ENGLISH VERSION

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SPACE, SILENCE AND A HINT OF THE PAST. THE ISE SHRINE IN JAPAN

The Origin of Shinto Shrines

Japan has its own ancestral religion called Shinto or "the path of the gods", an ancient animist creed based on a cult to Nature akin to the most primitive religions of many other peoples on earth. Shintoism worships not only anthropomorphic gods but also spirits or kami, which live in particular elements of nature, especially in certain rocks, trees and mountains. The same thing occurs, for example, in the adoration of the Australian aborigines for the sacred mountain of Ayers Rock (Uluru in their native language) or other outstanding geographic accidents. In the case of Japan, the Shintoist tradition attributes to little stones the virtue of growing into large rocks, and the sound of human footsteps on them is their voice, just as each of the different creaks of timber are given a specific name and respond to its laments and ailments.

In accordance with the above, the oldest Shinto shrines do not consist of any particular building but dedicate their worship to a mountain, as is the case of the shrines at Miwa and Kanasana in the prefectures of Nara and Saitama, respectively. In these cases, the sacredness of the place is marked by the presence of a wooden gateway or torii and the progressive delimitation of a sacred enclosure in concentric circles around the object of veneration. This delimitation, which is still used today, takes the shape of a rope called shimenawa, on which hang strips of paper bearing prayers.

With the advent of agriculture and sedentary life, this primitive type of worship in natural shrines, which the writer Bruce Chatwin associated with shepherding and nomadic life, was replaced by built structures intended to invoke the gods for a presage or in gratitude for good crops. We now have archaeological records, for example, that the oldest shrines of Mesopotamian civilisations consisted of buildings similar to round granaries. For that reason it is not surprising that Shinto shrines consist of a primitive type of barn elevated to the category of sacred shrines. (It is precisely in a granary that precious objects are kept.)

This is what the archaeological findings of the Yayoi era (4th century BC – 4th century AD) would suggest, since the configuration of the rice storehouses was very similar to the Shinto shrines, and not at all like the houses of that period, which stood directly on the ground. The archaeological findings also show that the sacred festivals of the agricultural cycle had been held since very olden times around these barns where the cereal that guaranteed their sustenance was stored.

It is interesting to note the similarity between these primitive Japanese granaries and Asturian and Galician hórreos, Portuguese espiguieros and other storehouses of similar features that exist in many other points of European, African and Asian geography. They are all characterised by the fact that they stand on piles, their roofs have two or more pitches and the semi-sacred character that several authors have mentioned. In the case of Galician hórreos, the presence of a cross on top of the roof replaced the stone phallus that augured good crops still to be found on some very old specimens. The transcendent substance of these ancestral constructions acquires greater importance after the discovery of funeral urns at Kusdeirah, Israel (3400 BC), Italy (C7 BC), Obliwitz, Lauenburg, Pomerania (ca. C3 AD), standing on piles, so similar that they even have the roof joists prolonged in a scissor shape like at Ise, in the second case, or flagstones on piles to prevent rodents from entering, in the third.

This character of Roman sarcophagus carried on a bier suggests the possibility of shifting these constructions, just as the old Shinto shrines seem to have developed from the little portable shrines (mikoshi) in the processions at Japanese festivals. In fact, the layout of the rocks used as foundations for the shrines at Kasuga (Nara) suggest that the structures were mobile. Is there any link between this mobility and the mobility of alternative sites at the Ise Shrine? For their part, Galician cabaceiros, an atavistic form of today's hórreos, have wickerwork walls and are built in the shape of a large basket. Besides, we must not forget that an old tradition in Galicia holds that hórreos go off for walks on their long legs at night.

The Buildings at the Ise Shrine

There is a group of buildings called Ise Jingu, consisting mainly of the Inner Shrine Kotaijingu (Naiku) and the Outer Shrine Toyoukedaijingu (Geku), dedicated to the sun goddess Amaterasu Omikami and the goddess of agriculture and manufacture Toyouke Omikami respectively. Besides, there are 14 auxiliary shrines (bekku) and 109 minor shrines. The origin of Naiku dates back to the 4th century AD when, at the request of Amaterasu Omikami herself, Princess Yamatohime no Mikoyo shifted the sacred mirror that represents the goddess (yata-no-kagami) to the current shrine at Naiku. The Geku shrine dates back to 477 AD, when it was made to house the goddess Toyouke, who provides sacred food for the goddess Amaterasu. One hundred priests take care of Ise Jingu today under the protection of the sacred priestess, who is at present Atsuko Ikeda, the emperor's sister.

The progressive delimitation of the holy place is present in all the constructions. For example, the Naiku Shrine is surrounded by four concentric palisades that clearly mark the inviolable character of the inner enclosure. Each of these fences has a characteristic shape and is given a specific name that symbolises the physical and psychological dimension of the prohibition barriers: the outer one is called mizugaki (fortified fence); the next uchigaki (inner fence); the following tamagaki (mental fence) and the last itagaki (border fence).

The entrance into this rectangular enclosure is through successive gates with hipped roofs located on the northern and southern slopes of the perimeter. At the centre stands the principal shrine or Shoden placed at an angle to the entrance and with a porch built on the southern side. It is built mainly of timber with a few metal ornaments and a straw roof. It is raised two metres on piles with steps leading up to a perimetral veranda 1.5 m wide protected by banisters around a single space measuring 5 x 11 m. The structure of this inner space is formed by nine perfectly cylindrical wooden trunks resting on the ground and the walls are made of planks placed between these pillars. The roof, with two hips of 45º exactly and consisting of a wooden frame covered with thousands of sheaves of straw carefully cut off at the eaves, rests on this nine-trunk structure. The ridgepiece is supported by another two large trunks called munamochibashira, independently erected separate from both gable walls and slightly set back from the outside plane. Eight metal-tipped poles (muchikake), whose purpose is unknown, project slightly from the upper part. On the top, whose ends are adorned with the scissor-shaped prolongation of the outermost joists (chigi), ten slightly spindle-shaped, also metal-tipped wooden trunks (katsuogi) are laid crosswise to prevent the wind from blowing off the roof. The total height from the ground to the tip of the chigi is ten and a half metres. This main shrine is flanked by two smaller buildings of similar characteristics, the Treasure Rooms (saihoden and tohoden), also located inside the sacred enclosure.

The style and proportions of the Geku Shrine are similar to those of the Naiku Shrine, although there are some small differences, for example, in the vertical cut at the end of the chigi, the odd number of katsuogi and the arrangement of the saihoden and the tohoden and the presence at the back of Geku of the mikeden or kitchen, where food is prepared every day for Amaterasu, who lives in the Naiku Shrine. The rest of the shrines at Ise Jingu, consecrated, for example, to the wind, the rain, etc., have a similar structure to the main shrines but always with a lesser number of katsuogi so as to indicate that they are less important.

These buildings have hardly changed at all in the reconstructions carried out over the last 1300 years, but some very slight modifications have been introduced. Some elements, such as the bronze details or hoju on the Naiku and Geku Shrines, do not belong to Japanese cultural tradition but come from the Tang dynasty in China. Naiku Shrine was apparently burnt down many times, so its form has undergone several changes and it has been more richly decorated. On the contrary, Geku Shrine has never been burnt down or suffered any damage except for the typhoon that knocked it down in 1040, so it conserves more exactly its original primitive force.

The Existence of Two Alternative Sites for Each Building

All the shrines and buildings that constitute Ise Shrine have two identical adjacent sites. Since the 7th century AD, with a few rare exceptions, this group of over one hundred buildings have undergone ritual reconstructions on their respective adjacent sites, followed by solemn nocturnal ceremonies to move the goddess's sacred mirror and other symbolic relics from the old buildings to the new and demolish the former. The only elements that survive this unbuilding and rebuilding process are the stone bases on which the piles of the structures stand and a post buried in the terrain called shin-no-mihashira, the unseen emblem of the sacred space.

However, during a magical period of a month or two the old temple and the new version stand side by side in a sort of mirage situated in unreal time which allows us to have an exceptional glimpse of the old building stripped of its relics. This mirage that duplicates the view of a single object –the shrine– fades rapidly as its reflection is dismantled.

The Shikinen Sengu or construction ceremony of a copy of the shrine and the removal of the sacred symbols of the kami (goshintai) of the old to the new is an elaborate Kannamesai ceremony (offering of the first fruits of the crop). In fact, this alternative cycle of erection and sacrifice of these buildings that look like ancestral storehouses has been interpreted as an allegory of the agricultural process of growth, blooming, fructification and immolation of the seed. The repeated cloning process of the sacred shrine also reflects the reproduction of vegetable species from seed.

In Ancient Greece, the Eleusinian Mysteries were related to the cereal god, Iacchus, the god of eternal youth who achieved this with the aid of the Great Goddess by means of repeated death and rebirth processes obviously related to agricultural cycles. This concept of puer aeternus, described by Ovid and borrowed by Jung to create his famous archetype, has enormous importance in the Japanese psyche, according to the Japanese psychoanalyst Hayao Kawai.

To support this interpretation of the unbuilding and rebuilding phenomenon at Ise as an echo of the agricultural cycle, a total of 1500 little ceremonies and 20 important rites take place at Ise Shrine every year, all connected with the annual rice cycle. Not only are the buildings reconstructed, however, but the sacred garments

and treasures kept in the shrines are reproduced in the same way as the buildings by contemporary artists and craftsmen following detailed traditional specifications. The 125 sacred vestments comprise a total of 1085 different garments, while the treasures number a total of 491 divided into 189 categories. Besides, another 1600 secondary objects are also reproduced in each cycle.

The Concept of Purity in Shintoism

The concepts of purity, freshness and novelty are fundamental in Shintoism. In the process of repeatedly making a copy of the buildings and destroying the old models adjacent to them, the sun goddess is believed to feel refreshed by the reconstruction of the new building. All the components (tools, building materials, craftsmen, priests, food, offerings...) that are part of the everyday liturgy of rebuilding, worshipping and demolition at Ise Shrine are submitted to strict norms of purity and cleanliness. In this way, salt is often used in the ceremonies as a purifying element and even the water used to irrigate the fields from which the straw for the thatch comes is brought from sacred springs and unpolluted fountains.

The science of anthropology tells us that in ancient cultures like Japanese Shintoism purity is the most important of all requisites. Examples of this in other civilisations are the written testimonies in Indian and Chinese cosmologies, the Jewish torah or, closer to us culturally, the books of Deuteronomy or Leviticus in the Bible.

Thus, for example, during the Yayoi period (300 BC – 300 AD) in Japan, the custom of erecting special buildings to house women during childbirth or menstruation still existed, as it was considered impure to live with them at that time. The Dogon tribes in Africa, which have conserved their ancestral culture almost intact until today, still use this type of menstrual house.

Japanese gastronomy is another reflection of this concept of purity and freshness in their most traditional dishes. The quality of sashimi (raw fish) and sushi (piece of raw fish on rice) depends on the freshness of the fish used and the short lapse of time between killing the animal and eating it. In fact the most select and expensive sushi is eaten little by little while the partly eaten animal is still flapping about on the chopping board.

Before entering Naiku Shrine, ritual ablutions are made in the River Isuzu, where the pilgrim stops to wash his hands and rinse his mouth in an act that symbolises the purification of body and mind before visiting the holy places. The significance of these ablutions is no different from those practised by Muslims in the courtyards of their mosques, Christian baptism or the ritual bathing of supplicants and priests before the oracles of Greek religion. The Japanese custom of submerging the whole body in their deep household bathtubs are a token of their cleanliness and comportment today, but it stems from the ritual ablutions instilled by traditional religion.

In coherence with this concept of purity, the consecration of the new twin shrine is presided by a young virgin (monoimi), representing the epitome of purity, like the Virgin Mary in the Christian religion. This maiden who plays the part of master of ceremonies is a perfect token of Shintoists' admiration of freshness and newness and their fervent wish to make the ritual as pure as possible.

The Reconstruction Process

All Shinto shrines traditionally underwent periodical reconstruction in search of this renovation and purification of the physical construction and the materials that composed it. Today Ise Shrine is the only Shinto religious complex that follows this tradition, because of the great expense of each of the processes. The structures of other known shrines date from the last reconstruction that was made of them, like the Izumo Taisha Shrine (twenty-fifth and last reconstruction in 1744), the Sumiyoshi Shrine (1807) and the shrines of Kamo Mioya, Kamo Wakeikazuchi and Kasuga (all in 1863).

At Ise, each reconstruction ceremony requires 13,500 trees, some of which are several hundred years old, to be cut down. The wood of Japanese cypresses (hinoki) that surrounds Ise Shrines, occupying a surface of 5,500 hectares, has historically provided the timber necessary for the reconstruction, but it has now been excessively ravaged. For that reason, in 1926 a cypress reforestation programme was put into practice on an area of 3,500 hectares on Naiku hills to cover future reconstructions. At the present time, the timber comes from the Kiso mountains, situated between the prefectures of Gifu and Nagano. Even so, for the next reconstruction in 2013, it will be necessary for the first time to join pieces together to achieve the proper lengths and scantling for the works.

For the reconstruction of the inner shrine Naiku alone, 80,000 perfectly identified pieces must be reproduced. In this preparation process that begins a good ten years before the actual reconstruction, two main carpenters are needed, a master carpenter and a disciple; a team of 28 carpenters and, in the rush of the final stages, as many as 170 assistant carpenters. In the first ceremony, the Emperor of Japan grants permission to cut down trees in the sacred woods to be taken to Ise, to an enclosure called Yamada Kosaku-jo or craftsmen's site. Before completing the reconstruction, thirty ceremonies related to it are held altogether. For example, when the trunks arrive at the workshop and before work on them is initiated, there is a ceremony during which salt is sprinkled on the ground and shared out among the carpenters to purify the place while prayers are recited to entreat a good result.

Once there, the trunks are submerged in the surrounding lakes for a year until they expel their sap so as to prevent deformation and attacks by woodworm. Then the straight hinoki trunks are cut down the middle to the centre to concentrate possible deformations in this crack and are left five years to dry. It must be taken into account that the timber is used without paint or varnish or any sort of chemical treatment, so the seasoning process is of crucial importance. After this, each of the trunks is prepared by the carpenters, depending on its precise destination indicated in the transversal cut. The marking of the pieces is still done by hand, although the cuts are made with machinery. The joining and coupling of the different pieces is done according to the most refined ancestral carpentry secrets and demands great skill unknown in Western tradition. The pursuit of cleanliness and purity requires the carpenters, dressed in spotless white, to bathe and wash frequently. If the timber is accidentally stained with blood, the piece is rejected.

The new columns, beams and other pieces must have exactly the same dimensions and occupy the same position as their counterparts in the adjacent shrine that is to be demolished. Before reconstruction, trial couplings are made in the workshop and dismantled again before taking the pieces to the site, which is temporarily covered over by a tarpaulin to conceal the rebuilding process. In the sixty-first and last reconstruction in 1993, some iron pins were used for the first time, while in earlier reconstructions only wooden bolts, pins and plugs were used.

The roof is made up of thousands of bundles of kaya sprouts (miscanthus sinensis), harvested in special fields. In order to obtain the necessary amount for the roof of Naiku shrine alone, eight harvests are needed, which gives a partial idea of the economic, material and human effort involved in the periodical rebuilding of the shrine.

Material Reused

However, the timber from the ritual demolition of the shrine buildings does not go to waste. The old shrines are systematically dismantled, and their materials, considered sacred, are sent to other shrines in the Ise region and other parts of Japan to be used for the repair, daily maintenance or even reconstruction of shrines that have been burnt down or suffered some kind of damage. These holy materials are graded in quality according to whether they are used for the second or –at the outside– the third time. The more often they are used, the more their aura of purity is lost, just as in Japanese cuisine, the more often the soya oil in which tempura (deep-fried vegetables in batter) is fried has been used, the cheaper the dish.

An illustrative example of this reuse took place recently on the occasion of the earthquake at Kobe in 1995, which destroyed, among other buildings, the Ikuta Shrine. This Shinto shrine was reconstructed with materials from the demolition of the Ise Shrine, which were adapted to adjust to a very different architectonic style from the original. When materials are reused, they are often given new uses, that is to say, the value of piece depends mainly on the material of which it is made and not on the purpose for which it has been used before.

Some reconstructions take place systematically and affect elements situated outside Ise. The two major routes of pilgrimage to Ise, consolidated during the Edo period (1615-1868), departed from the cities of Tokyo and Kyoto, went along the road called Tokaido that connected them both to the cities of Kuwana and Seki, respectively, and then ran south until they converged at the city of Tsu, from which a single road led to Ise. These pilgrimage routes are marked with mileposts made out of timber from Ise. Thus in Kuwana, at the point where the road veers south, two sacred posts stand at a certain distance from each other; the same occurs at the turn of the Seki road. In the city of Tsu, a wooden bridge over the river that runs through the city is a third milestone on the route. Later, in the city of Ise, it is necessary to pass though several torii or gates, as well as crossing the sacred bridge of Uji, before reaching the sacred Naiku Shrine. All these landmarks are periodically rebuilt with timber from Ise. Thus the end pillars, munamochibashira, of the Naiku Shrine became part of the jambs of the torii or outer gateway into Naiku and, twenty years later, they became posts in Kuwana. On the other hand, the munamochibashira at Geku were later used as part of Geku gateway and later became mileposts at Seki. Uji bridge is also rebuilt every twenty years. It is made of the same timber, Japanese cypress (hinoki) except for the pillars in the water, which are made out of resistant Japanese elm wood (keyaki).

Historical and Political Connotations of the Ise Shrine

The origin of the Ise Shrine is connected with the historical and political circumstances of its time. It was conceived as a genuinely Japanese creation promoted by the emperor as an answer to the modern Buddhist architecture imported from China and Korea, in vogue in Japan in the 6th century. As we mentioned above, it was an architectonic reelaboration of old Japanese religion, so the shrine was meant to express that the emperor was free from foreign influence.

The cohabitation of the two religions, national Shintoism and imported Buddhism, gave rise to years of conflict and civil war, that ended with the creation of a sort of hybrid religion, shimbutsu-konko, which brought peace by combining elements from the two creeds. For that reason, it is impossible to visit a Shintoist temple that does not have at least slight Buddhist influence in its form or decoration. Ise is considered to be the most genuine of all in spite of the Chinese bronze decoration and it is therefore

the epitome of national culture, a starting point for national Japanese architecture.
The Meiji era (1868-1912) brought the emperor back into power after the Edo era (1615-1868) under the rule of the shogun. The emperor, leader of his people once again, wanted to shun the Buddhist culture of the shogunate and bring back the roots of the autochthonous Shintoism by reinforcing the worship and the tradition of reconstructing the Ise Shrine, which had quietly and discreetly survived the passage of history. Today the Ise Shrine is deeply appreciated by the Japanese people as their cultural heritage, regardless of its religious meaning and importance.

