08

Ceramics. The protective matter

Eduardo de Miguel
Enrique Fernández-Vivancos

This article reflects on the material condition of architecture, understanding matter as the means of expression of ideas and the element which is capable of transforming them into a built construction. It focuses on the study of ceramics and displays it as a protective component that has come across its unique capacity for formal, functional and symbolic adaptation, which has enabled it to provide a contribution to the solution of new problems or to propose innovative approaches to its use. Through a number of visionary procedures which have been conducted with these materials since the end of the 19th century, and based on the possibilities of technology, its intelligent and rational use, its availability for recycling and the value of tradition, our aim is to provide an analysis which will help to conceive sustainable solutions from the same innovative force in order to tackle the major challenges and global commitments which have been undertaken.

MATERIAL AWARENESS

"Many tested images cannot live because they are mere formal games, because they are not truly adapted to the matter they must adorn". Gaston Bachelard, 1942[1].

In an increasingly compulsive, non-criteria-based era of globalised images, this statement is surprisingly valid and is a clear warning of the danger of allowing ourselves to be seduced exclusively by these, if we are not to fall into the trap of constructing trivial forms dissociated from the matter chosen to express them. Bachelard also clarifies that "for a dream to continue with sufficient constancy to generate a written work, so that it is not simply the celebration of a fleeting hour, it must find its matter, a material element must provide it with its own substance, its own rule, its specific poetics"[2].

These reflections, taken from an essay on the imagination of matter, could perfectly well refer us to the discipline of architecture. They show that for a thought to crystallize, it must necessarily transcend its immaterial dimension; that in order for a premonition, which by virtue of its intensity produces a work of architecture, and is not the product of an occurrence arising in a state of maximum elation, it is necessary to find the precise matter.

Gaston Bachelard, by means of these considerations, exhorts us to discover the radical link which is established between formal speculation and physical consistency, and makes us understand that the material condition of the constructed work is not the product of a whim, but the consequence of a process which requires the contemplation of the laws of construction in their final stage. It is true that it is necessary to go through different stages during the development of the project, and that in many of them matter can be dispensed with without it being affected, but in the end it becomes inevitable to consider the internal logic of the elements chosen to provide it with corporeality. From this perspective, matter becomes the means of expression of ideas and the element which is capable of transforming them into a constructed work[3].

In the same text he also speculates on setting "a law of the four elements that classifies the various material imaginations according to whether they are linked to fire, air, water or earth"[4]. Interestingly, ceramics, the first sintered compound in history, is made up of these very four elements. It is a simple material, originated by the mixture of earth and water, and transformed through air and fire, which has extraordinary properties: it is hard, inert, stainless, fireproof, and water-repellent. These characteristics, together with the ease with which it can be moulded, giving it any shape, texture or colour, and the naturalness with which it registers the expression of the hand, and with it, of time and space, allow it an unlimited field of application **(fig. 02)**.

Used in all cultures and civilizations, it symbolizes the past millennium of a substance that man, with his ingenuity, has been able to process and use in the most efficient way, achieving results which outlast all technological innovation. The history of architecture is also linked to this fascinating material, and the situations in which it can be found are innumerable because of its immense capacity for specialization, largely to protect itself from the four elements of which it is composed: from the earth through the terracotta tile pavements that harden the ground on which they sit to defend themselves from impurities; from water through the flat or curved tile roofs which are shaped to conduct the rain and protect us from inclement weather, or from the glazed tile coverings which cover the walls with an impermeable layer to facilitate hygiene and prevent contamination; from air through brick walls with which solid buildings have been built to protect themselves from any threats; and from fire through refractory surfaces or lattices that let light through but prevent direct radiation from the sun's rays, in order to temper and preserve the privacy of interior spaces.

