

APPENDIX Nº1

STUDY OF ALTERNATIVE SOLUTIONS

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1. INTRODUCTION

The purpose of this appendix is to explain the chosen placement of the footbridges and present the approach adopted in order to find the optimal design for both structures and to analyze and compare the proposed alternatives, while considering the external conditions and constraints.

The design requirements and aspects that were primarily taken into consideration were the environmental conditions, especially the constraints due to the possible water levels, aesthetics integrated into the surroundings and the difficulties of the construction process in that specific area. Simultaneously it was necessary to have in mind and comply with the functional purpose, security aspects, durability and economics of the project.

In the following section, the aim is to discuss the process of choosing and justifying the location of the bridges.

2. PLACEMENT OF THE BRIDGES

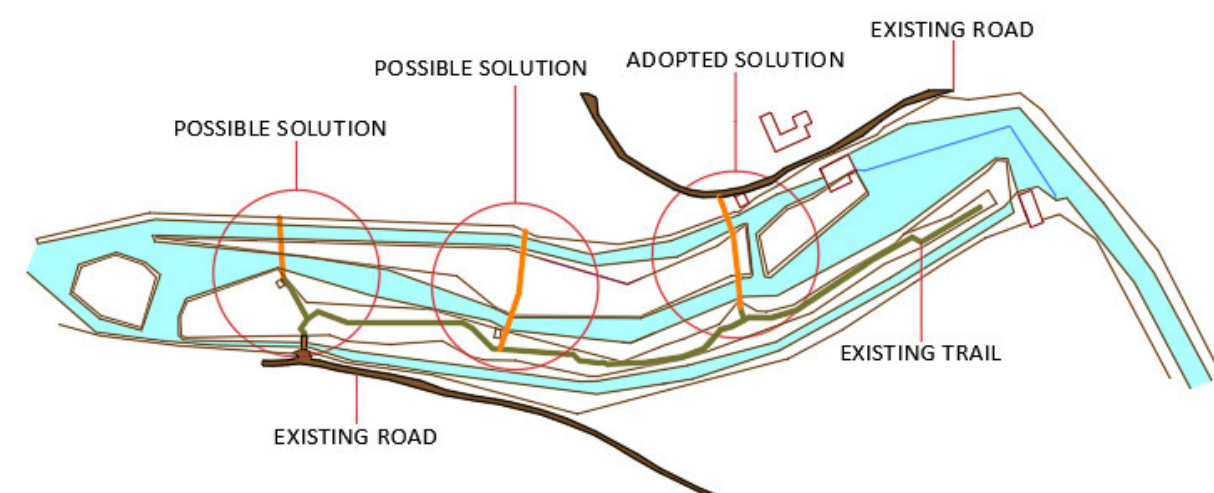
The most important part of the placement process was the site visit, where it was possible to gain an insight into the local area, the impact the surroundings have on the pedestrians and the importance of connections achieved by placing the bridges in the right spots.

The island offers many different solutions for the placement. The first one that was considered is near the small existing footbridge by the entrance to the island, where the trail takes a turn and leads the pedestrian to a small viewpoint, from where one can see the other shore clearly. In this location, the river is very calm, as opposed to the further upstream parts. This fact would make the construction easier, as it would not be problematic to reinforce the shores and it would not pose a big interference in the natural flow of the river. Additionally, the spans result to be similar, so it might be possible to slightly adjust the terrain in order to place two identical bridges and therefore simplify the whole process.

The second possible solution is located deeper into the island, where there is a sizeable rest area with benches and where the walking distance through the middle island to the second bridge would be the longest, as seen in the following outline plan. This option was considered, since the spot itself poses an interruption of the trail and thus the connection to the other side formed by the bridges wouldn't create a discontinuity.

By surveying the designated hiking path along the island and later by studying the plan of that area with its existing hiking roads, it was possible to determine the suitable solution. It was decided to position the structures deep into the island, to guide the pedestrian through its nature and invite him to take the whole path and not walk around it. The desired effect was to highlight the beautiful, recreational route and allow the passer-by to experience the area in its full potential by creating a pathway that is both practical and logical.

In the following outline plan of the area the idea behind the placement becomes even clearer. Regardless whether the pedestrian comes from the southern or northern section of the area shown, he has to walk through the entire island in order to get to the other side, which in this case is purely beneficial considering the fact that the area is mainly recreational. In addition, it is also clear that the existing roads, particularly the one nearest to the chosen location, match with the trail, bridges included, creating a coherent, lucid and fluent link.



2.1 Explanatory outline plan

Once the placement was settled upon, the next task was to consider the options of the planned structures from the bird's eye view, which could prove helpful in shaping the design of the bridges, while proceeding in a general view to a continuously higher level of detail. The following alternatives were taken into consideration:



2.2 Alternatives

The first option is a curved prolonged shape, which automatically defines the appearance of the footbridges. The benefit of this solution is the long flowing movement, which resembles the movement of the water underneath and rounds up the end of the trail in a way that is pleasant to the eye. Although an elegant idea, it was discarded due to the mentioned limitation of the form variety.

The second option presents the whole path creating one straight line parallel to the outside wall of the island. With this solution, it is possible to achieve shortest spans of the bridges, as well as a less complicated construction process. On the other hand, the straight form breaks the delicate flow of the river and produces an effect of a sudden change in direction, disintegrating the gentle shapes provided by the surroundings.

