

# Eduardo Torroja. 1949 Strategy to Industrialise Housing in Post-World War II<sup>1</sup>

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## ABSTRACT

The huge housing demand existing in Spain in 1949 could not be met by traditional construction systems. The severe social problem thus generated was not exclusive to Spain: the countries that had participated in World War II were facing the same challenge, i.e., the need to build large numbers of housing units in record time. Industrialised systems consequently underwent intense development, generating a wide range of alternatives specific to the material and industrial resources and policies in place in each country.

In that year, Eduardo Torroja, director of the institute that now bears his name, organised an unprecedented international competition around industrialised housing. A total of 89 designs were submitted by authors from 17 countries. The aim was to establish industrialised housing systems specifically intended for Spain. That competition, today a nearly forgotten chapter in the history of housing industrialisation, is one of the three most significant milestones in Eduardo Torroja's strategy to drive progress in housing construction. The absence of a single awardee did not detract from the effectiveness of this international competition. Torroja acquired a wealth of relevant information on the most advanced construction systems and patents in use in other countries to build low-cost housing. He also obtained the results of international reflection on how to solve this problem in Spain. This final factor strengthened and broadened the role played by Torroja's institute as scientific ambassador.

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## KEYWORDS

*housing, industrialisation, construction, competition, strategy*

«The architect of the future – if he wants to rise to the top again will be forced by the trend of events to draw closer once more to the building production», Walter Gropius, 1956

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### Spain 1949: Eduardo Torroja and the Housing Problem

The Spanish National Assembly of Architects held in May 1949 addressed the severe social problem generated by the inability of traditional construction systems to meet the country's enormous demand for inexpensive housing. New, more suitable construction methods were needed that would be able to improve the quality and speed of housing construction while lowering costs. Spanish society, however, including most of its architects, did not look to industrialisation for the answer, nor was it sure what weight tradition should carry in any modern approach to the predicament.

Eduardo Torroja was one of the chief advocates of industrialisation as the solution to this severe problem, adopting a premise set out by Le Corbusier many years earlier in his controversial book *Toward an Architecture* (more commonly known as *Towards a New Architecture*).<sup>2</sup> In it, the Swiss architect complained that the architecture of his times was insensitive to the needs of a new society, not only because of its inadequate design of habitable space, but also of the manual construction systems used. Such old fashioned systems had to be eliminated and the path toward industrialisation charted to produce structural members and construction elements industrially. That democratic path would manufacture more elements more quickly, more economically and to higher quality, capitalising on all the advances afforded by science and

2. Le Corbusier, *Vers une architecture*, Paris, G. Crès et Cie, 1923 (Eng. trans. Le Corbusier, *Toward an Architecture*, Los Angeles, Getty Research Institute, 2007).

technology in the new industries that would have to be created. The course toward such necessary industrialisation had to be charted to build what Le Corbusier called a «kit of parts». Unfortunately, as Le Corbusier himself predicted, the journey would be long and arduous, because neither society nor its architects were prepared to chart a clear and straight course toward the industrialisation called for to produce such «new architecture». Both would first have to be persuaded of its necessity.<sup>3</sup>

But even more unfortunate was the fact that 26 years after Le Corbusier published his ideas, in Spain, for many and varied reasons, the «kit of parts» was nearly empty. Moreover, a large fraction of society, along with the Government and architects themselves, were still dubious about the need to embark on this route. “Industrialisation” was often equated to “prefabrication” and all that purportedly would mean in terms of restraining architectural “freedom” and leaving many workers jobless. Such prejudice was completely contrary to the premises defended by the grand masters of the most forward-looking modernity, wherever they happened to be.<sup>4</sup>

Fortunately, after the end of the Spanish Civil War in 1939, Eduardo Torroja resumed his activities at the Institute for Construction Engineering. In the nineteen forties he not only headed Spanish construction research, but was one of the most outstanding and internationally admired leaders in progressive civil construction and architecture, and in fact presided the highly reputed Réunion Internationale des Laboratoires d’Essais de Matériaux, RILEM.

In 1939 Eduardo Torroja undertook a strategy that would lead, years later, to progress in the Spanish construction industry. In the early post-war years, elements had to be standardised and traditional construction system rationalised and adapted to the paucity of materials, seeking construction solutions that did not require large amounts of iron, which could not be obtained in Spain. Inexpensive, domestically available materials, such as clay-based brick and block, were the building blocks of choice. Masons, carpenters and others had to be retrained from new perspectives to optimise materials and working times while improving workmanship. Like Bauhaus, the institute headed by Eduardo Torroja became a school for *neues bauen* (new construction). The institute trained workers, labourers, carpenters and laboratory technicians and delivered specialised construction courses for architects and engineers. In addition, Eduardo Torroja used “Informes de la Construcción” to announce national and international competitions. Such competitions pursued different ends: the National Workers’ Competition in 1949 sought to empower and reward the work performed by Spanish masons; the first National Competition, likewise in 1949, to distinguish unpublished research on the «determination of concrete docility and compactness»; and the curious and innovative «Standing Ideas Competition» fathered by Eduardo Torroja, to encourage the development of new patents that would help fill Spain’s «kit of parts».<sup>5</sup>

3. L. Costa, *Razones de una Nueva Arquitectura*, in “Informes de la Construcción”, June-July 1949, No. 12, n.p.

4. W. Gropius, *Scope of Total Architecture*, London, Allen & Unwin, 1956.

5. P. Cassinello, *La revista Informes de la Construcción crisol científico de Arquitectura 1948-1960*, in C. Jordá (ed.), *La vigencia de un legado Eduardo Torroja*, Valencia, Vicerrectorado de Cultura, 2001, pp. 271-301.

Eduardo Torroja was also aware that Spain's pressing problem was shared by the countries involved in World War II: the need to build a large number of housing units in record time. For that reason, industrialised systems underwent speedy development in many countries, where a wide range of material, technical, industrial and political resources was available. Internationally, the «kit of parts» had been filled with patents for new industrialised construction elements and structural members, with the concomitant implementation of new construction systems that contributed to optimising construction times, costs and quality.

At the same time, an international consensus was forged around the need for progressive production and construction systems in architecture. It was around this time that all the major international associations for research were founded, with Eduardo Torroja as one of the most significant players and outstanding leaders of that process. In this scenario, he decided to organise an International Industrialised Housing Competition, a milestone in his strategy to obtain information on the solutions to the housing problem in place in other countries.

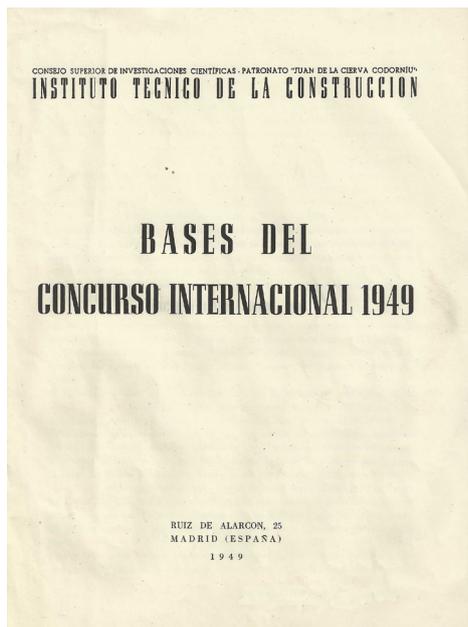
### **First Milestone. International Industrialised Housing Competition**

The next step in Eduardo Torroja's strategy to industrialise housing construction consisted of examining the international scenario to determine which solutions might be applicable to Spain. That would serve to map the route and steer Spanish industry in a specific direction. Torroja felt he needed to define "which" elements were the most suitable for industrialisation and "how" they should be manufactured to launch the modernisation of Spanish construction. Spain needed to create its own «kit of parts».

The reasons for organising the competition were stated very clearly in the rules: «This country is facing an economic and social problem of unprecedented dimensions. The shortage and high cost of housing force families to live in makeshift dwellings while traditional construction methods are proving to be unable to provide a solution. As in other areas of industry, inefficient traditional working systems must be set aside and new types of organization must be adopted – rationalised mass production to improve production and lower costs [...] This may call for a complete overhaul of national economies affected by the new procedures».<sup>6</sup>

The International Industrialised Housing Competition was announced in "Informes de la Construcción", the Institute for Construction and Cement Engineering's journal. «International Competition 1949: with a 100 000 peseta prize for the best design for industrialising residential construction to house 50 000 Spanish families yearly». With this announcement, Eduardo Torroja revealed the institute's primary concern: «to attain economic and social progress in Spain and gear its construction industry

6. "Informes de la Construcción", 1949, No. 12, n.p.



**FIG. 1** Instituto Técnico de la Construcción, *Bases del concurso internacional 1949*, 1949. Rules and Information on the 1949 International Industrialised Housing Competition (Instituto de Ciencias de la Construcción Eduardo Torroja, IETcc)

to that goal». Torroja made it very clear in the competition rules that the proposals submitted were to address the specific conditions prevailing on the Spanish market. To that end, in addition to the general rules, he prepared a detailed brochure in Spanish, English and French containing all the information that participants would need on the Spanish market and industry, namely, the short number of elements in the country's «kit of parts» and national workers' skills, expertise, specialities and wages, Spanish construction costs, and, naturally, the lay of Spanish land and other physical determinants (Instituto de Ciencias de la Construcción Eduardo Torroja, IETcc, 1949). [Fig. 1] The brochure was intended to provide foreign participants with insight into the situation prevailing in Spain in 1949, to enable them to put forward the most suitable alternatives to meet the need for 50 000 housing units yearly.

Due to the enormous international impact of the competition, the Institute for Construction and Cement Engineering, headed by Eduardo Torroja, was obliged to push the deadline for proposals back by nearly a full year, whereby the jury's decision was not forthcoming until 1952. A total of 89 papers were submitted, including 27 by Germany; 18 by Spain; 7 by France; 6 by Switzerland; 5 by Italy; 4 by Belgium; 4 by United States, 3 by Austria; 3 by Netherlands; 3 by Japan; and one each by Ireland, Argentina, Sweden, India, Finland, Morocco and what was then the Belgian Congo (Instituto Técnico de la Construcción y del Cemento, ITCC, 1949). This wide range of international proposals included a diversity of approaches, which not only mirrored the status of housing industrialisation outside Spain, but also the specific standardised elements in place in the industry, as well as the ancillary resources and modern machinery available in the most highly evolved international markets. Eduardo Torroja's challenge did not go unanswered. He had called upon the world to reflect on Spain's

specific housing problem. Most of the proposed solutions, put forward by construction companies and international organisations. Some were attempts to adapt their patents and systems to Spain, others entailed new designs, and yet others were industrialised construction systems that had been successfully implemented elsewhere.

The jury for the International Industrial Housing Competition comprised a total of nine members, seven of whom were Spanish: President/ Federico Turell, Members: José Fonseca Llamedo (appointed by the Director of the National Housing Institute), Rafael Cereceda Delgado (appointed by the Director General of Industry), Juan del Corro (Senior Standards Section Officer, appointed by the Director General of Architecture), Alejandro Suárez, Director General of Industry, Federico Mayo, Director of the National Housing Institute, M. Marini, Director of the French Centre Scientific du Bâtiment and Robert Fitzmaurice, Deputy Chief Scientific Adviser with the British Ministry of Works. Secretary: Jaime Nadal Aixalá. Indisputably, a jury with one English and one French public official reputed to be experienced in the construction of industrialised housing could more comprehensively address the suitability of the proposals for industrialisation as set out in the competition rules. The intention was to introduce foreign experience in the jury's deliberations and encourage debate from different perspectives and different areas of expertise. Although England submitted no proposals to the international competition organised by Eduardo Torroja, it made a very valuable contribution with the participation on the jury of the Ministry of Works' Deputy Chief Scientific Adviser. The specific and essential details on England's post-World War II experience in industrialised housing construction furnished by Robert Fitzmaurice were published by the Institute for Construction Engineering in 1950.<sup>7</sup>

Only a small number of proposals were submitted by individual architects or groups of architects due to the heavy emphasis on industrialisation laid down in the rules, which called for solutions involving a many-faceted and interdisciplinary perspective: architecture, housing and industrialisation, in which the third factor was decisive and indispensable. The aim was to provide new architecture with a suitable «kit of parts», without which it would be unable to provide a rational solution to the severe social problem that had arisen. Architecture needed to be industrialised and housing construction became the most important component of that machinery.

7. R. Fitzmaurice, *La Construcción en la Gran Bretaña*, No. 93, Madrid, Instituto Técnico de la Construcción y del Cemento, 1950.

### Proposals Submitted to the International Industrialised Housing Competition

A total of 89 submissions were received from 17 countries. With 27 proposals, Germany was the country with the highest number of submissions, followed by Spain with 18.

GERMANY	27
SPAIN	18
FRANCE	7
SWITZERLAND	6
ITALY	5
BELGIUM	4
UNITED STATES	4
AUSTRIA	3
NETHERLANDS	3
JAPAN	3
MOROCCO	2
SWEDEN	2
BELGIAN CONGO	1
ARGENTINA	1
IRELAND	1
INDIA	1
FINLAND	1

#### Germany

That Germany was the country to submit the largest number of proposals to the International Industrial Housing Competition was not surprising. Indeed, in addition to its scientific-technical working relations with the institute headed by Eduardo Torroja in Spain, it was the cradle, the birthplace of the new modernity which, largely championed by the Bauhaus, advocated the industrialisation of architecture. This new approach to design and construction was called *neues bauen* (new construction) to stress that what made it emphatically and radically new was the architectural production process itself: an approach involving a clean break with tradition and style; architecture intended from the outset to be industrialised, in which the standardisation and mass production of its elements were taken for granted. Of the many actors involved in this radical change, Walter Gropius was perhaps the most outspoken in his defence of the pressing need for architecture to participate in industrial progress. Architects should, then, design for these new production systems. «The architect of the future – if he wants to rise to the top again – will be forced by the trend of events to draw closer once more to the building production» (Walter Gropius).

From the time they sought exile in the United States in late 1941, Walter Gropius and Konrad Wachsmann sought to culminate their previous experience in the construction of prefabricated modular dwellings.<sup>8</sup> The indelible mark left on Germany by that generation of architects, in combination with its Government's World War II experience, hastened the development of its industry and the mass production of whole hosts of

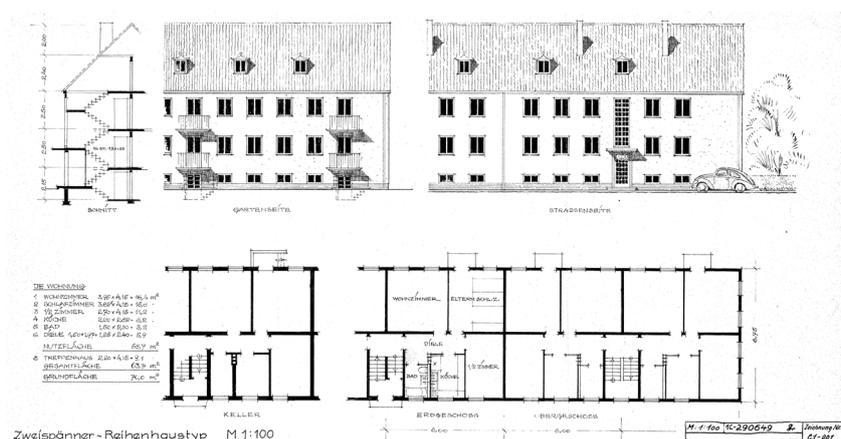
8. G. Herbert, *The Dream of the Factory-Made House. Walter Gropius and Konrad Wachsmann*, Cambridge, Massachusetts, MIT Press, 1984.

elements used to build housing for troops during the war and emergency housing in the post-war period. Industrialisation, the need for new materials and the production of structural members and construction elements were deeply entrenched in German cultural discourse during those years. German became the language of science and engineering *par excellence*.

