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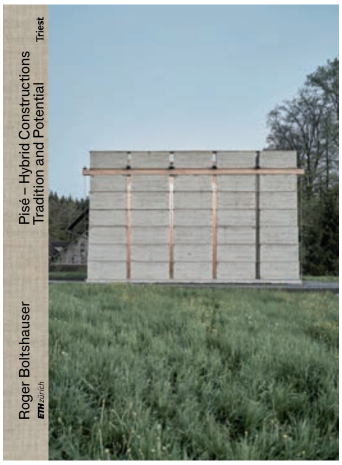
Hybrid constructions with natural building materials



Roger Boltshauser with Mirjam Kupferschmid, Janina Flückiger, Marlène Witry (eds.)
Pisé – Hybrid Constructions. Tradition and Potential

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- → **Strategies for a cultural change in the construction sector by example of hybrid constructions made from natural, renewable raw materials**
- → **Resource-efficient construction methods and their implementation in the construction industry**
- → **Examples from Morocco, Switzerland, England and Europe**

The follow-up volume to *Pisé – Rammed Earth* continues the application-based analysis and presentation of building with natural materials. Instead of investigating rammed earth structures, Hybrid Constructions describes construction with different earth building methods, also in combination with other materials. Based on an analysis of historical structures in Morocco, Southern and Central Europe, the book provides the knowledge required for current applications of hybrid earth construction – not only in terms of structure but also with regard to maintaining a comfortable indoor climate.

Projects conducted by students at EPFL Lausanne, TU Munich and ETH Zurich demonstrate what this can look like. In addition to this, structures such as the kiln tower in Cham, built with prestressed rammed earth, or the Hortus project in Basel – a timber building with a hybrid earth/timber ceiling structure – show how projects of this kind can be successfully put into practice. Research buildings by Florian Nagler in Bad Aibling and Munich show how low-tech hybrid structures can be used to realise modern architecture.

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About the editors

Roger Boltshauser, graduate architect ETH BSA SIA. Founded Boltshauser Architects in Zurich in 1996. In addition to his work at the firm, Roger Boltshauser was involved in teaching at ETH Zurich and EPF Lausanne, HTW Chur and the Chur Institute of Architecture CIA between 1996 and 2009. He was a visiting professor at EPFL Lausanne and TU Munich, as well as a guest lecturer at ETH Zurich, where he has been a full professor of architecture and regenerative materials since 2024. In the same year, he was awarded the Semper Prize.

Mirjam Kupferschmid studied architecture at ETH Zurich. As a research assistant, she has been researching and teaching at the Chair of Architecture and Regenerative Materials since 2022. She has been head of the chair since early 2025. She also publishes as a freelance author and is involved in the Countdown 2030 collective, which promotes a sustainable construction industry.

Janina Flückiger graduated in architecture at ETH Zurich. From 2013 to 2014, she was editor of *transMagazin* (a magazine for architecture and urban planning), from 2016 to 2022 she was responsible for public relations at Boltshauser Architekten, and from 2018 to 2023 she worked as a senior assistant at Roger Boltshauser's guest lectureship at ETH Zurich. She is studying psychology at the University of Zurich.

Marlène Witry studied architecture at the Technical University of Munich. From 2013 to 2016, she worked as an architect at Boltshauser Architects; in 2016, she founded Schürmann + Witry Architects. Parallel to her freelance work, she was a design assistant at Roger Boltshauser's chair from 2016 to 2021, first at EPFL Lausanne, then at ETH Zurich. From 2019 to 2020, she taught together with Theres Hollenstein at MSA Münster. Since 2025, she has been Professor of Design and Design Methodology at the HFT Stuttgart.

The focus is on the following questions:

→ How can new materials and constructions be integrated into the urban fabric or specific locality?
→ Can renewable raw materials be used to drastically reduce the amount of resources used?
→ Can prefabrication cut construction costs so as to make alternative construction methods competitive on the market?
→ Load-bearing structure, retrofitting the construction to absorb tensile forces.
→ Low-tech instead of elaborate technical building services not only reduces the consumption of raw materials but also energy.
→ Regulation of the indoor climate by means of passive measures instead of energy-intensive technical building services.
→ Maintenance and dismantling

With contributions by
Roger Boltshauser, Mirjam Kupferschmid, Jesús Vassallo, Salima Naji, Jasmin Kunst, Marlène Witry, Hubert Guillaud, Camilla Mileto, Fernando Vergas, Thierry Joffroy, Julien Nourdin, Arnaud Misse, Martin Pointet, Isabelle Brunier, Ernest Menolfi, Janina Flückiger, Felix Hilgert, Summer Islam, Paloma Gormley, Arno Schlüter, Andrea Wiegelmann, Romain Anger, Laetitia Fontaine, Ryszard Gorajek, Gregory Bianchi, Gian Salis, Rodrigo Fernandez, Laurent de Wurstemberger, Coralie Brumaud, Yi Du, Daria Ardant, Guillaume Habert, Jürg Conzett, Jörg Habenberger, Tobias Huber, Katja Fiebrandt, Michael Klippel, Tobias Bonwetsch, Götz Hilber, Oliver Kirschbaum, Florian Nagler, Jacqueline Pauli, Tobias Fiedler, Stefan Marbach, Marco Waldhauser, François Cointeraux

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Collective granary Aswani

homestead,[37] which gradually became a smaller fortified estate. Their designation as kasbah was so prestigious that it was worth borrowing.

