UNIVERSITAT POLITÈCNICA DE VALÈNCIA

School of Architecture

Rafael Leoz: harmonious systematisation of architectural space

End of Degree Project

Bachelor's Degree in the Fundamentals of Architecture

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Abstract

Rafael Leoz de la Fuente was a Spanish architect, with a great international prestige, focused on the improvement of social housing. He carried out theoretical research, reflected in his publication "Redes y ritmos espaciales", with the aim of industrialising the construction process. A study will be made of the causes that led him to initiate this research, as well as a theoretical and practical analysis of his work through the Hele module, the hyperpolyhedra and his only projects built based on his theoretical principles: the experimental social housing in Torrejón de Ardoz and the Spanish Embassy in Brasilia.

Rafael Leoz, industrialisation, Hele module, hyperpolyhedra, social housing

Resumen

Rafael Leoz de la Fuente fue un arquitecto español, con un gran prestigio internacional, centrado en la mejora de la vivienda social. Llevó a cabo una investigación teórica, plasmada en su publicación “Redes y ritmos espaciales”, con el objetivo de industrializar el proceso de construcción. Se realizará un estudio de las causas que le llevaron a iniciar esta investigación, así como un análisis teórico y práctico de su obra a través del módulo Hele, los hiperpoliedros y de sus únicas obras construidas basadas en sus principios teóricos: las viviendas sociales experimentales de Torrejón de Ardoz y la Embajada Española en Brasilia.

Rafael Leoz, industrialización, módulo Hele, hiperpoliedros, vivienda social

Resum

Rafael Leoz de la Fuente va ser un arquitecte espanyol, amb un gran prestigi internacional, centrat en la millora de la vivenda social. Va dur a terme una investigació teòrica, plasmada en la seua publicación "Redes y ritmos espaciales", amb l'objectiu d'industrialitzar el procés de construcció. Es realitzarà un estudi de les causes que li van portar a iniciar aquesta investigació, així com una anàlisi teòrica i pràctica de la seua obra a través del mòdul Hele, els hiperpoliedres i de les seus úniques obres construïdes basades en els seus principis teòrics: les vivendes socials experimentals de Torrejón de Ardoz i l'Ambaixada Espanyola a Brasília.

Rafael Leoz, industrialització, mòdul Hele, hiperpoliedres, vivenda social

List of contents

1. Introduction

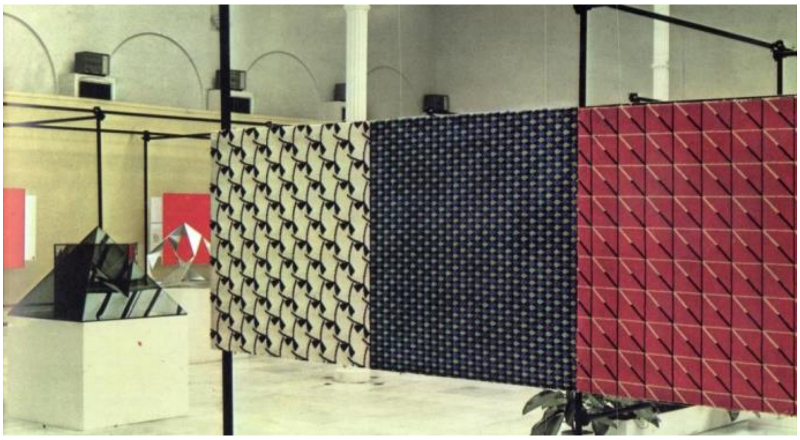


Figure 1. Exhibition at the Velázquez Palace in Madrid's Retiro Park (1978)

Figure 2. Exhibition about Rafael Leoz (UPV)

Background and current status of the topic

Numerous studies and publications have explored the work of Rafael Leoz, both in terms of its theoretical impact and its practical applications. The academic literature on Leoz has been diverse, ranging from detailed analyses of his geometric theories to studies of his built projects. Of particular note is the biography by Luis Moya Blanco – who presented Leoz as *"a scientific researcher who could not forget his condition as an architect. As a scientist he sought an ordering of abstract space, and as an architect he tried to find the order of space"*[1]– which provides a better understanding of the figure of Rafael Leoz and the reasons why he began his research work. Also relevant is the publication *Los dibujos de Rafael Leoz sobre vivienda social*[2] (Rafael Leoz's drawings on social housing) where all his sketches are shown, which help to better understand his proposals.

In the first years after his death, several exhibitions were organised to continue disseminating his ideas so that they would not fall into oblivion; however, with the disappearance of his Foundation in 1993, this was inevitable. Of all the exhibitions held, the one at the Velázquez Palace in Madrid's Retiro Park in 1978 (Figure 1), organised by the Ministry of Culture and inaugurated by the king Juan Carlos I, with the participation of such important architects as José Antonio Coderch and Jean Prouvé, is particularly noteworthy.

In recent years, several authors have sought to praise the work of Rafael Leoz, including the exhibition that was organised in this school in December 2021, showing a selection of the 440 existing documents on his research process (Figure 2).

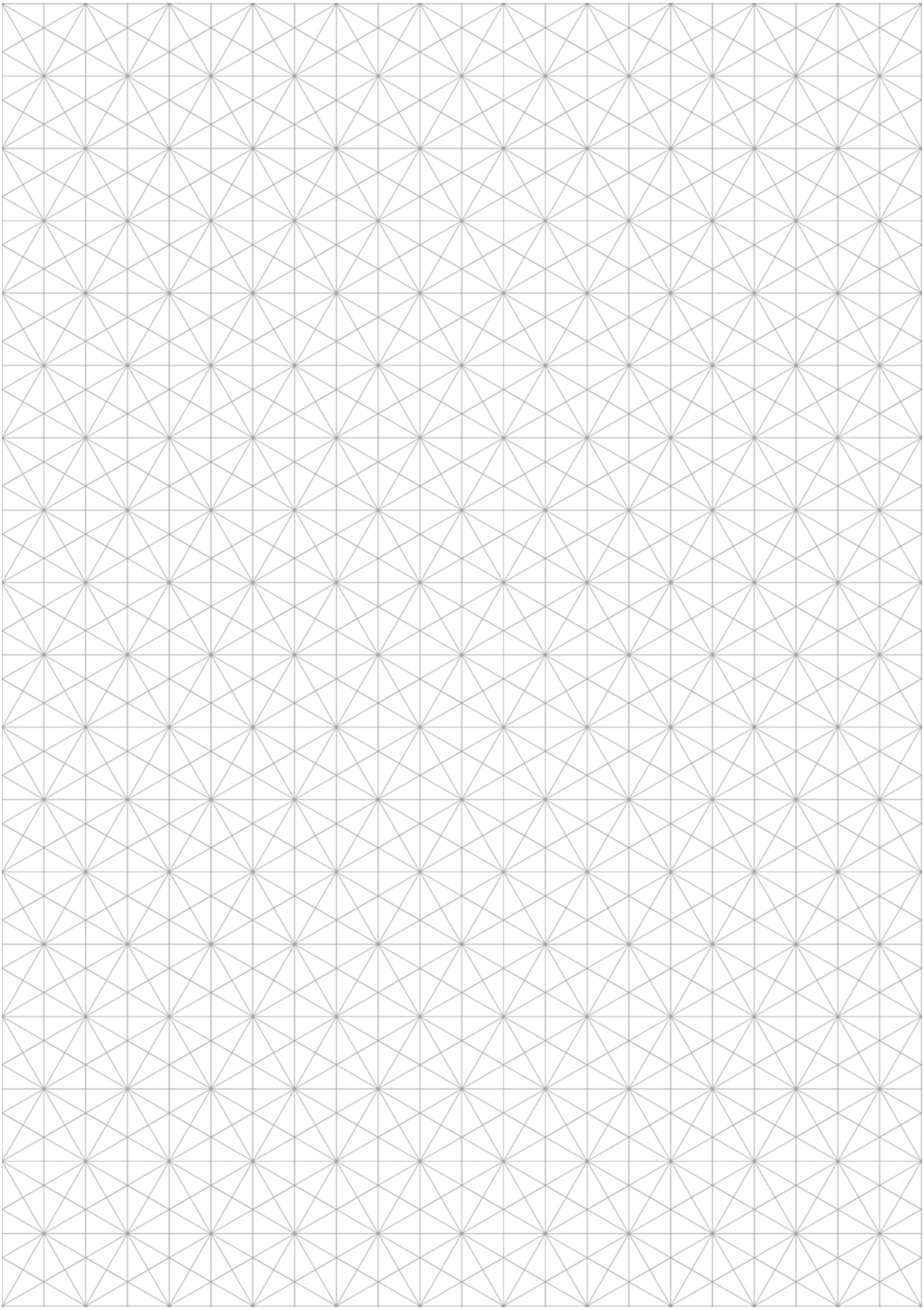
Today, Rafael Leoz's work remains highly relevant. His modular design principles and focus on sustainability resonate with contemporary trends in architecture, where adaptability and minimising environmental impact are key priorities. In the field of social housing the architect's principles also remain notable, as his modular approach allows for the rapid and economical construction of housing, crucial in a context where the demand for affordable housing continues to grow.

Objectives

The aim of this project is to analyse and contribute to the study of Rafael Leoz's work, an architect with a great social conscience who decided to abandon his labour as an architect to devote himself to research in the field of architecture. He also had a great international recognition, which was not matched by the recognition of his theories by the vast majority of the profession in a very artisanal Spain, where the idea of industry was new, which explains the existing vacuum on the work and thought of Leoz.

[1] (Moya Blanco, 1978), p.25

[2] (Ruiz Suaña & López Díaz, Los dibujos de Rafael Leoz sobre vivienda social, 2021)



2. Theoretical framework

Figure 3. Weissenhof Siedlung

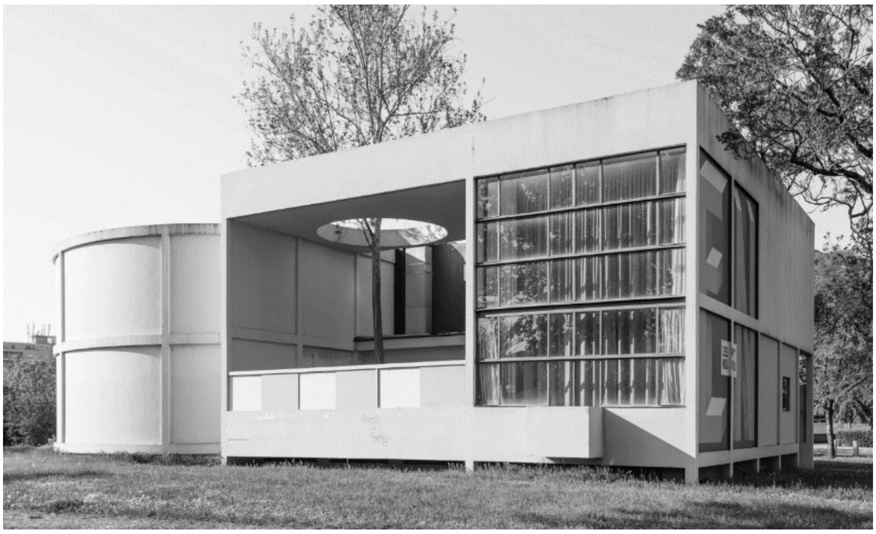


Figure 4. L'Esprit Nouveau pavilion

Theoretical framework

In order to begin to study the figure of Rafael Leoz and all his work, both theoretical and practical, we must first understand what is meant by *"harmonious systematisation of architectural space"*, as this is the idea on which all his research is based.

The *"systematisation of space"* in architecture involves the search for general laws that organise and structure the components of any architectural design. This organisation is based on geometrical and mathematical principles, allowing for an orderly and coherent arrangement of spatial elements.

The term *"harmonious"* adds a crucial dimension to this idea, as it suggests that architecture, as well as being functional, must preserve its essence as beautiful art. This means that, while looking for rules and patterns to organise space, the end result must be aesthetically pleasing and visually coherent.

The main objective of the systematisation of space is the industrialisation of construction, an idea pursued by several architects before Rafael Leoz formulated his own theories and practices in this field. Among them, the following are worth mentioning:

1. Deutsche Werkbund

Hermann Muthesius was the founder, who thought that art and industry should be linked, as industry was moving towards a strong development of industry, so that progress and improvement of architectural quality would come about by combining industry and art. He also believed that industrialisation would lower costs and make housing more affordable.

Prominent members of this movement included Henry Van de Velde, Bruno Taut and Walter Gropius. The first of these had a slightly different view from that of Muthesius, as he considered that it was industry that should follow the artist, and this discrepancy generated certain tensions in the movement. Gropius, however, was in complete agreement with Muthesius, and believed that it was the artist who should be trained by industry in order to improve the quality of the products.

In 1927 an exhibition was held in Stuttgart, organised by Mies Van der Rohe and in which architects such as Le Corbusier, Behrens, Gropius and Taut collaborated. An exhibition quarter was built there –the Weissenhof Siedlung quarter (Figure 3)– which was intended to show a series of dwellings adapted to modernity, a model of social houses that could be built from industry.

2. Le Corbusier

He was a figure who, in addition to influencing Leoz's thinking, would have great relevance during his years of research, as he would be one of his greatest supporters in the profession. We can see how Le Corbusier shared ideas with Rafael Leoz, such as that architecture should approach engineering without renouncing emotion or that geometry would be the solution to the problems of architecture, he spoke of abstraction and composition through simple forms until reaching something complex.

Le Corbusier published Towards a New Architecture in 1923, in which he spoke of the "serial maisons" and the social revolution fostered by the new architecture based on industry.

In 1925 he created L'Esprit Nouveau pavilion for the *Exposition des Arts Décoratifs* in Paris (Figure 4). It was a full-scale model of a new way of living, in which the architect sought to demonstrate that the industrialisation of construction through standardised elements was compatible with art, making use of materials such as reinforced concrete and steel –considered unworthy at the time by some of the masters of architecture–.

3. Jean Prouvé

He saw architecture as a combination of engineering, design and handicraft. He began his professional career as a blacksmith. This skill, combined with his architectural vision, enabled him to create innovative and functional structures using industrial materials and techniques. In 1929 he was invited by Le Corbusier to join the *Union des Artistes Modernes*, a group of mostly French architects, decorators and designers.

He succeeded in bringing about the prefabrication and standardisation of architecture with several projects such as the *Maison des Jours Meilleurs* in 1956 (Figure 5), a prefabricated house designed to address the housing crisis in France after the Second World War. This house was affordable and could be built in a single day, demonstrating the feasibility of prefabrication in solving urgent social problems.

4. Case Study Houses

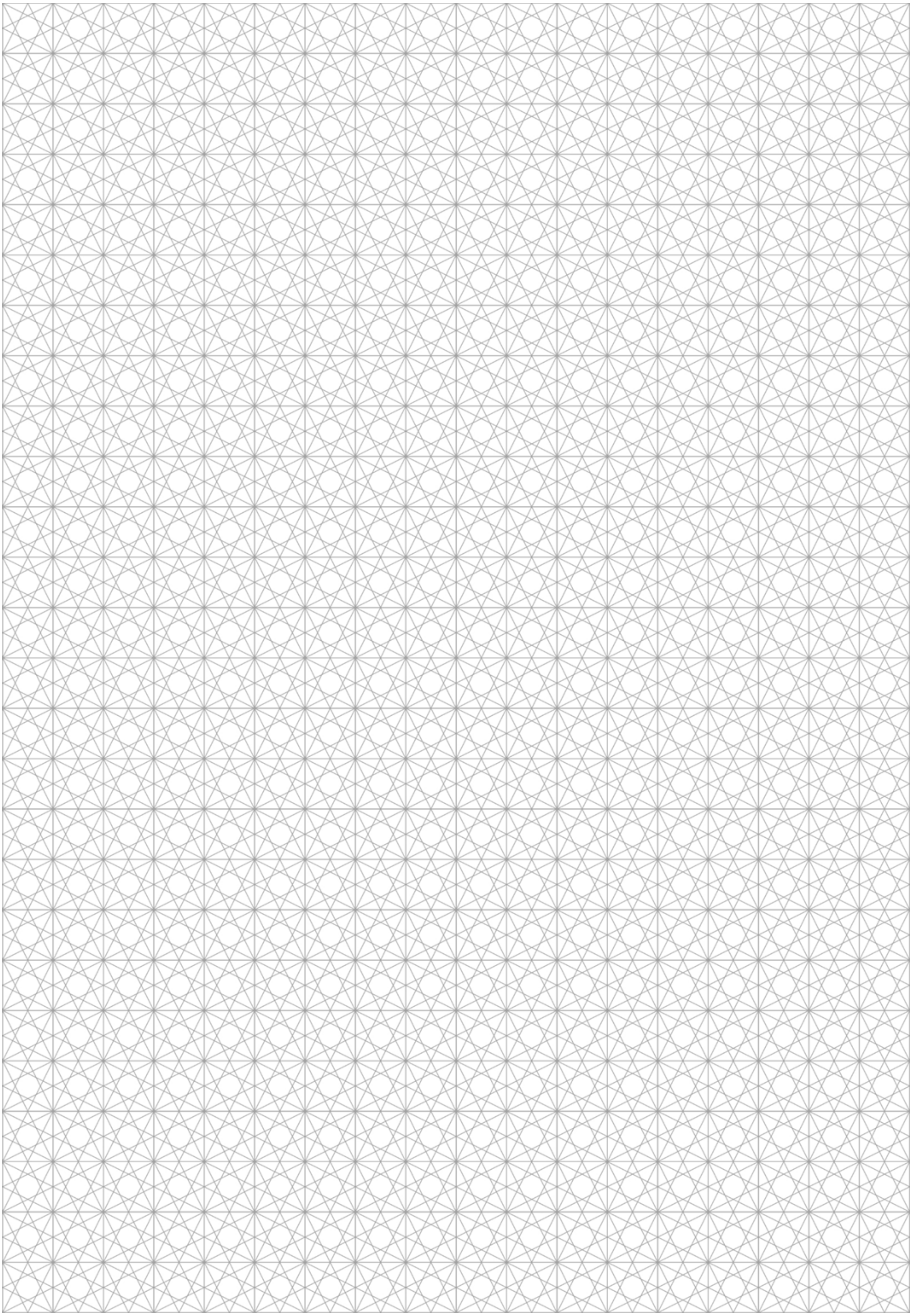
It was a programme that sought to design and build housing quickly and efficiently. It was created in 1945 by John Entenza, editor of *Arts & Architecture* magazine, who invited several architects to participate in it.

These dwellings came about due to the boom in residential demand in the United States after the Second World War and the return of millions of soldiers. The programme sought to bring this need for housing closer to modern architecture through technology. The architects who designed these projects –among them Pierre Koenig, Eero Saarinen and Raphael Soriano– explored new construction techniques and industrialised materials, applying principles of standardisation such as the use of steel structures, prefabricated panels and modular systems, in pursuit of greater efficiency in construction and greater accessibility for buyers. However, this last objective was not achieved, as they ended up being affordable for a minority.

The programme included a total of 36 dwellings that were designed and built between 1945 and 1966, most of them located in Los Angeles. The programme ended shortly after Entenza left the magazine in 1962, a decision prompted by the fact that the houses ended up being sold as consumer objects instead of becoming a mass-replicable prototype, which was the main objective.

