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Laboratory EAST, EPFL Lausanne (eds.)
**Mass Made Units.**
**Studies on Assemblies**

Book design: Omnigroup, Lausanne
English, 96 pages, ca. 60 images,
17,1 × 24 cm, softcover

Euro (D) 29.–, Euro (A) 29.90, SFr. 29.–
ISBN 978-3-03863-084-5

New Release March 2024

# Knowledge about solid construction methods

**→ Highly topical: solid construction is gaining in importance with regard to durable, low-maintenance constructions**

**→ Provides knowledge on solid construction methods in serial and elemental production – from a general thematic overview to exemplary projects**

In light of increased demands for resource-saving, long-lasting, and low-maintenance buildings, the potential of solid construction methods is coming back into focus. This publication takes a closer look at building with solid, serially produced components and elements using various construction methods and solutions, discussing both the joining of elements and components as well as the structure of the building itself. Each element is examined with regard to its specific function and its contribution to the wall system.

The publication evaluates traditional and contemporary design and manufacturing techniques and promotes responsible approaches to the future use of materials and modular elementary systems. Thus, the book is a perfect reference work for architects and students.

The first part of the book includes contributions discussing a variety of topics, from reflections on state-of-the-art developments to experimental building practices along with applications of building materials such as unfired clay bricks, the use of different stone dimensions and the role of solid building envelopes. These different findings are illustrated using examples of brick buildings from the Ghent and Leuven region in Belgium and the use of solid stone blocks in a residential building project in Geneva, expanding our understanding of elemental masonry construction.

The second part of the book features selected architectural works analyzed by students from the EAST design studio. This graphical study of exemplary projects offers an instructive overview of the constructive and climatic connections of the case studies.

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have the potential to be reused." Indeed, although the question of the potential for re-use is not directly raised in this study, the authors naturally and poetically highlight one of the first "hidden values" of stone. The study then looks at the notion of stone's invisibility from the point of view of its embodied energy compared with other materials. This long-term life cycle study also highlights the importance of energy performance and the ecological cost of maintenance. The authors conclude: "If the social aspect of stone is also taken into account through its reduced need for maintenance, then it is evident that the value of stone in the specific building is multifold."

Fig. 3. The cutting of a stone block.

Bringing Periods and Knowledge into Dialogue

The relevance of building in massive stone today is not limited to ecological questions. The Covid-19 pandemic brought to the fore the fragility of certain sectors of the economy due to their dependence on heavily processed products. The construction sector was severely impacted as a result of its long and complex supply chains. Choosing stone as a structural material makes it possible to evade such risks. The product of geological processes, stone is already available in the ground, in abundance and close to the surface. There is no need for chemical alterations to improve its intrinsic properties. After extraction, a few simple cutting operations are all that is needed to make a rough block ready for use. The massive stone buildings left behind by different epochs of human history stand testimony to a long legacy of know-how relating to the extraction, transformation, assembly and maintenance of this material. Far from adopting a nostalgic stance, we want our work today to be part of the continuity of these experiences, while maintaining a reflective approach to them. By

14

applied in cavity wall constructions. The limited stability of the facing leaf in the absence of mortar is compensated for by a multitude of wall ties and auxiliary structures, resulting in a shorter service life of the masonry. The developers of demountable brick facades promote short-term construction under the guise of circularity. With "brick as a service" being one of the possible new approaches, the circular economy raises the question of wether we have thought properly about the purpose of a material that can last for hundreds of years in the first place.


Fig. 9. dnA House, Asse. Photo: Stijn Bollaert.

For the dnA house and other BLAF projects, we chose to reuse reclaimed bricks for the following reasons:

- Quality
  The first machine-produced bricks in our region (early 20th century) are of a much better quality than most contemporary facing bricks. That high quality was the result of higher energy consumption and higher $CO_2$ emissions during the production process.
- Environment
  By reusing bricks, no new bricks need to be produced, lessening the impact on raw materials, water, air, $CO_2$, energy, and so on.
- Aesthetics
  Reclaimed bricks have a timeless aesthetic quality that is at once generic and banal. With this, BLAF wishes to counter fashion trends and take up a position against linear economy reflexes among brick manufacturers.