The citadel of Telouet is the model *par excellence* of this type of building. Erected and expanded over several centuries, it developed its highly decorative part within the last decades of the 19th century in the light of the Glawa tribe's powerful chiefs dwelling along one of the routes connecting Sahara and Marrakech via the High Atlas and a series of command kasbahs tied to each other by strategic alliances. The **Kasbah of Telouet** was expanded and modernized at the beginning of the 20th century, when central heating was installed – useful in an area of snow – as well as patio glazing in order to protect rooms recently added and illuminate them properly to create a fortified home mostly closed off to the outside. A new wing reminiscent of an urban palace was added, with a salon on the first floor in the pure Andalus tradition of Fez, with tiled walls and engraved cedar wood on the ceilings. In September 2023, an earthquake destroyed the citadel, which had already been in a bad state. It is no longer open to visitors.

An omnipresent material in the territory from the north to the south

The Moroccan pisé – capable of sovereign adaptability and developed to last – was presented here in all its known and unknown forms, used in perfect urban landscapes as well as for collective rural institutions. Pisé architecture assimilated a wide range of local, Eastern, African, and/or European technology transfers on the caravan routes before being exported to the Iberian Peninsula.

Another major characteristic of pisé is its diversity: the blend gave rise to a late process and is always combined with other materials: stone for the foundations, raw and burnt bricks.

In this slideshow on Moroccan Sharifian architectures originating in the oases, home to successive dynasties and forging the royal cities yet to come, architecture appears as the product of its environment. In Moroccan communities, agriculture and building are closely interrelated through the orchards and vegetable gardens of the medinas and the micro-plots in the oases. These built landscapes shaped the constructive models for pisé architecture and primordial hydraulic works necessary for field crops. The granaries as communal institutions, the first student homes, the madrasas, and the larger zawyas and other medieval Islamic schools served as models due to their architectural and eminent social capacities, spreading together with a thousand-year-old building process. From urban palaces and kasbahs to fortified estates and smaller family oases, the material continued to be used widely until the beginning of the postcolonial period, when the collectives increasingly replaced it with reinforced concrete and perpend stone.

37 Cf. Kasbah Amridil, Skoura, in: Denise Jacques-Meunié, *Architectures et habitats du Dadès,* Paris 1962, p. 27.

City of Orion

2019

spring 1994, they worked on their next earth sculpture, the *Golden Spiral*. It consists of nine quarter circles strung together that correspond to the principle of the Fibonacci sequence. A 260-meter-long quarry stone wall traces the spiral, slowly rising to its center. Along with this wall, the earth also rises in height from the desert floor. At the end of this spiraling earth ramp, at a height of six meters, a winding staircase leads into the interior of the spiral to the living and work rooms. From there, another 100 steps lead down to a well that is fed by a water vein.[11]

Today, nothing of the earth remains visible. Because motorcyclists and quad bikers have repeatedly caused damage to the earth floor of the spiral, its surface was covered with quarry stone slabs in 2013 to protect it.[12] Although the new surface resembles the wall structure and protects the monument from decay, it somehow alienates it from its surroundings, which was not planned originally.

City of Orion

In 1999, Voth returned to Morocco, wanting to get even closer to the stars than he had with the *Stairway to Heaven*. The **City of Orion** *(Stadt des Orion)*, a kind of observatory made of earth towers, is the last of his large-scale projects to be realized. It traces the constellation of the same name. Voth represents the seven main stars – Rigel, Saiph, Bellatrixa, and Betelgeus, as well as the stars Mintaka, Alnitak, and Alnilam, which form the belt – in the form of observation towers. These towers are positioned precisely to trace the constellation, connected by a wall that delimits the enormous size of the monument: the entire structure measures 40 × 100 meters. The towers not only reflect the position of the stars, their respective heights (4 to 15 meters) and width also indicate the brightness and size of the stars they represent. External stairs lead to the observation platforms on the towers. Through precisely placed slits in the towers, certain stars and constellations can be seen clearly at certain times.[13] The impressive images captured by Ingrid Amslinger clearly show that this project could not have been realized without local knowledge and skills.

11 IVAM Institut Valencià d'Art Modern, Voth, Amslinger 2003, pp. 46–47, 145.
12 Eike Roswag-Klinge, Hannsjörg Voth, Hans Brockmann, Andrea Klinge, Christof Ziegert, "Himmelstreppe, Goldene Spirale und Stadt des Orion. Erhalt der Werke von Hannsjörg Voth in der Maha Ebene, Marokko", in: *LEHM 2016, Dokumentation der Internationalen Fachtagung für Lehmbau,* Weimar 2016.
13 IVAM Institut Valencià d'Art Modern, Voth, Amslinger 2003, p. 126.