It was decided to go with the third option, which is combining the benefits of the other alternatives and eliminating their disadvantages. The path consists of three segments: one straight line in the middle island parallel to the outside wall and two slightly bent segments, creating a shape that is not as abrupt as the second option but also has the rounding effect of the first alternative. This solution offers a wide range of possible designs and harmonizes nicely with the shapes of the surroundings.

3. APPROACH

After visiting the site and deciding on the placement and general shape, the next step was to decide on the typology of the bridges. Considering the nearest environment - thickly planted area with a lonely path guiding the passer-by through the islands attention-attracting nature, it was an almost obvious decision to plan two simple beam bridges. By doing so, the purpose of blending in with the surroundings, not seeking attention and not adjusting the landscape to one's desire but rather playing with it would be fulfilled, creating an appearance of balance between human interference and nature.

Since there was only one type of bridge considered, conditioned by the environment, the process of choosing the appropriate design was rather a gradual consideration of many aspects, than a general distinction and comparison of different typological alternatives.

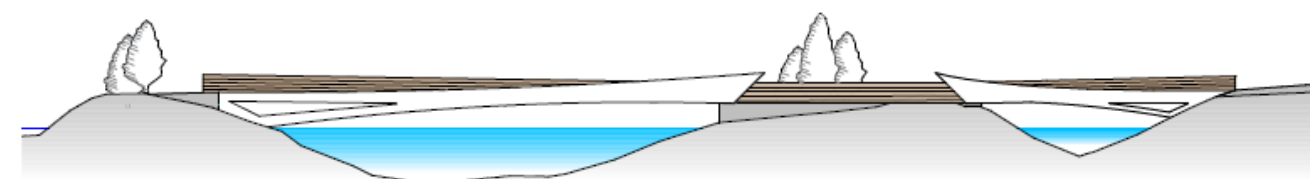
The work consisted of adjusting and specifying the concept, confronting more and more details throughout the way, which helped shaping and developing the desired result. This approach allowed a profound and thorough contemplation of the problem and as a result an adequate solution, not only simply chosen but also designed to fit and comply with the given conditions.

As a result, the following studies are a chronological thought process and show the continuous adaptation of the project while progressively considering more aspects of the situation.

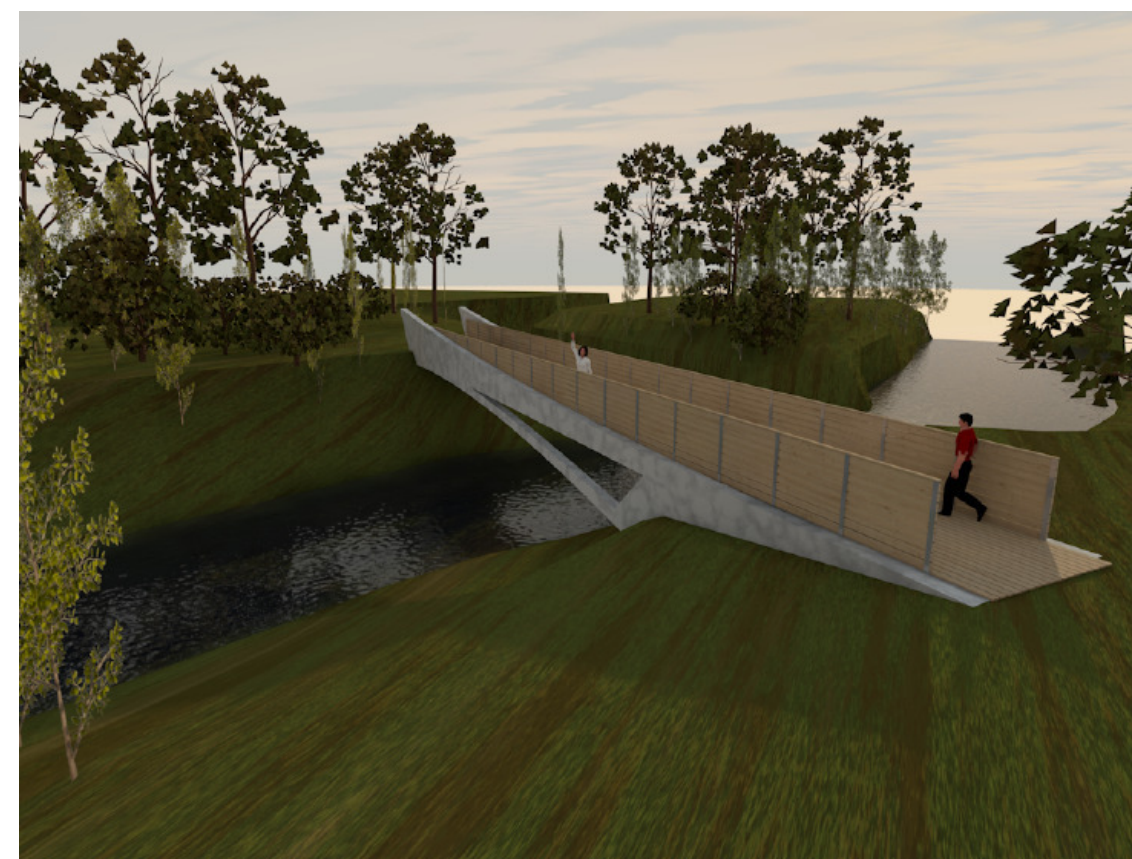
The process of studying possible solutions began even before all the external conditions were fixed, which led to making false assumptions, that could not meet the requirements, but helped understanding and concentrating on the issues, as will be shown in the following.