25

# About the editors

**EAST – Laboratory of Elementary Architecture and Studies of Types, EPFL Lausanne**

While the function of a building may change over time, its architecture remains. In lessons, EAST examines the aspects of construction that determine the use, morphology, and spatial structure of buildings.

The history and change of these aspects serve as a basis for analyzing the design of new buildings as well as for reusing and transforming existing buildings. Urban settlements are thus a laboratory for architectural ideas, which are further developed using the technical means and spatial concepts of our time.

The joint project work in the studio space facilitates a continuous discussion of different design approaches and helps the students to develop their own ideas.

**Team:** Anja Fröhlich, Martin Fröhlich, Tiago P. Borges, Vanessa Pointet, Lara Monti, Clemens Waldhart, Maria Sivers

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# Stone as Protagonist

A

Marlène Leroux, Francis Jacquier

When James C. Scott introduced the notion of métis to anthropologist Jean-Pierre Vernant, he sought to define a theoretical framework for "domesticating the state" that was still inclined towards simplifications and the levelling of local mores. Indeed, it is necessary to organise in order to modernise. That is undoubtedly why scientific and technological knowledge replace practical wisdom. Yet nowadays we must question the relevance of systematically distancing ourselves from this form of wisdom rooted in praxis and experience. *Métis* here evokes the idea of cunning, in the sense of all the ways in which an individual can act astutely in a particular context. Instead of following established dogma, this form of intelligence is fluid, elusive, and sometimes disconcerting.

The approach we develop at Atelier Archiplein emerges from this position: one that is committed yet ready for constant adjustment, drawing on the concept of *métis*. Avoiding both militancy and blame-seeking, the aim is to explore alternative strategies that take into account historical, geographical and cultural aspects, as well as energy and environmental considerations – in other words, a low-tech, culturalist approach. This undertaking could not be developed without reflecting on the economic, legal and political framework that extensively influences the values behind building production today, while redefining the background conditions necessary for quality production.

The use of massive structural stone and wood emerges as one of the most convincing answers to the question of the durability of buildings, as the abundant historical heritage of our towns and cities can testify. The use of these natural materials is an invitation to formal modesty, sobriety in constructive thought and integration of the various technical devices in the service of a coherent architecture that is open to easy transformation. In short, the aim is to identify the conditions necessary for fair and far-sighted architectural practice, through a skilful combination of the valuable contributions of history and the performance of today's techniques.

"The monuments of the past withstand time, endure for centuries, even after their function has been lost and their raison d'être has been altered, transformed, or even forgotten [...] In this vast and deep repository of presences, so typical and recurrent in European and Mediterranean towns, stone is the protagonist. It is so present and widespread that it almost becomes a synonym of architecture."[1] We can but agree with the words of Luca Ortelli: stone is still synonymous with architecture, starting with the fact that we continue to talk about "laying the foundation stone" of a building. Yet it is almost fifty years since massive stone has been used in

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ordinary production, such as stone farmhouse buildings or residential buildings. The last such operations on any scale ended in the 1960s with, at least as far as is documented, the massive stone apartment blocks designed by Fernand Pouillon, of which those in Paris, Aix-en-Provence and Algiers offer the best examples.

Fig. 1. Stone quarry sourcing for the housing project in Plan-les-Ouates.

However, for a number of years now, massive stone construction has seen a veritable renaissance. Exhibitions, publications and training courses focusing on this material continue to multiply, making stone a hot topic among professionals and the general public alike. At the same time, a growing number of architects are demonstrating the economic and technical feasibility of using this material to its full structural potential. No longer confined to the restoration of historic monuments or purely decorative uses, stone has (once again) become a contemporary material, accessible to all.

