Marcel Breuer and Jean Barets in Bayonne (1964-68): the use of architectural precast concrete panels in large public housing schemes

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Abstract

A new concept appeared in the field of precast concrete in the early 1960s: the architectural precast concrete panel. Unlike the first panels produced in post-war Europe, the architectural panel would be subject to an architect's specific design, not subject to contractors' patents, and applied to both singular, bespoke projects and large commercial projects with much repetitive construction. Marcel Breuer was the architect who more than any other supported this new concept, thanks to the knowledge of the precast concrete industry he had acquired in his early French projects. This paper highlights one of those works: the Zone à Urbaniser en Priorité in Sainte-Croix, Bayonne (1964-1968), by comparing it with previous projects. Within this project, Breuer and Jean Barets, chief engineer at the Compagnie Française d'Engineering Barets (COFEBA), developed a number of ideas relating to the design, manufacture and use on site of the architectural panel for the first time in a large public housing development in a competitive and cost-effective way and under strict budgetary constraints. The solution that they put into practice in France, represented an ingenious alternative regarding to the types of panels that began to be commercialised in the USA few years before, that were based on a plant production and for which attachment sophisticated and expensive anchors should be employed.

Key words

Marcel Breuer; Jean Barets; ZUP de Sainte-Croix; Bayonne; 1960s; architectural precast concrete panel.

From the post-war precast panel to the 1960s architectural panel

The economic and financial difficulties and the urgent need for housing arising from the two world wars in the twentieth century forced European countries to find new building systems in order to build both quickly and economically. For decades after World War II, and thanks to the technical advances in the use of prefabricated reinforced concrete, as well as the momentum of the European Recovery Programme, known as the Marshall Plan, hundreds of new patents appeared across Europe producing all kinds of new ideas needed for the construction of large-scale housing projects.

In Great Britain, following World War II, there was a surplus in steel and aluminium production, and an industry in need of diversification because, until then, it had been geared up for the war effort. These factors greatly influenced the development of prefabrication and over the next thirty years more than 500 new systems were registered; these included for example Cornish Units, Airey, Reema Hollow Panel, Wates and Unity which were the main precast concrete systems being used.[1] In Germany, the Plattenbauten prefabricated construction method was employed both in the East and West, particularly in public housing. There were different types of large-panel system such as WHH GT 18, WBS 70 and Type P2, created in 1960, and which became the most commonly used type in the German Democratic

Republic until the 1970s.[2] Furthermore, in the Nordic countries, major collective social housing programmes were promoted, such as the "Montage Program" in Denmark (1960) and the "One Million Apartment Programme" in Sweden (1964), where the Strängbetong precast concrete system was used mainly for the development of apartment buildings.[3]

However, it was in France where the prefabricated industry gained greatest momentum.[4] During the reconstruction period after World War II, a major renovation was led by the *Ministère de la Reconstruction et de l'Urbanism* (MRU). It drove the transformation of the construction industry by encouraging research into new ways of building in order to increase housing production.[5] In the mid-fifties, as a direct result of this policy, at least 144 systems of prefabrication for walls and building enclosures were developed in France, including the Camus System, Panobloc elements for façades, Mopin panels and the Balency & Schul patent.[6]

It was in fact in the domain of the external cladding of buildings where the largest number of systems and patents were produced. Panels of all types were developed, with varying degrees of prefabrication, some load-bearing, some with the incorporation of building services and with a wide range of finishes. Across Western Europe, as the transition between the reconstruction period of the early 1950s and social development occurring from 1960 onwards was virtually complete, a new concept emerged in the field of precast concrete: the architectural precast concrete panel. Whilst the European post-war systems consisted of standardised, economic patents with limited versatility, the architectural precast concrete panel would be developed within the rapidly expanding US industry for use as an *ad-hoc* prefabricated system. Its purpose was completely different from that of the panels used in social housing during the reconstruction period. In the early panels, social housing design had to be adapted to suit a previously manufactured product, whereas the architectural panel could be produced to suit a specific, bespoke design; this resulted in some remarkable buildings owned by large companies, such as the IBM Office Buildings in Kalamazoo (Michigan) and Omaha (Nebraska), both designed by Gordon, Levin and Associates in the mid-sixties.

Of all the architects of the Modern Movement, it was Marcel Breuer (1902-81) who contributed most to the technology of architectural concrete panels. His early work in France played a key role as it had helped him become familiar with the precast concrete panel industry, and he also had the chance to deploy a wide range of customized solutions. The knowledge Breuer acquired during the development of these buildings was crucial in the later development of architectural panels which were extremely successful in the United States until the early seventies.

The aim of this paper is two-fold. First, to look at some early projects in which precast panels were used by Breuer, and to show the development of his innovative ideas and techniques in design that were used in some important buildings. Secondly, to introduce a little-known project in which precast panels were used: the *Zone à Urbaniser en Priorité* (ZUP) in Bayonne (1964-1967), a Priority Development Area located in the borough of Sainte-Croix, in which 4,700 precast panels were specifically designed and manufactured on site between March 1967 and June 1968 to form façades to seven new residential blocks in the area. Breuer demonstrated with this project that architectural panels could also be used in large public housing developments where there was strict budgetary control, by making decisions that affected the design, manufacture and production on site.

