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A SECOND LIFE FOR PVC/PES MEMBRANE MATERIAL: RE-USE-MEMBRANE ROOF FOR A MODULAR TIMBER STRUCTURE PAVILLON

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Summary. Based on an internal student competition, Stuttgart Technical University of Applied Sciences is realising a modular wooden pavilion with a membrane roof [cp. **Fig. 1**]. The building (2 perimeter and 10 standard bays, each approx. 2.2 m x 5.5 m) houses the student association ‘Block4’ and will be a place for meetings, research, transfer and teaching.

The project fulfils the highest standards of sustainability, e.g. no coatings or glue, no nail plates, but instead single-material, detachable timber connections, use of calamity wood and a maximum of re-use-material[1]. The modular primary timber construction will be equipped with interchangeable rigid and movable filling elements, which will be used to investigate renewable raw materials in teaching and research projects. The membrane roof uses only recycled/re-use material and has been realised with a maximum input from students. We have produced as many of joints and fittings as possible in our workshops. The membrane material from a local construction site was processed, cut and cleaned by students at the university and put together with the help of a specialized company. All planning processes, design details and installation steps were harmonised with this. The primary structure was installed in early spring with a temporary roof, and the final membrane roof had been installed this summer semester and was complete in August 2025.

Fig. 1: Visualisation of the new “Block 4” as the result of a university-internal, interdisciplinary competition process, source: HFT Stuttgart.

1 INTRODUCTION

On the campus of Stuttgart University of Applied Sciences (HFT Stuttgart), behind the main building, there is a rectangular inner courtyard with a so-called experimental area, on which the university can erect and research building structures with an experimental character using a simplified building application procedure. Here, innovations in future-orientated planning and sustainable construction are to be examined in temporary, real, prototypical experiments on a 1:1 scale and tested for practicality. In the construction phase, research topics such as building information modelling (BIM), new digital planning tools and methods and digital production will be applied in practical implementation. During operation, the prototypes will act as a "living lab", providing further scope for investigations and user-specific issues such as climatic comfort, flexibility, variability and forms of utilisation.

This endeavour is currently being supported in the "HFT.Space" sub-project of the "HFT.Lab – Innovationslabor an der Hochschule für Technik Stuttgart" project[2] as part of EU funding. This in turn includes a larger sub-project, namely the replacement of the so-called "Block 4" on the above-mentioned experimental area with an innovative new building. For more than 20 years now, "Block 4" has been a place for events and encounters that students run and are responsible for themselves in their own association.

The previous building from 2006 [cp. **Fig. 2**], which was originally only intended to stand for a few years and had already been created as an experiment and realised by students, could no longer be renovated at a reasonable cost. It was therefore ultimately dismantled in a way that the components and materials with re-use-potential could be implemented for new projects such as the new "Block 4". This new building is based on a student design from 2021 [cp. **Fig. 1**], which was the winner of a student competition organised by the university and the 'Freunde der HFT Stuttgart e.V.' association. Like its predecessor, it will be managed by the Block Vier e.V. association and used by students as a meeting place and for various events. This includes a room with a bar including a small storage area, an open but covered area and a smaller multifunctional room for the cold season.

The competition was advertised across faculties and degree programmes, and interdisciplinary teams in particular were encouraged to take part.

These other goals were already part of the competition:

- The realisation should take place to the maximum extent at the university itself, i.e. with students and the university's own workshops. Following the competition, this is to take place in an iterative development and design process over several semesters.
- Upgrading and improvement of the inner courtyard, including the outdoor areas.
- Utilisation of the building not only for student "Block 4" operations, but also for other formats at the university (research, teaching, transfer).
- The building itself is to become the subject and location of research and teaching, and new materials, construction methods and technologies are to be tested and demonstrated. In particular, the ageing behaviour and suitability for use should also be able to be investigated (including acceptance research by students of business psychology, for example).
- High demands on sustainability aspects for planning and realisation. The topic of circularity (dismantlability / re-use / recycling) in particular should play a major role.

Fig. 2: (Old) “Block 4” (2006-2024) , source: HFT Stuttgart.