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Earth construction in the Iberian Peninsula

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Earth is one of the traditional constructive materials most widely used throughout the Iberian Peninsula. It is used in a number of constructive techniques, including rammed earth, adobe, half-timber, wattle-and-daub, etc., to build walls as well as cupolas, roofs, renderings, paving, etc. Factors such as the type of earth, climate, and geography have been decisive in the choice of certain techniques over others.[1] Among these, it is worth noting rammed earth as the most frequently encountered technique, with a richly complex and heterogeneous profile throughout the Iberian Peninsula.[2]

History of rammed earth buildings in the Iberian Peninsula

Rammed earth is one of the most ancestral constructive techniques of the Iberian Peninsula. However, the misuse of synonyms in archaeological excavations, with other techniques such as cob, poured earth, and even adobe erroneously labeled as rammed earth, complicate the dating process.[3] It appears that the first example of rammed earth distinguished and found in the Iberian Peninsula is the **Roman Domus** on the site in **Empúries,** possibly dating from the 1st century AD.[4]

However, Pliny the Elder (1st c. AD) mentions the towers and watchtowers built with earth and constructed with a mold,[5] as ordered by Hannibal (247–183 BC) centuries earlier. Saint Isidore of Seville repeats the same account, insisting on the use of molds for its large fortress, but no mention is made of tamping.[6] Unfortunately, to date no traces have been found of these defensive towers built by the Carthaginians using molds in the Iberian Peninsula in the 3rd century BC.

The Romans promoted the use of formwork as a system of construction, using *opus caementicium* made with lime and earth.[7] However, it was in the early 8th century, with the first Moorish peoples in the Iberian Peninsula, that earthen architecture saw its greatest expansion, as they spread the knowledge for construction with rammed earth. Treatise writers such as Ibn Hauqal, Ibn Abdun, and Ibn Jaldun included specific sections on earthen architecture in their work.[8] Over seven centuries in al-Andalus, the citadels, walls and watchtowers, such as the **Castle of Xió** in Llutxent or the **Tower of La Vilavella Castle** in Castellón, were built with rammed earth.[9] After the Christian conquest of the Moorish territories, rammed earth continued to be used for castles, churches, houses, etc. In fortresses, the end of the use of rammed earth was presaged by the controversy between the use of rammed earth, defended by Giovanni Battista Antonelli, and the use of stone, defended by Vespasiano I Gonzaga. King Felipe II was swayed by his prejudiced views and chose stone, although rammed earth could absorb the impact of artillery better.[10]

Rammed earth for other uses was later examined by treatise writers including Fray Lorenzo de San Nicolás (1639) and Juan de Villanueva (1827).[11] (Fig. 01) Furthermore, both treatises were particularly relevant to the training of architects in the past. It is also remarkable that a distinguished academic architect such as Juan de Villanueva, an important figure in Spanish neoclassical architecture, devoted much of his treatise to this type of construction. This was also later explored by other authors[12] in the second half of the 19th century. Nevertheless, from this century on, both rammed earth and other earthen techniques which had been continuously used in vernacular housing since ancient times were replaced by artisanal and industrial brick, which is less susceptible to erosion, relegated to rural settings, and shunned because of its connotations of poverty.

One interesting exception was the use which the architect Antonio Gaudí, going against the trend, made of rammed earth in Finca Güell (1884). He chose this constructive technique to build all the walls for "its affordability and great capacity for insulation,"[13] even though the owner, Eusebio Güell, was one of the wealthiest men in Spain at the time. Gaudí employed a lime-crusted rammed earth wall, externally either interposing a brick course between layers or covering with a Moorish cladding, internally plastered with lime mortar, so that the earth was protected and not visible at all. This was carried out by a group of specialist rammed earth builders from

Fig. 01

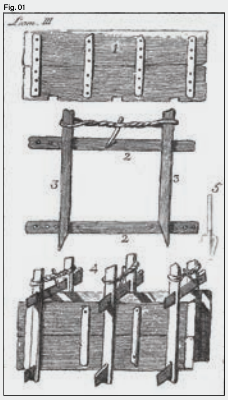

Fig. 01 (1) Formwork boards; (2) putlogs; (3) ribs; (4) formwork assembled; (5) rammer. Plate from the treatise by J. de Villanueva. Arte de Albañilería. 1827. Plate III, chapter 5.