The Ise Shrine and the West
The discovery of the Ise Shrine by the first Western authors and particularly architects belonging to the Modern Movement gave rise to greater knowledge and overall appreciation of Japanese architecture but also brought about an exaggerated exaltation of the building, which we shall discuss below.
In his book *Japanese Homes and their Surroundings* (1886), the zoologist Edward S. Morse did not mention the Ise Shrine although he did deal with many of its characteristics in his study of old Japanese architecture. Morse's book, which has been republished several times until recently, is nonetheless crucial because of the crucial influence it exerted on Frank Lloyd Wright, although he never admitted it. Wright visited Japan in 1905 but apparently did not visit the Ise Shrine either on this trip or on his later visits. In any case, he heard of it through Kazuko Okakura's *The Book of Tea* (1906), which spoke of Shintoism in connection with the systematic rebuilding of religious complexes like the Ise Shrine. Later, in his autobiography, Wright alluded to the concept of cleanliness and purity typical of Shintoism, although he did not refer to any particular shrine.
The art critic Justus Brinkmann published *Kunst und Handwerk in Japan* in 1889, where he mentioned the Ise Shrine, but only as an exotic curiosity. The British writer Lafcadio Hearn, who became a Japanese citizen with the name Yakumo Koizumi, visited Ise and described his feelings about the shrine in his last book *Japan, an Attempt of Interpretation* (1904): "You only notice the space, the silence and the suggestion of the past".
In 1911, the architect Robert Mallet-Stevens, born into a family of Japanese-loving art dealers who opened up the market of the French Impressionists and whose Uncle Adolphe Stoclet had had his famous palace built in Brussels by Hoffmann and Klimt, wrote "L'architecture au Japon" (1911), where he outlined the major features of Japanese architecture, albeit without making any mention of the Shinto Shrine.
At the same time a specialised analysis of Japanese architecture appeared in Spain in the article titled "Arquitectura doméstica japonesa" (Japanese Domestic Architecture - 1909), taken from the Tokyo publication Far Orient and included in the section Crónica e Información of the architecture magazine *La Construcción Moderna*, one of the most important publications on architecture at the time. It praised Japanese vernacular architecture because it was based on real, rational laws and Shinto shrines were identified as a glorified version of this humble architecture. Before this article, there had been an initial contact with Japanese culture in Spain through the Japanese pavilion at the World Fair in Barcelona in 1888, where some unique constructions from Kyoto like the Golden Pavilion were discovered and some new aspects of their culture led to the introduction of new works like kimono, hara-kiri..., although on a very superficial and merely anecdotic level.
A long time later, after the epic years of the Modern Movement, the German architect Bruno Taut escaped Nazism and lived in Japan from 1933 until 1936. On 1st October 1933, Taut visited the Ise Shrine for the first time. His personal diary reflects the deep impression it had on him: "...the central creation for Japanese culture and, from a universal viewpoint, classically brilliant: Ise [...] It is all mere construction, only pure material and elaboration, like a 'type' reduced to the maximum simplicity [...] The 'barn style' often underrated in Germany, here in the total classicism of the purest national shrine in Japan: modelled on nature according to Shintoism, of uncertain age [it may have been rebuilt more than 60 times]." in November 1934, Taut wrote a first article titled "The New Architecture in Japan", published a few months later in *L'Architecture d'Aujourd'hui*, which included an introduction about traditional Japanese architecture with pictures of the Ise Shrine and Katsura Imperial Villa in Kyoto.
Captivated by this "sublimated form of rural house", Taut tackled the ambivalence of its strange always fresh and renewed antiquity and even defined the shrine as Japan's first architectonic miracle. "It is a pilgrimage that every true architect from anywhere in the world should embark upon, because only here can one find ancestral Japanese culture in all its purity, free from the influence of China. The paradigmatic thing is that they are very newly made: they are rebuilt every twenty-one years (sic) by carpenters who observe the religious rites very strictly and do not vary the form in the slightest. They are old, austere, classical buildings, but without the aura of antiquity of cathedrals or Buddhist temples and without the remoteness from contemporary life of the ruins of the Acropolis, for example."
In his later books *Fundamentals of Japanese Architecture* (1936) and *Houses and People of Japan* (1937), Bruno Taut reiterated his admiration for the architecture of the Ise Shrine and the phenomenon of its eternal reconstruction and destruction and the surprisingly modern simplicity of the Katsura Villa in Kyoto, rather than the baroque-style Buddhist shrine at Nikko. He was also disconcerted by the lackadaisical attitude of the Japanese, who approved just as easily the preference of the Western World for Nikko at the end of the 19th century for Ise and Katsura in the nineteen thirties, one of the many examples of the inclusiveness of options that characterises Japanese culture.
At the same time three books by Japanese authors that bring Japanese tectonic culture closer to the West were published. In the first place, the important volume of Wasmuth publishing house that illustrated the history of Japanese domestic architecture under the title *Das Japanisches Wohnhaus* (1935), written by the architect Tetsuro Yoshida at the request of his colleagues Hugo Häring and Ludwig Hilberseimer. In the second place, *The Lesson of Japanese Architecture* (1936), written by Jiro Harada, conservator of the Imperial Museum in Tokyo, which described the sacred aura to be found in the simplicity of the Ise Shrine. In the third place, Aisaburo Akiyama's book called *Shinto and its Architecture* (1936), containing an overall study of Shinto architecture in Japan, including the Ise Shrine, influenced by the fervent nationalism rampant in Japanese politics in the nineteen thirties.
After World War II, in a conversation with Kenzo Tange, Antonin Raymond, an architect of Czech origin who collaborated with Wright in the building of the Imperial Hotel in Tokyo and who later settled and practised his profession in Japan, admitted how much admiration he felt when he first went to Japan and discovered the Japanese house and the Ise Shrine, where he found the features he wanted to introduce into a new architecture.
In 1960, encouraged by the publication of Arthur Drexler's *The Architecture of Japan* (1955) and invited by the above mentioned Kenzo Tange, Walter Gropius made a three-month trip to Japan and then narrated his experience in the book *Architecture in Japan* (1960). His ideas about the Ise Shrine, the Katsura Imperial Villa and the religious buildings at Nikko repeated and applauded the opinions of Bruno Taut, who thus began have the status of a canonical reference in the relationship between Japanese architecture and the Modern Movement.
In his little treatise about the history of architecture in Japan published in Tokyo in 1962, the critic A. Sadler not only spoke about the case of Ise, but added new data. This author gave an interesting explanation of the reconstruction rites, which he interpreted as stemming from the ancient custom of shifting buildings to a new site on the death of the emperor, which usually took place every twenty or twenty-five years.
Shortly afterwards, Manfredo Tafuri merely echoed the experience and opinions of Bruno Taut and Antonin Raymond about the Ise Shrine in his book L'Architettura Moderna in Giappone, published in 1963. For his part, that same year the critic Werner Blaser published the book *Struktur und Gestalt in Japan* in a bilingual German-English version, in which he mentions the Ise Shrine among other examples in his description of the main features of Japanese architecture, but apparently not knowing about the phenomenon of its ritual reconstruction or not paying any particular attention to it.
A few years later, John Burchard, the dean of Massachusetts Institute of Technology, supported Taut's opinion in the prologue of a book about Ise, and said that "it is one of the greatest architectonic achievements of all time" and that it "has many lessons to teach contemporary architects." The book in question is the most complete monographic work on the shrine by the architect Kenzo Tange and the critic Noburo Kawazoe under the title *Ise, Prototype of Japanese Architecture* (1965).
In the book, Kenzo Tange commented on two remarks by Bruno Taut and Walter Gropius about the Ise Shrine and the Parthenon in Athens. In Taut's opinion, both examples represented a climax in the history of architecture. For his part, Gropius emphasised the contrast between the semi-darkness of the woods at Ise and the dazzling radiance at the Parthenon, which Tange interpreted as a desire for integration and adaptation in the former as opposed to a gesture of dominion and conquest of nature in the latter. However, the purpose of this book was not to exalt the supposedly postmodern characteristics of the Ise Shrine but rather to explain the site from different viewpoints, such as architecture, mythology, history, anthropology... Kenzo Tange saw the Ise Shrine as a melting pot where Japanese culture, architecture and nationality were made, whereas Noboru Kawazoe analysed its architecture in detail on the basis of culture, history and mythology.
In fact, following the publications relating the Ise Shrine with modern architecture was no longer justified after this turning point in literature about the phenomenon, as the manifestations multiplied until they became mere references of the texts mentioned. It is worth mentioning, however, a recently published book with a peculiar title (*From Shinto to Ando*, 1993) by Günter Nitschke, a German critic who lives in Kyoto, who gives an overview of the principal features of Japanese architecture from the Ise Shrine to Tadao Ando's work, analysing the aspects that have lasted in time and their formal transformation.
This admiration that the Ise Shrine has aroused especially among Western architects as a paradigm of architecture with postmodern features is worth analysing in detail. In the first place, we must remember the admiration that members of the Modern Movement felt for vernacular architecture in general and particularly in the Mediterranean region. First we find the text by Ruskin

called "The Poetry of Architecture" (1834), where the author attaches the same importance to vernacular constructions and monuments. The sincerity inherent in these modest constructions can be compared to the concept of purity, sincerity and truth in Shintoism that leads to structural transparency and respect for matter, also defended by this author in "The Lamp of Truth".
Adolf Loos was ahead of his time in praising the hidden potential in the spirit of vernacular buildings as opposed to too well designed architecture in his article "Architektur" (1910). Closer to home, we can also mention an article by the same title ("La arquitectura") written one year earlier by Azorín, who was also ahead of his time in praising the vernacular architecture created by the local genius of master builders and masons over the affected style of academicist architects, in the broadest sense of the word. Behind this article lie the pioneer ideas about vernacular architecture to be found in the book Granada la Bella (1896) by Ángel Ganivet, his companion of the 1898 Generation, prematurely deceased.
Then, in the late nineteen twenties and especially the early thirties, an unusual interest in Mediterranean vernacular architecture arose among modern architects, which was exalted and studied by such different characters as Torres Balbás, García Mercadal, Sert, Le Corbusier, Raoul Hausmann..., particularly after the IV CIAM, held on board a cruiser that called at several Greek islands, whose architecture captivated the participants, especially László Moholy-Nagy, who made a photographic report of all the events.
This admiration aroused by the spontaneity, common sense, implicit functionality, essentially constructional character and lack of affectation, whim or "style" of vernacular architecture was no different from the fascination aroused by the Ise Shrine. The acclaimed purity and spotlessness of the white volumes of Mediterranean architecture had its equivalent in the implicit cleanliness of Shintoist culture.
In the case of Ise, we should, however, mention other additional factors arising from Japanese culture that made it even more attractive to Western architects: the fact that the principal material –timber– was used without any sort of treatment or finish, so that the constructional system of the building is even more evident without losing its clean, warm appearance; the modulation and standardisation typical of carpentry tradition in Japan and, therefore, its architecture; and the establishment of a relationship of continuity between interior and exterior because of the climatological characteristics and Japanese architecture, even more obvious than that found in the doors and windows of Mediterranean architecture in spite of the abundant courtyards and the richness of the intermediate spaces.

An Attempt to Interpret the Ise Phenomenon

It has always been a very difficult task to interpret Japanese culture in its different manifestations, especially if the viewpoint is excessively Eurocentric. It is all the more difficult in this case to explain the recidivist paradox that apparently undermines the foundations of Western concepts of restoration, conservation or authenticity.
In the first place, we should point out that the Japanese language has a dozen or so expressions to express the different nuances and degrees in the restoration of a building: the most all-encompassing one, implying reinstating with the same materials, is f*uku-gen = recover-original*; making a copy is expressed by the term *fuju-seihin = recover-copy*; isolated repairs are *shu-sei = maintain-straighten*; small-scale refurbishment (cracks, details...) *shu-zen = maintain-mend*; structural works are *kai-shu = renovation-maintain*; restoring to its original state after a fragment has been lost is *shu-fuku = maintain-original*; the rehabilitation of installations, finishes or facades is expressed by *kai-chiku = renovation-construction*; exact reproduction after a catastrophe (fire, earthquake...) is *sai-ken = repeat-erection*, whereas the simple reconstruction of a similar volume is *shin-chiku = new building*; reconstruction after anthropic destruction is *tate-kae = building-reerection*; a change of a building's use is *ten-yo = change-function*; integral conservation is *ho-zen = conservation-totality*; maintenance is *i-ji = connection-maintenance*; and the dismantling and shifting of a building is *ii-chiku + fuku-gen = move-building + recuperate-original*.
Nevertheless, none of these is used at the Ise Shrine, for which there is an exclusive verb whose etymology gives us an idea of the real original meaning of the destruction-reconstruction act: *zo-tai = make-change*. Indeed, the cyclic rebuilding of the Ise Shrine has no direct connotations with the semantic field of conservation and restoration in Japan. It is not so much a rebuilding as a change, a renovation for religious reasons with a profound implicit sense of freshness, cleanliness and purity. The relationship with matter is in this case symbolic, as is to be expected in an animist religion like Shintoism. New matter means purity and, for that reason, it is valued not so much for its physical condition as for its inherent spirituality.
The reuse of the material from the shrines is also symbolic. In this case, matter ages little by little, it loses purity and its figurative value decreases. After it has been used for the third time, the only value that remains is its physical material value and its possible use as building material is now free as it no longer deserves any special consideration.
In this process, not the matter but the desire to be is conserved, and here lies its explanation. It is not the object that is of interest, but awareness of the object. In any case, as we pointed out above, matter also has a value and that is why it is used again later. Everything that is subjected to a specific physical shape is condemned to degeneration. At Ise, what is conserved for posterity is the style, bearing the awareness of the object, not the physical constructions that embody it. Only style is indestructible.
It is apparently a simple reconstruction, but in fact it is an operation of maintenance, with the same maintenance philosophy traditionally put into practice in Japanese temples, understood in the light of Shintoist ideas of purity and renovation. Maintenance in this case is not applied to the physical object but to building tradition. The heritage conserved is the intangible heritage of skilled craftsmanship. The carpenters, the master and his disciple, separated in age by a generation which could well coincide with a twenty-year span, build the authentic heritage and are protected by Japanese law as living heritage. Therefore great importance is attached, at least indirectly, to craftsmanship and the conservation of traditional techniques.
In Western architecture permanence is manifested by the solid and long-lasting material nature of the work built. The permanence of the Ise Shrine is manifested by continuity and change, like a river, where the molecules of the water change incessantly but the water is always there; or like a garden, where the flowers and shrubs change with the passage of the years but the garden is always the same.
The alternation of sites at Ise is a curious phenomenon whose origins are linked to the provisional nature of abodes. In the distant past, at the death of the father of a family, it was considered necessary to build and move to a new house. In the same way, the early stages of the historical period in Japan are characterised by the founding of a new capital and the ensuing change of place every time an emperor died and a new one was crowned.
Similarly, nowadays traditional Japanese houses have private shrines that are renewed and relocated every year. The architect Bruno Taut remarked in his studies about local architecture that many Japanese people thought that it was against the Japanese spirit to build for a long period of time. Behind this desire for change lies the same need for ritual renovation that characterises the cyclical process of the Ise Shrine. There is an interesting, surprisingly pragmatic variation in the case of the Shimogamo Shrine in Kyoto, which has two permanent twin shrines and where this necessary renovation consists of the god being moved from one to the other every twenty years.
In any case, the bewilderment felt by a person from the Western World at the contrast between the built site and the empty site, that is, between existence and non-existence, is not shared by the Japanese mentality, which accepts quite naturally the options of any apparently opposing duality. An empty rice paddy waiting to be sown holds the hidden forces that will make the crop grow, just as the empty site at the shrine contains the potential otherness of its copy. The ultimate identity between existence and non-existence preached by monist Zen philosophy was embraced as familiar in Japan since it formed part of the mentality of the people, used to the coalescence and complementariness of opposites.

The Significance of the Primitive Cabin

Joseph Rykwert relates the Ise phenomenon with the ancestral cult to the primitive cabin in Greek, Roman, Jewish, Egyptian, Sumerian, Chinese and other civilisations. All these cultures built cyclically and would sometimes destroy a primitive cabin following certain rites whose intention was to reproduce a primitive state as a reminder of their origins. These ceremonies were tantamount to an act of renovation, purification and transition, just as occurs with the Ise Shrine.
In Ancient Greece, the Delphi temple was the scene of an Apollonian festival) held every eight years and known as Septentrion (for the seven years that elapsed between one celebration and the following one), during which a timber cabin was erected on a site called the threshing floor to be ritually burnt down immediately afterwards. This ceremony may have been a sacred festival reproducing the agricultural cycle, as it has been described in the case of the Ise Shrine.
In Rome the hut on the Palatine Hill or Romulus' cabin on the Capitoline Hill described by Vitruvius are relics in their own right that, in spite of periodical maintenance, replacement of parts and successive reconstructions in primitive style after fires, were a token of the antiquity of Rome and proof of its authenticity. The same applied to the Regia in the Roman Forum, a deliberately archaic building. Originally the home of the second king of Rome. Numa Pompilius, it became a sanctuary associated with ancient rites and the principal reliquary in the Roman State, housing, among other treasures, the mythical lances of Mars, the protector of Rome. In the particular case of Ise, the building is both a reliquary and a relic in its own right.
In Japan there still exists an act of provisionally erecting a group of primitive cabins that is in all likelihood related to the phenomenon of the Ise Shrine. It is the enthronement ceremony of the new emperor, during which over a hundred cabins are erected on piles, without foundations, made out of unstripped tree trunks tied together with wicker, floors of straw mats and a pitched roof of freshly-cut green grass, with the external joists (*chigi*) sticking out and crossed timber trunks (*katsuogi*) on top. The Feast of Tabernacles in Hebrew culture also includes the building of rustic huts made with green plants, and the provisional use of these as dwellings is associated with annual expiation and purification rites. These acts associated to the construction and provisional use of rustic huts like those used by their distant ancestors represent a ritual

procedure of returning to one's roots that constitutes a cosmogonic attempt at renovation of time by recreating the early conditions of a civilisation. As we shall see below, this return to their roots also characterises to a very great extent the way the Japanese culture approaches the world of restoration.

The Concepts of Copy and Reflection in Japan

The concept of a copy understood as a physical reproduction is relatively recent in Japan. A copy in the case of the Ise Shrine consists of a spiritual counterpart of the adjacent shrine, a single concept and two manifestations of it. It is interesting to note that in Japanese mythology there is very often no distinction made between the figures of mother and daughter, so that the goddess Amaterasu contains within her the two identities. At Ise and particularly at the Naiku Shrine that represents the goddess's dwelling place, the distinction between the original and the copy is not very clear either.

Shintoism does not attach great importance to the physical reproduction of the shrine, but to the reproduction of the ceremony based on purity and, underlying this, the perpetuation of the crafts required to reproduce it. In any case, the ceremony is the main aim, far more than the conservation of the crafts (which were flourishing when the rite of the shrine was first established) or the actual reconstruction of the building (which very quickly goes from being a copy to being the new original). Conceptually, it is a process that reproduces the way the copied object came about, half-way between a faithful representation and a total appropriation of the "original". The strange lapse of time during which the twin buildings stand side by side is apparently a peculiar synecdoche of mass production. However, unlike many other cultures that used to worship twins, premodern Japan hated them because they evoked a disturbing closeness to dogs, cats or rodents, and a mother of twins was given the disparaging nickname of *chikusho-bara* (animal womb). And this has been so until very recently. As a curiosity, the ex-boxer and architect Tadao Ando, born Tadao Kitayama (1941), was himself the object of discrimination because he was a twin. To avoid abuse, he was brought up in his maternal grandparents' house and took their surname. His twin brother Takao Kitayama, also a boxer in his day, is now a businessman extraordinarily like his alter ego.

On the other hand, the idea of reflection and the implicit force of the borrowed image is linked to the concept of a copy seen not as an imitation of itself but as a spiritual loan imbued with great transcendence. We must remember that the sacred object par excellence of the supreme goddess Amaterasu is precisely a mirror kept inside the Naiku Shrine, given by the goddess to man with these words: "Worship this mirror as though it were myself". That is, in coherence with the animist creed, divinity is a mirror that reflects everything. Divinity is not a rock, a tree or a mountain, because they are all subject to change, but the idea of the rock, tree or mountain, their reflection that permits them to transcend and resides within them.

There are mirrors in local fairy tales, like the story of Urashima, a fisherman seduced by a marine turtle-princess who spends three years at the bottom of the sea and when he comes back to dry land, he discovers in his reflection that more than seven generations have really gone by, and he is turned into a crane. In other words, there is an alternative world where the passage of time is imperceptible that could be the equivalent of the perpetually renewed sacred shrine at Ise. The story of Urashima, which means literally "he who forgets the passage of time", is told in a traditional song from Ise called *The Crane and the Turtle*.

An old Shinto ritual recuperated in the eighteen eighties involved the believer bowing before a mirror and looking at his own image to purify his soul. Mirrors appear in local traditional folklore and are hung from trees during certain festivals. The concept of the borrowed image has transcended the Japanese art of gardening , where the surrounding landscape is incorporated into the design by means of the careful location of plants and paths. In the sphere of traditional architecture there also exists the concept of shakkei, which places the openings of houses so as to frame part of the landscape when viewed from the inside.

Ise and the Japanese Concept of Restoration

The statement that the concepts of restoration, conservation of heritage and perpetuation of matter do not exist in Japan goes against the nature of the idiosyncrasy of any human being. It is necessary to do away with the idea that the Japanese pay no attention to the materiality of their historic buildings. It probably is true that they do not set great store by ordinary residential architecture, which they consider as something essentially practical and therefore requiring renewal according as it deteriorates physically and functionally.

No doubt the fragile, precarious condition of Japanese buildings, always submitted to natural catastrophes (earthquakes, typhoons...) and anthropic disasters (wars...) has contributed to this idea. The Kanto earthquake in 1923, for example, caused 134 fires that destroyed three quarters of the city of Tokyo, which was rebuilt and destroyed again twenty years later by incendiary bombing by US aircraft during World War II. The dwellings built on these sites have been replaced at least twice since then by new buildings in cycles of obsolescence, destruction and new construction lasting between twenty and forty years.

But in the case of historic monuments in Japan there is no symbolic relationship with matter as occurs in the case of the Ise shrine, but rather a physico-functional relationship with it. The deterioration of a fragment of these buildings that cannot be repaired leads to the replacement of this fragment. If we take it into account that most of these buildings are made of wood and that the traditional art of carpentry is still flourishing in the country, it is easy to see that it is possible to remake these fragments. In any case, there is no such thing as massive replacement but rather continuous maintenance and repairs.

Currently there are 3,600 protected architectonic monuments in Japan, 90% of which are made of wood. Nearly all of them have been partially or totally rebuilt throughout their existence or the original parts have even been dismantled, repaired and reassembled. This habitual dismantling and reassembly that has lasted until our time has collaborated in preserving traditional carpentry techniques and permitted a very high level of investigation, analysis and preliminary studies of historic buildings in Japan. The author Niels Gutschow goes as far as to say that architectonic research is the force behind restoration projects.

The continuous interventions practised on Japanese monuments cannot but remind us of the Western idea of maintenance, understood as the series of operations that make it possible to keep the building in proper working order. The series of operations defined under the name of maintenance is the attitude towards the monument prioritised by restoration charters, from the Athens Charter (1931) to the Declaration of Amsterdam (1975), not forgetting the Italian Charter (1932) and the Venice Charter (1964). Ruskin himself considered daily maintenance to be the most suitable intervention on historic built heritage, whereas Alois Riegl, who attached the greatest importance to the value of antiquity, considered maintenance to be the only possible intervention. In these cases maintenance was understood as the series of operations that prevented monuments from deteriorating without eliminating their patina and venerable appearance.

However, given that maintenance seems to be the attitude that best favours the conservation of the building, the problem resides in the definition of the operations that can be considered maintenance. In 1978, Italian law (L. 457/78, art. 31) regarding the recuperation of historic city centres defined the distinction between ordinary maintenance and extraordinary maintenance. The former includes all repairs and renovations of interior and exterior finishes and all repairs of installations to guarantee correct operation. The latter refers to operations intended to renovate and replace elements, including structural elements, and the addition or integration of installations, provided that the interventions do not alter the volumes and surfaces of the building or involve changes of use.

By virtue of this Italian law, most of the restoration works practised on Japanese monuments (especially religious buildings) could be considered maintenance, since in most cases no change of use is involved and structural and finishing elements are only replaced to ensure the permanence of the building in its configuration. In any case, the reconstructions of the Ise Shrine could not be included within this concept, because it is a case that defies any possible attempt at definition in Western terms.