All the proposals revealed the intense industrialisation that prevailed in Germany in 1949. Many proposed the use of structural members and construction elements manufactured with lightweight concrete patents (wall panels, deck slabs, façades, partitions), in the understanding that Spain could benefit from such industrialised products. On the one hand, their lightweight was an advantage for shipping and on-site assembly, and on the other they afforded good thermal and acoustic insulation, as well as mechanical strength. They deemed that small factories established to produce these industrialised products based on their patents could lower the cost of housing in Spain by up to 30 % and hasten construction, in keeping with the requirements set out in the competition rules. Two of the most outstanding German proposals based on such lightweight concrete elements were submitted by Bremer Wirtschaft Wiederaufbau M.B.H. and Arbeitsgemeinschaft Hebel, companies which, more than half a century after Eduardo Torroja organised the competition, continue to lead the international market for industrialised lightweight concrete elements.

The Bremer Wirtschaft Wiederaufbau M.B.H. proposal took the 10 000 peseta 3<sup>rd</sup> prize in the International Industrialised Housing Competition organised by Eduardo Torroja in 1949. The proposal was authored by engineers Víctor H. Härtl and Rudolf Opelt and architect Ernst August Steinbrink. Their team also included Christiani & Nielsen, the company that owned a Danish patent for the aerated lightweight concrete that was to be used to precast the modular DPa panels, the basic component in the industrialised construction of the homes. Their construction system was based on an orthogonal

lattice of high-strength, reinforced aerated concrete bearing walls and deck slabs. The patent used was under licence to Christiani & Nielsen. Partitions were made of twin plasterboard panels and all the construction elements, including windows, doors and parapets, were modular and prefabricated for the alternative designs envisaged. The likewise modular and standardised bathrooms and kitchens were designed to occupy adjacent positions to optimise pipe and drain distribution. Two types of roofs were designed: pitched and flat, in response to roofing solutions



**FIG. 2** Bremer Wirtschaft Wiederaufbau M.B.H., Housing blocks, 1949. Elevation and plan views (Eduardo Torroja's archive).

conventionally used in the various regions of Spain, depending on tradition and climate. The pitched roofs were to have traditional roof tiles resting on timber frames. The proposal included a full description of how to build and equip a 25 000 m<sup>2</sup> plant for manufacturing lightweight aerated panels whose output would suffice to build the 50 000 dwellings per year specified in the competition rules.

Two types of dwellings were proposed: [Fig. 2]

a) detached, semi-detached or attached one-story, single family units, with a small floor area (60.80 m<sup>2</sup>), and a number of alternative designs for units with more storeys for large families

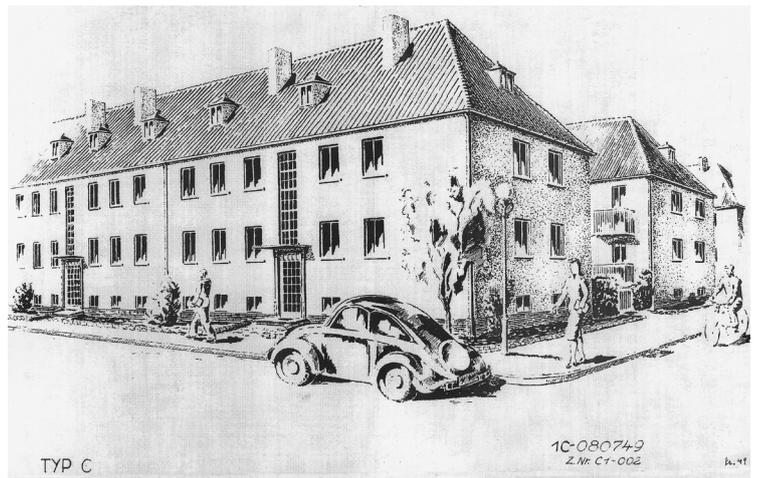
b) multi-dwelling apartment blocks with up to four storeys.

The housing blocks were arranged linearly with two-unit modules with a front/back orientation, divided by a stairway. This spatial arrangement and floor plan were very similar in most of the German proposals. [Fig. 3]

The total cost of the 50 000 dwellings was 6 600 000 German marks, including the 2 000 000 marks needed to build the precast panel factory. The authors presented a detailed construction time-cost analysis for the various types of dwellings. The estimated time needed to build a one-storey single-family dwelling was just 4 days, and the cost, 6400 marks.

The Arbeitsgemeinschaft Hebel proposal submitted by architect Ernst Julios was signed by a team of six, including Josef Hebel (owner and founder of his namesake company) and five architects: Erik Braun, Ernst Julios, Feistle Fuchs, Werner Wirsing

and Jacob Semler. Their proposal was also based on the use of porous lightweight panels, in this case manufactured by Hebel. In the six years lapsing between 1943, when this company initiated its industrial activity in Munich, and the date of Eduardo Torroja's competition, it had become one of the major manufacturers of this type of industrialised elements, used worldwide to build not only housing but all manner of buildings. Unfortunately, none of the graphic documentation for this proposal has been conserved in the Eduardo Torroja Institute's archives. In 2001, XELLA, a multinational, purchased the two companies of highest prestige and longest experience in the manufacture of air-entrained concrete industrialised elements: Sweden's YTONG and Germany's HEBEL. These patents, like many others submitted with the proposals for the 1949 competition, were introduced in the Spanish market by Eduardo Torroja, who had the foresight to predict their future utility, borne out in the interim by their successful development for over half a century.



**FIG. 3** Bremer Wirtschaft Wiederaufbau M.B.H., Housing blocks, 1949. Perspective drawing (Eduardo Torroja's archive).

The proposal submitted by engineers E.A. Steinbrink and J. Krause was also based on the use of large, high-strength, precast reinforced lightweight concrete panels for walls, deck slabs and roofs. [Fig. 4] These 2.50 m high and variable length (up to 10.00 m) panels would be manufactured using an ingenious system based on special machinery able to lay three consecutive lifts of concrete, while simultaneously embedding the reinforcement.

Five factories would be needed for the industrialised production of these panels, with an output sufficient for 10 000 dwellings each. The materials required for 10 000 units were: 92 500 t of coarse sand; 61 100 t of fine sand; 38 500 t of cement, 8500 t of steel and 375 t of coal. The housing blocks were very similar to the Bremer Wirtschaft Wiederaufbau M.B.H. buildings, except that they had large longitudinal balconies, accommodated by setting back part of one of the façades. The use of a second span length raised construction costs due to the need for a larger number of different sized industrialised members.

Ernst Blecker's proposal was eliminated by the jury in the first round because it called for thick bearing walls which were not only expensive, but particularly difficult to build. The walls were erected using industrialised



FIG. 4

E.A. Steinbrink, J. Krause, Housing blocks, 1949. Perspective drawing (Eduardo Torroja's archive).

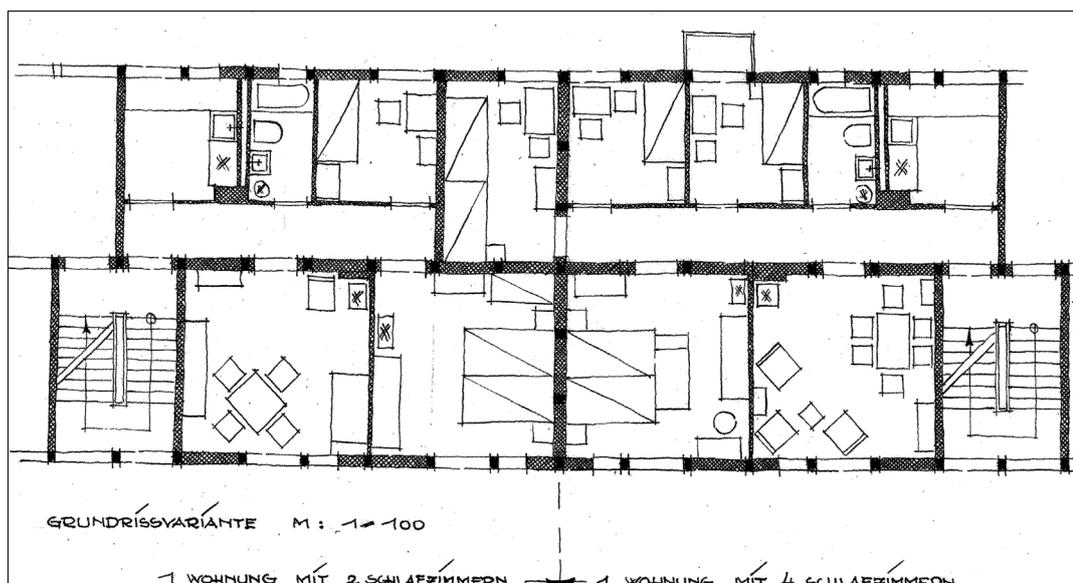


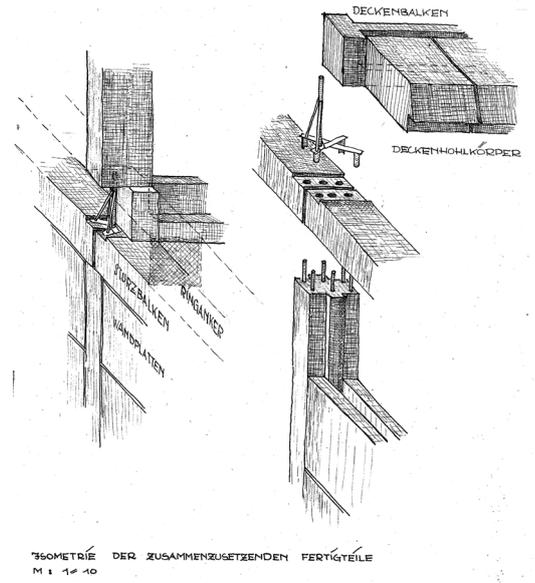
FIG. 5

Ernst Agonat, Housing block, 1949. Plan view (Eduardo Torroja's archive).

concrete elements that also served as permanent formwork. Once in place, these elements were filled in with on-site concrete, leaving ductways to house building services. While this construction system would have certainly afforded excellent insulation due to the thickness of the walls and characteristics of the materials, it was neither optimally industrialised

nor rationalised.

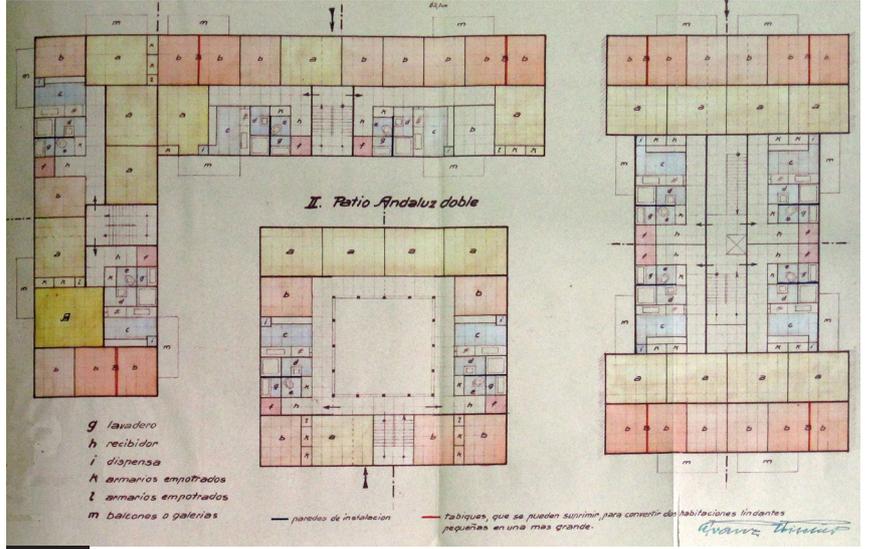
Ernst Agonat's proposal, based on the use of precast reinforced concrete elements, was also eliminated in the first round, for it entailed the use of large numbers of heavy elements with high steel ratios whose handling and shipping would raise costs. [Figs. 5-6] Reinforced concrete portal frames with a 4 m span formed three longitudinal bays, the bearing structure for the housing blocks: two running along the façades and the third along the centreline. Like most of the proposals submitted to the competition, in this housing block, the unit volumes and layout provided for front/back orientations and a compact floor plan in which the wet rooms were grouped to optimise building service pipe lengths. The size of the stairwell and its position between the façade and the central bay satisfactorily eliminated the need for header beams, although the proposal used too many columns (with spans of approximately 1 m), generating an inordinate number of abutments.



**FIG. 6** Ernst Agonat, Housing block, 1949. Construction details (Eduardo Torroja's archive).

The proposal by Ehrenfried Lorenz, also based on industrialised reinforced concrete elements, shared many of these characteristics. In this proposal, the author clearly attempted to organise the housing blocks spatially in a way that would avoid linear monotony, with alternating openings and enclosures that formed individual and communal yards.