4. DRAFT DESIGN

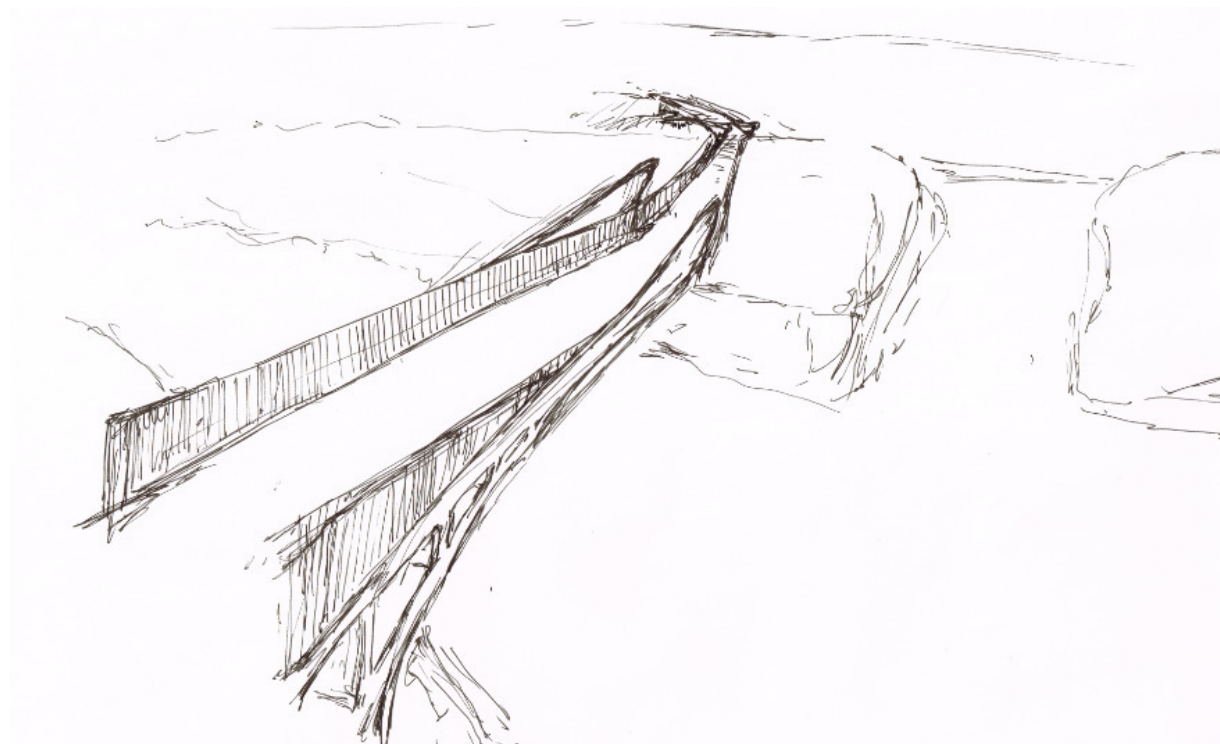
4.1 ASYMMETRICAL BEAM BRIDGE



4.1 Draft of the asymmetrical beam bridge



4.2 3D-View of the asymmetrical beam bridge



4.3 Study of alternative solutions

The wide range of architectural and structural possibilities and the many interesting solutions found in similar conditions, motivated and encouraged our research, which inspired the first idea for the design. Triggered by the Paul-Amann-Footbridge in Vienna, by the Architect Rudolf Brandstötter and finished in 2010, the goal was to create a similar effect as observed in Austria. Since in that specific area the river Júcar gives the impression of stretching its arms and spreading the land, creating therefore two small islands, the idea was to connect these islands in a similar manner – giving the impression of the bridges leaning against the slope of the terrain and with their stretched, slim silhouettes imitating the motive of the water. Simultaneously and in contrast to the flowing movement of the main structure, the railing, together with the travel surface appear to break out from the construction. Doing the same on both sides of the middle island it was natural to join the structures by prolonging these elements and thus creating continuity. Consequently, this secures the integrity and transparency of both bridges and gives them an aspect of a whole and not of two separate objects.

The materials chosen for the main structure were precast concrete elements, which would have been transported to the construction site and simply put into place and connected with each other. The gradual curve of the white concrete then reveals the inner body of the bridge, which consists of straight wooden slats, creating the walking surface for the pedestrians and the railing.

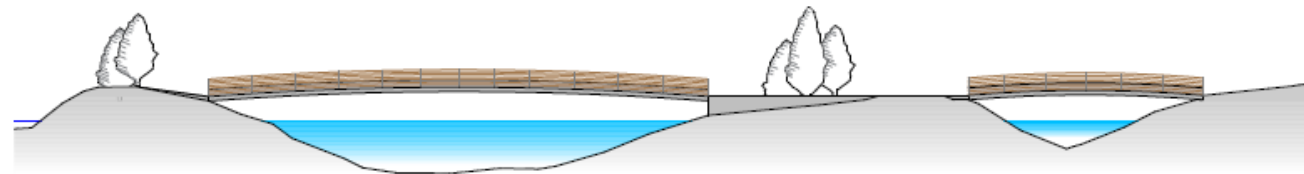
The prolonged curve, ending in a bold, forward facing manner invites to cross the river and guides the pedestrian in the desired direction. Furthermore, the triangularly shaped holes not only reduce the weight of the structure but also provide a positive visual effect so that the bridge appears more graceful and elegant despite the visibly massive material it is made of.