Furthermore, the Ise Shrine, the most highly valued historico-architectonic ensemble in the whole of Japan, is not included among the 3,600 protected monuments. There are two main reasons for this: in the first place, because the Heritage Law in force in Japan prohibits the destruction of officially appointed monuments; and in the second place, because, as occurs with other buildings belonging to the emperor and not officially appointed monuments, such as Katsura Villa in Kyoto, this protection would oblige it to follow a regime of conservation, control and public visits incompatible with the inviolable sacred nature of the site.

It is paradoxical to compare the underlying philosophy in Shintoist animism that attaches great importance to matter in a pure, immaculate state and Buddhism imported from the continent that considers matter untranscendental in its earthy condition. These two stances have brought about two apparently contradictory results: the atavistic forms of the Shintoist shrine at Ise are built out of new timber subject to permanent renovation, and the Buddhist temple of Horyu-ji at Nara, for example, is one of the oldest wooden constructions in the world since the original 8th century timber is largely conserved, precisely and paradoxically, as a result of their indifference towards matter.

On the other hand, the Shintoist concept of purity that leads to the periodical replacement of matter to avoid its decadence is opposed to the Buddhist concept of wabi-sabi, related with the beauty of imperfect, changing and incomplete things. In this way, as well as appreciating the ritual renovation of the shrines at Ise in search of eternal freshness, the patina of time is valued on other buildings, just as the great beauty of a humble flower which has begun to fade and wither can be valued above a rose in all its splendour. This added dimension from Buddhist philosophy that objects acquire with the passage of time is on constant tenterhooks with the Japanese desire for renovation conceived as the building's return to its initial state.

In fact, the general concept of restoration described, *fuku-gen = recuperate-original*, reflects the tendency that exists in Japan to recover the original appearance of a building and even includes reconstructions based on old documents and measurements. It is often a case of recuperating a pristine state of the building's evolution, considered the most significant, and even *perfecting* an original design never properly executed, regardless of the fact that the

destruction may have taken place in recent times, like the fire in Hiroshima castle in 1945, or thirteen centuries ago, like the Suzaku-mon in Heijo-kyo. The 1972 reconstruction of the original state of the famous Yakushi-ji temple in Nara, a city located 100 km from Ise, was based merely on archaeological data. The emphasis that Japanese law places on the antiquity of an object and on certain typologies of buildings may explain this desire to recuperate their original, unitary form. The material must be as old as possible in order to be considered authentic, but the idea of the building is in any case more important than the actual material, which may be replaced or removed in order to restore it to its original state.

In spite of the cultural and geographic distance, restoration in Japan is based on similar principles and pursues the same aims of authenticity as restoration in the West, with three peculiarities. In the first place, it is a country traditionally punished by natural and anthropic catastrophes that have often destroyed their monuments, so that they have had to consider the benefits of rebuilding monuments since olden times. In the second place, timber as the major raw material has involved the dry building of monuments and the ensuing ease with which they can be disassembled and reassembled, whether after a catastrophe or merely to replace a damaged part of it. In the third place, the fact that the country is an island and, in spite of the absorption of other cultures, their staunch defence of traditions and rigorous, in-depth, traditional knowledge of building techniques leads them to seek in restoration the original prototypes inherent in their culture, in a line we might compare in the Western World with the principles of Viollet le Duc, admirable in their scientific content in the 19th century but unacceptable in their alleged arbitrariness today.

These three peculiarities undermine the traditional concept of authenticity as we conceive it in the West, although there are many examples accepted or tolerated in general in Europe that have a lot in common with these peculiarities. The first circumstance can be seen in the postwar constructions after the Second World War, among which we can include the reconstruction of the Frauenkirche in Dresden, under way at the present time. The second peculiarity, with restoration works in areas in Central and Northern Europe, where timber monuments exist, usually restored by replacing damaged parts, such as the Greek Orthodox church at Stary Ladoga in Russia. The third peculiarity, with the recent reconstruction of buildings that were documented but do not exist at present, with a certain mythical aura of being prototypes and important from a cultural viewpoint, like Le Corbusier's *Esprit Nouveau* pavilion (originally dating from 1925, reconstructed in 1977), Mies van der Rohe's German Pavilion in Barcelona (originally dating from 1929, reconstructed in 1986) or José Luis Sert's Spanish Pavilion at the Paris World Fair (originally dating from 1937, reconstructed in 1992), magnificent apocrypha that permit us to evoke a heroic period of architecture.

The Nara conference on Authenticity (1994), significantly held in Japan, considered the cultural relativity of criteria about value and authenticity in monuments and, in this way, strove to support these peculiarities concurrent in Japanese culture, apart from many others pertaining to non European cultures, in an attempt to counteract the traditional colonial attitude of Western countries. In the Declaration of Nara the Ise Shrine is not mentioned but rather the place where it stands, a city appointed World Heritage Site, which houses countless timber monuments under permanent ordinary and extraordinary maintenance.

This generalised attitude of maintenance in Japanese architecture is not a basis to affirm that the concept of authenticity is entirely independent of the monument's materiality. Only in a few cases has the official overvaluation of certain prototypes of traditional Japanese architecture led to the dangerous reconstruction of long-lost buildings, in a difficult exercise of historic erudition and re-creative hyperbole under the exceptional skill of traditional crafts, exceptions to the rule bordering on the absurd. Traditional ignorance and misinterpretation of the reasons underlying the phenomenon of the Ise Shrine could well serve to jump to conclusions and frivolously justify even the current best-studied and nonetheless most ridiculous reconstruction projects in the West by denying material value its fundamental role in the history of the monument, in an attempt to recuperate the original volume but not the original space, since the perception of space has never been independent of its materiality.

Restoration in Japan is not related in principle to the process of cyclical reconstruction of the Ise Shrine, which originally has other aims of a religious type related to purity and spiritual renovation. The reproduction of these copies at Ise sustains the seed of Japanese cultural architectonic tradition and, at the same time, guarantees the survival of ancestral building trades, but it does not constitute a basis on which to create a theory for the general interpretation of restoration in Japan.

Javier Rivera Blanco

RESTORING GAUDÍ: FROM MIMETIC RECONSTRUCTION TO FORMAL ANALOGY WITHOUT OMITTING HARMONIC DIACRONY: THE LAST 25 YEARS

"*... decoration has been and will be polychrome. Nature does not present any monotonously uniform object. Everything, in the plant world, in topography, in the animal kingdom, always maintains a more or less vivid chromatic contrast. And that is why we absolutely must colour all or part of an architectonic element; it is a colour that may be evanescent, but in most cases this will be a way to confer to the colour itself another quality that is proper to it and beautiful: age*." A. Gaudí (in I. Puig-Boada, *Antoni Gaudí. Idée per...*, p. 72).

How has Gaudí been restored? Should there be a specific way to restore the Catalan maestro? Were the restorations made on his works applied with particular methods, techniques and criteria? The most modern restoration theory, critical restoration, answered all these questions some time ago. According to the principles of this theory, each monument is a case in its own right and there are no general prescriptions for its restoration. It is exhaustive knowledge of the particular features of a building that will provide clues about the right criterion to apply. In his Restoración objetiva (Objective Restoration), an even more recent methodological proposal, Antoni González has also pointed out that there are no established stances for restoration, regardless of whether the work is Gothic, Plateresque, classical or Gaudian.

In all cases, the priority must be to conserve the object to be restored; in this sense, the challenge is to the restorer's capacity to preserve intact the authenticity and transmission of the signs of identity of the object, concepts that may seem ambiguous but actually are not, because they mark precisely the boundary –the question raised by those who do not know it– that must make the difference in the intervention. The restoration of a building in all its conceptual variants is based on the capacity of safeguarding its preexisting state. If this is damaged, it is a work neither of restoration nor of conservation.

In the history of architecture there are no sacred or untouchable works as regards personality, because time has altered them and other agents have made all sorts of transformations on them. In this aspect, Gaudí's works are not untouchable either, provided that their authenticity and identity can be safeguarded. There are, no doubt, intervention philosophies, methodologies, rules and regulations that will give priority to some because of their classification when their uniqueness makes society want to protect them, for example, there are several laws that affect each of Gaudí's works; in Spain the 1985 Ley del Patrimonio (Heritage Law), the Catalan Heritage Law, the laws of the places that have these classifications, all applicable to Gaudí's works –the majority in Catalonia, El Capricho in Cantabria, Casa Botines and the Bishop's Palace in Astorga in the province of León. There are other less important local regulations that establish specific protection for some of them, such as catalogues, General Plans, Special Plans, Ordinances, etc. Therefore, in this same order there is no such thing as sacred works, just as the Prado Museum, the Roman theatre in Sagunto, the Colonia Güell Chapel or the Teresianas in Barcelona are not sacred buildings, because their very character requires that interventions be carried out on them every so often to guarantee their survival; the problem, then, is having enough common sense to understand the provisions determined by the institutions of society for their conservation, and acquiring previously the capacity to understand the values of the building.

From the same parameters and as regards monumental heritage and, specifically, Gaudí's work, there is not a single directive that can be cited to justify not completing buildings like the Sagrada Familia Church, a work that Gaudí must have known he would not finish personally, as an architect who never contemplated the ruin of his creations, as he was anything but an eighteenth century Ruskin-style Romantic. But this can be done because it is an unfinished work. In some cases it is permissible to add new parts to finished historic buildings, but in others it would be unthinkable, as for example interventions involving additions to Fallingwater or Rietveld's House to equip them better or add new functions to them.

Another situation arises too, the personality of Gaudí's works themselves, some aspects of which need to be submitted to common maintenance tasks to guarantee their survival, all the more so since many of them show a limited aspiration of perdurability, as we can gather from the specific choice of perishable materials in finishes and structures. The lack of such maintenance and the passage of time would have been well accepted by the architect from Reus, who, as a good professional, would have known that his creations would be restored, and did not seem at all concerned about it. Neither was he concerned about the fact that many others were left unfinished, to judge from the graphic details the architect left deliberately for the chimneys of the Güell Palace, the chapel at the Colonia Güell, the top floor of the Bishop's Palace in Astorga, the Sagrada Familia Church, etc., and Gaudí, like any sensible architect, knew that someone would somehow have to finish them. This probably did not worry him so much as other immediate problems that he would have had to solve. On the contrary, he could not have guessed what functions they would develop in the future as regards their use for commercial, tourist or merely residential purposes.

Aside from Gaudí's genius, which poses great difficulties to those who attempt to restore his deteriorated works, in other words, who must have the talent, intelligence and skill to do so, the concepts of his constructions are the same as everyone else's and his works must be restored according to the prior conditions mentioned above, that is, by studying his work in depth and giving it all due respect. This can only be done in the present and with exhaustive

knowledge of his theory and practice. The important thing may not be how badly the restoration of the lower floors of La Pedrera or the interior refurbishment of El Capricho was done (in the former, due to indiscretion and, in the latter, because of the lack of plans and evidence of the original state) because, if most of us agree, they can be de-restored and done all over again properly; the important thing may not be either that the Sagrada Familia Church should be continued, although the ethic battles have given rise to crusades, because if it is concluded with minimum respect for Gaudí's contribution, his part will always be valued as such, regardless of the additions and gap-filling. If indeed we have come to the conclusion that Gaudí's works are unique, the restorer's mission will be to transmit their values intact and authentic to the future. And this can be done without relinquishing the techniques of today, as today we have developed codes to understand it: the media that constitute it. The course "25 years intervening on Gaudí" offered the solution of applying today's codes for the conservation of monuments. In our case, we shall never renounce the philosophical key of Lefebvre's postulate: "History is written for the present". Without the reality that each present –which is becoming wiser and wiser and more and more conscientious– offers the past, this does not make sense.

On the other hand, the area of restoration has evolved sufficiently from the now long past Athens Charter (1931) and Venice Charter (1964) until the more recent Cracow Charter (2000) to create a genuine cultural basis of conservation, applicable at all times and in all circumstances.

GAUDÍ, FROM OBLIVION TO RECOGNITION: RESTORED WORKS

Many of Gaudí's works have already undergone remarkable interventions for their quality or their quantity, in spite of their short-lived existence. The oblivion they suffered until the hundredth anniversary of the architect's birth in the mid twentieth century was followed by their appreciation and acclamation. But before and afterwards many different sorts of interventions were practised on them, not always initially in an attempt to conserve the objects properly, because they were not yet considered by society to be part of the collective heritage. Most of them were given new uses, some of which were incompatible with the original. In other cases they were interpreted without due knowledge or sensibility of their worth. Also, there is no reason why we should not say so, because they were sometimes not believed to be the transcendental pieces of contemporary architecture that they are considered today. In his writing on "The modern cult to monuments", Riegl said that the new architectures would be added to the cultural treasure and become the new monuments of modernity.

Nevertheless, we cannot forget either that in restorations of Gaudí's buildings there have been and will always be complex cultural components that often have very little to do with conservation theories or the praxis of the project in architecture. I refer to matters of nationalistic, ideological, ethical, moral, historical, social, religious, traditional and modern type that underlie every intervention and add several complex factors that interfere even more in the issues of conservation or the discipline itself.

If we just concentrate on this last aspect, we should say that the phenomenon is scarcely appreciated because some of its basic components are removed from it. And the view of Spanish restoration in recent years does not include the Catalan context. Even so and with the express desire to value the object as a monument to be transmitted to the future, Gaudí's works have been restored with different criteria and a varying appreciation of the many problems involved in them and seldom without the necessary scientific debate and reflections necessary for this type of intervention. If we add to this the lack of critical awareness in the universes of architecture and restoration in our sphere, where differences of opinion or even disagreement are considered moral, professional attacks and not debates that enrich and expand scientific democracy, we can also understand certain damage undergone by certain of the Catalan architect's masterpieces.

In 1969 seventeen of his works were appointed National Monuments (list) and in 1984 three were included in the catalogue of UNESCO World heritage Sites (Güell Park, La Pedrera-Casa Milá and Güell Palace). At the present time the Nationalities and Regions containing works of his and the Spanish State have requested that the rest of his works be included. The idea is, then, according to the implications involved, to achieve the maximum juridical protection for all his production and, in consequence, to ensure strict conservation with all the means provided by the discipline of restoration.

Meanwhile, among the many new publications about different aspects of Gaudí's person and works from several different viewpoints, it is necessary to give special mention to works like the recent one by José Luis González: Gaudí y la razón constructiva. Un legado inagotable, the most advanced study about the architect, based on the direct investigation of the constructions thanks to the fact that the author collaborated in or witnessed the most important restoration works made on them by Antoni González, the foremost restorer of Gaudí's oeuvre. Thus, as French and Italian disciplinary tradition in this field claim and prove, restoration –fulfilling a painstaking work methodology– is the best source for the knowledge of any period or author.

RESTORATION OF GAUDÍ'S ARCHITECTURES: FROM UNITY OF STYLE TO STRICT CONSERVATION

As we said above, Gaudí's works have undergone several operations and interventions since they were finished until today. The first of these, which we could call historic, were of a neo-Gaudian type, for examples, those practised on buildings damaged during the Civil War (Güell Park). Others were done in an attempt to achieve "unity of style" according to the proposals of the 19th century French school, that is, in the manner of Viollet-le-Duc, trying to act not only as though one were the original architect but actually improving his ideas, as was the case of the entrance pavilion to the Park or the little tower there or the Colonia Güell Chapel, where the added parts were made imitating Gaudí's style. In some conclusion or completion works, the project was in modern style and had very little to do with the original (the Bishop's Palace in Astorga, for instance). In other more recent cases, work was performed by formal contemporary analogy (Güell Palace) or imitation (Sagrada Familia). This shows that there has not been a single modus operandi and that professional restorers have had very different approaches when working on these buildings. Some, in fact a large number of them, are justified by the philosophical conservation movements put into practice at each stage. It is therefore possible to understand them in context. They are more difficult to interpret under the values of those same philosophical movements when they were not the most advanced and progressive in Europe in the sense of integrity of the architectural assets, because, for example, the Violletian attitudes in vogue in Spain during most of Franco's regime had been discarded everywhere else in Europe and were considered sociologically and culturally to be a specific expression of 19th century restoration theories.

To revise all the restorations and interventions of all types carried out on our architect's works would require a much longer treatise and a much greater space than we have here. However, if we take a closer look at the most important operations carried out in the last twenty-five years, we can try to draw up a first approximation.

The Capricho de Comillas (Santander) is one of the most controversial of recent restoration works. Built between 1883 and 1885 for the indiano* Máximo Díez de Quijano and supervised by Cristóbal Cascante, it underwent important modifications after 1904, when it was enlarged to cater for a big family. The new work was made imitating the old. Other alterations on the roofs and the rooms followed over the next few decades (particularly in 1940) until the house was abandoned and fell into serious disrepair and was even vandalised. With the advent of democracy, people cried out for the building to be saved, but it was in fact auctioned by Sotheby's. Finally, between 1987 and 1989, the new owner had it refurbished by the architect Luis Castillo Arenal and turned it into a restaurant, which it still is today, although under a different proprietor.

The refurbishment attempted to restore the Gaudí "spirit". Since the original plans had disappeared, it was done by analogy with the existing building and other buildings by Gaudí. There was great discrepancy in the opinions about the results. The glasshouse was recuperated (with different materials and design), the elements added during the postwar repairs were destroyed and the interior layout was changed on the basis of historical, archaeological and architectonic studies, although without any certainties and with some very dubious additions. The new use of the building required important changes, albeit underground (the basements), but which altered the site. Many tiles and ornamental pieces were replaced and the whole structure was reinforced.

It would probably have been more coherent to conserve the additions made by Díaz de Quijano's first heirs, although their destruction was perhaps justified. The final result, particularly of some interior rooms and the glasshouse, go against the idea of Gaudí.

The Palacio de los Botines de León (Casa Fernández y Andrés) (1892-93), built by promoters Simón Fernández and Mariano Andrés as a textile shop and dwellings, was purchased by a bank in 1929. After several refurbishment works, especially on the lower floors in order to adapt it to its new use, the institution decided to have it refurbished entirely in 1991, and called in the architects Mariano Díez Sáenz and Compadre Díez, who first made in-depth studies and then proceeded to rehabilitate the house as the headquarters of the bank (Caja España) in 1994-96.

The intervention consisted of restoring the building to its original state, after the many variations –going from dwellings and textile store to the branch office of a bank– to its current configuration as the head office of a financial institution. When these works were decided upon, the builders' reports caused some alarm, because they said the building was in a very poor state of repair. A very prestigious architect, professor and expert on Gaudí also submitted a report saying that the only important thing in the whole building was the bottom two floors and that the rest could be altered.

The architects in charge then initiated serious scientific methodological studies with the collaboration of José Luis González from the Polytechnic University of Catalonia. It was discovered that the building did not have proper foundations and other areas with large cracks and settlement and a few corners were consolidated. Models were used to study its conditions in the event of an earthquake and other structural and constructional tests were performed (by A. Casals, P. Roca and C. Molina, of the Polytechnic University of Catalonia). The two lower

storeys were recuperated, relatively well conserved in spite of the changes, the attic floor was rehabilitated for bank meetings and the materials and carpentry of the different dwellings were also restored. Maybe the history of these rooms was not studied enough as regards colour scheme and other details, but the end results were excellent. The installation of lifts was inevitable, and they were added with the least possible effect on the upper floors, although the above mentioned architectural historian was indignant about the lifts, in spite of reporting that the floors were of no value whatsoever. The courts, vital to the understanding of the Gaudian architecture and the composition of the building, were also intelligently rescued. Turning the open-plan lower floors (basement and semi-basement) into an exhibition gallery made it possible to recuperate spaces and full aesthetic values in this part of the house.
But it was in Barcelona, where logically most of Gaudí's works and an awareness of their character are to be found, that intense debates about three recent restoration works arose:

The Palau Güell (1886-88), where the interventions on the terrace and the chimneys were very much discussed. The building was purchased from the original family by Barcelona Diputación (Provincial Council) in 1944 and some repairs were carried out on the main floor and the bedrooms between 1974 and 1976. The Heritage Department of that same institution, under the direction of Antoni González and Pau Carbó initiated preliminary studies of the site in 1982 and began the restoration of the basement, the vestibule and the roof in 1990-92. They achieved in-depth knowledge of the different aspects of the building, historical, cultural and material (and drew up a historico-constructional atlas, with the participation of important specialists like Raquel Lacuesta, Giorgio Croci, Javier Fierro, Alberto López Mullor, Antoni Rius, etc.). The behaviour of the structure in complex situations was also taken into account.
The greatest discussions had to do with the intervention on the chimneys. Some of them, deigned by Gaudí at the end of the 19th century (1890), had lost their ceramic finish and others had never had it applied to begin with.
The methodological proposal for the restoration and the suggestions of other professionals sustained that this chromatic value did not respond to the author's colourful character or give an overall view of the roof. Antoni González and Pau Carbó defined them as "false architecture" and argued that there was no justification for keeping them unfinished. They therefore commissioned ceramists and artists to finish them in 1992 with contemporary methods (Joan Mora, Robert Llimós, Juan Gardy Artigas, García Pozuelo Asins, etc.). With restoration criteria, the status quo could have been maintained as a sample of an unfinished work. With the operation done, we can ask ourselves whether it is actually "false historic", as it has been called. It certainly is, in the sense that it does not coincide with Gaudí's fundamental colourist style. The works contribute to recuperating the image, the texture and the chromatic perceptions of the palace without being mimetic neo-Gaudian works (the erroneous "unity of style" of the hypothesis) or contradicting them, since they conserve the original structure and are decorated in an attempt to find harmony between the preexisting building and today's means ("formal analogy" or "harmonious diachrony", as the authors would prefer to have it called).
The restoration also corrected the serious problems of deterioration and watertightness of the roof, redesigned the protruding pieces, thus enhancing the whole and recovering the interior luminosity. Without going into recuperation tasks, cleaning of the facades, necessary maintenance and conservation work carefully carried out on the rest of the palace, which had suffered many alterations since it was purchased or seized after the Civil War. Along with important studies for the prevention of catastrophes and other possible unforeseen damage.