One very original German proposal for block types was submitted by Franz Fischer. [Fig. 7] His analysis was based on the pre-definition and modular coordination of habitable space in buildings, where the modules were subsequently interconnected in different ways, leading to a wide

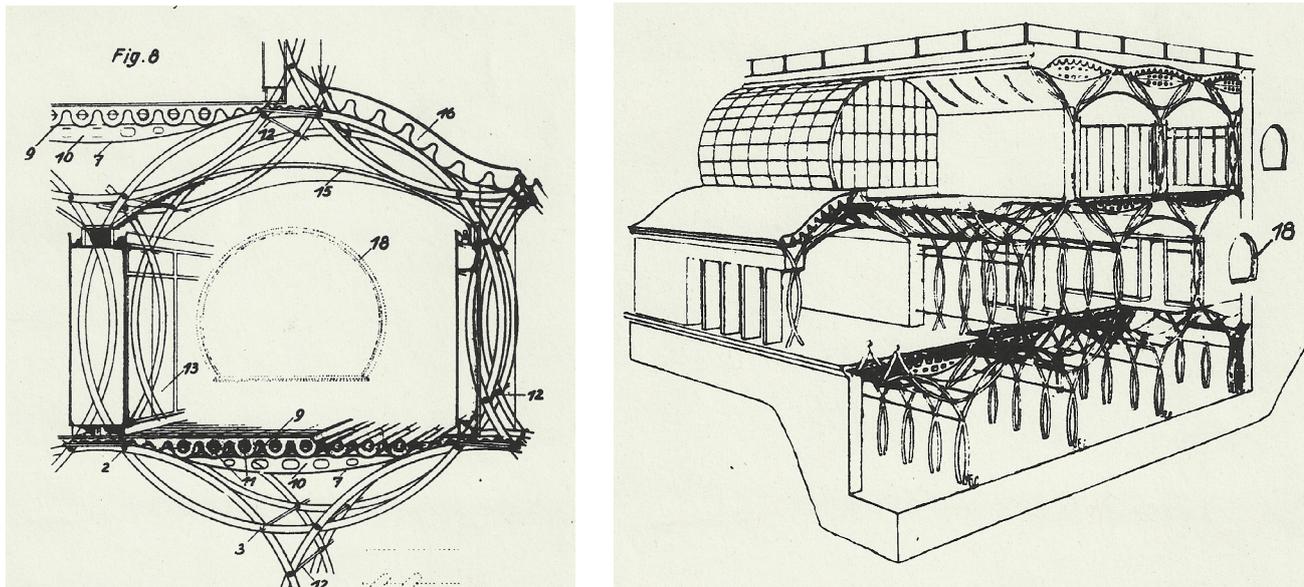


**FIG. 7** Franz Fischer, Housing units, 1949. Plan views (Eduardo Torroja's archive).

range of block type geometries. The coordinate dimension was a very important aspect to industrialise. We have to remember that Le Corbusier tried to do it with his *Modulor*. It was in 1943, in response to the French National Organisation for Standardisation's (AFNOR) requirement for standardising all the objects involved in the construction process.<sup>9</sup>

The basic unit used by Franz Fischer was a 62.50 cm module. According to the author, that measurement was the result of optimising the dimensions and geometry of the habitable space, including the position and size of the furnishings. He used that module to establish the dimensions of the formwork panels for the basement walls, the scaffolding, and all manner of

9. Le Corbusier developed the *Modulor* as a system based on human measurements, the double unit, the Fibonacci numbers, and the golden ratio. Le Corbusier asked an apprentice to consider a scale based upon a man with his arm raised to 2.20 m in height. Le Corbusier published *Le Modulor* in 1948. He used it to design his famous *Unité d'Habitation* (Marseille, France).



**FIG. 8** Alfred Lucas, Housing blocks, 1949 (Eduardo Torroja's archive).

construction elements. He submitted four types of blocks in all, which he labelled: a) oppositional (back/front orientation); b) Andalusian courtyard; c) four flats per storey; d) interconnected. Only Franz Fischer proposed a housing block with courtyard. It was a very traditional Spanish solution which some Modern architects used, as José Luís Sert.<sup>10</sup>

Industrialisation would consist of the on-site manufacture of blocks from reusable moulds, whose characteristics would differ depending on the function of the component. Most of the masonry blocks used were made of lightweight concrete and measured 50 x 25 x 20 cm. He proposed one-way (joist and pan form) deck slabs with 62.50 cm spacing and a number of industrialised alternatives for beams: steel, reinforced concrete or even aluminium. The pan forms would also be made on site with lightweight concrete.

The most original of all the German proposals, although it won no prize, was submitted by Berlin architect Alfred Lucas, author of several books on the «harmony» and biological aspects of construction materials and their effect on people.<sup>11</sup> [Fig. 8] He contended that the erection of large numbers of housing units was not just an engineering-construction issue, but also impacted the health of their future occupants, a notion that was in all likelihood accepted internationally. In the memorandum for his design Lucas stated that: «Intuitive reactions cannot be misled by questions such as the thermal conductivity coefficient or other apparently solved technical questions, and concrete structures are intuitively rejected for housing». That statement prompted the institute to explore the scope of the research on which the architect based such an amazing assertion.<sup>12</sup>

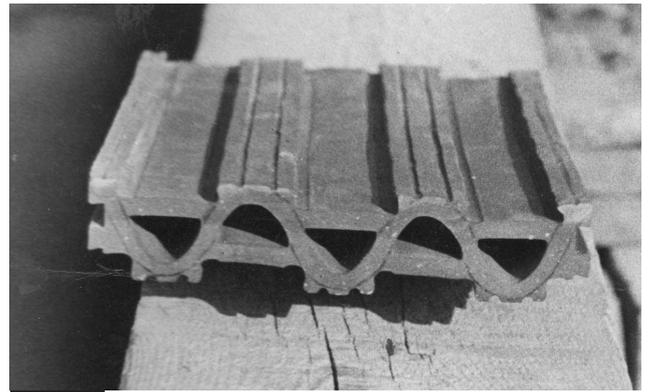
His proposal obviously did not use concrete elements, but one of the steel structure patents owned by Dyckerhoff and Widmann (Zeiss-Dywidag). A major player in many of the architectural and engineering innovations that characterised early Modernity, that German firm was closely associated with the birth and development of the huge reinforced

10. K. Bastlund, *Jose Luis Sert: Architecture, City Planning, Urban Design*, Basel, Birkhauser Verlag AG, 1967.

11. Some of Alfred Lucas's foremost publications included *Der hören Mensch, Vom Klang der Welt, Harmonikale Studien* (1943) and *Lehrbuch der Harmonik*.

12. On 2 February 1951 Alfred Lucas received a letter from the ITCC requesting more information on both his steel structure patent and concrete research. In his reply dated 26 February 1951, he noted: «In my experience, the reasons for this rejection of concrete housing lie in the domain of the compensation of energy between man and matter. The influence (or effect) of materials should be determined with ultrasensitive instruments. I've been working in this area for some time and hope to publish the results in a few months, but I must say that the aim is not to exclude concrete, but to overcome the adverse effect of concrete on human beings, using suitable measures to compensate the energies involved» (Eduardo Torroja Archives).

concrete roofs internationally known and admired as «thin concrete shells».<sup>13</sup> Alfred Lucas's proposal was based on the design of a structural model able to generate many types of housing block compounds. His intention was to optimise the amount of material needed to build each unit, based on a ring-shaped beehive structure. The ring would constitute the bearing structure, freeing the enclosures of any such function. According to the author's memorandum, he would have liked to build the ring with six 3 mm thick circular prefabricated sheet steel segments, but since such thin sheets would be industrially difficult to manufacture, instead he proposed using the Dyckerhoff and Widman circular beam patent to build his spatial membrane. Nonetheless, on 8 July 1949 he patented his idea as designed in the hope that the industrial complex would find a solution for his initial proposal.



**FIG. 9** Javier Modolell LLuch, Celetyp clay-based element, Madrid, 1948 (Eduardo Torroja's archive).

13. See P. Cassinello, M. Schlaich, J.A. Torroja, *De las láminas de hormigón a las nuevas estructuras ligeras*, in P. Cassinello, A. Bögle, P. Cachola Schmal, Schlaich Bergermann und Partner (eds.), *Estructuras Ligeras: Schlaich Bergermann und Partner*, Madrid, Marea Libros, 2011, pp. 9-20.

## Spain

As might be expected, the Spanish proposals all followed essentially the same pattern. Given the abundance and low cost of clay, most of the submissions revolved around the industrialisation of clay-based products. The Spanish participants were well aware that in the nineteen forties and fifties, the country's construction was characterised by abundant and inexpensive labour, readily available clay and a dire shortage of steel, whose use in structural and constructional solutions had to be optimised to the utmost. That would explain why most of the country's patents in those years were based on clay, a circumstance that, in addition, furthered its economic self-sufficiency.<sup>14</sup>

The Spanish proposals submitted to Eduardo Torroja's 1949 competition were authored by: Luís María Albín Sola (Celetyp), Justo Calcedo, Antonio Cámara, Jesús Carrasco Muñoz, Homs, Bartolomé LLongueras Gali, R. Lucini, Vicente Pascual Ocheda, A. Pastor, Isaac Peral Censio, P. Ramblas Pagués, J. Sabes Vita, F. Sagarzazu, Tournalayer, Termo Stabil, Stent, Baron de Abella, Semelas and Baselga, Estructuras Ligeras. Engineer Norman Barraclough Valls, while not competing for the prize, submitted a proposal for a promising post-tensioned structural system. One of the more outstanding of these submissions described a comprehensive system for industrialising housing, presented by Luís M<sup>a</sup> Albín Solá, under Mariano Giner Gallego's and Javier Modolell LLuch's Celetyp patent. In this proposal the homes were to be built with a single model of hollow (lightweight) and very long clay-based elements, into which bars were inserted for reinforcement as needed depending on whether they were to be used in deck slabs, beams, columns, façades or partitions. This appealing scheme optimised the industrial process, for it called for a

14. Report on the industrialisation conference held at the Eduardo Torroja Institute in 1961.

single hollow, lightweight element that could be used for building structure and enclosure both. Hence it was the element itself that modulated and enclosed all the inhabitable space, while guaranteeing absolute dimensional coordination among the components. It proved, however, to be more costly than desirable at the time, because although it had been used to build some housing units in Spain, construction processes were not as fully developed as required.

Celetyp submitted proposals for both single family units and apartment buildings. Unfortunately, none of the floor plans has been conserved in the IETcc archives. With its patents for clay-based materials, most prominently for deck slabs, Celetyp was among the domestic companies that

contributed to the development of Spain's depressed nineteen forties construction industry. [Figs. 9-10] One such product, a hollow brick consisting of two interconnected components, was used by José Antonio Coderch to erect housing in a seaside quarter in the city of Barcelona. Celetyp later participated in the 1956 Experimental Housing Competition.<sup>15</sup>

Spanish architect Jesús Carrasco-Muñoz (1869-1957), although not a member of GATEPAC (Grupo de Artistas y Técnicos Españoles para el Progreso de la Arquitectura, group of Spanish artists and engineers for architectural progress), adapted his designs to the principles of modern architecture defended and represented in Spain by that group. His proposal for the Industrialised Housing Competition organised by Eduardo Torroja in 1949 was awarded one of the two most highly valued honourable mentions. [Fig. 11] It drew from new patents for inexpensive industrialised elements and defined a rational construction process that optimised time and costs by using new ancillary equipment, such as a bridge crane adapted by the architect himself. His building experience since the end of the Spanish Civil War in 1939<sup>16</sup> included the construction of housing with «Schoa» or cement mortar blocks. One of his many patents for industrialised elements was a minimally reinforced concrete window frame that also served as a lintel, greatly rationalising construction. Eduardo Torroja used a very similar solution in the headquarters he designed for the institute that now bears his name.<sup>17</sup>

Vicente Pascual Ocheda submitted yet another proposal focusing on industrialised clay-based elements. In this case, contrary to the Celetyp proposal, the units were to be built with a wide variety of patented elements: walls, deck slabs, portal frames and window frames. While such a variety of elements raised housing construction and manufacturing costs, it



FIG. 10 Javier Modolell LLuch, Construction process: On-site assembly, Madrid, 1948 (Eduardo Torroja's archive).

15. VV. AA., *La Vivienda experimental. 1956 experimental housing competition*, Madrid, Fundación COAM, 1997, Annex, p. 179-Celetyp.

16. Jesús Carrasco-Muñoz's proposal, like some of his prior industrialisation experiences, was published in four articles carried by the "Revista Nacional de Arquitectura". All four focus on industrialisation and patents and none refers to the housing design submitted to the 1949 international competition. See J. Carrasco-Muñoz, *Mecanización en la edificación de viviendas*, in "Revista Nacional de Arquitectura", 1954, No. 148, p. 40; *ibid.*, No. 149, p. 39; *ibid.*, No. 150, p. 34; *ibid.*, No. 154, p. 45.

17. In 1953, on the occasion of the Institute for Construction and Cement Engineering's relocation to its new Castellares headquarters, "Informes de la Construcción" published seven articles on the design and construction of the new compound. They were grouped in a series entitled *Meet the institute...* One of the issues was devoted specifically to prefabrication.

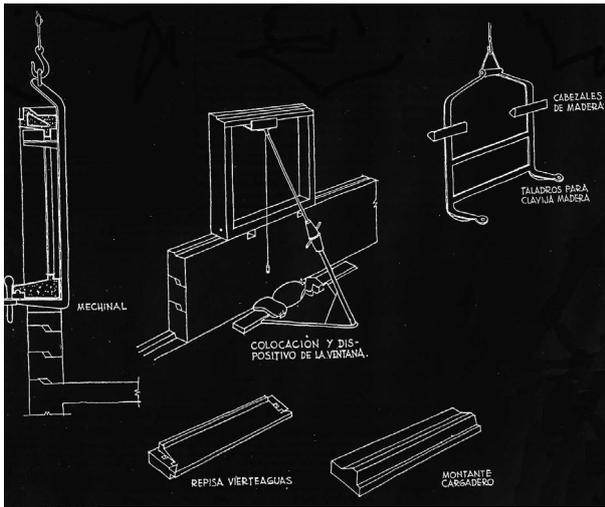
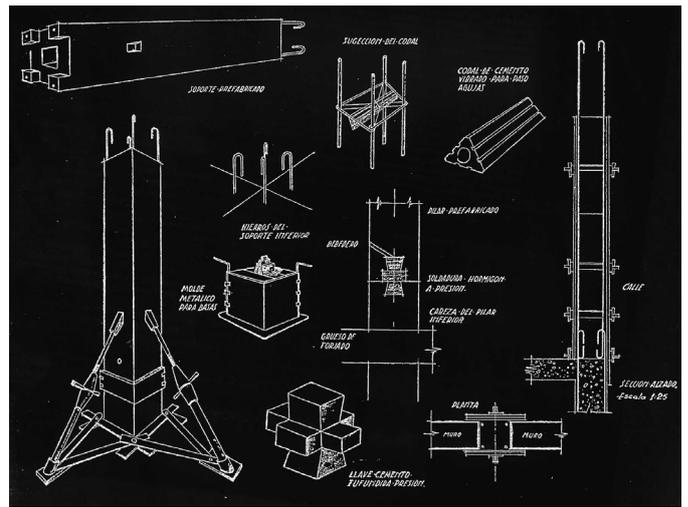


FIG. 11 Jesús Carrasco-Muñoz, Industrialised elements, 1949 (Eduardo Torroja's archive).



stood as proof of the indisputable effort made by Pascual Ocheda. These and many others of his useful patents contributed to the development of Spanish construction at the time. His very detailed analyses were especially commendable, for he sought not only to optimise the industrialisation of the elements in question, but also their dimensional consistency. That rendered his patents particularly usable for a variety of spaces and floor plans. His 1949 proposal included patents for reinforced clay-based elements for walls and one- and two-way deck slabs. Of all his patents, the most original was his «prestressed clay-based window frame».

[Fig. 12] This hollow clay element also had holes for housing post-tensioned reinforcement. Its author designed all the elements needed to interconnect the openings at different positions on the façade. In the post-World War II years, prestressed concrete revolutionised construction engineering. Prestressing optimised the structural performance of civil construction and building members and enhanced the synergies between technology and design. Pascual Ocheda took that revolution one step further and post-tensioned clay materials.

Spanish proposals based on the use of foreign patents were also submitted. One, Stent, consisted of using an English patent for precast reinforced concrete panels, while Bartolomé LLongueras Gali proposed a system highly developed in France, known by the name of its manufacturer. Mopin was in fact one of the pioneers in the instantaneous removal of concrete moulds.