Figure 5. Maison des Jours Meilleurs

Figure 6. Case Study House 21



3. Rafael Leoz

Figure 7. Rafael Leoz

Figure 8. Shanty town in Arroyo del Abroñigal (currently M-30)

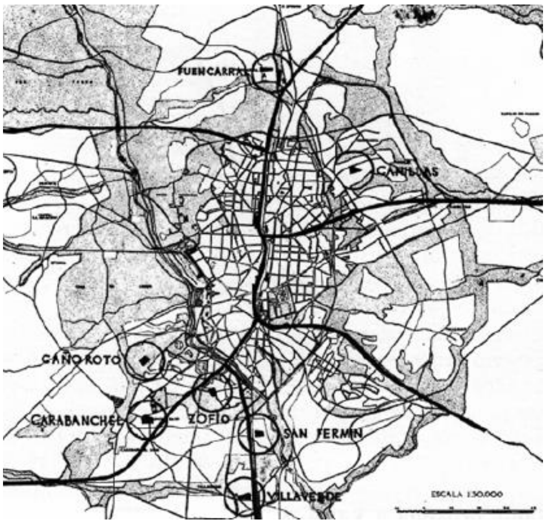


Figure 9. Location map of the first eight absorption settlements

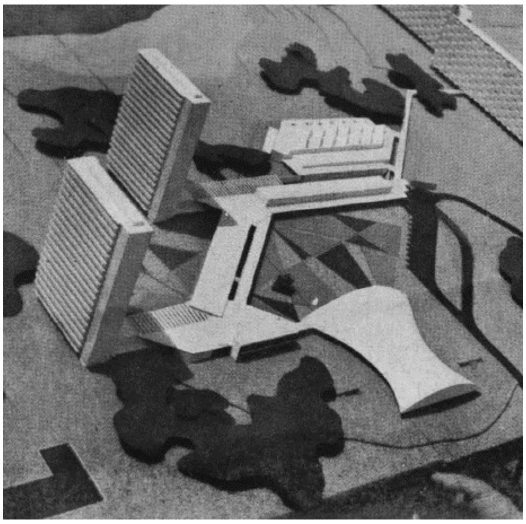


Figure 10. Workers residence in Mallorca

Biographical approach

Rafael Leoz de la Fuente was born in Madrid in 1921, and died at the age of 55 in 1975 of cirrhosis, caused by a virus he contracted on a housing project in Africa. From a distinguished family, he was the son of the renowned ophthalmologist Galo Leoz Ortín –a disciple of Santiago Ramón y Cajal–. The influence of his father, who published important results in the field of research, probably had a significant impact on Rafael Leoz's professional orientation and may partly explain why he decided to leave the traditional practice of architecture to devote himself to research.

He began his university studies in the exact sciences, which explains his knowledge of geometry and mathematics, which would be seen in his later research. However, although he felt a great passion for this career, he abandoned it to study architecture, graduating in 1955 from the *Escuela Técnica Superior de Arquitectura de Madrid* (Higher Technical School of Architecture of Madrid).

Context of Rafael Leoz's work[3]

From the mid-1940s onwards, the large cities –Madrid, Barcelona, Valencia and Seville– received a large number of emigrants from the countryside in search of new opportunities, due to the development of industry that was beginning to emerge in the country, which increased the problem of lack of housing that had been a concern since the end of the war, three years in which Spain had been destroyed and after which most of the buildings constructed were destined for civil servants or the military.

It was not until 1949 that an attempt was made to find a solution to the problem in order to deal with the scant activity carried out by the official bodies –National Housing Institute and Home Trade Union Organisation– which were responsible for the construction of subsidised housing. It was the architects of the time, at the 5th National Assembly of Architects, who realised how necessary it was to reflect on housing, specifically social housing. That same year, the Institute led by Eduardo Torroja called an international competition to build 50,000 homes in Spain, with a single condition: that they be built using prefabrication systems –the International Competition for the Industrialisation of Housing–. However, *"the government was opposed as it considered that industrialisation would reduce jobs, which would mean an increase in the number of unemployed in Spain, which was already quite high, which would worsen the situation at that time"*[4].

In 1954, the Home Trade Union Organisation organised a competition that failed to find a solution to the serious housing problem that existed in the big cities, as the people who came to the capital cities found themselves without housing and settled on the outskirts of these, forming settlements with minimal sanitary and hygienic conditions. Following this situation, the state finally intervened with the aim of promoting the construction of housing for the poorest classes. In an attempt to resolve this issue, Julián Laguna was appointed in 1954 as head of the Madrid Urban Planning Police Station.

Laguna organised a closed competition in which he invited a group of young architects to participate, including Oiza, Laorga, Sota and even Coderch. It can be said that 1954 was a turning point for social housing in the country because, from this point onwards, the team formed by Laguna began to work in a totally different way to what the architects of the Trade Union Organisation had been doing.

A year later, in 1955, Luis Valero Bermejo –managing director of the National Housing Institution– approved the second "National Housing Plan" to be developed in Madrid, which foresaw the construction of 550,000 houses in a period of five years. Thanks to this plan, Laguna carried out a settlement policy in which four stages were considered:

1. Absorption settlements: intended to absorb the population of dwellings in poor condition. This first phase was intended to allow the construction of ring roads and to complete the accesses to the capital.

2. Targeted settlements: to receive all migration.

3. New urban centres: completed with all urban services.

4. Complete neighbourhoods: an evolution of the previous ones. They were launched one per year.

This policy allowed the beginning of the creation of settlements around the city of Madrid to clean up the periphery and facilitate the expansion of the city. However, this proposal was never completed, only the first two stages were carried out and the absorption settlements, which were initially provisional, ended up remaining in time.

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[3] Information taken from (Sambricio, La vivienda española en los años 50, 2000) and (Esteban Maluenda, 1999)

[4] (Sambricio, Cuando la vanguardia arquitectónica fue construcción, 2012)

Rafael Leoz and social housing

Rafael Leoz began his professional life as an architect in 1955 forming, with his classmates José Luis Iñiguez de Onzoño, Antonio Vázquez de Castro and Joaquín Ruiz Hervás –Grupo 122–, which would last five years. They focused on social housing projects –such as the one they carried out in 1956 for a workers residence in Mallorca (Figure 10)–, and their last project together would be the construction of the Targeted Settlements of Caño Roto and Orcasitas. Due to the heavy workload, the four architects separated into two groups: Onzoño and Castro worked on Caño Roto while Leoz and Hervás worked on Orcasitas.

This project (Figure 11) was very important in Leoz's career, as it was there that he realised that the process of building social housing did not meet the expectations required for all the existing demand. The main reason for this was that production was still handcrafted, without taking into account scientific advances and the contributions of the Industrial Revolution.

Making so many repeated elements by hand did not make sense to Leoz, especially considering that the work was done outdoors, exposed to the weather. Due to the rush to build houses while demand continued to grow, the result was unsatisfactory in most cases: *"pavements were not well levelled, doors and windows did not close properly, plumbing was not well executed and there were leaks in the roofs. But this was not all, as the real defects were to be found in the foundations and the structure, with settlements that caused cracks and collapses"* [5]. All this led to the demolition of Orcasitas.

This whole process of building the Targeted Settlement of Orcasitas led Leoz –in 1960– to take the decision to leave his professional studio to begin research into social architecture on the industrialisation of housing, as he himself wrote in his book *Redes y ritmos espaciales* (Spatial networks and rhythms): *"During that period I became convinced that something was wrong in architecture and in the construction techniques that we had to use at that time. I was sure that there had to be other ways and other different and more effective solutions. And it was with this intimate and great concern that I continued to work in my professional life, now completely on my own"*.[6]

Research period in Rafael Leoz

When Leoz decided to devote himself to research, he focused on social architecture, with the aim of developing *"laws of harmony which have their roots in classicism and which, through mathematical invariants, open up unlimited horizons in the future of architecture as a beautiful art"* [7], so that these laws would allow him to understand the structure of architectural space in order to create architectural "molecules" that could be executed industrially. These laws would enable him to understand the structure of architectural space in order to create architectural "molecules" that could be executed industrially.

The Orcasitas experience led him to begin a reflection on architecture which he shared in a text entitled *¿Vamos por buen camino?* (Are we on the right track?) (Figure 12) in which Leoz criticised the backwardness of the profession by comparing it with *"other branches of knowledge and the work of contemporary man"* such as *"aeronautics, astronautics, the automobile industry, electronics, surgery, the naval industry, and cinematography"*. In his analysis of the causes of this delay, he highlighted the obsession of architects with *"originality to the extreme"* with *"contempt for everything that others have done"*. The *"sincerity and honesty of the great epochs"* of architectural history had been lost in the constant search for originality[8].

According to Leoz, it was unthinkable that houses should continue to be made "by hand" and with imperfections, which led to leaky roofs when this defect did not exist in aeroplanes or cars. For Leoz, the solution to the backwardness of architecture was to improve the technique, which meant going into industrialisation.

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[5] (Moya Blanco, 1978), p.12

[6] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.21

[7] (López Díaz, El módulo HELE de Rafael Leoz. Una historia de contradicciones: del éxito internacional a la difícil relación con la arquitectura española, 2015), p.38

[8] Quotations from the paragraph taken from (Leoz de la Fuente, ¿Vamos por buen camino?, 1960)

Figure 11. Targeted settlement of Orcasitas

Figure 12. Article written by Rafael Leoz: *¿Vamos por buen camino?* (Are we on the right track?)

His research consisted of three stages:

1. Pure research or study of the organisation of space. It was not possible for the construction to be industrial without an organisation of the architectural space, which is why Leoz began his research without giving measurements to the modules and dedicated himself to studying what would be the best organisation of the abstract space. Leoz's mathematical training was of great help to him in this first stage.

2. Applied research or metric determination of the spatial network. Having found the systems that would order the different spaces, it was time to measure these modules. In this phase, Leoz also carried out sociological studies of domestic behaviour to determine the most appropriate functional combinations, defining four types of units: living, work, rest and service.

3. Product research or material realisation in collaboration with industry. This last stage was aimed at manufacturing, and was completed by a gradual evolution of experimentation: first with traditional methods, then with industrialised methods and existing techniques, and finally with new techniques.

In the first stage it sought the ideal arrangement of space to meet the needs of man, as in many countries attempts were made at industrialisation resulting in serial prefabrication which produced monotonous dwellings. Several international meetings were held in Europe in order to find a solution to the problem, which resulted in the implementation of two options: closed prefabrication and open prefabrication.

The last one –which Leoz favoured– consisted of making single elements that could be combined in many different ways, but the "law" that was to govern the different combinations was missing.

The research that Leoz proposed led to the "harmonious systematisation of architectural space towards industrialisation"[9] thanks to the spatial networks and rhythms developed through the study of pure geometry.

At a meeting of architects in San Sebastian in October 1960, Rafael Leoz showed Coderch his work on modular coordination, showing him photographs of his models and research. Coderch told him to send these works to Jean Prouvé, a French engineer who was developing industrialisation work in construction, and he did so. The French builder was very interested in Leoz's theories and from that moment on they became great friends. As Leoz explained in his book *Redes y ritmos espaciales* (Spatial networks and rhythms), *"I met Prouvé and since then he has been the person who has helped me best, taking charge of ideas and circumstances"*[10]. In fact, because of the strong bond they created, Jean Prouvé organised a meeting between Leoz and Le Corbusier in 1962. The theory of the "Division and organisation of architectural space" that he showed Le Corbusier must have surprised him so much that he organised an event to present these theories at a conference for the French architects who made up the Cercle d'Études Architecturales – until then the only Spanish invited had been Eduardo Torroja–.

In 1961 he presented his work on the "Division and Organisation of Architectural Space" at the VI São Paulo Biennial and was awarded a Special Honourable Mention, despite the fact that it was stipulated that only completed works could be presented and that his were only theories.

Between 1965 and 1976 Leoz lived travelling abroad, winning important prizes and mentions –in Spain, Europe and America–, giving lectures at very important schools of architecture –the Polytechnic Institute of Zurich, the National School of Architecture and Visual Arts in Brussels, Columbia University in New York, etc.– and fighting to get the backing of Franco's government for the foundation of his research institute: the "International Institute of Architectural Research" –based in Madrid– which would be responsible for *"investigating architecture from the highest points of view, that is, philosophically, mathematically and aesthetically, taking into account mainly the social, economic and psychological projections that the results may have on man as an individual and on man as a society"*[11] and which would continue with his research after his death.

Despite his great success abroad, Leoz decided to stay in Spain to work, but his letters show his regret at having made this decision, rejecting José Luis Sert's offer from the United States and those of a group of Swiss industrialists he received through Jean Prouvé, who proposed to develop the prototypes proposed in his theories. Prouvé said: *"It is a pity that Leoz has not yet found the industrial and financial support to put his theories into practice. He would have found it here by now"*[12]. The aim of this message was to persuade the Spanish authorities to persuade Leoz to set up the research institute he was so keen on, which would finally see the light of day in 1969

[9] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.43

[10] (Leoz de la Fuente, División y organización del espacio arquitectónico: Módulo HELE, 1966), p.26

[11] (Leoz de la Fuente, División y organización del espacio arquitectónico: Módulo HELE, 1966), p.26

[12] (López, 2012), p.60

under the name “Fundación Rafael Leoz para la Investigación y Promoción de la Arquitectura Social” (Rafael Leoz Foundation for the Research and Promotion of Social Architecture).

But it was not only Jean Prouvé who praised Rafael Leoz, but also other architects such as George Candilis: *“With the theories of our Spanish colleague, any good contemporary architecture can be reproduced and industrialised economically”*[13] or Mies van der Rohe: *“Seeing what Spain is presenting at the* São *Paulo Biennial, specifically the new module by Mr Leoz, I think that Spanish architecture is the most honest, balanced and sincere at the moment. It can set a whole new standard”* [14].

However, all the admiration he received internationally had nothing to do with the opinions of his colleagues in Spain, who said they were just abstract theories. Leoz was aware that his colleagues did not understand his thinking, so he organised a talk at the Madrid College of Architects to explain his ideas on the “Division and organisation of architectural space”, receiving criticism from architects such as Oiza and Fisac, focusing above all on the fact that it was impossible to make architecture with a single volumetric module as Leoz proposed: *“I consider architecture to be something of such a category, as an art, in general, so complex, that it cannot be simplified by means of very simple laws. It is very difficult, if not impossible, to try to build the cathedral of Burgos with a single module*”[15]. Despite the criticism, Leoz continued to defend his theories: *“This is the great controversy I have with my colleagues, who tell me that in order to compose freely they need to have infinite elements [...] That's what I say, “Don Quixote” is written with twenty-nine letters. And terrestrial creation is completely limited to little more than a hundred simple elements, which make up the periodic system”*[16]*.* Although there was also some praise, the architect Secundino Zuazo intervened saying that *“I only have to say that I admire a professional like Leoz, who has done a job that makes us all proud. We must encourage him and tell him that the profession is behind him. [...] We must encourage him in this work which, until now, has been purely sacrificial, as he has only just begun it”*[17].

Leoz decided to leave the profession after the lecture at the College of Architects, although for a couple of years he continued to teach at the Madrid School of Architecture and to collaborate occasionally with the magazine *Arquitectura* (Architecture). From that moment on, his interest was focused on his foundation.

[13] (López, 2012), p.61
[14] (Moya Blanco, 1978), p.93-94
[15] (López, 2012), p.53
[16] (López Díaz, Pensamiento, filosofía y principios arquitectónicos en la obra de Rafael Leoz: el espacio como materia prima, 2014) p.517
[17] (López, 2012), p.55

4. Theoretical analysis. *Redes y ritmos espaciales* (Spatial networks and rhythms)

Figure 13. Cover of the book *Redes y ritmos espaciales* (Spatial networks and rhythms)

Figure 14. Sustainable Development Goals (SDGs)

Pure research. *Redes y ritmos espaciales* (Spatial networks and rhythms)

"Only law can give us freedom" (Goethe)

This is how Rafael Leoz opens his book *Redes y ritmos espaciales* (Spatial networks and rhythms). Published in 1968, almost a decade after he started writing it –1960–, although the author's wish was to publish it even later: *"I believe that the bad information that exists about the true nature of these works of mine has made it prudent not to delay this publication any longer, even if it is not as complete as one would like it to be"*[18].

Justification, process and reflections

In this first part of the book, he explains his beginnings in the profession, his meetings with Prouvé and Le Corbusier mentioned above and the existing situation regarding the lack of housing to justify his research, which aims at the industrialisation of housing: *"The need for industrialisation arises because of the explosive demographic growth and the rise in living standards"*[19].

As an example of why craftsmanship should be left behind, he gives the example of transport: "*When, as a result of the industrial revolution of the 19th century, the problem of transport arose, it was not solved by building millions of carriages pulled by millions of horses, but new massive industries arose, with completely different approaches and points of view from those that had been taken until then through craftsmanship, and craftsmanship was abandoned"*[20].

To end this part, Leoz criticises architecture, saying that *"today any advanced technique is far superior in perfection to ours"*[21], and warning the architects of the time that if they are not the ones to enter the world of industry, it will be the engineers who will start to build industrialised houses *"without sensitivity and dehumanised"*.[22]

New aspects of Architecture

In this part he gives a brief introduction to his theory "A harmonious systematisation of architectural space", based on mathematics –more specifically geometry–, an aspect that Leoz considered fundamental in the training of every architect.

He also re-emphasises the fact that it is the architects who have to get ahead of the engineers when it comes to industrialising construction: *"There is a danger that architecture as a fine art will disappear if we solve our problems and those of housing without taking into account any factors other than technical and economic ones. We would end up in a dehumanised monotony"*[23].

He concludes by mentioning the three problems that need to be solved not only in the country, but in the world as a whole, which are, in order of importance, the following:

1. Health
2. Education
3. Housing

This work focuses on the third problem, as it is the one that affects him directly as an architect and about which he has the necessary knowledge to be able to propose solutions, including *"the reorganisation and modernisation of the construction industry"* and the definition of urban planning schemes.

It is surprising to see that long before the Sustainable Development Goals were implemented in 2015 by the UN (United Nations) in its Agenda 2030 in search of *"achieving a better and more sustainable future for all"*, Rafael Leoz mentioned in his work three major problems to be solved at the global level, which coincide with three of these goals of current concern, and added that in the event of failure of any of the three *"the whole society will collapse because of huge internal conflicts"*[24]:

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[18] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.15
[19] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.28
[20] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.28
[21] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.35
[22] Quotations from the paragraph taken from (Leoz de la Fuente, Redes y ritmos espaciales, 1968)
[23] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.43
[24] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.49

SDG 3. Good health and well-being

SDG 4. Quality education

SDG 11. Sustainable cities and communities

In addition to these three objectives, it is clear that the one that is most present in Leoz's work is number 9 "Industry, innovation and infrastructure", since it is around this that all his theory revolves, dedicating practically his entire career as an architect to the search for the laws to achieve the industrialisation of housing.

Spatial networks and rhythms

SPATIAL NETWORKS

It begins by defining the two types of spatial grids that exist to divide three-dimensional space:

1. Those with a single central point: it generates concentric bodies.

2. Those with infinite central points of radial symmetry: generates equal bodies.

Leoz uses the second type as it is the one that allows an easier standardisation and repetition of elements, which is what is sought for industrialisation. Within this second group, the bodies that the architect considers most interesting are those which, when joined together, leave no gaps between them. *"There are only four polyhedrons with central symmetry that have the property of solidifying the Cartesian three-dimensional space"*[25]:

1. The regular cube or hexahedron (Figure 15)

2. The right prism with regular hexagonal base (Figure 16)

3. The rhombododecahedron (Figure 17)

4. The heptaparallelohedron or Lord Kelvin's polyhedron (Figure 18)

Moving on to the study of planar grids, and analysing the square, we find that it is formed by four isosceles right triangles –also known as a square–. From this we deduce that the right triangle could be the starting point. After this analysis, Leoz found that, for his research, there were only three important right triangles:

1. The square: contains the 45º, 90º, 135º and 180º angles (Figure 19)

2. The bevel: contains the angles 30º, 60º, 90º, 120º, 150º and 180º (Figure 20)

3. The hemipitagoric triangle (one leg is half of the other): contains the angles 26º 34‘, 53º 8', 63º 26‘, 90º, 116º 34', 126º 52‘, 153º 26' and 180º (Figure 21)

It can be seen that the 90º and 180º angles are present in all three grids, Leoz concluded that the right angle and straight line are fundamental elements in composition.

When comparing the three nets obtained through these three triangles, it can be observed that the square and the bevel net are not superimposable, however, the square and the hemipitagoric triangle net are superimposable, since both produce the square. From this it could be said that the two really essential nets are the first two, and therefore the two basic elements are the square and the equilateral triangle.

Leoz highlights Lord Kelvin's polyhedron as *"an extraordinarily interesting figure formed by six squares and by eight equal hexagons"* since *"if we cut the polyhedron by flat sections parallel to the square faces and passing through the vertices, we get polygons that belong to the square grid"* and *"If we cut the polyhedron by flat sections parallel to a hexagonal face, passing through the vertices or the midpoints of the sides, we obtain regular hexagons that belong to the bevel grid"*[26].