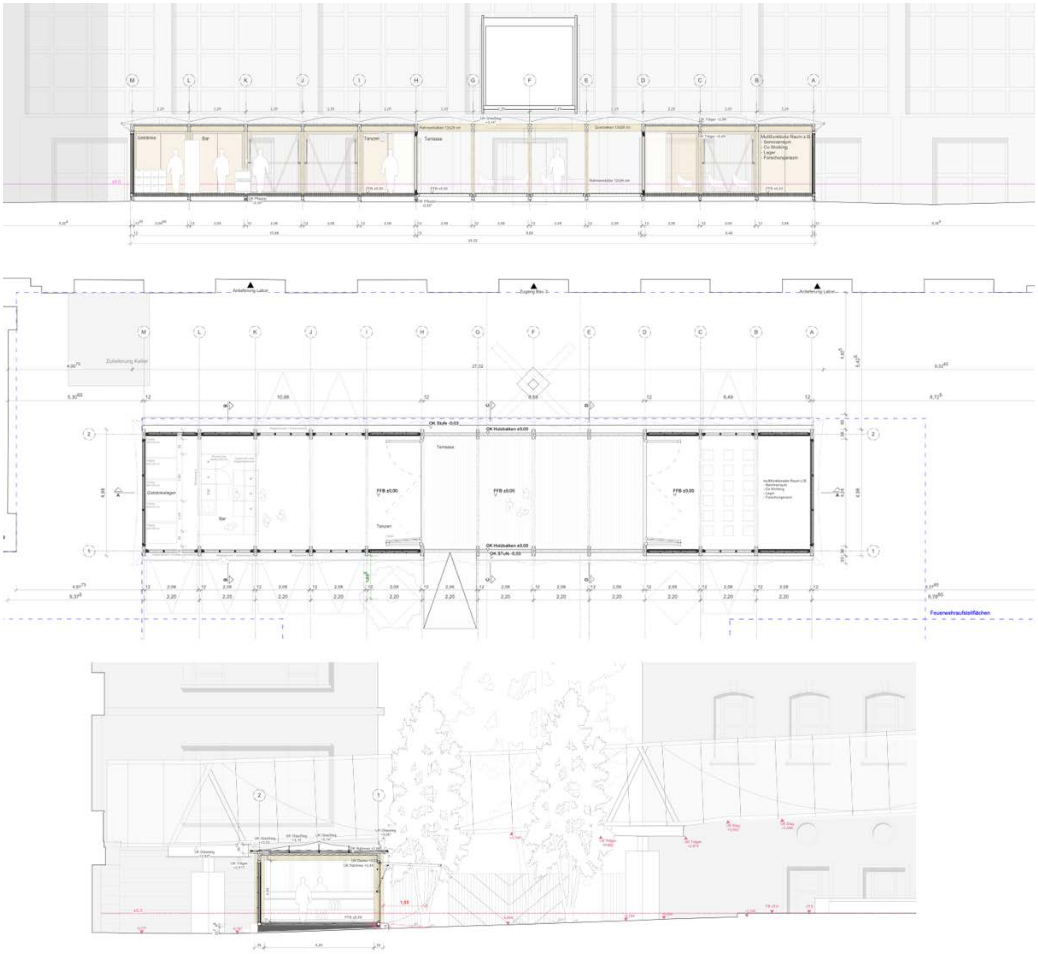

Fig. 3: Design drawings: longitudinal section, floor plan, cross-section and structural concept (red), source: HFT Stuttgart

2 PROJECT DESCRIPTION

The now fully planned and largely completed building is based on a completely different basic idea than its predecessor: the new “Block 4”, a timber frame construction made of calamity wood, is placed on the university's own area in the inner courtyard [cp. **Fig. 1**, **Fig. 3**]. It spans between the wings of an existing building at a distance of at least 5 metres from the building façade to allow access to the laboratories located there. The new pavilion is an elongated, horizontal bar and, with external dimensions of approx. 27 m long, 5 m wide and 3 m high, covers a gross area of approx. 135 m². It is divided into 12 grids with an axial dimension of 2.20 m and comprises three different zones. Five grids on the south side form an enclosed area in which a bar use with lounge/dance area and a separate storage area are provided. To the north, there is a smaller, also enclosed area across three grids, which can be used as a multifunctional space for seminars, co-working, exhibitions, research and/or storage.

The two areas are connected by an open-sided but covered lounge/passageway (outdoor terrace), which is also used as a passageway into the existing building. A membrane construction is stretched over the entire building, which is also divided into several fields by the grid. This roof is made of translucent re-use membrane material. The rooms to the south and north will also each have additional, insulated suspended ceilings to improve thermal comfort in these areas. There are no requirements for a thermal envelope.