### Ecological Consciousness

The revival of stone construction today is based on ecological awareness, a commitment to reducing energy consumption and ecological footprints. The renewed interest in stone goes beyond its timeless mechanical and aesthetic qualities. It goes hand in hand with a widespread awareness of the environmental challenges to which we must all respond as a matter of urgency: increasing scarcity of raw materials, energy crises, and unchecked damage to our living environments. Like wood, earth and plant fibres, stone represents a virtuous alternative to synthetic materials. Geo-sourced, very little energy is needed to extract and transform the stone before it is used. Carefully treated, a block of stone can be used indefinitely, within the same building or recycled. The construction sector, which is currently responsible for 43% of annual energy consumption and



generates 23% of France's greenhouse gas emissions, needs to radically rethink its production methods.

Stone has a clear role to play in this collective effort, as a precious and essential component of an environmentally friendly building culture. While there are multiple, interdependent pathways to reducing carbon emissions, the design and production of housing, whether new or renovations, plays a major role. A better appreciation of the various sectors helps to raise public awareness of the carbon footprint of our production and consumption choices, and engages us with architectural production and lifestyles that take resources and, more generally, ecosystem requirements into account. The great diversity of current approaches reflects a constant need for adaptation and micro-innovation in the face of normative hindrances and constraints, deaf to the specific characteristics of non-industrial materials, whether stone, wood or earth.

Fig. 2. Assessing a massive stone block at the quarry.

Stone is resistant to prescriptive frameworks and systems of evaluation, as shown by the article "The Hidden Value of Stone".[2] We could also pause to consider the issue of reducing embodied energy, as shown in Guillaume Habert's study. This confirms that, compared to buildings employing industrialised construction processes, a massive stone building presents an extremely low carbon footprint over 60 years of use and maintenance. This study is based on an analysis of the Résidence du Parc, a vast residential building constructed in massive stone by Fernand Pouillon. It should be noted that the authors underline the difficulty of assessing, over the long term, the scope of life cycle assessment, particularly in the case of a massive stone building: "The end of life of the different building elements is not taken into account, even though its inclusion in this case study would be a positive factor, since the blocks of stone used in the construction



Although concrete is intrinsically one of the most sustainable construction materials with a low proportion of embodied $CO_2$ per kg of material (Fig. 14), its scale of application makes it a large contributor to $CO_2$ emissions. 90% of emissions resulting from the production of concrete is due to just one of its constituents, i.e. clinker, which contributes to 6–8% of global $CO_2$ emissions but with a very uneven distribution among countries (Fig. 15). In some countries, cement-related emissions far exceed this percentage and these are therefore the primary target for remedial action to quickly achieve an effective reduction in carbon emissions.

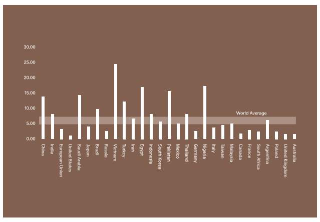


Fig. 15. Overall %$CO_2$ emissions from cement production.

The solution to the problem requires a multi-level approach: reducing the clinker content in cement, the cement content in concrete, and the concrete content in structures. The LMC (Laboratory of Construction Materials) group at the École Polytechnique Fédérale de Lausanne has been pioneering this approach and since 2004, in collaboration with UCLV in Cuba, has developed the breakthrough $LC^3$ (limestone calcined clay cement) technology.

$LC^3$ is a sustainable cementitious binder that removes up to 50% clinker ($LCC^4$-50) from cement by introducing calcined clay and limestone, reducing $CO_2$ emissions by up to 40% compared to Ordinary Portland Cement (OPC) (Fig. 16). This represents the most promising and ready-to-use solution for improving the sustainability of cement without penalising the structural performance and durability of the final concrete.

Other binders aim to reduce the clinker content using waste materials such as slag, fly ash, etc., but these too are depleting finite resources and



cannot provide a long-term solution. By contrast, a major plus of $LC^3$ is the widespread availability of clays and limestone worldwide. Indeed, they make up most of the earth's crust and are especially abundant in the Global South where economic growth is occurring at an increasing pace. Moreover, limestone and lower-purity clays, which are often wasted from ceramic and clinker production, can be used for $LC^3$.