Breuer's first architectural concrete façades

It is no coincidence that it was in France where Breuer and his partners began to test prefabricated concrete elements for the first time. France had already been using reinforced concrete for over 100 years and also there was already a close, fruitful relationship between architects and engineers, with State backing which resulted in new building systems and more efficient construction techniques for the reconstruction of the country.[7] It was the engineer and industrial entrepreneur, Jean Barets (1921-90), who played a major role in advising Breuer on his works, and whose system of single-storey-high load-bearing walls, known as the 'Barets method', had been used by at least twenty companies by 1962.[8]

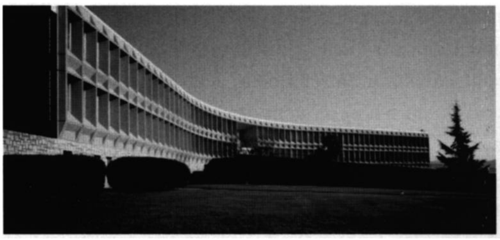
The first three projects in which Breuer and Associates used architectural panels were at the Flaine Ski Resort (Haute Savoie, France 1960-76) and the IBM Research Centre (La Gaude in the department of Var in southern France, 1960-62), and the offices of the Department of Housing and Urban Development Headquarters in Washington (1964-66). These three projects predate the Priority Development Area in Sainte-Croix, Bayonne, which commenced construction in 1964 shortly after the firm had opened its office in Paris. In this project, the architects wanted to show the advantages of using such panels; on the one hand, the way in which they could be designed gave great freedom to incorporate a window, or shading devices such as a parasol or a lattice; on the other hand, due to the ongoing development in precast production at that time on both sides of the Atlantic, the reduction in manufacturing costs of the panels became an important factor. These developments in design and technology allowed small batch production of panels to appear that were not subject to patents.

The architects used the panels to show off their own creativeness in design on the elevations of particular projects. Consequently, the precise form of the panels evolved differently in each project and gave each building its own identity. In addition there were other developments such as the differing textures of the panels. This was achieved by varying the colour of the aggregate and the matrix, the size of aggregate and by changing the finishing processes for the concrete.[9] It was evident that the industrial, economic and technological uses of these panels on these sites became an important factor in their development.

IBM-La Gaude (1960-1962)

The first project in which Breuer and Associates used these precast concrete panels was at the new research centre of the American multi-national company, IBM in La Gaude which was opened in 1962. It was a two-storey laboratory building in which the elevation (curved on plan) also acquired considerable height due to the use of deep edge beams, which were necessary to allow room for the air conditioning ducts to be located in false ceilings. (Fig. 1) In addition to giving protection against the weather, the panelling was load bearing carrying loads from the roof and upper floors down to the columns on the ground floor.[10]

On the advice of the contractors Dumez, Breuer and his partners used concrete panels to form the façades, influenced by the existing building façade on the site. Furthermore, the contractor suggested producing them *in situ*. Before making the final decision, the architects analysed each detail of the panels' manufacture, and ordered some full-scale prototypes from the contractor to check quality. Even if the panels were prefabricated, their final position was unclear, because the formwork used for their construction was made of dovetailed timber boards instead of using plywood or steel sheets. The texture obtained with the timber boards is one of the features of *in situ* concrete and contributes towards a natural integration between the façade panels and other nearby elements, such as the walls and columns that were built by using *in situ* concrete. The panels, which were designed to form a two-metre module, frame up the long narrow windows which were set back by about 90 cm from the external face of the building in order to protect the interior space of the laboratories from the Mediterranean sun. Breuer recreated the same façade six years later in a project designed for the laboratories of the Sarget Pharmaceutical Company in Bordeaux, on the Atlantic coast.



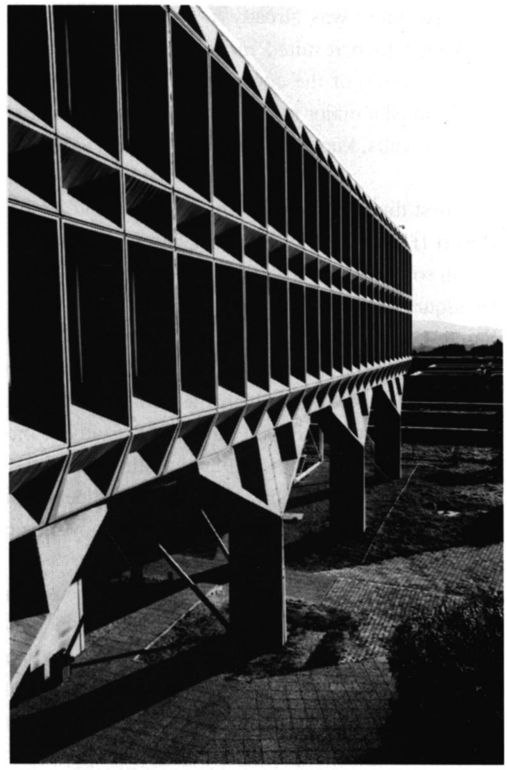


Figure 1. The research centre of IBM La Gaude. Photographs by Chris Wright@Electricalimage.

Flaine Ski Resort (1960-1976)

At the same time as the IBM Research Centre was being built in La Gaude, the businessman E. Boissonnas proposed the construction of a new Ski Resort in Flaine, in the French Alps,. Due to its large scale – a residential complex for 6,000 visitors – and a series of commercial uncertainties, the project took many years to complete. The developer decided to hire the *Compagnie Française d'Engineering Barets* (COFEBA) to design the production of the precast concrete panels. Rather than mass production in large factories, which required major investment, Jean Barets, the chief engineer of the company, suggested prefabrication which would allow the architect freedom of design. Hence, the production was based on medium-sized modules undertaken in temporary facilities adjacent to the building site.

The project would be built on a plateau at 1,800 m above sea level, at the foot of the Arve-Giffre Massif. Producing panels on site would have been risky, since interruptions due to bad weather might have reduced the periods of production to just a few months. Also, the access road to the site had yet to be completed.[11] Jean Barets proposed manufacturing the panels at a temporary workshop located at the bottom of the valley; the warmer climate would allow work to continue all year round, and the panels could then be lifted by cable car up to the ski resort. Barets used his own system to produce the lightweight slabs, the façade panels and the bearing walls. These elements were stored until their positioning and fixing in situ was carried out during the summer.