The new “Block 4” thus offers indoor and protected outdoor areas, it is simultaneously a lockable room, outdoor lounge area and courtyard furniture. The basic concept also offers a differentiation in a permanently designed primary structure made of added timber frames with rigid corners, which are linked in the roof area by additional horizontal trusses, including bracing, and including the roof structure on the one hand, and an extension level as a secondary structure on the other. This refers to the wall infill elements, which can be opaque, translucent or transparent, rigid or movable. Bracing is provided by the frames and partly by the timber trusses, as well as by the closed walls at the ends and one wall element on each of the long sides. Glue-free GFM boards are used here as a replacement for conventional OSB boards. The finishing and furnishings, which can also be part of the wall infill elements, are also part of this variable secondary structure, which is designed in such a way that it can be replaced and changed again and again.

This is achieved with the help of steel connecting elements ('Walcoverbinder'), a durable and robust solution that enables long-term and simple interchangeability. A large part of the building can thus become the subject of further experiments in research and teaching at a low threshold. The electricity and water supply is provided via supply lines from the neighbouring building, which are laid under the paving and installed under the building to the south. In the longitudinal direction of the building, each individual grid field can be supplied via a cable duct on the paving [cp. **Fig. 4**] to enable subsequent electrification, among other things. Regular inspection openings facilitate access. In the building, the installation should be routed openly on the primary supporting structure. Due to the height development, supply and waste water pipes can only be laid in the area of the bar.

The submitted designs were already analysed and compared in terms of their LCA balance[3] during the competition phase. Throughout the iterative design and planning process, which lasted several semesters, the LCA data was kept up to date and was therefore always a quantitative design criterion, especially when considering different variants.

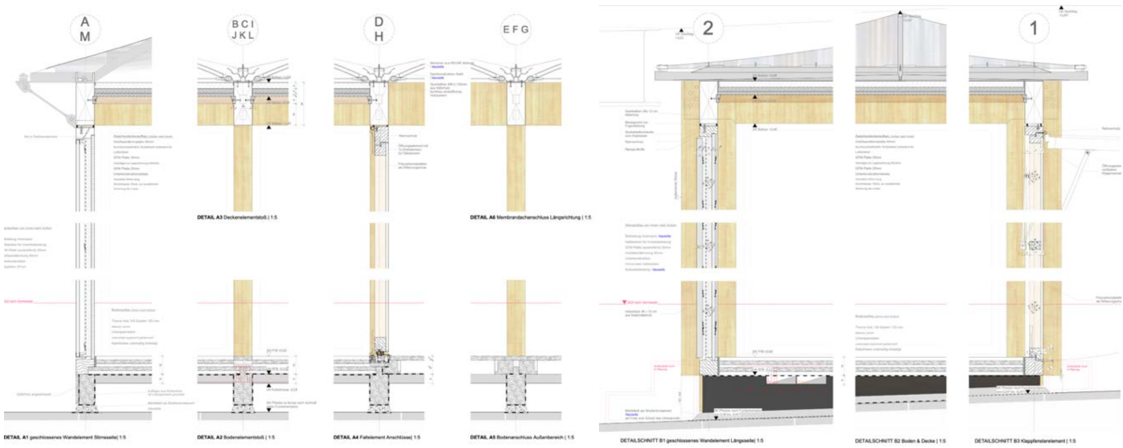

Fig. 4: Timber construction: details and sections, source: HFT Stuttgart.

3 DESCRIPTION PRIMARY TIMBER CONSTRUCTION

The primary structure is designed as a timber frame construction consisting of two supports and a beam as a rigid connection. The timber construction consists of prefabricated components to ensure short assembly times and easy dismantling. The entire timber construction is manufactured without glue and in a single-material solution[4,5]. The rigid corners of the block were developed and tested in a separate design project with civil engineering students. The aim here was to create a single-material connection as far as possible and to dispense with steel. All other connecting elements are also made of wood wherever possible. The 13 frames form the basic structure of the building and are founded on oak foundations on a 4 cm thick layer of in-situ concrete. A seal was inserted between the concrete and the timber to prevent rising water. The supports of the timber frames are slotted at the bottom and dowelled with wooden dowels.

Beams are mounted between the frames in the longitudinal direction for bracing. CLT panels with a sealed surface are to be installed on the beams as a floor. Underneath, a stapled wind board protects the construction from rising damp. A frame is installed in each of the individual compartments of the timber construction, into which wall and window elements are “hung” and can therefore be easily replaced. The wall and window elements are pre-produced as separate components and then inserted into these frames. All wall and window modules can be replaced in their entirety, but only the façades or interior panelling can be changed or replaced if required. They are only additionally fixed in statically important positions. The floor elements consist of three layered solid wood panels, which are connected to each other without glue using wooden dowels. The leitmotif for the design is the theme of circularity: It should be possible to reuse material, but it should also be built as far as possible with existing components and material. For example, materials and panel material from the old “Block 4” will be used for panel components.

