab, 1998), 6 (Noo.ma, 2021), 8 (Grcic, Sam Son, 2015), 9 (Toogood, 2023), 10 (Giovannoni, 2006))

Although contrast is somewhat subjective, some things can be said, for instance that the opposite of a heavy structure is a light one, and the opposite of a square, blocky structure is a rounded, organic one. Combine this with contrasting materials which can be interpreted as more colourful, more polished, or more natural materials like powder coated metal, chrome coatings or natural wood. Especially this last one seems to be used often at the Terrassenhaus in the form of tree stumps as doorstops and wooden furniture. This spot in the matrix often is occupied by playful designs. But also, some more classic wooden designs fit in here.

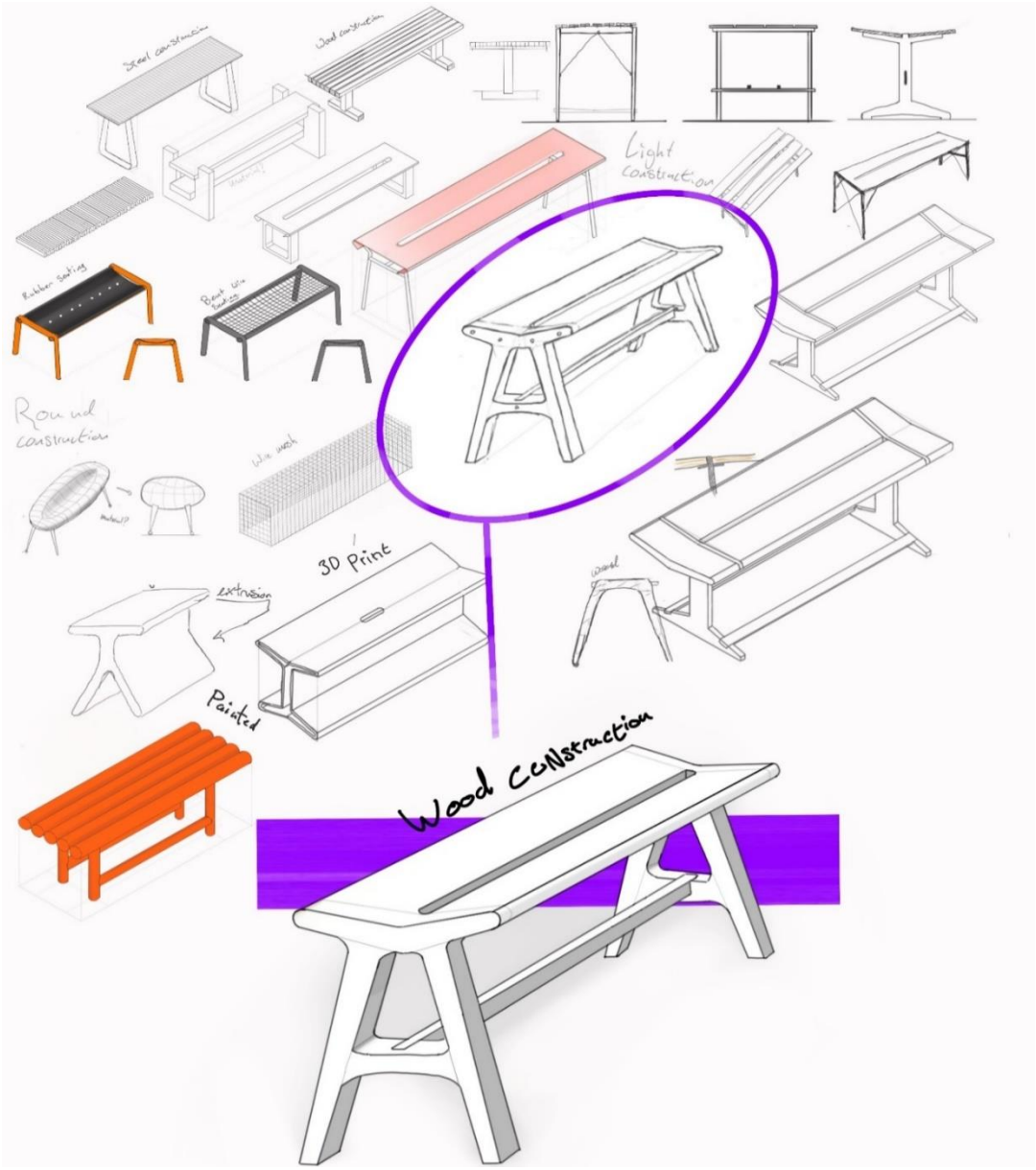


Figure 5.4 Contrasting form contrasting material ideation. (own work)

Concept 2 is a wooden bench with semi-organic shape, rounded corners but still sharp edges. The seating surface is slanted inwards for comfort and water management, construction can be done by glued dowel joints. This concept is chosen out of the ideation field because of its straightforward construction, and aesthetic value. It is not exceedingly avant-garde or experimental. But a well-rounded wooden bench design. Its weak points are its material, wooden construction is prone to rotting and can therefore degrade over time. Careful choosing of the wood type and joint types is therefore important in further development.

5.3 COPF CONM

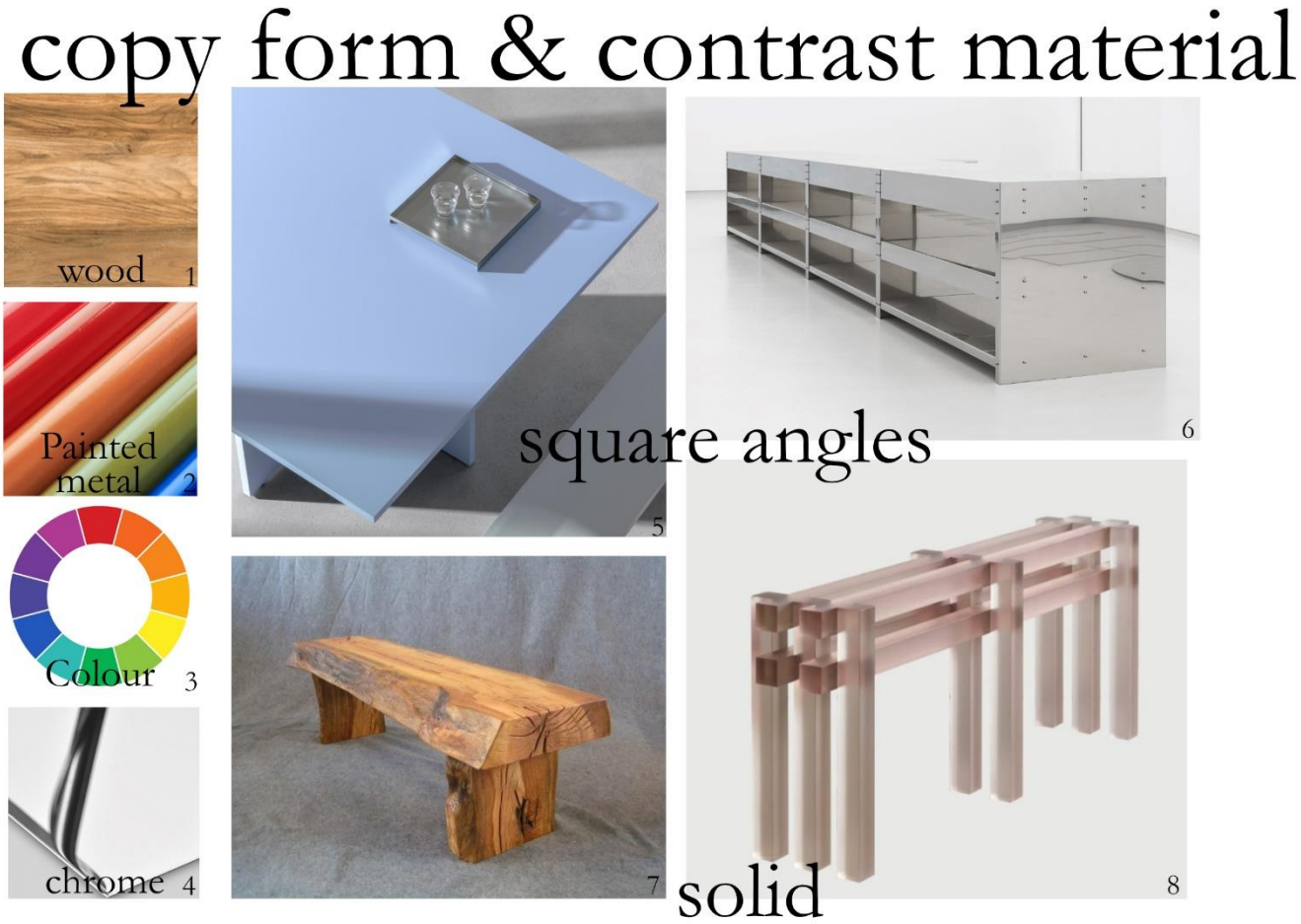


Figure 5.5 Copy form Contrasting material collage. ((1 own work, 2 (modular railing, 2018), 3 (Hendriksen, 2023), 4 (mirrorinox, 2012), 5 (Loehr & Loehr, 2021) 6 (nm3, 2020), 7 (forest creations, 2011), 8 (Gallee, 2023))

When the form stays blocky, solid and square, but the material changes to a more contrasting, there seem to be more simple constructions, working with solid colour planes or blocks. Or solid material blocks like thick natural wood. This solidness of course lends itself to some materials more than others and becomes difficult to realize when looking at painted metal. Here the use of sheet metal is used to give a solid appearance without the weight of a solid block of metal.

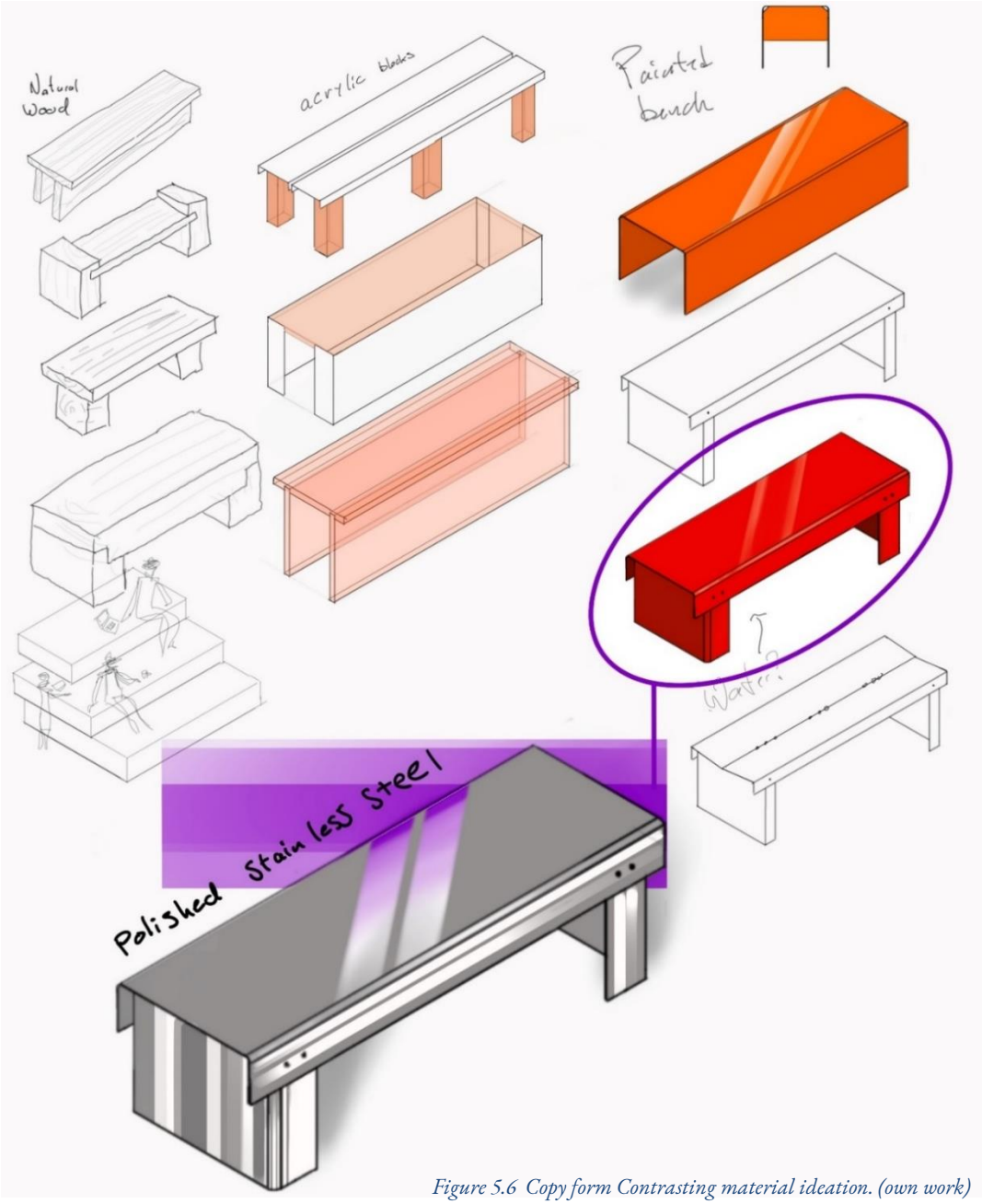


Figure 5.6 Copy form Contrasting material ideation. (own work)

Concept 3 is a simple to produce and construct sheet metal bench made out of polished stainless steel. Polishing stainless steel can bring it up to a mirror like finish and is extremely corrosion resistant, even more so than unpolished stainless steel. The simple bends and shapes of the metal and the possibility to take the legs makes replacement of parts possible and easy. The main yet to solve problem in further development is dealing with standing water. Next to that some practical things still need to be design through like the connections, attachment of feet and the ideal thickness of the metal.

5.4 CONF COPM

Figure 5.7 Contrasting form Copying material collage. (1-4, 8-9 own work, 5 (fialin, AC01-chair, 2024), 6 (fialin, spagetti shelf system, 2022), 10 (nm3, 2024))

When contrasting the form but copying the material, the previously blocky concrete structures become less classically concrete, and go more towards organic shapes. This is however not the ideal shape for concrete so focus on the other materials is laid. This than creates light and thin structures from raw metal or even organic shapes with it. This spot in the matrix often created more avant-garde designs and is home to more stylistically experimental designs.

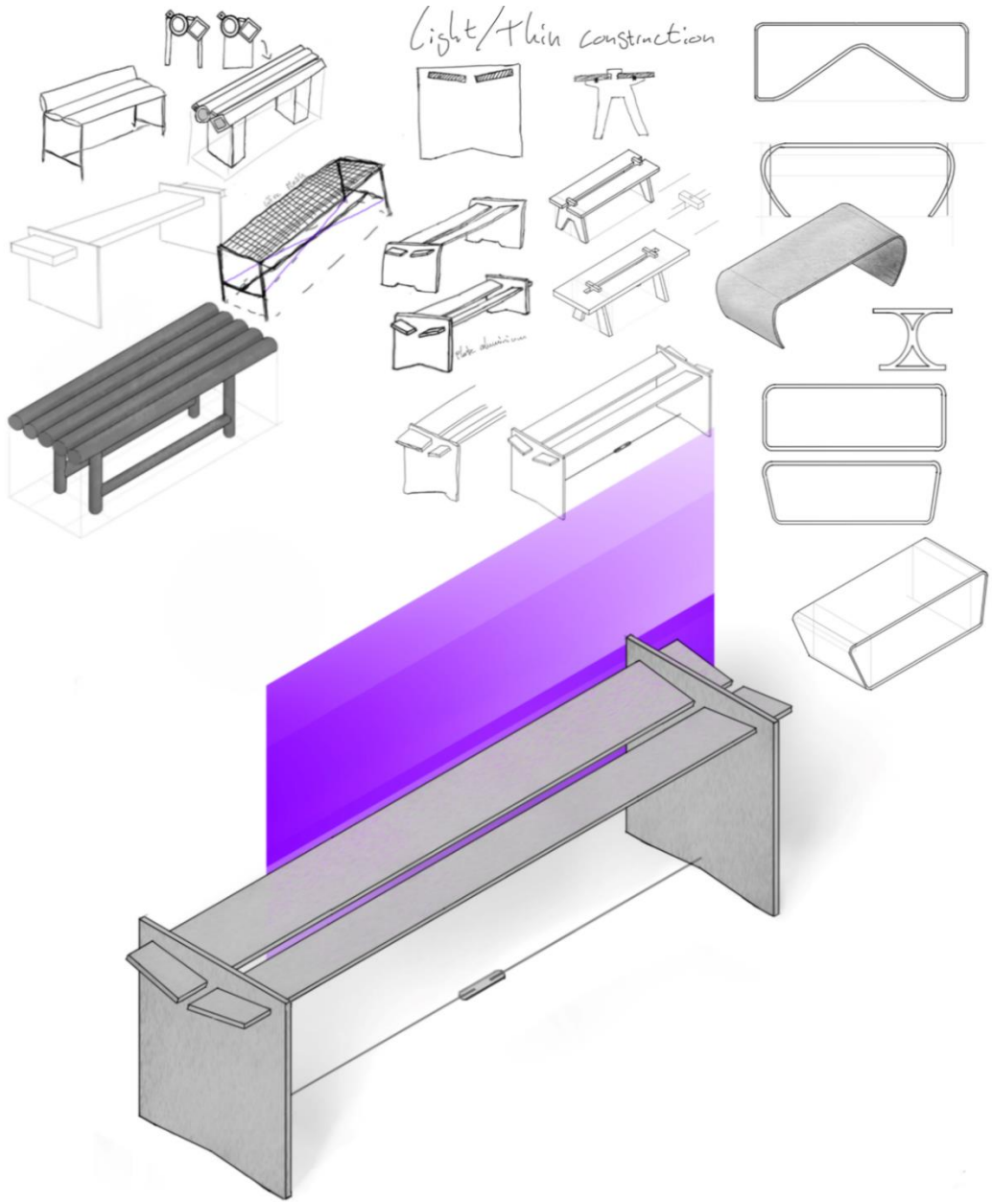


Figure 5.8 Contrasting form Copying material ideation. (own work)

Concept 4 is built around the mechanical idea of a sticky drawer or a screw clamp. In this case the moment created in the upper corners by tensioning the cable below causes the connection in to stick. This is very effectively used in screw clamps and is a reliable way of making an adjustable tensioned connection. With this connection it eliminates the need for more parts, welding or even screws. Making replacing parts exceptionally easy. The form is one of thin angled plates, giving it a certain lightness. The main points to consider in further development are the validity and optimisation of this mechanical connection and the resistance to bending moment.