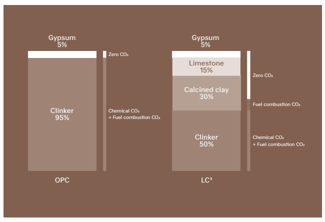


Fig. 16. Comparison of Ordinary Portland Cement (OPC) and $LC^3$-50 composition and related $CO_2$ emissions.

Given its low porosity, the use of $LC^3$ in concrete provides good resistance to weathering, such as permeability, sorptivity, chloride ion penetration, and sulphate attack. Thus, it is particularly suitable for exposed marine, groundwater, and damp-proof applications. It also has an extraordinary binding capacity and plasticity, making it ideal for indoor and outdoor plaster and mortar applications. Finally, $LC^3$ has a highly recognisable and distinctive colour, typically ranging from brick red to pale pink – a result of using iron-rich clays and of the clay calcination process under oxidation atmospheric conditions. Although this could be regarded as an added and desirable architectural aesthetic property, the standard grey colour of Ordinary Portland Cement (OPC) can be obtained by using clays with a low-iron content or conducting calcination in controlled atmospheric conditions.

Efforts are already underway to include the use of $LC^3$ in the cement standards. In 2018, Cuba approved the use of $LC^3$ as a ternary cement (NC 1208 standard) and since 2021, $LC^3$ has also been included in the European cement standard EN-197-5. Current initiatives are focusing on the inclusion of $LC^3$ use in concrete standards, which would legitimate its use in construction and encourage more widespread adoption. Updating

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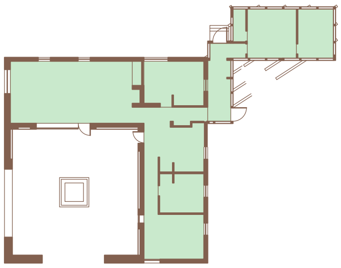
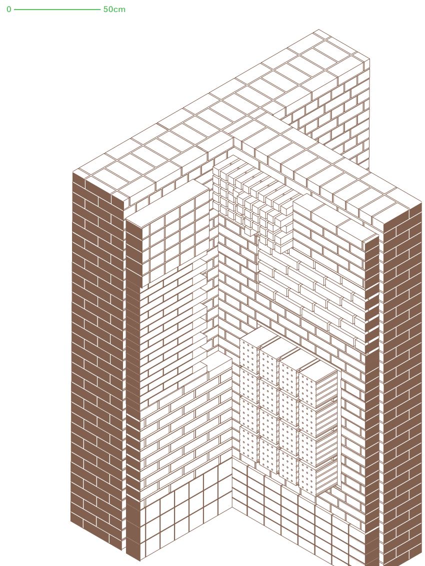
Muuratsalo Experimental House
Muuratsalo, Finland

Elissa Aalto, Alvar Aalto
1953



The external wall type that Alvar Aalto developed for his experimental house comprises parallel inner and outer leaves separated by an air cavity. This afforded Aalto the flexibility to create two different identities for one and the same architectural element. The walls of the courtyard-like composition, formed by an L-shaped building and a pair of enclosing walls, change from white stucco on the outside to exposed red brick masonry facing the courtyard. The inward-facing walls feature an experimental tapestry of different brick bonds, brick formats and mortar joints. The resulting mosaic-like composition of some fifty different brick masonry panels must, however, also withstand the harsh climate. The courtyard serves as a natural air-conditioning system: the high walls of the building shield the courtyard from cool winds, creating an internal microclimate, while the thermal retention properties of the brick panels when exposed to the sun are utilised for heating and cooling. The white stucco surfaces on the outside reflect the sun, while the exposed brick in the courtyard both absorbs solar radiation while providing sufficient thermal mass to keep the interior cool. The house has no insulation and was only used during the summer months.