Together with the re-use material of the roof, this also determines the design and aesthetics of the building. The joints should be glue-free and single-material. In addition, components made of d defective or calamity wood are used in the area of the replaceable wall and window elements. The wooden foundations are made of oak on a thin layer of concrete as a leveller. All fasteners are made of wood as far as possible (wooden dowels), metal screws are only used to prevent the wood from shearing, they are not necessary for force transmission. Tenon joints for the frames are also secured with wooden dowels. The construction process is designed in such a way that the desired quality can be achieved on the one hand, but on the other hand in such a way that the highest possible share of students' own work can be achieved in all areas. Many details have been developed in such a way that they can be realised in the university's own workshops.

4 DESCRIPTION OF MEMBRANE ROOF

The membrane roof[6] is a key design element of the new “Block 4”, but also establishes a link to the old “Block 4”, where this type of material had already been used in an innovative way as a space-enclosing element. However, it is also a very functional solution for achieving the project objectives, as it is translucent, requires very little mass or material, is cost-effective and allows a constructive solution to pass under the connecting bridge in the courtyard with a uniform surface without creating a height conflict. In addition to providing weather protection for users, the roof is also an important element of structural timber protection.

The use of reusable membrane material is particularly innovative. This idea was tested in advance at the university in a smaller design-build project (“Dächle”, see project description[7]). The specific material for “Block 4” is a printed, used technical textile (polyester fabric with PVC coating, “HEYtex frontlit lite eco” with a grammage of approx. 500 g/m^2), which would normally have been disposed of after use in the “Stuttgart 21” project (Stuttgart Central Station) and has been given a second life in this way. This specified material has already been tested in biaxial tests and found to be suitable. The details were developed by students in courses, including the required steel components, with the support of professors from the university and external experts [cp. **Fig. 5** to **Fig. 8**].