1 Camilla Mileto, Fernando Vegas, Laura Villacampa, Lidia García, "The influence of geographical factors in traditional earthen architecture: Iberian Peninsula", in: *Sustainability,* 11 (8), 2019.
2 Juana Font, "La construcción de tierra en los textos. Errores, olvidos, omisiones", in: *Actas del Octavo Congreso Nacional de Historia de la Construcción,* 2013, pp. 323–334.
3 Sergio Manzano, *Arquitectura de tierra en yacimientos arqueológicos de la Península Ibérica,* unpublished doctoral thesis, Technical University of Valencia, Valencia 2023.
4 Claire-Anne de Chazelles, "Les constructions en terre crue d'Empuries à l'époque romaine", in: *Cypsela,* VIII, 1990, pp. 101–118.
5 Claire-Anne de Chazelles, "Témoignages croisés sur les constructions antiques en terre crue: textes latins et données archéologiques", in: *Techniques et Culture,* 41, 2003, pp. 1–27; and Francisco Javier López Martínez, *Tapiería en fortificaciones medievales. Región de Murcia,* unpublished doctoral thesis, Technical University of Valencia, Valencia 2007.
6 Font 2013, pp. 323–334.
7 Fermín Font, Père Hidalgo, *Arquitecturas de tapia,* Castellón de la Plana 2009.
8 Basilio Pavón, *Tratado de Arquitectura Hispanomusulmana,* Madrid 2009.
9 Jacinto Canivell, *Metodología de diagnóstico de fábricas históricas de tapia,* unpublished doctoral thesis, University of Seville, Seville 2011.
10 Pablo Rodríguez-Navarro, "The defense of the technique of rammed earth made by Giovanni Battista Antonelli in 1560", in: Camilla Mileto, Fernando Vegas, Lidia García-Soriano, Valentina Cristini (eds.), *Vernacular and Earthen Architecture. Conservation and Sustainability,* London 2018, pp. 477–482.
11 Other writers are Covarrubias (1611), Torija (1661), Ardemans (1754), and Benito Bails (1802), for example.
12 To name but a few: Matallana (1848), Perier (1853), Espinosa (1859), Mariátegui (1876), Marcos Bausá (1879), Rebolledo (1889, 1896), and Ger y Lóbez (1898).
13 Joan Bergós, *Gaudí, el hombre y la obra,* Barcelona 1999, p. 59.

Molino de Pérez

Camino Bajo de Algarrobo, Vélez Málaga

Arab Baths, Alhambra

Granada

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The renewal of earth construction in France from the 1970s

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By the beginning of the 20th century, the tradition of building with earth was declining strongly due to the democratization of the use of cement and the massive loss of carpenters as holders of specialist knowledge, who had been mobilized during World War I for digging and maintaining the trenches, which also entailed a decline in the demand for new rural constructions. World War II had an equally destructive impact on traditional craftspeople and prompted the intensive use of steel and concrete: the latter would become the default solution in the Reconstruction period and spread all over the country. Like all other construction materials of local origin (timber, stone, etc.), raw earth would vanish completely from building sites.

However, from the 1970s on, France would soon experience a new interest in building with raw earth, especially in the wake of forthcoming ecological movements and inspirations by counterculture movements from the United States. Following those new ideas, some students of the Ecole d'architecture de Grenoble embarked on research for alternatives. After exploring the use of timber, they discovered by chance that the region in the north of Isère possessed a very rich heritage of building with rammed earth. "This is incredible, we can build with what is just under our feet", they said, sensing that the discovery represented an important potential for reacting to ecological issues and the successive oil crises at the time. The students and some of their teachers started to undertake research on that heritage. In order to complete their observations and analyses, they widened their research to include other countries such as Peru, Egypt, Morocco, Burkina-Faso, etc. and then took action, i.e. experimented with the material in order to better understand it and learn how to build with it once again.

A compilation of the results of ten years' research work led to the creation in 1979 of the CRAterre association, which first published *Construire en terre* (Building with earth), a book that offered a precise description of the techniques of building with raw earth. A few months later, this initial dynamism accelerated due to the considerable success of the exhibition *Des architectures de terre ou l'avenir d'une tradition millénaire* at the Centre Georges-Pompidou in 1981, that presented a world-wide overview of traditional earth architecture and showcased other highly contemporary initiatives for building with earth. These successive initiatives created a conducive institutional environment that would eventually lead to a first major project – the **Domaine de la terre** in Villefontaine. The Domaine was an experimental housing development inaugurated in 1985, consisting of 65 dwellings organized in twelve stages, each of which was assigned to a different architectural firm. The Domaine was an opportunity to demonstrate that earth was a highly flexible material that enabled a great variety of architectural forms, especially with rammed earth but also with compressed earth blocks and lightweight earth construction. Moreover, because of its strictly bioclimatic design principles, the project was considered one of the forerunners of future ecological neighborhoods that today have emerged throughout France. Although its general concept is convincing, most institutional developers remained skeptical regarding earth's durability. This is why its appreciation by potential users in metropolitan France was short-lived, except for some isolated operations that were often dealt with confidentially. Conversely, this special site had a strong impact beyond its borders, especially on Île de Mayotte and in Germany,[1] as well as in many African countries.