Admittedly, the whole concept relied on the specific shape of the terrain observed while visiting the site, since the structure was planned to take advantage of the slope and there were three support points planned – one on each end of the bridge where it meets with the ground and one in the lowest point just where the lower curve ends and the structure rests on the soil. During the process of applying the concept on the profile of the terrain with its possible high-water levels, there were many adjustments it had to undergo in order to fit. Firstly, the available space the slope offered was reduced because the water levels were far higher than expected, therefore the whole structure had to be moved upwards to guarantee secure space between the river and the bridge. This created a problem because the lower curve of the bridge now had far less space to expand, thus changing the appearance of the bridge. This aspect was emphasized by the fact that it also led to a considerable extension of the span, causing a far slimmer and disproportionate look. In addition, there might have been problems with the construction, as the precast concrete elements would have had to be far longer than planned and therefore their transport would pose an additional complication. Lastly, the appearance of

the smaller bridge started to seem out of proportion and as if imitating the bigger construction, which overall made the wrong unintended impression.

As a result, the accumulating problems led to a complete discard of the design and it became clear that the necessary step was to move the structure to the upper area, leaving a safe space between the bridge and the possible water level while respecting all the requirements.

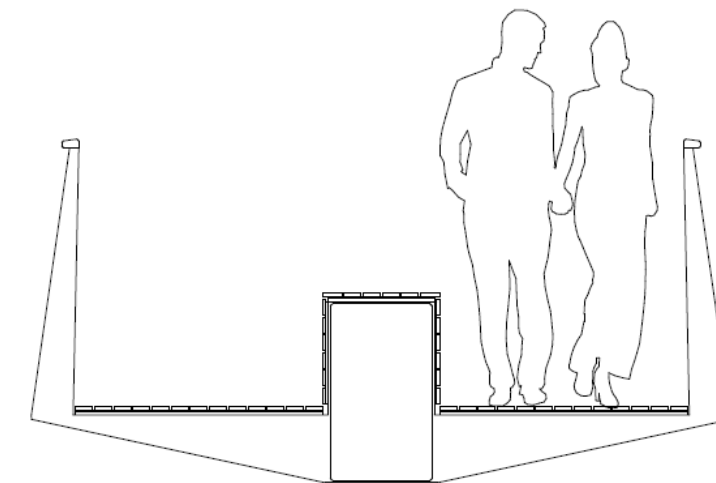
4.2 BEAM BRIDGE WITH A BOX STRUCTURE



4.4 Draft of the beam bridge with a box structure



4.5 3D-View of the beam bridge with a box structure



4.6 Cross-section of the beam bridge with a box structure

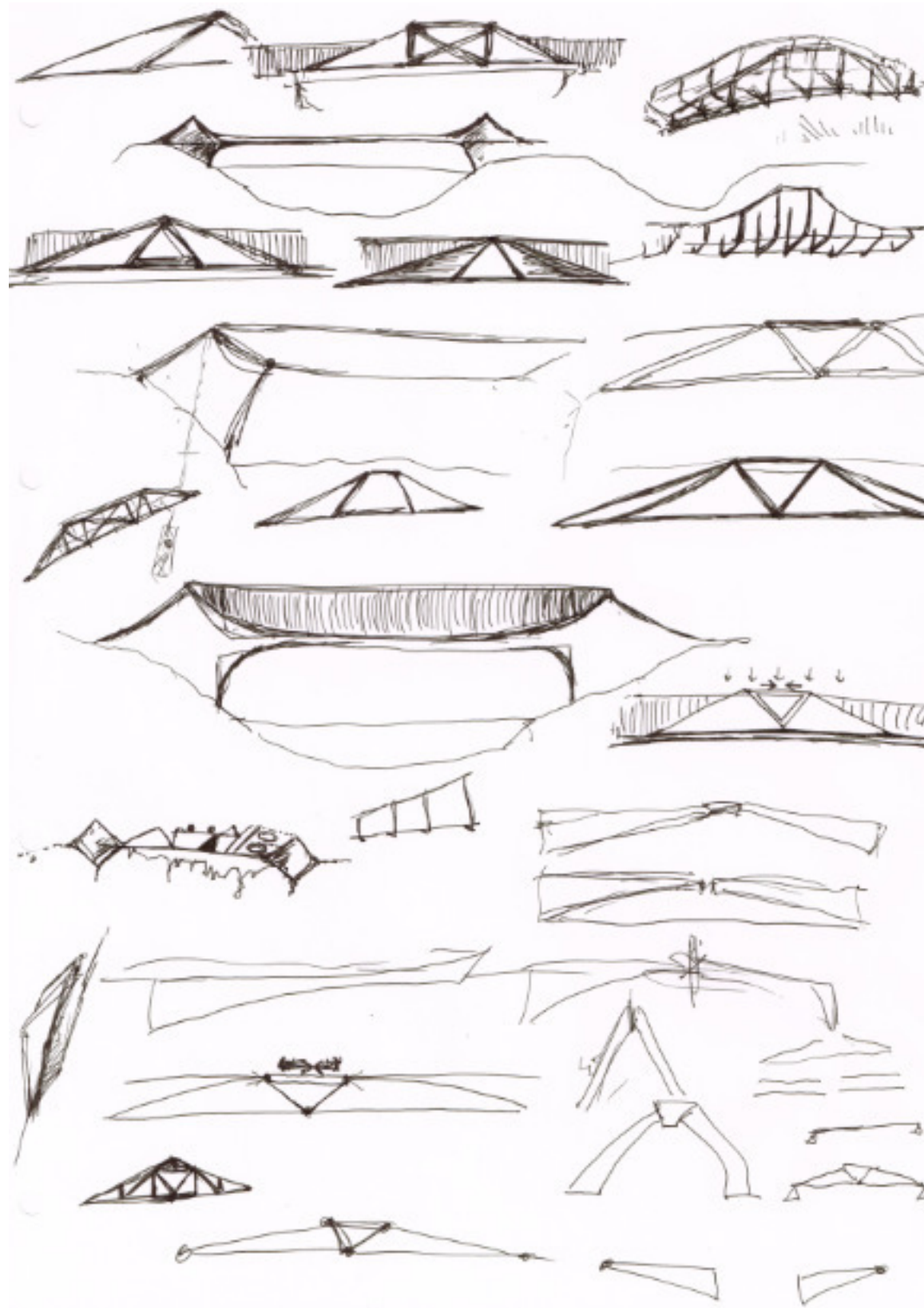
As the next goal was to create a simple design matching with the surroundings while maintaining the flood water clearance, the idea was to focus the attention on an exceptional cross-section, leaving the general aspect fluent and gentle.

