



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

Buchgestaltung: Omnigroup, Lausanne  
Englisch, 96 Seiten, ca. 60 Abbildungen,  
17,1 × 24 cm, Broschur

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

Neuerscheinung März 2024

## Was man über massive Bauweisen wissen muss

→ Hochaktuell: Massives Bauen gewinnt hinsichtlich lang-  
lebiger, wartungsarmer Konstruktionen an Bedeutung

→ Vermittelt Wissen zu massiven Bauweisen in serieller  
und elementierter Fertigung – vom allgemeinen themati-  
schen Überblick bis zum exemplarischen Projekt

Angesichts von Forderungen nach ressourcenschonenden, lang-  
lebigen und wartungsarmen Gebäuden rücken die Potenziale  
der massiven Bauweisen wieder in den Fokus. Die Publikation  
untersucht das Bauen mit massiven, seriell gefertigten und elemen-  
tierten Bauteilen anhand verschiedener Konstruktionsmethoden  
und -lösungen. Dabei wird sowohl das Fügen der Elemente und  
Bauteile behandelt als auch der Aufbau der Konstruktion selbst.  
Jedes Element wird im Hinblick auf seine spezifische Funktion und  
seinen Beitrag zum System der Wand untersucht.

Diese Publikation blickt bewertend auf traditionelle und zeitge-  
nössische Konstruktions- und Fertigungstechniken, um verantwor-  
tungsvolle Ansätze für die Verwendung von Materialien und mo-  
dularen Elementarsystemen für die Zukunft zu fördern. Das Buch  
richtet sich an Architektinnen und Architekten sowie Studierende.

Die im ersten Teil versammelten Beiträge reflektieren den Stand der  
Forschung und der experimentellen Baupraxis – von Baumateri-  
alien wie ungebrannten Lehmziegeln, der Anwendung verschie-  
dener Steinformate bis hin zur Rolle massiver Gebäudehüllen.  
Entsprechende Beispiele von Ziegelbauten aus der Region Gent  
und Leuven sowie der Einsatz von massiven Steinblöcken in einem  
Wohnbauprojekt in Genf veranschaulichen diese unterschiedlichen  
Erkenntnisse und erweitern das Verständnis für den elementierten  
Mauerwerksbau. Der zweite Teil dieses Buches stellt ausgewählte  
architektonische Arbeiten vor, die von den Studierenden des  
Designstudios EAST analysiert wurden. Diese grafische Studie  
exemplarischer Projekte bietet einen lehrreichen Überblick über  
die konstruktiven und klimatischen Zusammenhänge.

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 whether 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, Aals. Photo: Stijn Bolleert.

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<sub>2</sub> 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<sub>2</sub>, 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

# Über die Herausgeberschaft

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

Während sich die Funktionen im Laufe der Zeit ändern, bleibt die Architektur bestehen. In Unterricht untersucht EAST jene Aspekte, die die Nutzung, die Morphologie und die räumliche Gliederung von Gebäuden bestimmen.

Die Geschichte und der Wandel dieser Aspekte dienen als analytische Grundlage für den Entwurf neuer Gebäude sowie für die Wiederverwendung und Umgestaltung bestehender Gebäude. Ebenso dienen städtische Siedlungen als Laboratorium für architektonische Ideen, die mit den technischen Mitteln und Raumkonzepten unserer Zeit am Laboratory weiterentwickelt werden.

Die gemeinsame Projektarbeit im Atelierraum sorgt für eine kontinuierliche Diskussion unterschiedlicher Gestaltungsansätze und hilft den Studierenden, ihre Ideen auszubauen.

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



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

12

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".<sup>2</sup> 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

13

Although concrete is intrinsically one of the most sustainable construction materials with a low proportion of embodied CO<sub>2</sub> per kg of material (Fig. 14), its scale of application makes it a large contributor to CO<sub>2</sub> 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<sub>2</sub> 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.

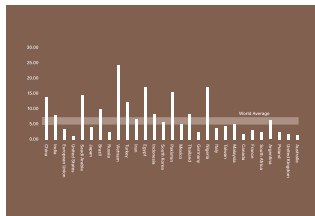


Fig. 15. Overall %CO<sub>2</sub> emissions from cement production.

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<sup>3</sup> (limestone calcined clay cement) technology.

LC<sup>3</sup> is a sustainable cementitious binder that removes up to 50% clinker (LC<sup>3</sup>-50) from cement by introducing calcined clay and limestone, reducing CO<sub>2</sub> 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

12

cannot provide a long-term solution. By contrast, a major plus of LC<sup>3</sup> 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<sup>3</sup>.