France

The authors of the French proposals for the international competition organised by Eduardo Torroja in 1949 were: Procédés J. Cauvet, Société française de Constructions & Travaux publics, M. Betinas, A-V Humbert, Julien V. Schreiner and Eduard T. Bowser. The first two were each awarded one of the five competition

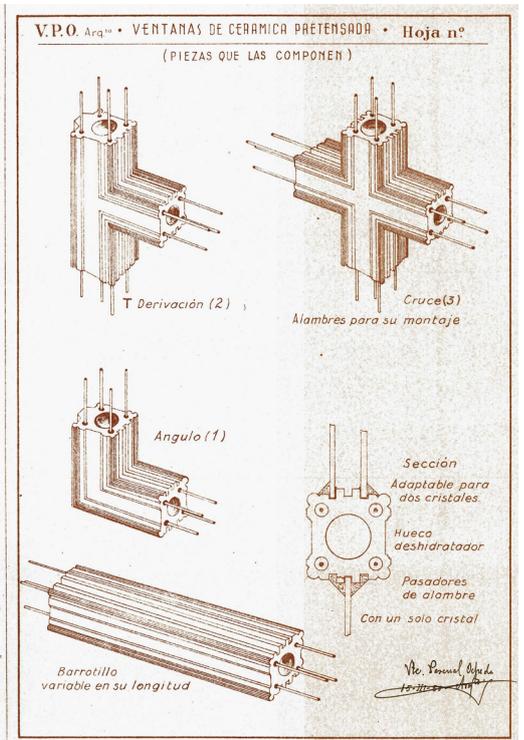


FIG. 12 Vicente Pascual Ocheda, Prestressed clay window frames, 1949 (Eduardo Torroja's archive).

prizes. Unfortunately, no copy of the Procédés J. Cauvet proposal could be found in the IETcc files. The Société française de Constructions & Travaux publics submission was awarded a 10 000 peseta prize. That company had been building low-cost housing in France since the end of World War II, using Freyssinet's famous patents (reinforced and prestressed concrete) and others authored by Jean Prouvé. Its proposal for the competition consisted of a patented system of hollow lightweight concrete blocks designed to house iron reinforcement. They resembled Frank Lloyd Wright's famous textile block system, although without the wealth of textured finishes and structural variables used in the American architect's emblematic Ennis home (1923-1924).<sup>18</sup>

In 1947, two years prior to Torroja's competition, the French Ministry of Reconstruction and Urban Planning organised a competition on research in industrialised housing to palliate the damage caused during World War II. Société française de Constructions & Travaux publics won first prize in that competition and was awarded the experimental construction of five large apartment buildings at Calais.<sup>19</sup> It submitted those same industrialised systems to the 1949 competition, along with its experience in constructing the experimental buildings. [Figs. 13-15]

18. B. Brook, *Frank Lloyd Wright: Selected Houses*, Tokyo, A.D.A. Tokyo Co. Ltd., 1991.

19. According to the Société française de Construction & Travaux publics memorandum, 560 proposals were submitted to the competition organised by the French Ministry of Reconstruction and Urban Planning in 1947.

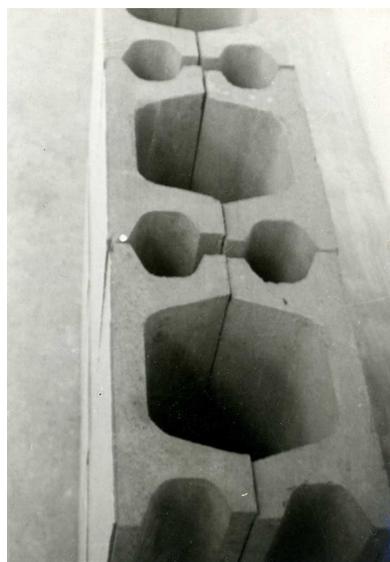
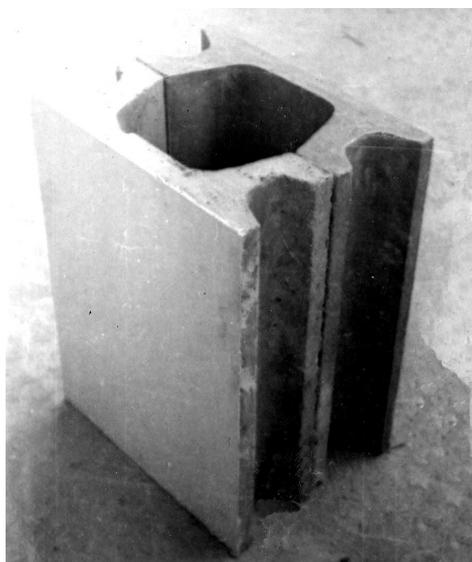


FIG. 13

Société française de Constructions & Travaux publics, Industrialised concrete blocks. Erection of walls with embedded columns, 1948 (Eduardo Torroja's archive).

One of the major advantages of the proposal submitted to the 1949 competition was that it based housing construction essentially on the industrialisation of a type of block that could be inexpensively manufactured in Spain. The main materials were Portland cement, sand, ceramic waste and a highly optimised ratio of iron. The structural skeleton and façades were built with these blocks, whose outer and inner sides could be surfaced with pigment or white cement. Moreover, neither specialised labour nor any special ancillary equipment was required.

A promisingly simple variety of apartment buildings was submitted

to the 1949 competition. These buildings could be adapted to house units of different sizes, depending on the number of children, without altering the basic modular approach. They consisted of three lines of longitudinally loaded walls or portal frames, and all the units had openings on opposing façades. Each stairwell provided access to two units per storey, regardless of the size of the dwellings. With that system, different building arrangements could be envisaged, either as detached or linearly interconnected blocks. Community services were to be housed in the mezzanine over the basement: laundry, clothes lines, trash, lumber room for bicycles and baby carriages. BA roofed walkway was provided for the buildings that had a community lawn area.

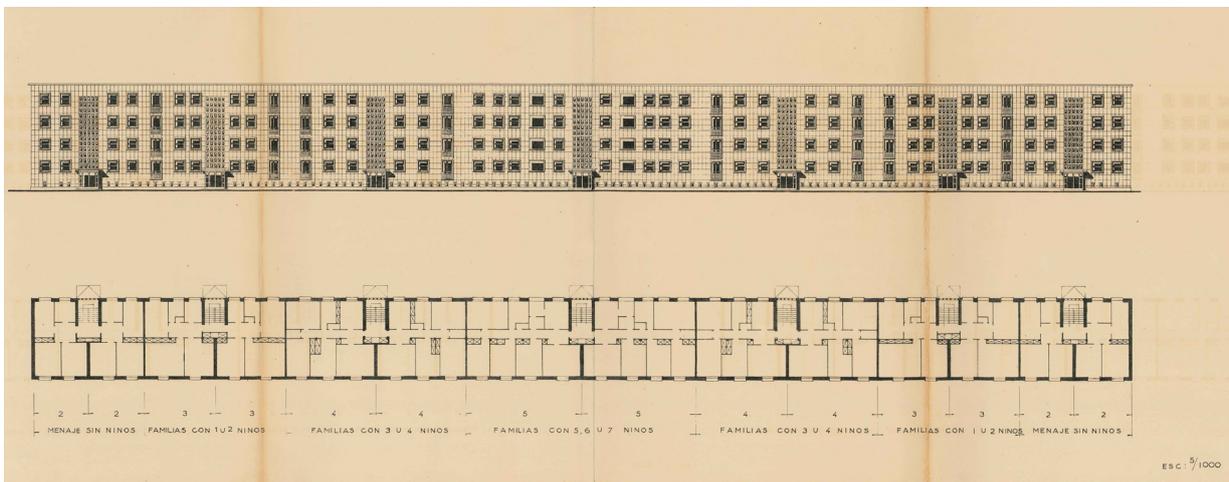
The façades were to have two types of openings: balconies off living rooms and windows in the other rooms, all dimensioned to the basic modules around which the units were built.<sup>20</sup> Light for the stairway was to be provided by a lattice opening in the façade. [Fig. 15] The proposal included two options: the use of the ground storey for commercial purposes, depending on where the buildings were sited, and a large balcony cantilevered off the roof and enclosed by a lattice with mobile slats. Single family units were to be built with the same system, with one or two storeys depending on the size of the family.

Other French proposals drew from patents already in use, although they failed to include a detailed study of how they could be industrialised in Spain's specific circumstances or the planning required to build the 50 000 units per year set out in the competition rules. Such was the case of the proposal submitted by M. Betinas, based on the «Mont» patent for building walls and roofs using concrete blocks with a vertical T-section; and of the solution authored by A-V Humbert Laxou-Nancy, which deployed SGD's patents and procedures for reinforced concrete.



**FIG. 14** Société française de Constructions & Travaux publics, Housing block under construction, September 1947 (Eduardo Torroja's archive).

20. Oddly, despite the lightweight concrete block modulation of windows and balconies, the photograph of the façade shows that some of the blocks had to be sawn, for what would appear to be a mismatch between the indoor clearances and the module.

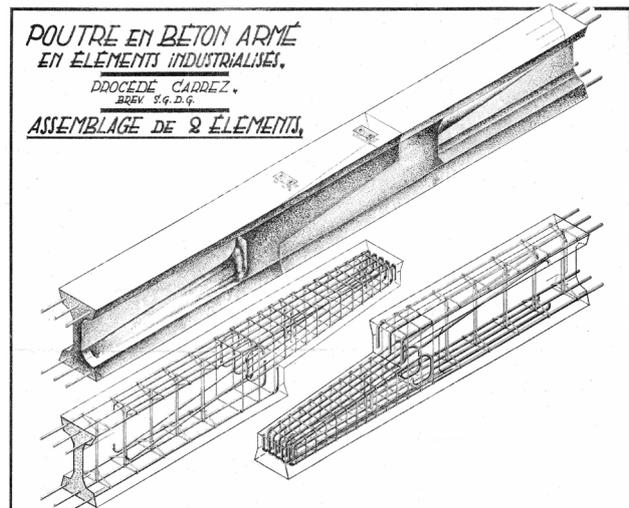


**FIG. 15** Société française de Constructions & Travaux publics, Linearly interconnected standard apartment buildings, 1949 (Eduardo Torroja's archive).

## Italy

The authors of the Italian proposals for the international competition organised by Eduardo Torroja in 1949 were: Saverio Farruzzi (Ravenna), Agostino Gurrieri (Ragusa, Sicily), Marcello Cini, Casimiro Dolza and Marco Gamna (Turin), Frido Cruciani (Rome) and Luigi Re (Cagliari).

A proposal submitted by Marcello Cini, Casimiro Dolza and Marco Gamna was particularly striking for its constructional originality, despite its high cost in Spain. It consisted of filling steel plate formwork, which enveloped the entire inhabitable space, with cast-in-place reinforced concrete made with lightweight porous aggregate for better thermal and acoustic insulation. Saverio Farruzzi proposed an innovation with respect to the type of unit. This single family dwelling, which he called the *unifamiliare minima crescente*, was able to “grow” with the family. Farruzzi designed six solutions for horizontal or vertical enlargements. The standard single-storey unit could be enlarged upward thanks to its over-engineered structural members. This proposal lacked any system for industrialising the building elements and its “growability” entailed extra costs that made little sense for mass application in the construction of low-cost housing.



**FIG. 16** A. Carrez, Detail of beam assembly, 1949 (Eduardo Torroja's archive).

## Belgium

The authors of the Belgian proposals for the international competition organised by Eduardo Torroja in 1949 were: A. Tasin (Bruges), A. Druart (Woluwe St Albert), Marcel Lermينياux (Loverbal), and Arthur Carrez (Brussels). Most of the proposals were based on the use of reinforced concrete. According to the competition jury's minutes, the most promising was submitted by A. Carrez.

It was based on the use of a wide variety of industrialised reinforced concrete elements. [Fig. 16] What the jury found to be of particular promise was the construction process: a continuous, rational “element manufacture-housing construction” sequence. The problem was that it called for the manufacture of many different elements and large amounts of iron, a construction method that could not be economically deployed in Spain at the time.

## United States

In the post-World War II period, the United States was the world leader in industrialisation. Not only did its large corporations prevail on the international construction market, but a substantial share of the

masters of modern architecture had taken up residence there. Like Walter Gropius and Richard Neutra, many of these professionals were European immigrants who engaged enthusiastically in housing industrialisation.<sup>21</sup>

The authors of the U.S. proposals for the international competition organised by Eduardo Torroja in 1949 were: Arthur Gales Company (Racine, Wisconsin), Stone and Webster (Boston), Realp W. Verney (Honolulu, Hawaii), J.E. York (Boston, Massachusetts) and Wallace Neff (Los Angeles, California). All these proposals were overly developed and their cost far too high for affordable housing in Spain at the time. Nonetheless, the wealth of industrialised alternatives developed in the United States contributed to Torroja's subsequent decision to involve institute engineers and architects in Spain's so-called «Industrial Productivity Commission». During the nineteen fifties, the commission visited a significant proportion of American manufacturing plants, worksites and architectural studios in pursuit of practical data to chart the necessary course toward industrialisation in Spain.<sup>22</sup>

Realp W. Verney submitted a single family unit built with an innovative system in which a small crane assembled industrialised reinforced

21. For their involvement in industrialised and experimental housing, Walter Gropius and Richard Neutra stood out among the masters of modern architecture who emigrated to the United States. Torroja's institute published articles on many of their housing projects in its "Informes de la Construcción".

22. P. Cassinello, *Eduardo Torroja y la Industrialización de la "machine à habiter". 1949-1961*, in "Informes de la Construcción", vol. 60, 2008, No. 512, pp. 5-18.



FIG. 17 Wallace Neff, Airform bubble houses, Litchfield Park, Arizona, 1942 (Eduardo Torroja's archive).



concrete walls and deck slabs. Construction times and labour were rationalised but the system was too costly for Spain, where ancillary equipment, in particular latest generation machinery, was in short supply. Under the slogan «anyone can build a house», the Arthur Gales Company submitted an industrialised construction system it was using on a large scale in the United States. It consisted of a Jones and Laughlin Steel Corporation patent in which a series of industrially manufactured steel columns and beams that could be put together on site like a Meccano.

Stone and Webster, both a pioneer and a major player in industrialised civil and architectural construction in the United States, as well as in most other areas of the country's heavy industry (space, atomic energy, aeronautics), also participated in Torroja's competition. With its

economic buoyancy and the company's world leadership in innovation and technological progress was the fruit of its economic buoyancy and the expertise of its staff of distinguished engineers, architects and scientists, many of whom were European and Asian immigrants. I.M. Pei, a renowned architect of Chinese origin, worked at Stone and Webster from 1942 to 1946, where he produced patents for low-cost prefabricated housing units made of wood panels, and designed reinforced concrete elements. In 1944 the proposal for prefabricated housing designed by I.M. Pei and E.H. Duhart took second prize in the Design for post-War Living competition organised by the journal "Arts and Architecture".<sup>23</sup> The IETcc archives unfortunately contain none of the documents that accompanied the Stone and Webster submission to the 1949 competition.