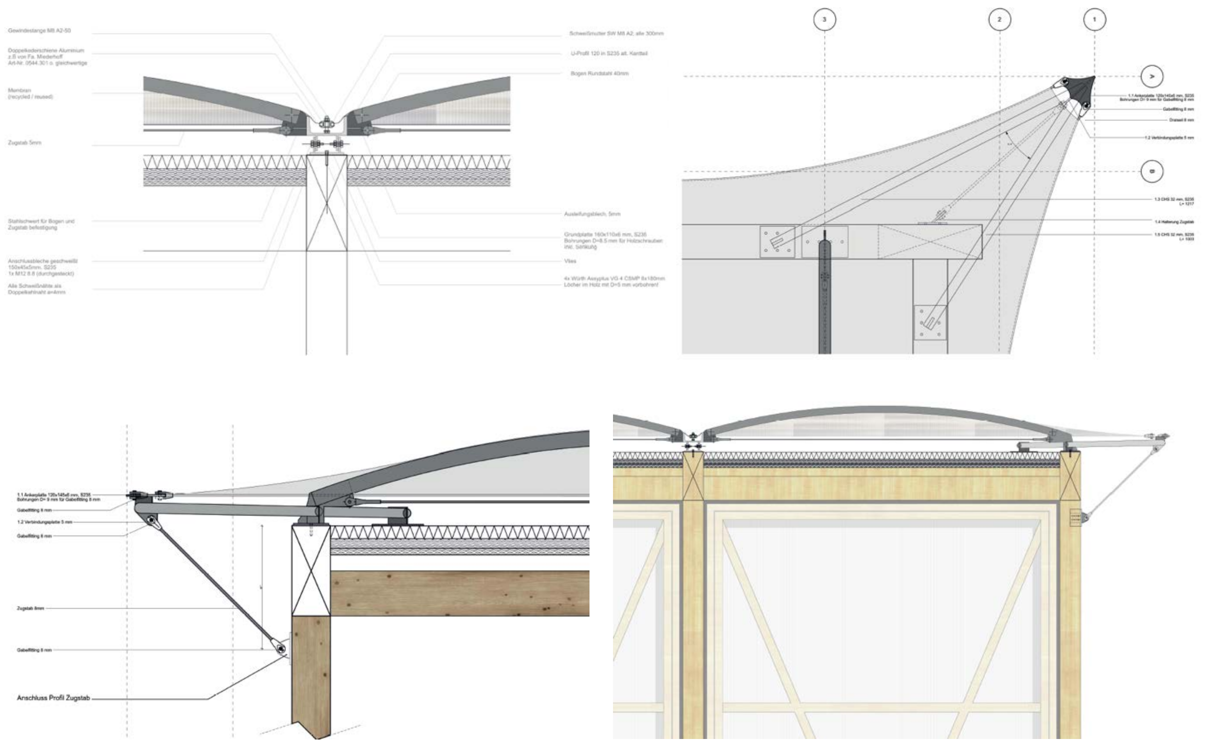

Fig. 5: Membrane roof, details, source: HFT Stuttgart.