**Climate**
Subarctic climate, Dfc*
no dry season, cold summer

**Units**
Clay brick, clinker brick, outer leaf
Different dimensions and types
of brick, facing brick

Clay brick, inner leaf
215/102/65 mm
Reinforced masonry, load-bearing

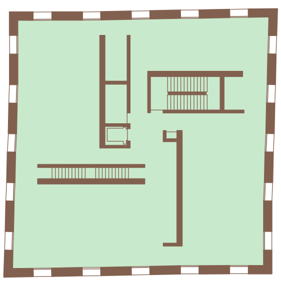
**Wall construction: double leaf**

| | |
|---|---|
| Patchwork of bricks | >100 mm |
| Air space | 40 mm |
| Clay brick | 340 mm |
| Total | 480 mm |



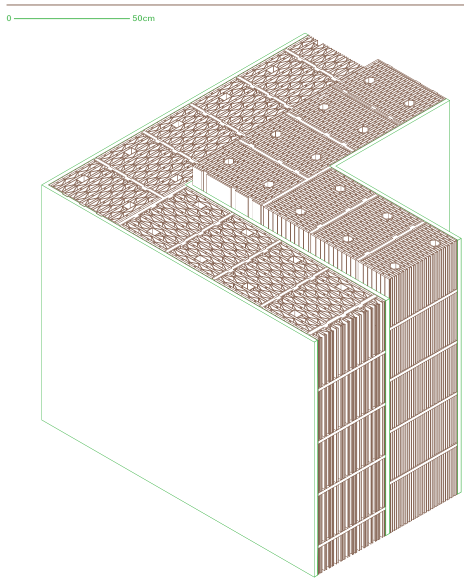
Haus 2226
Lustenau, Austria

Baumschlager Eberle Architekten
2013



The need to tackle energy wastage led the building industry to pursue a strategy of equipping buildings with highly insulated, airtight envelopes and complex, high-tech heating and ventilation systems. The architecture office Baumschlager Eberle presents an alternative to this trend and the accompanying standards, by creating a building that draws on vernacular traditions such as monolithic masonry that serves both as load-bearing structure and thermal mass, and no cooling. The building shell comprises two layers of 36 cm thick brickwork: a denser inner leaf for sustaining compressive loads and an outer leaf for insulation. This construction also obviates the need for heating. The façades are defined by a grid of well-proportioned identical wood-frame windows with triple glazing and sensor-controlled window vents for night-time cooling – the only technological system in this minimalist concept. Similarly counter-intuitive is the seemingly wasteful floor height, which ranges from 3.40 to 4.50 m – far higher than building codes require. Nevertheless, the project promises its occupants indoor room temperatures of between 22 and 26 °C in a climate zone that is cold in winter and hot in summer – hence its name. The 2226 concept appears to run contrary to all energy-saving regulations, as well as the investment market's fixation with maximum floor areas. After more than 10 years of controlled monitoring, however, it has shown that its claim to sustainability is justified.






**Climate**
Warm-summer humid continental climate, Dfb* no dry season, warm summer

**Units**
Clay block – outer leaf
250/380/238 mm
Insulating

Clay block – inner leaf
250/380/238 mm
Load-bearing

**Wall construction: double leaf**

| | |
|---|---|
| Lime plaster | 8 mm |
| Lime-cement base plaster | 12 mm |
| Clay block | 380 mm |
| Mortar joint | 18 mm |
| Clay block | 380 mm |
| Lime-cement base plaster | 15 mm |
| Lime plaster | 5 mm |
| Total | 818 mm |

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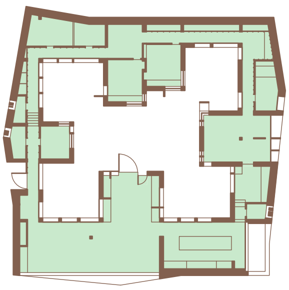
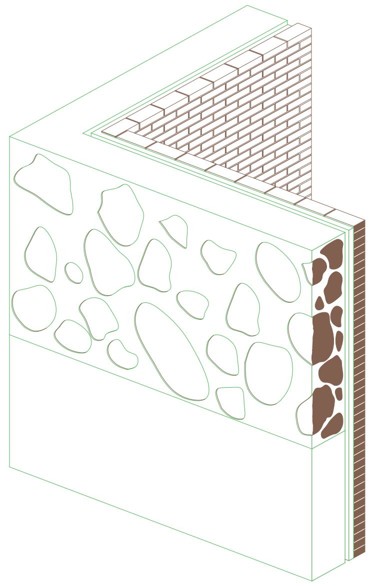
Jaime and Isabelle's Home
Palma, Spain