This resulted in a simple, slightly bent slim beam as seen in the side elevation, marked by a discrete bench right in the middle of the walkway. The idea behind it was to make the load-bearing structure - the mentioned bench – visible but well integrated into the whole appearance, so that the intentional rest area was welcomed and blended in rather than seen as a disturbing element.

The streamlined, smooth shape of the bridge and its minimalist appearance accentuate the views while also allowing the pedestrian to relax and admire the nature and at the same time listen to the delicate sounds of the river below him.

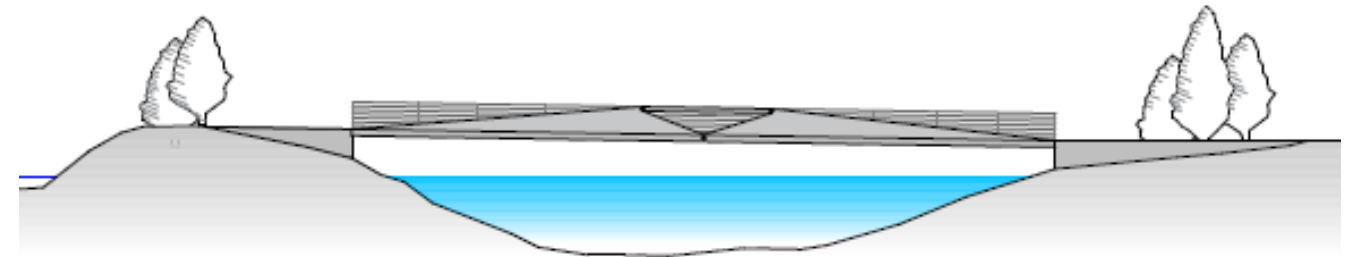
As seen in the cross-section there are wings on each side designed to bear the deck and its loads, coming out of the box structure, which itself rises through the deck. Covering the whole section with wooden boards running longitudinally and coating the bench in the same manner creates an effect of continuity and integrity while emphasizing the minimalist look.

However, while performing a pre-measurement it became clear that the planned box beam would have to be far higher than initially assumed in order to comply with the static requirements, which affects the entire aspect of the bridge since the beam is visible. As a result, the bench would become an obstacle instead of a discrete rest area and would divide the cross-section into two separate walkways. Consequently, this solution could not be adopted because it did not correspond with the initial idea and would appear conspicuous and inelegant.



4.6 Study of alternative solutions

4.3 BEAM BRIDGE WITH ARTICULATION POINTS



4.7 Beam bridge with articulation points



4.8 3-D View of the beam bridge with articulation points

This solution is yet another inspiration by the “Footbridge Bleichwiese” in Backnang, Germany, by the architects Andreas Keil, Christiane Sander and Finn van Reeken. With similar landscape conditions, span and demand on a high level of prefabrication, it was an admirable example, which considerably helped shaping the final design.

The structure consists of a single-span girder and lateral box sections that rise in height towards the center creating two triangular shapes on each side, connected by a joint at the bottom and at the top by a compression rod and a joint on each side respectively. The lateral box sections provide structural support as well as a banister. They are connected by the deck, which is secured against lateral buckling by cross ribs.

By designing the joints as visible bolted connections and linking the lateral sections with a rod, at the position of the maximal bending moment, the construction process, the transparency and creativity of the idea become apparent. Furthermore, the emerging triangular gaps add to the light appearance of the bridge, generating an innovative design, which by its easily perceivable structural clarity contributes to the visual appreciation by the observer. The harmony between the functional and aesthetical elements makes this structure unique and logical, while a short construction time provides for an extra benefit.