SPATIAL RHYTHMS

Once the way of dividing up the space had been studied, the "norm" had to be sought to unite the elements. Starting from one of the basic figures, the square, Leoz proposed three rhythms, neither too simple nor too complex:

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[25] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.62

[26] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.150

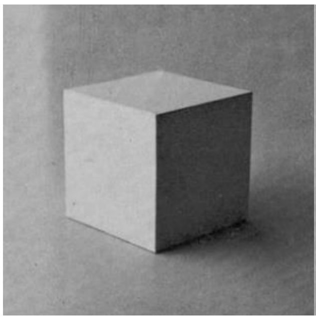

Figure 15

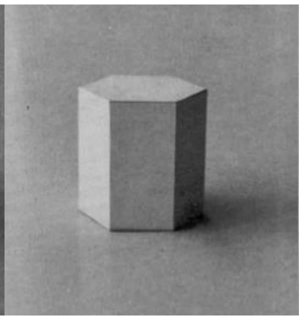

Figure 16

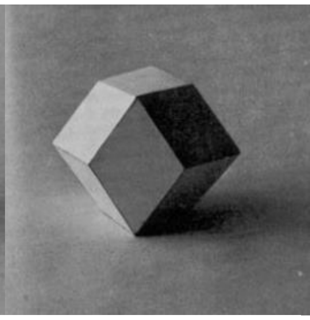

Figure 17

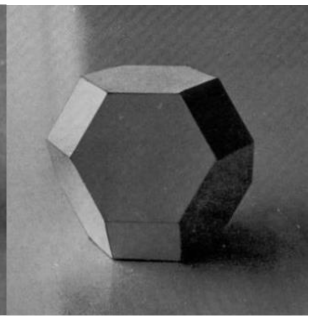

Figure 18

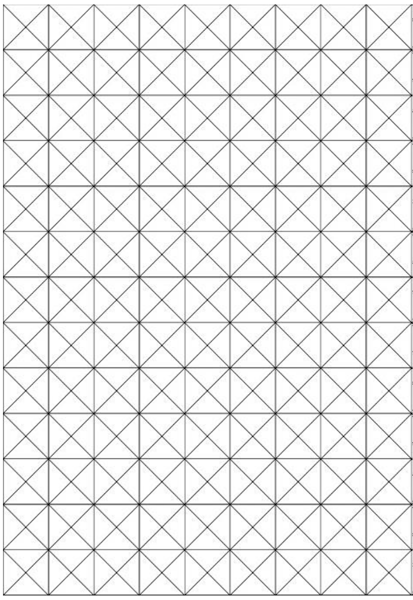

Figure 19. Square net

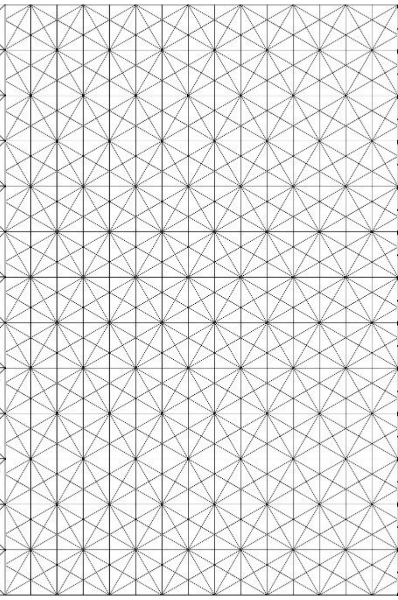

Figure 20. Bevel net

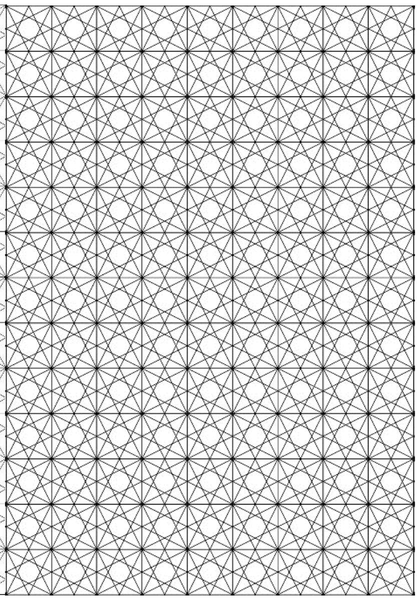

Figure 21. Hemipitagoric triangle net

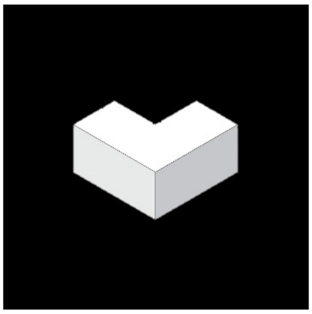

Figure 22. Symmetrical L

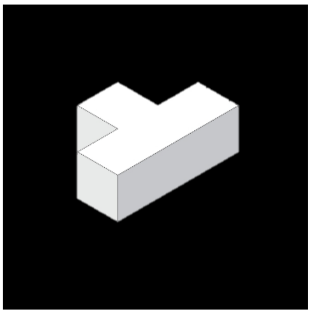

Figure 23. T

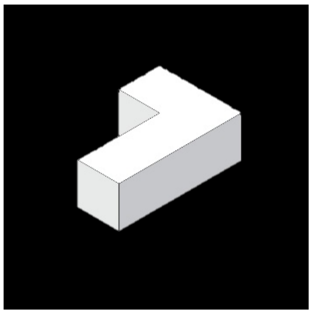

Figure 24. Asymmetrical L

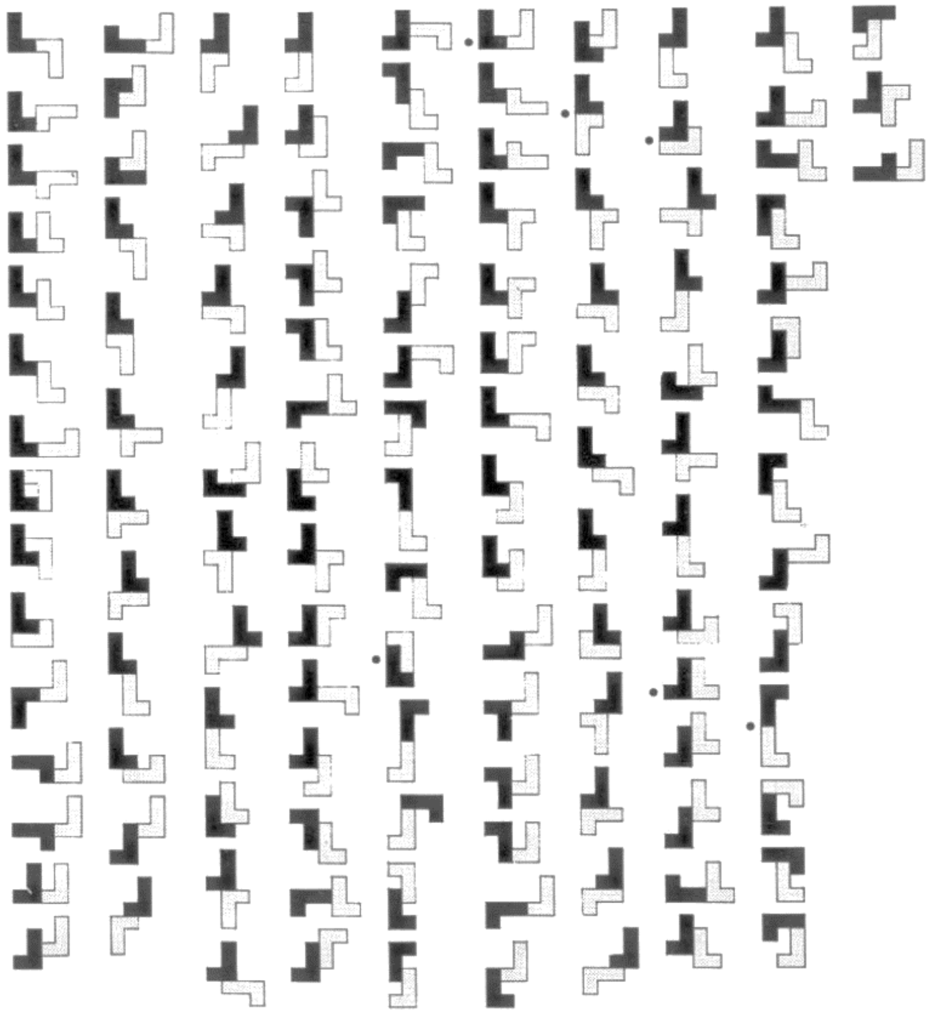

Figure 25. Combinations of the asymmetrical L

1. Symmetrical L: 3 squares (Figure 22)

2. T: 4 squares (Figure 23)

3. Asymmetrical L: 4 squares (Figure 24)

After comparing the three figures, he concluded that the one that offered the greatest advantages was the "asymmetrical L", as it was the one that required the fewest pieces to form the other two figures, itself and a square:

With 12 "symmetrical L", with 4 "T" y with 4 "asymmetrical L" a square is formed.

With 36 "symmetrical L", with 12 "T" y with 12 "asymmetrical L" a "symmetrical L" is formed.

With 12 "symmetrical L", with 16 "T" y with 4 "asymmetrical L" a "T" is formed.

With 12 "symmetrical L", with 16 "T" y with 4 "asymmetrical L" an "asymmetrical L" is formed.

It can be seen that, in order to form the same shapes, the number of pieces needed from 'L asymmetric' is much smaller compared to the other two –72 "symmetrical L", 48 "T", 24 "asymmetrical L"–. Moreover, by combining two "asymmetrical L", 123 different shapes are obtained (Figure 25), while two "T" yield half as many and two "symmetrical L" a quarter as many.

HELE module

Leoz called this rhythm, made up of three elementary units aligned and a fourth forming a 90º angle with the previous ones, the "HELE Module" (Figure 26). The name comes from joining the first two letters of Hervás and Leoz, and the fact is that when the architect began his research he did so together with his colleague Joaquín Ruiz Hervás, and they arrived at this figure in that period. However, Hervás would confess a year later to the director of the magazine *Arquitectura* (Architecture), Carlos de Miguel, that the proposal for the HELE module is exclusive to Leoz:

"In order to clear up any possible doubts, I wish to clarify that in my collaboration with Rafael Leoz de la Fuente, some works or studies have been carried out entirely by one of us, and others by the other, and most of them jointly. The study on HELE, of which an article has been published in this journal [...], both in the authorship of the idea and in its subsequent development, is due exclusively to my colleague Rafael Leoz de la Fuente"[27].

The presentation of this module was made by publishing an article in the magazine *Arquitectura* (Architecture)[28] and describing it as a *"composition system, invented by them (Hervás and Leoz) mainly for urbanisation and housing, although its usefulness extends to other fields of architecture"*. This article explained why they chose this module: *"as long as the force of gravity exists, the most economical spatial structures that work best aesthetically are reticular structures with vertical supports, and if the grid in the horizontal plane is orthogonal or a grid, so much the better"*. Although it is true that the key to his diffusion was the Honourable Mention he received at the VI São Paulo Biennial in 1961.

The interest of this module lay not only in all the possible combinations it offered or in the ease of prefabrication, as it was made up of a single element, but also in the harmony of its perimeter, as we see the Fibonacci succession (1-1-2-3). And it should be remembered that, in this process of reaching the industrialisation of housing, Leoz never abandoned the search for the beauty that for him must remain in architecture, preserving its condition of "beautiful art".

In spite of all the criticism Leoz received from his colleagues claiming that the use of a single volumetric module for architecture would result in identical and dehumanised buildings, he always defended himself by arguing that *"The personality and talent of each designer will give each work an unmistakable, personal stamp, as has always been the case with good architecture [...]. we believe we have found a simple element to construct, whose repeated repetition leads to solutions of infinite variety and great beauty; and which will be of extraordinary help to the architect in the first steps of his work"*[29].

The HELE module materialised for the first time in the construction of a demountable pavilion for Ensidesa at the *VIII Feria del Campo* in Madrid in 1970 (Figures 29, 30). The project was carried out by the company Huarte in 30 days -including 7 days of assembly- which meant a great step forward for Leoz.

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[27] (López Díaz, El módulo HELE de Rafael Leoz. Una historia de contradicciones: del éxito internacional a la difícil relación con la arquitectura española, 2015), p.40

[28] Citas del parráfo extraídas de (Leoz de la Fuente & Ruiz Hervás, Un nuevo módulo volumétrico, 1960)