In Flaine, the formwork shaping the panels was made of steel sheet which gave them a smooth finish. In addition to this, a number of measures were taken to deal with the cold temperatures and to accelerate the curing time of the concrete. One method of achieving this was the use of electric resistances fixed to the metal formwork in order to increase temperatures within the panels. Another method used was adding antifreeze and plasticizer to the concrete used in the panels; and finally, the aggregates and mixing water were preheated prior to mixing to make a concrete that was smooth and homogeneous.

Breuer was pleased to work with the French engineer as thinner panels could be manufactured using his methods. In fact, unlike at IBM in La Gaude, thickness was less important as these elements were not load-bearing; the floors were supported on the cross walls. In terms of size, the panels also did not need to be very high: the span covered by the slab was shorter and a reduced depth of false ceiling was still sufficient to hide the building services for the hotel rooms; thus, four Flaine panels equalled the height of two panels used on the La Gaude façade. Thousands of panels were used to make up the building envelopes at the ski resort. Breuer designed the façades with an asymmetric pattern of trumpet-shaped holes, probably inspired by some of Le Corbusier's works, such as the Ronchamp church, alternating with some hole-panels in a herringbone pattern, with some prism-shaped blind panels. (Fig. 2)

Figure 2. Façade of Flaine Ski Resort. © Gilbert COQUARD, Centre Culturel de Flaine.

Department of Housing and Urban Development Headquarters, Washington (1964-1966)

In 1964, Breuer and Associates designed the offices built to accommodate the Department of Housing and Urban Development Headquarters (HUD) in Washington. This was the first project in the United States in which the firm used precast concrete panels, and it was also the project that preceded the ZUP in Bayonne. As in the IBM building in La Gaude, the panel was a structural element. The panels form a wall which carries the loads down to the large columns in the lower part of the building. As the building was nine storeys high, Breuer and his associates designed thicker, sturdier panels, based on a 3-metre module. The structural character of the wall is further emphasized by the unequal proportion between the small holes and the large blind areas of the panelling. (Fig. 3)

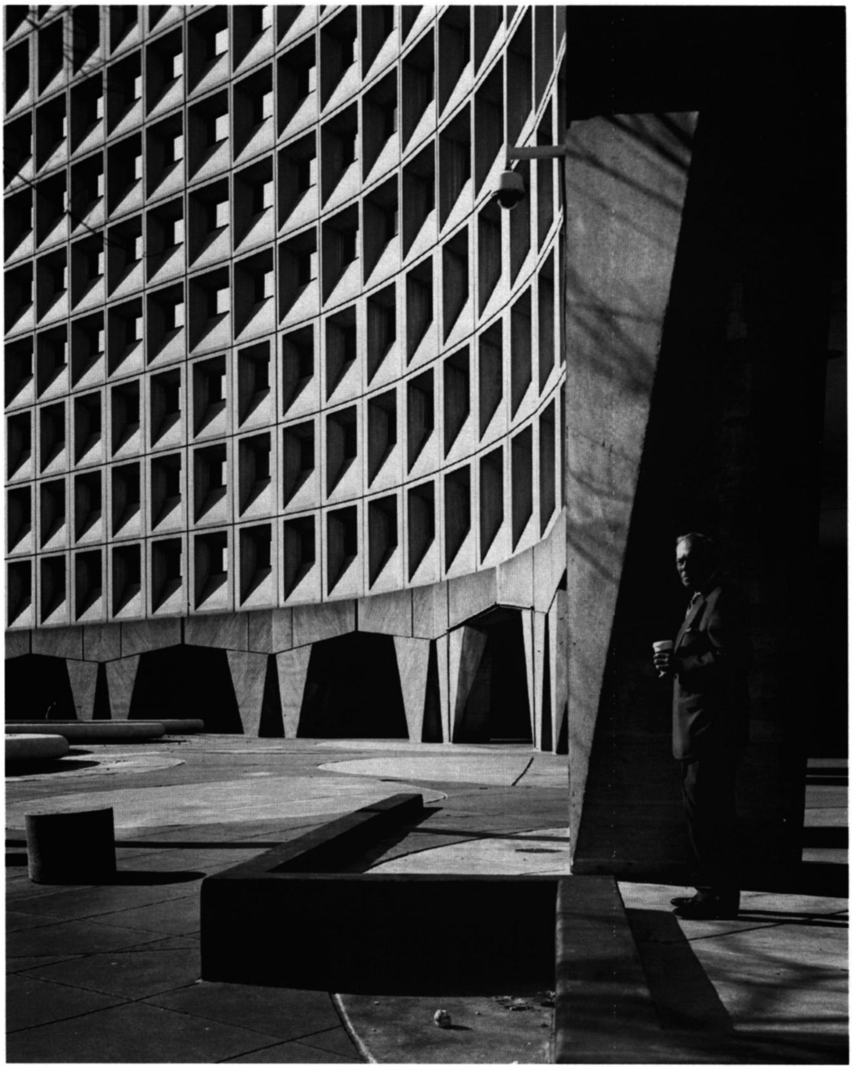


Figure 3. Department of the HUD Headquarters. 2009 - Flore de Préneuf

In addition to their structural role, the panels incorporate another function: they accommodate the heating, ventilation and air conditioning (HVAC), the fan-coil units and the vertical air extraction ducts. In this way, the space corresponding to each workplace in the office can have its own individual HVAC system.[12] Both functions have an impact on the ratio between the void and the blind part of the panels at each stage, as this ratio varies subtly: the panels on the lower floors have thick walls and a sturdy covering due to the heavy loads they have to carry, and the upper-floor panels adopt a similar appearance in order to hide the vertical pipework. Hence, the panels located on the intermediate floors have larger voids gaps and smaller opaque surfaces. The varying design of these panels meant that the formwork had to be made with moveable parts with counter-mould and retractable pieces to allow them to fit different widths. In addition, the panels were arranged in a curved plane, requiring special care in the construction.