The proposal by architect Wallace Neff was based on the use of his own patent for monolithic reinforced concrete domes built over inflatable balloons (airform bubble houses) that served as reusable forms. In the nineteen forties, Neff used these balloons made by the Goodyear Tire and Rubber Company to build thousands of homes in over 17 countries.

**[Fig. 17]** More bubble houses were built in the United States, primarily in California, than anywhere else, however.<sup>24</sup> In 1944 the journal "Architectural Record" carried an article eulogising this modern innovation for housing that combined inhabitable space with new technologies. In 1945 Neff expanded his company, which he renamed Airform International Construction Company (AICC). While very speedy, this construction system was not genuinely industrialised. It consisted of casting a reinforced concrete foundation ring in place to anchor the inflatable formwork. The reinforcement was then set into position around the inflated balloon and gunnited. After the concrete shell hardened the balloon was deflated and removed. The speed of this construction system optimised labour which, along with the small amounts of materials required, lowered costs, making it apt for building affordable housing. Neff developed and perfected his system over the years, conducting experimental strength trials on bubble houses with different geometries, sizes and slenderness ratios. He also researched the outer gunnite finish. Depending on climate, these bubble houses could be coated with waterproofing and insulation, in turn covered over by a second layer of gunnite, to enhance the quality of the dwellings. Nonetheless, as in the case of other innovative proposals submitted to the 1949 competition, this system could not be economically deployed in Spain at the time.

23. In January 1944 "Arts and Architecture" published the results of its Design for post-war Living competition. The jury comprised Richard Neutra, Gregory Ain and Charles Eames. First prize went to Eero Saarinen and Oliver Lundquist, second to I.M. Pei and E.H. Duhart, students at Harvard University supervised by Walter Gropius, and third to Raphael Soriano.

24. F. Szokoloczi and A. Danielis to Eduardo Torroja, 3 November 1949, IETcc Archives, AHT/C/A/002/005.

## Netherlands

The authors of the Dutch proposals for the international competition organised by Eduardo Torroja in 1949 were: Jac Koolhaas (Groningen), H. Groefsema (Groningen), and Austermuhle, Grossimling Haus N.V Baenen (Maastricht).

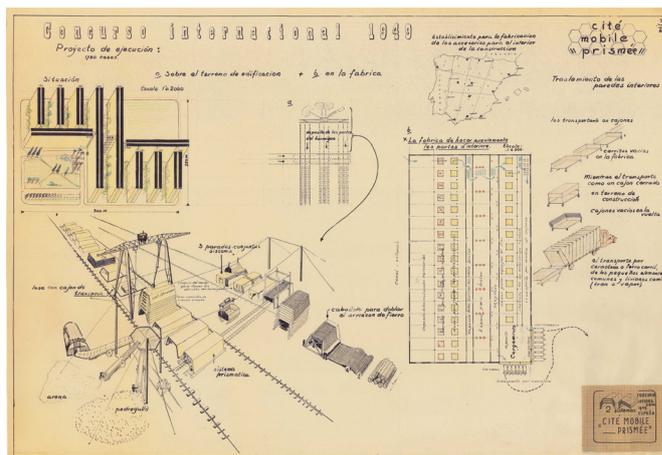
The title of the Jac Koolhaas and M. Lovwrenburg submission, the «Mobile Prismatic City», describes in a nutshell the key characteristic of the homes and the system for industrialising their construction. [Fig. 18] The proposal envisaged the industrialised erection of three-dimensional, reinforced concrete modules with a rectangular base that could be readily stacked during storage. These modules, which comprised the outer structural envelope, were to be built on site. When grouped, the housing modules could be arranged to form a wide range of different types of multi-dwelling units. In some cases the landscaped roof would be reserved for community use, as in Le Corbusier’s famous *Unité d’Habitation* at Marseille. As in that legendary building, the Koolhaas and Lovwrenburg design provided for alternative duplex dwellings, which in this case were built inside shells with a hexagonal cross-section built with two precast reinforced concrete modules. The living room, kitchen and master bedroom with its bathroom were located on the ground storey, while the children’s bedrooms and a large bath were on the upper storey.

The advantages of dividing the hexagonal shell into two modules to delimit the living space instead of a single whole element were, on the one hand, readier industrialisation and on the other lighter weight, which facilitated shipping and on-site handling. The joints between modules and deck slabs were very cleverly designed: the upper angles of the modules were mortised to receive the piece and reinforced on the inner corner with a small gusset. [Fig. 19]

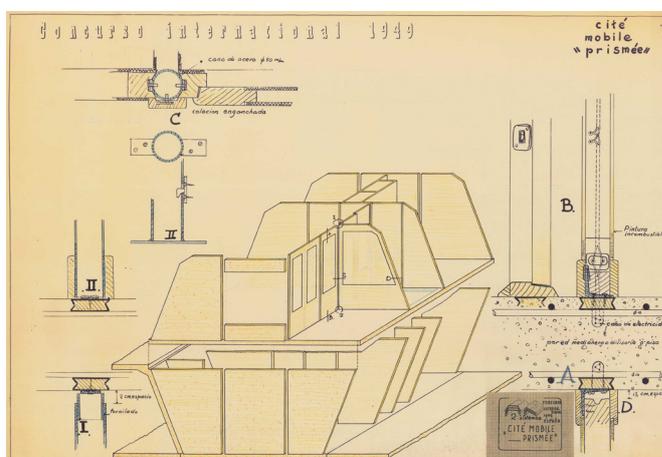
Although the similar use of the housing block roof, the construction system used by Jac Koolhaas and H. Groefsema it was very different to the Le Corbusier (*Unité d’Habitation*). [Fig. 20, Figs. 22-23] Le Corbusier used a mixed construction system: an in place reinforced concrete bearing structure in conjunction with prefabricated elements for façades and modular housing units.<sup>25</sup> [Fig. 21]

**Japan**

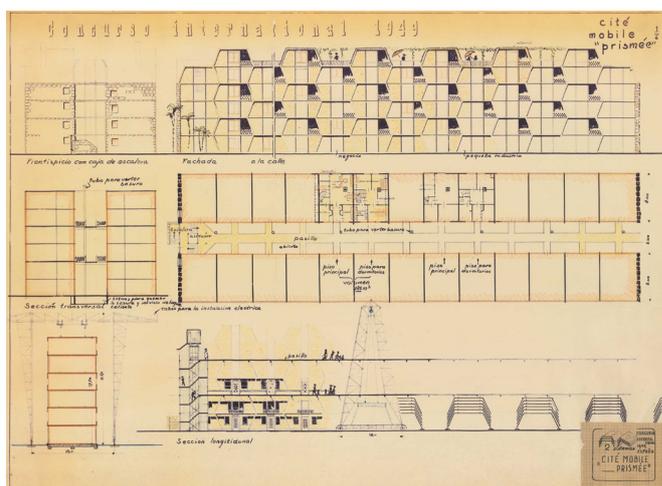
In 1949 Japan was undergoing intense industrial development despite the post-World War II changes in its land area, politics and economy.<sup>26</sup>



**FIG. 18** Jac Koolhaas, H. Groefsema, Reinforced concrete module manufacture and shipping, 1949 (Eduardo Torroja’s archive).



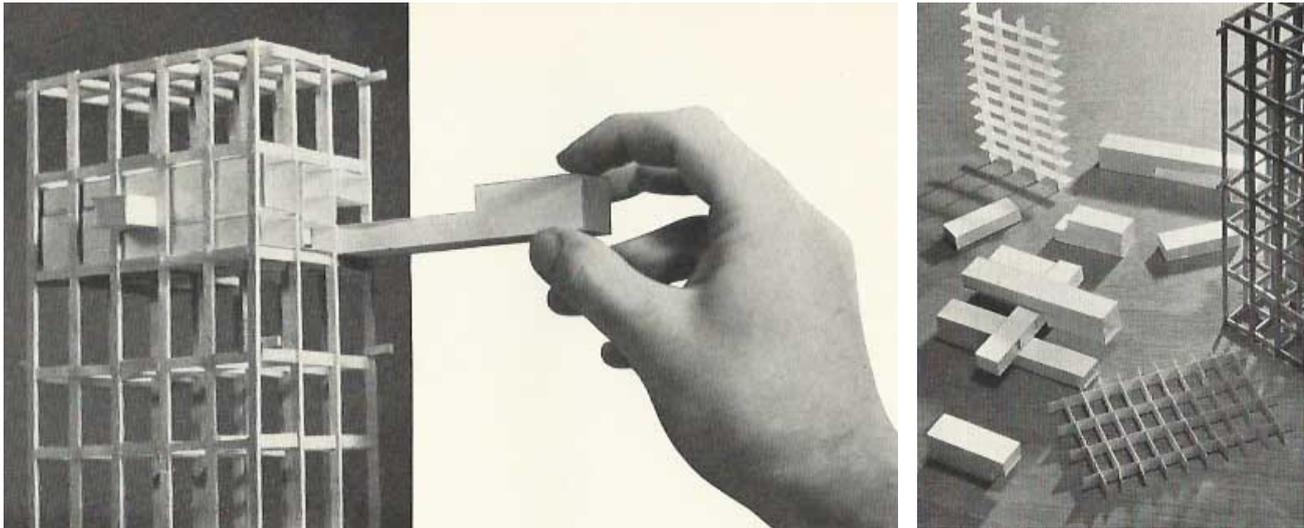
**FIG. 19** Jac Koolhaas, H. Groefsema, Module manufacture and assembly, 1949 (Eduardo Torroja’s archive).



**FIG. 20** Jac Koolhaas, H. Groefsema, Process of Construction, 1949 (Eduardo Torroja’s archive).

25. These modular housing units were not used to build it (*Le Corbusier 1938-46*, Zürich, Girsberger, 1950, pp. 178-93).

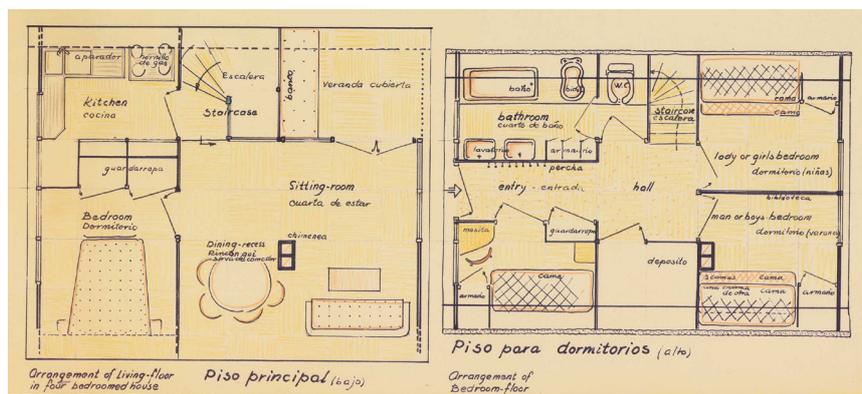
26. T. Nakamura, *The Post-war Japanese Economy. Its Development and Structure*, Tokyo, University of Tokyo Press, 1981, pp. 49-54.



**FIG. 21** Le Corbusier, Prefabricated elements for façades and modular housing units, 1947 (Eduardo Torroja's archive).

One of the factors that indisputably favoured industrialisation in Japan was the country's traditional modulated and coordinated approach to housing, which affected not only the dwelling per se, but also its furnishings, decoration and even domestic utensils. An article entitled *My house* by Japanese painter Sabro Hasegawa, carried in the same issue of "Art and Artist" as a paper by Eduardo Torroja, is particularly revealing in this regard. Hasegawa explained how Japanese homes are generated around a *tatami* or module with which a lattice of rectangular meshes is formed to build the floor. This lattice defines the proportions of all the rooms, which are sized to a certain whole number of *tatamis*.

The authors of the Japanese proposals for the international competition organised by Eduardo Torroja in 1949 were: Yoshiteru Tackechi (Tokyo), S. Seisaku Yoshikawa (Tokyo) and Gonkuro M. Kume (Tokyo). Architect S. Yoshikawa's proposal called for building continuous linear housing blocks across long lengths of Spanish soil, and using the roofs as roads. The proposal was reminiscent of an idea put forward by Le Corbusier in 1929 in Brazil.<sup>27</sup> Whereas the Swiss architect envisaged adapting the structures to Brazil's uneven terrain, however, the Yoshikawa proposal would have constituted an architectural blight on the landscape, as shown



**FIG. 22** Jac Koolhaas, H. Groefsema, Distribution of duplexes, 1949 (Eduardo Torroja's archive).

in the drawings of the units intended for construction in Spanish coastal cities. [Fig. 24] These continuous masses of housing blocks crowned by a road would have abruptly interrupted harmonious land – sea interaction and established a formidable physical barrier, depriving residents of both the view of the sea and the sound of its waves. This was indisputably a mistaken approach.

27. J. Guiton (ed.), *The Ideas of Le Corbusier on Architecture and Urban Planning*, New York, George Braziller Incorporated, 1981.

The justification for building a road over the flat roofs of the apartment buildings was the tolls that hypothetically could have been charged for its use. [Fig. 25]

The proposal included several types of duplex units, depending on the size of the family (two to seven members). The area of the smallest, for a two-member household, was 28.125 m<sup>2</sup> (single storey), while the largest, for families of seven, measured 75.00 m<sup>2</sup>. All the units had a balcony along the entire façade, accessed from the living-dining room and master bedroom. The dwellings designed for two-, four- and five-member families also had a large roofed balcony on the opposite façade. The units for families with six or seven members did not however, for this was the space used to add extra bedrooms in the larger units.

All the units could be enclosed in the same envelope built with the same bearing structure, i.e., the same number and arrangement of reinforced concrete portal frames. Under this attractive and efficient idea, the apartment buildings would be generated by stacking identical virtual boxes, which would either be empty or occupied depending on the number of family members. [Fig. 26]

The linearly interconnected housing blocks featured a number of community service areas spaced at 3 km intervals: churches, nursery and elementary schools, clubs and markets. The result would be miniature road cities where the inhabitants could find all the necessary facilities for everyday life. The construction system proposed was based on the use of a number of precast reinforced concrete elements, which could be optimally industrialised because most were identical components for the virtual boxes that defined the inhabitable space in each unit. The only elements that did not fit that pattern were the ones needed for the community service buildings. One of the many details that made the construction and structural design particularly promising was the thoroughly modern approach to the reinforced concrete parapet on the roof. Like other masters before him such as Frank Lloyd Wright or Le Corbusier, Yoshikawa used this element to ensure water-tightness at the abutment with the deck slab. In other words, the parapet and roof constituted the self-same construction unit. Construction was optimised by stacking the reinforced concrete wall, slab and portal frame modules from scaffolding positioned on the two parallel façades and raised section by section. In addition, the road on the roof of the finished sections could be used to move industrialised elements.