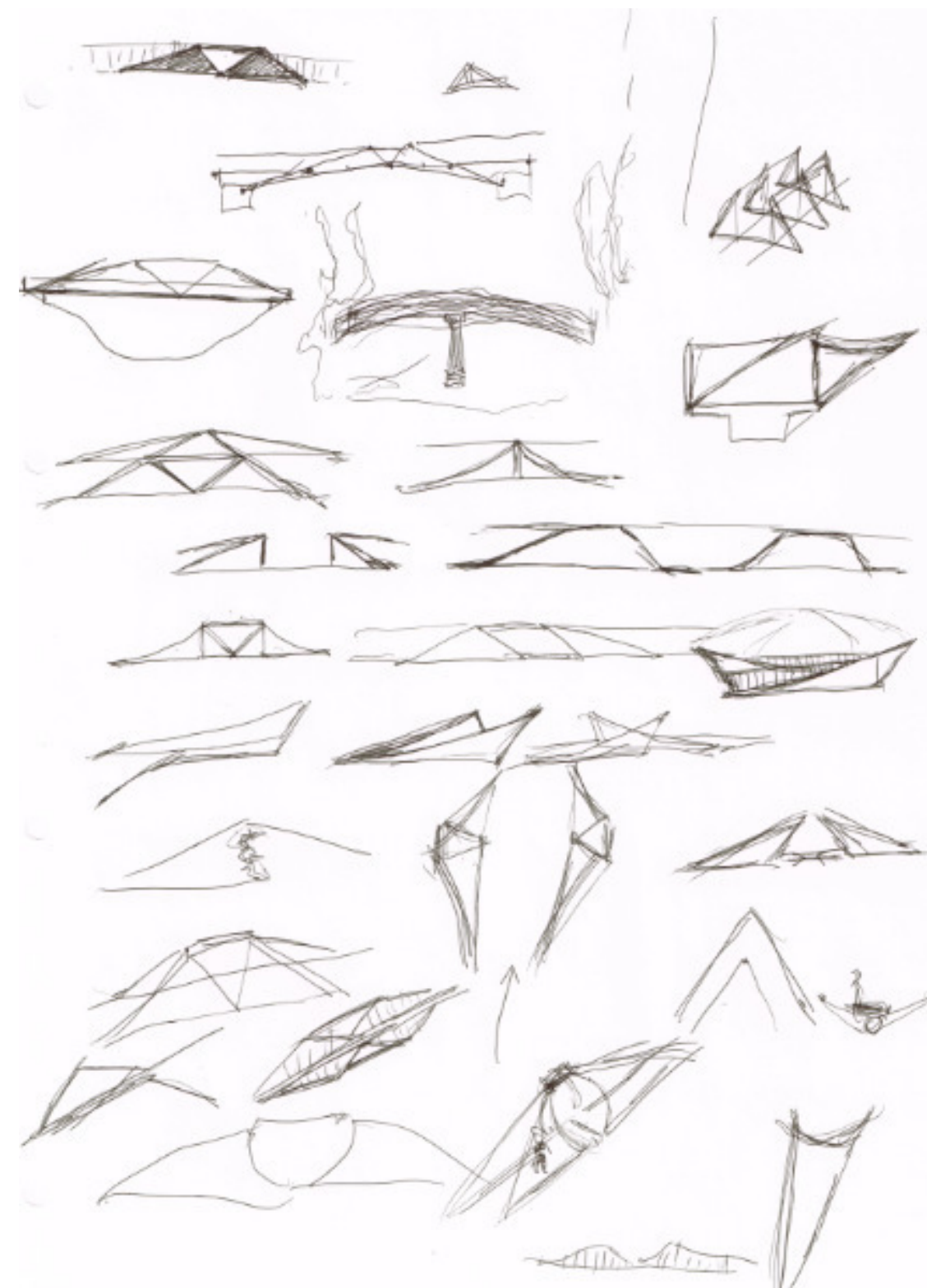
Although an excellent solution in Germany, it would have been problematic in the present project with regards to the smaller bridge, which could appear unproportionate with the same dimensions but much smaller span. As a result, it was regarded only as an inspiring alternative, that influenced the shape of the final design as will be presented in the following.

4.4 TRIANGULARLY SHAPED BEAM BRIDGE – THE ADOPTED SOLUTION

Recapitulating, the important aspects that had to be considered were creating a coherent connection of the hiking path, highlighting that both bridges belong together as a whole, designing structures that would not interfere with the future possible water level, keeping both bridges in mind to avoid the smaller one being disproportional and ill-considered, taking the construction process into account from early on, and preserving the tranquil character of the area.

As a result, admiring the triangular shape of the preceding bridge, a solution based on this particular shape was developed. The superstructure, rising in height towards the center is not only aesthetically appealing, but also marks the point of the highest moment, where more material is needed in order to withstand the forces, creating therefore a logical and lucid design. Additionally, the shape softens the whole aspect by appearing lighter and not as massive as it would be if the height stayed the same, which is a considerable advantage for such a long span.