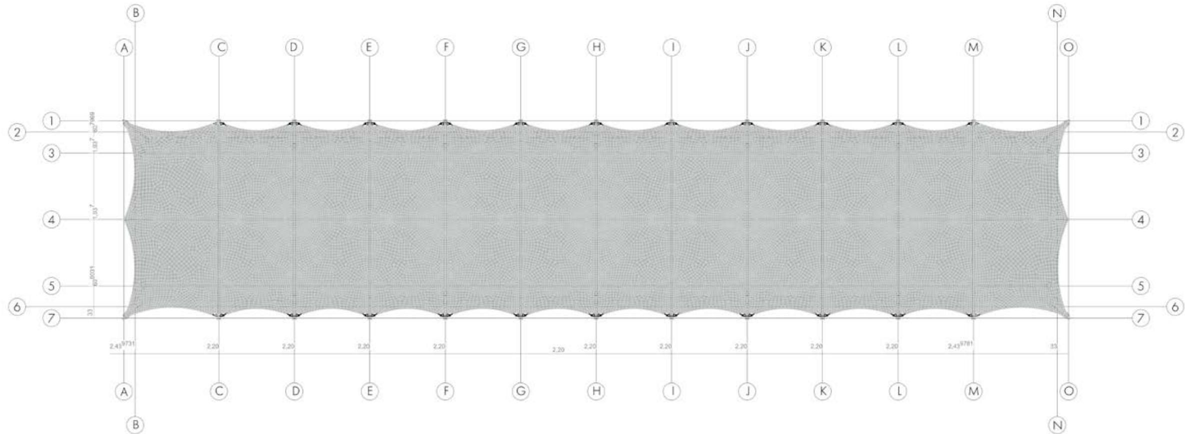

Fig. 6: Membrane roof, roof view, source: HFT Stuttgart

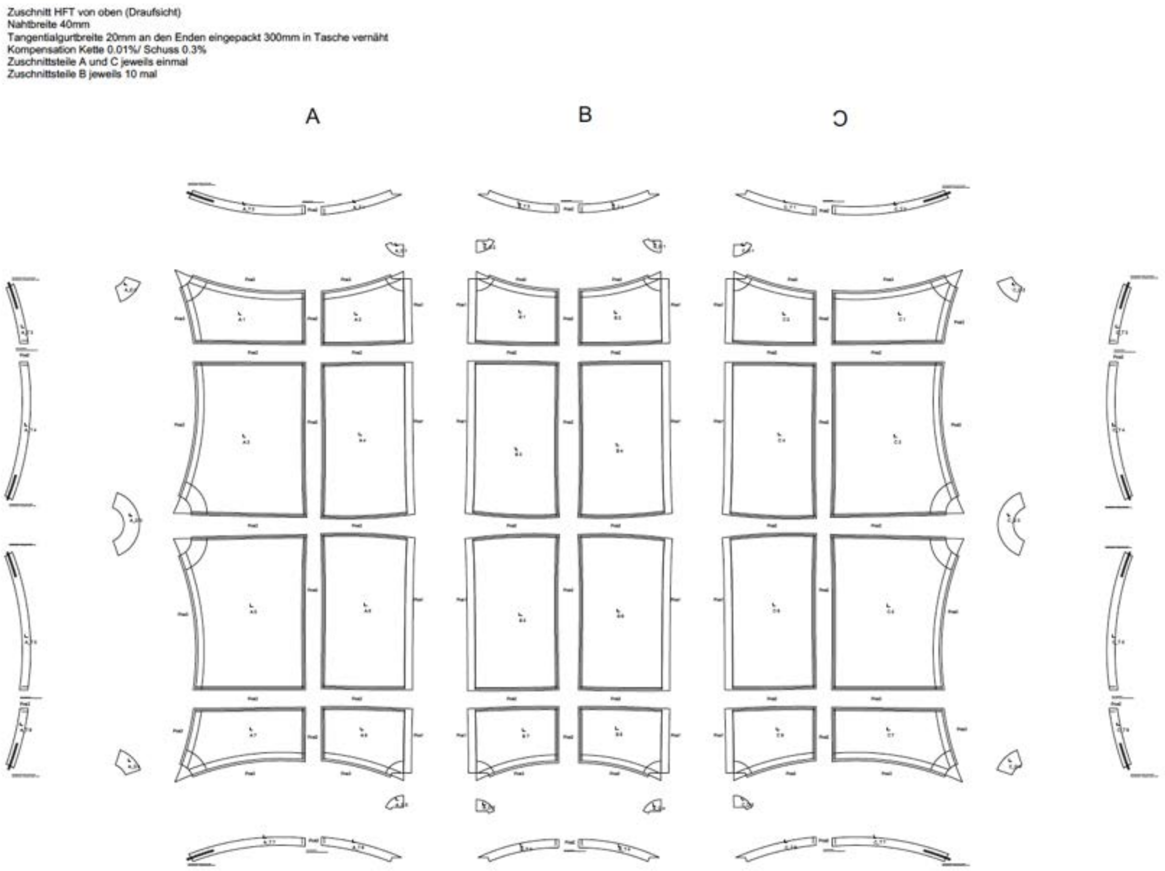

Fig. 7: Membrane roof, cutting patterns, source: HFT Stuttgart.