Hence, French architects who were keen on promoting earth architecture were sorely tested by that situation at the end of the 20th century, although some notable projects were implemented: that of cutler Christian Moretti in Corsica for instance, who started an initiative inspired by the book *Construire en terre* and launched a self-build project in 1982 for his house with a workshop, followed by the Casa communal project in the village of Pigna. A bit later, in 1988, farmer Alain Bozier, also inspired by some elements of the *Construire en terre* book, started to build the rural cottages of La Buissière in La Vienne. In 1992, the leisure center in Saint-André-le-Coq, Puy-de-Dôme, was inaugurated: its huge curved rammed earth wall made architects Jacky Jeannet and Pascal Scarato (Abiterre) famous. The two became the principal ambassadors of pisé in Auvergne. In the same year, a social housing development consisting of eight buildings made of Breton earth was handed over by architect Dominique Urien in Romille, showing that rammed earth technology could catch on and be exported outside its original region, in this case, in an area where cob buildings[2] had been the traditional reference up to then. In 1994, pisé was honored in the Ain by the inauguration of the **Salle des fêtes** (village hall) in Fareins and of the Foyer Sacerdotal (Priest's Foyer) Jean Paul II in Ars-sur-Formans. In the same year, the Panier Fermier opened in Albon, a house built by and for a group of young producers of organic food. This project had been the subject of research beforehand with the aim of developing formwork and enabling the manufacture of partition walls of greater accuracy in shorter execution times. Similarly motivated and after having tested this approach with a single-family house in Sorbiers, Nicolas Meunier, a creative mason craftsman, opened his first major building site: a small two-story building in Montbrison in Loire realized with rammed earth blocks manufactured in situ. The blocks were handled with a crane and assembled with lime mortar.

The development of a truly contemporary industry

By the end of the 1990s, activities in the earth sector were resumed and progressed and progressed rapidly, opening up a market for individual clients wishing to build differently and for a handful of avant-garde entrepreneurs. A major player at the time was Andreas Krewet, an engineer who created the AKterre company in 1997 after working at the German Claytech[3] company and training with "DSA architecture de terre". Besides distributing products developed by Claytech, he introduced and developed an excavation activity to prepare and sell ready-mixed soils including for pisé, thus solving many problems encountered in prospecting and mining clay pits, especially for small projects. By additionally proposing consultancy and training services on numerous building sites, his company furthered craftsmanship and skills alongside historical figures such as Nicolas Meunier and Xavier Auplat. The latter had specialized in the renovation of ancient heritage buildings – a significant market in the region. AKterre's activities strongly declined during the crisis in 2008. Nevertheless, the company contributed significantly to the relaunch of the sector, as testified by the fact that several former employees created earth-construction enterprises. Among the most famous are Heliopsis (created in 2002) and Caracol (created in 2005). The arrival of these new players on the market consolidated and boosted the sector by improving its visibility even though it remained small, with fewer than approximately ten projects carried out each year – a rather marginal position in the French building sector.

In this structuring period, most projects were carried out in the Auvergne-Rhône-Alpes region, mainly in Nord Isère, Loire and Puy-de-Dôme. A majority of them of them were single-family houses, public projects in pisé being practically non-existent. Surprisingly, all local authorities launching pisé projects in this period were from outside this region: the Auditorium in Pigna, Corsica, inaugurated in 2000 which combined rammed earth walls with an impressive dome realized with compressed earth blocks[4] and the leisure center Bonne Terrasse in Ramatuelle, Var, completed in 2005.

From 2010 on, all efforts led to a true intensification of earth-based architectural production, both regarding the number of projects realized, their scale and ambition.[5] The change of scale is probably

1 Jean Déthier, Patrice Doat, Hubert Guillaud, Hugo Houben, Philippe Michael, "Terre d'avenir. Atouts et enjeux du Domaine de la terre et du futur Institut International de la Construction en Terre à l'Isle d'Abeau", in: *H: revue de l'habitation sociale,* 111, 1985.
2 Shaping technique similar to pisé in terms of its installation method in the form of horizontal layers of 60 to 80 cm thickness each.
3 Founded in 1984, the company sells and installs clay plasters, clay building boards, earth bricks and rammed earth. It also develops equipment for their production.
4 Project following those of the 1980s, built by the outstanding craftsman Christian Moretti who was inspired by the book *Construire en terre.* Patrice Doat, Alain Hays, Hugo Houben, Sylvia Matuk, François Vitoux, *Construire en terre,* Paris 1979.
5 The analysis is one outcome of an inventory of 540 projects from a period of 50 years. It was carried out in the framework of a doctoral thesis by one of the authors of this chapter, Julien Nourdin.

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low-ceilinged spaces can work really well if they are punctuated by moments of decompression. This is the case in Margent Farm's **Flat House,** which we mentioned in the interview (p. 224). There, we developed materials using the hemp grown on the surrounding farmland to create a beautiful, low-impact home drawn from the land that surrounds it.

In addition to spatial possibilities, we consider the cradle-to-cradle life of each element within the building. Bio-based materials are naturally biodegradable, and they also store atmospheric carbon. Plants fix carbon as they grow, and this carbon is locked in the body of the harvested plant for as long as it is prevented from decomposing. This is one of the reasons why there is a resurgence of interest in building with timber. While it is an important strategic bio-based material, the transition towards a plant-based building culture cannot rely exclusively on timber. Supplying the amount of wood needed to feed the construction industry at current levels would have a catastrophic impact on biodiversity.[4] Instead, lightweight timber frames can be combined with straw and other bio-based materials. Materials that take longer to grow store more carbon, and should have longer lifespans within the building. Calculations for Britain today show that a timber structure needs to be maintained for many decades for the carbon storage to be effective.[5] Meanwhile, the infill and the insulation materials, which grow much more quickly, can have shorter lifespans, depending on whether they are combined with a binder. Similarly, each element of the outer skin – whether it is a timber or hemp cladding, lime render or clay plaster – has a different lifespan depending on the type of climate and construction.