Casa Milá-La Pedrera (1905-10) also gave rise to argument and reflection and more when the work was finished. It underwent important refurbishment works in 1954 when Barba Corsini built apartments in the attic, whose quality was excellent for the time but the works involved destroying fundamental elements of Gaudí's creation. In 1966 it was Gil Nebot who transformed the apartments on the main floor. In 1986 the building was purchased by a bank as a cultural centre and emblem of the institution, leading to the recuperation and restoration of some elements and the rehabilitation of different spaces.
The facade was cleaned and restored between 1986 and 1989 by J. Emil Hernández-Cros and Rafael Vila.
From 1989 onwards, a Restoration Master Plan was drawn up by these same architects and until 1992 they worked on the basements, demolishing a bunker, installing an office of the bank in part of the semi-basement and intervening on the main floor to locate the exhibition gallery there. Studies of the roof were made by R. Lacuesta (1991) and the paintings in the hall were restored by Mª A. Heredero (1993).
In 1994 the Bonamussa-Tomás studio completed the auditorium-cum-assembly hall in the basement, causing great polemic. Finally, in 1995-96, Francisco Javier Asarta and the technical service department of La Caixa finished the restoration of the attic and roof. Thus Barcelona Heritage Department included again among its cultural assets one of the most remarkable monuments that had hitherto been in a disgraceful state of repair.
The loss of the Italian architect Barba Corsini's Rationalist apartments is a great pity –perhaps one of them could have been saved– but sacrificing them all meant recuperating entirely Gaudí's attic structure, which was the most important thing. The same occurred with the roof, an exceptional example of Gaudí's intelligence and skill, which the restorers managed to return to its original state with enormous patience in finding the original sources and the maximum delicacy in treating them , and finally offered the finished works to visitors and admirers of the genius of Modernism.
The facade was thoroughly cleaned and restored (this was necessary in order to repair the metal structure and because of the bad condition and erosion of the stone and the iron girders), so that original patinas and those resulting from the passage of time were lost, but the poor restoration works of the previous decades were also removed. However, the "identity" was guaranteed, as in the railings on the balconies. Rehabilitation as a bank was a more complex matter, as the institution wished to assume the architect's image of historical and aesthetic prestige at the same time as it fulfilled a great social task by purchasing and saving the building. However, the use and tourist load to which the building is exposed is too drastic. An exhibition gallery has been installed on the ground floor with contemporary elements that clash with the spirit of the building. It is totally different from the original space. It is an excessive rehabilitation work. In the auditorium –the old coach house– there has been an even more radical intervention with new elements that are not in keeping with the old spaces. Work on the paintings and frescoes was performed with prudence under the guidance of international and Catalan experts; without this restoration and the rescued colour scheme it would have been impossible to understand the meaning of the ensemble.

The Parque Güell (1901-14) was another site by Gaudí that was neglected and in a very poor state of conservation. The arguments about the last restoration concentrated on the rebuilding of the ceramic bench on the terrace of the Greek theatre in very different colours from the original. The park was little used and badly maintained for a long time, so that it had suffered a lot of damage and vandalism, like most parks without proper surveillance.
In 1987 the architects Antonio Martínez Lapeña and Elías Torres Tur were commissioned to draw up the project and carry out the restoration works (which lasted until 1994). The most important tasks carried out so far are the refurbishment of the pavilion on the left of the entrance (by Council architects), the repairs of the roof and the remaking of the trencadís (mosaic) on the vault of the Hypostyle Room and the reconstruction of the ceramic finish of the undulating bench.
The drainage system of the Hypostyle Room through the hollow iron column was in bad condition due to rust; damp had also damaged the soffits of the little cupolas and the roof, changes in temperature had caused cracking and the prefabricated pieces: capitals, columns, mouldings, etc., were also in very poor condition. The works solved all these problems. The missing parts of the trencadís on the roof were completely replaced, although, according to the Italian Buconi, "without respecting Gaudí's colour scheme or composition criteria", done this time by craftsmen from Castellón, who have not managed to do it very well.
The bench had similar pathologies caused by damp, cracking and vandalism... After the structure had been studied by Ignacio Paricio and the whole ensemble had been painstakingly examined, the missing parts were replaced. However, this task has been the most criticised by the Italian architect Giulio Pane, and rightly so, in my opinion, because the white majolica pieces have been replaced by stoneware pieces, which, according to the works managers, is "a material that stands up very well to the elements and which Gaudí would surely have used if it had existed in his time", which, like all hypotheses referring to the past, is mere conjecture and there is no way of verifying it. However, we do approve of the work performed on the areas of colour, which have been faithfully reconstructed with pieces of tiles taken from old palaces; a reconstruction that is "faithful" to the original design, according to the above mentioned Buconi. As a modern intervention, all the pieces bear the date, so that there will be no misunderstandings "secondo una libera reinterpretazione della poetica gaudiana, negando in tal modo ogni acquisto principio su cui fondano gli attuali orientamenti técnico-operativi del restauro". It was a complex and difficult task because the intrinsic value of the trencadís is lost when the intervention breaks the authenticity of the composition, but we also believe that the polychromy was perfectly restored. The loss of gargoyles or the addition of some steps at ground level alter little details of the original work and should have been better designed. Behind all this process, it must not be denied that the intervention could have valued better the "authenticity per se" of the deterioration.
The exterior and interior of the pavilions at the entrance to the park were restored and their structures reinforced between 1996 and 2002, especially the one on the left, which underwent numerous repairs after 1936, and refurbishment works made by Adolfo Florensa in 1955, which transformed the cross tower and other elements, according to the principles of "improving" the original project in the "stylistic restoration" method defended by Viollet-le-Duc. The recent works restoring them strictly to their past were carried out by municipal architects and draughtsmen like Ana Ribas, María Luisa Aguada and

Carmen Hosta, in collaboration with the Gaudí professorship department.

The chapel at the Colonia Güell was left unfinished by Gaudí, who abandoned the building in 1914. In the three years that followed, work went on without him. In the nineteen sixties, several works were carried out on the surrounding area, the exterior paving, ramps and crowns of the walls, and central heating and other little improvements were added to the building, all in imitation of Gaudí's style, under the directorship of Mosén Règul Casas and apparently under the guidance of Juan Bassegoda Nonell. In 1989, exhaustive studies were initiated by José Luis González (structures), P. Roca and A. Casals (structural behaviour and models) from the Polytechnic University of Catalonia, while R. Lacuesta, from Barcelona Diputación, carried out studies on the history and other preliminary studies, thanks to which this became one of the best documented of all Gaudí's works. In 1996 the project drawn up by Antoni González and the above mentioned Heritage Department of Barcelona Diputación was put into practice. The works lasted from 1999 until 2002. There was huge polemic at the time this work was completed, when a manifesto ("Disbarat...") was presented against it at the MACBA with the signatures of Catalan intellectuals, artists and professionals like Antoni Tàpies, Juan José Lahuerta, Carmen Arús, Ricardo Bofill..., in which they basically recommended that the restoration be reversed and the building returned to its former state, that is, as it was in the nineteen sixties, which was obviously a mistake, as it was based on a romantic valuation of the changes made and not the actual work created by Gaudí in the first two decades of the 20th century.
Aside from this polemic, of interest because it is always useful to have cause for reflection and debate in Spain and Catalonia, in our opinion the intervention practised on the Colonia Güell Chapel is one of the most sensible of all those carried out on works by the Modernist architect, since it solves the problems of deterioration and structure and restores the building to the way it was when Gaudí built it.
A large iron net ties the roof together and solves the tectonic problems. A new entrance staircase has been made leading up to the platform and the original treatments have been applied to the exterior pavements. The finishes at the edges and the crownings to achieve the consolidation of unfinished perimetral forms were performed with modern materials so that the distinction between old and new would be very obvious, which gives perhaps a rather surprising image but certainly does not lead to confusion or error of any sort. The use of basalt is indeed a great contrast with the "poorer" materials of the building, although it was used by Gaudí in other works of his and in some columns of this one.
A reflection about the intervention here could raise the doubt about whether to have left it as it was, in which case the pathologies would have gone from bad to worse, or carry out mere consolidation works, which is always a prudent measure, but insufficient to solve the load-bearing capacities of buildings more and more frequently visited by tourists and used for other cultural purposes. The methodology chosen with contemporary commitment seeks to recuperate Gaudí's authenticity and is more concerned with durability and use than other issues. We consider the protest against the monolith and the text that marks the beginning of the work and the end of the restoration more anecdotic than transcendental ???. As Antoni González has expressed it, the refusal to continue and the recreation of the chapel have been done with the greatest respect for Gaudí's work, a principle we consider essential, because indeed "you cannot do Gaudí without Gaudí". A work that will fortunately remain unfinished, let us hope, forever. A restoration that, for its rigour and seriousness, has offered the best of Gaudí; thanks to this restoration, its methodology and application, an unknown facet of Gaudí has been revealed, free from clichés.

There is now some doubt about the Casa Batlló, restored some time ago according to the conservationist ideas of Bassegoda Nonell, regarding the colour of the balconies. The current restorer, Botei, defends black, and Bassegoda is in favour of a light colour. The latter seems to be right to judge from old black and white photographs (c. 1910), where they seem to be a pale shade.

The Sagrada Familia Church has given rise to another heated debate about whether it should be completed or not, and this debate has now been going on for some time, and is of great interest as regards the issue of whether or not unfinished buildings should be completed, and if so, how should this be done, giving rise to a theory that for obvious reasons we shall not go into here and now. In 1965 there was a great rumpus at international scale because the works were going to be continued, and a manifesto was written against it and signed by the most important professionals in architecture in Europe at the time, such as Le Corbusier, Zevi, Pevsner, Espriu, Dorfles, Argan, Pane, Rogers, Miró, Cirici, Coderch, Tàpies, González, Bohigas, Moragas, Gregotti, Quaroni, Portoghesi, etc., all essentially contrary to the applied mimesis, arguing about the financial cost and the use. A new document in the same line was drawn up in 1971. In spite of all this, the works continued and are still going on today. The Barcelona newspaper Avui and other media have been the round table for a debate full of ideas and reflections of enormous interest (Bohigas, Arús, Martorell, J. L. González, etc.).
The short/long history of the work on this church started in 1882 when Francisco del P. Del Villar laid the first stone and one year later Gaudí took over the management, greatly modifying the project. In 1925 the San Bernabé tower was completed. After the maestro died, the works continued under the supervision of D. Sugrañes i Gras (1926-35) and F. Quintana i Vidal (1930-50). In 1954 architects and professionals like L. Bonet Garí, Isidre Puig i Boada or Francesc de Paula i Blanch joined the team... In 1985 Jordi Bonet Armengol took over the coordination of the works with discipline and enthusiasm, and in 2000 the vaults of the nave were completed. The application of reinforced cement columns with a stellar base and a shell of stone sculpted by using numerical control machines characterise this part of the work, very different from Gaudí's methods. It is clear that the continuation of the Sagrada Familia Church is not a restoration, either conceptually or empirically.
Indeed, after Gaudí's death, the continuation of the work raised all sorts of aesthetic, historic, moral, etc. problems. The most interesting aspect of the restoration is the idea of authenticity with respect to the original project, which is supposed to be the line followed. According to Bonet i Armengol, the project strictly follows Gaudí's plaster model in scale 1:10 that he himself followed. For that reason, Marconi, the Italian theoretician, considers it "un'architettura inesorabilmente 'autentica' dunque, lo puó essere oggi la messa in musica di un manoscritto autografo di Mozart; un'esecuzione differita e nulla più". But there is an argument we consider important and it is that, according to the 2000 Cracow Charter, the most modern and avant-garde text ever drawn up about restoration, Heritage exists if the society that configures its context identifies it as such and interprets it as its identity, and this is what has occurred and occurs in the case of the Sagrada Familia, which exists thanks to the financial backing of Barcelona and Catalan society and for no other reason.
The Provisional Schools (1909) have also been moved and installed inside the Sagrada Familia, although they had been burnt down in 1936 and rebuilt (by D. Sugrañes) and rebuilt again in 1939 (by F. Quintana).

Other buildings, on the other hand, have hardly been altered at all since they were originally built, whether finished by Gaudí or not, such as the Palacio Episcopal (the Bishop's Palace) in Astorga or the Colegio de las Teresianas in Barcelona. Other interventions have been practised on the Cooperativa La Obrera mataronense (1883), currently being restored by M. Brullet, or the Casa Vicens (1883-88), expanded in the nineteen twenties. The stables of the Finca Güell (1884-87) were restored in the nineteen sixties and seventies, maintaining their character fairly intact.

The Bishop's Palace in Astorga poses interesting issues related to this debate. A Neo-Gothic building designed by Gaudí, it took the place of the previous palace that had been burned down. The works were performed between 1887 and 1893 by Gaudí himself, although he only visited the site occasionally. He was given the commission by the bishop of Astorga, Juan Bautista Grau i Vallespinós, who was from Reus like himself, and had been the vicar of the Archbishop of Tarragona, for whom Gaudí built an altar (Chapel of the Children Jesus and Mary).
Gaudí worked very hard on the project (residence and diocesan offices and a museum in the basement), obtaining photographs of the city, its monuments and the urban area, so the bishop was delighted with the result. However, the same cannot be said of the Academia de San Fernando and the Ministry of Grace and Justice (who were financing the works), so Gaudí had to make great modifications that affected mainly the central layout of the building, which was, incidentally, much improved in the final version.
The palace is clearly inspired on Gothic architecture, on Viollet-le-Duc's theories and has elements copied directly from the Sainte Chapelle in Paris (the column and the capital on the main floor). Gaudí achieved one of the best samples of a mixture of civil and religious Neo-Gothic made in Spain at that time: great luminosity, symbolic values by using granite from Montearenas, ceramics by Jiménez de Jamuz, Mahón vaults, etc.
The bishop died before the upper storey had been built and there were problems between the Astorga canons and Gaudí, so the latter stopped the works and took his plans away with him (they have never been found to this day). The final solution was provided by another architect, Ricardo García Guereta from Madrid (1909), who carried out an extremely simple intervention closing the building with vaults and a slated, pitched roof, very different from Gaudí's idea. Perhaps his intention was not only to finish the job quickly and safely but to show respect for what had been built.
Although the minor works were completed in 1915, the building was not inaugurated until 1961, when it was opened as a museum, one of the aspirations of both Bishop Grau and Gaudí, as we can see from the early drawings. During the Civil War and afterwards, it was transformed and fairly badly damaged. But thanks to its perfect construction, it is one of the best conserved buildings by the Catalan architect and the one that has had the fewest restoration and alteration works, although a better joint maintenance programme should be drawn up for it. The architect Pablo Puente Aparicio has recently (2000-2001) proposed turning the lower floors into a museum also.
At the end of this brief summary of Gaudí's architecture, we can see that there have been slight consolidation works or complete ripristinos stilistici, according to Boccuni,

who, without going into details of specific cases, says, "Accade cosi che si prediligano soluzioni che, sotto l'etichetta di 'recupero analogico', 'diacronia armonica' o 'ricostruzione mimetica', cadano facilmente nell'equivoco del ripristino stilistico o, peggio ancora, nella gravisima espunzione delle tracce materiche originarie ed autentiche".

RUIN, GAPS AND REINTEGRATIONS IN GAUDÍ'S WORK

As everyone knows, some works by the Catalan architect were not finished in his day: Astorga, the Sagrada Familia, etc., nor did he leave plans or sufficient material to finish many of them.

What should be done in these situations? Should they be completed? If so, should they be completed following the "style" of the existing building, with modern materials, by analogy...?

"Ruin" is a longstanding concept in the Western World. It is a way of idealising matter and it has usually been applied to cases where the object to be conserved incomplete is felt to be untouchable because of its historic and documentary merits rather than its aesthetic values. Thus it has been applied to the remains of declining cultures or those discovered or consolidated by archaeology as the science of interpreting Roman, Greek, medieval, or other ruins from a mere fragment; or the ruins left after catastrophes, wars, earthquakes, volcanoes, etc. But from a conceptual viewpoint, the word ruin can be applied to "lost" cultures or "dead monuments", to use the term popular among archaeologists and architects at the end of the 19th century and the beginning of the 20th, a theory that could be extrapolated and applied to castles, neglected monuments, unused buildings, etc.

However, ruin was a prevailing concept of Romanticism and the Picturesque period, although not exclusively. Nevertheless, the 20th century has always been memorialist and utilitarian, in spite of great catastrophes like the World Wars, civil wars and all sorts of misfortunes. Most of the edifices were rebuilt and, as the century advanced, there was an attempt to eliminate the gap in many monuments that seemed to have been accepted as ruins, such as the Parthenon or Dresden Church, Dubrovnik, Russia, etc. As a philosophical entity, there is no such thing as a contemporary or 20th century ruin, except in those places where Heritage has not yet been appreciated or identified, such as industrial architecture, etc. So to leave the Sagrada Familia as it was when Gaudí died, in spite of his popularity afterwards, has no philosophical basis. Enric Miralles' proposal for his sunken work was not welcomed either because of the same mentality towards ruins of contemporary buildings. As regards the "reintegration" of what is missing for some reason or the "completion" of the unfinished, the trend is to do so if there are funds for it. There has always been a desire to finish Santa Teresa Church in Béjar, but it has never been feasible for financial reasons, unlike Gaudí's works.

There are many different ideas about how it should be done. In Astorga, García Guereta provided a free personal solution of his times, but very different from what the Catalan architect would have done himself. On the contrary, in the Sagrada Familia, the plan is to continue Gaudí's design, albeit with modern materials for the structure, but concealing them under the same old texture to give the whole a feeling of continuity.

The doctrine in restoration depends on the fragment missing, its size, its impact, its relationship with the existing pieces, etc. All the International Charters and legislations in force in Europe in the last fifty years defend filling gaps with contemporary architecture, in other words, modern at the time the works are performed. The problem is to maintain the "potential unity of the work" incomplete, mutilated, etc. How to achieve its formal continuity is a field where conjecture has a role to play; how to avoid the image of the work becoming altered or lost, both from a historic viewpoint and as far as authenticity is concerned. The thesis of these "Dominant Theories" is always in favour of distinguishing the original work from the additions in a critical manner.

The predicament here is that continuing with what is supposedly the original plan would be an empirical way of doing things, endangering the end result and running the risk of damaging the initial work.

Gaps, incompleteness or absences certainly tarnish the value the work would have if it were complete or had been finished. This vacuum breaks the formal idea of the ensemble or, as Philippot himself would say, is "an interruption of the continuity of the artistic form and its rhythm" (*Historic Preservation*, 1976, p. 7). But hence arises another issue, although very often "lo stato frammentario ha acquistato un valore com'è". In this sense the action must make a clear distinction between the original part and the additions and, as the same author points out, the field of action "can be extended to the point where the intervention would be hypothetical, where only a modern creation would avoid a fake. For this creative, modern intervention, the old parts would be the basic element of the problem, and the aim would be to achieve the unity of the ensemble... this type of creative integration would require a special sort of study of the old construction, its context and an examination especially of the whole historic centre, depending on the need, to establish the irregular rhythm of the underlying structure in the old complex and adapt the design of the modern creation to the original models and materials"; where, furthermore, "a detailed assessment by means of an in-depth examination of the monument or the group of monuments should always precede a study for adaptation to new functions. Otherwise, the restoration will inevitably be an exercise in modern architecture made to the detriment of old buildings" (*Historic Preservation*, 1976, p. 9-10).

And why not philological restoration? In Gaudí's works, and especially in the Sagrada Familia, there have always been those who have sustained the possibility of continuing according to the model, the already built part and some instrumental graphic details. There is no agreement about this point, but rather a heated debate. The most appropriate position seems to be the one adopted for Güell Chapel, also unfinished and completed now by Antoni González Moreno Navarro in accordance with the general principles mentioned above.

The philological system was widely applied in the 20th century to many buildings reconstructed after the World Wars or other catastrophes, but it has proved insufficient in many cases, apart from the fact that, as Marconi quite rightly sustains, this method is only applicable when there is a well-defined style and stylistic codes for a linguistic intervention and this is clearly not the case of Gaudí and his architecture. In some cases, falsification has been alleged, in others, as Carbonara says, to avoid this situation disoriented ("fuorviante") positions have been reached, with a tendency to end up with "neutral" treatments, "oversimplification", etc., with which I do not agree either. Here the theories of both the Athens Charter (1931) and the Venice Charter (1964) failed, and the Cracow Charter (2000) was undoubtedly nearer the mark.

Continuing unfinished buildings is also supported by those who believe in "retarded execution", according to the concept coined by Renato Cevese (1985) and later developed by Marconi (1986) and Manieri Elia (for the latter, "esecuzione differita", 1991), that is, the completion of "masonry whose exact design and place are known, as well as the constructional and physical features". In these cases, according to these theoreticians, the "ripristino" or "completamento" are defensible and legitimate, so that even authenticity is relaunched and developed in time. Marconi approves of the continuation of the Sagrada Familia, as he considers it the perpetual work in which it is the effort of several successive generations, so that masonry embodies "il paradosso dell'autenticità infedele, dell'infedeltà autentica, che è pol il paradosso di chi crede nell'architettura e non solo nella miserable materia di cui è impastata", in contrast with the defenders of "conservationism" who only set store by the commercial value of things. Masonry where the works of "delayed execution continued dauntless from the first project by F. de P. del Villar i Lozano (1882-83), the course of which was revised and changed by A. Gaudí i Cornet between 1884 and 1926, limited to the crypt, the apses and the Nativity Facade... where some sculptures have been remade, paraphrased, in view of their state of pending ruin..."