The accurate production of each part was crucial. As they could not be manufactured on site, a company near Baltimore which built structural components for bridges and garages, was given responsibility for their production, even though the firm had little experience in the production of precast concrete panels for façades.[13]

The complexity of the façade, the high degree of prefabrication of all the elements of the building, the speed with which the building was completed and the fact that the final cost of the building was significantly less than budgeted, are all factors that demonstrate the technological and industrial versatility of the North American east coast.

The borough of Sainte-Croix, Bayonne: the result of the ZUP administrative procedure

In the early sixties, the post-war reconstruction (1945-1960) had just been completed in France and at the end of this period the population began to grow again. In response to the mounting demand for housing in all French cities, the Official Journal of the French Republic decreed a new urban administrative procedure in January 1959. The Ministry of Construction could designate a *Zone à Urbaniser en Priorité* (ZUP) – a Priority Development Area - in those municipalities where housing construction was increasingly urgent.[14] The developer of a ZUP could be a public institution or even a commercial company with public and private capital. The designated area had to have enough land to accommodate at least five hundred homes, including various associated amenities and facilities. For a ZUP to be considered, it was necessary to prepare drawings, written documents, City Council approval and a report describing the proposed site with the number of houses and facilities to be constructed. The roads and infrastructure necessary to develop the site also had to be considered. After approval by the Ministry of Construction, a Chief Architect was appointed. This type of management involved rapid land acquisition with compulsory purchase of land for public use. The institution in charge would oversee the land acquisition and manage the construction. This administrative procedure was the main instrument for providing social housing in France during this period of growth. Between 1959 and 1969 a total of 195 ZUPs with more than 800,000 houses were built.[15]

ZUP in Sainte-Croix, Bayonne (1964-1968)

The Basque town of Bayonne, near Biarritz in southwest France, is in a region where the economy was based on tourism and agriculture. It saw a sharp increase in population after World War II once it had re-established economic growth. During the decades between the early fifties and late seventies, the population of Bayonne rose by 30 per cent, reaching 43,000 inhabitants. Following the City Council's request and in response to the urgent housing needs, the Council of Ministers passed a decree on 12th December 1963 for the designation of a ZUP – a Priority Development Area - in the borough of Sainte-Croix, on the opposite side of the river Adour from Bayonne.

The facilities, Breuer's appointment and the architectural solution for the blocks

The planning documents for the combined facilities for the future ZUP were prepared by the *Bureau d'Etudes et de Réalisations Urbaines* (BERU), an agency located in Paris which conducted a rigorous analysis of the needs for the area.[16] The resulting proposals were highly ambitious: in addition to 3,500 houses, the area would have four primary schools, two high schools and a canteen, two sports centres, a healthcare facility including child and tuberculosis care, a social centre, a cultural centre for young people, administrative facilities such as a post office, a social office and a police station, and finally, a Catholic church including space for meetings and religious instruction.[17] (Figs 4 and 5)

Figures 4 and 5. The residential blocks of the ZUP in Sainte-Croix, Bayonne, in their final phase of construction. Source: Musée Basque et de l'Histoire de Bayonne (Photographs by Robert Hourgras).

The Council of Ministers of the Republic were responsible for appointing the Chief Architect. Since the appointment of the architect came from a very high level in government, it allowed the appointment of an internationally renowned Architect. One of the members of De Gaulle's Council of Ministers at that time was André Malraux, the Minister of Culture, a writer, political activist and admirer of Le Corbusier. He showed both knowledge and passion for the Modern Movement. Malraux supported Breuer's appointment, which was proposed by Max Ernst, who was head of the BERU office which had already carried out several public housing developments elsewhere in France. On 21st September 1964, with the approval of the Minister of Construction, Marcel Breuer was appointed as Chief Architect of the ZUP project.

The residential part of the scheme included low-rent housing. Breuer adopted the concept of *Unité d'habitation*, an approach introduced by Le Corbusier in 1945. The initial project included the construction of a curved row comprising large 13-storey blocks on top of a hill where the old Jewish quarter of the city used to be located. (Fig. 6) Although 14 blocks were initially planned, only half would be built. The interior layout of the residential blocks not only had to be well-designed architecturally, but also had to satisfy the strict standards dictated by French law about the design of social housing.[18] The war experience, which included much badly-designed housing with poor insulation and many power-cuts, meant that the construction of new apartments with more than one bedroom had to have cross-ventilation through windows on both elevations, kitchens with an external window, chimneys for smoke extraction, and a bathroom provided with ventilation ducts and extractors; likewise, all lift systems had to be carefully considered.

Figure 6. Model of the ZUP of Sainte-Croix. Source: Musée Basque et de l'Histoire de Bayonne (Photograph by Robert Hourgras).

Breuer chose the concepts he had already proposed in the 1920s to respond to all these requirements: duplex apartments and centralized lifts with long corridors arranged on each of the three levels from which the dwellings were reached. (Fig. 7) Convenient access to the apartments and effective escape routes also had to be guaranteed – the bad memories of bombings and fires that had occurred during the war were still strong in the collective memory of French inhabitants.