[29] (Leoz de la Fuente & Ruiz Hervás, Un nuevo módulo volumétrico, 1960), p.41

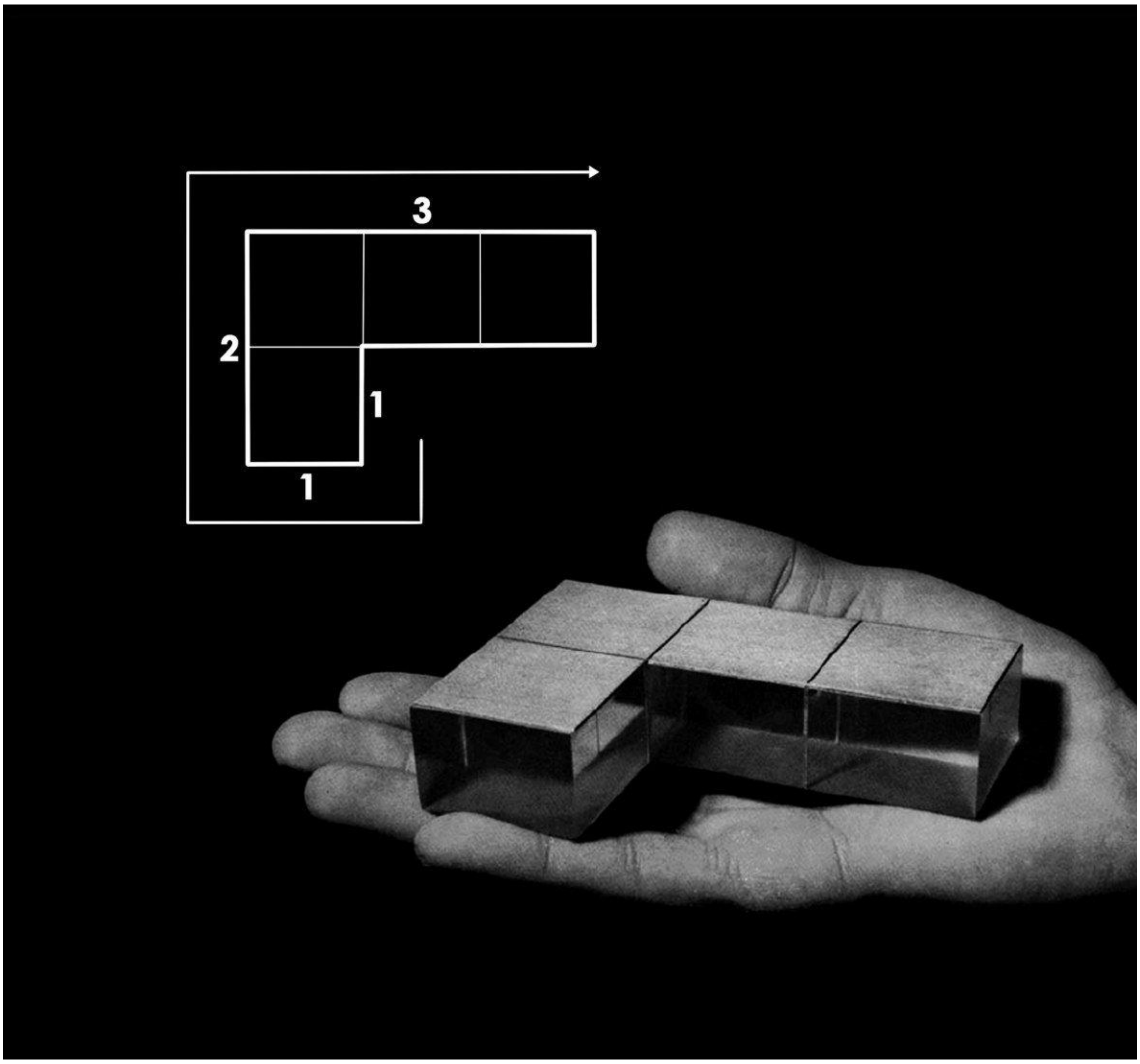

Figure 26. HELE module

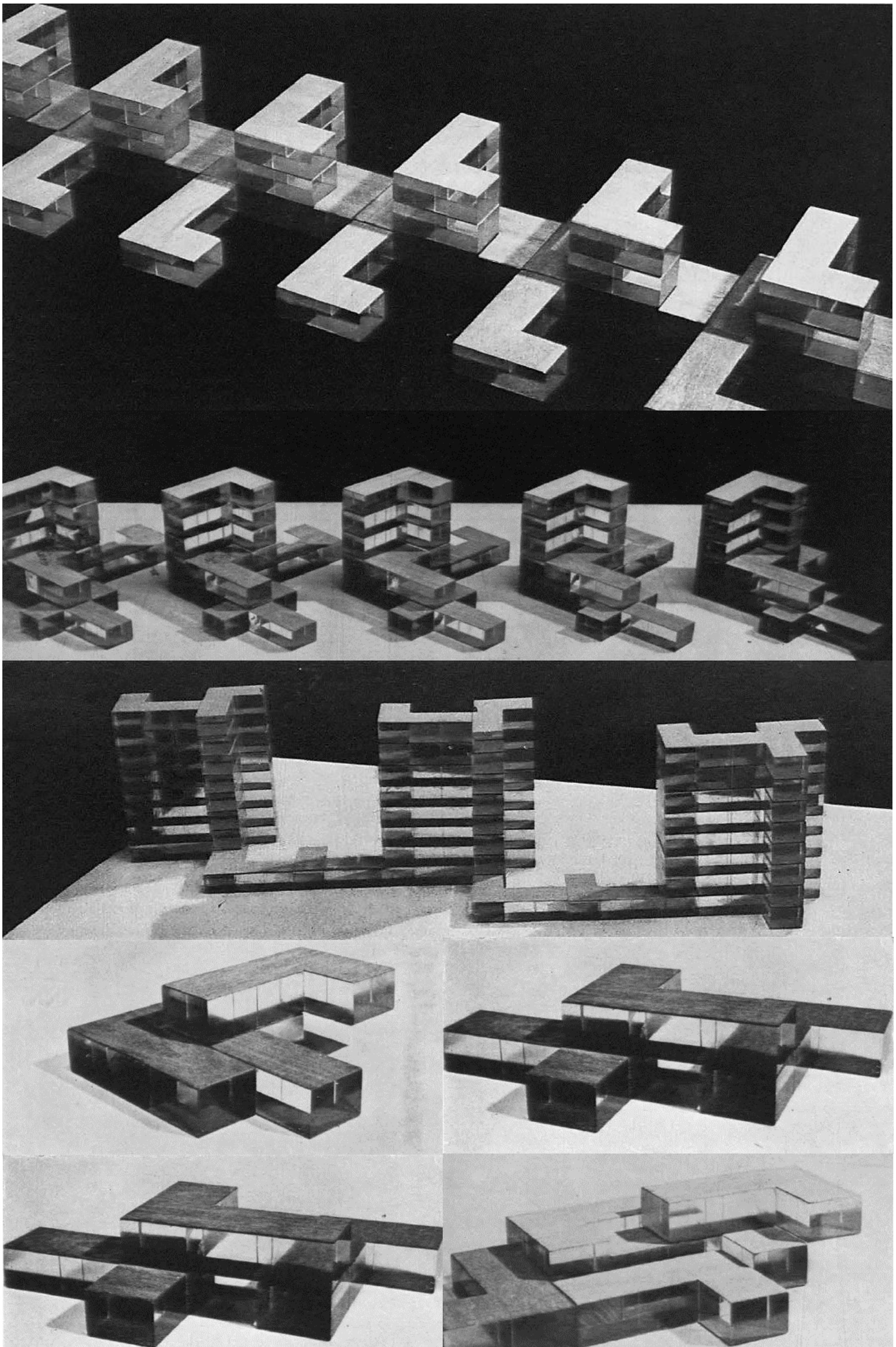

Figure 27. HELE module models

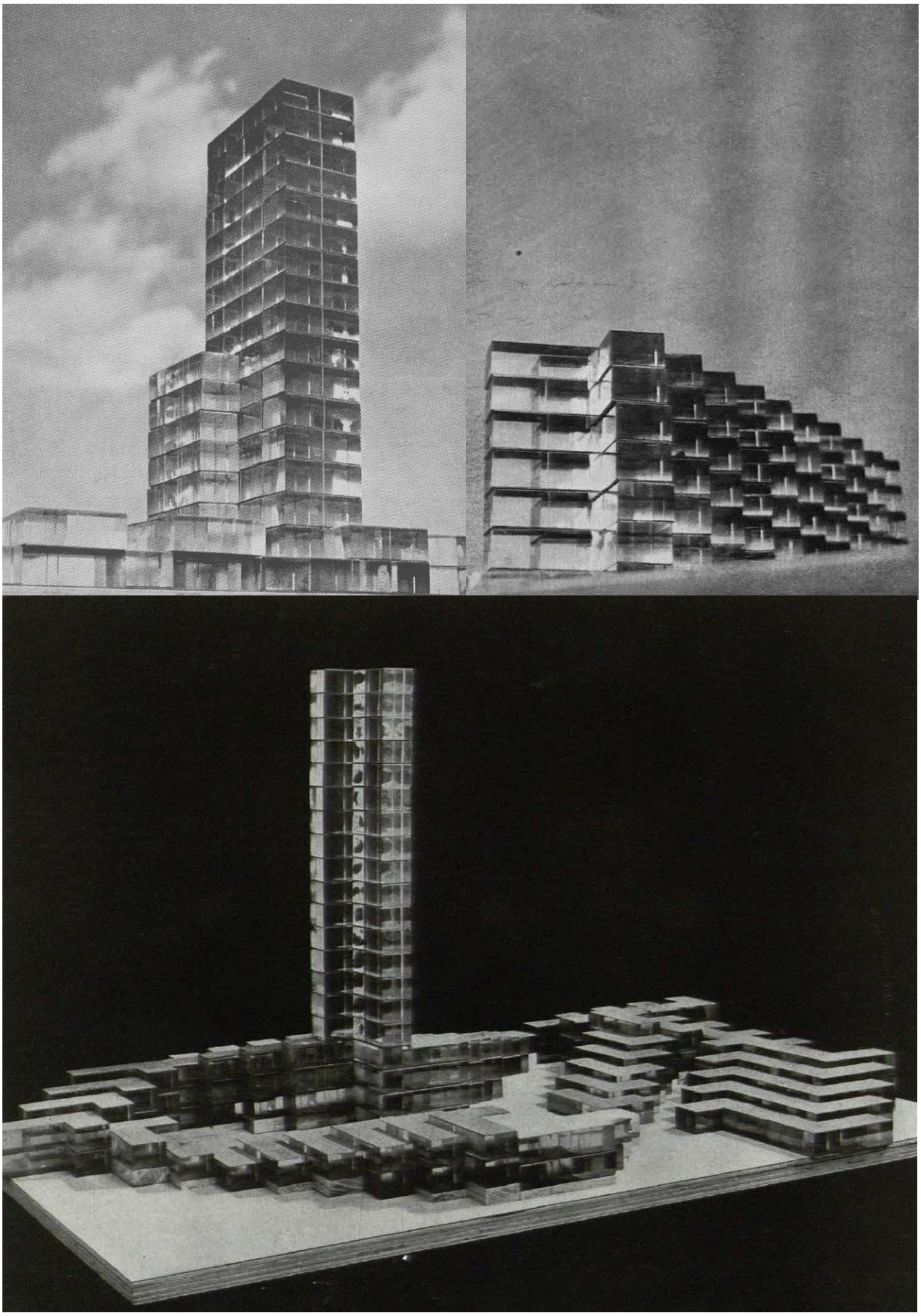

Figure 28. HELE module models

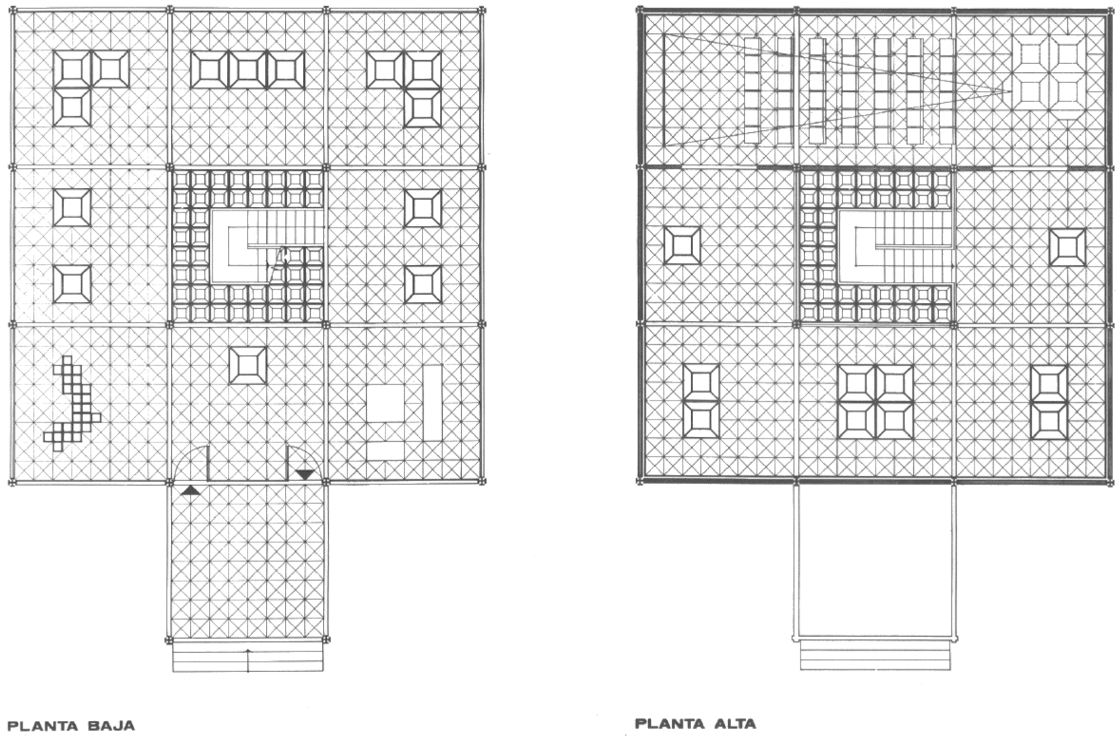

Figure 29. Plans of the demountable pavilion for Ensidesa

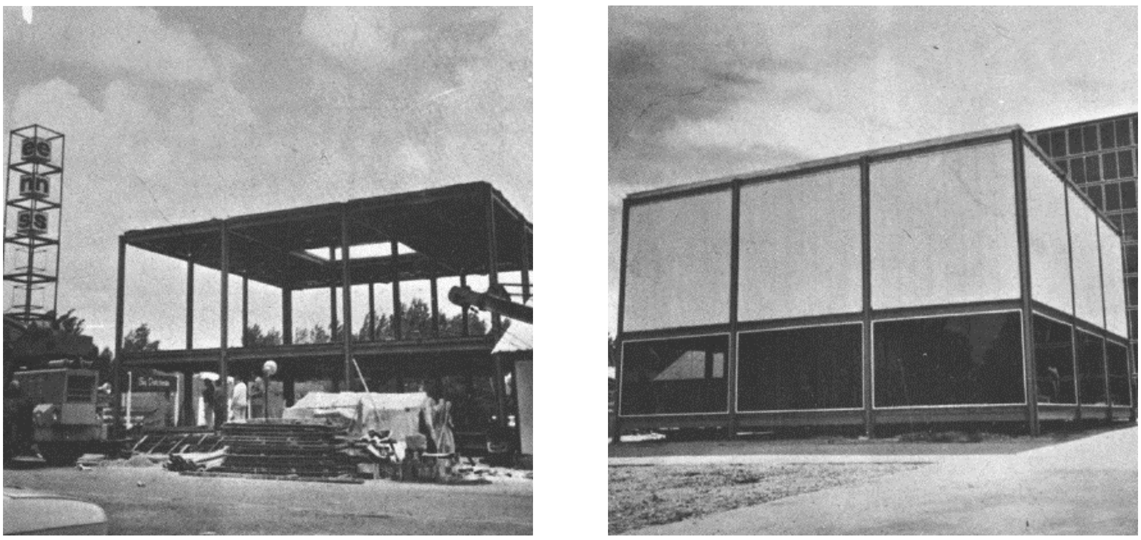

Figure 30. Photographs of the demountable pavilion for Ensidesa

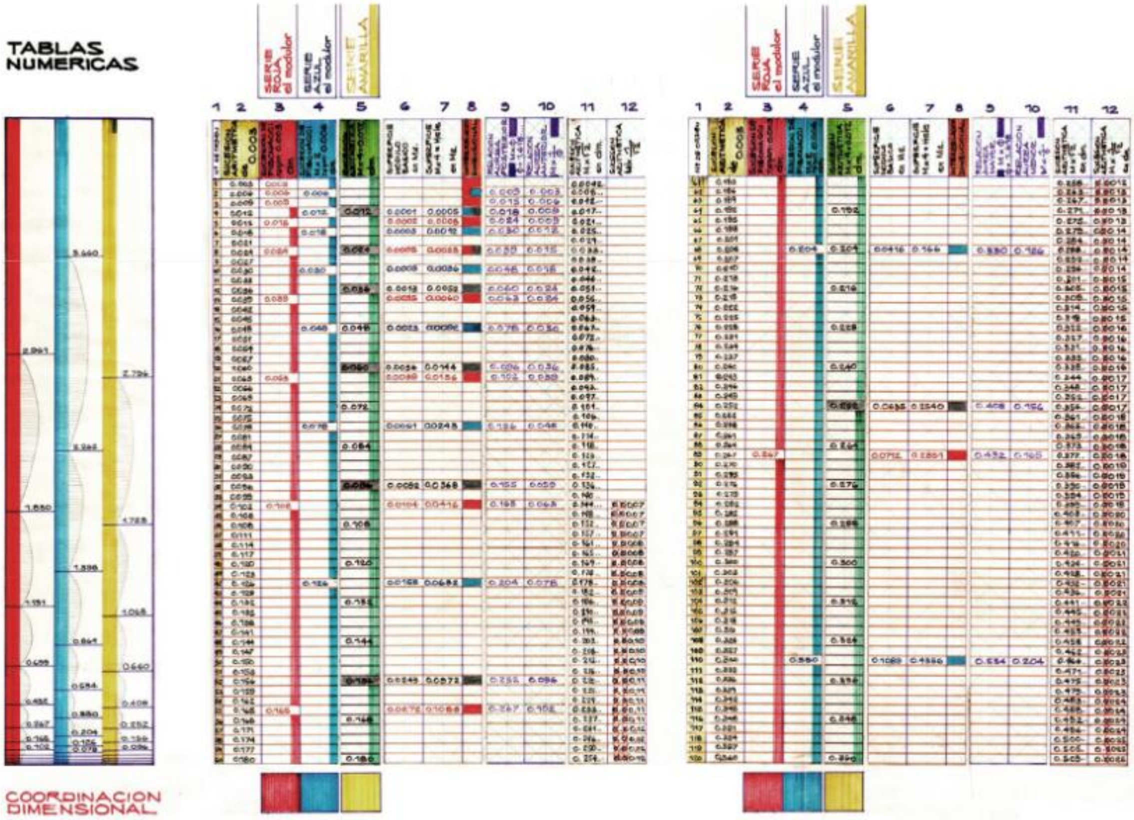

Figure 31. Table of numerical proportions

Applied research. Spatial dimensioning

Once the first phase of the research, known as "Pure research or study of the organisation of space", has been completed, after having found the networks that form the space and the optimal rhythm to achieve the greatest number of combinations with the least possible number of elements is passed on to the second phase, that of "Applied research or metric determination of the spatial network".

"In order to give the modules some dimensions, Leoz took as his starting points Le Corbusier's Modulor, the book L'humanisation de l'espace. Le système Φ by Alfred Neumann and Neufert's Industrialisation of Construction. He adds that the Fibonacci sequence starting from 12 cm and the arithmetic progression of the ratio 12 cm are also very useful, as he considers this to be a very important dimension in the field of construction"[30].

At first he tried to relate all the numerical series considered at the beginning, but he thought that there were too many and decided to reduce them to three: the series of *The Modulor* –because of its relation with human dimensions– arguing that *"it is a real milestone that marks a stage in the history of Architecture"*[31], and both the Fibonacci series and the arithmetic progression starting from 12 cm.

When comparing the three series he realises that *The Modulor* initially has no relation with the 12 cm module, however, when starting from 12 mm in the Fibonacci sequence *"'we find the surprise that each module by ½ coincides with the Blue Series and by logic it will be of the Red Series when multiplying by ¼"*[32]. Leoz calls this numerical series the *Yellow Series*.

Now all that remained was to relate these three series to the arithmetic progression of 12 mm. Initially, *The Modulor* had no relation to it, but Leoz noticed that all three had 3 mm as a common denominator, so he decided to change the arithmetic succession to one starting from 0.003 m, which would include both the Red Series (0.003 m), the Blue Series (0.006 m) and the Yellow Series (0.012 m).

The table of proportions that Leoz creates by relating the Red, Blue and Yellow Series to the arithmetic progression of 0.003 m is made up of twelve columns:

1. Order number of rows

2. Arithmetic succession of 0.003 m

3. Fibonacci sequence starting from 0.003 m (Red Series of *The Modulor*)

4. Fibonacci sequence from 0.006 m (Blue Series of *The Modulor*)

5. Fibonacci sequence starting from 0.012 m whose multiples are the modulus proposed by Rafael Leoz (Yellow Series)

6. Contains the surface of a square module corresponding to the measurement of the Yellow Series.

7. Contains the surface of the HELE module (4 squares) corresponding to the measurement of the Yellow Series.

8. Dimensional interrelationships between the three Fibonacci series.

9. Major golden ratio: the three Fibonacci series are multiplied by Φ to correctly provide any rectangular surface.

10. Minor golden ratio: multiply the three Fibonacci sequences by 1/Φ to obtain the heights of the elevations.

11 y 12. Relate the square modules to the square system.

After creating and defining this table, Leoz explains in his book how to use it when designing any project:

1. The surface area that will be necessary for each housing programme is studied according to *"three variables: the programme, the budget and the quality of the materials"*[33].

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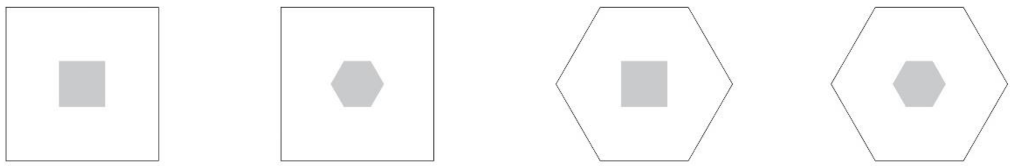
[30] (López Díaz & Ruiz Suaña, El epígono de El Modulor: La serie amarilla en las investigaciones de Rafael Leoz, 2015), p.11

[31] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.237

[32] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.238

[33] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.197



■ Registrable space
□ Habitable space

Figure 32. Hyperpolyhedra

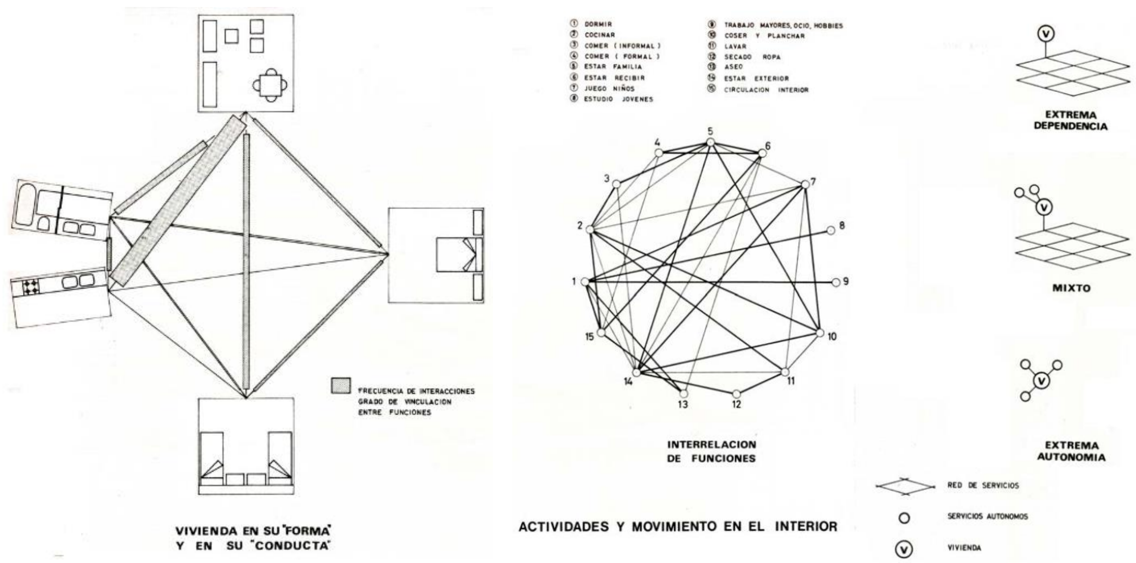


Figure 33. Intensities of use of rooms and relationships between them

2. We go to the table of proportions and from the surface area we have calculated, we look for the corresponding measurement in columns 3, 4 and 5 to obtain the dimensions of the square we are going to work with.

3. We go to column 10 to be able to dimension the elevation following a golden ratio, so that the architecture does not lose that beauty that must always be present.

4. Once the measurements of the module have been obtained, we will use one of the two basic grids.

Hyperpolyhedra

Leoz opened a new path of research, that of hyperpolyhedra (Figure 32), about which he began to write a book in 1974 that he was unable to finish due to his death in 1976, this book was to be entitled *Arquitectura molecular Hiperpoliédrica* (Hyperpolyhedral Molecular Architecture).

He wanted to differentiate between two types of spaces within a dwelling: habitable and registrable. The habitable ones were those in which life took place –where people were, where they worked, where they rested– and where comfort was needed, while the registrable ones were those where the installations necessary to guarantee that comfort could be found. In this way, Leoz came to define hyperpolyhedra as polyhedrons that enclose another polyhedron within it –reproducing its shape or not–, the space between them being the habitable one.

With these new investigations, Leoz tried to find *"a spatial law that could be considered the "dna" from which forms, rhythms, networks…"*[34].

Three years before his death the architect gave an interview to the engineer José Antonio Fernández Ordoñez talking about hyperpolyhedra:

"Lately I have come up with an interesting concept, which is that a house is a theoretically closed element that has a skin; it has a skeleton, which is the structure; it has an arterial and venous system; it has an information centre and an emission centre. Then I found that the bodies, the polyhedra, which, with the pedantry of the Spanish, I had handled exclusively until then, believing them to be fundamental, were not what was fundamental, but I found, I repeat, that what was really important were the hyperpolyhedra, which are formed by a polyhedron inside another polyhedron and an enveloping layer. So, there is a curious thing, and that is that, if you study these hyperpolyhedra, which are implosive or explosive, fantastic things appear [...] It is like a cancer, of a complexity that, individually, personally, nobody is capable of creating, nor of imagining, ever in life. You have to turn to computer science, to topology, to combinatorics, to get a glimpse of its importance"[35].

Although it was not until the last years of his life that he explored the idea of the hyperpolyhedron, in his publication Networks and spatial rhythms he already presented some sketches of the two types of spaces in a house:

"Analysing the partial forms of the building we see that there will be some that will have a "static" character and others that will have a "mechanical" character. In the latter forms we will have to organise the vertical and horizontal circulations and we will treat them as independent elements of the general structure of the building. We will do the same with the cores, where we will group together as much as possible the different installations and water, gas, etc."[36].