Building with traditional and bio-based materials requires a skilled workforce to process and work with these materials. In May 2023, Material Cultures launched MAKE Workshops, which support the dissemination of forgotten skills and knowledge within the design and construction industries. The programme bridges architecture and construction. It seeks to address structural issues within the construction industry, where women and minoritised people are hugely underrepresented, and where workers are exposed to accidents, injury and occupational illness at higher rates than in most other occupations in Britain. Some courses are targeted at specific audiences, including makers, designers and built environment workers. Others aim to bring these skillsets into communities, allowing

4 Rasmus N. Hansen, Jonas L. Eliassen, Jannick Schmidt, Camilla E. Andersen, Bo P. Weidema, Harpa Birgidsdóttir, Endrit Hoxha, "Environmental consequences of shifting to timber construction: The case of Denmark", in: *Sustainable Production and Consumption,* 45, 2024, pp. 54–67 and Abhijeet Mishra, Florian Humpenöder, Galina Churkina, Christopher P. O. Reyer, Felicitas Beier, Benjamin L. Bodrisky, Hans J. Schellnhuber, Hermann Lotze-Campen, Alexander Popp, "Land use change and carbon emissions of a transformation to timber cities", in: *Nature Communications,* 13, 2022, 4889.

5 In most cases, at least as long as it took for the tree itself to grow, and ideally longer, to offset the emissions associated with its harvest.

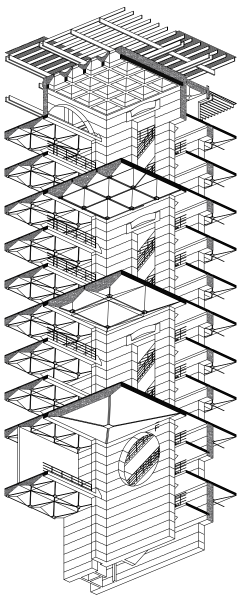
Fig. 02

Fig. 03

Fig. 02 Growing Place Project. Participants of an experimental hands-on workshop are involved in the construction of a demonstrator building at a north London farm site.
Fig. 03 Workshop participants applying clay plaster to the Panel House.

Margent Farm, Huntingdon, Oldhurst Road

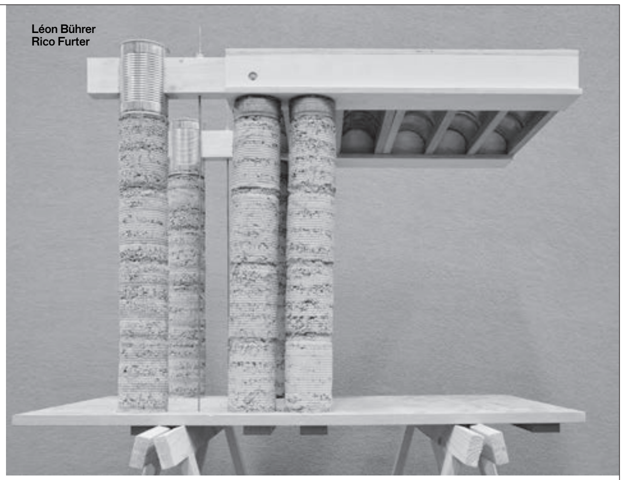
David Eckert
Kim Nipkow



This project focused on developing an earth ceiling system. The construction and design of the funnel-shaped earth elements are based on the idea of a mushroom column and absorb compressive forces. The elements rest on steel supports that are connected to each other as well as to the walls via tension rods. The system can also be implemented with supports, in which case the elements resemble a coffered ceiling. These elements can be prefabricated as standardized components in various sizes. The resulting, bulky ceilings create a unique spatial experience and have very good thermal storage properties.

0 1 2 5

Léon Bührer
Rico Furter



This static system is based on recycled oil drums as base-level building modules. The drums are used as formwork for rammed earth columns, then halved, removed, and reused in the ceiling system as permanent formwork. Timber beams support the ceiling and form a rigid frame. The individual support elements rest on two concrete-lined oil drums at the ends of a girder. Clamps attached to the columns serve as a secondary support system. Various elements such as partition walls, floors or shelves can be attached to these clamps. Almost the entire building consists of prefabricated elements and provides the infrastructure needed for small, urban manufactories, start-ups, offices, and studios.