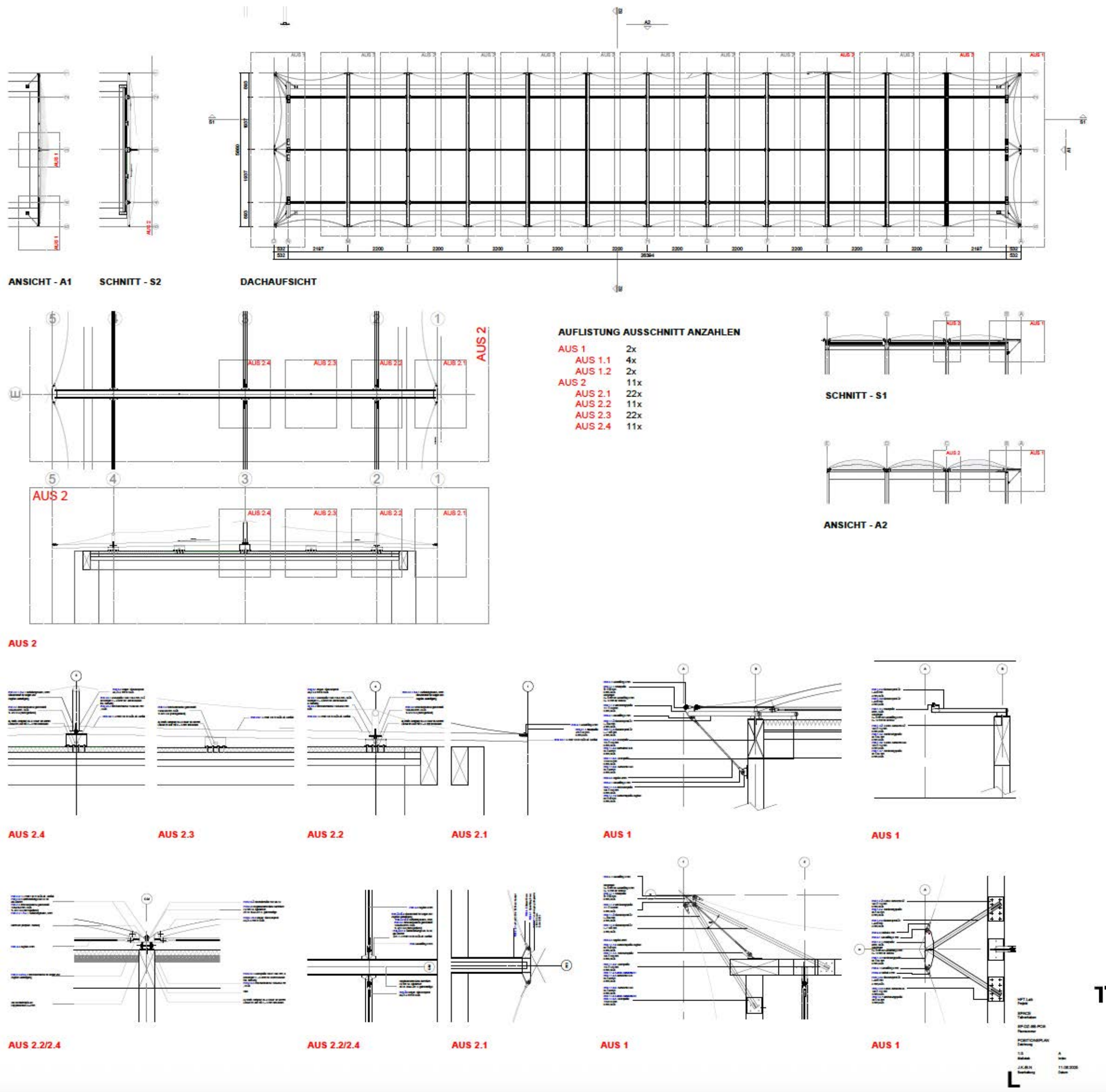

Fig. 8: Steel parts, position plan and details, source: HFT Stuttgart.

5 FAÇADES AND INTERIORS

As described above, the façades and interior fittings are part of the secondary structure. Both are designed in such a way that they can be replaced with simple means, meaning that new things can be installed and tested again and again, for teaching and research. The modular concept allows a wide variety of combinations and a high degree of flexibility. In these areas, the new “Block 4” itself will become a laboratory and experimental field on a 1:1 scale, allowing, for example, construction variants, materials in many respects including ageing behaviour under real conditions of use, user acceptance and, last but not least, design qualities to be investigated. For the first realisation, for example, various reused components and materials from the old “Block 4” are installed and tested [cp. **Fig. 9**].

Fig. 9: Façades with reuse of parts of the old “Block 4”, source: HFT Stuttgart.

6 DIDACTIC CONCEPT, INTEGRATION INTO TEACHING

A central element of the project is its didactic integration into the university's teaching concept. Students are actively involved in all phases - from planning to construction and realisation. The “Block 4” therefore not only serves as a demonstration object, but also as a learning platform on which theoretical knowledge can be tested in practice on a 1:1 scale. This integrative learning model promotes both technical and conceptual skills and contributes significantly to the training of future players in the field of architecture, civil engineering and other players in the building industry in terms of sustainable development. In addition, the project pursues further objectives in the sense of consistently circular construction. For example, deconstruction, reuse and recyclability are to be systematically optimised, single-origin materials used and reversible connection techniques applied. As early as the design phase, attention is paid to “design for disassembly”, which enables components to be disassembled and reused at a later date. The use of regional value chains contributes to the ecological balance, while digital methods such as material passports and the integration of life cycle analyses (LCA) enable transparent documentation of material flows. In addition, a scientifically sound evaluation of the materials and energy concepts used is to be carried out in order to derive findings for future projects.

7 CONSTRUCTION PHASE

The building project was and is being realised with the active involvement of specialist companies and students. The focus was not only on the structural quality, but above all on the learning process in the interplay between planning and realisation. The students were able to gain valuable experience in the areas of design, detailing, project management, construction site organisation, material processing and cooperation with external partners. The construction work itself was seen as an integral part of the curriculum [cp. **Fig. 10**]. **Fig. 11** shows a collection of photographs illustrating the individual steps involved in installing the membrane roof: removal of the temporary protective roof, measurement and installation of the steel substructure (trusses and arches), installation of the prefabricated membrane surfaces, formation of the edge connections, etc.