Product research

Leoz took some steps in the last phase of research "Product research or material realisation in collaboration with industry", but without providing a concrete solution. Thanks to the Rafael Leoz Foundation Archive, today we can see drawings made by the architect that show us his progress in this last phase, as well as several typology tests with the HELE module. In these plates we can see how Leoz carried out a study of the rooms in the dwellings, as well as their relationship with each other and their intensities of use (Figure 33), and he also studied the growth of the dwellings according to the evolution of the family itself and its needs over time. Following this analysis, Leoz defined four types of units: living, work, rest and service.

We can see in his drawings an in-depth study of the HELE module on the ground plan and the different typologies it can take up, each with its advantages and disadvantages. In each prototype he makes, he has three aspects in mind:

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[34] (López Díaz, Pensamiento, filosofía y principios arquitectónicos en la obra de Rafael Leoz: el espacio como materia prima, 2014) p.515

[35] (López Díaz, Pensamiento, filosofía y principios arquitectónicos en la obra de Rafael Leoz: el espacio como materia prima, 2014) p.516

[36] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.203

1. The possibility of growth of the dwelling itself

2. The possibility of grouping with other dwellings

3. The position of the installation cores

After having developed numerous typologies, he comes to the conclusion that there are four basic schemes, in each of which the position of the service core varies (Figure 34), which will offer different advantages in each case. Leoz determines that the one that offers the most advantages is the one that locates the wet areas in the middle square –of the three that are aligned–, since when they are placed at the ends the bathroom is too far away from the night area.

In these drawings he already applies dimensions to the module, and it can be seen that he uses the measurements obtained in the Yellow Series of the "Numerical Tables of Proportions" –module of 4.8 metres–.

Having studied the different layouts that the HELE module allowed, Leoz went on to design possible groupings of dwellings –from one-storey units to towers of more than ten–, as well as their façades, providing different elevations for each room of the house according to its level of privacy.

Leoz also developed perspectives of groupings and blocks of flats with which he intends to demonstrate that it is possible to build pleasant urban environments starting from a single module: *"Here we have potentially a gigantic step forward with enormous consequences for the future harmonious systematisation of the industrialisation of Architecture. To be able to combine very few different elements that can be industrialised, through a perfectly systematised combination that leads to a practically infinite repertoire of extraordinarily harmonious final forms. It is a great achievement towards the solution of the almost insoluble problem that monotony and dehumanisation were in the industrialisation of architectural construction"*[37].

Finally, these sheets propose different methods of assembly –describing the size of the pieces, their packaging and their transport–, as Leoz began to work with some industries *"At the moment we are studying, in collaboration with the iron and steel, glass, aluminium and plastics industries, and through the different techniques of concrete, all the aspects of practical implementation to achieve a process of maximum industrialisation, both in the production of the different parts and in their assembly on site"*[38]. He establishes three basic types for the cutting of each cell (A, B, C) and each of them has three different solutions (Figure 35). In all of them, he clarifies that the junction point of four pillars –where there will be a void– will be used either to increase the resistance or to introduce the downpipes of the installations and ducts.

In addition to developing the whole assembly process, he also thought about how the different prototypes would be named, as follows (Figure 36):

1. Number of cells to be built.

2. Letter of the spatial grid used: E (square), C (bevel) or H (hemipitagoric)

3. Number of variant: in case there are different typologies within the same project.

[37] (Ruiz Suaña & López Díaz, Los dibujos de Rafael Leoz sobre vivienda social, 2021), p.893-894

[38] (Leoz de la Fuente, Redes y ritmos espaciales, 1968), p.246

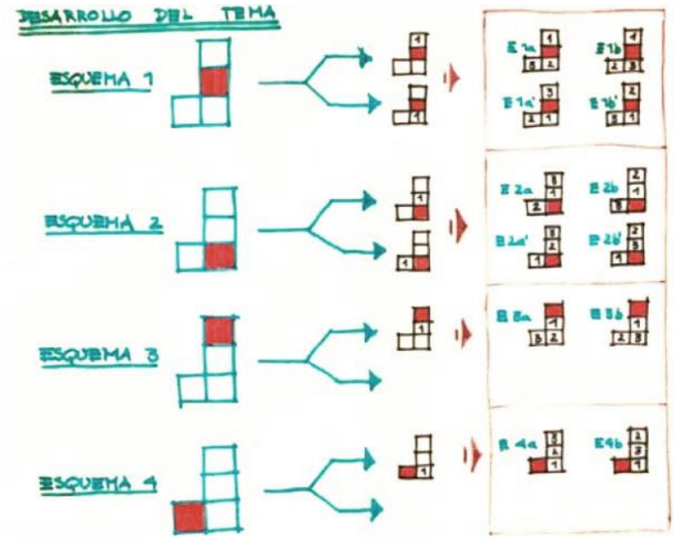


Figure 34. Basic schemes of typologies

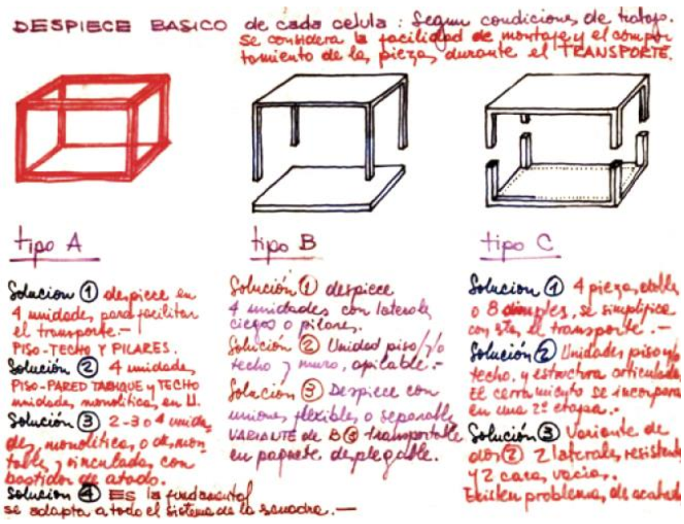


Figure 35. Basic exploded view of each cell

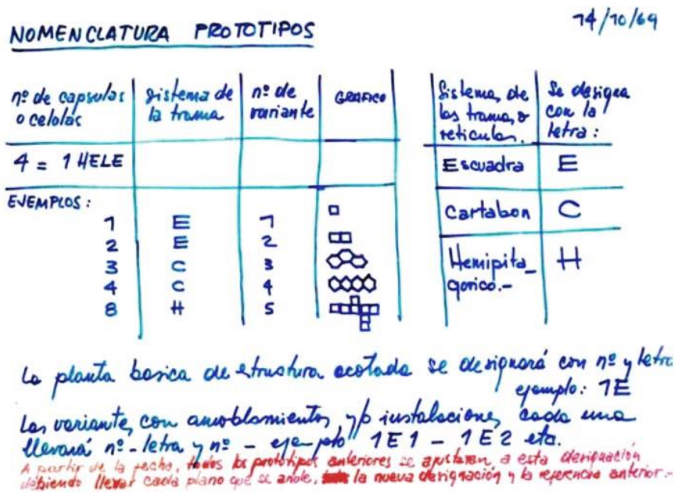


Figure 36. Prototypes nomenclature

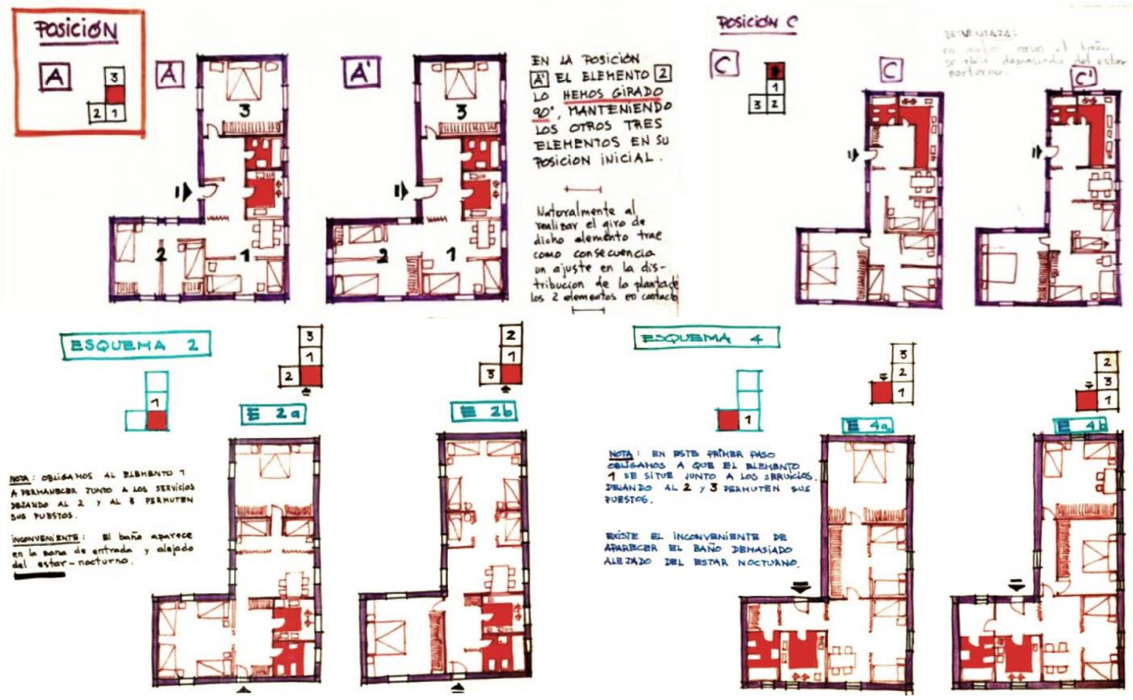


Figure 37. Typologies study

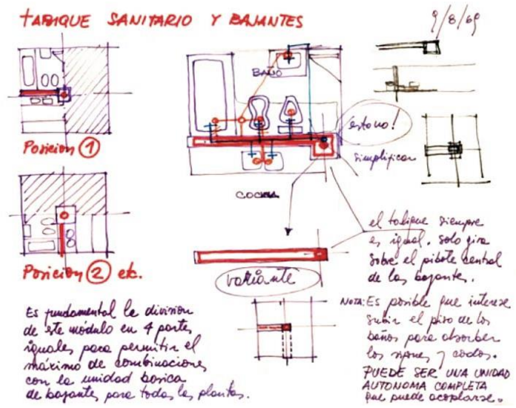


Figure 38. Wet core detail

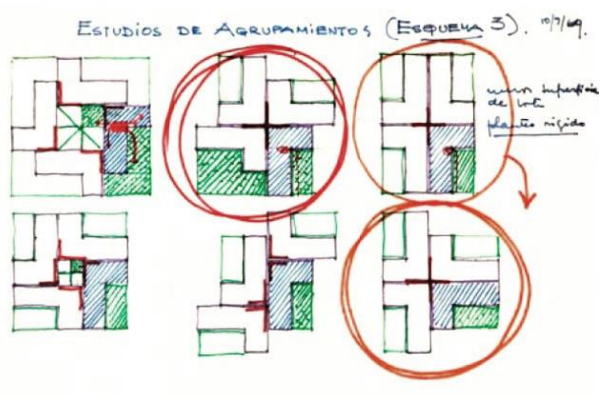


Figure 39. Clustering studies

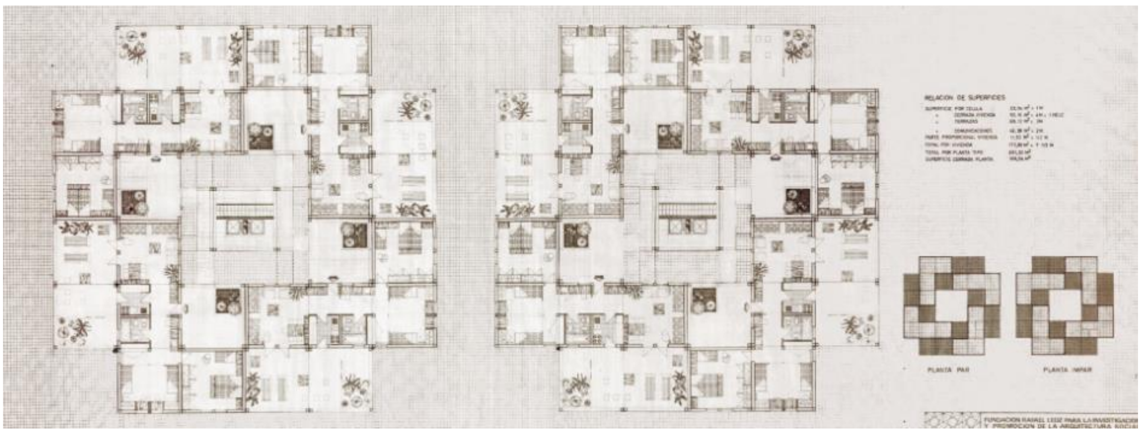


Figure 40. Building proposal

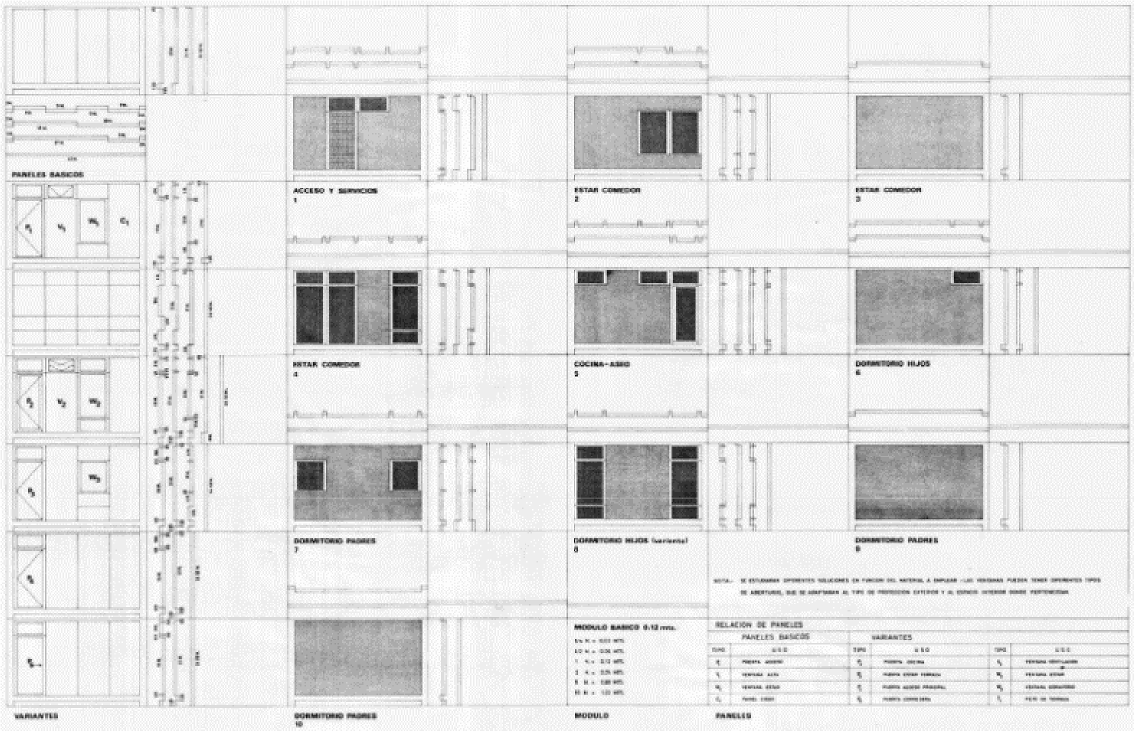
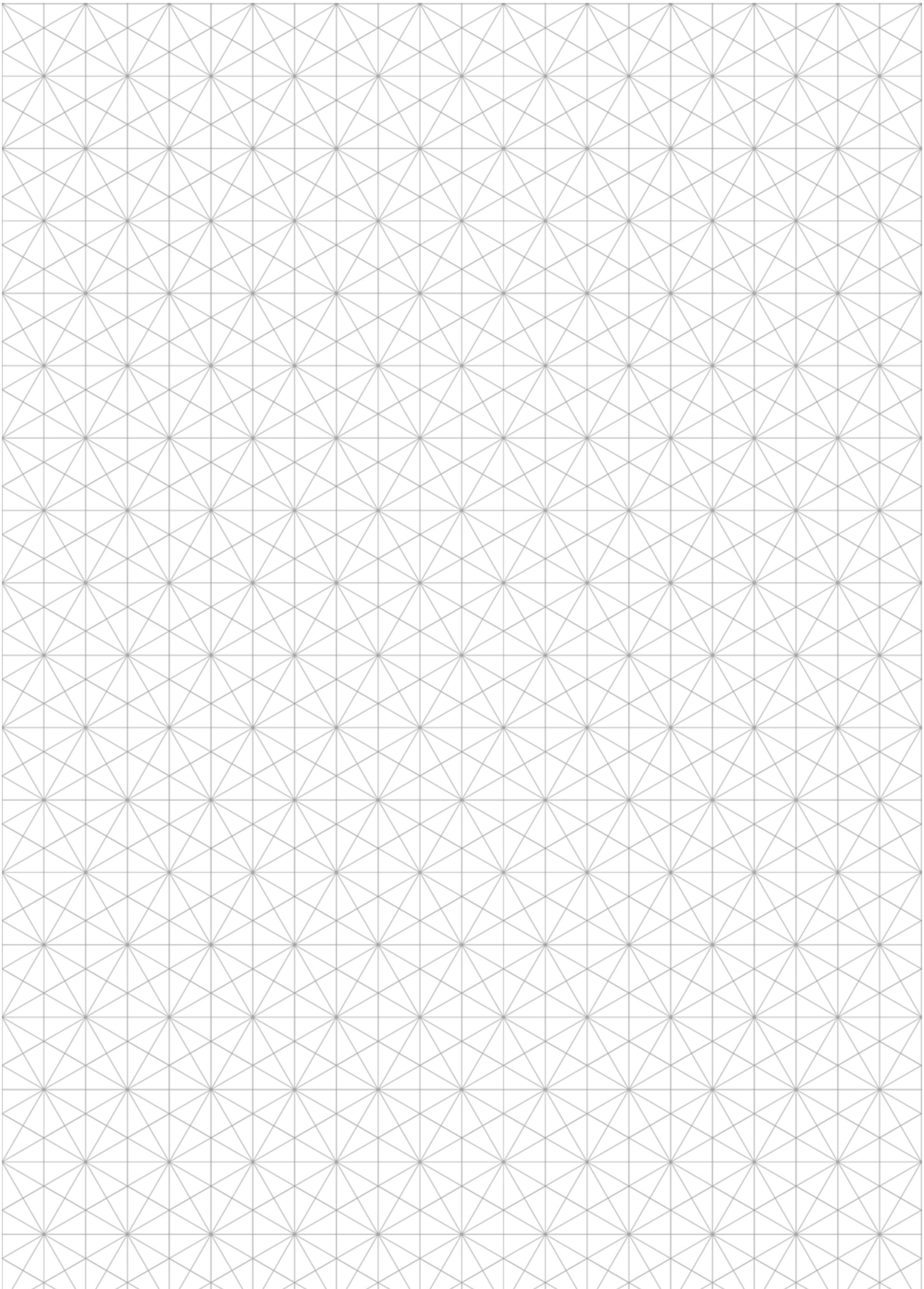


Figure 41. Elevations proposal

Figure 42. View



5. Practical analysis. Projected experimentation

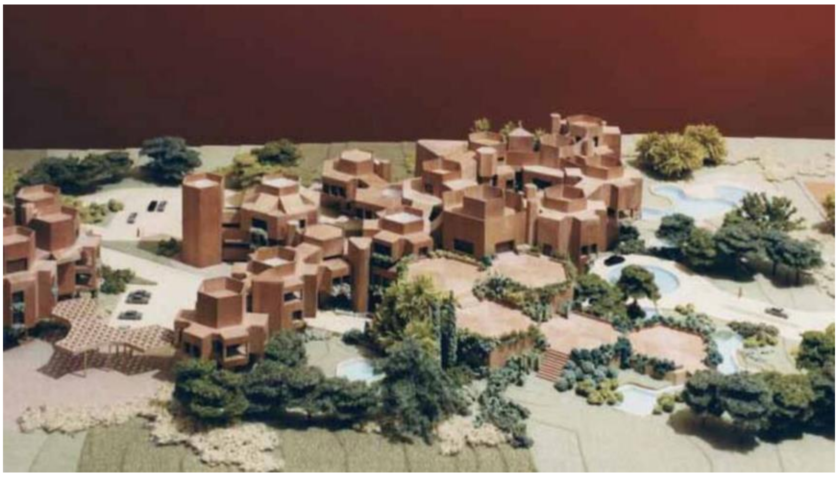


Figure 43. Embassy model

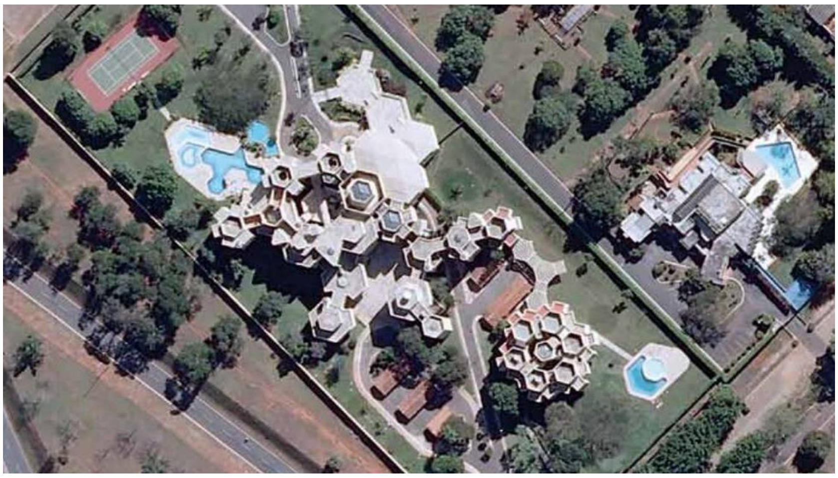


Figure 44. Aerial view of the Embassy

Figure 45. Aerial view of the Embassy

Spanish Embassy in Brazil (Brasilia)

Despite Rafael Leoz's constant quest to industrialise housing, the first opportunity the architect had to put so many years of research into a building was not in a block of flats but in a public building: the Spanish Embassy in Brazil.