This reality, which shows the unlimited configuration potential of the ceramic materials used in architecture, allows for a distinction to be made between those designed to take on structural functions and provide firmness, and those designed to clad it in order to protect it from the elements. The first category includes the brick, a universal construction element designed in perfect harmony with the human body and whose origin dates back to the middle of the third millennium BC[5]; it is such a superb synthesis that it has not required significant modifications since it was first created and with just one piece, and a few accessories, it has allowed practically everything to be made. Nevertheless, the second one reveals the existence of an infinite number of pieces shaped to solve a specific problem in each case. This fascinating metamorphosis of matter, which involved reformulating dimensions, adapting thicknesses or engineering complex shapes, led to the renunciation of its load-bearing capacity, but it showed that the naturalness with which it is modified to safely respond to new demands belongs to its idiosyncrasy, resulting in an endless number of highly qualified wrapping skins which characterize the surfaces they cover, ready to defend themselves from almost anything.

If something can be said about this protective material, which is largely responsible for the colour and texture of our cities since it is present in floors, walls, ceilings and roofs, it is that it has

succeeded in responding honestly and intelligently to all the problems it has had to face, and in the process, and whenever possible, it has expressed the characteristics of a particular place and time with grace and ingenuity. It should be made clear that this "attribution of human qualities to materials -honesty, intelligence, elegance, ingenuity- is not intended to explain; its purpose is to heighten our awareness of the materials themselves and thus to reflect on their value"[6].

TIMES OF STEEL AND CLAY

The choice of a material is determined by the need to solve a functional problem, to respond to a desired shape or to produce a precise meaning, an aspect which is often forgotten at the expense of the other two, but as Richard Sennet reminds us, paraphrasing Lévi-Strauss, "symbolic value is inseparable from awareness of the material condition of an object"[7]. Coherently meeting these requirements calls for in-depth knowledge of its technical properties, expressive capacity and eloquence; three determining aspects in the qualification of space which allows it to achieve its raison d'être when, once placed, it provides an appropriate response to all of them.

The soft origin of ceramics, hardened in later processes, is one of its most attractive qualities since it confers all the possibilities of configuration and formulation of its technical characteristics. This particularity has made it an ideal material for continuous reprocessing and, if we consider the extraordinary lessons history has taught us, we can see that it has not stopped evolving over time and has always discovered a suitable way to do so, either by contributing to the solution of new problems or by proposing innovative ways of applying them.

However, the question that arises at the moment, in which awareness is being called for of the global commitment made at the Summit for Sustainable Development held in New York in 2015, and in which a set of 17 Goals to be achieved by 2030 was defined[8], is to find out what this direction should be. The challenges we have to face call for a radical change, in the shortest possible time, in certain harmful habits which are threatening the planet. In order to be fully aware of this vulnerable situation, it is necessary to find, within a short period of time, ways to straighten out this course and, although it is very likely that a large part of the future solutions will come from science and technology, we should bear in mind all those past experiences from which it is still possible to learn.

One of the most interesting episodes, and one that has many similarities with the current situation since it is a time of deep transformation, can be found in the innovations that took place at the end of the 19th century, when industrialised manufacturing processes were developed and which constitute the current basis of ceramic technology[9]. This revolution involved the mechanisation of all the production stages, from the processing and composition of raw materials, through the processes of configuration, surface treatment and decoration of the pieces, and concluding with the firing methods, giving rise to a new generation of ceramic materials that was unprecedented in the history of architecture[10].

Simultaneously, the rise of steel structures, which together with the invention of the elevator gave way to the new typology of high-rise buildings, had a decisive impact on the construction industry, two of its most important consequences being the need to lighten enclosures and partitions, and the obligation to secure structures against fire, and this is where hollowed-out ceramics proved to be unbeatable in responding to all these demands thanks to the development of a very wide range of highly specialised products [11] **(fig. 03)**. William le Baron Jenney, one of the main actors in the history of the American skyscraper, foresaw the arrival of times of steel and clay with which to meet the demanding challenges of its construction. "The hollow arch of refractory terracotta clay was invented, strong, light and less costly than the old methods, and more effective. With this material it was easy to completely cover the I-beam and form a flat roof that only required plastering and protection of the columns, because it could be easily moulded into the most convenient shapes for each purpose"[12].