Moreover, although the typological organisation of different sized dwellings was impeccable and the industrialised reinforced concrete

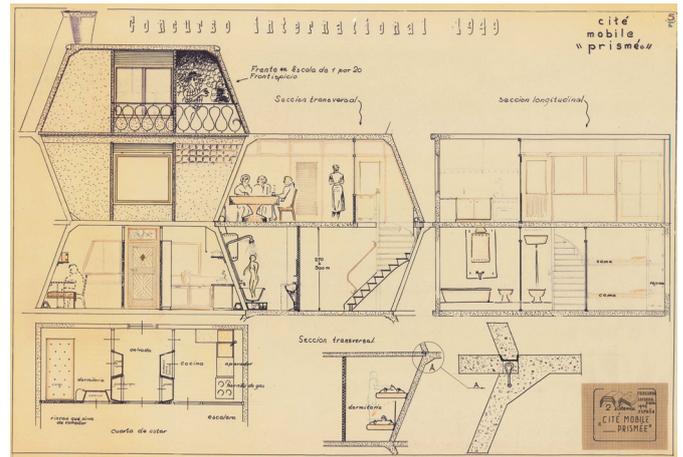


FIG. 23 Jac Koolhaas, H. Groefsema, Duplex cross-section, 1949 (Eduardo Torroja's archive).

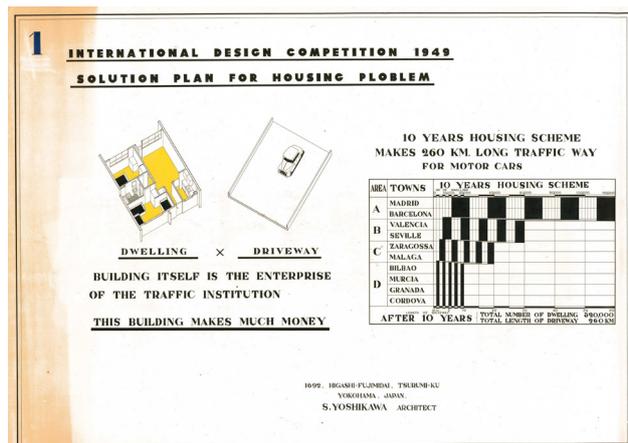


**FIG. 24** Seisaku Yoshikawa, Continuous mass of housing blocks crowned by a road, 1949 (Eduardo Torroja's archive).

members proposed would have optimised both the use of materials and the construction process, the economic viability of the proposal for mid-twentieth century Spain was questionable at best, irrespective of the suitability or otherwise of the road-city concept.

The proposal submitted by Japanese architect Yoshiteru Takechi included the design for only two types of single-family homes, and provided no data on their structural or construction systems, services, or the industrialisation of possible alternatives that would have been economically feasible in Spain at the time. [Figs. 27-28] Architectural space in these dwellings expressed the sentiment that had arisen after the establishment of New China in 1949, in which architecture echoed modernity's foreign influence while nonetheless conserving its traditional features. Although the design of these single-family dwellings was of excellent quality, the absence of specifications on industrialised construction, in conjunction with the failure of the units to comply with the standards in place for low-cost housing, led to the disqualification of the proposal by the judges for the international competition organised by Eduardo Torroja in 1949.

The schedule of uses and net floor areas in both units were in fact designed to standards much higher than applicable to low-cost housing.



**FIG. 25** Seisaku Yoshikawa, Road integrated in housing block, 1949 (Eduardo Torroja's archive).

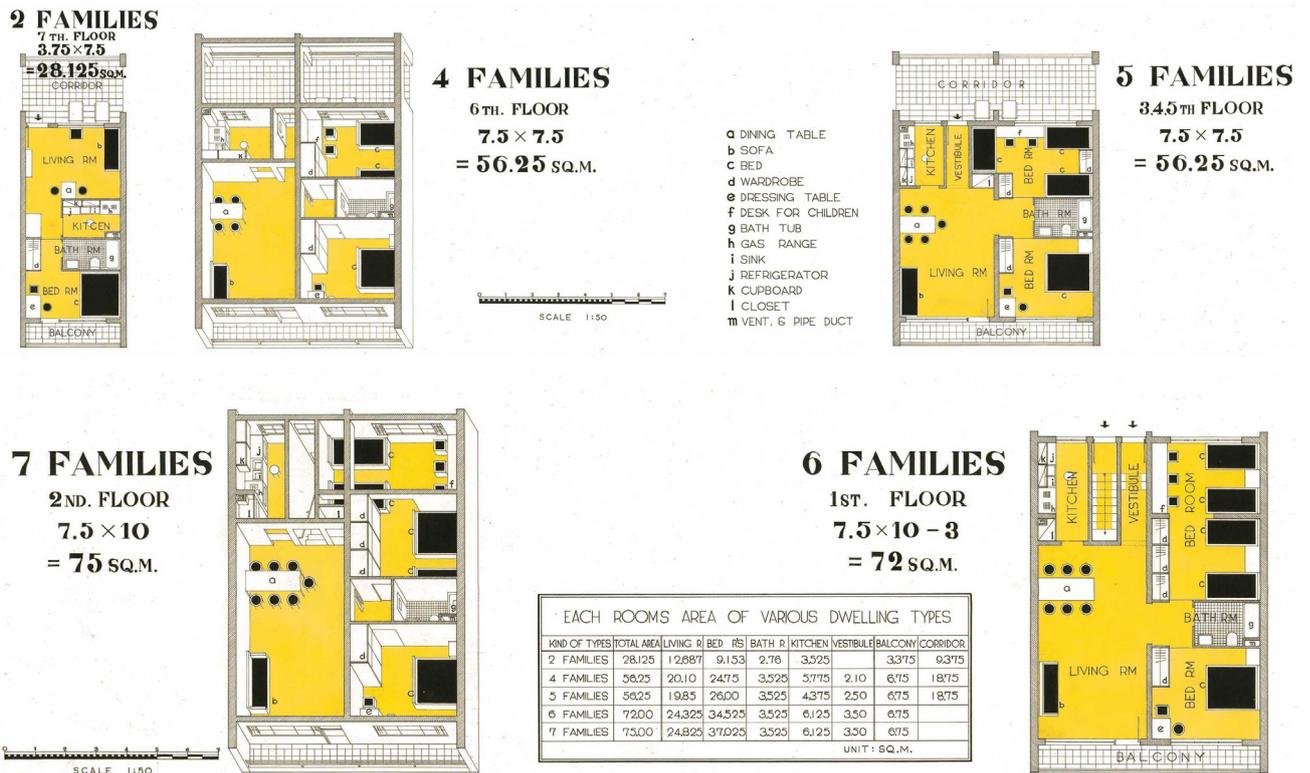


FIG. 26 Seisaku Yoshikawa, Types of units and floor areas, 1949 (Eduardo Torroja's archive).

These units would even today be regarded as luxury homes. Type A, a two-storey dwelling, featured a roof formed by two slanted planes of different sizes and heights pitched very steeply inward. [Fig. 27] The ground storey housed the vestibule, living room, dining room, kitchen, two children's bedrooms, the guest bedroom, a bathroom, a game room and a glazed gallery. The master suite, comprising a sun room, bedroom, dressing room and bathroom, occupied the upper storey. The home also had an indoor/outdoor garden in keeping with the Japanese tradition of integrating the garden into the home. Its organic form was frequently used by modernists such as Alvar Aalto for small gardens with geometric ponds and pools.<sup>28</sup>

While type B was smaller than type A, it was also designed to luxury dimensions. [Fig. 28] This flat roofed, linear, rectangular, one-storey home had a living-dining-kitchen area, two children's bedrooms, a master bedroom and a bathroom. A separate building connected to the house by a roofed pathway contained the garage and a lumber room. In the north wall, which delimited the hallway flanking the bedrooms, built-in closets alternated with "flower windows". This dwelling also had an indoor/outdoor garden, although here the geometry was trapezoid. The sun porch had a small pool. The volumes in this home were particularly attractive and characteristically modern. The main elongated box-shaped unit was perforated by a roofed porch along the south façade that projected outward at a right angle on one side to separate the home per se from the garage and lumber room.

The proposal submitted by Japanese architect Gonkuro M. Kume

28. J. Jetsonen, M. Lahti, *Alvar Aalto Houses*, Helsinki, Rakennustieto Oy., 2005.

was based on the construction of different types of dwellings with the masonry wall frames traditionally used in Spain. [Fig. 29] The novelty was that the bricks were made from coal ash. The quality of the dwelling layouts and their architectural design stood out among all the proposals submitted to Eduardo Torroja's 1949 international competition, but the floor areas were much larger than found at the time in low-cost Spanish housing. The result was that Kume's project had a higher cost than any of the proposals finally selected.

Gonkuro M. Kume had won the housing competition organised by the Japanese Ministry of Construction that same year and had been honoured with a distinction for his contribution to housing design in Japan.

The single family home proposed by Kume consisted of two storeys with two parallel façades and two party walls for attachment to other units. He

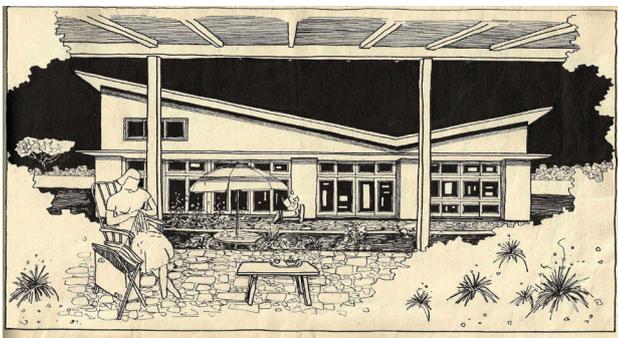


FIG. 27 Yoshiteru Takechi, Type A unit, 1949 (Eduardo Torroja's archive).

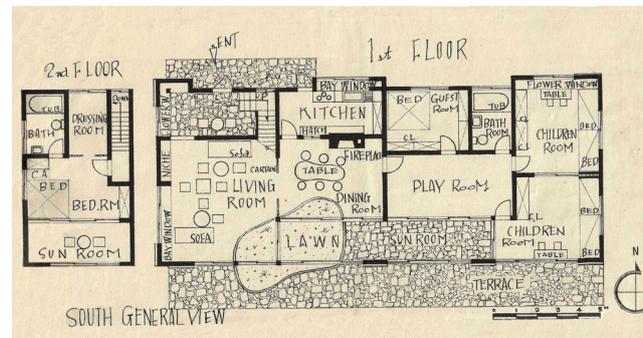
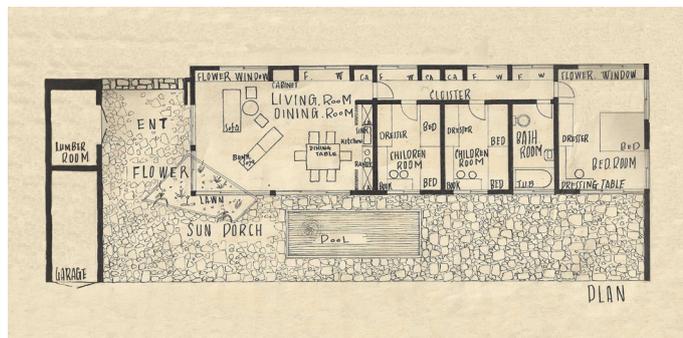


FIG. 28 Yoshiteru Takechi, Type B home, 1949 (Eduardo Torroja's archive).



proposed arranging the homes stepwise to break the linear monotony, a solution that would not only create moving shadows on the façades, but also guarantee each family greater privacy. The ground storey was to house the living room, dining room, kitchen, laundry room and porch, and the upper storey, two bedrooms, a bathroom, a small store room and a balcony along the master bedroom. The basic module measured 7 x 8 m in the plan view, with a void under the stairway positioned on the outer wall facing the private yard. The orthogonal bearing wall structure ensured suitable bracing for the building as a whole. The existence of four lengths with different span clearances raised costs, however, for the system would have called for industrialising joists and reinforcement bars of different lengths.

The rectangular four-storey apartment building, measuring 47.80 x 10.00 m, was to house twelve 10 x 6.80 m (68 m<sup>2</sup>) duplexes (in groups of six units). The dwellings were accessed from a roofed walkway that ran along the façade from the stairways positioned at the two ends of the building. The flat roof housed community services under an undulated lightweight awning. As in the case of the apartment blocks authored by Jac Koolhaas and M. Lovwrenburg, this arrangement for community services for building inhabitants was inspired by Le Corbusier's emblematic and innovative *Unité d'Habitation at Marseille* (1947-1952), where that revolutionary idea was put into practice for the first time.<sup>29</sup> The duplexes had living room, dining room, kitchen and balcony on the lower storey, and three bedrooms, a bathroom and tiny lumber room on the upper storey. The wet rooms were positioned to optimise pipe lengths, not only by placing kitchens and bathrooms back-to-back, but also by vertically aligning the lower storey kitchens with the upper storey bathrooms, for the lower storey was set back to make room for the aforementioned outdoor walkway.

While none of the Japanese proposals was awarded a prize, they all contributed to the modernity and rationality of the architecture present in the 1949 competition.

### United Kingdom

Although no British proposals were submitted to the 1949 competition, the U.K. made a significant contribution to the objectives pursued. The primary aim was to obtain information on industrialisation endeavours in other countries geared to solving the same problem that Spain had been facing since the end of its Civil War: an enormous housing shortage. The information gathered would be used to chart a straight course toward housing industrialisation in Spain.

As noted earlier, Eduardo Torroja designated Robert Fitzmaurice, at the time Deputy Chief Scientific Adviser to the British Ministry of Works, as a member of the jury. Fitzmaurice had engaged actively in solving London's post-World War II housing problem. Moreover, in addition to his specific expertise and direct involvement in housing construction, Robert Fitzmaurice was a scientist who shared with Torroja the conviction that production could not be researched in the laboratory, for the data had to be collected in factories and on worksites. He believed that the promise of the greatest success in production research lay in direct cooperation between research centres and the industry and identified the need for multi-disciplinary research teams able to address all the technical, industrial and scientific questions involved.<sup>30</sup> Fitzmaurice also shared Torroja's modern vision of construction, and applauded his untiring endeavour to turn housing into Le Corbusier's much craved machine à habiter.<sup>31</sup> The

29. The *Unité d'Habitation* at Marseille was without a doubt Le Corbusier's most significant and influential contribution to multi-dwelling housing. It consists of an enormous block characterised by innovative architecture and engineering, in which the Swiss architect established the guidelines for a new community lifestyle in which apartment buildings constitute miniature urban cells with all manner of shared facilities (nursery school, gym, infirmary, social club...).

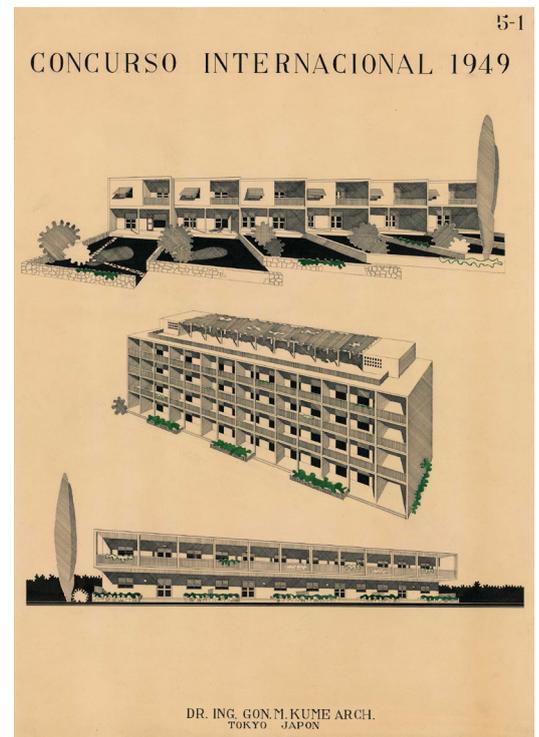


FIG. 29 Gonkuro M. Kume, Proposal for single-family and multi-dwelling units, 1949 (Eduardo Torroja's archive).