5.5 Conclusion to the concept generation.

Four basic concepts are the result of the concept generation, all made with different construction techniques, forms and materials (on materials there is some overlap). Working with the COP/CON matrix has helped with exploring the different ways of harmonizing with a particular context.

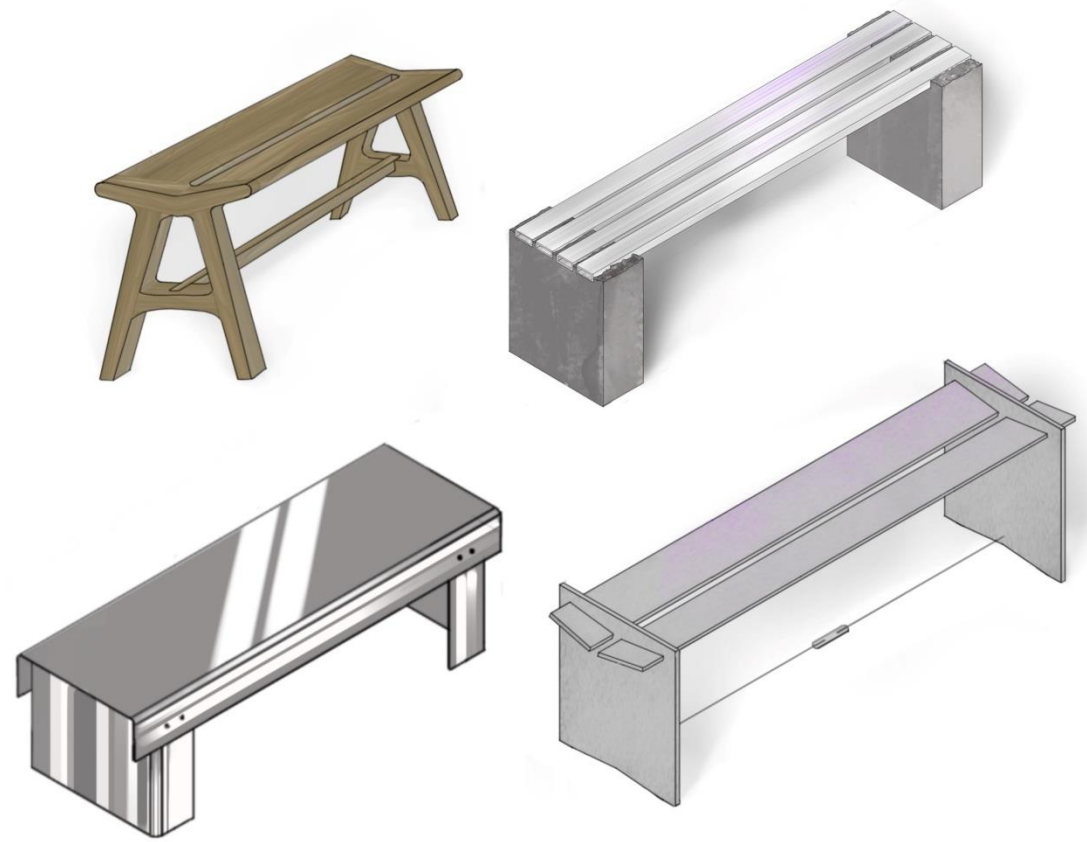


Figure 5.9 Basic concepts collection. (own work)

6 Concept development

In this chapter, the basic concepts generated in the previous chapter 5. Concept Generation are being developed further. This is done in a pragmatic way. This is a similar way the Terrassenhaus was designed as concluded in *3.2.7*. Emulating the same design ethos, will help the further development get closer to fitting the Terrassenhaus. One of the ideas this design ethos is centred around is designing by solving problems in a low effort way. This means solving the concepts main flaws regarding the Design requirements in with the least amount of effort.

With this technical and aesthetic conclusion of the different concepts a choice can be made as to which one is most promising and should be developed further in the concept detailing phase.

6.1 Concept 1

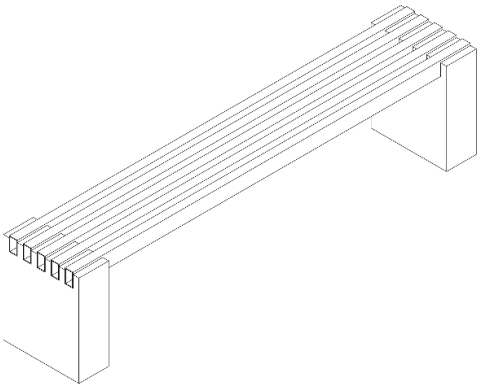


Figure 6.3 Concept 1, line drawing. (own work)

Further development of concept 1 is concentrated around one point, trying to reduce the weight of the design, this is its most significant problem at the moment.

The main weight comes from the two concrete blocks. These weigh 80KG each. There are two options for weight reduction. Using a different material or using less material.

Figure 6.2 porous concrete. ((Chen & Chen, 2019)

Porous concrete can be about 30% lighter than regular concrete, (Islam, 2023). Using porous concrete in the design is not an option due to the different texture and aesthetic quality, which does not match the concrete at the Terrassenhaus. Therefore, using less concrete is chosen to tackle the weight problem. In Figure 6.1 some SolidWorks mass calculations are done, the basic concept, It. 1 is as seen way over the weight limit. The other iterations are lighter, but not light enough, with the lightest one being 37.78 KG per block, this is almost than twice the design requirement limit of 50 KG when doubled for both sides and the aluminium extrusions added.

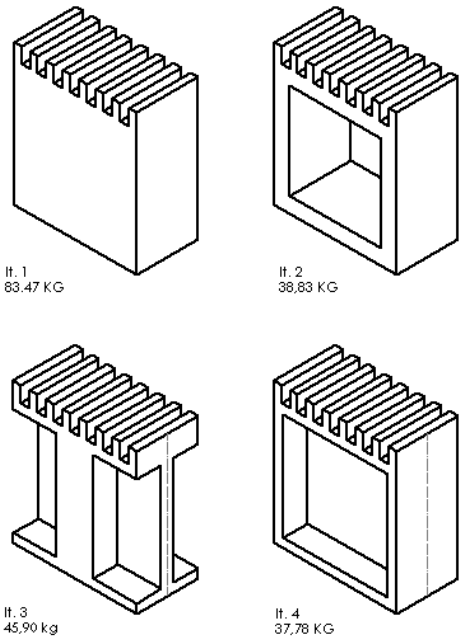


Figure 6.1 Concrete block iterations. (own work)

To conclude, the weight has not lowered enough to have the bench carriable, and further weight reduction is difficult with this design, given the material use. Having a heavy bench does also have benefits like, being harder to steal or break. Although this does change the typology, and is less suited for use at a table, for which it should be movable to bring it closer or further away from the table. All of this will be taken into account when choosing the concept for the next phase. As for choosing an iteration, as is the theme for the Terrassenhaus *3.2.4*, simplicity in form is important, something that the first Iteration of the concept had more than any further Iterations. Thus, this basic concept is held as the basis to build on in the next phase.

6.2 Concept 2

Further development of concept 2 is concentrated around the problem of using wood outdoors, and how to minimize the problems it might cause.

The basic concept 2 is a simple wooden bench, which is fully constructed with dowel joints.

Simply screwing together would not be advisable because of the uncontrollable outdoor environment the differential expansion and contraction of the screws can become a problem, creating lose joints and entry points for water. (Hoadley, 2000)

A glued dowel joint does not have this weakness.

Although, dowel joints bring their own disadvantages, dowel joints are impossible to take apart later

Figure 6.4 Concept 2 first iteration. (own work)

without the risk of serious damage, this restricts repairs or replacement of parts, making the bench have a limited life. Going against Wish X.

To solve the above-mentioned problems, the second version is conceived, it has symmetrical metal uprights and horizontal wooden sitting surfaces.
This design uses metal screw inserts and no dowel joints, this way all joints can be retightened whenever needed.
Because the wooden parts are simple to manufacture wooden planks, they are easily replaceable if they get damaged or rot over time.

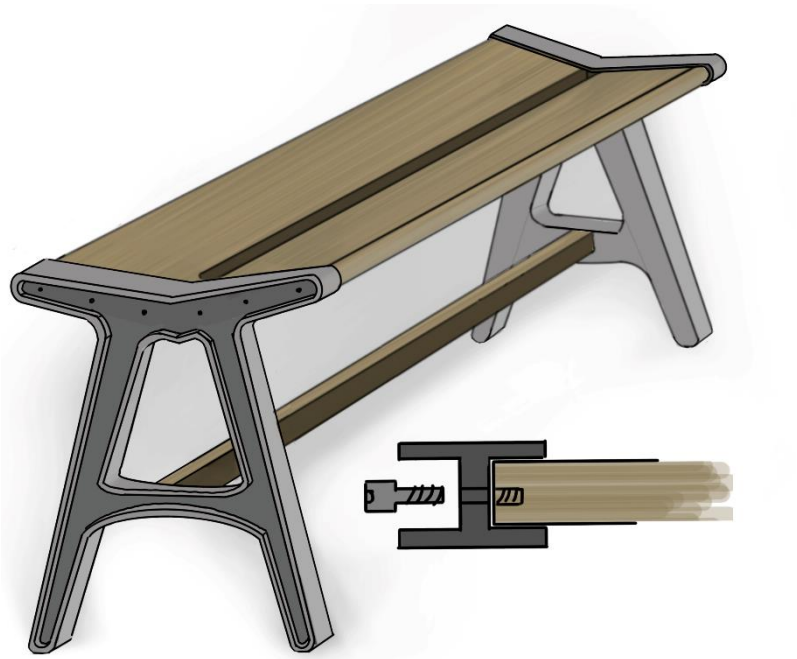


Figure 6.7 Concept 2 second iteration. (own work)

Figure 6.6 Cast iron bench with wooden slats. (Demak, 2008)

Figure 6.5 Threaded nut inserts. (KOSHIFU, 2022)

The metal would be cast iron, which can be painted with an oil-based enamel paint that sinks into the material and stays water resistant for a long time. The wood should be treated with a varnish but will still be susceptible to rot over a long period of time. Using the right kind of wood like, Iroko, Oak, Western Red Cedar, Cherry or Maple (duffieldtimber, 2022), can already greatly elongate the life of the wood but it will need to be replaced after a long period. This is made possible due to its construction, which is inspired by old cast-iron and wooden benches that have lasted centuries due to exactly this idea. See Figure 6.6.

6.3 Concept 3

Further development of concept 3 is concentrated around two points, formalizing the attachment of the legs, and solving the water drainage problem.

Concept 3 will be constructed with clinch nuts *Figure 6.10* and socket head cap screw. These together give a strong connection for connecting Sheetmetal and are easy to install.

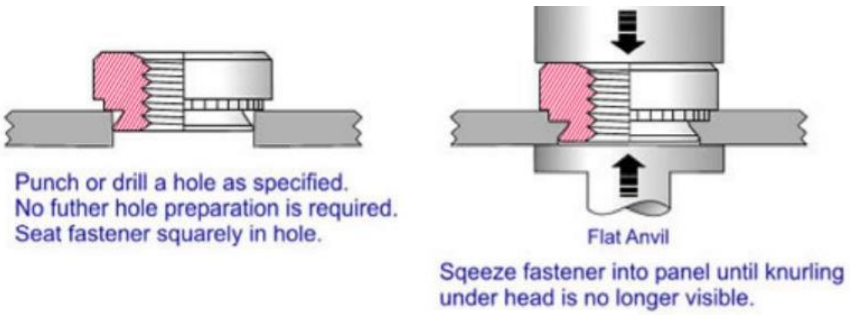


Figure 6.10 clinch-nut diagram. (Gupta & sons, 2008)

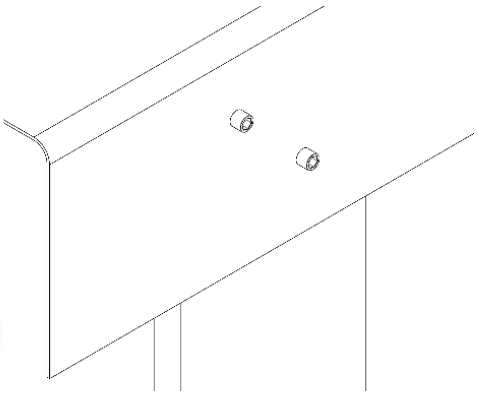


Figure 6.9 construction close-up (own work)

The main force transfer will occur between the friction of the bare stainless steel that is facilitated by force applied between the clinch nut and the bolt. The water drainage problem can be solved in several ways, as seen in *Figure 6.8.*

Iteration 1 is the original design without water drainage.

Iteration 2 has a perforated top surface, this would give excellent water drainage and cut down on weight.

Iteration 3 has a slanted surface which would drain water adequately and has a bonus to improve the ergonomics of the bench. The legs of this iteration are also folded to match the top.

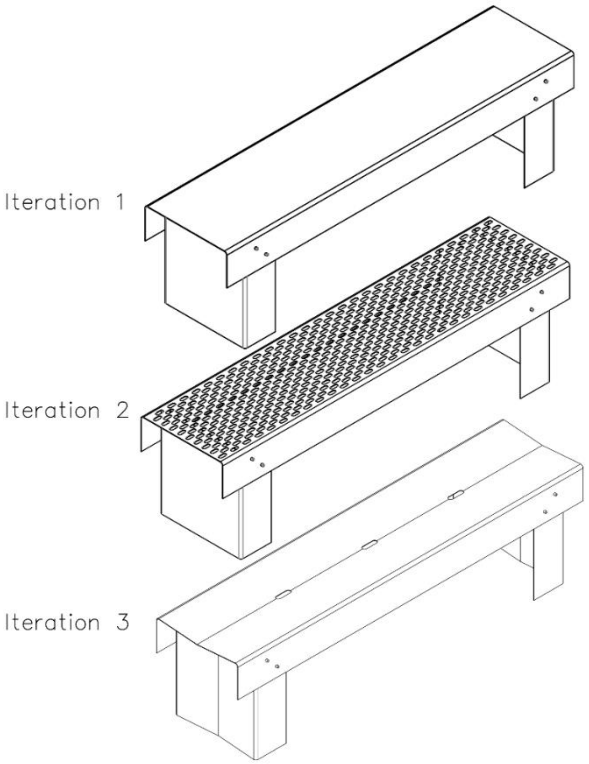


Figure 6.8 Concept 3 iterations. (own work)

The choice between the iterations has fallen on iteration 3, this bench has drainage added without losing the original design ideas. Iteration 2 has stepped too far away from the original solid design. The added ergonomic bonus is also very welcome since metal isn't a naturally ergonomic material.