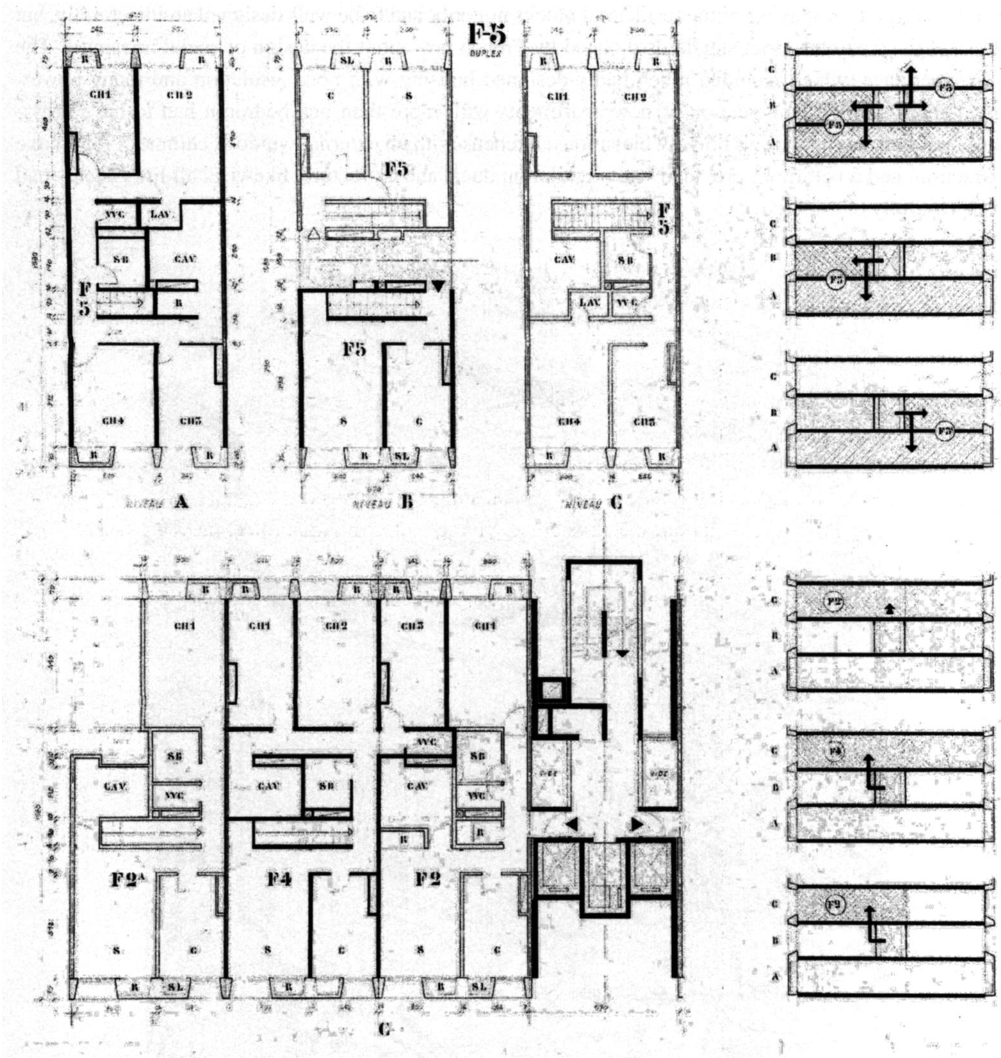


Figure 7. Internal layout of the duplex apartments. Source: Archives départamentales, Pôle de Bayonne et du Pays Basque.

Cellular structure via tunnel formwork

The structural concept of the building consisted of a cellular structure with walls and floor slabs of reinforced concrete, similar to a collection of tubes, and its construction was supervised by COFEBA which had been incorporated into the organisation chart drawn up by the City Council of Bayonne. Each cell-frame comprising the main structure of the residential blocks was 5.7 m wide and 2.66 m high and 15.3 m deep spanning the full width of the building. The vertical central core was made up of lifts and staircases and was located in the centre of each block, with seven cell-frames on either side. The foundation structure was made up of ground beams arranged perpendicular to the axis of the building. In order to prevent cracking in the structure of such a long building due to thermal expansion, movement joints were incorporated.[19] On the ground floor, where the entrance halls and shops were located, the structure consisted of a transverse framework made up of deep edge beams and columns. In this way, with few vertical elements reaching the ground floor, the units could be combined if necessary. The open nature of the construction allowed considerable freedom of design. A wall-based cellular structure, regularly arranged to construct the 13 upper floors, was placed above the transverse framework.

The tunnel formwork technique used to construct these cells consisted of a metal framework to form a tunnel mould that rested on the slab below. (Figs 8 and 9) Once the concrete had been poured and cured, the tunnel-forms were folded, slipped and lifted by crane onto the newly finished floor and re-erected to construct a new cell, achieving important time and labour savings. This tunnel formwork system was developed in France and widely used in the construction industry in the mid-sixties. However, due to its complexity and the specific equipment required, it was mainly used on larger projects carried out by specialized companies such as Blaw-Knox, Sectra or Outinord[20] whose main business became the production and marketing of these moulds.[21] The system was used not only for the construction of the floors, but also the other vertical elements of the structure by attaching auxiliary upright sections. The connection between the cellular structure and the two longitudinal walls located in the central part of the blocks, built in a second phase was achieved by connectors whose purpose was to brace the module in the perpendicular direction. The new construction system radically changed the nature of traditional formwork and concrete pouring techniques, and also had a huge impact on the project design process.


Figures 8 and 9. Construction process of the cellular structure, using the tunnel formwork technique. Sources: Mediathèque de Bayonne and Musée Basque et de l'Histoire de Bayonne (Photographs by Robert Hourgras).

The manufacture and placing of the panels

The façades of the seven residential blocks making up the ZUP in Sainte-Croix were formed using precast concrete panels placed at both ends of each structural cell. Breuer appreciated the possibility of using this element repeatedly, as he had already tried it out in La Gaude, Flaine and Washington. With this repetition, he tried to recreate and revive some of the urban façades he admired, such as the Rue Rivoli in Paris, the Royal Crescent in Bath in England, or the Georgian neighbourhoods in Bloomsbury in London.[22] Breuer and Associates reduced the number of panel types as much as possible, which allowed them to cut costs. They managed to create the façades for hundreds of homes by repeating two windowed panels, two blind and plain panels, a sunken panel and a long panel to form the roof. The panel arrangement was determined by the three-dimensional geometry that the cellular structure created; all panels are 2.66 m high and their width varies from 3.14 to 2.56 m, depending on the internal layout. The way the singular design of the panels were displayed in the façades made the blocks resemble a honeycomb. The key feature of the façade was the trumpet-shaped sunken windows whose considerable depth shaded the apartments from the sun in summer and created strong shadows which gave the whole building some striking appearances at different times of day. The unusual shape of this recessed panel also allowed cupboards to be fitted on the internal face of the panels. (Fig. 10)