When Brasilia became the capital of Brazil –in an attempt to ensure that it was equidistant from the rest of the country's states– 25,000 m2 were set aside for the different nations to build their embassies there, allowing them to showcase the different international architectural styles of the time. Due to Rafael Leoz's great prestige in Latin America after the Sao Paulo Biennial –having been offered several jobs in countries such as Cuba and Brazil to continue his research there–, he was commissioned to design the Spanish embassy.

The proposal to design the building came in 1970, and construction began in 1973. It was designed together with Fernán Bravo, Ricardo Novaro and Juan A. Boix, and it is the only work that the architect was able to see built.

The architect wanted to reflect Spanish architecture in this building, as he stated in the project report: *"The basic premises with which we responded to the programme of the Ministry of Foreign Affairs were to define construction units which, by grouping them together, would reflect the character and typology of Spanish architecture, easily materialisable with the most advanced techniques"*[39]. For this reason Leoz gave a hexagonal shape to the different volumes that make up the building –a formal resemblance to the Serrano Towers– and the reddish color –similar to that of the Alhambra in Granada–: *"The volumetry or volumetric macrostructure will be in exposed concrete, with a warm, reddish colour, very similar to that of the Bermejas Towers of the Alhambra in Granada"*[40].

To design this project, Leoz uses the spatial network of the bevel, composing the building with hexagonal hyperprisms, which are formed by four hexagonal prisms –4 metres on each side– superimposed with prisms with a rectangular base and square faces –4 x 3.5 metres on each side and 3.5 metres high– that emerge from the second and third prisms. The hexagonal prisms are the main uses, while the rectangular ones serve as connections and are designed as terraces or bedrooms. The hexagon is not only present in the external form of the buildings, but is also present in every detail such as flooring, cladding, door and window grilles, swimming pools, terraces, sculptures and even in the structure, using pillars with a hexagonal section.

Unlike the floor plan, which follows a grid, the elevations do not follow any system, but reflect the functions of the interior space, as the openings vary in size depending on the privacy required in the room in which they are located.

The building is divided into two zones: residence-reception and chancellery-consulate-cultural area. Both are articulated around a courtyard. The layout of the representative area of the embassy took into account the topography of the terrain –with a 10-metre difference in height–, and placed it at the highest point. The residential area is made up of two nucleus: the ambassador's dwelling together with the guest dwellings, and the civil servants' dwellings –three of them in duplexes–.

The original programme for each floor was organised as follow:

"Ground floor: access to the Embassy Secretaries' residences, to the Residence of the Minister-Counsellor and, from the inner courtyard, to the Chancery, Consulate and Cultural Zone.

First floor: offices of the Ambassador, Minister Counsellor and Attachés, Consulates, Cultural Zone Library, Minister Counsellor's Residence and garages.

Second floor: from the main courtyard there are two entrances, one to the reception rooms of the Ambassador's residence and the other to the Ambassador's private residence, as well as to the cultural zone, assembly hall and guest area of the Minister Counsellor's Residence.

Third floor: lounges, gala dining room, terraces in the reception area, living rooms, dining room, children's bedroom and suite of the Ambassador's Residence. Joining the two areas is the kitchen, which serves Receptions, the Ambassador's private residence and terraces.

Fourth floor: two guest suites and service areas, which communicate with the whole building by means of their own vertical circulations."[41]

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[39] (Agrasar, 2012), p.76

[40] (Agrasar, 2012), p.76

[41] (López Díaz, La obra del arquitecto Rafael Leoz de la Fuente (1921-1976): Teorías e investigaciones sobre la vivienda social, 2011), p.405

There are several aspects to highlight in this project:

1. The shape used: it offers enormous growth possibilities if the building is to be extended, as it can be extended in any direction in completely different ways.

2. The importance of light and ventilation: zenithal lighting is used strategically to illuminate the different rooms, and the connection of the spaces through patios and terraces means that the building is always ventilated –an important aspect considering the high temperatures reached at certain times of the year in the city–.

The materials used in the construction of the Embassy are a mixture of industrial and traditional. The structure is made of reinforced concrete –showing the triangular-shaped coffered ceiling at the entrances and cantilevers–, and the exterior joinery is of anodised aluminium, in contrast to the varnished wood of the interiors. There is also a contrast in the flooring: while the interior was more comfortable as it was ochre-coloured, the exterior was laid with prefabricated tiles of chickpea. The walls are masonry clad in a reddish tone, while the interior is predominantly white. Finally, *"the skylights are made of amber-coloured glass pieces that replace the triangular coffered roof, protected on the outside with polyester".*[42]

[42] (Agrasar, 2012), p.81-82

Figure 46. Exterior view

Figure 47. Interior view staircase

Figure 48. Interior view living room

Figure 49. Interior view staircase sculpture

Figure 50. Interior view dining room

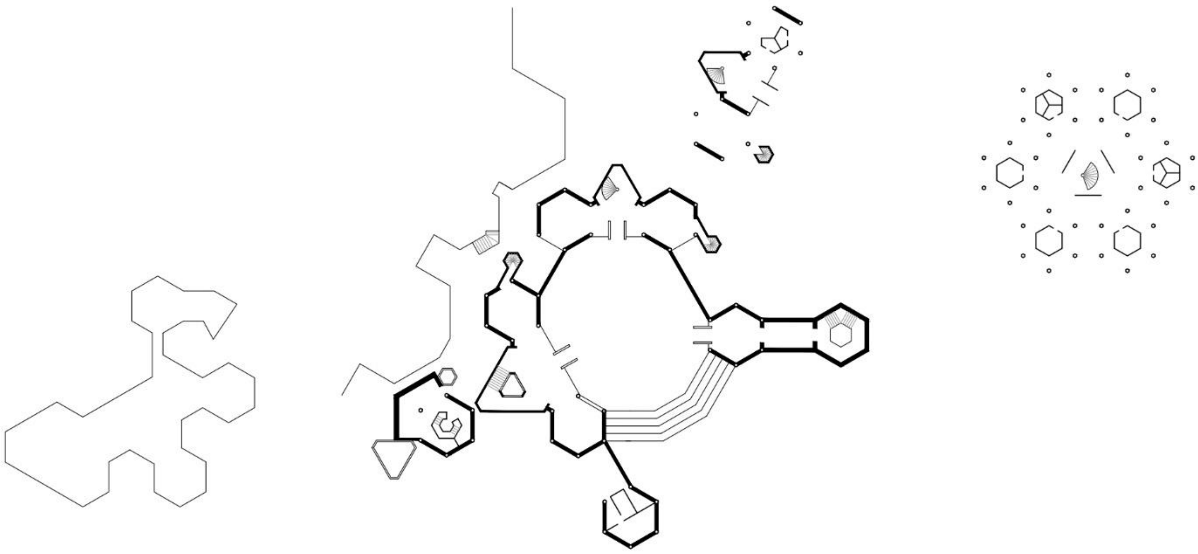


Figure 51. Ground floor

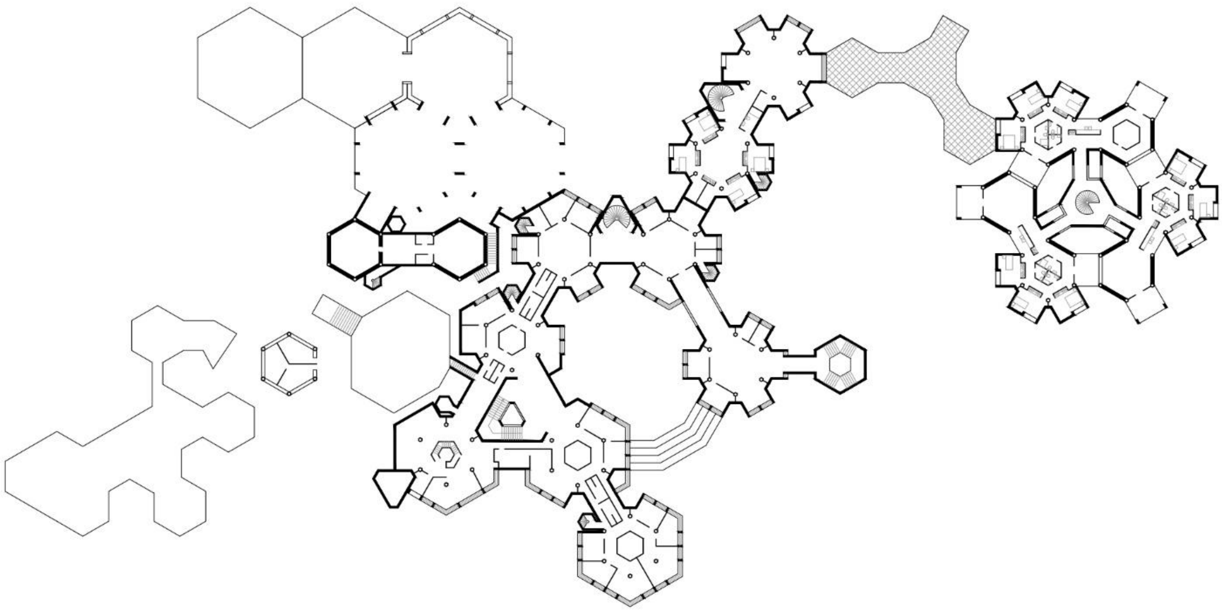
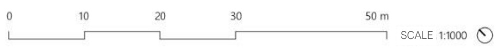


Figure 52. First floor



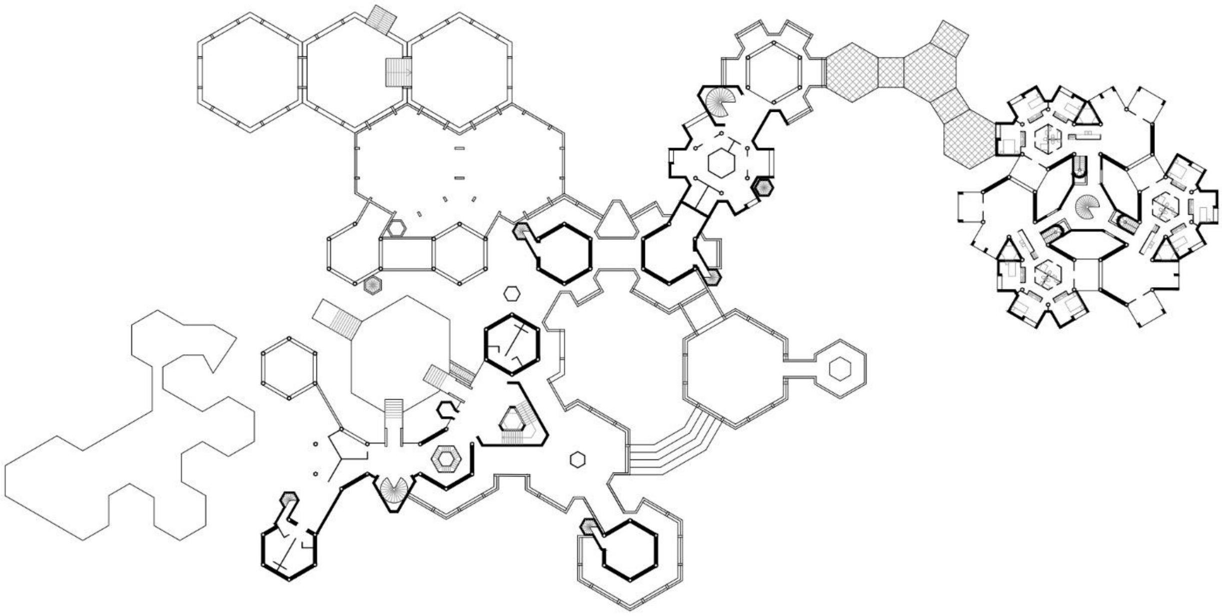


Figure 53. Second floor

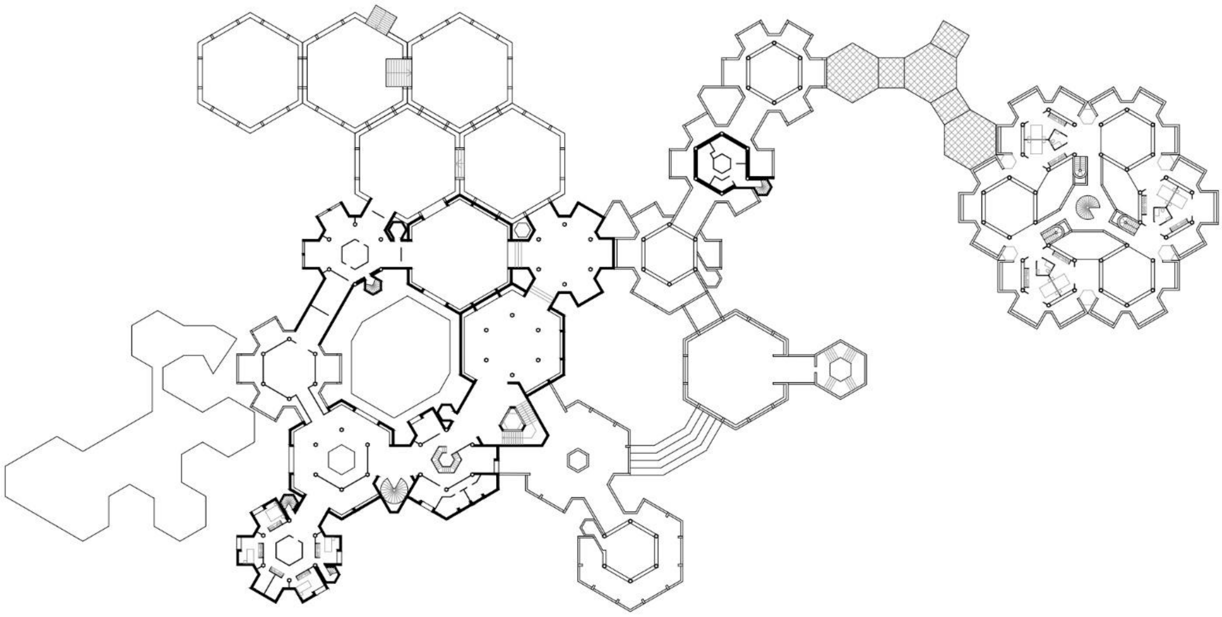
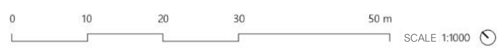


Figure 54. Third floor



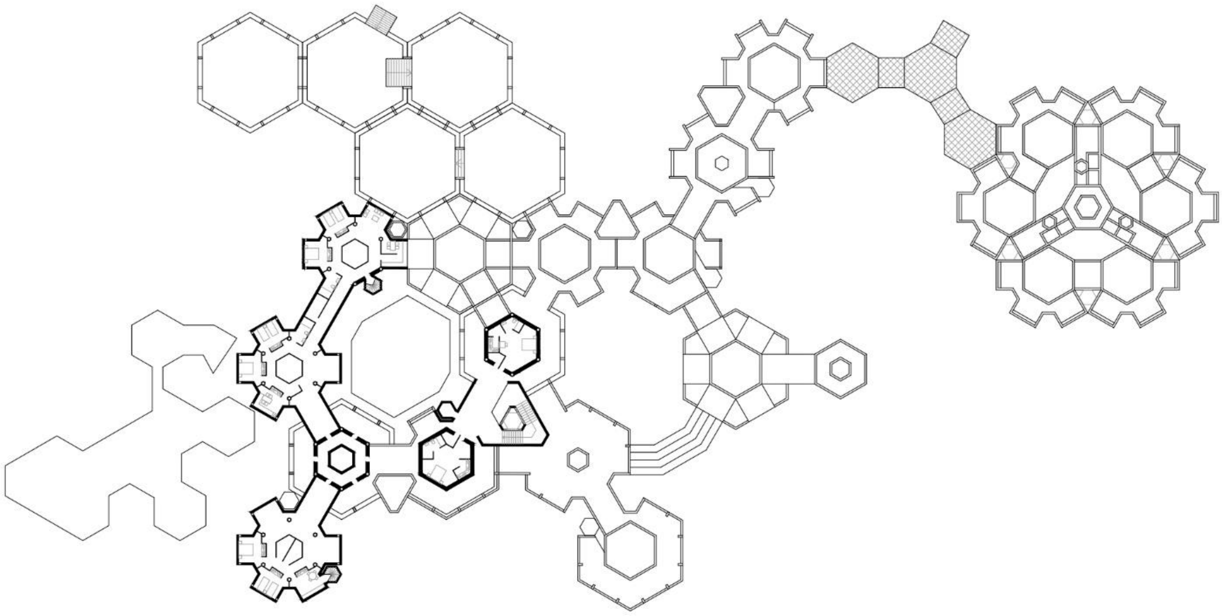
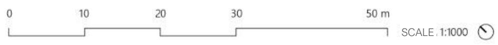