It is not surprising, therefore, that a great many pioneering projects in the use of these modern materials emerged in a very short time, but the past experiences to which I was referring are not so much focused on the most outstanding or most influential achievements of the time, which were many and important, but rather on highlighting, through a particular series of actions, the radical nature of certain visionary procedures and attitudes that are still fully valid and which can be of great help in conceiving, with the same innovative force, the transformation that the new times demand.

A building that congruently exemplifies this impulse is Louis Sullivan's Prudential Building in Buffalo (1896) **(fig. 04)**. The building proposes an enclosure built in terracotta in accordance with Sullivan's theories on the organic function of ornamentation in architecture, incorporating floral embossing as a means of expressing the poetic and rational meaning of the construction[13]. Not only does he lighten the enclosure with the introduction of ceramics, but he also expresses this condition through his plastic proposal. To a large extent, this evanescent and lightweight appearance of the facade is achieved through the presence of the shadows contained in the natural forms which cover it, thus managing to dematerialise it and transmit the sensation that the building is protected by a vegetal fabric which allows the air to pass through its wicks. He gave life to a material as had never been seen before and Frank Lloyd Wright, his former collaborator, referring with respect and admiration to the authority with which he used terracotta, and in the face of the feeling that this dominion would never be achieved again, stated: "No. Materials never die. This material is only sleeping, waiting for some master to wake it up to life"[14].

One of the most interesting contributions made with the aim of preventing the buildings from being consumed by flames, and which stands out for the uniqueness of the approach, is that made by Rafael Guastavino when he eliminated the problem at its root and replaced, wherever possible, the steel structure with ceramic vaults due to its proven resistance to combustion. His great opportunity came during the construction of the Boston Municipal Library (1895), when Charles Follen Mc Kim, of the firm Mc Kim, Mead & White, discovered the advantages of his patent **(fig. 05)**. In his hands, this construction system, based on the intelligent arrangement of a simple material which was capable of assuming structural functions not originally foreseen - a small, thin scraper designed to cover surfaces - and characterised by its solidity, lightness in relation to the light it covers, speed of execution and economy of means when it was put into operation, was developed to a totally unexpected limit[15].

Another creative manifestation which is surprisingly original is the invention of the *trencadís* technique conceived by Antonio Gaudí and adopted by Catalan modernist architects. This innovative procedure, based on the reuse of ceramic fragments for their ornamental application in the covering of facades, reached its maximum expression in the Batlló house (1906) and the Güell Park (1914), both in Barcelona. To make these mosaics, all kinds of plates and cups made of broken white china, pieces of glazed tiles and disposable ceramic material were used to add chromaticism and colour to the sinuous walls and breathe life into them through the reflections of light on the glazed surfaces, with each piece adding its own particular nuance to the whole. Working with a recycled material adds a sublime factor to the character of the envelope because the use of pieces of the same colour, but from different sources, produces slight shades which provide a depth and warmth to the coating which is impossible to achieve by other means[16]. This is an unexpected enrichment resulting from the rational decision of using materials discarded by the industry as unusable.

Ceramic materials were widely used until after the Second World War, after which new construction systems based on standardisation and prefabrication were consolidated, giving way to glass, steel, aluminium, or concrete. However, the so-called second-generation architects have undertaken a critical review warning of the danger of forgetting the lessons learned from the humblest version of history, the one linked to popular wisdom, which has been able to build a strong identity through common sense and economy of means. This vindication of the vernacular, of architecture without architects, was not so much due to the purpose of recovering a heritage which was disappearing, as it was to recognize the value of the culture and traditions which make the places where we live unique.