TEd'A arquitectes
2018



Patio houses are part of a Mediterranean tradition that incorporates means of climate control in their design and construction. For centuries, they have employed methods that help keep their houses pleasantly cool in summer and sheltered against excessive cooling in the winter months. The patio serves here to provide valuable shade in summer and protect the plants in winter. Its thick external walls act as thermal mass. This project for a single-family home in Mallorca sits in this tradition. Its perimeter walls convey the impression of a fortress – impenetrable and robust. Designed as a twin skin construction with a central air cavity and thermal insulation, it has a thickness of 0.56 m. The outer skin is concrete with embedded 'Cyclopean' stone blocks collected from the site. The use of larger stones in the concrete mix reduces the proportion of smaller aggregates. Thermal insulation is applied to the outer face of the inner leaf of exposed brick, with an air cavity between it and the outer leaf. Air circulation ensures that any condensation accumulating on the other shell can dry.

0 — 50cm



**Climate**
Cold semi-arid (steppe) climate, BSk*
steppe, hot

**Units**
Clinker brick – inner leaf
240/120/50 mm
Facing brick

**Wall construction: double leaf**

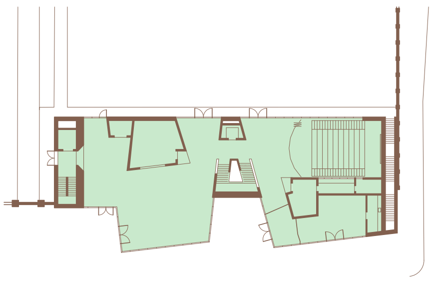
| | |
|---|---|
| Cyclopean concrete wall | 350 mm |
| Air space | 40 mm |
| Insulation | 50 mm |
| Facing brick | 120mm |
| Total | 560 mm |





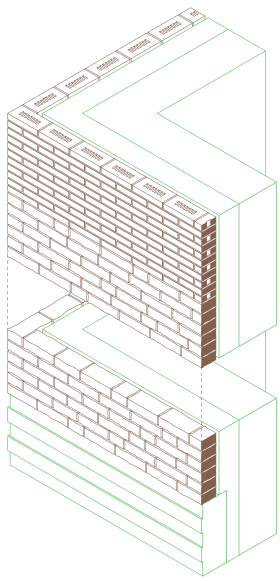
Spore Initiative
Berlin, Germany

AFF Architekten
2023



Concrete constructions gave architecture the freedom of the simultaneity of rigid and flexible free floor plans, of spaces that can flow over many storeys, and of structural systems that dissipate loads in ways that seem to contradict the usual force of gravity. The previously dominant form of brick-on-brick masonry has been unjustly displaced rather than utilising the strengths of each to achieve new qualities. The Spore Initiative combines both approaches. The structural load-bearing concept allows the ground floor to act as an extension of urban space, creating two large exhibition spaces whose solid external walls support the smaller-scale residential floors above. The external skin of concrete facing, reclaimed clinker and new fired clinker bricks not only divides the volume into plinth, bel étage and "attica" zones but also puts the varied materiality of the different surface zones to the test. The conflict seen in curtain wall designs from the past decades in which the hermetic solidity of walls of masonry is interrupted periodically by expansion joints is resolved in this project through the use of flexible, movable wall ties that link the two leaves, along with fibre-reinforced mortar joints. The use of bricks reclaimed from other demolished buildings was accepted by the client after seeing the results of laboratory tests on the frost resistance of randomly selected brick specimens.

0 — 50cm



**Climate**
Temperate oceanic climate, Cfb*
no dry season, warm summer

**Units**
Recycled clinker brick, outer leaf
240/115/65 mm
Facing brick

Clinker brick, outer leaf
240/115/40 mm
Facing brick

**Wall construction: double leaf**

| | |
|---|---|
| Facing brickwork | 115 mm |
| Air space | 25 mm |
| Insulation | 160 mm |
| Reinforced concrete wall | 300 mm |
| Total | 600 mm |