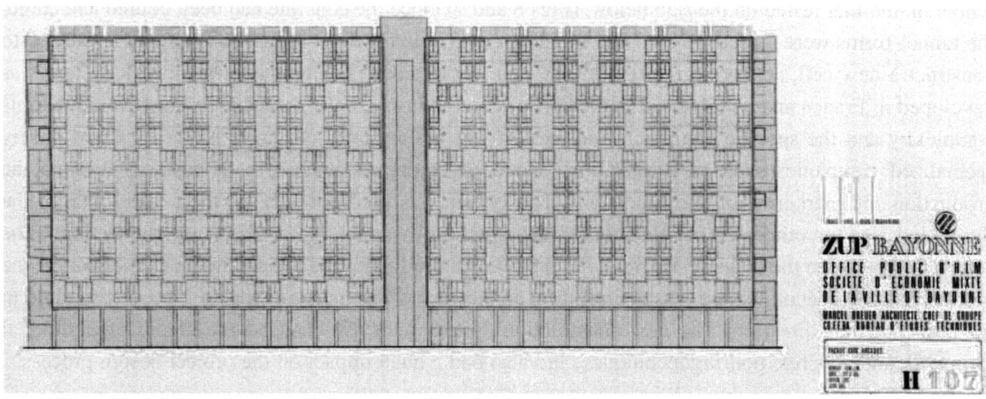


Figure 10. Elevations of a block from the original Architectural Project. Source: Archives départamentales, Pôle de Bayonne et du Pays Basque.

The French Government proposed and supported the temporary installation of a central panel production plant on site, primarily to reduce transport costs.[23] A plant was set up in the winter of 1966 on a nearby plot to manufacture the concrete panels. All the expenses that would have arisen as a result of shipping the precast elements from companies located more than a hundred kilometres away, near Bordeaux or other locations, were avoided. COFEBA supervised the layout of the temporary production facility, since it was responsible for the technical coordination of the works. The panel plant, in a temporary building, was located at the centre of the seven blocks. The cement, sand and gravel silos were placed at one end, whilst the main part of the manufacturing facility had an overhead crane to move the panels and store them at the other end. Due to the length of the residential blocks, a crane on rails was used to hoist and erect the façade panels into place.

Thus 4,700 100 mm thick panels were completed under rigorous control using a set of folding formwork made of steel sheets. After applying a releasing agent to the bottom of the panels, an electrically welded mesh reinforcement was placed on spacers to strengthen the concrete. This mesh not only provided structural strength and stiffness, it also carried the stresses generated by the shrinkage of concrete during curing. Window sub-frames were placed in position before pouring the concrete in order to provide greater strength and to leave an accurate opening for the window units that were fitted later. While the concrete was poured a needle vibrator was used to compact the material. The concrete itself consisted of 210/235 Portland cement, sand no larger than 5 mm and gravel with a maximum size of 25 mm, all of which were washed in accordance with the conditions set out in the document *Cahier des Charges applicables aux travaux de maçonnerie, bétonarmé, plâtrerie*.[24] This process was strictly controlled, not only to ensure the strength of the panels, but also to prevent variations in texture and colour.

A number of specific products were required by the architects in their specification to prevent the panels from absorbing moisture from the air that would freeze in winter, leading to an increase of pore size, and thus causing the outer face to spall. H. Smith, a partner in the architects' firm, was an expert in matters relating to new chemical products for use in the building industry, and was responsible for advising about sealants, additives and release agents within the ZUP project. This research activity was sponsored by several large companies and led to considerable progress in terms of new construction products after World War II, especially in the United States, and the specifications written by H. Smith were considered to be the most accurate ones available at that time. Concrete used in the construction of these panels contained the 'Pozzolith' additive made by Master Builders to improve the characteristic strength of the concrete. Another additive used in the panels was similar to DAREX produced by the Dewey and Almy Chemical Company to make the concrete waterproof, more workable and self-compacting.

Once the façade panels had reached sufficient strength, they were removed from the folding formwork, moved by crane and hoisted directly into the space between the slab and cross walls. Once in place, the panels were temporarily held in place while the final connection to the main structure was made. This required a final pouring of concrete to close the unfinished edge of these panels which were specially shaped to allow them to fit together closely and avoid the need for additional formwork. Pre-inserted connectors cast within the walls and slabs provided the anchoring of floors, walls and panels to the main structure, forming a monolithic union. (Fig. 11)