Figure 55. Fourth floor



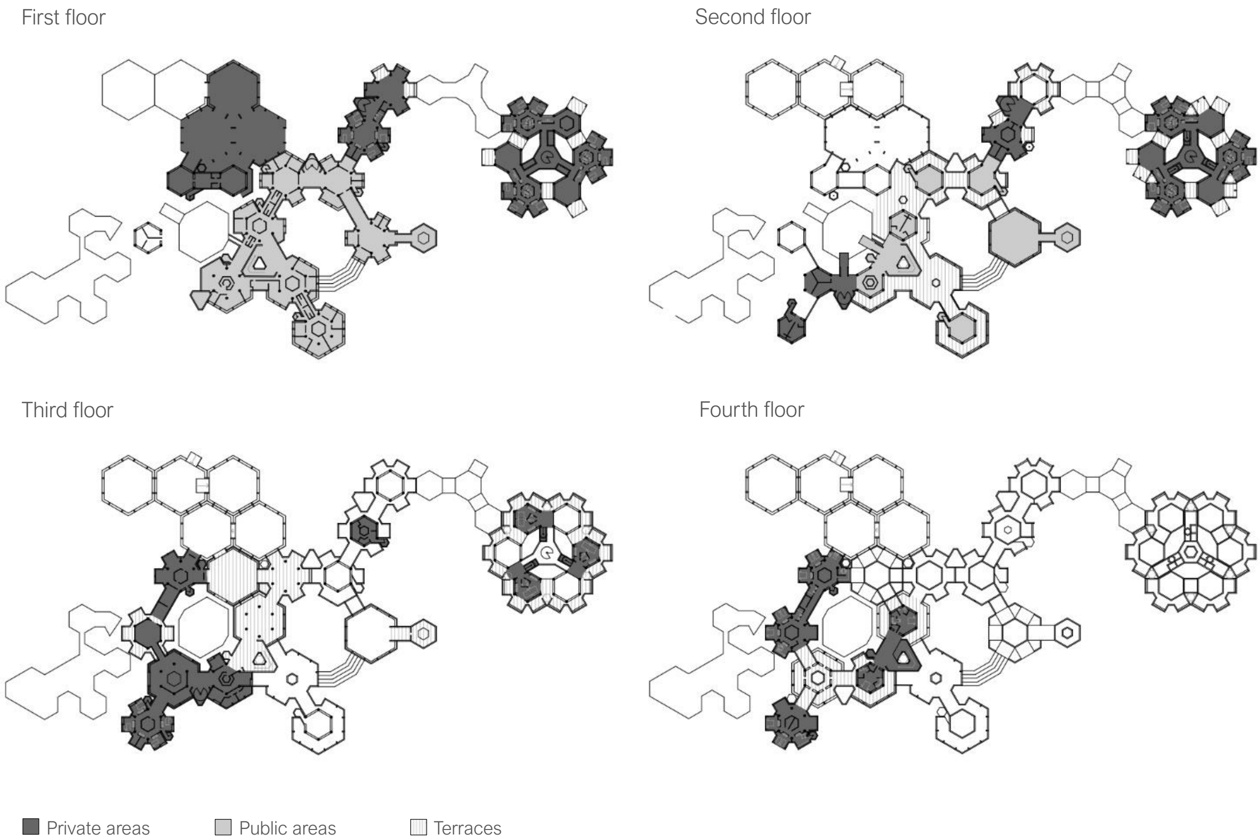
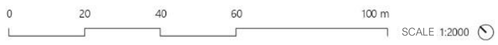


Figure 56. Zoning schemes



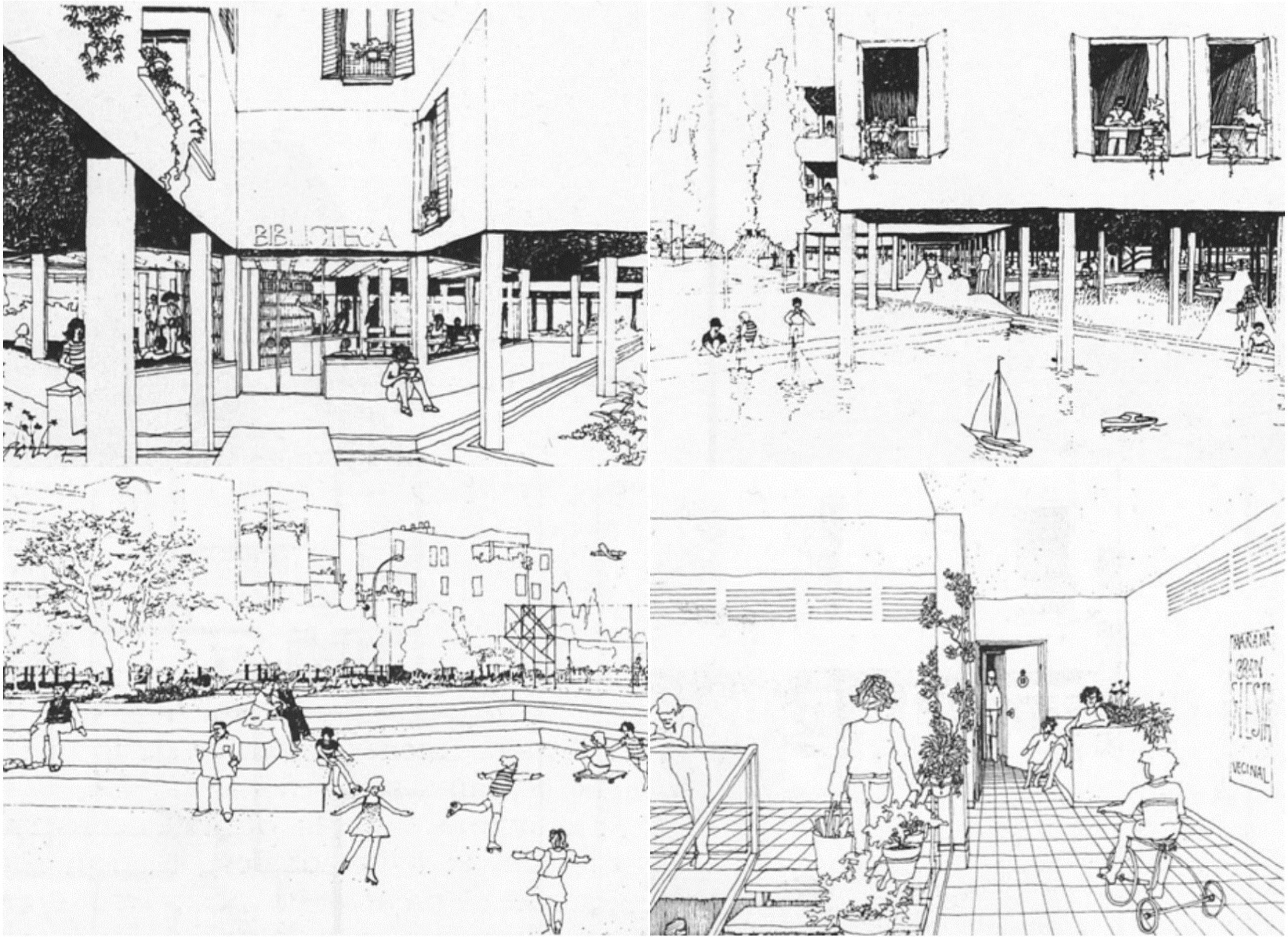


Figure 57. Project drawings

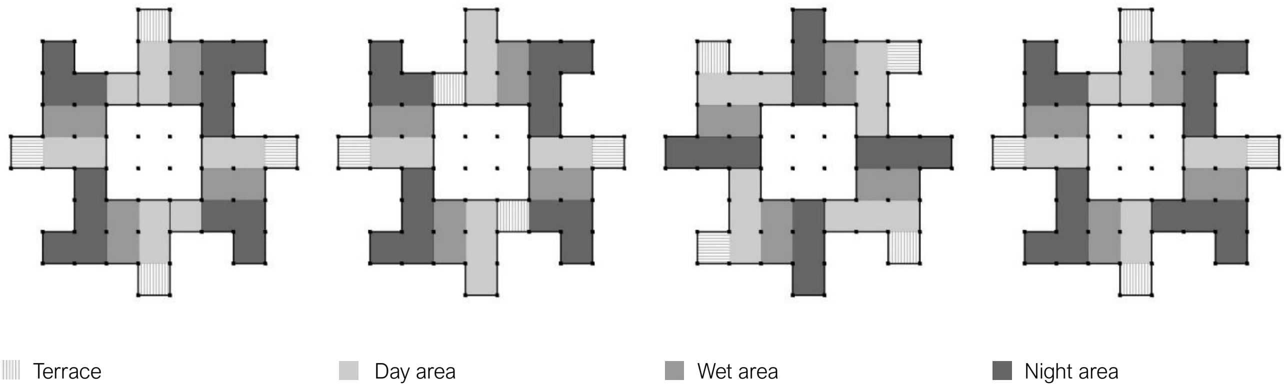


Figure 58. Zoning scheme 3x3 block

218 experimental dwellings in Torrejón de Ardoz (Madrid)

The same year in which the construction of the Embassy in Brasilia began –1973–, the National Housing Institute commissioned the Rafael Leoz Foundation to design 218 experimental dwellings in Torrejón de Ardoz.

To carry out this project, the architect used the square grid with a module measuring 3.40 m x 3.40 m x 2.75 m in height –including 25 cm of slab–. If we look at the table of proportions drawn up by Leoz, we can see that the 3.40 m module does not correspond to the height adopted in the project, but rather to the application of the minimum free height of the house.

With this project, Leoz was trying to demonstrate the viability and versatility of his theoretical proposal.

The blocks

The 218 dwellings are grouped into thirteen blocks, which can be classified into two large subgroups: the 3x3 module block and the 2x2 module block. This classification is due to the number of modules occupied by the stairwell in each block. All blocks have four storeys and four dwellings per floor.

The thirteen blocks were built on two plots separated by a street, with the five 3x3 blocks located on the northernmost plot and the eight 2x2 blocks on the southern plot. All of them have a completely free ground floor that, together with the ventilated skylight above the stairs, allows air to circulate throughout the central nucleus, which has a laundry-clothesline area at the entrance to each dwelling that acts as a filter, making it go unnoticed through a lattice. The decision to free up the ground floor was the result of the search for continuity in the communal garden área –with trees, lawns, slopes, ponds and even a greenhouse–. In addition to leaving the ground floor free, Leoz decided to turn the square grid 45º with respect to the blocks in order to "*generate a continuous fabric of imprecise limits*"[43]. This twist, together with the combination of different typologies on each floor, generates a complexity that exemplifies one of Rafael Leoz's main objectives: *"to prevent architectural industrialisation from falling into monotony and dehumanisation"*[44].

The dwellings

All the dwellings had the kitchen-bathroom wet area as the central core, which separated the day and night areas. It is also worth mentioning something atypical in the social housing of the time: the incorporation of a terrace –of 11.56 m^2– in all the dwellings as well as a great diversity of orientations –three per dwelling–, because social housing does not have to be synonymous with minimum housing, anyone deserves decent housing. In this way we see how Rafael Leoz pursued the same objectives that are being pursued today with the 2030 Agenda, seeking to eliminate inequalities –SDG 10. Reduced inequalities–.

The dwellings are classified into eleven different typologies depending on the number of rooms they have, varying between two and five. In the 3x3 block, two and five-bedroom typologies predominate –5 and 10 modules respectively– while in the 2x2 block, the majority have three and four bedrooms –7 to 9 modules–.

Access to the dwellings is in front of the wet core, consisting of a toilet, a fully equipped bathroom and the kitchen, which also separates the day and night areas. This core remains immovable on each floor, allowing the great variety of existing typologies, but keeping the installations always in the same place, which makes it easier to reduce costs.

It is worth noting that the incorporation of unusual features in the social housing of that time, such as terraces or the large dimensions of the living-dining room area, provoked criticism from some of his professional colleagues such as Mariano Bayón, *"who did not agree that social housing should acquire the standards of higher categories"*[45].

Construction

The construction system that was initially proposed adopted industrialised elements with a single type of column, forged beam and façade panel. However, the execution and budget deadlines meant that the work had to be built with traditional systems, although it is true that the standardisation of the elements made it possible to reduce costs by facilitating the execution and control of the work by having a single column section of 25 x 25 cm –made of in situ reinforced concrete– and unidirectional reinforced concrete slabs of 25 cm.

[43] (Ruiz Suaña, 218 viviendas experimentales en Torrejón de Ardoz, Madrid, de Rafael Leoz de la Fuente), p.9

[44] (Ruiz Suaña, 218 viviendas experimentales en Torrejón de Ardoz, Madrid, de Rafael Leoz de la Fuente), p.11

[45] (Cervero Sánchez, Rafael Leoz. Vivienda experimental en Torrejón de Ardoz, 2020), p.71

As for the staircases, they are enclosed on the ground floor by a gate. They were initially designed with reinforced concrete slabs in situ and masonry steps covered with paving, but were finally built with a metal structure and handrails, and the steps, without partitions, are made with prefabricated concrete and ceramic pieces, thus allowing for greater ventilation, lightness and visual permeability, which better corresponds to the character of the central communication nucleus.

"The enclosures are made of half-round brick masonry, chamber and partition wall filled with urea-formol. The partitions are made of single hollow brick masonry partition walls, metal carpentry, and ceramic flooring"[46].

The change of the façade material to brickwork nullified the industrialised aesthetic sought by Rafael Leoz, demonstrating for some the impossibility of materialising the architect's theories. However, the clear example that it was possible to industrialise housing is Moshe Safdie's Habitat 67, a 12-storey residential complex with 158 dwellings, for which 354 prefabricated modules measuring 11.7 m x 5.3 m x 3 m –significantly larger than those designed by Leoz–, were used, and which has now become an architectural landmark. We can find great similarities between this project and Leoz's, firstly because Safdie also provided each home with its own terrace, providing a private outdoor space that emulates the advantages of a suburban house within an urban environment, which combined with the search to maximise the possible orientations for each home, greatly improve the quality of life of the inhabitants. In addition, both projects incorporate the idea of creating communal spaces to encourage social interaction and a sense of community among the residents.

Urban environment

By raising the dwellings on pillars, Leoz aimed to break with the idea of the traditional block and reclaim land for the enjoyment of the inhabitants. The pedestrian walkways and the squares created between the blocks, together with the green areas, were intended to contribute to the environmental and social development of the complex.

The architect sought at all times to separate traffic and to favour spaces for both personal and individual relationships, helping to combat the dehumanisation of the modern city.

[46] (Ruiz Suaña, 218 viviendas experimentales en Torrejón de Ardoz, Madrid, de Rafael Leoz de la Fuente), p.13

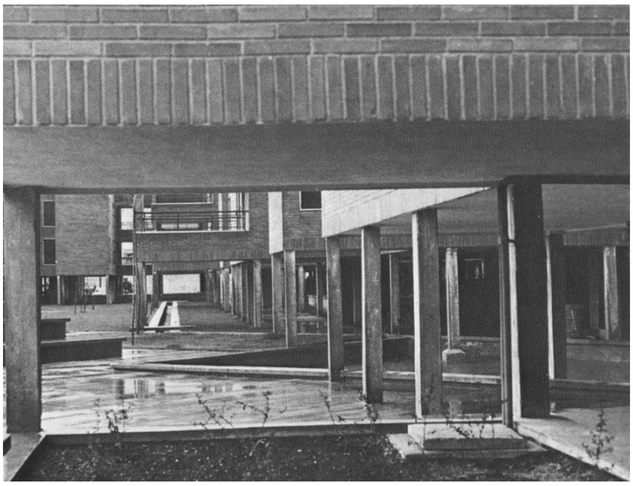


Figure 59. Exterior view (1978)

Figure 60. Exterior view (2019)

Figure 61. Exterior view (1978)

Figure 62. Exterior view (2019)

Figure 63. Construction Habitat 67

Figure 64. Habitat 67

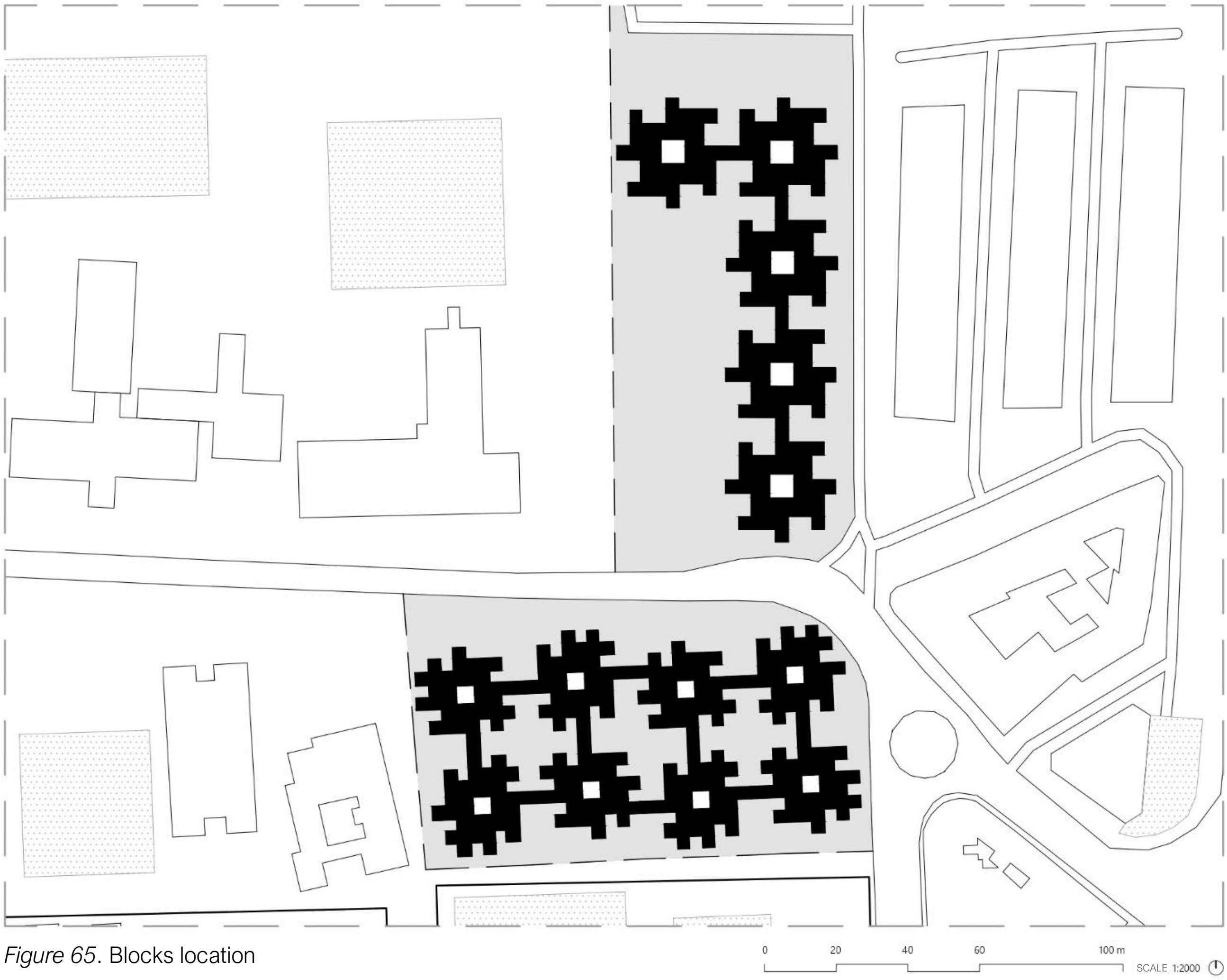


Figure 65. Blocks location

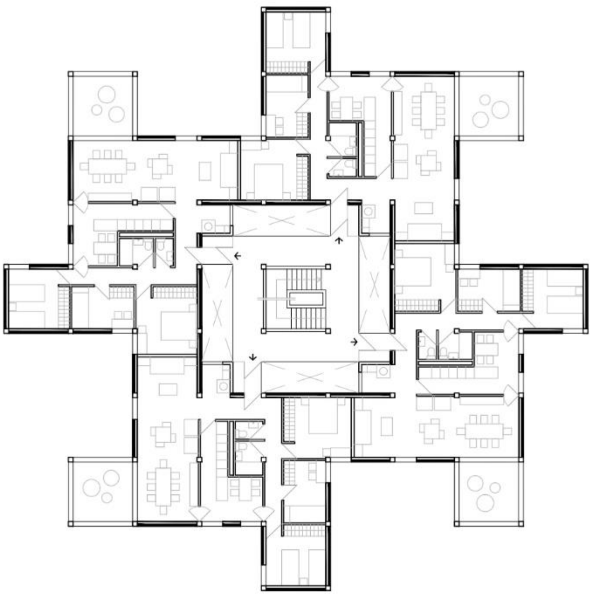


Figure 66. Floor plan 3x3 block

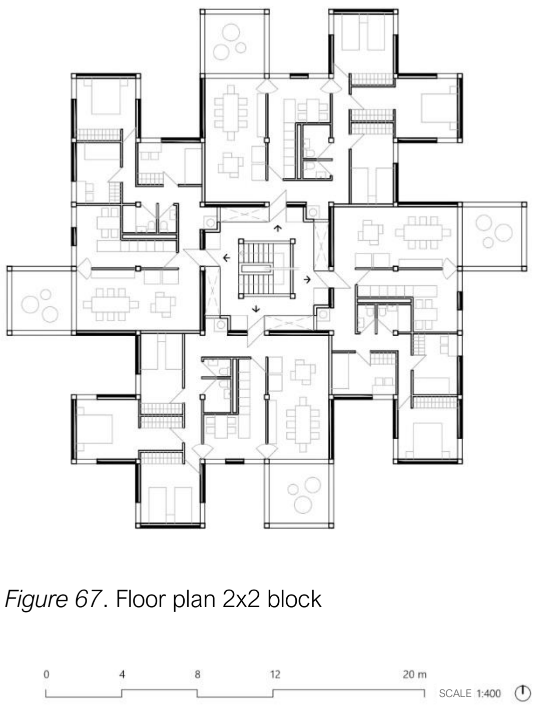
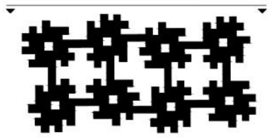