After Gaudí's death, D. Sugranes i Gras continued them until 1935 and F. Quintana i Vidal between 1930 and 1950... the Passion Facade was continued by F. Quintana i Vidal, Luis Bonet i Gari, Isidre Puig i Boada, Francesc de Paula Cardoner i Blanch following Gaudí's sketches since 1951...

"...the continuation works on the transept are being made with reinforced cement columns with a star-shaped floor plan protected with a shell of stone sculpted by using numerical control machines made in Italy, demonstrating the versatility in a work"

ORNAMENTATION IN GAUDÍ'S OEUVRE: ITS CONSERVATION & RESTORATION

We have already mentioned the presence of very perishable materials in Gaudí's works. Deliberately chosen by the architect so as to play with their composition, their perceptions, in his buildings they not only form part of the finishes but they often become part of the structure or the fundamental sense in which his constructions should be understood. His use of clayey materials (very highly valued in Catalonia since the exhibition of Artistic Industries of Barcelona in 1982 and all over Europe since the Paris World Fair of 1878) reveals his skill in this field –where he developed his famous trencadís technique, which started with the Finca Güell), but also the risk they run with the passing of the years, as is the case too with the wrought iron he used on his facades and in other parts of his buildings.

This part, the ornamentation, is a rapidly decaying factor, as we have seen in many works by the architect from Reus. It is an issue that has caused concern from a theoretical and a practical viewpoint. As regards the former, we can mention the works by Giulio Pane and Veronica L. Boccuni. As regards the latter, interventions have been carried out, amidst a great deal of controversy, by José Antonio Martínez Lapeña and Elías Torres in the Parque Güell, by Antoni González and the Servei de Patrimoni Arquitectònic Local on the Palau Güell, etc., in which, apart from problems with the structure, there has been a need to make replacements or fill in gaps, the former in the Hypostyle Room and on the bench in the park, and the latter in the famous chimneys and the terrace of the building in the historic centre of Barcelona.

The importance Gaudí attached to the finish and decoration is known by everyone and we shall not repeat it here for obvious reasons, apart from the fact that it can be found in his Reus manuscripts and in most of the studies dedicated to him, such as those by Bohigas, R. Pane, Bassegoda i

Nonell, Zevi, Lahuerta, Flores, Puig-Boada, J. Bergós, Martinell, etc. To put it in a nutshell, rather too simply, we can say that for Gaudí, composition, structure, materials, ornament, colour and geometry all formed an unicum, that is to say, his architecture, and they cannot be separated or understood independently from each other. And it is in this context that the problem of their restoration arises when it affects the whole or figurative parcels. We shall have to quote a sentence of his referring to polychromy in nature and therefore in his works, a quality, according to him, that would give them a special character of "age", because not only was he aware of the passage of time but he valued it to achieve an "aura" of the past for his creations, which the above mentioned G. Pane called "diperimento programmato", the deterioration studied by Gaudí.
Thus the restorer must tackle this unitary concept of the work when intervening on it. The analysis of his "ruled forms" (geometric structures like hyperboloids, paraboloids and helicoids) and his enormously complex and skilful traditional and modern materials and building systems. From concrete to natural and artificial or prefabricated stone, from gypsum to tiles, bricks, lime, etc., all appear in his work integrating functions and meanings.
In the work quoted above, Boccuni says that when the restorer works on these works and especially on ceramic mosaic, "he cannot solve situations with improbable ripristino interventions, especially when it is clear that they are not a mere finish but in fact works that play a greater role that that of ornamentation" (p. 206).

PATINA: THE CLEANING OF GAUDÍ'S FACADES

Having made a clear distinction between dirt and patina, the latter must be safeguarded because of its historic and aesthetic values.
Conserving the original materials is a very important point. This is not an architectonic issue in the strict sense of the word, but a matter for the specific "restorer" of the material in question. Cleaning a facade like La Pedrera poses several problems: the dirt must be removed, but to what extent, so as not to interfere with the patina. Is the patina Gaudí's? Is it the result of time? What patinas should be conserved?
Theories about patinas have been under discussion since the time of Giovannoni and Ruskin. More recently and with a more scientific basis, the subject has been broached by Brandi and theoreticians like P. Philippot, his follower in this aspect: patina is a valuable historic residue, but with aesthetic values that are just as important or more, so intervening on it is an "atto critico" and therefore an "atto creativo". But for this author the problem of patina, cleaning and restoration "recherche de l'équilibre actuellement realizable qui soit le plus fidèle à l'unité originelle". He means that it is impossible to restore something to the state in which its creator left it, for today it expresses the "etat actuel des matières originales" and nobody, no restoration process, can bring it back to the way it was originally. Thus patina is a "critical" concept, not only a physical or chemical effect, which are both normal effects of time on matter.
It is true that there is a debate on this subject and that, for example, the most recent positions of the Istituto Centrale per il Restauro of Rome, which sets more store by the conservationism of materials than the critical value.
As regards Gaudí's works, we are all aware of the position dating back to the stance of Italian "critical thought" about patina made by Salvador Tarragó regarding the cleaning of La Pedrera in Barcelona (1905-10).

EPILOGUE

The most recent restorations performed on certain works by Gaudí have shown a new universe hitherto unknown, in spite of the voluminous bibliography that exists about the architect from Reus. The methodologies applied in La Pedrera, the Palau Güell, the Colonia Güell Chapel, the Casa Botines in León, for example, express with new rigour different boundaries of the personality, aesthetic, history, capacity and constructional creativity of Gaudí.
All restorers usually cite in-depth knowledge and profound respect for the building to be restored as the principle and basis of their work. But in so many cases this is a mere convention of the language used and not a real way of working, whether through lack of information, lack of means or both at the same time. Contemporary restoration does not exist if it does not follow this process strictly, gather together all the preliminary studies drawn up by qualified multidisciplinary teams, analyse them meticulously, examine and understand perfectly the building and determine the intervention project with the most sensible criteria stemming from specialised training and real common sense.
The argument that it is the monument that "speaks" to the technician and "demands" the treatment it requires is a sophism, since the way of "listening" is absolutely subjective and is not based on any scientific principle, but only on aesthetic issues. The difference in "understanding" can be demonstrated by mentioning two personalities as different as Grassi and Chueca Goitia, who have so often expressed the above mentioned conviction in the very same words when referring to their projects.
The "SCCM method", so enthusiastically developed by the Catalan architect Antoni González –the best restorer of Gaudí's work today, in our opinion– or the principles of "critical restoration" as they are understood in Italy today, together with the contributions designed by the 2000 Cracow Charter, form the most advanced theoretical and pragmatic bases of our time when faced with the responsibility of conserving and restoring our heritage, and still more, of guaranteeing its survival and its recuperation as a social asset belonging to society.

Raquel Lacuesta

PRELIMINARY STUDIES ON THE WALL FINISHES IN CASA MILÁ

Case history

In the spring of 1992, when the Caixa de Catalunya decided to embark on a new phase of restoration, it was necessary to carry out preliminary studies of a documentary, artistic and constructional nature before beginning to work on the roof and attic. It was then that the head of the building department in the Caixa at that time, Mr Enric Mira, phoned me to speak about the possibility of my collaborating in the project as an art historian, on the recommendation of the architect Francisco Javier Asarta. The idea was to draw up a document to complement the project and to give an idea about how to act depending on the conclusions. A team was then formed, coordinated by Asarta from the outset. Other tasks followed this one as the work progressed and intervention on other sectors was scheduled. The preliminary studies I made were the following:
1. Documentary, artistic and constructional study of the sculptural-architectural elements on the roof: stairwell, ventilation towers, chimneys and little cupolas on the parapet walk. 1992.
2. Complementary technical report about the roof (finish and colour tests on steps, chimneys and banisters, and identification of the attic windows designed by Gaudí). 1994.
3. North facade and service stairs: finishes, colours and carpentry work. 1994.
4. Original finishes in the interior courtyards (mural paintings). 1994.

Historic background of the roof elements

These studies were carried out with two main priorities: on the one hand, to make a historico-constructional analysis of each of the elements that stand on the roof and the interventions or operations performed on them throughout the 20th century; on the other, to produce a documentary on which to base the restoration of these elements.
When Gaudí finished the Casa Milà in 1911, the only things that protruded on the roof were 6 stairwells, 2 ventilation towers and 7 single or compound chimneys and 4 little cupolas located on the parapet walk that could be reached from the attic floor. All of these were conserved, but were accompanied by another 16 chimneys built according as the floors inside were refurbished, some of which, in spite of the fact that they had been fairly recently built, were considered Gaudí's work in the collective memory.
To draw up the study, apart from the necessary bibliographic consultation, I examined the existing photographic documentation in the oldest archives in order to reconstruct the history of those functional and at the same time sculptural elements step by step.
In fact, the bibliography reproduced over and over again photographs from the same or similar viewpoints, with remarks usually intended to interpret Gaudí's message, all more or less imaginary or fantastic literature, but not of very much use for the work I was trying to do.
Once I had gathered together all the archive photographs or the ones that provided new data among the bibliography consulted, I took photographs myself from the same angles establishing a chronological comparison to find out when and why the new elements had been added and what alterations or changes had been made in the original ones made by Gaudí.
One difficulty I came up against was, indeed, the subject of the finish and the colour. Until the late nineteen sixties, no coloured photographs had been published, or I found none, that allowed me to discover the original finish of some of the pieces on the roof. The black and white photographs suggested stucco finishes at times, or paint on plaster, and at least three shades of colour. In some photographs I detected repairs or mutilations that could indicate removal of the original plaster, so that an analysis of the mortars now would add no data to the history of the finish. From the sixties onwards, the biography began to contain coloured pictures, which helped us clear up our initial hypotheses.
In broad outlines, the reconstruction of the history of the elements on the roof of the Casa Milà goes as follows:
In 1910, Gaudí had completed work on the roof; all that remained to be done was to place the protection railings around the two interior courts of the building and a third lightwell to provide light and put the glass in the fanlights of the exits from the stairwells.
Of the six stairwells, 4 bore a finish of irregular flat fragments of stone, marble and tiles, and two were plastered. The two ventilation towers and the seven chimneys were also plastered, except for one, which forked off and was covered with six hoods, finished with fragments of glass from champagne bottles.
Finally, the four little cupolas were covered with marble and stone trencadís.
In photographs of 1927, new chimneys could be seen connected with the first through the courts. Much plainer and not so well finished as the ones designed by Gaudí, although clearly imitating them, their finish or plaster was the same as on the courts. Some of the hoods on the

chimneys had been interfered with during repair works on the flue.
Between 1927 and 1954, most of the protruding parts without the protection of the trencadís were in a very poor state of repair; the hoods on other chimneys had also been tampered with, some plaster had been partially altered and some decorative reliefs had disappeared, which suggests that the interventions were practised without professional supervision. We must not forget that, however monumental the roof of the Casa Milà may be, it was never intended for any use but for hanging out the clothes to dry, and its majestic figures were, above all, mere ducts for extracting air and smoke.
In 1946, Pedro Milà's widow, Rosario Segimón, sold La Pedrera to the real estate agency Inmobiliaria Provenza, which was not long in trying to make a profit out of its new acquisition. Thus, between 1954 and 1955, the architect Francisco Juan Barba Corsini was commissioned to remodel the attics to turn them into apartments to be rented.
These apartments, with their respective bathrooms, kitchens and fireplaces, made it necessary to built another fourteen chimneys on the roof as smoke vents or air flues, either in isolation or connected to the stairwells or the ducts already in existence. Some of them, the ones that could be seen from the street, were built in Gaudian shapes, repeating or imitating some of the existing pieces the same size or on a smaller scale, and even the stone or plaster finishes. The furthest in were built with much less artistry and only their hoods are vaguely reminiscent of the ones designed by Gaudí that had been previously made in plaster by the sculptor Joan Beltran. However, Gaudí's chimneys, which had deteriorated little by little, were left untouched.
Finally, between 1971 and 1975, due to the fact that some stone fragments had come loose and fallen off the main facade into the street in October 1970, restoration works were started under the supervision of the architect Juan Antonio Comas de Mendoza. At that time, the roof and the buildings on it were in a very poor state of repair. The plaster was cracked and had partly come away from the brickwork, and the bare metal frame could be seen under some of the chimney-hoods. Taking advantage of these restoration works, it was decided to make some repairs, consisting mainly in replastering the elements without a stone or ceramic finish (which were the only ones in good condition), restoring some of the hoods that had been altered some time before to their original form and painting it all a reddish brown, very much in vogue at the time, thereby doing away with the original plaster finish that had endowed these elements with a texture and shine rather like ironed stuccowork. However, the pipes, wires and other objects that had been built into the walls over the years were not removed.
In 1986, the Caixa de Catalunya bought the building and the roof, which had until then been used only by the residents and visited only with special permission, lost its original use and was turned into one of the areas open to the public to visit. Thence the restoration works.

Analysis of the roof elements

To analyse each and every one of the elements protruding from the roof, I put into practice a methodology similar to the one I had used a year earlier on the trencadís chimneys on the Palacio Güell. Using cards like the ones used on that occasion, I defined a series of concepts to develop according to the characteristics of each element.
At the same time, a set of plans of the roof had to be drawn up, as this had never been done before; so a general plan and a roof plan were made, as well as floor plans, elevations and sections of the chimneys. This made it possible to study the construction system, obtain the measurements of each element and put it in its place on the floor plan with the numeration it had previously been given according to its typological group.
In the case of La Pedrera, the card type was not a closed model as for the Palacio Güell, but I decided on open fields to develop the content of each concept in greater detail, since each group of forms, composition and finish was less varied and complex and, in many cases, repeated. The concepts developed were defined under the following headings: the "volumetric description" of each element, the "construction system", the "finish materials", the "composition analysis", the "construction date", the "restorations practised", the "documentary references" on which the individualised study was based, the "state of conservation" and the "action proposals" for the future restoration works.
Thirty-five elements were studied altogether. The construction system was the same for them all, with walls and Catalan-style vaults made with whole or broken floor or roof bricks, one or two layers depending on the area, and jointed with mortar, in different geometric forms (parabolic, helicoidal, truncated pyramidal, truncated conical). The stairwells and the ventilation towers started from the attic floor, supported by the beams of the framework. The chimney pipes started at the different floors of the building and branched off on the roof to form one or several fusts or cowls, decorated with reliefs in whimsical forms (sinuous edges, hearts, spirals, vertexes, pointed beads, etc.). The hoods were in turn divided into two types: a cylindrical element and a pointed bulb-like cupola like a helmet. Between these two pieces the almond- or eye-shaped smoke vents were situated. On the outside, these structures were usually plastered with lime mortar. Of all the elements built by Gaudí, only four stairwells and the four little cupolas on the parapet walk were finished with a mosaic of stone, marble or enamelled pottery. The rest were left with the typical plaster finish and gloss.
Trencadís finish had been used by Gaudí in earlier works, such as the Palacio Güell, where he made very different polychrome compositions and pictorial effects from the ones he later designed for La Pedrera. Here it is practically a monochrome, with slight changes of shade, going from white to grey and from yellowish white to beige, very similar to the colour scheme on the exterior walls and the courts. The different types of stone applied in the trencadís came from leftovers of the same works, and the tiles, plain white or in pastel colours, were typical Valencian tiles and were mainly waste material. Here, too, as in the Palacio Güell, he used fragments of marble and glass; but in the case of La Pedrera, it was pieces of broken green bottles stuck into the mortar, so the surface obtained is rounded and bulging.
There are four different models among the six staircases, two of which are repeated. The first four run along the facade and, as I said above, they are finished with stone and ceramic material. The trencadís plays an important role in the composition of the forms and the creation of light and shade.
In staircase number one, the lemniscate or alveolar forms unfurl in alternate vertical strips of a slightly different shade due to the change of material: some are covered with fragments of Ulldecona limestone of Sénia, Xert and Borriol types and the others Carrara, Macael and Tranco. Chemical tests carried out on the different stone fragments at the Geology Faculty under the direction of Professor Màrius Vendrell confirmed what I had already been told by an experienced marble worker about the different types of stone.
The original colours and textures had been lost due to the effects of erosion and environmental contamination, although it could be verified that these pieces had not been polished, but just cut with a hand saw. The colours, originally going from a yellowish beige to pink and white, were practically the opposite of what they had been, due to the effect of the elements on the different types of stone: the beige had turned greyish and the white had become creamy or brownish. The same thing had happened to the finish on staircase number 4, covered with the same materials, whose colours had also changed.
In staircase number 2, with a helicoidal rhythm around a virtually conical shape, the finish was Carrara-type marble and white enamelled Valencian ceramic tiles, although with a few scattered touches of pastel shades. The two materials combine in alternative stripes, following the trajectory and the rising movement of the helixes and creating luminous effects of different intensity. Number 3, with similar characteristics, has Ulldecona stone instead of marble, so the surface is rougher and coarser.
When the architect Barba Corsini turned the attics into apartments, two of the new chimneys he built imitated Gaudí's as regards form and materials. These are the ones people call the Child Jesus protected by the Virgin Mary, because they were attributed to Gaudí.

Tests on materials and finishes

Once work on the roof had been started, I was asked to draw up a "Complementary Technical Report" about it comprising the data collected from the different tests in order to confirm the construction materials and the finishes, textures and original colour scheme of the pavement, banisters, steps and structures as well as identifying the attic windows designed by Gaudí and distinguish them from those designed by Barba Corsini.
The roof had originally been built in typical Catalan style, with three layers of flat roof bricks on top of which a pavement of 28 cm square tiles had been laid. The different levels caused by the different heights of the catenary arches in the attic were connected by steps, whose treads were lined with square tiles; the flattened nosing and the risers were plastered and painted a dark reddish brown.
The same sloping undulating mansard as on the attic formed the perimetral parapet of the roof, made out of a double brick-covered vault rounded at the top. On the main facade, the finish was made with fragments of Ulldecona stone, whereas the north facade (the one giving on to the back of the house) was plastered and painted brown.
The inside surface of the parapet had originally been covered with a layer of lime mortar and plastered, but in the refurbishment works carried out between 1971 and 1975, they were replastered and repainted, this time with cement and brown paint.
The interior railings on the roof around the courts of the house were installed in 1911, probably to avoid the danger of falls. They are made with iron brackets and wire meshing. In 1993, in order to discover the characteristics of the finish of the roof structures, some sectors of the two stairwells were stripped, as were the two ventilation towers and some of the chimneys. These yielded no results in any case, because the whole surface had been scraped down and no traces of the original plaster remained. Only on one chimney, number 22, with six hoods, were remains of the original plaster found, and this served as a model for in situ trials of two different types of finish, one natural and the other artificially aged, so as to decide on the final texture and colour to apply to the rest of the figures. Finally the natural plaster was chosen, in a yellowish ochre, and chimney 16 was provisionally restored with bottle glass on the hoods. In photographs taken before Comas de Mendoza's restoration, this chimney was the one that most clearly showed that the original finish had been the same as the

one found on chimney 22.
In the same way, the masonry parapets and the iron railings were stripped; it was established that the former bore the same stucco as the figures and that the railings had been treated with a coat of bluish grey paint.
As regards the little cowled windows on the mansard, great differences were found in comparison to what could be seen in the old photographs. This was logical, because when the fourteen apartments were built in the attic, they required light and ventilation, so among the little openings designed by Gaudí, many others had been installed, breaking the sinuous layout of the original ones. They were identified individually, and it was discovered that some of them had even been closed over by carpentry work, so it was not easy to recuperate them entirely with their English-style cross muntins.

Restoration proposal
One of the criteria adopted for the restoration of the roof was to "free" the space of all the objects that had not been designed by Gaudí. After making the study, my proposal was to apply a "pure", strict method not only to the original Gaudian elements but also to the originals by Barba Corsini that had a good image and contextual equilibrium while eliminating all the objects that got in the way of the fantastic sculptural landscape and which also happened to be the least attractive and the worst built. Finally the team decided to leave only one of the chimneys added around 1927, because it was still in use, and to remove the rest, which added nothing to the play of volumes designed by Gaudí. I also proposed that the same type of stone and tiles as the original should be used to repair the trencadís. As regards the towers, chimneys and stairwells that were not adorned with ceramic or stone pieces, and for the parapets and steps, my suggestion was to restore plaster of the original texture and colour, using the ones still conserved on the walls of the courts of the building as a model, so as to achieve and complete the colour and material sequence that Gaudí had no doubt designed intentionally. Another proposal had to do with the original openings in the attic mansard, restoring the authentic timberwork (this timberwork was restored and later eliminated again when the "Espai Gaudí" was opened as a museum).

The north facade and the service staircase
Scraping and colour and texture tests were performed on the north facade at the back of the building and on the three service staircases, both on the vertical surfaces, columns and vaults and on doors, windows and iron railings. The dark pink lime and gypsum stucco that had appeared beneath the layers of paint and dirt was imitated for the facade; the windows were painted the original beige and the railings of flat, sinuous strips joined with ridge tiles were painted very dark grey. On the service stairs, ironed stucco appeared underneath some coats of beige paint, in a mottled reddish shade imitating marble in the socle and pale green on the rest of the walls and the vaults. The aim of the restoration was to reproduce the original techniques, texture and colours as closely as possible, since the old stucco was full of cracks, holes or simply did not exist in many spots. The banisters, with the handrail and the whiplash curve of the iron, the service doors with their gratings and the metal framed glass doors giving light to the stairs from the interior courts were uniformly painted beige or light brown; these were also stripped and revealed the different layers of paint or varnish that they bore and they were then repainted in the original colour, light beige in some cases (doors and secondary windows) and pale "Pedrera" green in others (glass doors, the doors into the different flats and the banisters on the staircases.)