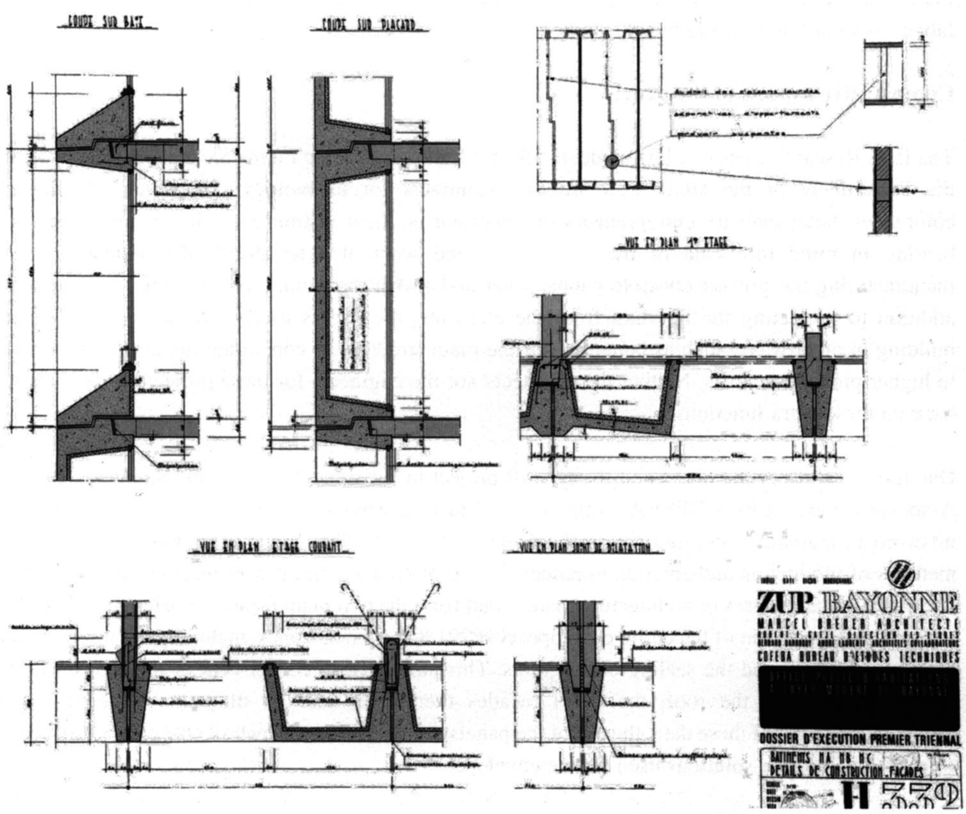


***Figure 11**. Details of the attachment of the main structure with the precast panels. Source: Archives départamentales, Pôle de Bayonne et du Pays Basque.*

Since closing each cell required two panels, a column was located in the centre to secure them; this vertical element was formed with *in situ* concrete in the vertical joint between the two panels. (Fig. 11) In this way, each panel was stiffened all around its perimeter. The tightness of the seal was further guaranteed by a triple solution: a bituminous cord on the outside of the joint, an Isorel Mom plate made of wood fibres in its central part, and a bituminous material, Paxalumin, reinforced with glass fibre and protected with a goffered aluminium sheet on the inside.

As for thermal insulation, the panels of the ZUP lacked a thermal protector because this would have caused difficulties during the manufacturing process, although it is worth mentioning that in the 1960s there were panels on the market that did in fact have an insulation layer on the inside. However, French legislation was strict in this matter since a decree stipulating the thermal performance of façades was passed on 22nd October 1955. Consequently, an insulation layer was added to the panels of the ZUP. The Polyplack thermal insulation, comprising 15-mm plasterboard and a 20-mm polystyrene sheet, was glued to the interior faces of the panels. This remained hidden behind the plywood forming the built-in cupboards, or was painted where fixed to exposed internal walls. In this way the heat transmission coefficient of the panels was 1 W/m^2 °K, as specified in the technical documentation of the project.

The window frames were made of Iroko, an exotic hardwood with a high density and very resistant to xylophagous insects. The windows were installed from the interior of the apartments, and the process was fast and straight forward, due to the fact that the sub-frames had been inserted into the panels beforehand. In addition, the architects avoided the need for roller blinds which would be expensive and laborious to install by using bi-fold shutters instead.

Comparative aspects of the panels

The IBM Research Centre in La Gaude, the Sarget Laboratories, the Flaine Ski Resort and the offices of the Department of the HUD were building contracts for technology companies, pharmaceutical companies, hotel industry entrepreneurs or important political institutions. They were all prosperous, bearing in mind the scale of the investment, and were able to absorb the additional costs of manufacturing the precast concrete panels, over and above the minimum functional requirements. In addition to protecting the building from the elements, the panels used in these projects served the building in other ways, such as being part of the main structure or containing the air ducts, which lead to higher production costs. Neither the architects nor the engineers for these projects were asked to cut back on these extra functions.

Due to the nature of the client and the type of project in Bayonne, however, the architects Breuer and Associates, advised by COFEBA, were required to find ways of saving time and reducing the cost involved in manufacturing and fitting these external panels. The design team had to find innovative methods of production and erection to render the use of architectural panels feasible and cost-effective. The 5,505 square metres of architectural panels that form the two main façades of each residential block, comprising 60 per cent of the entire envelope, cost 791,844 French francs, including the joinery, glazing, thermal insulation and the sealing of the joints. This amounted to 55 per cent of the cost of the entire envelope, including the roof, the panel façades themselves and all the other concrete envelope elements.[25] In light of these data, the use of the panels did not add to the overall cost of the building when compared with other solutions used for the envelopes.

Comparing the characteristics of the Bayonne panels with the solutions used by Breuer in earlier projects leaves no room for doubt: they all reflected a willingness to save. (Fig. 12) The formwork for the panels did not incorporate any heating system, so the winter frosts of 1968 were accommodated by using antifreeze and accepting temporary interruptions to production. Unlike the Torrington Factory at Nivelles in Belgium, another project by Breuer,[26] the formwork installation did not incorporate vibration devices, so the concrete had to be compacted using traditional, hand-held, needle vibrators. Whilst the panels used at the Department of the HUD had thermal insulation on the inside, requiring their manufacture in layers, in Bayonne it was attached to the surface from inside, after the panels had been fixed. Regarding the dimensions of the window apertures, in Flaine, the openings had different sizes depending on their use, and in the Department of the HUD the proportions varied subtly and in a carefully designed way: in consequence, the design of the formwork was more complex and had a great impact on the joinery and glazing costs. In Bayonne, on the other hand, all the windows had the same height and only two different widths. Furthermore, the windows were attached to wooden sub-frames, which were permeable to air, and were much less expensive than the air- and water-tight aluminium frames used in the IBM laboratories at La Gaude which allowed the indoor quality of the air to be carefully controlled, as required by the client.[27]