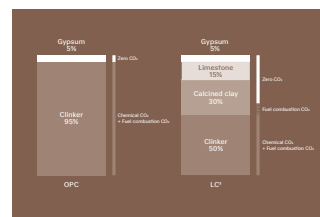


Fig. 16. Comparison of Ordinary Portland Cement (OPC) and LC<sup>3</sup>-50 composition and related CO<sub>2</sub> emissions.

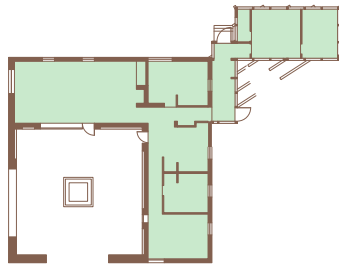
Given its low porosity, the use of LC<sup>3</sup> in concrete provides good resistance to weathering, such as permeability, sorptivity, chloride ion penetration, and sulphate attack. Thus, it is particularly suitable for exposed marine, groundwater, and damp-proof applications. It also has an extraordinary binding capacity and plasticity, making it ideal for indoor and outdoor plaster and mortar applications. Finally, LC<sup>3</sup> 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<sup>3</sup> in the cement standards. In 2018, Cuba approved the use of LC<sup>3</sup> as a ternary cement (NC 1208 standard) and since 2021, LC<sup>3</sup> has also been included in the European cement standard EN-197-5. Current initiatives are focusing on the inclusion of LC<sup>3</sup> use in concrete standards, which would legitimate its use in construction and encourage more widespread adoption. Updating

13

Muuratsalo Experimental House  
Muuratsalo, Finland

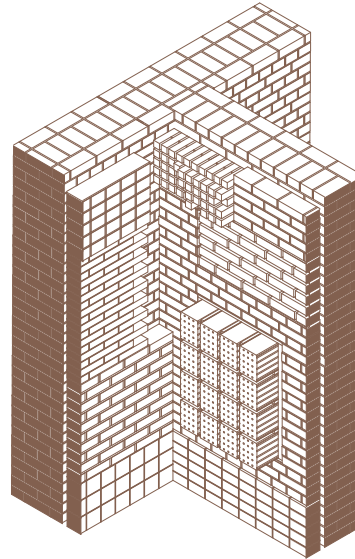
Elissa Aalto, Alvar Aalto  
1953



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.

58

0 50cm



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

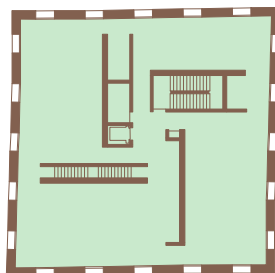
Units  
Clay brick, clinker brick, outer leaf  
Different dimensions and types  
of brick, facing brick  
  
Clay brick, inner leaf  
215/102/65 mm  
Reinforced masonry, load-bearing

Wall construction: double leaf  
Patchwork of bricks >100 mm  
Air space 40 mm  
Clay brick 340 mm  
Total 480 mm

59

Haus 2226  
Lustenau, Austria

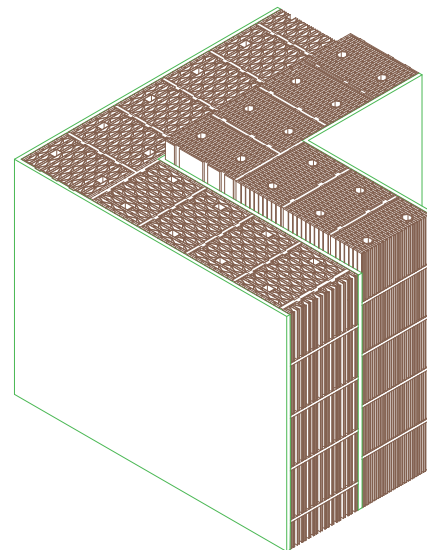
Baumschlager Eberle Architekten  
2013



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.

74

0 50cm



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

75

**Jaime and Isabelle's Home**  
Palma, Spain

**Ted'A arquitectes**  
2018

0 — 50cm

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.

Climate Cold semi-arid (steppe) climate, BSk* steppe, hot	Units	Wall construction: double leaf
	Clinker brick – inner leaf 240/120/50 mm Facing brick	Cyclopean concrete wall 350 mm Air space 40 mm Insulation 50 mm Facing brick 120mm Total 560 mm

80
81

**Spore Initiative**  
Berlin, Germany

**AFF Architekten**  
2023

0 — 50cm

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.

Climate Temperate oceanic climate, Cfb* no dry season, warm summer	Units	Wall construction: double leaf
	Recycled clinker brick, outer leaf 240/115/65 mm Facing brick Clinker brick, outer leaf 240/115/40 mm Facing brick	Facing brickwork 115 mm Air space 25 mm Insulation 160 mm Reinforced concrete wall 300 mm Total 600 mm

84
85