6.4 Concept 4

Concept 4's main point of focus is its structural soundness. The concept uses a construction technique that is highly unusual for furniture, with the most common use being screw clamps. Thus, this technique must be calculated and tested before any further design work can be done.

The '**sticky drawer effect'** is the mechanical jamming of a slide on a guideway due to tilting. This tilting is caused by an asymmetrical force (**T**) that is applied to the slide, this causes friction between the slide and the guideway, with a certain geometry between the guideway, the slide and the offset of force, this mechanical connection jams, only stopping when all force is taken off T. Concept 4 relies on this jamming for its corner connections.

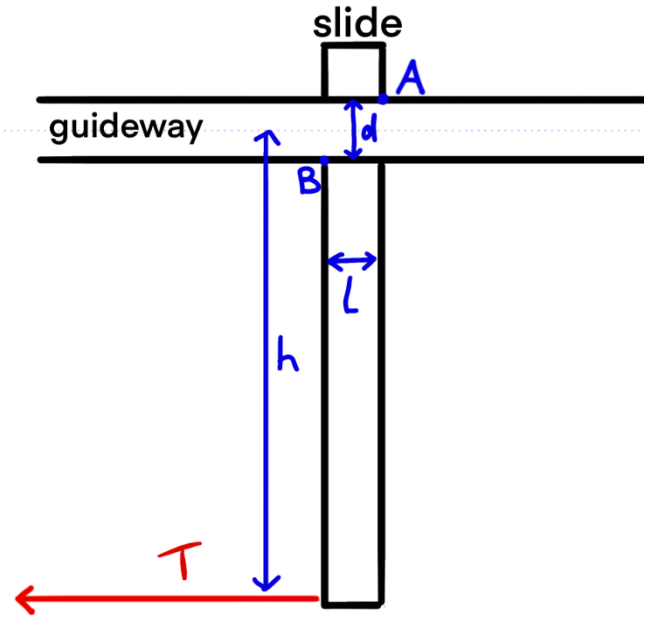


Figure 6.11 Sticky drawer effect diagram (own work)

The formula for jamming in this effect is:

$\boldsymbol{\mu > \frac{l}{2h}}$, the full explanation of this formula is found in *Appendix*.

In concept 4 the material thickness ***(l)*** would be between 5-20 mm, and the hight ***(h)*** would be around 460mm. For the right side of the formula this results in: $\frac{20}{2*460}$=**0.022**

The friction coefficient (***μ***) of aluminium on aluminium is 1,05-1,35 when dry and clean, and 0,3 when lubricated and greasy (The Engineering ToolBox, 2004).

This means that the worst-case scenario, with a greased-up contact surfaces and the thickest material expected to be used, the friction coefficient (***μ***) is more than13x bigger than necessary. And best-case scenario almost 250x bigger. For concept 4 this means that the reliability of the corner connection is high.

To test this in practice a 1:10 model is built out of 2mm thick aluminium.

No formal test are done on the model, but the connection between the plates did not slip with any of the informal testing. Thus further reassuring this part of the construction.

Knowing this, further iterations of concept 4 are made.

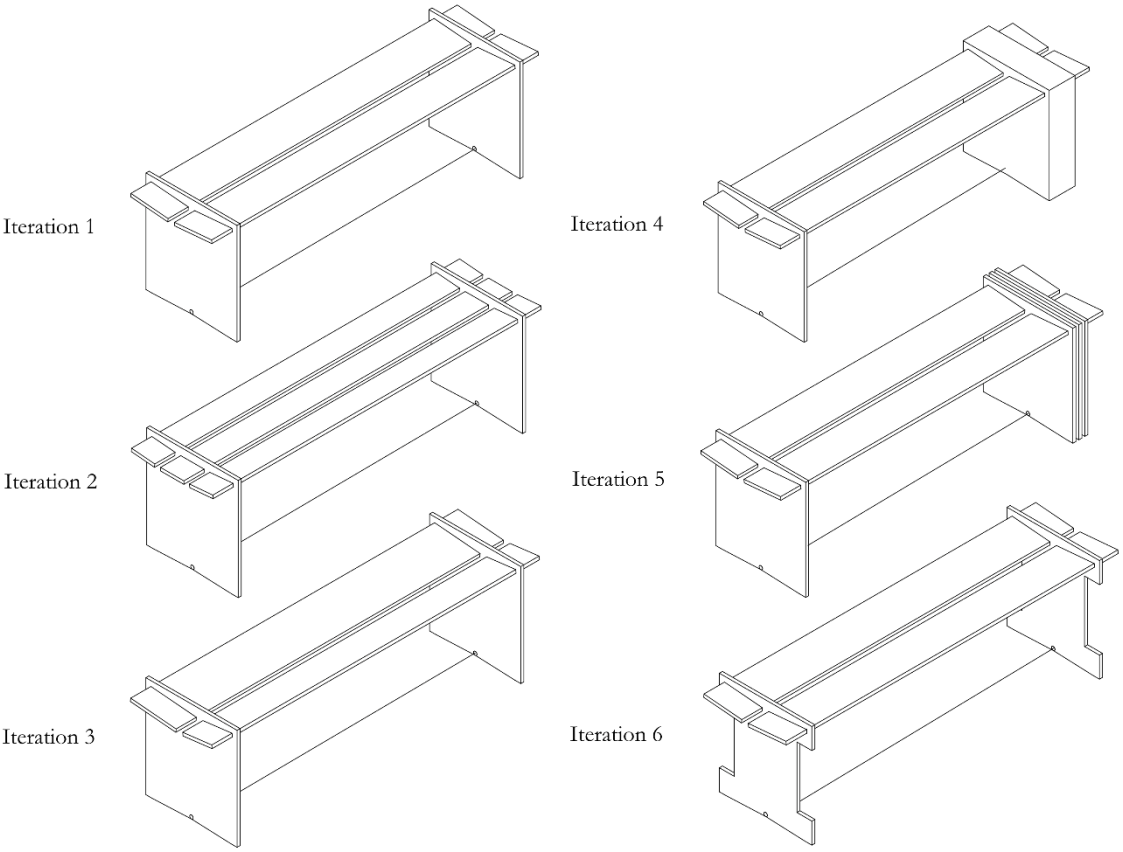


Figure 6.12 Concept 4 iterations (own work)

Allthough many iterations of concept 4 were made, none were deemed an improvement on the first concept. For iterations 2 and 6 the problem was increased visual complexity withouth any added functionallity. This goes against the design ethos of the Terrassenhaus.

Iteraions 4 and 5 do have an added functionality of a flat surface to perhaps put a drink or a plantpot on, but this does not weight up against the added complexity. For these reasons iterations 2, 4, 5 and 6 are not pursued.

Iteration 3 does not have this complexity problem, but does have the problem of stepping away from the symetrical design. This symetrical design was a bonus for production and replacement parts, having less unique parts and for use, giving the same amount of comfort either way you sit.

To conclude, no improvements to the original concept could be made at this stage, this does serve to build trust in the current concept.

6.5 Choosing a Concept

To choose a concept, an assessment table of all concepts with several weighted factors is set up. This is done because there are many factors that go into the design, all with different importance, using a weighted assessment table therefore can take all of these into account and give the most accurate assessment of the given concepts. These factors are selected from the design requirements 4.2. Some design requirements were not used as all concepts complied with them equally or were not known yet because they were outside the scope of this chapter. The most important factor is the fit with the Terrassenhaus, because this is essentially the whole point of the thesis, weather resistance and repairability are also important because of the need for a long lifespan of the product and for this, these factors are essential. The weight is less important because the bench does not have to be especially mobile, although the possibility to move it around should still exist and be within reach of the average person(s). The producibility is also not a main concern because the initial production run is low and the product is not meant as a market product. Thus, production is less important. It is important to note that if the design is not producible at all, this would be a reason to decline the concept, since any form of production would still be needed.

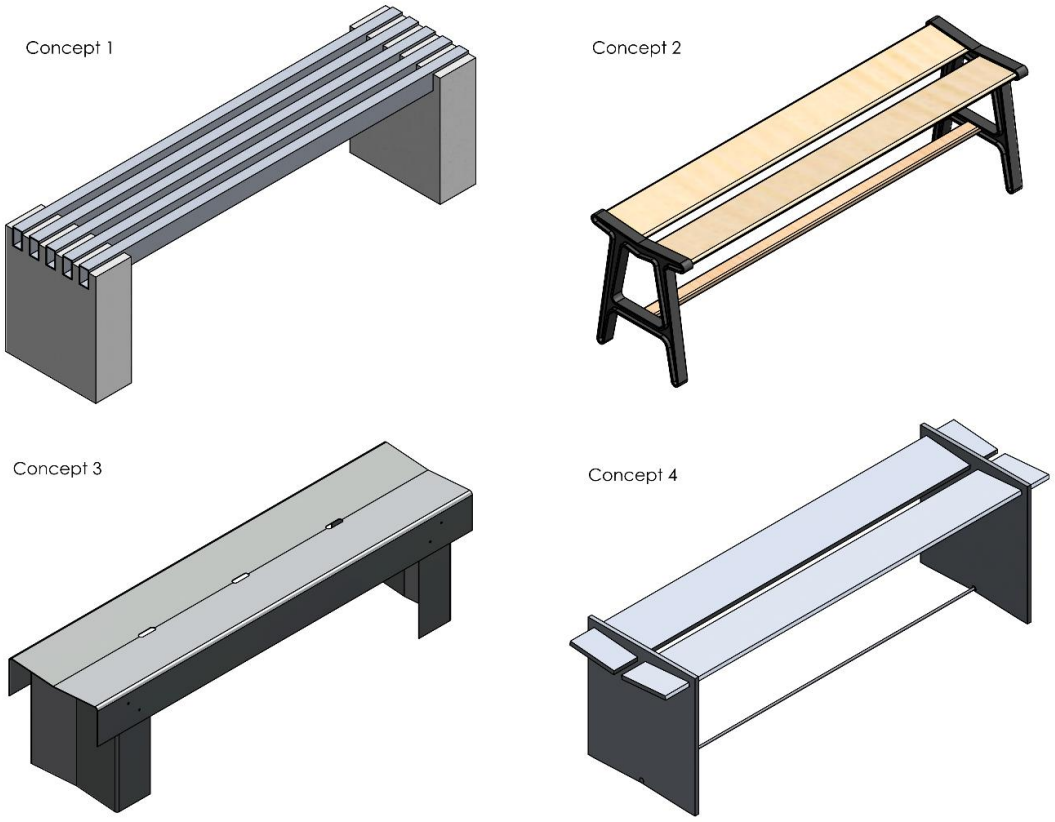


Figure 6.13 Concepts from concept development stage (own work)

	weight	0/5	1/5	2/5	3/5	4/5	5/5
Fit with the Terrassenhaus	3	There are no aspects that are coinciding with the narrative and/or design ethos.	There are very few aspects that are coinciding with the narrative and/or design ethos.	There are few aspects that are coinciding with the narrative and/or design ethos.	Either the narrative or the design ethos matches the TH well.	There are several aspects that are in line with the narrative and/or design ethos of the TH.	Both the narrative and design ethos match the TH perfectly.
Weather resistance	2	All materials are not corrosion or rot resistant and have no protective coating. Standing water is not eliminated.	All materials are not corrosion or rot resistant but have a protective coating that is easily damaged. Standing water is not eliminated.	All materials are not corrosion or rot resistant but have a robust protective coating. No standing water.	Most used materials are corrosion and rot resistant. No standing water.	All materials are corrosion and rot resistant. No standing water.	All materials are corrosion and rot resistant. No standing water. There is no chance of significant aesthetic blemishes over time due to water damage.
Repairability	2	The need for repair is likely but parts cannot be replaced.	The need for repairs is likely and replacement parts are not easily sourced and replaced	The need for repairs is unlikely but replacement parts are not easily sourced and/or replaced	The need for repairs is likely but replacement parts are easily sourced and/or replaced	The need for repairs is very unlikely but replacement parts are not easily sourced and/or replaced	The need for repairs is very unlikely and replacement parts are easily sourced and/or easily replaced.
Weight	1	<50KG	50-44 KG	43-37 KG	36-30 KG	29-25 KG	>25KG
Producibility	1	The concept is not producible.	The concept is not producible in the intended numbers.	The concept is producible in the intended numbers but there are high costs with the process.	The concept is producible in the intended numbers.	The concept is producible in the intended numbers and uses generic production methods.	The concept is producible in the intended numbers and uses generic and easily scalable production methods.

Figure 6.14 concept assessment table

Concept 1

Fit with Terrassenhaus:

Concept 1 is deemed to fit well with the Terrassenhaus, its pragmatic way of construction. (using concrete for compression forces and aluminium extrusions for bending forces) capture the ethos of the Terrassenhaus. Also the narrative is partly emulated with its longevity of materials. The only thing that is missing is the changeability for the future that is important for the narrative. **4/5**

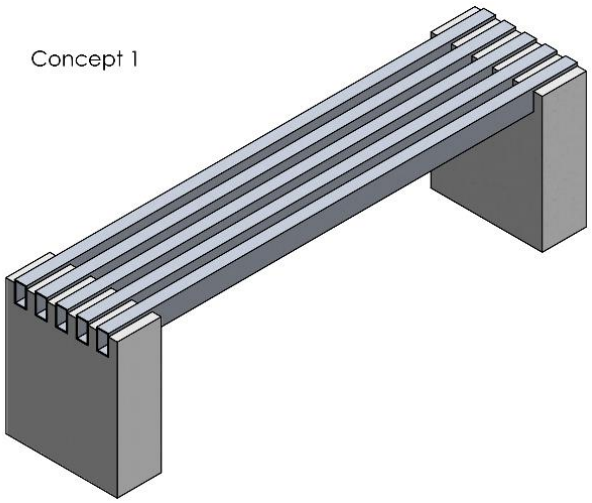


Figure 6.15 Concept 1 (own work)

Weather resistance:

Concept 1 is made out of non-corroding materials, these will last for a long time, only some dullness may occur from surface oxidation on the aluminium. **4/5**

Repairability:

Concept 1 has no replaceable parts, this is caused by its production technique that pours the concrete around the metal. Luckily the materials used are all fairly corrosion resistant and will not degrade meaningfully over time. **4/5**

Weight:

As earlier mentioned in 6.1, the weight of this bench is too much (127KG). This gives it bottom marks. **0/5**

Producibility:

Although concept 1 is produced with a single production technique, (pouring concrete) and once set up, the intended numbers can be produced, technique is not generic for furniture builders **3/5**

Concept 2

Fit with Terrassenhaus:

Concept 2 is deemed too complexly shaped and ornamental to fit well with the design ethos of the Terrassenhaus. Also, the narrative is not exactly followed, with mediocre toughness and the need to replace parts after a long-time use. Although the initial idea of this bench was to contrast the Terrassenhaus, the route taken did not yield a fitting design. **1/5**

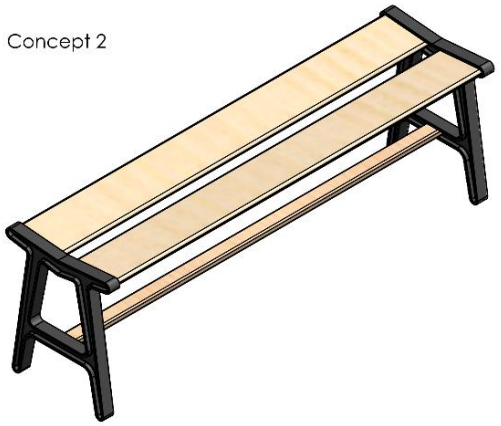


Figure 6.16 Concept 2

Weather resistance:

Concept 2 has a wooden sitting surface and a cast iron side construction. The wood is the main concern and even though it might get a protective coating, damages to that coating cannot be avoided during its lifetime. This will eventually cause wood rot. The metal is less of a concern due to a tougher coating and a tougher base material but essentially has the same problem. **2/5**

Repairability:

The planks of the seating surface will need to be replaced multiple times given the expected lifetime of the product, which is long given the narrative *3.2.2.* **3/5**

Weight:

Weight of concept 2 is only 24KG, This is under the 25kg wish, *See* Data sheet design requirements.*4.3.* Thus, granting it full marks. **5/5**

Producibility:

This bench, although a complicated shape, has only two production methods. Both of which are common. One major problem is the iron casting, which is often more used for higher quantities, not the initial 9-piece production run that is planned. This makes the production with casting extremely expensive. Another option would be machining the metal legs from plate steel, this however would extremely wasteful in material and cost a lot of machining time, which is costly. This however would be better suited for a small production run. **3/5**

Fit with Terrassenhaus:

Concept 3 is fairly robust, given its material choice, but is missing some of the changeability or modifiability that is also sought after in the narrative, the design choices are fairly pragmatic, using a simple production technique to establish a strong bench, although the middle bend in the vertical parts might be considered an aesthetic choice. **4/5**

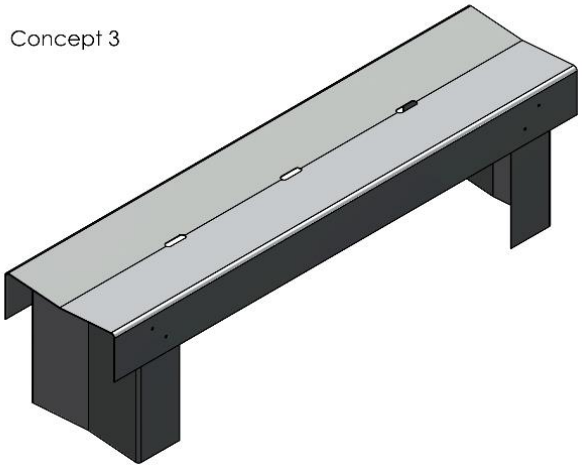


Figure 6.17 Concept 3

Weather resistance:

Stainless steel outside is very good at resisting corrosion, especially when polished. With its slanting surface it should not have standing water so even water staining should be kept at a minimum. Full marks. **5/5**

Repairability:

Although the parts are fairly robust, the thinner metal sheet is partial to dents, although this would not make the bench unusable. Also polished stainless steel can get scratched over time and might need repolishing to keep its mirror finish. The parts themselves are fairly easy to make and replace if bigger damages would occur. But all parts would require some specific fabrication to be replaced. **3/5**

Weight:

At 43 kg it is not particularly light, but it should be manageable with two people, it might become lighter due to material thickness optimisation, something that is not withing the scope of this chapter. **2/5**

Producibility:

As it is made of laser cut and bent Sheetmetal, both these actions can be performed quick and accurately at one producer, the finishing is often done at a different producer for polishing stainless steel is a somewhat specialized and time-consuming action and thus harder to scale up. Other than this the production is very straightforward. **4/5**

Concept 4

Fit with Terrassenhaus:

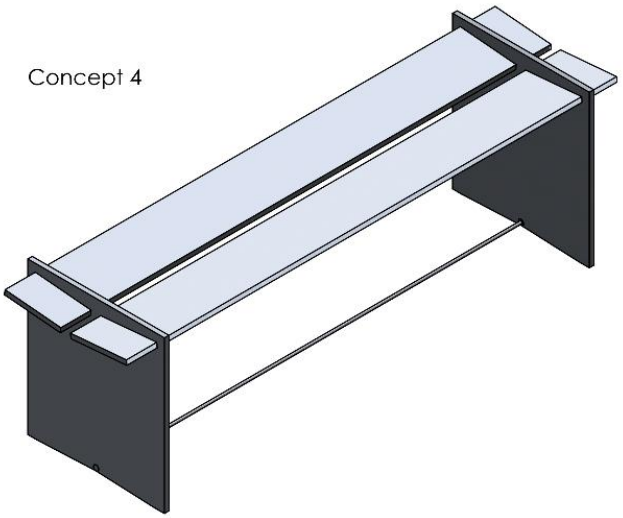


Figure 6.18 Concept 4

Concept 4 fits well with the Terrassenhaus, the narrative is clearly reflected in its robust construction and the possible modifiable and adjustable nature of the bench. The bench also fits well with the design ethos, only exhibiting design choices that are purely pragmatic, from the choice to keep all machining in the vertical plates, leaving the horizontal plates to be easily made and replaced, to the material choice which enables this construction, with aluminium needing no surface coatings that can get damaged. **5/5**

Weather resistance:

The weather resistance of aluminium can be very good, this heavily depends on the alloy of the material. Which will be specially chosen for its corrosion resistance. With the slanted surfaces there is no standing water. The only problem might be some surface oxidation which can bring some cloudiness to the bench. **4/5**

Repairability:

Not only are the parts and materials easily sourced and made, especially the top surface, they are also extremely easily replaceable. On top of that, because of the thickness of the material and the lack of any coatings that could get damaged, it is very unlikely that it would need to be repaired or parts would need to be replaced. **5/5**

Weight:

At 44 kg it is not particularly light, but it should be manageable with two people, it might become lighter due to material thickness optimisation, something that is not withing the scope of this chapter. **1/5**

Producibility:

The seating surface plates can be ordered directly from a plate cutting company, which is the cheapest and easiest way of production, the vertical plates can be cut with a waterjet cutter. The interesting thing about this design is that the tolerances don't matter as much as with the other designs. This is due to the tension-based construction method that takes up any slack from that might be caused by too loose tolerances. **5/5**

All of the previous analysis of the concepts results in the following table.

	Weighting factor	Concept 1		Concept 2		Concept 3		concept 4	
Fit with TH	3	4	12	1	3	4	12	5	15
Weather resistance.	2	4	8	2	4	5	10	4	8
Repairability	2	4	8	3	6	3	6	5	10
Weight	2	0	0	5	10	2	4	1	2
Producibility	1	3	3	3	3	4	4	5	5
			31		26		36		40

Table 6.1 Assessment table results

The result of which is clear, using this weighted factor method concept 4 come out the best. This therefore the concept to pursue in the next chapters. And this will become after further detailing the final design proposal.

7 Concept detailing

In this chapter the concept chosen in 6.5 will be developed further, this means to first identify the parts that need development and than to develop these parts of the design. The development includes simulations and technical models. The result of this chapter is the final design proposal and a 1:1 prototype to be evaluated.

Although the simplicity of the design, some concerns and unknowns are still to be looked into at this stage. These include the following:

The resistance to the forces / weight optimalisation.

Seat geometry.

The tensioning system.

The first one, resistance to the forces / weight optimalisation, is done by several simulations to determine the necessary thickness and construction of the bench. After this a wood 1:1 prototype is built to check the ergonomics of the seating surface.

With these final measurements several options for tensioning system are compared and once is chosen.

All these choices then come together in the final aluminium 1:1 prototype, this prototype represents the final design and is used to evaluate the success of the thesis.

7.1 The resistance to the forces / weight optimalisation.

To check if this construction can hold the needed weight and if not, to create solutions to improve this. With this the weight of the bench will possibly lower.

This step is done with SolidWorks simulations. With these an educated choice can be made on how to proceed with this concept.

There were several considerations to be take into account when doing these simulations.

a. **The design of the bench**
b. **The length of the bench**
c. **The thickness of the material**

Two options per consideration are taken to keep down the number of simulations.

a. There are two different iterations made of concept 4,

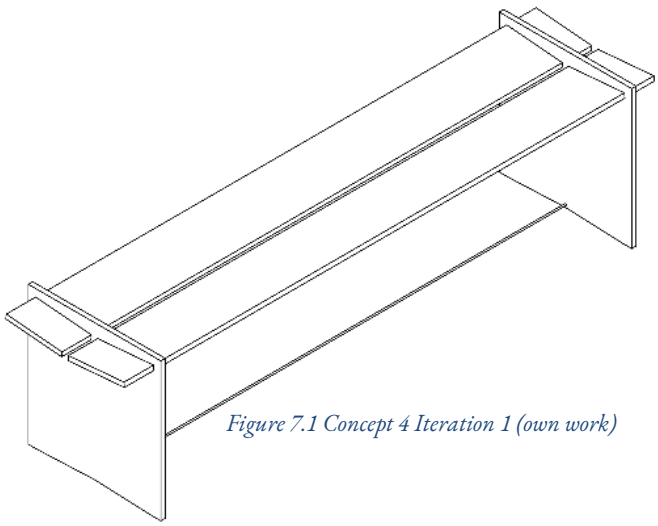


Figure 7.1 Concept 4 Iteration 1 (own work)

Iteration 1 is the original basic concept. Only consisting of four plates of aluminium.

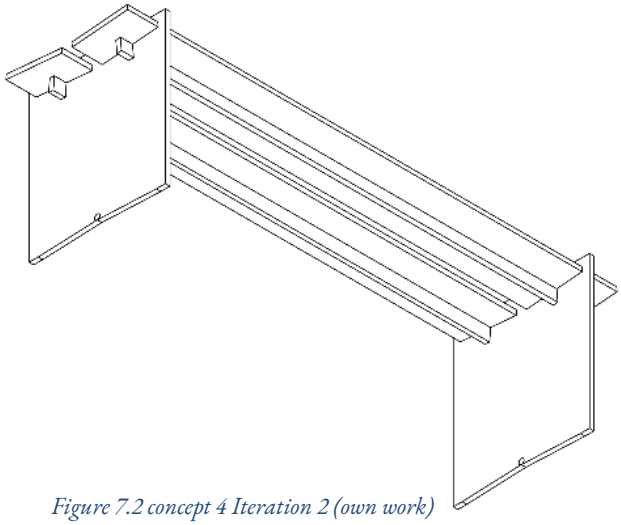


Figure 7.2 concept 4 Iteration 2 (own work)

Iteration 2 has two extra aluminium plates added under the seating surface, this is to give added resistance to bending stress.

b. Two lengths are chosen for the simulation. These are based on the two lengths Loehr uses for their JL8 Faber benches (Loehr J. , 2018). These seating surface lengths are 1400 mm and 1800 mm.

c. Two material thicknesses are chosen for the simulation: 10mm and 15mm. These two were chosen because thinner than 10mm would result in excessive bending in preliminary simulations and thicker than 15mm would make the bench heavier than 20KG, which is the wish limit in design requirement VI, *Table 4.1 Data sheet technical requirements.*

With these variables, 8 different configurations can be made. All these configurations were simulated in SolidWorks.
The aluminium alloy is 6082, a common alloy with a yield strength of 2.6 E +8 N/m^2. This alloy is chosen for its corrosion resistance and high specific strength. (matmatch, 2024)
In these simulations the bodies of the vertical and horizontal plates are bonded together but with separate meshes.
This means it is assumed that the sticky drawer effect stays and does not slide. This bonding is done because attempts at no penetration contact was met with hour long and subsequently failed simulations. The sticky drawer effect seems to be difficult to simulate, and since this mechanism is already in theory proven to work in 6.4, it is not necessary to simulate it further.
The forces applied were:
-4500N / 3750N for the 1800mm and 1400mm bench respectively (1400mm is seen as a 2.5-person bench) *Table 4.1.*
-1000N in tension on the cable.

Here are the results of the simulation.

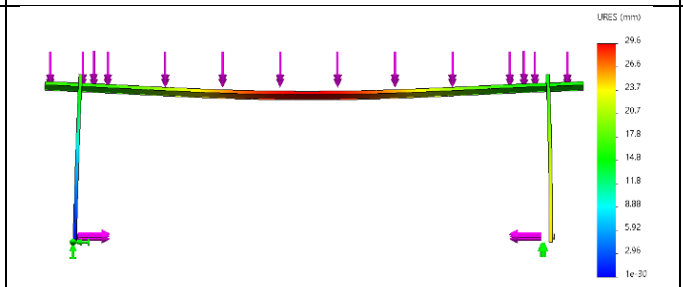
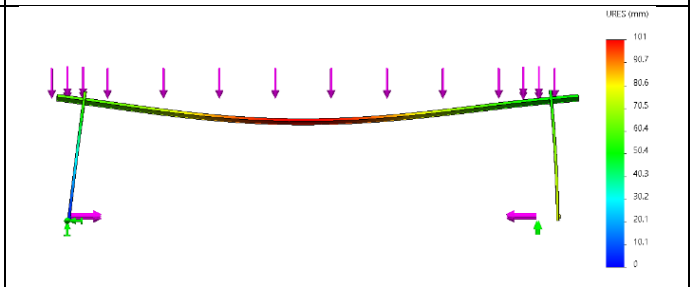
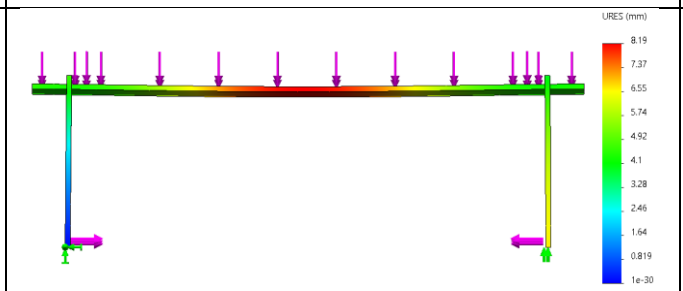
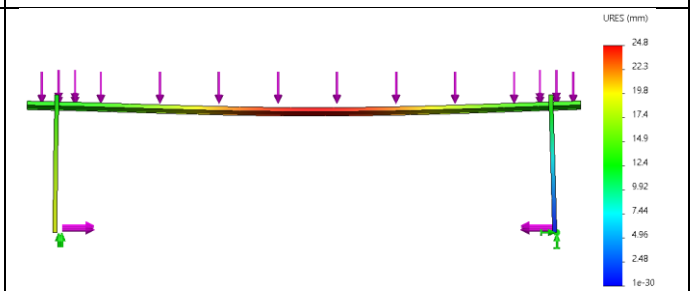
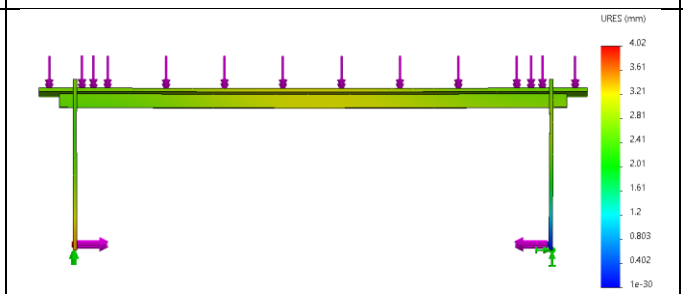
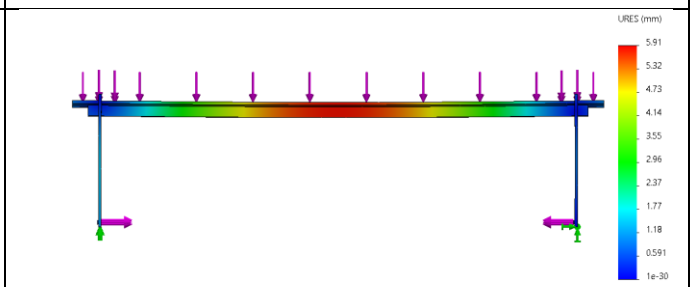
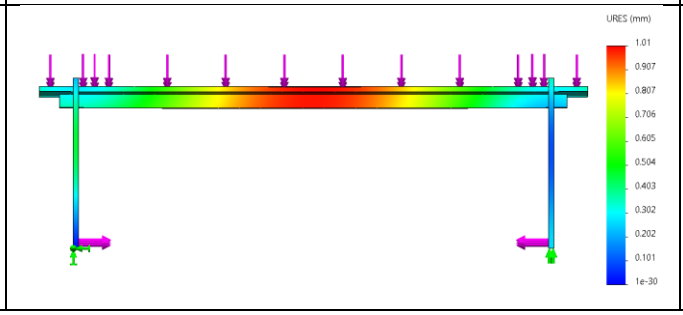
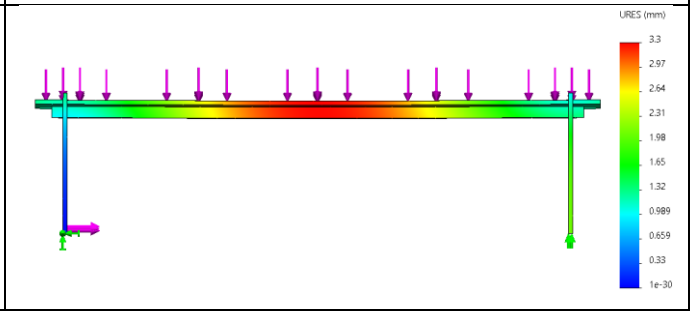
	1400mm	*1800mm*
10mm It. 1		
15mm It.1		
10mm It. 2		
15mm It.2		

Table 7.1 concept 4 deformation simulation

Side forces on the seating surface of 600N/500N per horizontal axis were added next to the vertical forces during separate testing. This added extra stress to the system, but never enough to exceed even a third the yield strength. So, these forces should not pose a problem to the structural integrity of the bench.