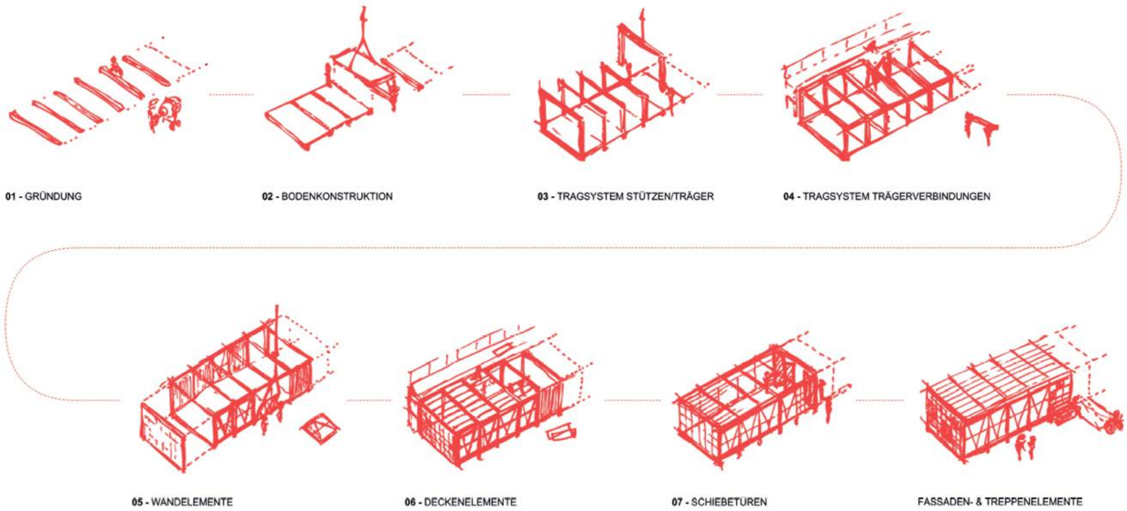

Fig. 10: Planned construction process, source: HFT Stuttgart.

7 CONCLUSION AND OUTLOOK

To assess the ecological and functional qualities of the pavilion, a holistic view and a comprehensive life cycle analysis are carried out. This is intended to provide information on the environmental impact and sustainability of the building. No final results are currently available. Various further utilisation and development options are conceivable in the future: The pavilion can be easily dismantled or adapted to new uses.

The new “Block 4” project makes an innovative contribution to the development and practical implementation of sustainable construction methods. It combines the principles of sustainable construction with an interdisciplinary approach that promotes learning. The resulting structure is not only architecturally and technically forward-looking, but also serves as a source of inspiration for future research and educational formats in the context of the transformation of the construction industry. As an interdisciplinary design-build project, the new “Block 4” is part of a long tradition at HFT Stuttgart. Particularly noteworthy here are a pavilion in Ingersheim, which was realised in 2024 as part of an international student workshop[8] and the university's two contributions to the Solar Decathlon Europe 2010 and 2021/22[9]. In all three cases, however, the results could not remain at the university site as a living showcase due to lack of space. This is different with “Block 4” and this project therefore represents a very valuable model basis for further interdisciplinary design-build projects at the university with added value for teaching that can hardly be overestimated, because nothing is as convincing as a high-quality executed and functioning project on a 1:1 scale that you can study with your hands and all your senses.

Fig. 11: Documenting photographs of construction and installation process of membrane roof, source: HFT Stuttgart.

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REFERENCES

[1] Hillebrandt, A. et al.: Manual of Recycling. DETAIL, 2019

[2] cp. https://hftlab.hft-stuttgart.de/en

[3] Cremers, Jan: 'Environmental impact of architectural fabric structures' in: 'Fabric Structures in Architecture', ed. by Josep Ignasi Llorens, Cambridge, 4/2015, pp. 257-282

[4] Bauer, S.; Pauli, D.: The Joinery Compendium. Ruby Press, 2025

[5] Kaufmann, H. et al: Manual of Multi Storey Timber Construction. DETAIL, 2022

[6] Knippers, J.; Cremers, J.; Lienhard, J.; Gabler, M: Construction Manual for Polymers and Membranes. DETAIL, 2011

[7] Hörmann, Fabian; Stasi, Frank: DesignBuild-Projekt 'Dächle', 2024, cp. https://www.hft-stuttgart.com/studies/fields-of-study/architecture-and-design/projects/real-lab-the-daechle-in-the-design-built-week

[8] Kretzer, A. et al.: IMIAD International Workshop Ingersheim, 2024, cp. https://www.hft-stuttgart.com/studies/fields-of-study/architecture-and-design/projects/imiad-international-workshop-2024-living-lab-youth-center-ingersheim

[9] HFT-Beitrag coLLab zum Wettbewerb Solar Decathlon Europe 21>22 in: Team Deutschland Solar Decathlon Europe 21/22 [Hrsg.]; Team LOCAL+; Team X4S; Team MIMO; Team RoofKIT; Team Deeply High; Team levelup; Team coLLab: Solares und kreislaufgerechtes Bauen: die deutschen Beiträge zum Solar Decathlon Europe 21/22, KIT Repositorium, 2023, cp. https://doi.org/10.5445/IR/1000153927

[10] cp. https://2021-27.efre-bw.de/projektbeispiel/hft-lab/