Mural paintings on the interior courts
At the beginning, the walls of the two main courts of Casa Milà were completely covered with polychrome mural paintings up to the cornice from which the mansard springs; the mansard, as we have seen above, had the same sort of finish as the chimneys. These paintings had been made on a roughly finished lime mortar plaster containing some marble powder and gypsum, and over this a smooth layer of yellowish ochre lime and gypsum had been laid. Laboratory tests confirmed that the layer of paint had been applied with a mixed technique of fresco and tempera, since some organic matter (casein) was found in its composition. This combination was useful for working on large surfaces, because it did not dry as quickly as lime.
In the composition of the paint, ultramarine blue (artificially elaborated), chrome green, red iron oxide (both natural), white and yellow were found. These analyses were made by the chemist A. Palet Casas.
The paint appeared above the cornice of the framework of the main floor, both in the court in calle Provenza and the one in Paseo de Gracia, because below this line the pillars and the walls are stone. Only the walls and the ceiling of the ground floor and the main staircases of the mezzanine are decorated with oil paints depicting scenes of mythological subjects (figurative, architectonic and floral) inspired on some tapestries of the National Heritage. These paintings had been restored between 1987 and 1991.
On setting about restoring the paintings in the courts that were in the open air, they were found to have suffered from neglect and exposure to the elements, and only some parts still existed (although very brightly coloured) in the places where they had been sheltered by cornices or windowsills. The ones on the pillars, however, which coincided with the vertical line of the gargoyles, had been washed away by the rain. The same had happened at the area around the cornice on the fourth floor, where the paintings had completely disappeared under a coat of yellowish beige paint due to some repair works.
The coloured patches were set out gradually, from darker to paler, depending on the luminosity of the place and from the bottom upwards. Thus around the balconies looking north they are mostly blues, from darker to lighter intensity, and, on the other hand, according as the facade turns towards the south, greens started to appear, becoming paler and paler in the windows looking south. Virtual diagonal lines could be drawn from the first floor to the fourth, from bottom to top, to mark the blue-green-blue areas. The change from one colour to the other was also gradual, although on some arches of the openings (above all on the third floor), the change is more sudden, since there are apparently two symmetrical vertical stripes, one blue and one green. The union between the diagonal lines was also an area covered in paint, limited by an almost virtual horizontal line in reddish earth colour.
The floral decorative motifs were concentrated mostly around the windowsills, jambs and arches on the first and second floors, and the higher up on the facade the more sketchy they became, until eventually they were mere splotches of colour. The degradation was so bad on the upper storeys that it was practically impossible to distinguish the original design.
On the surfaces around the lift of the Provenza entrance, figurative images were still visible (the god Aeolus, for example, and some geometric patterns). There were no traces of the paintwork on the left in the Paseo de Gracia entrance, however, probably because they had already disappeared when the architect Leopoldo Gil Nebot made some alterations on the area in 1966.
The composition as a whole sports an aesthetic akin to Impressionism in some respects, not only because of the topics broached, but in the technique in treating pure colours and the influence of light on them; but it also reveals to us an almost secessionist side of Gaudí. The three base colours (earthy red, blue and green) remind us of earth, water and air, and end up on the mansard in the monochrome ochre yellow, which continues upwards to the figures on the roof.
Nobody knows for sure who painted these pictures. They have been attributed to Pascual or Aleix Clapés, indistinctly. But one thing is sure, as it figures in the 1970 Gaudí Professorship Report in the article "Cómo era Antonio Gaudí" (What Antonio Gaudí was Like), written by a witness of the time: Ramón Dedeu, a young apprentice mason who worked for the Bayó company on the Casa Batlló and La Pedrera. According to him, in La Pedrera he met "many architects, sculptors, assistants and students; the closest to him and the ones who were always with him were my boss, the architect Jaime Bayó, and the also architect Mr Rubió and the sculptor Mr Llimona". Referring to the mosaics, the furniture and the paintings, he said the mark of Gaudí was on everything. "Of the paintings all I can say is that they were all artists that painted them; there were some young men and some girls too, and their director was a man whose name I can't remember, but I think he was Julol, an architect."

Restoration of the paintings
Before setting about restoring the mural paintings in the courts and in the course of the preliminary studies, I suggested to Enric Mira that a polychrome diagram of the interior facades be made showing the patches of colour that remained in order to appreciate the dynamism of the composition as clearly as possible. A Fine Arts graduate, Jordi Soldevila, was hired for that purpose. When he had completed the work, the drawings showed the outlines of colour and the lines and showed the thematic sense of the pictures: areas where there was a concentration of plants, with brightly coloured flowers and leaves; areas of bright blue, areas or earthy red, with another variety of flowers, areas of watery green. The next step was to repeat the drawings in the elevations, but filling in the gaps with the lines and the patches of colour that could be deduced from the existing parts, the flowers, the blues and the greens.
The result was a composition of undulating diagonal lines rising from the first floor to the cornice and then falling as though they were mountains, with a horizon in the background perspective. In the article mentioned above, the apprentice mason, Ramón Dedeu, compared these creations to Richard Wagner's music (the operas Tannhaüser and Parsifal). Let us recall that in one of the old legends about Tannhaüser, a German poet, he spends a year living a life of earthly pleasure; then, filled with remorse, he travels to Rome, where the pope refuses to give him absolution, alleging that it would be easier for flowers to sprout out of his staff. He returns to the mountain in desperation, but a few days later the pope's staff begins to put forth flowers and leaves.
The discovery of the rhythm and the content of the composition led me to suggest how to complete the paintings on the walls, as there were enough testimonies to fill in the gaps. I never imagined Gaudí's architecture without its original polychromy, because it was the complement. The painting, in this case, was part of the architecture, it was also architecture. Although the technical restoration team agreed with this procedure, the painting restorers did not, so in the end a strict consolidation process was put into practice and only where the ochre paint looked out of place and interfered with the overall reading of the polychrome facades was a sort of pictorial homogenisation made based on the colours that could be seen in the composition.
To analyse the state of repair and the general

characteristics of the paint, tests were made on the jambs and sills of some windows on the first floor giving on to the courts, precisely on the ones closest to the lifts, because that was where the greatest amount of flower motifs was concentrated. Samples of salts and pigments were taken, and also of the primer to find out its composition. They were then consolidated with several consolidating agents chosen according to their adhesive properties, penetrability, their resistance to light and humidity and their gloss. Then the soluble salts were removed (there was superficial efflorescence up to 2 cm thick), with a dry sable brush. Very degraded areas appeared underneath, and even gaps, which were filled in to give a global view of the painting and unify the chromatic surface. Finally, a very strong concentration of protective coat was applied –which produced excessive shine– in order to safeguard the paintings provisionally from the temporary dust caused by the works. This shine was reduced at the end of the restoration works. All these tasks were performed by the team of Maria Antònia Heredero, a lecturer at Barcelona fine Arts Faculty.

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TREATMENT OF STONE SURFACES IN VENICE: SOME STUDY CASES

Study Methodology

The study of the stone surfaces of the facades of Sansovino's library (from 1537 onwards), the Corner la Ca' Granda Palace (from 1532-37-1545 onwards) and the Foscari Arch (late 15th century) of the Ducal Palace in Venice are part of a broader research work on the treatment of stone surfaces in Venice.

The analysis methodology used goes from the study of the written sources to the observation of the morphological features of the surface and the stratigraphic survey of the stone surface (identification of the substitute or added ashlars), and includes the taking of samples, important for the chemical classification of the different surface situations found. An essential factor in the analysis is the examination of the surface, as well as the written documents, as a fundamental source to discover the possible interventions carried out over the years, following the hypothesis of interpreting the effects of deterioration not only as material decadence, but as a series of signs that have witnessed the building's evolution. According to this working hypothesis, deterioration is not only conceived as the decay of material but as a sign of the construction and transformation process that plays an active part in the contribution of knowledge. From this point of view, the different conditions of blackening to be found on the stone walls are possible signs of treatments and allow us to make a compared reading of the morphological observation of the sediments and the identification of the restoration and maintenance works performed in the course of time. This process is carried out by making a stratigraphic analysis of the stone walls and studying the written sources.

MORPHOLOGICAL ANALYSIS OF THE "LAYERS"

The surface of the Istria stone in the three cases studied (Sansovino's library, Corner de Ca' Granda Palace and Foscari Arch) presents zones of wash and zones with sediments more or less coherent and adhered to the surface. The word sediment is broadly applied to everything other than the apparently unaltered stone and is initially defined simply as a stratum or surface. With an correct chemical classification later carried out, we shall be able to refer to it with more specific terms like patina, surface alteration, surface sediment proper, black crust, etc. The morphological reading of the sediments was based on the observation of the following parameters: the colour, the reflection of light (luminosity/opacity), the feel to the touch (smooth/rough), the visible thickness, the adhesion to the medium (strongly adhered/not adhered). By observing these factors, homogeneous areas have been identified and have served to orient and direct the sample taking for the classification of the layers by chemical tests. Mapping revealed a complex series of different sediment conditions that can be illustrated by the cases described in tables 3-4, 5-6 and 17-18.

The development of the analysis and the chemical and morphological classification stage of the different types of layers and surfaces –see relevant paragraph– made it possible in some cases to replace these general terms with the more specific patina, defined as an intentional surface with a consistent thickness never more than 20-30 μm, easily distinguished, both morphologically and chemically, from the stone.

In the case of Sansovino's library (Figure 4-5), the chemical tests allowed us to identify clearly two different types of patina: one made up of silica and calcium oxalates (layers 1, 2, 3, 5, 7, 9); and another made up of gypsum (layer 6). In Corner Palace, three types of patina were identified: the first consisting of phosphorus and silica (sample 3), the second of phosphorus, silica and lead (samples 4 & 13) and the third of gypsum (sample 23). In the third case, Foscari Arch, patinas made up of silica, with and without iron, were identified.

In general, patinas with different compositions and black layers were found. These layers do not necessarily correspond to the black crust phenomenon, but to blackening caused by the sedimentation of particles, chromatic alteration of the components of the patina or the colour of time. To understand the cultural significance of the presence of different patinas and/or colouring characterised by a clear composition, it was necessary to study the transformation processes of the three buildings over the years by using the stratigraphic analysis method on the stone surface with the support of the written sources.

STRATIGRAPHIC-DESCRIPTIVE ANALYSIS OF THE STONE SURFACE & THE WRITTEN SOURCES

The written sources describe the restoration and maintenance works performed since the end of the 19th century. Studying them reveals the presence of many stages of works, the main tasks being rejointing and replacement of ashlars or parts of ashlars. The sources which, on the one hand, provide a great deal of information about the replacement interventions, on the other hand, do not always indicate their exact location. In the three cases studied, the stratigraphic method and the logico-constructional method were used to identify these substitutions. Only in a few cases was it possible to relate these interventions with a precise date, while in other cases no link was established with any specific intervention.

Study of Sansovino's Library

In the case of Sansovino's library, the history of the interventions on the stone wall of the facade consisted of two different phases, made between the late 19th century and the early 20th: the "repair and ordinary maintenance of facades and roofs" and the "restoration of the decorative elements". The restoration, initiated in 1839 on the dock side and completed in 1854 on the St. Mark's Square side, involved a series of operations to remove and replace parts of the ashlars, "add patches" and "restore capitals". In 1894, while the facade was being restored, the texts about the work refer to mortising, stuccoing, adhesion of pieces of the cornice "necessary to avoid greater and greater damaged caused by the separation of the stones due to ice [...] Besides avoiding this damage, I deemed it necessary to affix the cut stone parts, which were out of place and threatened to come loose and fall on passers-by".

The bell tower side –which was rebuilt after St. Mark's bell tower collapsed in 1902– was analysed in closely relation to the traces detected on the stone surface and the documentary sources in order to identify the part that had collapsed and been rebuilt and the stones that had been relocated and replaced" (Figures 6 & 7).

By comparing the morphology of the sediments and the data from the stratigraphic-descriptive mapping, it was possible to relate some sediments with the restoration works performed on the stone surface.

For example, the patinas containing silica can be found both in the parts attributed to the first building stage of the library and on the mortises and the early substitution ashlars, but not on the pieces replaced in the 1903 works. Therefore, the treatment containing silica was in all probability used at an earlier date (Figures 8, 9 & 10).

On the bell tower side, the metopes and the triglyphs have a condition similar to the one detected in layer 6 and in parts of layers 3 and 4. Layer 6 consists of a patina consisting above all of gypsum (Figure 11).

With the knowledge we have today, we can see that the layers with gypsum treatment date back mostly to the reconstruction works or subsequent repairs and that in any case they are always placed on top of the silica layer; therefore, we know that the silica layers were applied before 1903; the iron treatments are applied on top of the mortises and some dentils on the Piazzatta side; the layers with black brushstrokes are on the dentils and on the carved elements. These latter treatments may be related to the application of some products to accompany the colour of time on the substitute stones, as was discovered on studying the restoration and maintenance works performed on the stone surface. The work carried out "for the maintenance of the tiled roofs, the cleaning of chimney pipes and stoves and the cleaning of the interior and exterior facades", regulated by specific contracts, reveals concern about the periodical verification of the state of conservation of the joints. This involved periodical control of the sealing of the joints between ashlars and the elimination of the vegetation. Apart from the problem of water, it is possible to identify the material and the method used for the replacement of damaged parts, the cleaning and the treatment of the substitute stones so as to insert them in the chromatic context of the facade. The material result of these interventions con be related to surfaces 8, 9 and 10.

In the "restoration of the decorative part of the facade" in 1839, it states, for instance, that cleaning by "bathing with rock alum" must be done "in a moderate manner so as to clean it without interfering with the idea of age". In the description of the interventions, this cleaning is indicated for application "only on the blackened parts so as to make the colour uniform but without eliminating the idea of age from the facade, and done carefully enough to conserve it". This refers to the intention of not altering the colour of time that, in the restoration and maintenance works carried out on the Public Prosecutor's Office and the Napoleonic wing of the Royal Palace, involved the control of the chromatic integration of the mortises inserted in the facade "harmonizing the shade of the new mortises with the old parts to avoid the unpleasant effect that the different colour of the different parts would otherwise produce on eye of the observer". As regards the mortises, they speak of the "ink with acid on all the new parts that must be applied to harmonize colour of the nearby decorations in each case"; they allude to "chemical procedures that will be carried out during the works in order to imitate the colour of the old stones [...]" or, in any case, a procedure that "will be indicated when the time comes to apply it", a procedure

that will vary in each case "so as to imitate the colour of the surrounding stones, so that these inks will vary according to the place where they are to be applied". In general they refer to "cleaning the whole facade with water and Rovigno powder".
We can quote, among others, Giacomo Boni, who in 1833 describes how "in some modern restorations the new stones can be given a colour similar to the old parts" by applying silicates and fluorosilicates mixed with ochre or products derived from the sublimation of smoke.
Besides this general information, in 1870 the need was established to "darken the new ashlars replaced on the facades" of the library. This can refer to surfaces 8, 9 and 10, related to the mortises, characterized by a dark red background colour with some darker strokes. Examination of the photographic documentation from the end of the 19th century until today seems to reveal the existence of blackening almost identical to what can be seen at the present time. We can, therefore, think it is a blackening that remains over the years and to which the different restoration and maintenance works have adapted.

Comparison of Sansovino's Library, Corner Palace and Foscari Arch
Among the characteristics shared by the library, Corner Palace and Foscari Arch, it is worth mentioning especially the presence of a "smooth black layer" that corresponds to a intentional patina –with different compositions– where the dark coloured component may possibly be due to the sedimentation of particles or the alteration of components; underneath this patina, the stone is in a good state of conservation (see the paragraph on chemical testing).
The "smooth black layer" on Foscari Arch is present on ashlars that apparently date from the initial building stage –also in areas with wash phenomena, where whitening would be expected – whereas on Corner Palace it is also present on some substitute ashlars.
These elements lead us to think that the blackened or degraded surface may be due to a more complex situation where these phenomena overlap with intentional treatments, like on other stone facades in Venice. This is the case of interventions on stone surfaces in which the "age of the facade" and the "care put in conserving it" characterise restoration and maintenance works whose main aim is not the actual "cleaning" of the facade but stopping deterioration mechanisms linked to water leaks and replacing damaged ashlars by treating the surface of the new pieces added to match the dark colour of the surrounding area. These interventions have led to a complex superposition of layers and surfaces in which the black colour –with the exclusion of obvious deterioration phenomena– can correspond either to interaction with the environment or the desire to match the colour of the substitute pieces with the rest of the facade.
Apart from the black layer, layers in colours going from ochre to pink and grey layers have been identified on Corner Palace and Foscari Arch.
The greatest variety of layers on Corner Palace is at the bottom of the socle, columns and pillars, where traces of pale grey and ochre were found. At the entrance to the embossed parts, carved with a chisel, there is a light pink layer similar to one found on Foscari Arch.
On Corner Palace a fairly large amount of phosphorus was found also and calcium oxalate from the same period. This can be associated with treatments with casein and/or organic products. However, on Foscari Arch there is a majority of silica occasionally mixed with iron. Most of these treatments may have been used as a preparatory layer for the successive layers of colour. The presence of lead, iron and in some cases zinc could suggest the use of colours like white lead, zinc and lithopone, commonly used to colour/treat stone surfaces. The presence of iron could be due to the use of ochre or other yellowish shades.
In the different restoration and maintenance works carried out on the two buildings over the years, the main aim was to remove deterioration phenomena connected with the infiltration of water and the need for constant control of the state of repair of the stone walls by repairing the joints. There are, in fact, ten-yearly contracts for the maintenance of the facades. In the 19th century there are maintenance contracts for Corner Palace that involved examining the facade twice a year, in spring and in autumn, to remove vegetation from the walls, to check the joints and to replace any ashlars that so required. The maintenance of the joints is acknowledged to be very important because "the said grass not only damages the solidity of monuments but seriously spoils their appearance".
Methods found on the library are referred to here also: water and Rovigno powder and treatment of the "added" parts with acids. By comparing photographs from the 19th century to 1982, we can see that there have been few modifications with respect to its current state, which would suggest that no works have been performed on the facade since the late 19th century. This observation suggests that the different treatments detected on the surface may date back to before the end of the 19th century.

CHEMICAL CLASSIFICATION OF LAYERS & SURFACES
A morphological examination of the walls yielded a large number of different sedimentation conditions (see figures 4-5, 6-7 and 17-18). Macroscopic viewing of the layers identified in the different stone walls oriented the choice of the most suitable test techniques to be applied to the samples taken in order to obtain the information required to discover the deterioration phenomena and decide on the maintenance treatments to use.
The morphological difference of the layers, understood as a combination of thickness, colour, consistency and adhesion to the medium, was analysed by using an optic microscope (OM) and an electronic microscope (SEM), on fine slides, to view the most characteristic specimens of each condition.
The size of the samples did not permit traditional chemical tests to be made to classify the materials, due to the typology of the surfaces examined and because, at this stage of the research, the intention was to examine the frequency with which the layers appeared. A qualitative analysis of the layers was therefore carried out directly on the transversal sections using an electric probe (Electron Proba Micro-Analyzer) in energy dispersion (EDS), a process that consists of identifying the chemical elements with an atomic number over five. Using this technique permitted us to draw up some tables with the elements present in significant quantity so as to decide on the specific treatment necessary for each particular stone surface.
Because of the scant material available, for the examination of special chemical components, FT-IR spectrophotometry technique was used (infra-red spectrometry). With the help of a scalpel, the outside layer was removed from the samples of the different types of surfaces and the dust obtained was mixed with a suitable proportion of potassium bromide and then compressed to form discs that could be placed on the slide stage of the instrument.
The results of the most significant layers identified on the Marciana Library, Corner Palace and Foscari Arch can be seen in figures 21 and 22.
The morphological investigation of the different types of layers and surfaces led to the classification of some of them as "patinas", attributing to this term the meaning of a deliberate fairly thick layer over 20-30 μm, which can be distinguished from the stone both morphologically and chemically. In any case, there is a layer of atmospheric sedimentation (dust, pollution) on top of these patinas, acquiring different thickness and consistency depending on its exposure to the elements and particularly to rainwater.
By means of this process, different types of patina and colours have been identified: on the library, silica and calcium oxalate and gypsum patinas: on Corner Palace, patinas made up especially of phosphorus and silica or of phosphorus, iron, lead, and gypsum patinas; on Foscari Arch, silica patinas with or without iron.
As we have mentioned above, at this stage of the investigation it was apparent above all how often certain typologies of surface can be found in the three cases studied. In any case, this choice of methodology was not limited to examining the most common layers only, but all significant layers, that is to say, those that were not caused by deterioration of the stone.
An example of this are the gypsum patinas identified on the facade of Corner Palace that represent an important case of intervention typology, but not as regards the extension of the surface treated.
It is considered important to emphasize the interest of the coloured layers in the cases of Corner Palace and Foscari Arch, described above. The stone surface of Foscari Arch presents a series of different cases, not described in this text, with the presence of layers of lapis lazuli, gold leaf and other more or less bright colours obtained from iron pigments.
In the case of the library, silica turned out to be an important component of the layer, together with calcium oxalate, according to the tests made with infra-red spectrometry. The oxalate possibly derives from the alteration of organic components present in the mixture used on the stone surface, whereas the silica could be the result of maintenance treatments made with inorganic silicates.
The study of the gypsum patinas yields a peculiar morphology common to many samples, which can be differentiated –though not always very clearly– from that found on the sedimentation layers, where other particles (iron, aluminium, silica, sodium, etc.) can be found apart from gypsum, as well as pollution. In this last case, the layer is more porous and less homogeneous with respect to the treatment layers. The morphology of the patinas where the gypsum is found suggests the possibility that they may be treatments made with products containing or producing gypsum. This sort of hypothesis has been forwarded also in earlier studies made on other buildings, where similar black layers that could not be identified as caused by deterioration phenomena were found.
In the case of Corner Palace, in general there is a good deal of phosphorus contemporaneous with the calcium oxalate, identified by means of the FT-IR spectrophotometry. This fact can be associated, as we pointed out above, with treatments with casein and/or organic products used as a primer for the successive applications of colour.
Another interesting aspect, which still needs final verification, is the state of conservation of the stone underneath the layers of colour. As there are no definite time references about the period in which these patinas were applied, it is not possible to evaluate to what extent these treatments have protected the stone surface from degradation. However, the specific arrangement of the gypsum in the samples permits us to forward a few ideas. Above all, the gypsum considered a degradation phenomenon, according to its morphology, is usually located between the patina and the stone, producing the macroscopic effect of the tendency of the same patinas to come loose from the stone because of mechanical actions. Because it is soluble in water, gypsum tends to migrate outwards to the patina through tiny orthogonal

cracks. There are fewer samples where the sediment and/or deterioration gypsum is on the surface than between the patina and the stone. This fact, also related to the different exposure of the samples to atmospheric agents, could also point to colouring treatments applied to surfaces that were not perfectly clean or were already deteriorated, apart from taking into account that water tends to wash gypsum away and therefore it would only be possible to identify the gypsum located in a sheltered place (between the patina and the surface).
From the analysis of the samples taken on Foscari Arch, similar conclusions can be drawn, although there are certain differences because of the different chemical nature of the treatment and the different location on the stone. The presence of gypsum is observed more often on the interface between the patina and the stone than on the surface of the samples, possibly due to the fact that the treatments were applied to a degraded surface.