One of the most lucid retrospectives, conducted with the aim of finding the best version of the path which allows us to move towards a better future, belongs to Josep Lluís Sert. He discovered a source of renewal inspiration in the harmony of the Mediterranean peoples, "the product of patience, love and time", and in his architecture "born to limitations and resolved with great simplicity in shapes"[17], which led him to use local materials in many of his works. Particularly fruitful was his collaboration with Joan Miro in the projects of his own studio in Mallorca (1956), the Maeght Foundation in Saint Paul de Vence (1964) and the Miró Foundation in Barcelona (1975). In all of them, he used ceramics as he perceived it to be a simple material - a piece of baked clay - but tremendously dignified and one of the most consistent in terms of its history and meaning. Among these three works, the interior and exterior handmade terracotta floorings of the Maeght Foundation stand out for their sensuality, completely impregnated with the expression of the craftsman who modelled them, making each of the pieces unique through routine and diverse movement while providing mastery of the trade **(fig. 06)**.

MATERIALS NEVER DIE

This brief journey, conducted with the aim of learning from past experiences, shows the enormous capacity for transformation of ceramics and, although throughout this time the industry has not stopped evolving and conceiving new products, the technological base, in essence, remains the same. This is why all these paths taken by the great masters of architecture since the end of the 19th century are still an endless source of inspiration. Their proposals, based on the intelligent and rational use of ceramic materials, opened up the innovative ways of using these materials which, in their essence, are still valid today.

The course taken by Sullivan, committed to the use of the most adventurous components of his time and adopting lightweight terracotta to squeeze it to its very end, is revealed in the figure of Renzo Piano, an architect with industrial hands who transforms all the materials he encounters. Among his most significant works are those made with ceramics: starting with the Ircam (1990) and the Rue du Meaux apartments (1991) in Paris, continuing with the Postdamer Platz (2000) in Berlin and the New York Times (2007) and concluding with the Central St. Giles (2010) in London and the Botín Foundation (2017) in Santander. In all of them, his innovative mark is revealed, and the close collaboration he establishes with manufacturers to tackle these challenges has managed to bring this noble material back to life, thus allowing us to appreciate its extraordinary expressive potential.

Following the trail that Guastavino walked, who did more with less thanks to ceramic vaults, and hand in hand with technology through the incorporation of sophisticated design and parameterized calculation programs into professional practice, there is once again a basis for continuing to explore the possibilities offered by a structural system that had supposedly been exhausted. In this field, renowned academic centres are conducting their own research, including the Block Research Group of the EHT Zürich[18], one of whose research lines focuses on exploring low-tech building systems made with local materials and traditional construction techniques. Part of these proposals were shown at the Venice Biennale in 2016 with a prototype of the *Droneport Project* promoted by the Foster Foundation **(fig. 07)**, which proposes facilities for drones, designed to facilitate the distribution of medical material in emerging countries which currently lack the adequate infrastructures.

Gaudí's brilliant commitment to reusing unusable material and dignifying it until it becomes the leading figure, could not be more in line with the times, since this behaviour is clamoured for through the so-called 3 R's of ecology: reduce, reuse, recycle. Within this context, albeit at a slower pace than desired, solutions committed to a system based on circular economy are beginning to emerge, as can be seen in the project *Ceramic Sustainable Urban Drainage System*, recently completed in Benicàssim (2019) and carried out within the LIFE programme promoted by the European Union for adaptation to climate change, and in which five different partners have participated: the university, technological institutes, local administration, manufacturers, and construction companies[19]. This proposal, which aimed at implementing a demonstrator to respond to soil sealing in cities by developing a sustainable urban drainage system, uses an innovative water-permeable ceramic paving stone made of low-commercial value tiles **(fig. 08)**.

And the commitment to valuing what is local, which in Sert's case arose from a personal reflection on the meaning of tradition, is now vindicated by the global urgency to find sustainable solutions to the problems we are facing. A claim which demands the restoration of common sense and the economy of means, and which we have rediscovered in attitudes such as that of Francis Kéré in his Primary School in Gando (2001) **(fig. 09)**; a precursor project of this new sensitivity built against the tide in the era of greater architectural excesses, which aspires to something as simple as giving an adequate response to the setting by using only the materials at hand. Fortunately, and with the help of a generation of emerging architects committed to sustainability, it is becoming increasingly common to find projects in which both the discourse and the proposals are coherent and of a high architectural quality of their own.