From the simulations in

the following conclusions can be made:

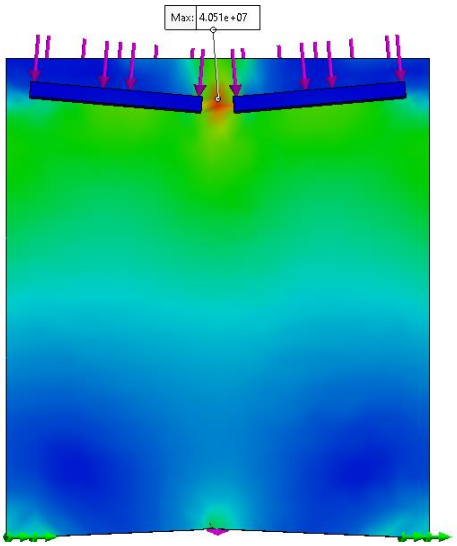


Figure 7.3 Sideview simulation 15mm 180 It. 1

Conclusion 1

The maximum Von Mieses was constantly seen in between the two horizontal plates, as seen in *Figure 7.3.* But all models simulated in Table 7.1 did not show any signs of exceeding the yield strength, thus deformation is the main point to be improved.

Conclusion 2

The addition of the extra plate under the seating surface in Iteration 2 *Figure 7.2* does significantly help with strengthening the seating surface.

	1400mm	*1800mm*
10mm It. 1	27.5 KG	31.5 KG
15mm It.1	38.6 KG	44.2 KG
10mm It. 2	30.6 KG	34.3 KG
15mm It.2	45.8 KG	53.0 KG

Table 7.2 Weight chart detailing iterations

Conclusion 3

All configurations except both lengths of Iteration 1 with 10mm plates were within the maximum requirements of Table 4.1.

Conclusion 4

As long as 15mm or thicker plates are used, Iteration 1 is strong enough to handle all expected loads.

From this the final choice on material thickness and construction can be made.

Although the extra strength and reduced weight (when using 10mm plates) of Iteration 2 is appreciated, with the use of the proper thickness of material this added plate is not deemed necessary for strength, and it does not reduce weight enough to have it carriable by one person. And because this added plate ads more complexity and parts to the design, it strays away from the design ethos of the Terrassenhaus, which involves reducing parts and complexity, as seen in *3.2.3 Design ethos*. Therefore, the choice falls on Iteration 1 with 15mm plates.

With the construction figured out, the first wooden 1:1 model is built, the goal of this prototype is to see if the full system works together well, this includes the ergonomics, corner construction and tensioning the bench. Also, a first look at the 1:1 aesthetics is seen. All of this will result a recommendation on changes, adjustments or additions to the final 1:1 prototype.

Figure 7.4 Multiplex 1:1 model corner (own work)

The 1:1 practical model is constructed out of multiplex wood, this is chosen for its strength and availability. This material cannot accurately represent aluminium as a material and thus needs have a thicker material thickness. The material properties are therefore thing that cannot be explored before the final prototype. Which will be made from aluminium.

Information 1:1 Multiplex model	
Length sitting surface	1800 mm
Total length	2000 mm
Weight	21.1 KG
Width sitting surface	375 mm
Angle sitting surface	5 degrees
Hight sitting surface	460 mm (lowest point) 475 mm (highest point)
Gap between surface plates	4 0 mm

Table 7.3 1:1 multiplex model datasheet

Figure 7.5 Multiplex 1:1 model full view (own work)

Some observations are made from this 1:1 model.

These observations are made by a small test panel of 4 people, 2 woman and 2 men of ages between 24 and 62. The following are the collected observations throughout these test sessions.

Observations:

1. The gap between the two top plates causes some discomfort in certain sitting positions.
2. When tensioning the bench, over tensioning caused the top of the vertical plates to crack. *See Figure 7.6.*
3. The angle of the sitting surface could be more severe for aesthetical and ergonomic reasons.
4. The seating surface could be a little lower, pressure at the inside of the knee is experienced with the shorter testers. This is caused because the measurements of the seating hight can be interpreted two different ways for this seating surface. With the multiplex model, the 460mm was seen as the lowest surface of the seating. This caused the added hight.

Figure 7.6 Structural failure 1:1 multiplex model

With these observations new dimensions for the following 1:1 prototype are defined.

The changes include:

+ 1 degree seating angle

+ 1 degree bottom cut

- 10 mm gap between surface plates

- 15mm seating hight (this brings seating highest point to 460mm)

With this new seating geometry, the next steps can be taken to define a fully functional prototype.

These steps include the defining of what feet to use and how to put tension on the system.

7.2 Tensioning system

The tensioning system consists of a cable or rope in between the two vertical plates. It attaches to these plates and can be easily put into tension. This tension can go up to 2000N, so the tensioning cable needs to be sufficiently strong.

These are the options considered for this part of the design,

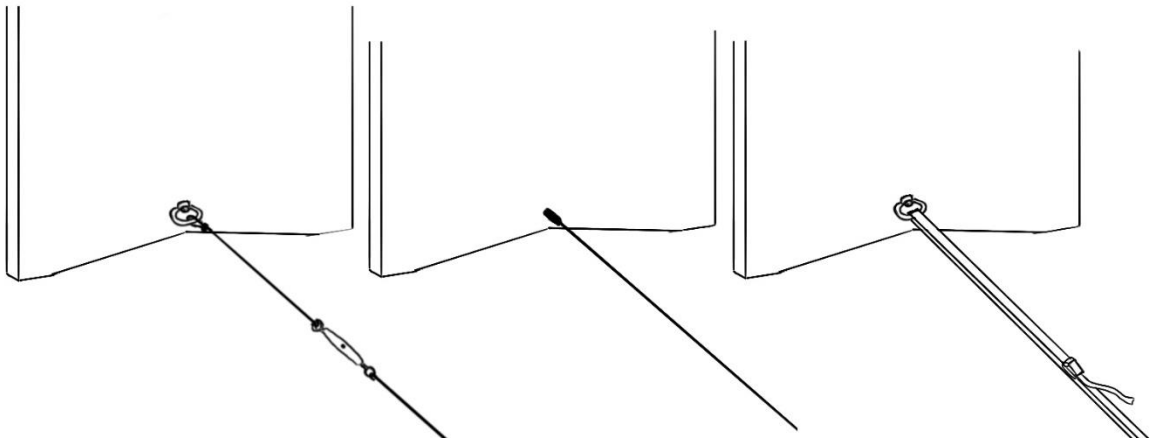


Figure 7.7 Cable detailing options
Left to Right, Wire with turnbuckle, Wire with Threaded terminal, Strap with ratchet, (own work)

Wire with turnbuckle

This solution gets its tensioning system from a turnbuckle, this is easily tensioned and adjusted. It uses steel cables with crimped eyes. This solution has the advantage of being easy to tension and weather resistant, but with the four crimped eyes, an eyelet on the plate itself and the turnbuckle, is more messy than ideal following, 3.2.4.

Figure 7.8 Wire with eyes (Drahtsteile24, 2023)

Figure 7.9 Turnbuckle (Drahtsteile24, 2023)

Wire with threaded terminal

This solution rethinks the attachment method to the legs and uses an internal threaded terminal on the end of the wire, this than acts as the tensioning system on both legs, having it tightened by screwing the thread in deeper. The has all the advantages of stainless-steel cables without the messiness of several crimps and a turnbuckle. The downside of this solution is that the ease of tightening has gone down because of the necessary use of a tool.

Figure 7.10 Wire with threaded terminals (Drahtsteile24, 2023)

Strap with ratchet

This solution focusses fully on ease of tightening and adjustability. Using a strap and ratchet system it is easily tension-able by hand and adjustable for longer or shorter bench lengths. This adjustability is a point that also came out of the analysis as a design aspect of the Terrassenhaus, *3.2.2.* The downside of this option is the more D.I.Y. feeling and messiness of this option.

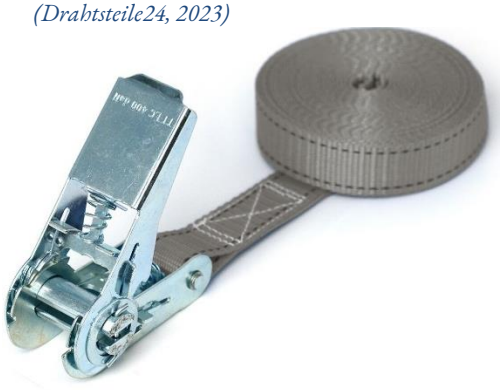


Figure 7.11 Strap and ratchet (metaltis, 2024)

The choice has fallen on the wire with threaded terminals. This exemplifies the Terrassenhaus the best in its aesthetics due it its simple nature. This simple nature of the solution is also fitting with the rest of the design. The relative difficulty of tensioning is accepted due to these qualities.

All important design choices have now been made, which all accumulates into the final design proposal and prototype.

7.3 Final prototype

Figure 7.12 Final prototype photos (own work)

Figure 7.13 representation of the bench at the Terrassenhaus (augmented work from (TIMPAU))

Figure 7.14 representation of the bench at the Terrassenhaus (augmented work from (TIMPAU)

Information final design prototype	
Length sitting surface	1400 mm
Total length	1600 mm
Weight	38.5 KG
Width sitting surface	375 mm
Angle sitting surface	6 degrees
Hight sitting surface	445 mm (lowest point) 460 mm (highest point)
Gap between surface plates	30 mm

Table 7.4 Data sheet prototype 2

7.4 Materials

The material properties of 6082 aluminium are excellent for this application, "Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys." (matmatch, 2024).

The little amount oxidation that will occur over time does not effect the structural integrity of the material and will not create big blemishes on the aluminium due to its brushed finish.

The cable and other hardware are made from V4A AISI 316 stainless steel. (Drahtsteile24, 2023) this does not corrode or oxidate in any environment that the bench will be subject to.

7.5 Production

There are only three separate parts to be produced for the bench

The vertical plates

The horizontal plates

The cable

The costs of these production processes will not be closely calculated, the exact price is not as crucial as it might be with other higher quantity products. As long as production costs stay manageable, which they are expected to do, there is no need for optimalisation or calculation at this stage.

7.5.1 Vertical plate production

The production of the vertical plates can be done with water jet cutting, this is a flexible way to cut thick materials like aluminium and is advisable over laser cutting for aluminium thicker than 8mm (Velling, 2019). This method can cut several vertical plates at once, which only would need to be finished, drilled, and countersunk to be ready.

This method would be easily accessible for Loehr via a separate producer and thus not pose a problem during production.

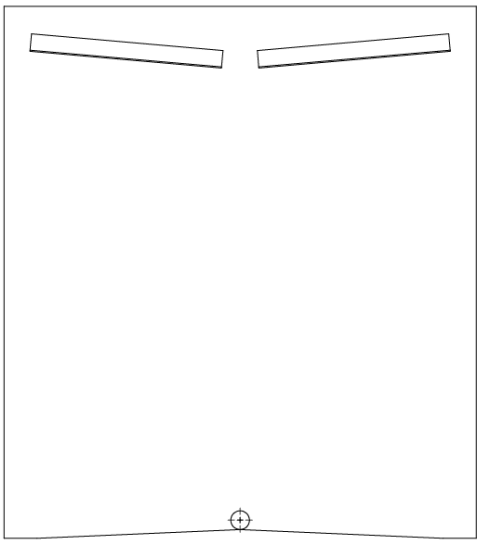


Figure 7.15 Vertical plate shape

7.5.2 Horizontal plate production

The horizontal plates are simple rectangular plates with a finished surface. The shape can be sawed directly at the aluminium supplier from big plates, this is possible because it is nothing more than two rectangular plates, which afterwards would only need finishing.

7.5.3 Cable

The cable is produced by a separate production company and is easily and accurately made and send.

All together there are four different production processes. The cutting of the plates, the making of the slots, the finishing of the plates and the production of the cable. All of which are accessible for Loehr.

8 Evaluation

In the previous chapter the main question, *what would a fitting outdoor furniture solution look like for the Terrassenhaus?* was answered. In this chapter the validity of the answer is evaluated against the design requirements.

This will be shown in the following Table 8.1, which, where necessary, will refer to a later part of the evaluation.

The design proposal should...

I	R: Resemble a bench that is to be used with a table.	*See 7.3*
II	R: Have limited or no backrest	*See 7.3*
	B: Have a movable or partial backrest	*See 7.3*
III	R: Comfortable for 90% of the population. (Seating hight is 460mm and seating depth minimal 304mm.)	*See Table 7.4*
IV	R: Not flex excessively or deform permanently during normal use.	*See 7.1*
V	R: Not corrode or rot in a way that diminishes the life of the product.	*See 7.4*
	W: Not corrode or rot in a way that diminishes the aesthetics of the product.	*See 7.4*
VI	R: Movable by two people (weight less than 50 KG)	*See Table 7.4*
	W: Movable by one person (weight less than 25 KG)	*See Table 7.4*
VII	R: Use feet	*See 7.3*
VIII	R: Fit the Terrassenhaus	*See 8.1*
IX	R: Be produceable by contractors of Loehr	*See 7.5*

Table 8.1 Evaluation sheet

8.1 Requirement VIII, Fit the Terrassenhaus

In the following chapter, the main question, *What would a fitting outdoor furniture solution look like for the Terrassenhaus?* is answered.

To evaluate if the final design proposal fits with its intended context, two actions are performed. The first is to determine if the design ethos and narrative of the design proposal matches that of the Terrassenhaus, secondly, there are two surveys done, a qualitative and a quantitative one.

The qualitative survey is to get specific insight into perception of the design and into the perception of it fitting with the Terrassenhaus.

The quantitative survey is more focussed on comparing its fit with the Terrassenhaus to that of possible furniture alternatives.

These two surveys than confirm or deny that the first step of the evaluation, aligning the design ethos and the narrative, also translates to a fitting design.

8.1.1 Fit evaluation

To see if the bench fits with the Terrassenhaus, a deeper look into where the design, design ethos and narrative of the two matches, and where it differs.

Material

Material-wise the two match well, not only is unpainted aluminium used in the building, the rawness and honesty of the material in the building is also seen in the bench. On top of that, reasoning behind the choice of material is similar, with both the building and the bench the material choices have been purely practical. No other material could have done the job as well.

Form

The form is not very similar, although some parts are reflected from the building like the thick material, the use of angled surfaces to deal with standing water and the use of cables. The main shape is not very much alike and the Terrassenhaus is a heavier and blockier shape. The reasoning behind the choices however is similar, both adding nothing for purely aesthetic reasons. Both shapes are distinctly unornamental.

Design ethos

As mentioned above, the reasoning behind the choices is very similar for both designs. The main point is that nothing is done for pure aesthetic gain. For the bench, it has created a design that is extremely simple in

its construction and design, this search for simplicity and low effort has shaped most of if not all of the bench, this is definitely in line with the Terrassenhaus. "*Maybe not minimizing but fulfilling the things that we try out with the least effort. Not over complicated somehow because of any conceptual or any aesthetic thoughts." Appendix 1 Interview with Jonas Janke, line 104-105.*
This is seen in the choices made for instance in *7.1 The resistance to the forces / weight optimalisation.* Where there is chosen for a thicker material over adding extra construction parts.

Narrative
The goal the building tries to achieve is a long-lasting structure that can be interpreted and changed to fit the needs of the current time. Some elements of this can already be seen in the bench, especially the long-lasting structure. The homogeneous non-corroding and thick material makes it that the bench will survive for many years in harsh environments, having no paint to chip or metal to rust. The interpretability and changeability are harder to see at this stage, other than the easy to lengthen or shorten bench length. There is however more to this, given that the next steps in the development of the design and its accompanying furniture plan would be additions to the bench, this would be easily added backrests, side tables and a soft seating option. These addable features would make the bench truly be aligned with the narrative of the Terrassenhaus, for instance, these features would allow the user to transform the bench from a backrest-less bench to one with backrests and a separate side table, transforming its use more towards a piece of lounge furniture than a bench for at a table.

8.1.2 Fit survey qualitative

This survey includes visualisations of the design at the Terrassenhaus, Figure 7.13 and Figure 7.14, as well as more detailed pictures of both the Terrassenhaus and the design.

The survey has two questions, the first a rating 1-5 if the bench fits with the building in their opinion. The second question is their reasoning behind the given rating or some other remarks

12 persons answered the survey, of which 6 are architecture students which had prior knowledge of the building. The answers to the first question are seen in Table 8.2 below.