SOME LAST REFLECTIONS

The study carried out on the stone walls of the three examples analysed showed the presence of patinas caused by intentional treatments, although at first sight they seem to have the characteristic appearance of the layers of alteration of stone.
The presence of intentional patinas suggests new ways of reading stone surfaces that do not necessarily mean that a dark appearance is tantamount to degradation. The stone surface goes from a passive role (understood as the place where the alteration and deterioration processes take place) to an active one (the place where voluntary modifications of the surface appearance are documented). Patinas are in direct contact with the stone surface and superimposed on them we find surface sedimentation of different types depending on the exposure to the elements. This exposure in fact involves great variability in the thickness and the appearance of the layers of surface sedimentation, to such an extent that it is possible to distinguish clearly what layers correspond to one particular type of patina. The stone surface exposed to the direct action of rain does not have a patina –except in some areas of Foscari Arch– and acquires the typical whitish appearance of washed Istria stone. Underneath the patina, the stone is mostly in a good state of conservation.
In general, patinas have different composition and black layers. These layers, as we mentioned above, do not necessarily correspond to a black crust phenomenon but point to more complex blackening processes, for instance, the sedimentation of particles, chromatic alterations of the patina components or even an intervention to match the "colour of age".

Elia Gutiérrez Mozo

TEATRO CIRCO DE ALBACETE

On 9th September 2002, Her Majesty Queen Sofía presided the opening of the refurbished Teatro Circo in Albacete, and the National Ballet of Spain danced Fuenteovejuna to celebrate the occasion. Almost immediately afterwards there was a violent reaction and a heated polemic about the result of these works. It is the intention of this article to delve into the history of the building and the philosophy behind the intervention on it with a view to providing, on the one hand, sufficient information to understand the issue and, on the other, giving an opinion that cannot but be subjective coming, as it does, from a subject, but striving at least to be impartial and equable.

At the end of the 19th century, the people in the city of Albacete began to dream of awakening from the historic lethargy of a small town located in the middle of the plains of La Mancha with the same name and embarking on a path of modernity already reached with enthusiasm by other provincial capitals, echoes of which had come to their ears. Perhaps a series of events that took place mainly in the second half of the 19th century brought about this spirit of prosperity: the conclusion of the building of the Canal de María Cristina, which drained the land; its appointment as provincial capital, a political decision that involved the creation of a Court of Justice and a Diputación (equivalent of County Council); the disentailment, which freed sites in the city centre; the railway, connecting the city with the centre and periphery of the peninsula; the category of City, which involved the official recognition of a series of basic conditions that would permit the desired development and, finally, the shift of the city centre from the old Plaza Mayor to the Plaza del Altozano, supported by the City Council by opening there its new City Hall, today the Municipal Museum.
The star of this awakening of the city of Albacete from the very outset was to be Architecture. Architecture became an emblem of what Albacete wanted to be and, on most occasions, it was one step ahead of the urban reality. A paradigmatic example of this statement are the theatres, with which Albacete seems to have maintained a love-hate relationship, lasting, for better or for worse, until the very recent events we mentioned above.
The first specific theatrical project for Albacete that we know of was designed by the provincial architect José Moreno de Monroy and dates from 1886. It is curious to note that Albacete still did not even have running water (electricity arrived first) and yet it dreamed of a theatre where citizens would go to see and, above all, be seen, like Beauty in medieval religious plays. This project was not passed by the Fine Arts Academy, so it was revised by the architect Manuel Portillo that same year. His proposal met the same fate, because he wanted to build it on an interior site behind the Justinian Convent and giving on to the above mentioned Plaza del Altozano. It was considered, and rightly so, that the location was unsuitable from the viewpoint of security and urban representativity.
In 1880, Tomás Rico Valarino tried again with an absolutely superb project whose monumentality is reminiscent of Garnier. But it failed due to the same error of location. The graphic documentation conserved at the Provincial Historical Archive of Albacete shows his total dominion of the subject and the great beauty of its design. Since the Council was unable to finance the theatre project for the city, private enterprises decided to do so. Thus, in 1887 the Teatro Circo was built in Albacete, with facades giving on to Isaac Peral and Carcelén streets, that is, very near the Plaza del Altozano and the Paseo de la Libertad, which connects the former with the railway station.
The plans were drawn up by the Assistant Engineer of Public Works Juan Pérez Romero. The composition of the building, which was to be used indistinctly as a theatre and as a circus, which is what makes it unique and of great interest from the outset, consists of three parts: the entrance body, with a dubious facade, originally designed by the Public Works Draughtsman Emilio Vergara and never resolved, containing the social spaces; the auditorium, where the spectators could face the stage or the stalls; and the stage.
The quiddity of the matter resides in the auditorium. A matter that, in the case of the Teatro Circo, had to fulfil two different functions. As a theatre, the model it is based on is what is known as an Italian-style theatre, in other words, an auditorium in the shape of a horseshoe whose section holds a variable number of floors divided into private boxes. The theatre was able to hold circus representations by turning the auditorium into a circus ring whenever the occasion called for it.
The roof of the auditorium is a light forged metal spatial structure, made in this particular case by the Fundición Primitiva Valenciana, with an outstanding resolution of the pieces and the joints between them, with a perfect workshop finish, as the popularity of this type of structure at that time permitted it to be mass-produced. In this way, the structure of the auditorium, with its columns and its arches, becomes its greatest exponent and its greatest merit.
Whether because of the few circus performances held or the increase in the number of plays put on by the competitors (on 19th March 1919, the Teatro Cervantes was inaugurated in calle Ancha on the corner of calle Mayor, with greater capacity and comfort), in 1919 important refurbishment works were performed on the Teatro Circo de Albacete, the first in a long series that finally led to the total adulteration of the original building.
These works were performed mainly for two purposes: in the first place, to increase the capacity of the theatre, to which end a new floor was erected on top of the ground floor boxes. In the second place, the conditions needed improvement, so central heating was installed in the building. But this would have been of no avail if something were not done about the draughts that blew in through the original roof. A false vault was built over the auditorium. Taking advantage of the works, the stage was enlarged towards the calle Carcelén.
The result of this first intervention was a substantial change of volume in the auditorium and the abandonment of its use for circus performances, whose traces from then on only remained in the name of the building.
The second intervention, less aggressive from an architectural point of view, was the extension built over the main facade to house the Ateneo Albacetense, which had been installed in the theatre in 1924.
The last intervention before deciding what to do with the building many years later took place in 1940 and, in keeping with the times, it was a dreadful decision: the entrance was demolished to build dwellings, and the only way into the theatre was down a dark alleyway.
The theatre continued in this way along a sadder and sadder path until it was finally closed for good on 31st December 1985.

However, the Teatro Circo de Albacete has always occupied a place of honour in the citizens' memory. Perhaps because it was the only one that survived the demolition fever of the period of uncontrolled urban expansion (the Teatro Cervantes in the calle Ancha and the magnificent Teatro Capitol, located in the Plaza del Altozano and designed by Julio Carrilero in 1932, were both knocked down) or perhaps because of its essential uniqueness. We do not know: the fact is that it appears in the Subsidiary Norms in 1981 under the heading of Buildings with Second Class Merit and, as such, one on which restricted works could be performed (let us remember, too, that it was not included in the preliminary catalogue drawn up by the Provincial City Planning Committee in 1985 and that this document was expanded thanks to the participation of the citizens). The 1985 General City Ordinance Plan also included it on its list of protected buildings with the classification of 3rd Grade (Buildings of great historico-artistic interest, on which only a restricted intervention is authorised).
After a long expropriation process, the building was

taken over by the Council (on 30th June 1993, the then mayor Carmina Belmonte signed the expropriation deeds of the building). In 1994 the Board of Communities of Castile-La Mancha announced a competition of ideas for its restoration, which was won by the architects Juan Caballero González, Emilio Sánchez García and Carlos Campos González. As we said at the beginning of this article, eight years later, on 9th September 2002, the refurbished Teatro Circo de Albacete was inaugurated.
The architects have shown a different approach to the challenge posed by each of the three bodies of the building we have described above. Let us begin, then, at the beginning. The entrance and social part has been conceived, in the words of the architects, as a sort of bridge. As it was obviously necessary to demolish the dwellings built in 1940, the facade of the Teatro Circo became a great opportunity. Not only because it was a new building but because it had always been the great unsolved problem of the theatre. In this way, the programme of requirements suggested they way to resolve this part of the theatre. It was to contain rehearsal rooms, classrooms and offices that had never existed in the old building. So the architects decided to take these new uses to the bottom and the top respectively. The rehearsal rooms could be placed in the basement and it was only right that the administration and management offices should be located on high.
To connect both levels, the authors of the project built what they call the "pylons" of their bridge, which is, in actual fact, more of a frame. A frame, although its bottom lath is built into the floor to highlight the main point of attention: the auditorium. Because this frame has been designed as diaphanous as possible, especially on the ground floor, to bring the auditorium, the real protagonist of the show, closer to the street.
The other very important idea was the treatment of the facade: they chose an extremely modern solution, at least at first sight, in the line of the much celebrated high-tech. It is a sort of neutral parasol that the authors of the project describe as a curtain. During the daytime, it conceals everything. At night, with the lights on inside, it reveals to the city the show that consists of the public attending the event. In this way, it is as it used to be long ago: people go there to be seen, no trivial matter for a provincial city that is not so sure it likes being provincial.
As regards the auditorium, the idea of the refurbishment was to recuperate the original, pre-1919 space as closely as possible. In other words, the false vaults were demolished and the old arches standing between the slender wrought iron columns, which have also recovered their initial proportions. As for the spectators, there seemed to be no logic in insisting on the idea of an Italianate theatre (the section is not tall enough to house enough floors), so a circular seating arrangement has been used. When necessary, the stalls can be used as a central stage.

And here it is time to make a pause for reflection. When the matter of the rehabilitation of the Teatro Circo first arose in the city, there were opinions to suit all tastes. Basically, there were two opposing schools of thought: those who wanted to save the building at any cost and those who thought that this was impossible because it simply could not be done. As usually occurs, the final solution was a compromise somewhere in between both positions.
If there was a preservation order on the building, it had to be saved and if it was necessary to intervene on it (the state of ruin in which it had fallen was a disgrace for all the inhabitants of the city), it was necessary to decide how to do so. The problem is, as is all too often the case, that the investigation took place after the event, so that those who wanted to recover the original appearance based it more on the memories of their youth and childhood than on what the building had really been like to begin with. So for a long time, the reality and the undeniable power of the built work has disappointed both groups, the first, because they have not recovered the Teatro Circo they remember (is there anyone still alive who knew the theatre prior to the 1919 refurbishment?); the second, because it is clear to see that a new theatre has been built but without actually admitting it.
Who is responsible? Everybody and nobody. Perhaps the architects who drew up the project, who, in my opinion, have proceeded with entire loyalty, should have had the courage of their convictions and explained what they were going to do. Perhaps the administrations that promoted the project should have done the same. Or perhaps not, because neither the former not the latter could have foreseen the consequences of the final result. It is very meaningful, for example, that what now justifies the huge investment is the recuperation of the theatre's double function and that this decision responds to a refurbishment demanded, quite rightly, by a group of citizens represented by the Association of Friends of the Teatro Circo. It is true, therefore, that as a new theatre it is not large enough or in the best location in the city; it is true that it would have been ridiculous to conserve it as history had handed it down to us; consequently, the only solid argument consists of the uniqueness of the building and we must admit that this was not the point of departure of the project. But the enterprise is justified today and is a cause of pride for the city.

Finally, the stage has been completely adapted to meet the needs of a modern theatre. The facade giving on to Carcelén street has been conserved and now houses three floors with dressing rooms, toilets and workrooms, underneath which are the rehearsal rooms, which are connected with the orchestra pit. In this way, the theatrical equipment is in keeping with the requirements of our times.
The issue raised after the Teatro Circo de Albacete was reopened concerning the visibility from the seats demonstrates that the spectators are also typical of our times, times in which visual matters take precedence over all else. For that reason it is difficult to make the public understand that the only thing that can be shown at present (theatre) cannot be seen very well; that what they would be able to see very well (circus) is not at present and may or may not in the future be included in the programme, and that music, for which it is only fair to say, the acoustic is excellent, has other auditoriums in the city of a more suitable size for the number of music lovers in the city.
If the Teatro Circo is to be a worthwhile enterprise and if we take it into account that it has serious limitations as a theatre (not being able to see very well is not very well considered by audiences today), it is clear that it would be better justified with a different programme of events. Of course nobody is thinking of elephants or lions typical of the sort of circus whose future is rather uncertain, but there are other sorts of shows nowadays that would be suitable for the Teatro Circo. The problem is that such shows are not usually found circulating around the quixotic lands of La Mancha, but must be sought farther afield. It would be good, fair, necessary and even European to do so.

Juan Francisco Noguera Giménez

RESTORATION OF SANTA QUITERIA BRIDGE BETWEEN ALMASSORA AND VILA-REAL, CASTELLÓN

Santa Quiteria bridge was probably built over the River Mijares in the last quarter of the 13th century and, according to tradition, over the road that was the great axis of communication in Valencian territory, the Via Augusta, although there is no evidence to support this hypothesis. Until the present time it has not been possible to verify whether it was built on top of the remains of a Roman bridge. However, although there are no grounds for attributing it to the Romans, this bridge is a magnificent example, almost unique in Spain, of a medieval structural type, of exceptional constructional value, with arches instead of vaults.
The place where the bridge crosses the River Mijares is between the limits of Almassora (Santa Quiteria parish) and Vila-real (Madrigal parish), before the confluence of the river and close to La Viuda ravine, beside Santa Quiteria Hermitage and the adjacent housing estate. The bridge, on the northern boundary of the town of Vila-Real, is the connection between the two towns for pedestrians and vehicles and is an essential route inland, absorbing quite a lot of traffic because of the many industries in the surrounding area. The main link between the two towns, a very long way if one is on foot, is by the national road.
The hermitage, the bridge, the ravine, the river and the surrounding area with its many trees form a landscape of great beauty. This spot was transformed some years ago with the construction of a dam beside it, which has caused the flow of the river to change from season to season, so that four of its buttresses can be surrounded by water or its bed can be completely dry.

HISTORICAL DATA

We do not know the exact date when the bridge was built. It has traditionally been considered Roman, merely because it coincided with the Via Augusta. Those who defend this theory base their conviction on the data found in the Vasos Apollinaires, where there is a reference to the Via Augusta going from Borriol to Vila-real over the Mijares, and as no other remains were found, they identify this bridge as necessarily being part of the Roman road.
There are other opinions with more solid grounds, which defend its medieval chronology. P. Ramón de María contributed a crucial detail when he published a document according to which on 18th April 1275, Jaime I grants Pedro Dahera (a resident of Vila-real) permission to build a hospital and supervise the building of a stone bridge to be laid over the River Mijares. Apart from this document, the building type of the bridge leaves no room for doubt about its medieval origin. After the above mentioned document, the next historical references to a bridge over the Mijares date from August 1513, when the jurors and syndics of Vila-real summoned their counterparts from Castellón, Burriana and Almassora to a meeting about the bridge, and 1563, when Viciana mentioned it again. In 1652 an important event took place: the boundary cross built in 1583 on a pyramidal pedestal on one of the central cutwaters was struck by lightning and went on fire, a fact commemorated with an inscription on the pedestal. The works undertaken afterwards did not only affect the pedestal of the cross with the inscription but took advantage of the opportunity to carry out some repairs on the railings, as can be seen from the existence of a different type of limestone from the sedimentary stone from the area used in the arches and most of the bridge. It was probably at that time, at the latest, that the props were made, since the different building type of the rubblework

on the ashlar buttresses would suggest that they were probably built at a later date.
It has not been proven that the course of the Via Augusta in the province of Castellón ran over the Mijares with a bridge possibly situated where the Santa Quiteria bridge stands today. The traditional interpretation sustains that the road ran along the Camino Real or the Cova del Colom and headed straight for Vila-real, first going over La Viuda ravine and then crossing the Mijares over Santa Quiteria bridge. But this course, which seems to respond to the existence of Vila-real, which was founded in the 13th century, is not logical at the time of the Roman Empire because it involved crossing two rivers instead of one if it were situated further east; besides, no Roman remains have been found between the river and the ravine. Further east, however, the straight course of the Roman settlement known to have existed beside Na Tora stables (Castellón de la Plana, a little over 2 km north of the Mijares), in the direction of the fork formed by both rivers, would allow us to conjecture that the Roman engineers would have preferred the road to cross a single river in a place where the presence of an archaeological site occupied in the Iberian and medieval periods (Almassora Castle) indicates the possible existence of a ford disguised when the current bridge of the national road was built in the 18th century. The presence of the above mentioned archaeological site at Na Tora and another Roman settlement on the bank of the Mijares, in the parish of Ramonet (Almassora), would support this hypothesis. In this way the foundation of Vila-real in the 13th century would explain the course of the Camino Real and the building of Santa Quiteria bridge. The tests performed on the foundations of the two buttresses of the bridge at the beginning of the works did not reveal the existence of earlier foundations than those of the current buttresses. In the light of these facts, we can conclude that there is no reason to believe that the course of Via Augusta ran over the site of Santa Quiteria bridge or that another bridge existed before the present one, whereas the historical data found support the fact that it was built in the last third of the 13th century, probably when Vila-real was founded.

DESCRIPTION AND TYPOLOGICAL ANALYSIS OF THE BRIDGE

Santa Quiteria bridge belongs to an almost unique structural type of medieval bridge. The bridge consists of two abutments at the ends, seven intermediate buttresses and eight bays, seven of which are similar, with a span of between 11.59 and 12.65 metres each from buttress to buttress, and a shorter span of 6.80 metres closest to Vila-real. The length of the bridge is 154.88 metres and the average width of the road is 3.37 metres plus two parapets measuring 55 centimetres each. The arches are approximately 0.67 metres wide and are made up of a band of 0.50 metres.
The following building materials were used: the buttresses and cutwaters are made with ashlars up to the springing point of the arches. From this height on the side where they rise until the topmost part of the parapet they are made of rubblework except for the corners, which are also made of ashlars. The arches are made with a band of sandstone voussoirs. The spandrels of irregular rubblework stand on this band up to the level of the deck, made of stone slabs placed in the form of lintels. The parapets are also made of rubblework. There are three types of materials apart from the mortars: limestone, sandstone and stone conglomerate. The roadway was paved with a layer of asphalt before the restoration works began.
The tests carried out by the Laboratory of Applied Physics of Valencia Polytechnic University yielded the following results: the arches are built with a very heterogeneous sedimentary type conglomerate stone, with rounded pebbles of different size and composition embedded in a limestone matrix. In the parapet, there are two kinds of different coloured stone, one grey and the other beige. The grey one is a carbonated stone (limestone and dolomite). The beige is a limestone that was used in the 18th century intervention. The historic mortars were mostly made of limestone and calcareous and quartziferous aggregates.
The unique feature of this bridge is the structural system:
- All the bays are covered with four independent diaphragm arches, on which rest rectangular transversal stone lintels 20 cm thick and with a span of 0.63 cm, going from arch to arch and forming the base of the deck. This way of covering the bays contrasts with the procedure habitually used in rubblework bridges, which consists of a continuous vault.
Other outstanding features of Santa Quiteria bridge are detailed below:
- The arches that cover the bays have a depressed directrix, instead of the more common round or pointed arches usually to be found in medieval bridges. The only exception is the arch with a much smaller bay than the others, the first one from Vila-real, which is pointed, which raises a new doubt about the construction of the bridge, since no plausible explanation has been found for it.
- The buttresses have triangular cutwaters on either side. The cutwaters under the water finish at the height of the springing point of the arches, whereas the ones above water level are prolonged up to the parapets, so that on the roadway on the countercurrent side there are some additional lateral triangular shaped spaces known as "supports" or "props". These spaces permit carts or vehicles to pass at the same time as pedestrians in spite of the narrowness of the roadway.
Very few references for this building type have been found in other bridges. Nevertheless, the building system of covering large spans with barrel vault or round arches was the most commonly used all along the west coast of Spain in churches and civil buildings during the period to which we refer. Numerous constructions of this type are still conserved, such as San Salvador church in Sagunto, Sangre church in Liria, the churches of San Pedro, San Félix and San Francisco in Játiva, the refectory of the Carmen convent in Valencia and civil buildings like the Ropemakers' Workshop in Valencia. It is not surprising, therefore, that a system that had proven to be simple and efficient was also used to build bridges like Santa Quiteria. Under "bridge" in the Dictionnaire raisonné de l'Architecture, Viollet-le-Duc refers to a type of bridge in which the arcades "are built with diaphragm arches separated by an interval filled with thick stone slabs underneath the deck". Furthermore, he mentions the fact that "the rainwater that always seeps in through the pavement flows freely out through the joints between the slabs and does not cover the haunches of the arches with saltpetre, as is usually the case when they are continuous. This arcade system has the added advantage that it is light and loads the buttresses less, and economical because it uses a third less of materials. On top of these diaphragm arches the spandrels are built of rubblework and can be very easily replaced without having to interrupt circulation. Examples of bridges built according to this method seem to date from the early 13th century or perhaps the late 12th." In this same text, Viollet-le-Duc affirms that in France this type of bridge can be found mainly in the Poitou region.
In Spain, very few examples were found with arches and they are limited to the province of Castellón. Apart from Santa Quiteria, other bridges with the same typology are the old bridge over the River Palancia in Jérica, the one on the Camino Real from Valencia to Aragón and the bridge over the River Sonella in Onda, on the old road to Valencia. Of the first of these, the one in Jérica, all that remains is a fragment of a buttress in the middle of the river and a few traces of the abutments, but according to the contract executed by the notary public P. Farnós in 1393, it had three stone arches instead of vaults covering five bays and Miguel García is mentioned as the stonecutter. The Onda bridge is very similar to Santa Quiteria, although smaller, with two bays, a total length of 36 metres and a width of 3.15 metres. The bays are also covered with four diaphragm arches with a reduced directrix. Both bays rest on a buttress with triangular cutwaters on either side that are prolonged to the parapets to form two props. The first known written reference to this bridge is in Relaciones geográficas, topográficas e históricas del Reino de Valencia by T. López, dating from between 1770 and 1780, but it was probably built at the same time as Santa Quiteria, to judge from the similarity between them.