30. R. Fitzmaurice, *op. cit.*

31. R. Fitzmaurice, *Principles of Modern Building*, vol. 1, London, H.M. Stationery Office, 1949.

British expert provided Torroja with a detailed report of the his country's post-World War II mass housing experience. That report was published in 1950 by the Institute for Construction and Cement Engineering on Torroja's instructions, to provide the Spanish industry with information not only on the industrialised systems in place in the UK, but also on the specific reasons why certain alternatives were chosen over others. The report also described the research conducted in conjunction with builders and manufacturers with the intention of paving the way to the country's industrial future, a goal shared by Torroja for Spain. Robert Fitzmaurice brought invaluable experience to the competition jury's deliberations on the suitability of the proposals submitted.

### **1949 Competition/ Jury's Decision**

As a result of the international interest roused by the competition organised by Eduardo Torroja, the deadline for submissions had to be pushed back and the jury's decision was not forthcoming until December 1952.

As expected, in light of the extremely demanding requirements established, none of the 89 proposals submitted to the International Housing Competition on industrial design singly furnished an industrialisation scheme that could be implemented economically in Spain, given the material, economic, industrial and human resources available in the country at the time. For that reason, the jury decided not to award the 100 000 peseta first prize, which, according to the rules, was to be granted to the «best project for industrialising housing construction and building 50 000 units yearly».

Nonetheless, in recognition of the quality of many of the submissions, the obvious significance of the reflections taken as a whole and the effort deployed by the 17 participating countries to respond to Torroja's request for international support, the jury also decided to divide the 100 000 peseta prize among five projects: two, for 35 000 pesetas each, were awarded to Jules Cauvet (France) and Jesús Carrasco-Muñoz (Spain), and the other three, worth 10 000 pesetas each, to Arbeitsgemeinschaft Hebel (Germany), Bremen Wirtschaft Wiederaufbau-gesellschaft M.B.H. (Germany) and Société française de Constructions et Travaux (France) (Jury Report, signed on 29 December 1952). As the jury's report explained, these five submissions proposed the industrialised systems best suited to the conditions prevailing in Spain.

The objective of the competition was to collect proposals for industrialisation in building to solve social housing demands. Nonetheless, in light of the dates when those proposals were authored, anyone looking back on them today nearly inevitably seeks signs of modernity in their architectural designs. Indeed, at the time, one of the most important

changes in society was being driven by architecture itself at the hands of the many masters of modernity who focused on solutions to the housing problem that arose after World War II. Architects such as Walter Gropius, Frank Lloyd Wright, Richard Neutra, Le Corbusier, Jean Prouvé, Fuller, Kahn, etc. were directly involved in finding solutions to this problem, building emblematic homes that became milestones in this exciting part of the history of architecture. Another factor meriting retrospective analysis is the suitability of the approaches to the schedule of uses and distribution of inhabitable space in the low-cost housing adopted in each of the 89 proposals. The competition rules left key issues such as housing types, areas and volumes to the discretion of the participants. The message was that the architecture and types of units proposed would be the result of “freedom of design”, irrespective of the requisite to put forward industrialised construction schemes.

Leaving the choice of types of home and spatial distribution to the authors was an indisputably wise decision. As Walter Gropius and Frank Lloyd Wright contended, industrialisation in building did not need to curb freedom of design, although the type of housing and the lifestyle of its inhabitants had to be pre-defined to be able to establish the industrialised elements actually required for a given project. Unfortunately, none of these master architects took part in the 1949 competition, although some of the proposals submitted stood out for their architecture and housing programme. The three proposals submitted by Japan constitute prominent examples in this regard. Architect S. Yosikawa’s design, irrespective of his ill-considered proposal to turn the flat roof over apartment buildings into a road, envisaged excellent ideas for housing types, as discussed above. While the housing proposed by architect Yoshiteru Takechi involved no industrialisation scheme and was designed to luxury rather than low-cost standards, its spatial approach, straddling modernity and ancient Japanese tradition (with a small-scale indoor/outdoor garden) was inherently attractive. Gonkuro M. Kume, who had been distinguished with honours by the Japanese Ministry of Construction for his contribution to housing, submitted a proposal for apartment buildings that unquestionably sought their inspiration in Le Corbusier’s emblematic *Unité d’Habitation* at Marseille, built to the revolutionary premise that multi-dwelling buildings should be fitted with a generous variety of community facilities to foster inter-relationships.

In another very promising proposal submitted by German architect Franz Fischer, all the units were generated from a single module. While its suitability might be questioned, it afforded the advantage of providing for all the construction elements and structural members needed for the inhabitable space and alternating inter-block interconnection areas. He put forward the attractive and necessary idea of standardising architecture to a single module at around the same time that Le Corbusier put forward his famous *Modulor* concept for the *Unité d’Habitation* at

Marseille. Furthermore, Fischer, in an attempt to avoid the monotonous abuse of linearity that characterised apartment buildings, proposed blocks with large inner courtyards, in keeping with the Mediterranean tradition advocated by José Luís Sert.<sup>32</sup>

32. E. Munford, H. Sarkis, N. Turan (eds.), *José Luís Sert. The Architect of Urban Design, 1953-1969*, Cambridge, Massachusetts-New Haven, Harvard University Graduate School of Design, Yale University Press, 2008.

### Effectiveness of the 1949 Competition

The absence of a single awardee did not detract from the effectiveness of this international competition. Torroja acquired a wealth of relevant information on the most advanced construction systems and patents in use in other countries to build low-cost housing. He also obtained the results of “international reflection” on how to solve this problem in Spain, as well as a considerable number of helpful new international connections with engineers, researchers, manufacturers and government bodies in the 17 countries that submitted proposals. This final factor strengthened and broadened the role played by Torroja’s institute as scientific ambassador at a time when Spain was contained within air-tight borders and in dire need of doors and windows onto scientific and technological progress.

The 89 proposals submitted contained descriptions of a total of over 200 patents (IETcc, 1949). That valuable information was to serve Torroja to chart the course toward Spanish industrialisation, based on decisions on what and how to manufacture in Spain, which international patents were to be preferably given access to the national construction market, and which were to be acquired for domestic production. He was able to make those decisions on research and scientific and technical priorities drawing from the authority of his position as Director of the institute and the Central Laboratory, and from the financial support he garnered outside Spain.<sup>33</sup>

33. P. Cassinello, *Razón científica de la modernidad española en la década de los años 50*, in *Los Años 50: La Arquitectura Española y su compromiso con la Historia*, Pamplona, T6 Ediciones, 2000, pp. 21-38 (conference proceedings, Pamplona, Escuela Técnica Superior de Arquitectura de la Universidad de Navarra, 16-17 March 2000).

Clear documentary proof of the effectiveness of the competition can be found in the greatly enhanced internationalisation of “*Informes de la Construcción*”, the institute’s voice in print, after 1952. Many of the patents submitted to the competition found their way into its pages. Others began to appear on the Spanish market under the guidance of the institute headed by Eduardo Torroja, along with yet others that arose on the international marketplace in the prosperous nineteen fifties and sixties, as countries everywhere slowly recovered from World War II. The journal acted as a scientific and technical crucible, publishing information on the most innovative prefabrication systems used in countries such as the United States, Germany, France and Sweden. In keeping with Torroja’s emphasis on the transfer to the industry of research results, the articles describing advances always explained their specific utility for the materialisation of modern architectural design. The journal consequently carried a mosaic of articles dealing with different but inseparable information: reflections on design, patents, construction systems, prefabrication, innovative housing and the research underway. The vast

number of articles published is neither possible nor necessary to list here. Nonetheless, some of the more prominent included: the evolution of the lightweight precast concrete panels used by Walter Gropius; the use of the Ytong patent to build mass housing in Sweden,<sup>34</sup> which had been submitted to the international competition a few years earlier and which is still evolving today; the homes built by Chermayeff and Cutting in Massachusetts with lightweight industrialised steel elements, with a simple post-tensioned structure based on thin wires concealed behind the façades; the new ICO forms devised by British Engineering; the new home built by Frank Lloyd Wright (who gave Torroja an original watercolour of his famous Falling Water), subsequently featured on the cover of "Informes de la Construcción"; Zerrfuss's experimental buildings at Pont de Sèvres-Paris; a bubble home in Florida, U.S.A; the new Dutch folding form system; the Venezuelan National Building Plan; prefabrication in France; German construction equipment; the use of Shockbéton in precasting; the HB-timber prefabrication system; the U.S. organisation and hiring method followed on European worksites; Goff's Bavinger House; SOM's (Skidmore, Owings, Merrill) Lever house; the Italian housing problem; a modular building in Pretoria; Lewicky's prefabricated housing with large-scale elements; an enlargeable single family home; housing in Sweden; the household arts exhibition in Paris; apartment buildings in Zurich; the Baur-Leonhardt prestressing system; Marcel Loods's housing design for the Strasbourg Congress; a housing block in Lausanne; construction of 168 low-cost units in Seville; and the Interbau, International Construction Fair at Berlin. Soon after the 1949 ground breaking, Le Corbusier's *Unité d'Habitation* at Marseille was the subject of several journal articles on a variety of design and construction matters.<sup>35</sup>

In parallel, the journal carried articles on the most prominent housing projects underway in Spain, authored by architects such as Gabriel Ruiz Cabrero, Luís Moya, Francisco Javier Saenz de Oiza, Miguel Fisac, José Antonio Coderch, Antonio Fernández Alba, Antonio Lamela and Rafael de la Hoz, to name a few, and on domestic patents that were developed with the technical and scientific support of Eduardo Torroja's institute. Likewise in a 1952 issue of the journal, in the wake of the 1949 competition, the institute announced the creation of a special publication service for domestic and international construction patents and systems. That the announcement was published in Spanish, English, French, German and Italian stands as further evidence of the journal's international affinities.<sup>36</sup>

[Fig. 30]

### Second Milestone/ Industrial Productivity Commission

After the 1949 competition, the second milestone in the strategy implemented by Torroja to chart a suitable course toward Spanish industrialisation was the establishment of the Industrial Productivity

34. G.A. Rychner, *El hormigón ligero en Suecia*, in "Informes de la Construcción", 1953, No. 56, n.p.; W. Schmidt, *Sistemas de prefabricación en Suecia*, in "Informes de la Construcción", 1954, No. 79, n.p.; and *Empleo de elementos constructivos YTONG en la construcción de viviendas prefabricadas en Suecia*, in "Informes de la Construcción", 1956, No. 79, n.p.

35. P. Cassinello (ed.), *Eduardo Torroja 1949. Strategy to Industrialise Housing in post-World War II*, Madrid, Fundación Eduardo Torroja, Fundación Juanelo Turriano, 2013.

36. P. Cassinello, *El Espíritu impreso de una idea/ The spirit of an idea in Print*, Madrid, Instituto de Ciencias de la Construcción Eduardo Torroja, Consejo Superior de Investigaciones Científicas, 2008. Full book freely available on-line on [www.csic.es](http://www.csic.es) (Spanish National Research Council website).

Commission by the institute he headed, in conjunction with the Spanish Government. The Commission's remit was to analyse industrialisation in housing on the U.S. market, where the wealth of material and economic resources, together with the immigration of reputed master architects, afforded a unique opportunity to obtain information that would be highly relevant to the ongoing task of industrialising Spain. Institute engineers and architects travelled to the United States, where they visited manufacturing plants, works underway and many of the leading modern architects involved in housing construction, including Richard Neutra, Frank Lloyd Wright, Mies van der Rohe, SOM and others.

The team members were the institute employees who sat on the Low-cost Housing Sub-commission: Eugenio Aguinaga, Salustiano Albiñana, Ignacio Briones, Cayetano Cabañes, Fernando Cassinello, Vicente Figuerola, Juan María Martínez Barberito, Julio P. Frade and Carlos de Miguel. The mission was to ascertain WHAT was manufactured, HOW the products were used on site and WHAT type of architecture drew from these industrialised elements. That was, in essence, the full cycle of the *raison d'être* of industrialisation in civil engineering and architecture. The data gathered by the commission added to the list of known foreign patents and experiences, in this case with all sights trained on the progress made in the United States. Moreover, as Eduardo Torroja and Robert Fitzmaurice noted on the occasion of the 1949 competition, the scientific understanding acquired through the in situ visits to cutting-edge American manufacturers and the worksites using their products could never have been obtained from the mere review of the respective designs.<sup>37</sup>

Although the construction industry varies from one country to another due to differences in financial and social systems, economic development and governmental organisation, the common denominator in all countries is the difference between the building and manufacturing industries. Architecture cannot be "industrialised" unless the same organisational and rationalisation principles are applied to design, material and element manufacture, dimensional coordination and on-site assembly. From that perspective, the analysis of experiences in other more industrialised countries was to be of utmost utility in Spain, which was saved the chore of embarking on costly experimental ventures to verify the viability of the enormous variety of alternatives on offer, and testing their technical suitability with scientific methods and specific systems. Torroja well knew that such experimentation and testing are requisite to the implementation of even the simplest untried assembly line method.

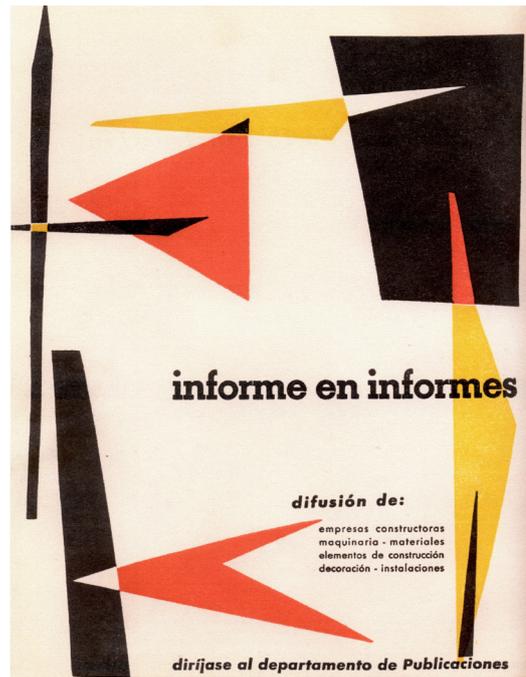


FIG. 30

Announcements in "Informes de la Construcción". Domestic and foreign patent and corporate publication service, 1952 (Eduardo Torroja's archive).

37. See *Announcement of the International Housing Competition on industrial design*, in "Informes de la Construcción", No. 12, n.p.