Figure 67. Floor plan 2x2 block

Figure 68. North elevation 2x2 blocks



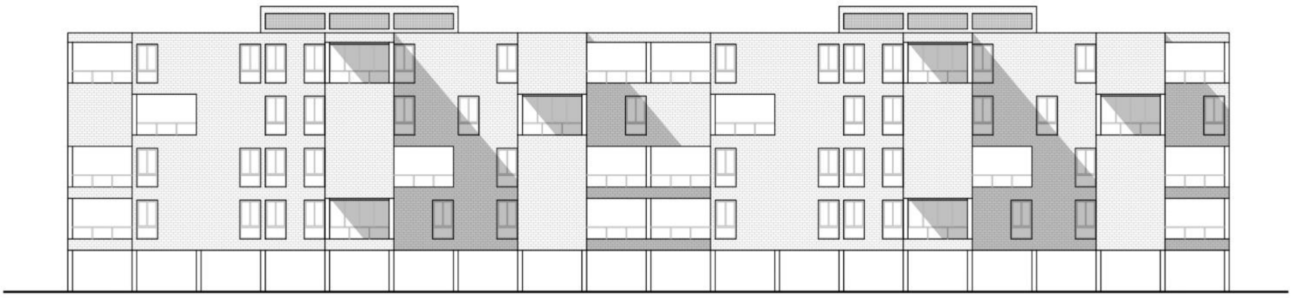
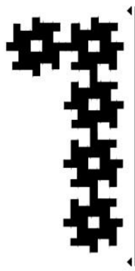
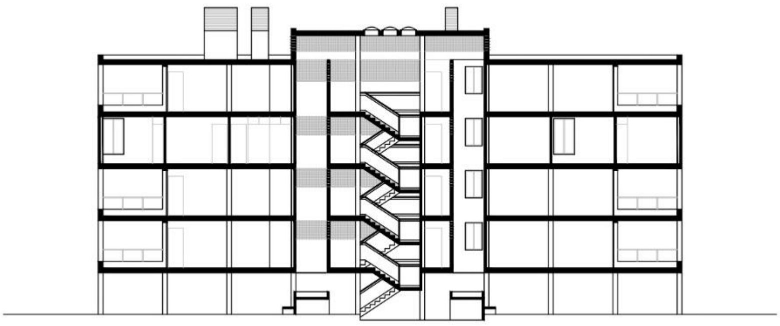


Figure 69. East elevation 3x3 blocks





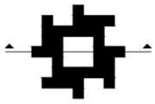
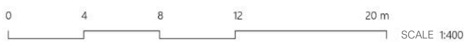
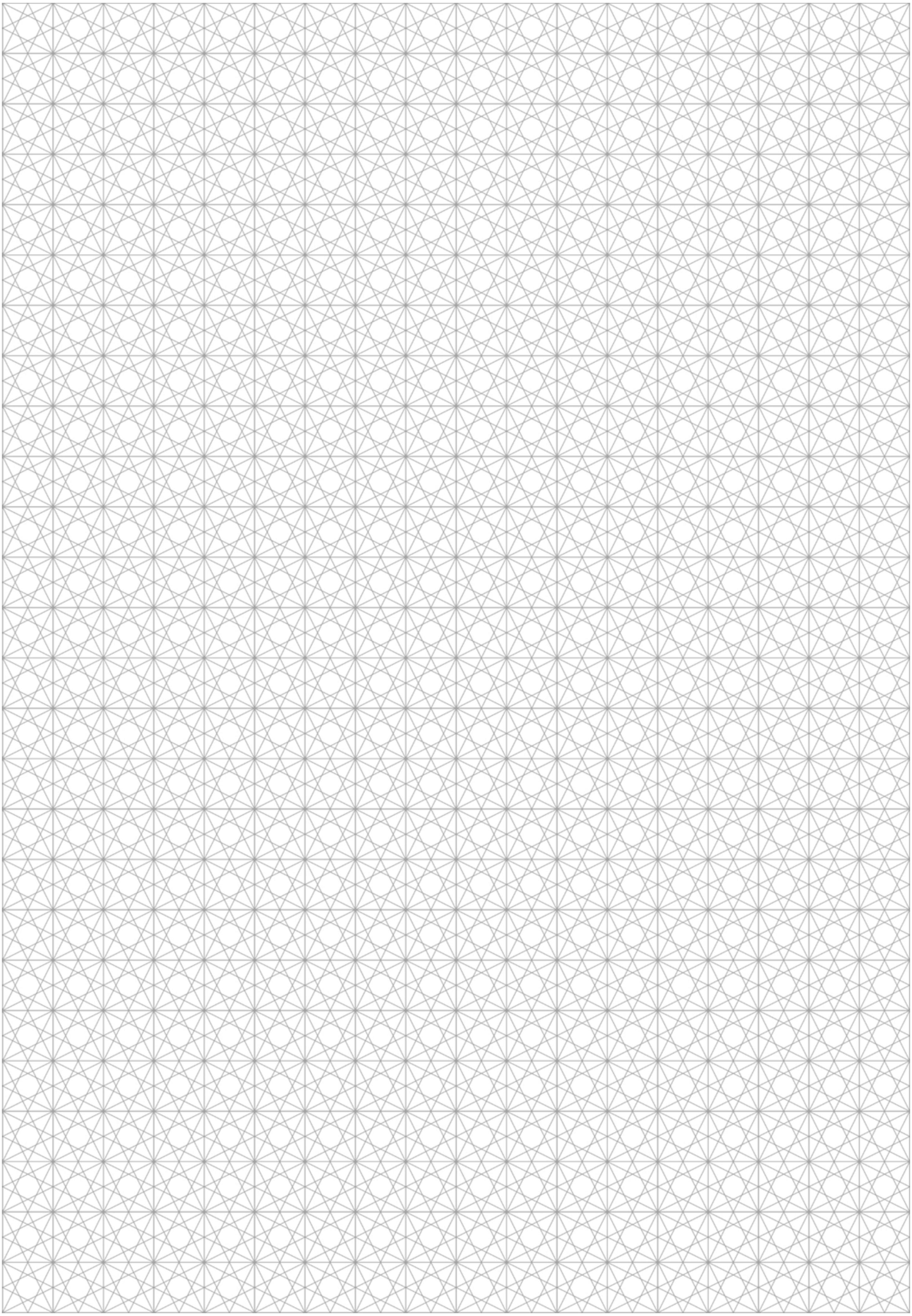


Figure 70. Section 3x3 block





6. Conclusions

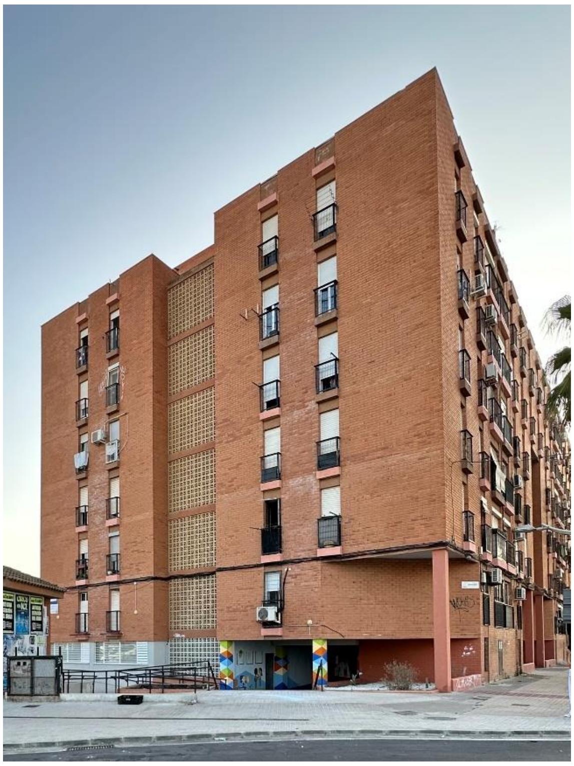


Figure 71. View of dwellings in Alfafar

Figure 72. View of dwellings in Alfafar

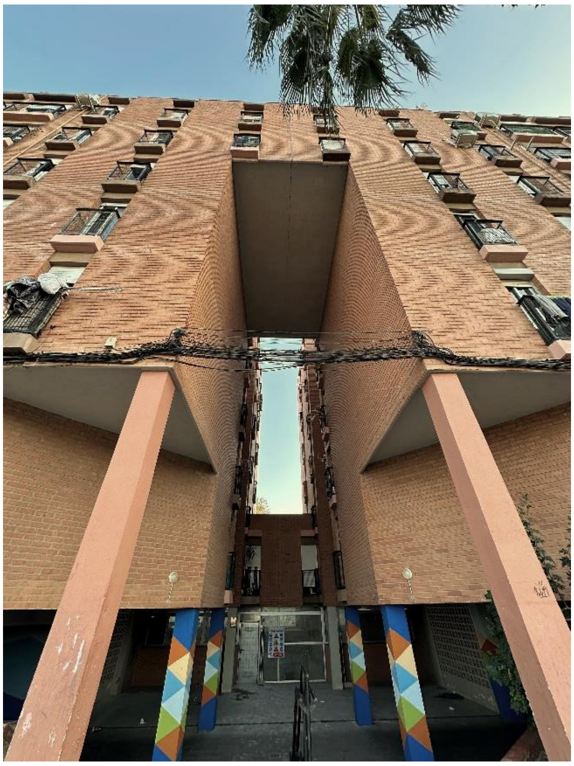


Figure 73. View of dwellings in Alfafar

Figure 74. View of dwellings in Alfafar

Conclusions

The research carried out in this work has allowed us to explore in depth the figure of Rafael Leoz, his theoretical and practical contribution to the field of architecture, as well as his legacy in the design of social housing. Through the analysis of his book *Redes y ritmos espaciales* (Spatial networks and rhythms) and his two built works –the Spanish Embassy in Brasilia and the 218 experimental dwellings in Torrejón de Ardoz–, the originality, innovation and relevance of his architecture can be appreciated.

His premature death in 1976 at the age of only 55 influenced –together with the lack of support from his colleagues in Spain– the current lack of knowledge of his figure, as Leoz left his theories unfinished and their translation into works barely begun, depriving us of one of the best theoreticians of contemporary architecture. Despite the creation of the Foundation with the aim of continuing his path of research, it never gave us a mind like his capable of completing his theories, although we must highlight the important work of the Foundation –under the leadership of his wife, Carmina Ayuso– in the dissemination of Leoz's study of social housing after his death, by continuing to organise International Research Meetings on Social Architecture in Latin America and continuing with the construction of buildings following Leoz's proposals: *"five schools in Cadiz, housing in Extremadura, Toledo, Cuenca, Tenerife, Lanzarote, Equatorial Guinea, Valladolid, Palencia, Albacete and Valencia –in Alfafar–"*[47]. Finally, in 1993, in a difficult economic situation, with no headquarters and with hardly any staff working there, the Foundation, which had fought so hard to continue defending Leoz's ideology, came to an end.

Leoz made important contributions in the field of social housing –being even nominated for the Nobel Peace Prize in 1968–, addressing one of the greatest challenges of post-war Spain: the urgent need to provide decent and affordable housing. His work in Torrejón de Ardoz is a clear example of how architecture can be used as a tool to improve people's quality of life. This project reflects his commitment to social justice, demonstrating that architecture can, and must, play a crucial role in creating more equitable societies.

He was also a visionary in identifying fundamental problems and their interconnectedness long before the international community formalised the UN Sustainable Development Goals (SDGs). He stressed the importance of addressing social, economic and environmental issues, identifying fundamental problems such as the need for decent housing or equity, warning about the risks of ignoring these problems. He insisted that to achieve a truly sustainable society, it is essential to ensure that all people have access to basic resources and equitable opportunities. This inclusive view is at the heart of the SDGs, which call for eradicating poverty (SDG 1), reducing inequalities (SDG 10) and fostering sustainable cities and communities (SDG 11). It also explored how innovation in architecture can solve key problems, focusing on modulation and efficiency to optimise resources and create accessible, quality housing, which is reflected today in efforts to promote sustainable industrialisation and the creation of resilient infrastructure (SDG 9).

One of the aspects of the architect's work that stands out is his concern for the user. His designs always put the needs and well-being of the people who would inhabit his spaces first. This humanistic approach is evident in the way he organised spaces, always seeking to maximise functionality and adaptability –allowing spaces to be reconfigured to suit the changing needs of the user– as well as in the way Leoz conceived of the relationship between buildings and their surroundings, integrating elements that encourage social interaction and community well-being, improving their quality of life.

At a time when sustainability has become a global priority, it is timely to consider how Rafael Leoz's ideas could be applied using materials such as wood. Perhaps in Leoz's time the challenges associated with timber construction, such as durability and fire resistance were more difficult to overcome, however, technological advances and modern processing techniques have transformed timber into a highly viable building material, offering structural strength comparable to concrete and steel, as well as good fire resistance. From an economic point of view, prefabrication in timber offers significant advantages, being a lighter material than concrete and steel it can significantly reduce transport costs and foundation requirements.

[47] (Escudero, 2021)

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Table of figures

Figure 1 Extracted from López Díaz, J. (2011). *La obra del arquitecto Rafael Leoz de la Fuente (1921-1976): Teorías e investigaciones sobre la vivienda social.*

Figure 2 Extracted from <https://cultura.arq.upv.es/cultura/exposicion-rafael-leoz-dibujos-sobre-vivienda-social/>

Figure 3 Extracted from <https://www.iba27.de/iba27/100-jahre-weissenhof/>

Figure 4 Extracted from <https://es.wikiarquitectura.com/edificio/pabellon-lesprit-nouveau/>

Figure 5 Extracted from <https://veredes.es/blog/aquel-invierno-de-1954-la-maison-des-jours-meilleurs-alberto-ruiz/>

Figure 6	Extracted from <https://www.archdaily.com/798710/pierre-koenigs-historic-case-study-house-number-21-could-be-yours-for-3-dollars-million>
Figure 7	Extracted from <https://alfavino.blogspot.com/2016/06/668-natalicio-rafael-leoz.html>
Figure 8	Extracted from Esteban Maluenda, A. M. (Diciembre de 1999). *La vivienda social española en la década de los 50: Un paseo por los poblados dirigidos de Madrid*
Figure 9	Extracted from Esteban Maluenda, A. M. (Diciembre de 1999). *La vivienda social española en la década de los 50: Un paseo por los poblados dirigidos de Madrid*
Figure 10	Extracted from Proyecto de residencia de trabajadores en Mallorca. (1956). *Revista Nacional de Arquitectura*(174), 33-35.
Figure 11	Extracted from <https://urbancidades.wordpress.com/2011/04/26/orcasitas-usera-madrid/>
Figure 12	Extracted from Leoz de la Fuente, R. (1960). ¿Vamos por buen camino? *Temas de Arquitectura*(18)
Figure 13	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 14	Extracted from <https://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/>
Figure 15	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 16	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 17	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 18	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 19	Own elaboration
Figure 20	Own elaboration
Figure 21	Own elaboration
Figure 22	Own elaboration
Figure 23	Own elaboration
Figure 24	Own elaboration
Figure 25	Extracted from Leoz de la Fuente, R. (1968). *Redes y ritmos espaciales*
Figure 26	Extracted from <https://www.metalocus.es/es/noticias/218-viviendas-experimentales-de-rafael-leoz-de-la-fuente-miradas-academicas-de-una-modernidad-ignorada>
Figure 27	Extracted from Leoz de la Fuente, R., & Ruiz Hervás, J. (Marzo de 1960). Un nuevo módulo volumétrico. *Arquitectura*, 20-41
Figure 28	Extracted from Leoz de la Fuente, R., & Ruiz Hervás, J. (Marzo de 1960). Un nuevo módulo volumétrico. *Arquitectura*, 20-41
Figure 29	Extracted from Pabellón desmontable para Ensidesa en la Feria del Campo VIII (1970). *Arquitectura*(139), 28-30.
Figure 30	Extracted from Pabellón desmontable para Ensidesa en la Feria del Campo VIII (1970). *Arquitectura*(139), 28-30.
Figure 31	Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.
Figure 32	Own elaboration
Figure 33	Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 34 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 35 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 36 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 37 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 38 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 39 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 40 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 41 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 42 Extracted from López Díaz, J., & Ruiz Suaña, J. A. (2021). *Los dibujos de Rafael Leoz sobre vivienda social*.

Figure 43 Extracted from <https://www.elconfidencial.com/cultura/2021-11-13/embajada-espana-brasil-leoz_3320464/>

Figure 44 Extracted from <https://www.elconfidencial.com/cultura/2021-11-13/embajada-espana-brasil-leoz_3320464/>

Figure 45 Extracted from <https://www.elconfidencial.com/cultura/2021-11-13/embajada-espana-brasil-leoz_3320464/>

Figure 46 Extracted from <https://www.urbipedia.org/hoja/Embajada_de_Espa%C3%B1a_en_Brasilia>

Figure 47 Extracted from <https://www.urbipedia.org/hoja/Embajada_de_Espa%C3%B1a_en_Brasilia>

Figure 48 Extracted from <https://www.urbipedia.org/hoja/Embajada_de_Espa%C3%B1a_en_Brasilia>

Figure 49 Extracted from <https://www.urbipedia.org/hoja/Embajada_de_Espa%C3%B1a_en_Brasilia>

Figure 50 Extracted from <https://www.urbipedia.org/hoja/Embajada_de_Espa%C3%B1a_en_Brasilia>

Figure 51 Own elaboration

Figure 52 Own elaboration

Figure 53 Own elaboration

Figure 54 Own elaboration

Figure 55 Own elaboration

Figure 56 Own elaboration

Figure 57 Extracted from 218 viviendas experimentales en Torrejón de Ardoz (1978). *Arquitectura* (213), 32-35.

Figure 58 Own elaboration

Figure 59 Extracted from 218 viviendas experimentales en Torrejón de Ardoz (1978). *Arquitectura* (213), 32-35.

Figure 60 Extracted from <https://docomomoiberico.com/edificios/conjunto-de-viviendas-modulo-l/>

Figure 61 Extracted from 218 viviendas experimentales en Torrejón de Ardoz (1978). *Arquitectura* (213), 32-35.

Figure 62 Extracted from <https://docomomoiberico.com/edificios/conjunto-de-viviendas-modulo-l/>

Figure 63 Extracted from < https://arquitecturayempresa.es/noticia/50-anos-de-habitat-67>

Figure 64 Extracted from <https://montreal.ctvnews.ca/take-a-tour-apartment-inside-habitat-67-for-sale-for-1-3m-1.4827191>

Figure 65 Own elaboration

Figure 66 Own elaboration

Figure 67 Own elaboration

Figure 68 Own elaboration

Figure 69 Own elaboration

Figure 70 Own elaboration

Figure 71 Own elaboration

Figure 72 Own elaboration

Figure 73 Own elaboration

Figure 74 Own elaboration