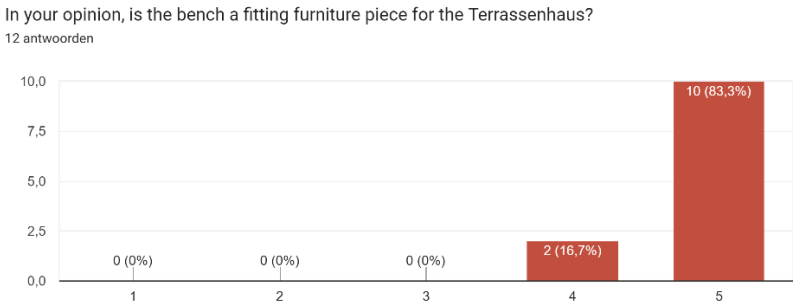


Table 8.2 survey answers question 1

The answers to the second question have been instructive in explaining the numbers seen above.

Some conclusions are drawn from the answers, the full answers are found in appendix 4

Conclusion 1

The bench fits well with the building in a non-contrasting way, this was one of the points where aesthetic approvement could still be, to make the bench contrast more with the building.

Conclusion 2

Many of the points of *8.1.1 Fit evaluation* are reflected in the opinions of the survey takers. Especially the material choice, and shape were mentioned often to be fitting with the building.

Conclusion 3

The addition of an added colour or "softness" like fabric could work well to counterbalance the uniformity of the current design and contrast well with the bench and the Terrassenhaus.

8.1.3 Fit survey quantitative

As said before, the quantitative survey is there to compare the fit of the bench with the possible fit of other benches with the Terrassenhaus. The idea being that comparative evaluation can give a more objective argument than the previous qualitative evaluation. This quantitative survey however will not get into depth on why certain opinions were given. Together the two surveys hope to give a full image of the opinion of the fit of the bench.
The survey is performed at the Terrassenhaus itself, here people that enter and leave the building are asked to give their short opinion on the fit of several benches (including the design proposal) and specifically on which one is most fitting with the Terrassenhaus. This survey is done while the people are waiting for the elevator, thus cannot be too long of complicated. Quantity over quality.
These people are chosen for their already existing knowledge of the building. This helps expediate the process, making it possible to get many different opinions.
To keep it as objective as possible, the participant is not informed on which bench is designed in this thesis, thus will give their honest opinion.
The participant is shown photos of six different benches (5 popular outdoor benches and the design proposal) and is asked to give their top 3 of fit with the Terrassenhaus.
First place getting 3 points, second place 2 points and third place 1 point.

Here are the results of the quantitative survey:
There were 34 participants, all of whom had been at the Terrassenhaus before.
The design proposal got the most points, but with a close second of the HAY palisade bench. This shows that although the bench does fit the Terrassenhaus well, there are also alternatives that would work well. Some of this popularity of the HAY palisade bench in the survey could also come from its general popularity and versions of this design already being used at the Terrassenhaus. This does not necessarily mean the survey was biased, because popularity is a valid reason for choosing a certain type of furniture.
The full scores are seen in Table 8.3 Quantitative survey score sheet on the next page.

Bench	Points
 *Figure 8.1 Weltevree bended bench (Weltevree, 2022)*	23
 *Figure 8.2 HAY palisade bench (HAY, 2023)*	55
 *Figure 8.3 Final design proposal (own work)*	62
 *Figure 8.4 Moormann Kampenwand bench (Moormann, 2009)*	3
 *Figure 8.5 Muuto Linear bench (Muuto, 2023)*	21
 *Figure 8.6 NOKK bench (noo.ma, 2023)*	40

Table 8.3 Quantitative survey score sheet

Discussion

From the evaluation of the design proposal 8.1, it can be concluded that the design proposal fits the Terrassenhaus. This then in turn makes the design proposal the answer the main question of: *What would a fitting outdoor furniture solution look like for the Terrassenhaus?*
This means that it is expected that if the design proposal is produced, placed, and used at the Terrassenhaus, it would fit well with the building and harmonizes well with all its features.

An unexpected finding that changed the outcome dramatically was found during the interview with Jonas Janke. Before the interview it was thought that the architects made a lot of choices aimed at creating this particular aesthetic and the material choices were cost and aesthetic based. The reality was that there was an underlying narrative and design ethos that strongly influenced all choices in the building, making it not about aesthetics or costs but about longevity, simplicity and maximizing within the boundaries. Understanding and using this narrative and design ethos had great implications for future design decisions, especially material and detailing choices. Because of this, the most simple and rational choices were made, rather than those that aim to create a certain aesthetic.

Although the design proposal fits with the Terrassenhaus as determined in 8.1, the opinion in the qualitative survey remains that it copies the Terrassenhaus perhaps more than necessary in order to achieve its goal of fitting. Therefore, it can be said that it may be more "inspired by the Terrassenhaus" rather than fitting with the Terrassenhaus. Of course, to make or choose furniture that fits with architecture is a subjective matter, depending on the taste of the beholder, which makes it difficult to design a clear and logical design path for. The creation of such a logical design path was attempted with the COP/CON matrix *5,* and the analysis of and alignment with, the design ethos and narrative*,* but might have been more successful if done in a more analytical way, perhaps first analysing existing and successful building/furniture combination, and gaining insight from those. Although, to do this properly it could have been a whole thesis subject onto itself.
The quantitative survey showed that the opinions of people are divided and although the final design proposal did get the most points in this survey, it conclusion was not convincing, thus the necessity of designing a custom set of furniture for a building is brought into question. Just coordinating the furniture

across the building would maybe have been enough to deal with the problem of incoherence explained in *3.3.*

Of course, this does not take into account added value of the alignment of the narrative, which was concluded to be successful in *8.1.1 Fit evaluation.*

This added value, together with the general opinion of fitting (although it is not the only design that would fit) makes the final design proposal be a worthy companion to an architectural significant building. And a good start to the transformation of the furniture on the Terrassenhaus.

9 Conclusion

To conclude this design thesis, the answer to the main question, *What would a fitting outdoor furniture solution look like for the Terrassenhaus?*

The final design proposal is in the form of an aluminium bench. It consists of 2 horizontal plates, which pushed through the two vertical plates. The geometry of these vertical plates causes the horizontal plates to stand on an angle, letting water slide of them. These two plates are connected by the friction that occurs when the vertical plates are put under tension. This makes the bench easy to build, take apart, modify, and produce, which aligns with the narrative of the building.

The design fulfils all design requirements set and with that fits the Terrassenhaus.

Figure 9.1 Final design proposal prototype

10 Recommendations

Possible next steps in the development of the design proposal itself would be:

-Setting up further production with the production companies.

-Designing and producing a soft seating surface insert or addition to counteract the cold aluminium, perhaps from coloured felt to create more contrast. To also answer to problems brought up in *8.1.2* Fit survey*Fit survey qualitative.*

-Designing and producing other additions to the bench, like an attachable side table, a removable backrest, or a umbrella holder to expand the product and create a wider modifiable system.

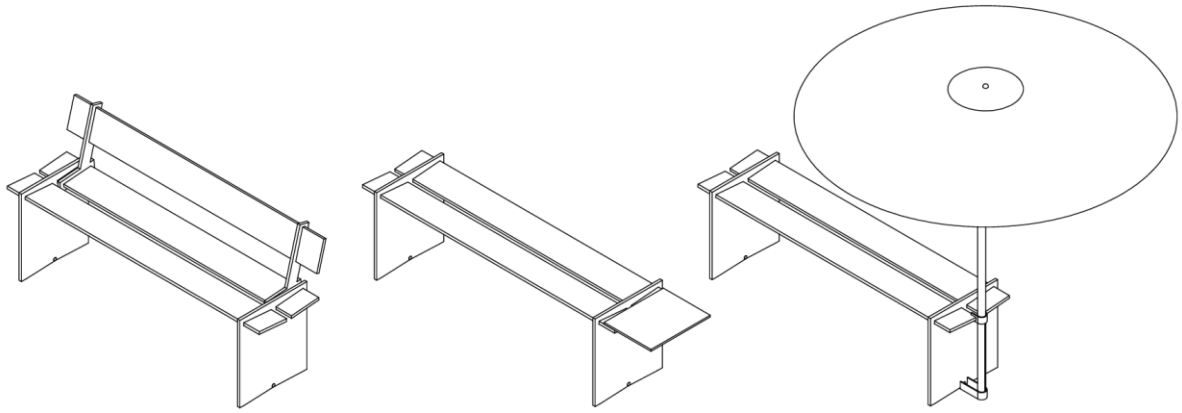


Figure 10.1 Possible additions to the design proposal (own work)

After the finalisation of the bench, next steps in the transformation of the Terrassenhaus can be taken. These steps include a fuller furniture plan for all current scenarios that keeps in mind the narrative and the design ethos. This would include the bench as the basis for seating furniture, adding aforementioned additions to make it applicable the possible scenarios. These scenarios include but are not limited to, group seating areas, lounge areas, event areas and exhibitions. This would result in a set of changeable furniture (benches, chairs, stools, tables and additions) that can be transformed into the needs of the moment.

References

BPLUS architekten. (2010). *0113 Brunnenstrasse 9*. Retrieved from bplus: https://bplus.xyz/projects/0113-brunnenstrasse-9

Chen, J., & Chen, X. (2019). *how roads can help cool sizzling cities.* Retrieved from Rutgers.edu: https://cait.rutgers.edu/how-roads-can-help-cool-sizzling-cities/

Demak. (2008). *eplacement Merbau Timber Slats for Wrought Iron Garden Furniture*. Retrieved from demak.com.au: https://www.demak.com.au/shop/timber/timber-decking-melbourne/replacement-merbau-timber-slats-for-wrought-iron-garden-furniture/

Deutsches Institut für Normung. (2013, 08). DIN CEN ISO/TR 7250-2:2013-08. *Basic human body measurements for technological design - Part 2: Statistical summaries of body measurements from national populations (ISO/TR 7250-2:2010 + Amd 1:2013)*. Deutsches Institut für Normung.

Donahue, P. T. (2024). Renner's theory of color harmony.

Drahtsteile24. (2023). *Edelstahlseil mit Kauschen und Karabinerhaken mit Öse und Gewinde*. Retrieved from drahtsteile24.de: https://www.drahtseile24.de/

Drahtsteile24. (2023). *Wantenspanner Edelstahl Gabel / Gabel*. Retrieved from drahtsteile24.de: https://www.drahtseile24.de/wantenspanner-edelstahl-gabel/gabel

duffieldtimber. (2022, 10 05). *Water & Rot Resistant Timber Species: The Best Types to Choose & Finishes to Apply*. Retrieved from duffieldtimber.com: https://duffieldtimber.com/the-workbench/categories/buyers-guides/water-resistant-timber-species-treatments#:~:text=The%20best%20water%20resistant%20wood,in%20the%20face%20of%20moisture.

Eger, A., Bonnema, M., Lutters, E., & van der Voort, M. (2013). *Product design.* the Hague: Eleven International Publishing.

Feizhou, R. G. (2001). A methodology to determine the optimum seat depth. *International Journal of Industrial Ergonomics.*

fialin, f. (2022). *spagetti shelf system*. Retrieved from frederikfialin: https://store.frederikfialin.com/Spaghetti-Shelf-System

fialin, f. (2024). *AC01-chair*. Retrieved from frederikfialin: https://store.frederikfialin.com/AC01-Chair

forest creations. (2011). *benches*. Retrieved from forst creations: https://forestcreations.co.za/product-gallery/Benches

Frama. (2011). *rivet box table*. Retrieved from FramCPH: https://framacph.com/collections/rivet-collection/products/rivet-box-table-aluminum

Gallee, L. (2023). *tralucid console 210*. Retrieved from objects with narratives: https://objectswithnarratives.com/collections/laurids-gallee/products/tralucid-console-210

GalvaTech2000. (2023, 10 10). *understanding galvanic corrosion*. Retrieved from Galvatech2000: https://galvatech2000.com/understanding-galvanic-corrosion/?lang=en

Giovannoni, S. (2006). *stone design sofa VONDOM*. Retrieved from barazzi: https://www.barazzi.com/en/p/164-stone-design-sofa-vondom.html

Grcic, K. (1998). *Hut-ab*. Retrieved from Moormann: https://www.moormann.de/en/hut-ab.html

Grcic, K. (2015). *Sam Son*. Retrieved from magisdesign: https://www.magisdesign.com/product/sam-son/?codice=BE&showprice=&codiva=21&valuta=EUR&stato=Belgium

Gupta & sons. (2008). *Self Clinching Fasteners*. Retrieved from JCfastners: https://www.jcfasteners.com/products/self-clinching/

HAY. (2023). *hay palissade bank*. Retrieved from andlight.de: https://andlight.de/shop/hay-palissade-bank-32525p.html

Hendriksen, M. (2023). *bright and bold colors in webdesign*. Retrieved from markhendriksen.com: https://www.markhendriksen.com/bright-and-bold-colors-in-web-design/

Hoadley, R. B. (2000). *Understanding Wood: A Craftsman's Guide to Wood Technology.* The Taunton Press.

Hornbach. (2018). Retrieved from hornbach.nl: https://www.hornbach.nl/p/hettich-meubelglijder-opschroefbaar-50x14-mm-wit-20-stuks/6794634/

International Organization for Standardization. (2011, 08 15). *Ergonomics — General approach, principles and concepts (ISO Standard No. 26800)*. Retrieved from https://cdn.standards.iteh.ai/samples/42885/27d65cdc5d7a437da1680589fa7ba671/ISO-26800-2011.pdf

Islam, D. a. (2023). APPLICATION OF POROUS CONCRETE FOR NATURAL SLOPE PROTECTION. *Journal of Bangladesh Agricultural University*.

islandliving. (2020). *Concrete Long Bench - 190cm*. Retrieved from Islandliving: https://www.islandliving.sg/products/concrete-long-bench-190cm

KOSHIFU. (2022). *KOSHIFU Pack of 325 Screw Nuts Threaded Insert Wood M4 M5 M6 M8 Zinc Alloy Threaded Sleeves Wood Insert Nut for Wooden Furniture Wood Thread Insert*. Retrieved from amazon: https://www.amazon.de/-/en/KOSHIFU-Threaded-Insert-Sleeves-Furniture/dp/B0BNV4RRLR

Loehr, D., & Loehr, J. (2021). *L4 BASIL*. Retrieved from Loehr.co: https://loehr.co/collection/L4-BASIL/index_en.html

Loehr, J. (2018). *JL8 FABER bench*. Retrieved from Loehr.co: https://loehr.co/collection/JL8-FABER/index_en.html

Márquez Cecilia, F., & Levene, R. C. (Eds.). (2018). *Brandlhuber+ 1996-2018: arquitectura como práctica discursiva* (Vol. 194). El Croquis Editorial.