The need to create a responsible architecture which is consistent with social, economic and environmental factors opens up a new stage in which it is essential to set up alliances with all the sectors involved: the scientific-academic sector to research and determine potential new materials, the professional sector to come up with innovative ways of using these materials and the productive sector to transform these materials into concrete reality. At present, and thanks to the extraordinary qualities of ceramics, successful experiments are being carried out in the implementation of digital design methods, robotic manufacturing and 3D printing applied to the automated production of advanced ceramic systems[20]. The progressive incorporation of these new technologies, many of which are still in their experimental stage, will have an impact which is at least equivalent to that produced by the industrial revolution.

Since we are aware that we are facing a decisive crossroads if we want to meet the global commitments acquired through the Sustainable Development Objectives, the proposal of systemic responses from a holistic and interrelated vision is imperative in order to achieve a clear improvement in the economic, social and environmental integration. The challenges we face are of such magnitude that disruptive visions are needed to radically transform the current model, and to this end it is necessary to once again vindicate the profound meaning of concepts such as: sustainability, resilience, ecology or environment, worn out to a large extent by the misuse that has been made of them, and sometimes causing absurd scepticism, when more evidence exists of how urgent it is to address them.

As far as our activity is concerned, and as we have seen through all these inspiring proposals, there are plenty of reasons to confirm that change is underway and is irreversible, but decisive and

hopeful policies are still lacking to break the established inertias and accelerate the transition towards the new patterns of behaviour[21]. Times are coming full of opportunities behind the important transformations aimed at reducing environmental impact in all processes and in each of the different stages of our complex work. It is evident that a large part of these opportunities will come from technology, but those offering an attentive look at tradition should not be underestimated; if we keep to this legacy, architecture has always managed to be a driving force for innovation when, in investigating the root of the problems underlying the challenges to which we have to respond, it comes up against unexpected solutions.

To a great extent, these innovations have been related to the matter which allows to support the ideas pursued by the projects and to their intelligent way of disposing it according to the laws of construction. This is the most precise stage of the whole process before it becomes a reality, but it is also the one which allows it to be configured according to its particularities over which the architect should never lose control if he is to guarantee a full and coherent work at all scales.

> "Fired clay, even if not perfectly hardened by fire, is, with the exception of its fragility, the most imperishable material; it lasts much longer than stone or metal and it even provides greater solidity and quality in its technical use". Gottfried Semper, 1863[22].

This quality has allowed it to be one of the materials chosen over the centuries to give architecture its own substance, its own rule and its specific poetics. Few materials have such a noble and simple origin as ceramics, and few have developed such a wide and versatile spectrum of components for the purpose of protection. The times to come will bring new masters who will reawaken it, fascinated by the inexhaustible possibilities of technology, and hopefully also enriched by the common sense of tradition, with the aim of providing innovative solutions to ensure the greatest possible wellbeing, but on this occasion, moreover, taking into account those laws which ensure respect for the planet in order to preserve it for future generations.

Eduardo De Miguel
Pamplona 07/10/1959. Phd Architect (Universidad de Navarra/ ETSAM), He is currently Professor of Projects at the Polytechnic University of Valencia, co-director of the research group Proyecto Arquitectura PAr and director of the Cátedra Cerámica sponsored by ASCER, being the editor of the digital platform www.ceramicarchitectures.com. His projects have been recognized at the III, V and VII BEAU, the IV and VII BIAU, the IX Biennale di Architettura di Venezia, the FAD Awards 2004, 2005 and 2009, the European Prize for Urban Public Space 2010 or the European Prize for Cultural Heritage 2011, and have been published in magazines such as: El Croquis, A&V, Architectural Record or Architecture d'Aujourd'hui, and in international publications such as: Young Spanish Architects de Birkhäuser, Landscape Architecture Now! by Taschen or The Phaidon Atlas of 21st Century World Architecture.
Afiliación: Universidad Politécnica de Valencia
E-Mail: emiguel@pra.upv.es
Orcid ID 0000-0003-1866-6591