Underlining the inclined lines of the superstructure, underneath the walking surface, there is again a change in direction, with the lower part gradually gaining height towards the ends as opposed to the movement above. The milder inclination of the lower part clearly separates it from the upper one and therefore focusing the



4.9 Study of alternative solutions

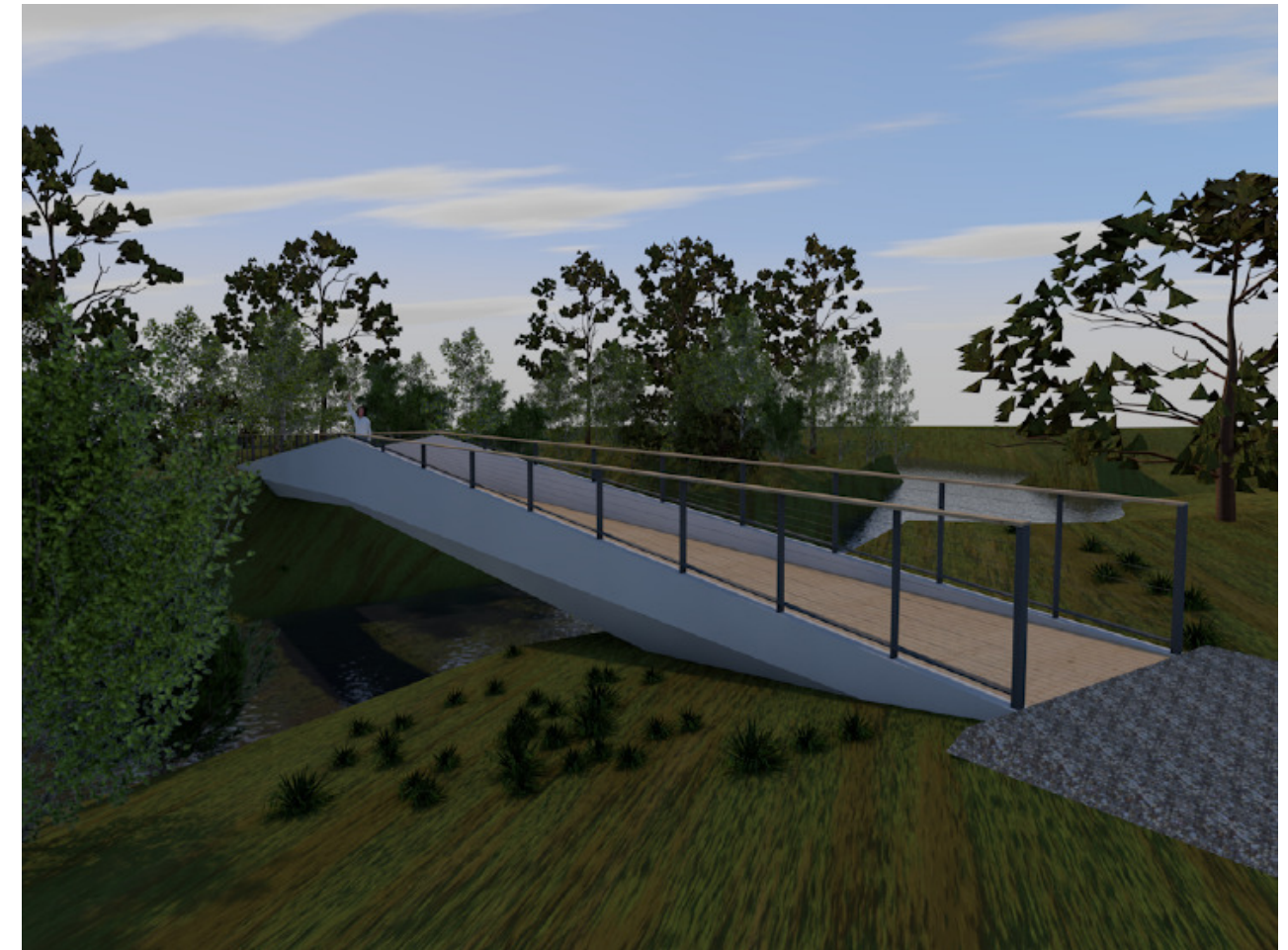
attention on the latter, putting the load bearing structure in a shadow, which makes the bridge easier to grasp in its full extent.

Yet another inclination that fitted into this concept is in the cross section, where the shape bends outwards at the same angle throughout the bridge, creating thus one smooth plane. The inclined bottom sides and the straight upper part remind of a shape of a ship, which was the leading idea of the cross section. Since the base of the structure rises towards the center while maintaining a rather small inclination of the surface, the cross section loses height gradually hence appearing much slimmer in the center.

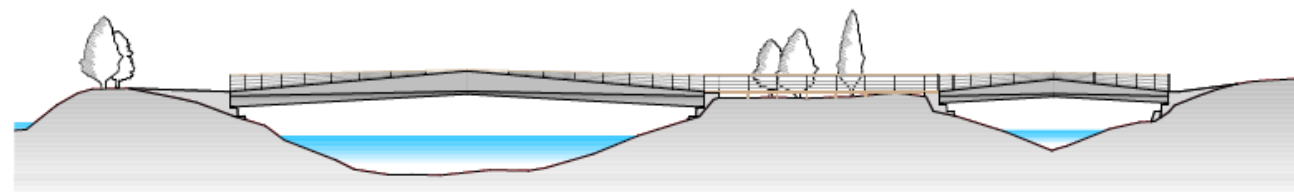
Having that shape defined, one can determine the basic dimensions, and the remaining measurements result from the geometry. This way the smaller bridge can be defined easily, adjusting the proportions accordingly.