Why the United States? Because its vast economic resources and much criticised “wasted imagination” had already led to the development and subsequent rejection of a wide range of prefabricated element production systems, and each new failure had contributed to mapping the road to follow. By 1957 most of the compact precast reinforced concrete or prefabricated timber systems had given way in the United States to the prefabrication of industrialised elements. The enormous variety of standardised products available aimed to expedite and simplify construction tasks, lower production costs and enhance quality while at the same time protecting the “freedom of design” that ensured the personalisation of architecture at any place or time. In this regard, despite the differences in their training, personalities and specific approaches to architecture, the master architects who had emigrated from Europe to the United States, including Walter Gropius, Richard Neutra, Mies van der Rohe and Saarinen, shared one conviction: «architecture is the offspring of freedom and as such should not be constrained by the industrialisation of its production process».

The members of the Industrial Productivity Commission visited the major U.S. prefabrication factories and plants, a number of worksites involving very different types of housing, highly reputed general contractors and a host of official bodies and institutions engaging in standardisation, dimensional coordination and industrialisation. In addition, they interviewed all the masters of modern architecture in their respective studios, visited their worksites and gathered their opinions on the future of industrialised architecture. The commission also benefited from the cooperation furnished by the International Cooperation Administration in Washington, the Public Housing Agency (PHA) and the Federal Housing Administration (FHA), as well as the National Association of Homebuilders (NAHB), a trade association that accounted for a significant share of the American market. They were also assisted by prominent architects such as Frank Lloyd Wright [Fig. 31], Satterle, Smith and Goormann in Washington, Goleman and Rolfe in Houston, Pereira and Luckman in Los Angeles, Shaw, Metz and Dilo in Chicago, Skidmore, Owings and Merrill (SOM) and Webb and Knapp’s New York office, in addition to the aforementioned Walter Gropius, Richard Neutra, Mies van der Rohe, Saarinen, Spanish architect José Luis Sert and the professors and deans of Columbia University and the University of Urbana.

Despite the unanimous position in favour of the industrialisation of architecture adopted by these masters of modern architecture, as narrated in the Industrial Productivity Commission reports, their ideas and concerns revealed different perspectives. Frank Lloyd Wright believed



**FIG. 31** Industrial Productivity Commission interview with Frank Lloyd Wright at Taliesin West, Arizona, 1953 (Eduardo Torroja's archive).

that while industry was still far from being able to define the scientific, technical and artistic premises from which to evolve, he did not rule out the possibility. At the same time he staunchly defended freedom of design, which he felt might be enhanced if industrialisation proved to be “suggestive” for architects. Mies van der Rohe, by contrast, stressed the advances made to date by the industry, which had enabled him to build his extraordinary steel and glass skyscrapers with industrialised elements that could be rationally and readily assembled on site. He also insisted that, given the decisive impact of the “structural skeleton” on the possibilities and limitations that go into architectural personality, it is a necessary and prominent lodestar in the sort of industrial evolution without which his “glass boxes” could never have existed. Spanish born architect José Luís Sert, in turn, at the time Dean at Harvard University, shared Walter Gropius’s and Richard Neutra’s opinion on industrialisation and, like them, used the interview as a sounding box to complain about architects’ lack of involvement in architectural production, particularly in the case of housing, which he deemed would remain an endlessly unresolved issue, for architecture would need to continually adapt to scientific and technical progress and changing social demands. He also identified the need to revisit the industrial market and reconsider the existing “architectural housing types”, which had been distorted, despite having been analysed by both the Federal Housing Administration (FHA), created by an act of Congress in 1934, and the National Association of Home Builders, which at the time had 277 member associations and 40 000 members across the country, primarily contractors and manufacturers.<sup>38</sup>

Walter Gropius and Richard Neutra were unquestionably the commission’s two beacons. These masters of modern architecture had led industrialised housing for many years and repeatedly called upon architects to become directly involved in the industrialisation of their craft. Both were engaging at the time in the difficult venture of defining unit types for industrialised low-cost housing and designing patents adapted to the contemporary American market. More or less oblivious to the criticism levelled at them from many angles for their failure to find the “philosopher’s stone”, they encouraged architects not to forsake the industrial production of low-cost housing. In that respect as well as in others, they contributed to the development of promising albeit short-lived proposals, for even in the nineteen fifties their adopted country was characterised by a dizzying pace of change. Walter Gropius, in an attempt to recover the ground lost by architects in the United States, mostly to home builders, had founded his General Corporation with Konrad Wachsmann to prefabricate patented timber elements for housing, in keeping with American construction industry tradition. For their famous packaged houses, they developed a four-way metal connector to allow architects greater freedom of interconnection in their designs.<sup>39</sup> Moreover, this system reduced the number of different elements that had

38. The National Association of Home Builders (NAHB) is one of the largest trade associations in the United States. Headquartered in Washington, D.C., NAHB’s mission is “to enhance the climate for housing and the building industry”. Founded in 1942, NAHB is a federation of more than 800 state and local associations. About one-third of NAHB’s more than 140 000 members are home builders or remodellers. The remaining members are associates working in closely related fields within the housing industry such as mortgage finance and building products and services.

39. B. Bergdoll, P. Christensen (eds.), *Home Delivery: Fabricating the Modern Dwelling*, New York, The Museum of Modern Art, Birkhäuser Architecture, 2008.

to be manufactured, simplifying and lowering the costs of manufacturing and on-site assembly. Richard Neutra, in turn, who called his own home a «research» house, developed patents for affordable housing with very different materials and layouts. One of his projects, the Diatom House, was designed to be built with steam-hardened earth, portable steel foundations adapted to the terrain, wooden structural panels (Los Angeles 1936 World's Fair) and standardised steel shapes, all under the umbrella of a concern for the attainment of social integration through decent housing.

Standardise, industrialise, prefabricate.... but what and for what? These were the questions that the members of the Industrial Productivity Commission constantly posed. Walter Gropius contended that housing could never be mass produced in the same way as compact and impersonal products such as refrigerators, car, airplanes or fans. Construction elements and structural members, whether linear, superficial or three-dimensional, needed to be industrialised to guarantee many connection and interconnection alternatives with which to personalise not only inhabitable space, but the architecture itself, while securing the advantages of mass production: quality, low cost and convenient assembly. This opinion, shared by a growing group of professionals, was nonetheless countered by widespread prejudice against prefabrication, based on the erroneous belief that it would necessarily father monotony and constrain freedom... as if manual construction systems were a paradigm of creativity.

Although Eduardo Torroja's institute also analysed the models for industrialisation in building in Europe, its analysis of the, at the time, economically prevalent American market<sup>40</sup> was decisive in many respects. In the nineteen fifties labour was already expensive and in short supply in the United States, accounting for 60 to 70 % of total building costs, with the remaining 30 to 40 % spent on materials. Despite their relatively low cost, the latter were high quality industrial products. Spain's problem was just the opposite: materials were overpriced and of poor quality, often amounting to 70 % of the total cost of the works. The need to lower labour costs had already been addressed in the U.S., not only in the implementation of industrialised elements, but in the rationalisation of building itself. The use of small crews and advanced ancillary equipment rationalised construction of the end product – architecture. Most low-cost single family homes were prefabricated, 80 % with timber patents and elements, while multi-dwelling blocks were built with different types of industrialised materials: 60 % reinforced or prestressed concrete, 30 % steel and 10 % lightweight cement blocks. The types varied with the region of the country.

After analysing the data collected, the Industrial Productivity Commission raised its recommendations for the adaptations that would

40. Although Spain was excluded from the Marshall Plan, the U.S. accepted the request for scientific-technical assistance posed by Eduardo Torroja through Spain's Industrial Productivity Commission. The Marshall Plan (officially the European Recovery Program, ERP) was the American programme to aid Europe, in which the United States gave economic support to help rebuild European economies after the end of World War II. The plan was in operation for four years beginning in April 1948.

be needed for implementation in Spain of the systems, patents, materials and processes reviewed. In this long list of reflections, analyses and proposals for the future of Spanish industry, all the sub-commissions concurred in identifying a pressing need for “standardised types”. They further called for scientific support to be able to rationalise production processes, for manufactured elements as well as for architecture itself, beginning with the design stage.

While a full account of the commission’s survey is not relevant here, it was an indisputably overwhelming, useful and fascinating experience. Like the industrialised housing competition organised by Eduardo Torroja in 1949, it constituted a significant and emblematic encounter with the state of the art that would help Torroja to pave the way toward Spanish industrialisation while reinforcing his international connections and with them the institute’s “ambassador” role. This experience was also echoed in “*Informes de la Construcción*”, which soon after began to expand its list of chosen authors and reinforce its international affiliations, just as it had after the 1949 International Housing Competition on industrial design. In this new phase, Eduardo Torroja’s institute established close working relations with the famous Sidmore, Owings and Merrill, or SOM architectural partnership, many of whose designs and works received write-ups in the journal. Richard Neutra, in turn, who had been writing in “*Informes de la Construcción*” since 1949, also intensified his relations with the institute, to which he bequeathed a considerable portion of his writings and drawings. This legacy was the subject of journal articles for over 11 years and finally published in a book edited by Fernando Cassinello.<sup>41</sup>

### Third Milestone: Meet the Institute...

The third milestone in Torroja’s strategy to industrialise Spain was the construction of the institute’s new headquarters, which he turned into a “field laboratory” for the on-site prefabrication of many of the structural members and construction elements called for in the design.<sup>42</sup>

### Conclusions/ Effectiveness of the Strategy

Eduardo Torroja’s industrialisation strategy was in fact effective, as regards not only housing, but Spanish architecture and civil engineering in general. His success was mirrored in the research conducted and the activities undertaken around the three aforementioned milestones:

- 1949 International Housing Competition on industrial design
- Spanish Industrial Productivity Commission in the United States
- The construction of the new ITCC (Instituto Técnico de la Construcción y del Cemento) headquarters/ *Meet the institute...*

41. Architect Fernando Cassinello was designated by Richard Neutra as the executor of the legacy bequeathed to the Institute for Construction and Cement Engineering. At the time, Cassinello was editor-in-chief of “*Informes de la Construcción*”. He also served on the Spanish Industrial Productivity Commission that visited the United States. In 1969, eight years after Torroja’s death, he was appointed director of the Eduardo Torroja Institute.

42. *El Instituto es Así: Prefabricación*, in “*Informes de la Construcción*”, 1954, No. 58, n.p.

These milestones, in conjunction with Torroja's untiring research and support for the industrial development of new patents in Spain contributed to the modernisation and internationalisation of the domestic market, enabling the country's architecture to follow the road to modernity. Pier Luigi Nervi placed particular emphasis on the institute's role in that regard in the conference he delivered at the new headquarters in 1959 on the occasion of its 25<sup>th</sup> anniversary.<sup>43</sup>

In addition to developing its own patents, the institute provided technical and scientific support for the development of innovations put forward by professionals, builders and manufacturers. As a result of that endeavour, many new products and systems were patented in Spain in the years of greatest need, when a wide variety of elements, including joists, bolts, window joinery, insulation, pan forms, bricks, prefabricated products and prestressing systems, flowed onto the domestic market. Each and every one was the outcome of dedication and effort at a time when development was especially challenging. Some, such as the Barredo prestressing system (1952), even competed with international patents (Freyssinet, Mangel, BBR, VSI, CCL and others) and came to be known as the Spanish prestressing system. Torroja used that patent in many of his works, not only because of its technological suitability and the lack of foreign prestressing systems, but also to further the development of Spanish industry.<sup>44</sup> Engineers and architects such as Ildefonso Sánchez del Río and Miguel Fisac engaged directly in the commercialisation of new patents, some of which, including the former's famous bricks or «bones» (hollow prestressed concrete blocks) were developed and tested at the institute. Spanish professionals contributed individually with their own private efforts to fill the «kit of parts» proposed by Le Corbusier, the intentional leit motif of this paper. That very popular simile was echoed in the design and promotional activities conducted by the Bauhaus, which even put together an educational kit of parts for children, a toy that enhanced their creativity with a series of miniature "industrialised" parts for building all manner of objects: homes, ships, airplanes, bridges and many others. Other patents developed with the institute's support were directly associated with the low-cost housing competitions organised in the nineteen forties and fifties in Spain and with the national home building plans. The institute also blueprinted national competitions for industrialised elements sponsored by the National Housing Institute, such as a steel tie bars competition held in 1956, with a view to the practical application of the proposals in the construction of low income housing. Its creation of quality seals, in

43. Pier Luigi Nervi, *La Arquitectura Moderna*, in *Sesión Académica conmemorativa del 25 aniversario de la fundación del i.t.c.c. (bodas de plata 1934-1959)*, Madrid, ITCC, 1959.

44. P. Cassinello, *La relevante labor del Instituto Técnico de la Construcción y del Cemento en el desarrollo del hormigón pretensado: Material, Técnica y Arquitectura*, in F. Gonzalez (ed.), *Fisac. Huesos varios*.

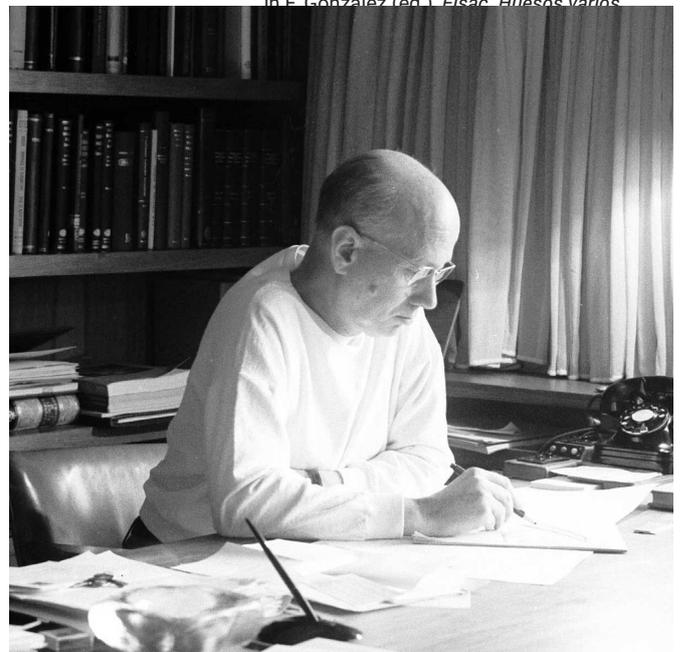


FIG. 32 Eduardo Torroja, 1955 (Eduardo Torroja's archive).

turn, led the way to the control of manufactured elements, and it engaged actively in drafting standards and publishing the Spanish translation of the books of greatest interest authored in other countries. This extensive and multi-directional task took the *raison d'être* of research full circle.

By 1961, the year of Eduardo Torroja's death, the Spanish kit of parts was nearly full. [Fig. 32] And its industry continued to move forward toward architectural progress. The course had been charted.

«To those of you who worked with me: [...] others will be able to judge the work that was done better than I. But more important than that is its potential. My only contribution was successfully selecting the people and creating an atmosphere of teamwork and cooperation; the rest of the merits are all yours. And much more than the technical results themselves, I value the human, social and professional dimensions of the experience», Eduardo Torroja, 1961 (Excerpt from his last letter)