Enrique Fernández-Vivancos
Granada 26/12/1967. PhD Architect (Universitat Politècnica de València). He is currently Associate Professor in the Department of Architectural Projects of the UPV, Associate Professor of the UCH-CEU and Visiting Professor of Urban Design at the UTE-FAU of Quito. His projects have received various awards at the: X Biennial of European Cities, 2013; XI Spanish Biennial of Architecture and Urbanism, 2011; III Mediterranean Landscape Prize of the European Union, 2010; Hispalyt Award for architecture with brick, 2009, Construmat Award for innovation, 2019; and the JAE Young Spanish Architects Exhibition of the Ministry of Culture, 2008. His research work has been published in: PPA, EGA, Zarch, DPA.
Afiliación: Universitat Politècnica de València
ORCID: orcid.org/0000-0003-4806-0910
E-Mail: efernan1 @ upvnet.upv.es

Notes

01. BACHELARD, G., *El agua y los sueños. Ensayo sobre la imaginación de la materia*, Fondo de Cultura Económica, Mexico, 1978 (1942), p. 10.

02. Ibid. p. 11.

03. As such, projects which fail to consider or assimilate construction as an inseparable part of the process, may end up being incomplete architectures by generating incoherent images since their lines are not adapted to the chosen material.

04. Ibid. p. 10.

05. The shape of the brick is born according to the anatomy of man: light, adapted to the hand and 1 foot long, 1/2 wide and 1/4 thick in proportion. GRANGEL, E., "Origen y tipología de los materiales cerámicos", *La ruta de la cerámica*, Asociación para la Promoción del Diseño Cerámico, Castellón, 2000, pp. 17 ff.

06. SENNET, R, "El relato del ladrillero", *El artesano*, Anagrama, Barcelona, 2009 (2008), p. 172.

07. Ibid. p. 162.

08. The Sustainable Development Goals call for universal action to eradicate inequality and extreme poverty, unsustainable consumption patterns and environmental degradation, and to strengthen institutions and global solidarity in order to protect the planet and ensure peace and prosperity.

United Nations, n.d., *Sustainable Development Goals*. Available at: https://www.un.org/sustainabledevelopment/ [Consultation: 27 February 2020].

09. ESTALL I POLES, V., PORCAR, J. L., "El desarrollo industrial y tecnológico durante el siglo XIX hasta el primer tercio del siglo XX", *La ruta de la cerámica*, Asociación para la Promoción del Diseño Cerámico, Castellón, 2000, pp. 144-154.

10. A sign of the impact of this change can be traced back to Eugène Viollet-le-Duc, a pioneer in claiming the need for a rational, standardised, hygienic and economic architecture, by foreshadowing a hopeful path in the new ceramic materials. "We had the chance to see, in the last exhibitions, to what extent Germany, and especially England, have perfected the manufacture of fired clay, bricks and moulded and glazed earth". VIOLLET-LE-DUC, E., "Décimo octava conversación (sobre la arquitectura privada)", *Conversaciones sobre la arquitectura, Vol II*, Colegio Oficial de Aparejadores y Arquitectos Técnicos de Murcia, Murcia, 2007 (1872), p. 327.

11. This situation gave rise to the flourishing of a new industry in the United States whose golden age, in which more than 30 companies were established throughout the country, spanned from 1880 to the Great Depression of 1930, and the birth of a new material called *architectural terra cotta* as a lighter and less expensive alternative to stone.

12. JENNEY, W. L. B., "An Age of Steel and Clay", in *Inland Architect and New Record*, 1890, vol. 16, no. 7, p. 76.

13. See WEINGARDEN, L. S., "Louis H. Sullivan's System of Architectural Ornament", *Louis H. Sullivan. A System of Architectural Ornament*, Rizzoli, New York, 1990, p. 24.