Martlewood. (2020). *VOLUME ARMCHAIR, BRUTALIST INSPIRATION*. Retrieved from martlewood: https://www.martlewood.com/portfolio-item/volume-armchair-brutalist-inspiration/

matmatch. (2024). *AA Standards Grade 6082 T6*. Retrieved from matmatch.com: https://matmatch.com/materials/mitf374-aa-standards-grade-6082-t6

metaltis. (2024). *800kg - 25mm - 1-delig - Ratel - Gepersonaliseerd*. Retrieved from Metaltis.be: https://www.metaltis.be/800kg-25mm-1-delig-ratel-gepersonaliseerd.html?_gl=1*873xwl*_up*MQ..&gclid=Cj0KCQjwir2xBhC_ARIsAMTXk8737wIZ62MR2q8YswuPmM6tf67dzmY1z3hpmcDKq8HqFQA2uC-5N5IaAjOaEALw_wcB

mirrorinox. (2012). *mirror polished finishes*. Retrieved from mirrorinox: https://www.mirrorinox.de/en/products-stainless-steel-surface-finishing/mirror-polished-finishes

modular railing. (2018). *powedercoated railings*. Retrieved from https://modularrailing.com/services/pre-assembly/

Moormann. (2009). *Kampenwand bank*. Retrieved from moormann.de: https://www.moormann.de/en/kampenwand-bank.html

Muuto. (2023). *linear steel bench*. Retrieved from Muuto.com: https://www.muuto.com/product/Linear-Steel-Bench--p4499/31226/?select=it

Ngo, A. L., Nehmer, A., & Dünser, N. (Eds.). (2018, 05 28). Eine neue Ethik de Hetrogenen. *78, 78*. Arch+&Siedle.

nm3. (2020). *Pistoletto*. Retrieved from nm3.xyz: https://nm3.xyz/works/nmgt-2/

nm3. (2024). *https://nm3.xyz/works/nmat-2/*. Retrieved from nm3.xyz: https://nm3.xyz/works/nmat-2/

Noo.ma. (2021). *Nokk bench orange peel*. Retrieved from Noo.ma: https://noo.ma/products/nokk-bench-orange-peel

noo.ma. (2023). *NOKK bencn orange peel*. Retrieved from noo.ma: https://noo.ma/products/nokk-bench-orange-peel

Overmeer, E. (2018). *Terrassenhaus Berlin / Brandlhuber + Emde, Burlon + Muck Petzet*. Retrieved from Archdaily: https://www.archdaily.com/907233/terrassenhaus-berlin-brandlhuber-plus-emde-burlon-plus-muck-petzet

Shepherd hardware. (n.d.). *1-Inch x 3-3/4" Heavy Duty Self-Adhesive Felt Furniture Pads, 4-Pack*. Retrieved from Shepherdhardware.com: https://www.shepherdhardware.com/product/1-inch-x-3-3-4-heavy-duty-self-adhesive-felt-furniture-pads-4-pack

Tctile. (2021). *Non Slip Furniture Pads Premium12 Pcs*. Retrieved from tctile.net: https://tctile.net/product_details/6146112.html

The Engineering ToolBox. (2004). *Friction - Friction Coefficients and Calculator.* Retrieved 04 12, 2024, from https://www.engineeringtoolbox.com/friction-coefficients-d_778.html

Thein, F. (2018, 09 13). Terrassenhaus Berlin. *digital fertigen*. Bauverlag BV. Retrieved 02 29, 2024, from BAUWELT: https://www.bauwelt.de/themen/bauten/Terrassenhaus-Berlin-3256671.html

TIMPAU, A. (n.d.). LOBE BLOCK / TERRASSENHAUS. *PHOTO ESSAY BY ALEXANDRA TIMPAU.* Divishare, Berlin.

Toogood, F. (2023). *Roly poly sofa ocra yellow*. Retrieved from dirade.con: https://www.driade.com/en/roly-poly-sofa-ocra-yellow-d30125c278019.html

van Reeth, b. (2013). Good Architecture? *Oase, 90*(What is good architecture?), 39. Retrieved from https://www.oasejournal.nl/en/Downloads/52a206bbc79eb33cc6000015/OASE%2090%20-%2042%20Good%20Architecture.pdf

Velling, A. (2019, 5 29). *What You Should Know About Laser Cutting Aluminium*. Retrieved from fractory.com: https://fractory.com/aluminium-laser-

cutting/#:~:text=We%20would%20not%20advise%20laser,choice%20for%20thick%20aluminium%20plates.

Vitesco Technologies. (2014). *Explainations of ergonomics, Requierments; physical exposure.* Retrieved from https://www.vitesco-technologies.com/getmedia/66328f9a-7bf3-4ea8-8253-fc0cca392d28/Explanations-of-Ergonomics-Requirements-for-External-Suppliers-(EN).pdf

Weltevree. (2022). *bended bench*. Retrieved from weltevree.eu: https://weltevree.eu/de/product/bended-bench/1558

wonderewoonwereld. (n.d.). *HOUTEN BANKJE | BEELDBOUW*. Retrieved from wonderewoonwereld: https://wonderewoonwereld.nl/winkel/beeldbouw/houten-bankje/

Tables and figures

Appendix

Appendix 1

Transcription Interview Jonas Janke.

M: I kind of did everything in three steps: material, the form and then the design ethos or design philosophic idea.

J: Okay.

M: I don't have to tell you what material it is but it's more like why concrete? Is it purely aesthetics, is it also the cost that is effective with concrete or is it more something else, e.g. the creativity that it lends you?

J: I think there are several reasons in this case. As I said before, this building is somehow seen as a rigid structure within everything can happen, although the kind of the units can change in size. So, the basic elements are slabs, pillars and the cores. The cores are distributed within the volume that they are very efficient. That they can serve for not only one unit but for even more units. There is as little circulation as possible in the inside. There are only these two elevators with things attached to the elevators, always a bathroom and a kitchen, so it's kind of like a service core. And the other circulation is on the outside, the outside staircases. So, it's slaps, pillars and of course the staircases. The windows are aluminum, and the dividing walls are wooden or gypsum board constructions. To provide a kind of structure that can stand for, let's say 200 years, which is very robust and very durable. It serves as an empty shell that can be equipped in several ways. There is a term from the Belgium architect, it's called *intelligent ruin*. So, it's thought in the beginning that it's not supposed to be this kind of studio units forever. It can also become a school. One story can become one unit. That it somehow thought from the beginning, that it can also contain different usages. And the idea is then to provide a very durable kind of system in which change can happen. And therefore, also then concrete is kind of legit in a certain way because this will stay. It will not get demolished maybe only the kind of temporary fixtures in between that can be changed; so, in that way this intelligent ruin idea is established. But also, unfortunately according to German building regulations, you could have thought about doing all these things in wooden construction, but I think the legislation is not at the point so far that you could easily build a structure like that in wooden construction on an economic level because the dimensions would grow. E.g. the pillar would be instead of 30 times 60 would then be one meter to something only to fulfill the fire regulations and therefore concrete was in this case the best suitable material. But it is never about creating an aesthetics. It's more coming from the concept and what is the best material or the sufficient material to reach that. It´s not because concrete looks so beautiful, it's about fulfilling certain requirements, first legal requirements and then the other requirements that this should be, distribute a rigid structure that can host several things. And in the case of San Gimignano, we were very lucky because the concrete was already on site. In the case of the Terassenhaus there was no concrete on the site, so we had to use it out of the silo.

M: But there you hoped to create that for later generations to be able to reuse that.

J: Let´s say today it's a prototyping workshop. We don't know what it can be in the future or what it will be in 50 years. I mean in this case (San Gimignano) it's a little bit more limited what it can become on not become.

M: But there you indeed, like an intelligent ruin, think about what it could become and keep those options open.

J: I mean this is an internal discussion if we would consider this building (San Gimignano) to be an intelligent ruin or not. I would argue for instance that this tower in this condition is not an intelligent ruin.

M: It´s just a ruin.

J: Maybe the ruin before was so intelligent that we can reuse it into this facility which is in it right now. M: But it was never meant to become this.

J: No, it was meant to be an industrial storage and now it became this prototyping workshop. But this industrial facility was already so open or let's say so flexible that we could adapt it to that.

M: Interesting. So that's exactly what I was kind of hoping to talk about that's.

J: Okay.

M: So, it's not that much... It feels very pragmatic there. All choices feel very practical but still in form and in everything it feels very ... I think it's a very beautiful building but how do you get from that very practical idea of what you just said to something that looks like this? For me there were some different ways of getting there. Do you go concept first and then see how it fits in? So is it really a puzzle that you try to solve and do that in the most beautiful way possible or in the most elegant way possible.

J: I think there's never the aim to do it in a …, that you think somehow it should be done in a beautiful way. For instance, the whole shape of the building: it's the maximum space that could have been occupied on the plot. This is why there's also this kink or bend in the facade because this is the plot line. It's just filling the maximum and then it's a replication of the floors. And there is this idea that every unit should be equipped with a kind of let's say private property, that's these six meters of balcony or terrace in front. And then it's stepping back and by doing these steps the depths of the units are changing. The idea is that we do not program what should be in this units, it's somehow programming itself by the supply of daylight and the depths. Because you know there's a 26-meter depth deep unit and the one on top is 11-meter or even less I think 8 meters. And I think there's always the question of daylight from one side and the other side. And the 26-meter unit is then maybe not the best unit to live in for instance but the 11-meter unit which is supplied by daylight from both sides is more a livable space. So somehow the depth and the supply by light is defining what can be inside the unit. So, there's no thinking that this unit can become an office, this unit can become restaurant or canteen or kindergarten or whatever. The thing is it's just open for appropriation.

M: But that feels almost lucky that it works out that way. But there must be some thought behind it that enables that possibility because there's plenty of people that build buildings and think about very practical ways, but it doesn't look that way or it looks…

J: I think the aim was to create a building where a heterogeneous crowd of people can move in. And therefore, you need to offer different varieties of units.

M: So, you had to had that in the beginning because of the zoning there which is very ambiguous now and probably will be for a long time.

J: I mean there's this very old zoning plan which somehow says there should be only like commercial space but also the whole neighborhood is a residential neighborhood so there's this kind of conflict and I think then the solution was more or less that it's a mixed-use building which is somehow then fulfilling, or it can be studios and ateliers, studio is always a very open term, and depending on future legislation or interpretation it can become residential or it stays the kind of … I mean it cannot be fully residential as I said before since there are units that are not made for housing.

M: I mean you could probably live there but it's not ideal.

J: The concept is that because of this variation of units it will stay in this very heterogeneous mix of units and usages.

M: So, you kind of force that concept through. But what I'm most intrigued by is that every choice feels the most logical choice. Nothing is ornamental, nothing is extra put on because you want to have it look nice or you put something there because it looks then more special. But yet it becomes this thing that is very special and that feels very special. And because I'm also designing things and I am quite a practical designer. I think about the mechanics first, I came up with this mechanic in my first week of thinking about this stuff. But this is how I work, I go from practical to designing. I start with way of building and then I see how can I use this in a design.

J: I mean in the architecture you can somehow relate to that. A property is always, I mean there's a property or plot, and it's always enweaved into a context of legislation: What can we build, how much can we build, in what kind of manner it needs to be built. And then it's very pragmatically that you somehow try to push it to an extreme, like what is the maximum that you can build there. And then I mean this is the goal to do only as much as needed. You don't need a third staircase, you don't need a third core, you don't need a kind of ornament or a flag on top or whatever. It's just the elements that are needed are on site and that's it.

M: And that's it. That will become what it is. I find it very interesting that there's no facade covering.

J: I mean there's also saying that you don't need more than circulation, where are the bathrooms and somehow the outer perimeter and then it's done. Because this can answer all the questions.

M: Really everything already?

J: 90%. The rest is decoration.

M: But that feels like that step is completely skipped. But even things that seem very necessary or even most important, like water drainage and stuff like that. That´s then rethought in like how can we do this but just less.

J: It's not that we don't want gutters, we don't want pipes drainage. So, the thing is just that the floor is two degrees tilted in one direction. So, it becomes this kind of cascade of water.

M: Exactly, but these kinds of choices that … Is this kind of thinking is it very structural to this design or is it more or I think we have to too much we have to make it less?

J: In this case, I have to say I don't know 100% where this decision came from that it should flow in one direction. I can just think about it. If you would do it in a kind of conventional way, you would have a gutter on kind of every side of these kinds of terraces and you would have these pipes and the idea was to just somehow get rid of this.

M: But this seems like an aesthetic choice. Or is it also somehow easier and more cost effective to do it in a different way?

J: I don't know what in terms of costs. I mean there were already these slaps and I think if you decide then it should be two degrees tilted it…

M: … doesn't matter. You don't add any extra hardship to that.

J: Also the curtains, that some people think that are just decorative things, they are also just to provide shade in the summer.

M: I heard from the people that live there that's really warm in the summer. And, that's what my bosses heard when they were wanting to do like the outside concept, that it's mainly just really warm there because it's this big slab of concrete and you sit in the south sun.

J: I mean we all know that there is this phenomenon of heat islands on concrete surfaces and yes that's true. But the idea was also that every kind of these terraces that can be appropriated by the users of this unit, so they can do whatever they want, they can put like umbrellas there, they can put a micro biotope there to create shade and …

M: … or a lot of plants. One has gigantic planters and that must also help I think.
I think this we already had so this was about the minimizing as much as possible.

J: Maybe not minimizing but fulfilling the things that we try out with the least effort. Not over complicated somehow because of any conceptual or any aesthetic thoughts.

M: So, if you then run into a problem, you don't think what can I add but more what is the root of the problem and how can I take this route away or how can I shift something?

J: There is never a decision how can we make it more beautiful or how can we make it more appealing somehow. If the concept is somehow fitting and if it's somehow bringing value to the concept and how can we do it. This is always the question: is this somehow bringing benefits for the concept. But not does this look cooler or would it be nicer in red or blue or this is not a question at all.

M: Well, there must be some of those ideas. I mean if you have these kind of aluminum windows that is that is an aesthetical choice that that cannot only be a practical choice right.

J: I mean this is a gigantic topic and it's a little bit overstretched but it's also about this material honesty. That you don't put any additional finishes on top when it's not needed.

M: True, this is one of the things that I really felt in everything also in the inside.

J: So, the wood is not painted, the floor is raw, the concrete is raw, the outside railings is just galvanized steel, because steel would just corrode or rust.

M: And stainless-steel would be way too expensive. So, as honest as it can be, practically. Is it that if you pick concrete for a building that that enables it but if you would pick wood for a building and you could do it that would be maybe even better because it's more into the new age.

J: I mean, the problem is somehow we need to think in every direction what can be future building materials because I mean sand, it´s one base of a concrete, is also limited. The sand that you can use for concrete is very limited because you cannot use the sand from the sea because the grain of the sand is too round. I mean also the production of cement, we all know, is one of the… it's crazy in terms of energy consumption. So therefore, concrete is more or less and evil material. But we also know they are not enough trees on this planet and then suddenly also questions of soil, bamboo, etc. arises. I mean steel, also a material that can be used but then you open suddenly a lot of cases down here. How is it built, are all the materials glued to each other or are they made to be reassembled again and then can they be resembled in a way that you have then raw steel again? And the raw aluminum from the window and the more or less raw wood from something then it's better when you can sort it again in it's essential material. But there's no preference for a material.

M: It's just this happens to be the best provider of these things that you need.

J: And of course, concrete is the material which is probably the most energy consuming.

M: It's not the greenest material at all.

J: And therefore, the use of it should be minimized.

M: What I do find interesting, because I was looking into aluminum, there's actually a company that does completely carbon neutral aluminum and they also do it for buildings.

J: I mean also apple is doing always the advertisement this iPhone is done out of 100% recycled aluminum.

M: It can be done. I mean it is possible and there are actually buildings made out of completely recycled and with green energy aluminum and it does work. There is this company in Norway Hydra doing that.

J: Interesting.

M: I find it interesting because I was really hoping that I could make the bench out of that but I don't think I can get a piece of aluminum.

J: I mean the thing is it's in Norway then.

M: Right. I would have to pick it up.

J: It needs to come to Germany or to the Netherlands or whatever.

M: But having this process that you can have a very good building material that can be carbon neutral if you have green energy and if you have all the time in the world to pick up all that aluminum and it is very hard…

J: And also the facilities that are transporting it are let's say supplied by green energy.

M: I think they're trying to make it this legit hundred percent, but they probably got in some corners. But that´s always I guess the thing. So, material choice it is. Next to practical choices it's also about honesty and seeing what you have. It feels like you don't hide much anyway in the building, I mean if you look at a normal building it's all facade pieces almost glued on top of some structure that probably will hold and this is such a different way of building.

J: I mean with all those glued facades we just create this gigantic amount of trash.

M: If you accept that concrete is an aesthetic that you can get along with and that you can like from the outside and from the inside, then you don't need anything else: it can be your floor, it can be your walls, it can be your outside walls, all in the same piece.

J: And it could also have been wood on the ceiling on the window frames.

M: If Germany would have allowed that.

J: I mean it's possible, but I guess then we are jumping immediately to a smaller scale. So in single family houses it's totally possibly.

M: I've seen some stuff come by.

J: When it comes to school buildings or other public buildings, there are also cases but sometimes then it turns in a kind of hybrid construction. Then it's kind of concrete pillars and wooden slabs or wooden beams.

M: I think a friend of mine actually lives in the building that has that. It is very beautiful, like having this completely wooden floor and the ceiling being the exact same. It's very calming. But I think I have everything I wanted to talk about. I mean it is how I kind of imagined it.

J: Good.

M: I personally was more, maybe because this is how I think in a product, it's more thinking about the costs and if you don't add any gutters, you also don't have to pay for any gutters.

J: I mean then it also comes with maintenance. This is also a thing, somehow reducing the amount of maintenance or do the maintenance very self-explaining that you don´t need any specialists.

M: So all those small little things of taking it away makes everything easier and cheaper.

J: And in the best case self-explaining.

M: And this is really I guess also why I really like the building because this is what attracts me, this is what I find interesting myself.

J: The thing is it would be nice to somehow find out what is for instance the carbon footprint of it. Somehow, just as a site. I mean these are all questions from today and I mean probably not everyone is asking for it but somehow deliver this information from the beginning without being asked for it. That is also showing that you are aware about certain points and issues of our time.