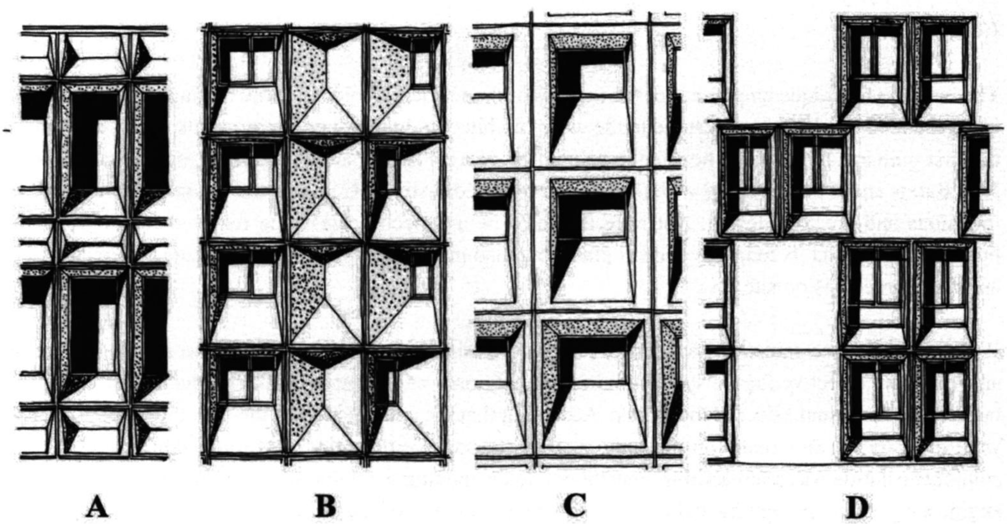


Figure 12. Comparative drawings of four façades: (A) IBM La Gaude (1960); (B) Flaine Ski Resort (1962); (C) Department of Housing and Urban Development (1964); (D) ZUP of Sainte-Croix, Bayonne (1965). Drawing by Lauren Etxepare.

From a conceptual point of view, the structure of the blocks at Bayonne was similar to that used in Flaine, although at the ski resort, all the structural elements had to be prefabricated lower down in the valley to be later hoisted and assembled on site, in line with the cellular concept.[28] In contrast, the structure of the apartment blocks of Sainte-Croix was cast *in situ*, using tunnel formwork, resulting in a fully- monolithic building. Furthermore, it was more economical, as it was not necessary to transport the structural elements and assemble them *in situ*. Unlike the thick panels used at La Gaude or at the Department of the HUD, the panels in Bayonne lacked a load-bearing function; this was fully consistent with the cellular structure which did not require the façade panels to carry loads. Regarding the positioning of pipes and cables internally, the Bayonne panels did not require their integration as the requirements in terms of networks or facilities for social housing were simpler. Forming gaps, using cores in the moulds for the perimeters of the panels, as was done in La Gaude, would have increased the manufacturing costs. Breuer and Barets were able to use their considerable experience of the methods and costs of production on their earlier projects to achieve significant savings in cost and time in the apartment blocks in Bayonne. Especially important were the four thousand linear metres of connections between the façade panels and the main structure. Firstly, the verticality and the correct positioning of the panels were determined by the slot in the panel beneath, against which the element was placed. Thus, no alignment operation was required. Secondly, the connection between the panels and the main structure was achieved by a single, final concrete pour, without requiring any new formwork. In this way, it was not necessary to use steel anchors or bolts of any kind, nor even welding. Such procedures were already familiar in the USA, for example in the construction of the Police Administration Building in Philadelphia (1959-62) by Geddes, Brecher, Qualls and Cunningham, or the Agricultural Building at Laval University, Quebec (1964), by Gauthier and Guité.[29] Finally, the adhesion of the panels by means of the concrete joint was made after finishing the concreting of the cell structure. Thus, the decision to carry out the concrete work in two phases ensured that the two processes should follow their own course, unlike the process applied at Flaine. In this way, the vicissitudes arising in one phase did not affect the other, and the development of the main structure did not depend on the pace at which the panels were produced.

Conclusion

The building technique employed for the façades of the residential blocks in the borough of Sainte-Croix in Bayonne marked a new milestone in the use of architectural precast concrete panels, being applied for the first time in a large public housing development. Marcel Breuer and his partners, in conjunction with Jean Barets and COFEBA, and with the support of the Ministry of Construction, managed to achieve an ingenious and creative design. Not only did the new approach achieve the required functions of the building façade and its long life once in place, but also made significant improvements the erection and assembly processes on site.

With the experience gained in La Gaude, Flaine and Washington, Breuer and Barets were able to develop an even more effective façade system, based not only on a more cost-effective production of the panel, but also on the visual effect of the façade. Accepting that the construction of the structure and the façade were inseparable, they relied on the same material to produce their final union: the concrete poured *in situ*. This solution was a remarkable contribution to developing the traditional use of concrete and French engineering, since the sealing and monolithic structural union of façade and structure was achieved in a cost-effective way. What is more, this solution led to significant savings in cast and time, as it was not necessary to use the expensive anchoring techniques that were being used in precast concrete panel systems, above all in North America.

Nevertheless, the system that Breuer and Barets applied in Bayonne was inextricably associated with cellular structures which were erected employing tunnel formworks – a significantly rigid arrangement on formal grounds. So, from 1970 onwards, as the use of the tunnel formwork diminished even in France, the architectural panel industry tended to use anchoring techniques from the USA, more adaptable for all types of façades and more suitable for buildings in which structure and envelope were dissociated. Examples are the McLennan Library of the McGill University in Montreal (1967-69) by Dobush, Stewart and Bourke,[30] the buildings of the ZUP La Rode, in Toulon (1971-76) by Mikélian,[31] and the tower block 'Les Horizons' in Rennes (1970-73) by Maillols.[32]

Acknowledgments

We would like to express our gratitude to all the employees of the Archives départamentales de Bayonne et du Pays Basque. Thanks are also due to Rafael Zulaika, Director of the Musée Basque de Bayonne, and to Christine Rivière, Director of Cultural Affairs at the City Hall of Bayonne. Finally, we want to show our gratitude to Chris Wright, Flore de Préneuf and to Gilbert Coquard, for allowing us to reproduce their photographs in Figures 1, 2 and 3.

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