14. WRIGHT, F. L., PFEIFFER, Bruce B. ed., "In the cause of architecture V: The meaning of materials - The Kiln", *Frank Lloyd Wright. Collected Writings. Volume 1 1894-1930*, (originally published in The Architectural Record, June 1928), Rizzoli, New York, 1992, p. 288.

15. The ceramic vaulting system was so popular that the Guastavino Fireproof Construction Company founded in 1889 was active until 1962, 12 years after the death of his son Rafael Jr. The cathedral of St. John Divine in New York (1909) is one of his greatest achievements, as it has a 30 m span vault with a thickness of only 11 cm.

16. In the restoration of Park Güell (1987-94) undertaken by architects Elías Torres and Juan Antonio Martínez Lapeña, in collaboration with Cerámicas Cumella, 21 different shades of white were used. An intervention, which was not without controversy, for which they received the Europa Nostra prize in 1995. El País, 26/ 12/1994.

17. SERT, J. L., *Ibiza, fuerte y luminosa*, Ediciones Polígrafa, Barcelona, 1967, pp. 14 and 16.

18. ETH Zurich, 2009, *Block Research Group*. Available at: https://www.block.arch.ethz.ch/brg/project/venice-biennale-2016_droneport [Consultation: 27 February 2020].

19. Project LIFE15 CCA/ES/000091. *Ceramic Sustainable Drainage System*. Instituto Tecnológico de la Cerámica, n.d., *Life Cersuds*. Available at: http://www.lifecersuds.eu [Consultation: 27 February 2020].

20. Currently, renowned academic centres are conducting their own research, including: Material Processes and Systems (MaP+S) at the Harvard University Graduate School of Design, Garmazio Kholer Research at EHT Zürich, the Bio-Integrated Design Lab at the Bartlett School of Architecture at UCL and the Institute of Ceramics Technology at the UJI.

A reference book on the subject is BECHTHOLD, M., KANE, A., KING, N., *Ceramic Material Systems*, Birkhäuser, Basel, 2015.

21. According to the International Energy Agency, the building sector is responsible for 30% of global energy consumption and 28% of CO2 emissions.

International Energy Agency, 2020, IEA. Available at: https://www.iea.org [Consultation: 27 February 2020].

22. SEMPER, G., "La cerámica, la tectónica, la estereotomía y la metalotecnia, consideradas en sí mismos y en relación con la arquitectura (1863)", *Escritos fundamentales de Gottfried Semper*, Fundación Arquia, Barcelona, 2014, p. 311.

Images

01. Llorens Artigas modelling a vase in his workshop in Gallifa. Photograph by Catalá-Roca, F., 1970. Source: Arxiu Fotogràfic COAC, Barcelona.

02. Interior of a Hoffman kiln in the Oliva *La Salvadora* pottery factory. Photograph by De Miguel, E., 2019.

03. Pages 4 and 23 extracted from the catalogue *Fireproof Construction in Terra Cotta Hollow Tile*, 1914. Source: Canadian Centre for Architecture, Montreal.

04. Detail of facade of the east entrance of the *Prudential* building in Sullivan. Photograph by Boucher, J. E., 1965. Source: Library of Congress, New York.

05. Rafael Guastavino i Moreno on the arches of the Boston Public Library under construction. Photograph by Steven, E. F., 1889. Source: Boston Public Library, Print Department, Boston.

06. Craftsman making handmade terracotta in the Oliva *Decorativa* pottery factory. Photograph by De Miguel, E., 2009.

07. Full-scale prototype of a module of the *Droneport Project* for the 15th Venice Architecture Biennale. Photograph by Block Research Group, 2016. Source: ETH Zurich: Block Research Group.

08. Laying of the *ceramic* paving stone for the sustainable urban drainage system in Benicàssim. Photograph by Villalba, M., 2018.

09. Laying of ceramic pots on the roof slab of the school to introduce natural light inside. Photograph by Kéré, F., 2001. Source: Kéré Architecture.