M: So adding that's just as an extra.

J: Yes, I mean you can be super honest and say this is just an assumption, I try to do it the best I can, I don't have certain tools to calculate it, but it's probably going in this direction. To somehow already provide a kind of, in case somebody wants to get rid of it, I take everything back and if they want to change it in size I provide a service that they can change the size of it. I do a kind of spare part collection of it and I mean this is also interesting for you. I have a product, but I also offer you a service to this product.

M: That´s quite interesting. I am really reconsidering the material.

J: I mean you can also offer that for different purposes it comes in different materials. I mean for the outside it can be in metal for the inside it can be of course also aluminum, but it can also be wood.

M: Plywood would very much work.

J: You also say, I don't treat it, and therefore it can only be inside, or for a limited time outside. What I am thinking about is, that you can maybe add certain things to your design. What I think is a bit of a pity is that you are always confronted with this kind of final piece. I think it's interesting to be also involved in the work in progress somehow. What was leading you into this direction, what are the material components, why this material components. I mean it's all about the narrative, so you saw this building, you thought about something is missing here, we need outside furniture, then you thought about somehow picking up the logic of the building and I was observations, that …, I had several alternatives and then I chose that and in the end somehow I also come to the conclusion that this bench can also become a stool or this bench can also become that and in case somebody wants to exchange it. I think I'm very intrigued by also this service or what can we provided in addition to that, to look beyond it's just a final design. There is this whole canteen or the restaurant downstairs and they want 100 or 50 stools or benches let's say. And one day they unfortunately must close as someone else comes, then the next owner says I only need half of them, I want to give them back and then you can create a kind of second-hand platform. I think today it's all about keeping material in the circle, avoiding creating trash, valuing good crafted objects and also sometimes people are annoyed by it but if there's not the awareness you will must raise the awareness. This is a kind of sustainable object.

M: I like what you said that sometimes people are done with it. The only way that I am done with it, if it's not actually an object you can use. That it's a nice concept but in the practical world it would just break. Sometimes you see this chair or a thing that's all made from mushroom. It looks beautiful it's a great concept, but it is…

J: I think this will improve within time. Maybe we are not there yet but it's definitely interesting, but I also have my doubts with those materials, but I totally believe in tit hat there will be one day a proper mushroom chair. I mean at the architecture biennale this year there was this kind of facade out of mushrooms. And somehow, I'm always questioning how long does it last or is it growing, is self-sustaining somehow. I have to say I did not 100% dive into this topic but it leaves some questions for me it's definitely interesting.

M: I find that always a little frustrating that we are also always trying to create new things but not taking good enough care of the things we have or not making things that may actually last. Like in the grand scale you can have.

J: I mean it's also to somehow to tell such a strong story about an object that everyone is valuing it already just because of the story.

M: Or because of this idea behind it and it has some intrinsic value other than a chair or a bench. It must have something else. That's why these couches (Martin Visser) are still worth the money that they are and that's why I also felt okay buying one because it won't devalue because it's been a popular couch for a lot of years and it's not something that will devalue and I mean these couches get reupholstered so often.

J: I mean this is also a good point. Is this super easy to somehow touch up or to I mean there's probably like zero maintenance cost I would say but this is also part of your service. That there can be a touch up, I can repolish it, whatever.

M: And how it's slides in and out that you get scratches and that's okay. The only thing with that is if I would like use metal and then a coding, the scratch will t…

J: Therefore, I would not recommend a coating because I mean why a coating. It can only go off and it is already one aesthetic layer.

M: And that's all why I use aluminum because then you have this material that all the way through will not rot. It might get a patina, it might get a little bit duller, but it will not rot and if you put a layer on top of it…

J: I have one question. If you, let's imagine you took them like a hundred times out and you were stretching it again, it somehow loses some material. The thing is they would maybe move a little bit more in this direction.

M: I mean that is the only thing that I don't want. I'm afraid that at some point with a lot of use it will go more and more. But maybe it's somehow an asset that you can see that this one is old.

J: I mean you have this tension cables and you can adjust it.

M: Yes, you can tighten it like a thing.

J: I mean, I know it's nice when you see somehow this is the first edition and second patch…

M: is still a little bit straighter. The thing that attracts me the most is so easy to make. I can make this in my backyard from wood.

J: This is also interesting: you can also provide kind of the construction memory. That people can also start to build it on their own. You can then also say you can saw this material there and there, and this is also part of the service. You can say you can buy it and then it costs let´s say 750 Euros but you can also just download the manual for 4,99 Euros. It´s open source and then you can decide if you want to do it out of wood or whatever.

M: Or even only provide these difficult parts to make and then just say source some materials.

J: You can also say, I offer workshops to build it. I mean this service idea is endless

M: That's nice to have some interaction with a very simple product. The concept is very simple. Also mechanically, if you if you load it, if you sit on it, this connection only gets stronger because it bends.

J: I mean this is also interesting to think about what are other perfect context for this, because you can easily dismantle it. I mean, this is maybe also perfect for like performance bases or concepts, things where you need immediately furnitures that can be dismantled. Also then it makes sense in terms of shipping, I can reduce it to a very limited …

M: That's actually nice.

J: These are all considerations that is just enriching the kind of very simple thing. This is also about the project. You can talk for hours about it, even though it looks so simple.

M: And that is the magic of something like that.

J: But of course the project took four or five years or even longer to develop and build it. So that means there is a lot of time spent in concept, in thinking. This, most of the people don't see.

M: And this is the the part that I'm most interested in, because I am in that process. And this is what I also enjoy in that process. Of seeing something. Think like, oh, maybe I can use it this way or this way. Or maybe just take this whole part off or make it.

J: And I mean then always thinking further. Are there additions? Are there things that you can put as a backrest? Is there a kind of pillow in case it needs to be more comfortable for old people or whatever. Are there some add-ons that you can provide?

M: Yeah, some extra things.

J: I mean this is, I mean this is very then starting from a design and then it goes really into the whole universe around the project and an object.

M: I mean, that would also fit with the Terassenhaus in the way of you can change it and you can add something on and take something off.

J: It's the same logic. You have a thing which looks like that that you can just put it here and it's also because of this thing it's somehow stable and then you can just put this to it.

M: You can use maybe the same width of plank.

J: Yes, this is also nice when it becomes modular. This is also a Lobe Block, it's following a rhythm or let's say a modular. I mean, this is promising.

M: Thank you. I'm very happy with this concept. My boss didn't believe that it would work this way, like it would be stable. Because if you take the tension off it's not a stable bench. But also because I didn't make the holes of the model precise enough and therefore it's not stable.

J: But I think this is more an advantage. You don't need to be a super Craftsman to build it. The holes can be also a little bit clumsy done, but it still works.

M: Yes, because you have this tension.

J: Yes, but this is then the kind of difference between super high engineered and this pragmatic design.

M: I think that's why I like this one for the Terassenhaus at least the best. But I like this idea of having more things to add on. This is going to be the next step. The only thing I don't know is, if it's structurally good enough yet. This is a long way to bridge. But I might just make the material thicker, and that's when the problem is solved.

J: There can be also like gadgets that you can put an ashtray here or I mean it's it's endless.

M: Yeah, and all with the same mechanic of having something hang on.

J: Yeah, with the same logic somehow to hang it on. Maybe it's also good or one version it could be it, it could have holes in order to decrease weight and also to use less material. And when it rains on there, there are holes. I mean now it's also fine, because it will go

there, but I mean holes are also then always points of opportunities. You can also say the very luxury version is I will put like a rope around it in every hole and then it becomes softer. Whatever, as I said, endless. But I think this is already a good point when others are starting to think about and are starting to say ah, this can happen and this can happen and this is interesting.

M: I'm happy I brought the models, it was a last minute decision.

J: Definitely.

M: I'm happy you share my enthusiasm about it. It's good.

J: And you definitely have to share then the final project or final photos or final, let's say brochure with us.

M: Yeah, I will. I'll send it along whenever that is done.

J: But it's always good. I mean, it's just helping yourself. I mean, we are somehow not the biggest fans of writing texts etcetera, but if it's once written down, it's also your kind of personal manifesto sometimes. That you know, these are rules or kind of things I stick to. This is also what we are always learning from in every project. We are always learning. We always developed a certain toolbox. This helps in decision making when you suddenly have a certain methodology or way of thinking, you can just say if we strictly follow our agenda, it only leads to one solution. So therefore, it's sometimes good to write down the thoughts and the final outcome, and why every decision is done. This is why I think it's crucial to. visualize your way of how decisions were made, and some detours that you made. I imagine it in the kind of diagram that you see. It was not this linear direction. It was always back and forth and like it is.

M: No, of course. So you also remember all those thought patterns that you had like, oh, maybe we should do this and maybe this and maybe you can reuse some of that later or you can rethink it and be like not for this one, but maybe for a different one.

J: And there is sometimes in university this unfortunate situation that people say: this is so simple, did you start like, yesterday? And I said no, no, it's not yesterday. I mean, there's also the saying, the simple things are the most complicated things to come up with. That you say, this looks very intuitive but there is a process behind it…

M: That's also the whole point, right? It's supposed to be looking intuitive.

J: But there are some people who cannot understand that.

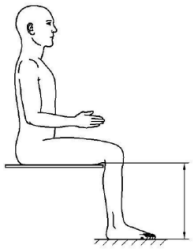
M: And I think that's why I mean showing the whole process and showing what you did is important.

Great! Thank you so much. It was really nice to be here, of course.

J: Yes. And I think we, we took a perfect time and a perfect position.

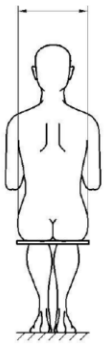
Appendix 2

LOWER LEG LENGTH INCLUDING FOOT



	Male			Female		
	P5	**P50**	**P95**	**P5**	**P50**	**P95**
Germany	410	450	490	375	415	450
Euro (n.a.)						
Italy	412	460	511	362	411	472
Japan	370	405	442	340	369	403
Korea	365	399	437	333	369	403
Thailand	380	413	450	355	389	423
USA (n.a.)						
China	383	413	448	342	382	405
Mexico	374	412	453	338	376	406
Malaysia (n.a.)						

HIP BREADTH, SITTING



	Male			Female		
	P5	**P50**	**P95**	**P5**	**P50**	**P95**
Germany	350	375	420	360	390	460
Euro	333		368		440	
Italy	305	343	397	312	355	417
Japan	327	358	393	327	359	398
Korea	315	346	385	317	347	383
Thailand	310	343	382	310	350	400
USA	329	372	435	348	403	557
China	295	321	355	310	344	382
Mexico	328	372	423	347	392	472
Malaysia (n.a.)						

SHOULDER BREADTH (BIDELTOIDAL)

	Male			Female		
	P5	**P50**	**P95**	**P5**	**P50**	**P95**
Germany	440	480	525	395	435	485
Euro	395		474		485	
Italy	421	459	500	368	406	459
Japan	423	457	500	377	405	444
Korea	425	465	506	381	417	458
Thailand	407	446	489	362	397	448
USA	440	486	550	385	426	493
China	398	431	469	363	397	438
Mexico	422	472	544	389	435	521
Malaysia (n.a.)						

Figure A. 1 Anthropometric data Data Germany from: (Deutsches Institut für Normung, 2013) Picture from: (Vitesco Technologies, 2014)

Appendix 3

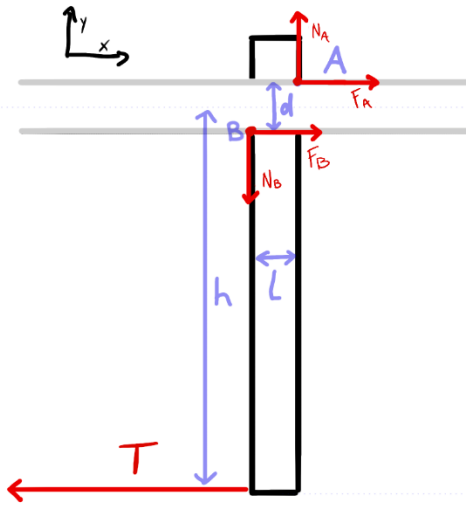


Figure A. 2 FBD Sticky drawer effect

Left Figure A. 2 shows the freebody diagram of the plates under tension of the cable. At point A and B the horizontal plate hits the vertical plate and create forces F_{NA} and F_{NB} respectively. Because there is no movement expected in the y direction we can say $\boldsymbol{\Sigma F_y = 0 \rightarrow N_A = N_B = N}$

As a reaction to **T** we get a friction in **A** and **B** called $\mathbf{F_A}$ and $\mathbf{F_B}$ respectively.

from $\boldsymbol{\Sigma F_x = 0}$ we find the balance of $\boldsymbol{F_A + F_B = T}$

This only counts when the system is static, this changes when **T** rises so much that $\boldsymbol{F_A > \mu N}$ and $\boldsymbol{F_B > \mu N}$**.** Then the maximum static friction has been reached and the two plates slip. This results in the equation: $\boldsymbol{T > \mu N_A + \mu N_B \rightarrow T > 2\mu N \rightarrow N < \frac{T}{2\mu}}$ **(1)**

If the system is still static, but only just, we can say about the moment round **B:** $\boldsymbol{\Sigma M_B = 0}$

$$\boldsymbol{T\left(h - \frac{1}{2}d\right) + \mu N d = N l}$$

$$\boldsymbol{\rightarrow N(l - \mu d) = T\left(h - \frac{1}{2}d\right)}$$

$$\boldsymbol{\rightarrow N = T\frac{\left(h - \frac{1}{2}d\right)}{(l - \mu d)}} \quad \textbf{(2)}$$

When T becomes too high and we move from static to dynamic, the change is instant, thus we can substitute (1) and (2) to create:

$$\boldsymbol{T\frac{\left(h - \frac{1}{2}d\right)}{(l - \mu d)} < \frac{T}{2\mu}}$$

$$\boldsymbol{\rightarrow \frac{\left(h - \frac{1}{2}d\right)}{(l - \mu d)} < 2\mu \rightarrow l - \mu d > 2\mu\left(h - \frac{1}{2}d\right)}$$

$$\boldsymbol{l - \cancel{\mu d} > 2\mu h - \cancel{\mu d}}$$

$$\boldsymbol{l > 2\mu h}$$

This is the formula for when the system slips. The reverse gives us the formula for jamming:

$$\boldsymbol{l < 2\mu h \rightarrow \ \mu > \frac{l}{2h}}$$

Appendix 4

Qualitative survey answers

Figure A. 3 full survey answers

Participant	Rating 1-5	Reasoning behind the rating (optional)
1	5	Its very complementory to the building by the material used. Its looks very comfortabele and moveable. Its very durable for the wheather conditions for outside use. Most of all i like its lightness and transparency of the design. I love the well thought about simplicity.
2	5	In terms of materiality, the bench blends in. Therefore you could reason it fits the context. Next to that, the simplistic design features, the lack of paint and ornamentation, as well as the tilted form suit the design language of the Terassenhaus.
3	5	Seems to fit well, material wise it matches good and the design language is also close to the building.
4	5	-
5	5	-
6	5	It is fitting when or if wanna blend the design into architecture. It might have more of a visual eye catcher and still and merge furniture into the surrounding if there might be metal and another material or metal/ some sort of color added to it. Might that be an idea?:)
7	5	
8	4	I think the bench fits the Terrassenhaus well! Although the stiff photoshop perspectives makes it seem way stiffer than it seems to be. Maybe it needs to be placed by the actual house? And isn't it way to sensitive to climate to be an outside piece? I could imagine the bench in many different places, an attribute that many great pieces of design share :) Furthermore, I could really see the bench being part of for example a Hund&Hund campaign. They are a fashion store right at Lobe Block. Your bench with a little bit of textile softness and people using it could be a great fit.
9	4	-
10	5	The colours match and the simplistic design of the bench aligns well with the building. Both seem sturdy and "raw". It also seems that the railing of the terrace has the same brushed material as the seating-part of the bench.
11	5	The combination of concrete and aluminum is a perfect match!
12	5	The simplicity and use of materials completely match the building's aesthetic, the alumnium and simple shapes and honest use of material are obvious in both the building and the bench

Acknowledgments:

Special acknowledgement goes to following people who played an instrumental role in completing this assignment: (in alphabetical order)

Marcel Aaldering

Esther Geuting

Jonas Janke

Manoëlle Janssen

David Loehr

Julian Loehr

Leon Loehr

Janneke Massa

Marten Toxopeus

Jana Warlo