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Case Study Steel House

Jürg Conzett

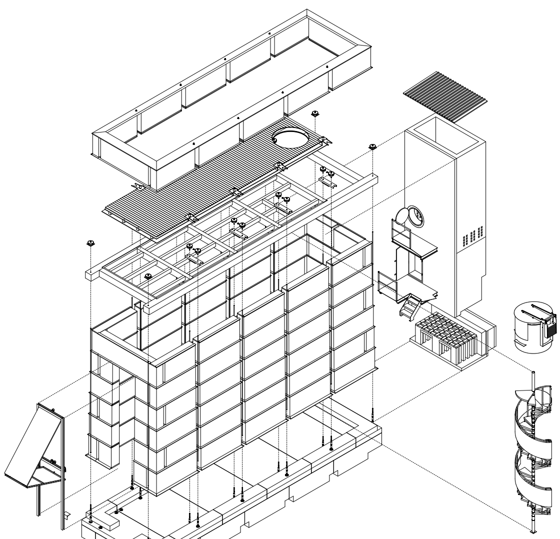
"Rammed earth is the building material of the future", said Anna Heringer a couple of years ago to students at the Harvard Graduate School of Design. She had presented very pleasing buildings with walls made of rammed earth that she had carefully designed and executed herself. Afterwards, we discussed ideas on how such structures could be made earthquake-resistant. What at the time had seemed to be a construction method that was executed in distant regions where the technology was familiar and labor cheap started to gain topicality when Roger Boltshauser gave me Thomas Kleespies's dissertation on *Schweizer Pisébauten* to study.[1] Pisé (French: rammed, tamped) is the name French master builder and publicist François Cointeraux (1740–1830) gave to rammed earth construction in his books, which, as a result, became a widespread term. In his work, Kleespies shows how the rammed earth construction method was used for the first time in 17th century Switzerland. It was the Gonzenbach family in Hauptwil (Thurgau) who erected a large linen factory consisting of multi-story buildings using the rammed earth construction method. Those buildings were used in a twofold way: for producing linen cloth and as accommodation for 200 workers. The buildings in Hauptwil were based on rammed earth buildings in Lyon, where the Gonzenbachs ran a trading station. The largest among the Hauptwil buildings was the so-called "Kaufhaus" – completed in 1667 – encompassing two stories proper upon a basement floor topped by a three-story timbered gable roof.

Another rammed earth building was erected in Geneva on Rue des Amies at about the same time, which was discovered during rebuilding work on Cornavin railway station. There, the course of construction was able to be studied especially well: The holes, in which the timbers lay transversely to the wall, thus holding together the formwork panels, are 65 centimeters apart when horizontally measured. Their vertical distance is 80 to 85 centimeters, thus corresponding to the height of one wall section into which earth was inserted in layers of about six centimeters in height and then tamped. Wall thickness varies between 45 centimeters in the plinth area and 35 centimeters at the coping. The grain size of the stones contained in the earth was up to 50 mm. The joints between the wall sections were finished with five-to-ten-centimeter-thick coatings of lime mortar.

From 1820 on, school buildings and dwellings were erected in rammed earth upon the initiative of the Thurgauische Gemeinnützige Gesellschaft. Other rammed earth buildings include schools in Hauptwil, Thundorf, Mühlebach and Gottshaus, with further buildings outside of the Canton of Thurgau. Particularly striking is the dwelling on Schmiedgasse 60 in Herisau, as it stands on a steep incline and has five stories on its downhill side.

1 Thomas Kleespies, *Schweizer Pisébauten,* dissertation, ETH Zurich, Zurich 1997.

Rapperswil-Jona, Güterstrasse, study



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improved by simply replacing concrete with earth building materials to the greatest extent possible.

The garden house:
A house without cement

This house is designed as an expansion of the living and office space of a Munich residential building dating back to 1934, which we already remodeled 16 years ago. (Fig. 08) The initial challenge for this project was to preserve as much of the beautiful garden as possible. For this reason, and to minimize soil sealing, the building was planned as a three-story structure. The three similar, stacked spaces can be used as apartments or offices, or a combination of the two. If necessary, an accessible apartment can be created on the ground floor.

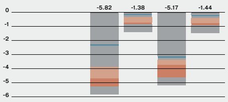
For this design, we applied the key findings from the *einfach bauen* research project. These not only included a minimization of building services, but also appropriate window sizes and simple constructions, as well as the use of thermal mass to ensure natural ventilation and effective nighttime cooling. A photovoltaic system mounted directly on the roof insulation will cover part of the area's electricity needs. Furthermore, we wanted to demonstrate that it is possible to construct a building entirely without cement.

Instead of concrete, earth ceilings and solid wood walls provide the necessary thermal inertia for the garden house. Earth's storage capacity will only unfold if it is directly exposed to the interior. Therefore, industrially produced earth bricks were inserted into rebated solid wood ceiling joists. This way, they remain visible and effective throughout the space. (Fig. 09) The earth bricks add the weight to the ceiling structure necessary for soundproofing.

The garden house has no basement. To provide an appropriate foundation, galvanized steel screw foundations were drilled through the two-meter-thick, non-load-bearing top layer of the soil. The ventilated area beneath the floor slab and the terraces allows rainwater to seep into the soil; thus, the site's water balance remains largely unchanged.