As in the case of the preceding bridge, the lateral sections are part of the structural system as well as part of the railing. The bridge consists of several steel transverse profiles placed at regular distance throughout the length and is covered by a steel sheet, creating even planes. Additionally, the metal sheet is placed at several spots in the inner body of the structure, providing the necessary stiffening. The rectangularly shaped profiles located at both lateral sections that continuously follow the triangular shape, accumulate the inertia in these parts of the structure, guaranteeing more stability.

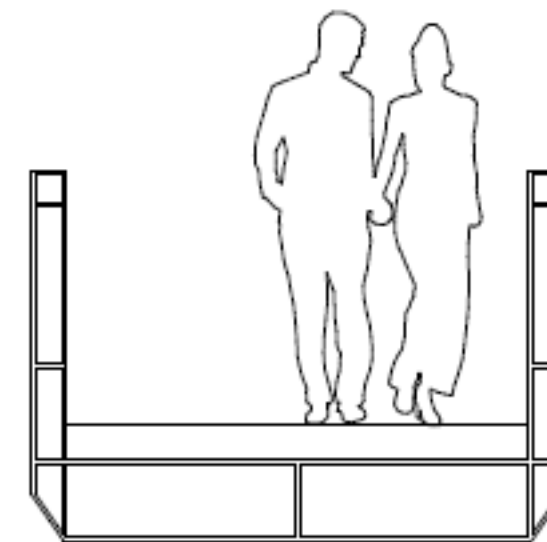
Aiming to adapt to the difficulties of the construction process that the rural area presents, it was settled on steel as an adequate construction material, with the goal to prefabricate as many elements as possible. In addition, steel fits very well into the environment, creating a graceful connection and allowing the hiking path to continue. The wooden walkway generates a smooth link between the nature and the structure.



4.11 3-D View of the triangularly shaped beam bridge



4.10 Triangularly shaped beam bridge



4.12 Cross section of the triangularly shaped beam bridge

5. COMPARISON OF THE ALTERNATIVES

To summarize and justify the chosen solution, the following comparison of the alternatives was made. Analyzing the four ideas under the aspects of construction, aesthetics, durability, economics, the following advantages and disadvantages were found:

Asymmetrical beam bridge:

- + Eye-catching design
- + Relatively lower costs than the steel alternatives
- Difficulties with the transport of the precast concrete elements due to the location
- Design might prove too striking for the rural area, hence resulting in disapproval from the inhabitants
- Difficulties with adapting the solution to get a flood water clearance
- Lower lifespan of the material in comparison to steel
- Smaller bridge out of proportion

Beam bridge with a box structure:

- + Easy adjustment of the proportions of the smaller bridge
- + Minimalist design suits the environment
- Box turns out too high for static reasons and creates a visual and functional obstacle
- The bridge would have to be wider, which means unnecessary costs just to adopt the design
- Box in the middle might result in a security issue, not suitable for the disabled

Beam bridge with articulation points:

- + Relatively easy construction
- + Well integrated into the environment
- + Solution proved to be working well for a similar span
- Problems resulting from adjusting the proportions of the smaller bridge

Triangularly shaped beam bridge:

- + Easy to adjust proportions of the smaller bridge
- + Extraordinary yet not extravagant design
- + High level of prefabrication, hence less problematic on-site construction

The last solution was considered best, as it combines the positive aspects of the other ideas and provides answers to the problems that appeared throughout the design process.

6. SPECIFICATIONS OF THE ADOPTED SOLUTION

As mentioned before, the triangularly shaped beam bridge consists of several steel transverse profiles placed at regular distance. Agreeing upon a height of 1,10m from the deck up till the highest point of the steel structure in the center of the bigger bridge, a height of 0,20m from the bend line to the lowest plane and a bending angle of 125°, and considering that the span of the bridge is 33m, the geometry was defined. Furthermore, the line of the deck surface was fixed with a 0,4m distance from the bending line for the bigger bridge and 0,3m for the smaller one. Other fixed points were the lateral sections lowering down from the middle towards the ends with their lowest points being the deck surface. The transverse profiles are placed every 2m in order to obtain regular intervals, leaving 0,5m space on each side for the installation of the supports. The metal skeleton is then covered by a 15mm thick sheet throughout the length, that gives the bridge a smooth, even plane.

As for the 16m bridge, its geometry was defined by cutting the bigger bridge 8m from the center on each side and leaving the lower load bearing part unchanged. However, the upper lateral sections were adjusted to preserve the proportions of the bridge. By lowering the highest point in the center to 0,7m counting from the deck, the sections keep their smooth angle and end in the same spot as in the bigger bridge.

7. CONCLUSION

In this appendix, the alternative solutions for the design of the two footbridges over the Júcar River in Casa de los Nuevos were introduced.

Four alternatives were considered and analyzed in order to choose the best solution which complies with all the requirements given by the location. By comparing them and studying their advantages and disadvantages it was concluded that the fourth alternative, the triangularly shaped beam bridge, results as the optimal solution, because it does not restrict the aesthetics while meeting the feasibility criteria.