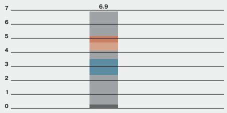
We already conducted a life cycle assessment during the design process, which we then continuously updated. This assessment encompasses the building's entire environmental impact, from the extraction of raw materials to replacements needed throughout the years of use to the treatment of demolition materials at the end of its life. The graph (Fig. 06) shows the amount of greenhouse gases generated by the building and associated technology over its entire life cycle. In kgCO_2 eq/m² net internal area per year, the embodied emissions of the entire building only amount to 6.9. Conventional new buildings achieve values between 10 and 12. The second graph (Fig. 07) shows the building's recycling potential. This involves estimating the ecological benefits that can be achieved by using the building materials after demolition – for example, if the used

Fig. 05
RECYCLING POTENTIAL (MODULE D)
IN RELATION TO GLOBAL WARMING POTENTIAL (GWP)
per net internal area and year [kg CO_2eq/m²NIA*a] after 50 years



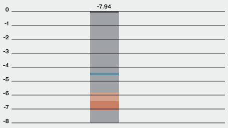
	Lumber (hewn logs)	Lightweight Concrete	Solid Wood	Masonry
FOUNDATION	-0.04	-0.04	-0.04	-0.04
EXTERIOR WALLS	-2.20	-0.11	-3.05	-0.05
WINDOWS / EXT. DOORS	-0.13	-0.10	-0.13	-0.10
SLABS	-1.49	-0.16	-0.15	-0.16
ROOF	-0.82	-0.37	-0.36	-0.37
INTERIOR WALLS	-0.59	-0.11	-0.88	-0.11
BUILDING SERVICES	-0.56	-0.56	-0.56	-0.55

Fig. 06
THE GARDEN HOUSE: EMBODIED EMISSIONS FOR PRODUCTION, REPLACEMENT, DISPOSAL IN RELATION TO GLOBAL WARMING POTENTIAL (GWP)
per net internal area and year [kg CO_2eq/m²NIA*a], observation period 50 years



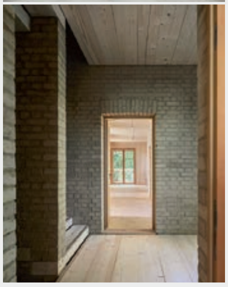
	Lumber (hewn logs)
FOUNDATION	0.29
EXTERIOR WALLS	2.09
WINDOWS / EXT. DOORS	1.12
SLABS	0.64
ROOF	0.55
INTERIOR WALLS	0.49
BUILDING SERVICES	1.72

Fig. 07
THE GARDEN HOUSE: RECYCLING POTENTIAL (MODULE D) IN RELATION TO GLOBAL WARMING POTENTIAL (GWP)
per net internal area and year [kg CO_2eq/m²NIA*a] after 50 years



	Lumber (hewn logs)
FOUNDATION	-0.12
EXTERIOR WALLS	-4.25
WINDOWS / EXT. DOORS	-0.21
SLABS	-1.23
ROOF	-0.62
INTERIOR WALLS	-0.63
BUILDING SERVICES	-0.86

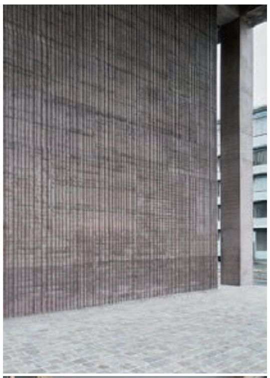
Abb. 08–10

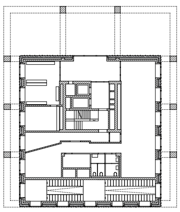


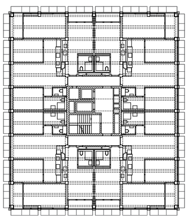
timber is burned after demolition, replacing the need for natural gas. Of course continued use of the building would be preferential, but the calculation rules do not reflect this, as they currently assume thermal recycling of the building after 50 years. The recycling potential of our building is 7.94 kgCO_2 eq/m² net internal area per year and can thus offset the embodied emissions of the building.

Frugal and responsible use of resources should guide our actions. In the foreseeable future, there will be no adequate replacement for concrete, especially in civil engineering. In areas where alternatives exist, however, it is therefore all the more important to use and further develop such alternatives to concrete. Wood and earth can make an important contribution in this regard.

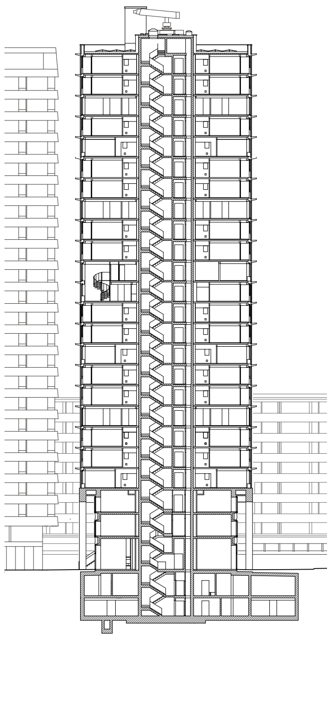
Fig. 08/09 The garden house – A house without cement.
Fig. 10 Research project *einfach bauen*, Research House 4.







Floor plan ground floor
Floor plan standard floor



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