STATE BEFORE RESTORATION & STRUCTURAL ANALYSIS

The dividing line between the two townships is approximately at the centre of the bridge, which explains the very different state of conservation of the two halves. In the part that belongs to Vila-real, the exterior vertical surfaces were parged with cement, including the voussoirs of the arches, after consolidation works carried out by the Council in 1944 on the bays inside their district. This side, in spite of being covered by a layer of cement that concealed the age of the bridge and interfered with its aesthetic and building system, was much more solid that the Almassora side. However, its poor grey appearance was quite unworthy of the quality of the historic building materials.
Near the hermitage on the Almassora side, the initial span was in a very precarious state of repair, with the stone very loose where the mortar had disappeared. At the bottom underneath the arches, there were large cracks in the deck stones running longitudinally along the bridge, and some of them were actually broken. The voussoirs of the arches, made of stone conglomerate, had lost cementing material with the ensuing loss of volume, serious in places. Several centimetres of the lime mortar had also come loose in many places in the voussoir joints, and only a nucleus of mortar remained permitting contact and the transmission of tensions between the voussoirs. The arches in the first stretch were also observed to have sagged horizontally about 5 centimetres at the centre and on both sides, as though they had opened. On this part of the Almassora side there is also a great deal of vegetable matter adhered to the masonry, with the resulting damage that the roots inflict on it. There are also many plants at the sides of the roadway and on the parapets.
Trucks coming to the bridge from Almassora up a slope and curving towards the left were thought to be the main cause of the breakage of several stone slabs in the decks of this first stretch, along with settlement due to the weight and braking of vehicles. This was the first hypothesis deduced by observing the bridge: the fact that the right hand parapet in the bend coming down from the hermitage was broken showed that some drivers had entered the bridge too fast. However, as the "technical structural analysis of the bridge" drawn up by the civil engineer Pere Roca Fabregat demonstrated, the accumulation of earth on the stone deck due to an increase in the grade on the two end stretches by Santa Quiteria Hermitage had been a crucial factor causing the instability of this part of the bridge.

The TECHNICAL STRUCTURAL ANALYSIS pursued the following aims:

- To identify the causes of the damage detected on the first stretch of the bridge.
- To evaluate the load capacity of the bridge.
- To propose a consolidation treatment for the first stretch.
- To propose reinforcement works that would permit heavy vehicles to cross the bridge if necessary.

The structural behaviour survey was carried out by the CRIPTA analysis code specially developed for non linear to breakage testing of brick or stonework masonry formed by curved and variable section spatial elements. By using the test method described, the arch type was modelled with its masonry spandrel and the upper part of the slab, taking into account an isostatic load distribution.

Several hypotheses were made with an imaginary average-sized truck of 4.45 – 5 metres between axes, with one or two individual loads depending on its position. In position I, the first axle, simulated by an individual load, is approximately at a quarter of the span while the second axle is not on the arch. In position II, simulated by means of two individual loads, the first axle falls over the keystone of the arch while the second axle is situated approximately at a fifth of the span.

Given the steep downward inclination for vehicles approaching the bridge, on studying this arch the vertical loads simulated by the vehicle in position I were combined with horizontal forces to represent the effect of braking. Following the provisions of the Instructions about the actions to be taken into account in projects of road bridges (MOP, Madrid 1972), the effect of braking was taken as a horizontal force of a value equal to 1/20 of the weight of the axle. This force was introduced maintaining an angle of 20º with respect to the axis of the bridge to take it into account that access to the bridge by this arc is also on a bend.

The following conclusions were the result of the calculations made:

- The formation of longitudinal cracks and chinks all along the lintel slabs between the diaphragm arches was caused by the joint action of the weight of the filling that existed in the initial part of the bridge and the effect of the horizontal thrust on the lateral walls produced by this same filling, increased by the passing of heavy vehicles.
- Two effects also caused by the superior filling may have contributed to accelerating the breakage of the blocks of conglomerate. On the one hand, the tensional state of compression produced by the large quantity of soil in the areas most affected by this sort of deterioration (a tensional state that reaches a maximum of 2,000 kPa, 20 Kp/cm2 in areas near the springing and the upper surface of the keystone). These tensions were found to be a great deal less without the filling. On the other hand, the filling could accumulate humidity, thus producing conditions that would favour the breakage of the stone in a shorter time.
- The partial disappearance of the mortar at the joints of the voussoirs could have been caused by the increase of water and damp, as described above.
- The excessive weight of the filling was also considered to be a cause of the deformation of the arches and the diagonal cracks found in the spandrels of the first arch.

In current traffic conditions, due to the width of vehicles and the roadway, it was also found that by far the greatest part of the load tends to fall on the central arches. This unequal distribution of the bearing capacity of the arches when overloaded is a consequence of the features of motor vehicles today. The design of the bridge was logically more coherent with the traditional historic use to which it was put. A certain amount of filling with soil is very effective as it spreads the weight of the vehicles between all the arches. However, an accumulation of soil results in the lintel slabs being overloaded and excessive lateral thrust. The final conclusion was that, once the bridge had been repaired and its safety guaranteed, it would be able to support the passage of vehicles of two single axles and up to 10 T maximum load per axle. This limit is slightly inferior to the legal limit per axle in Spain, set at 12 T for single axles and 21 T for double axles. The need to establish some sort of restriction on the vehicles passing was all the more evident if we take it into account that the bridge cannot safely support the freight train defined in the Instructions about the actions to be taken into account in projects of road bridges.

AIMS OF THE RESTORATION

The project had two main aims: the consolidation of the bridge by improving its load-bearing capacity for the passing of motor vehicles and enhancing its status as a monumental bridge that had lost its historic appearance. Both aims had to be made compatible.

Although the technicians from the different Administrations responsible for the bridge were very cautious regarding the future use of the bridge, limiting circulation to pedestrians and light vehicles –cars were permitted to pass but trucks were prohibited– the intervention should foresee the possibility of their changing their minds or any other contingency, so the priority was to improve the load-bearing capacity to support single-axle trucks with a maximum of 10 T per axle –which includes almost all the trucks in this type of heavy vehicle. This objective must be achieved if possible without altering the constructional qualities of the historic bridge. Now, after the restoration, trucks are not recommended, since their size is limited, but in fact the bridge is prepared to support the load if necessary.

In order to increase the load-bearing capacity of the bridge and permit the passage of heavy traffic by repairing it and consolidating the arches, it was seen that, to maintain the present gradient and filling, the reinforcement required would have to build a 20-centimetre layer of reinforced concrete on the first two stretches of the deck of the bridge. If this layer were spread all over the bridge, it would permit the passage of articulated vehicles but it would not comply with the above mentioned Instructions about the actions to be taken, so the bridge could still not be open for general traffic. A rigid layer of such characteristics, albeit concealed, would involve a considerable undesirable alteration of the structural system.

Once this solution had been discarded, the idea of replacing the original soil filling in the first two stretches –which had been calculated to be the main cause of the pathologies and deterioration– with a light filling of dry-expanded clay, a solution that had been applied to roads although never to bridges. After making the calculations with the new lighter weight, it was found that the solution would be a minimal layer of 6 cm of concrete on the stone slabs of the deck (with a separating sheet between them), which would guarantee contention and load distribution, a light expanded clay (arlite) filling with a density under 600 kg/m^3, covered by a 60 cm layer of structural foundation (ballast and pavement). This solution would increase the load-bearing capacity of the bridge considerably, guarantee better behaviour for possible future uses and be less aggressive and much more coherent with the structural system of the bridge. We felt that this proposal would ensure the survival of the constructional features of the bridge.

Finally, although once repaired as described the bridge would be able to bear the weight of heavy vehicles (trucks), it is not advisable because of the narrowness of the roadway and the sloping bend as you approach from the hermitage side, since more than one vehicle has bumped into the parapet and knocked part of it down. This layout, which it would be very difficult to modify, could only be corrected with an urban intervention on a large area surrounding the hermitage, and it would not be justified merely to increase the type of vehicle that can use the bridge.

As regards the appearance of the bridge, the aim was to enhance its historic character by endowing it with greater uniformity, eliminating as much as possible the differences between the Almassora side and the Vila-real part, recuperating the unity of the bridge and eliminating the cement finish added during the most recent intervention. It was felt that a layer of cobblestones would provide greater unity and be more in keeping with the historic merit of the bridge.

RESTORATION PROCESS

The following were the major tasks performed:

- Suspension of the traffic of both pedestrians and vehicles in order to prepare the area for the works.
- Elimination of the vegetation adhered to the masonry of the bridge by extracting and burning the roots, as well as removing the vegetation concealed under the arches that hindered the restoration works.
- Chipping of the layer of asphalt and part of the underlying layer of the whole bridge.
- Removal of the surface of stretches 1 and 2 near the hermitage down to the deck.
- Restoration of the interior surface of the parapets (Almassora side) and the application of a uniform treatment to them all along the whole bridge.
- Restoration of buttresses, arches and exterior surfaces.
- Restoration of the voussoirs in the arches and the slabs on the deck.
- Restoration of the truncated pyramidal piece at the centre of the bridge.
- New filling in sections 1 & 2 and a new surface.

Following the Project, the first step was chipping the asphalt and removing the filling of sections 1 and 2, on the hermitage side, the most badly damaged parts. The operations considered necessary for section 1 according to the structural calculation were also performed on section 2, which, albeit in slightly better condition, was similar to section 1, and even though its earth filling was finer, it was thicker than in the rest of the bridge due to the steep upward slope here.

Once these areas had been emptied out, the cracks and breakages in the slabs of the deck were seen to be limited to the ones visible from underneath, and the rest of the structure was found to be in a good state of repair with a few exceptions. Before emptying it out, a plank moulding with stays was set up on solid ground under the damaged slabs. The stone slabs were repaired by introducing fork-shaped stainless steel rods inside and sewing both parts together and filling the gaps with R-KEM Rawlplug resin made by Deltoro (which comes in cartridges of 300 mml), attaching these rods to a stainless steel mesh inserted in the layer of concrete placed on top of the deck. The cracks were sealed on top with dry mineral mortar for restoration with hydraulic binders, manufactured by Kein-Restauroground. Once these tasks had been carried out, the cracks were sealed again on the bottom, trying not to erase their tracks so that they could be identified from below by making the repair mortar a slightly different shade.

Once these sections had been emptied out, the interior surface of the parapets was consolidated. This surface had first been cleared of plants and restored on the outside, like the spandrels of the arches. By placing a geotextile on top of the stone slabs and on the inside of the parapet as a separator, about six centimetres of concrete was spread on a 20 x 20 stainless steel mesh. Then the layer of G-3 arlite light filling was laid down to meet the weight reducing requirements according to the calculation hypotheses. The arlite was pumped from a tank truck and the surface was smoothed manually and then covered with a cement grout of 2 cm at

most in order to provide a more rigid base on which to place the waterproof surface and prevent the 50 cm layer of ballast from sinking into the arlite. Once this layer had been compacted, the cobblestones could be set down.
Although the buttresses showed no signs of settlement problems, three wells were opened up in different positions beside the two buttresses in sections 1 and 2 to see the state of the subsoil and the foundations. The buttresses were found to be placed on very compact rocky ground at a depth of about -2.5 metres. This ground was found to be in a good state of repair, so the interventions carried out were limited to tasks of cleaning, restoration of some ashlars and especially the mortar joints whose external surface showed loss of volume or cohesion. After several tests and trials, necessary because of the hardness of the stones in the buttresses and the difficulty in eliminating the paint from them, some graffiti was also removed by using a jet of sand at moderate pressure so as to avoid damaging the stone.
Depending on the area, the exterior masonry of the bridge was dealt with in different ways. The first three arches on the Almassora side were in an advanced state of deterioration, with loss of adhesion material leaving a great deal of the uncut stone naked, especially in the first two sections mentioned above, whereas on the Vila-real side the masonry was covered in cement mortar. On the Almassora side the mortar missing from the joints was replaced by a mixed lime and cement mortar with the same characteristics as the one applied to the interior surfaces of the parapets. This finish leaves part of the stone of this masonry visible by not covering the rubblework completely in order to reinforce the masonry without relinquishing the rustic appearance they had before the intervention. The voussoirs of the arches were thus left visible, showing the arches as the most essential elements of the process and building type of this part of the bridge as they had been throughout history.
Unfortunately this was not the case of the Vila-real side, which had been repaired previously. The greyish cement added, darkened by the passage of time, covered all the masonry and concealed the arches. The same applied to the inside of the parapets, divided in two very different parts. This apparently degraded cement finish was chipped away from the interior surfaces of the parapets, according to the Project, and both sides of these parapets were restored with a unitary building and formal treatment, which helped provide uniformity to the bridge as a whole by recuperating the historical constructional dignity that it had lost. However, once the manual chipping of this cement finish applied in the nineteen forties was initiated, it was found to be a very resistant type of mortar. This made it necessary to think twice about removing it from the exterior surfaces, because if the main reason for the works was to reinforce and consolidate the bridge, it was deemed unwise to carry out any action that would go against this idea by weakening the bridge instead of strengthening it. After some tests had been performed, it was obvious that this cement finish had halted the deterioration of the bridge in these places, so it was not a good idea to remove it, and far less so by using a compressor, which would be absolutely necessary to remove it. In view of all this, it was decided to keep it in place and try to use other means to give it a uniform appearance given the great contrast between the two sides of the bridge. The mortar was cleaned, a layer of liquid adhesive resin was applied, followed by a layer of mixed mortar similar to that used on the rest of the bridge in order to make the bridge harmonise as a single unit and with its surroundings, although without erasing the traces of the previous intervention, by maintaining the difference between both ends caused by the fact that at this side the masonry was not visible. Nevertheless, the stone of the voussoirs was left bare, thus helping understand the structural system and decreasing the differences between both sides.
The last stage of the intervention was the paving. According to the Project, the layer of asphalt was replaced by a pavement of granite stones laid on top of a layer of dry sand and an impermeable layer, more in keeping with the historical character of the bridge.
The commission of the Project by the Department of Culture contemplated the initial intervention stage described here. Castellón Diputación (Provincial Council) financed the works. Unfortunately, the second phase, probably considered unessential, seems to be running the risk of being cancelled sine die. In this second phase, the intervention would be on the illumination of the bridge, whose preliminary installation consisting of flexible tubes for functional lighting has been imbedded in the pavement, and even the points for anti-vandalism appliqués have been placed on the inside of the parapets. A general exterior illumination of the bridge would highlight it at night, especially on summer nights, when there is much more movement because of the number of tourists present in the area. In the report drawn up at the end of the works, it was also recommended to make a new design in the second phase for the elements to limit the passage of vehicles that were to replace those that existed before the works were carried out, which spoil the appearance of the bridge. Finally it would be a good idea, in order to enhance the image of the bridge, to place a cross with a modern design and in modern materials made by some prestigious sculptor on the stone pedestal that has been repaired and stands in the middle of the bridge. This pedestal did bear a cross, which was destroyed by the bolt of lightning mentioned above.
The illumination, suitable height and weight control devices and a cross would definitely improve Santa Quiteria bridge and enhance its appearance in such a beautiful setting.
People should pray to the saint for her intercession. The best time for prayers will no doubt be the next pilgrimage to Santa Quiteria hermitage. The religious fervour and the festive atmosphere are extremely auspicious. I, personally, shall make my invocation to the saint.

Camilla Mileto & Francisco Cervera Arias

RESTORATION OF THE SERRANOS TOWERS IN VALENCIA

In 1999 Valencia City Council adjudicated the contract for the "drawing up of the basic restoration project and the execution of the first stage of the maintenance, conservation and cleaning works of the Serranos Towers" to the company Construcciones Exisa and a multidisciplinary technical team directed by the architect Francisco Cervera Arias.
The contract had two peculiarities: in the first place, it was directly assigned to a building company and a technical team and, in the second place, it included the preparation of the preliminary survey and the works themselves in a single package. This second feature made it possible, on the one hand, to make a continued study of the monument (from the first examination of the building for the elaboration of the preliminary study to an in-depth inspection once the scaffolding had been erected and afterwards while the works were being performed) and, on the other hand, to shorten considerably the bureaucratic time of adjudication and approval of the different stages of the project and the works, so that it would be completed in a shorter time than usual without stinting the time needed for the works themselves.

BRIEF HISTORICAL INTRODUCTION

Conception and Building of the Serranos Gate

The construction of defence walls was one of the most important municipal works in medieval cities. Within the fortification of cities, gates were an important item as defence bastions and ways for visitors to go into the cities. It is not surprising, then, that with the boom in civil architecture in the states under the Crown of Aragón in the 14th and 15th centuries a type of gate that deserves to be considered one of the major architectonic works of the time was defined, a good sample of which is the Serranos Towers.
The need to protect an urban area first increased under the Muslim threat until 1340 and later against the Castilian army of Pedro I the Cruel, who laid siege to the city in 1363 and 1364. After 1358, the Fàbrica de Murs e Valls, an entity that saw to the maintenance and construction of the city walls and moats, bridges, roads and irrigation ditches, was in charge of the construction and improvements of the ramparts.
From the spring of 1392 onwards, Pere Balaguer, appointed master builder of the Serranos Towers, dedicated himself entirely to the works, choosing the most suitable materials for them. According to the documents conserved, the stone used for the building was taken from the Tosal de Rocafort, Almaguer quarry in Alginet and the pieces to be sculpted from Bellaguarda quarry in Benidorm. The finishing touches were performed on the site by the stonecutters, first in a timber shed with a bamboo roof mentioned in the documentation, and later in a covered area next to the staircase leading to the towers of the gate. Pere Balaguer himself prepared the tar needed to adhere some of the sculpted pieces and attended to the auxiliary machinery required to raise the stone to its location in the masonry.
In the same year 1392, the municipal administration paid Pere Balaguer for trips to different parts of Catalonia to visit other gates to use as models for the new one to be built in Valencia. It is common knowledge that the Serranos Gate is similar to the Royal Gate of Poblet monastery. However, we must not forget that there is a coetaneous model of a gate in the walled city of Morella built in the second half of the 14th century, the Sant Miquel gate, often compared to the fortification works carried out by master builder Doménech Taravall between 1358 and 1362.
The works began in March 1393. On 2nd of June of that same year the mechanism per obs de muntar los volsors, pedres, reble e altres coses necesàries per la dita obra was prepared and on the 5th of July the intradoses of the arches and vaults of the main door were set up. In the second fortnight in October the keystone of the vault was in place and Marçal de Sas was paid for painting it and the corbels of the angles, while Pere Nicolau painted and gilded some letters in 1394. The participation of these painters, among the most prestigious in Valencia, is a token of the meticulous care taken with the works and their artistic finish.
In the first quarter of 1398 the staircase leading to the first floor of the gate was built, and the building of the Serranos Gate was considered to be concluded after three days' cleaning of the monument on 19th March 1398.
Throughout the 15th century, the Serranos Gate was considered to be the most renowned monument in the city (image 2), a privileged way in and the backcloth for spectacular royal entries; in 1424 torches were lit in the towers to welcome Alfonso the Magnanimous; in 1429, the gate was used for the official reception of saint Augustine's relics and in 1459, it was the scene of the entry of King John II.

The Serranos Towers: from triumphal arch to prison

On 19th January 1586 King Philip II made a solemn entrance into Valencia through Serranos Gate, which presented its most splendid appearance as a "triumphal arch". On the night of 15th February 1586, a dreadful fire broke out in the City Hall and the Jurors let nearly all the prisoners go free, with the exception of the most dangerous criminals, who were taken to the towers of Serranos Gate, the County Council tower and the prison of the Holy Office.

The solution adopted by the Jurors the day after the fire was to use the house of Saint Narcissus' confraternity and the towers of the Serranos Gate as prisons. The works were completed on 18th March 1586, when the cavallers y homens honrats (gentlemen and honest people) were taken to Serranos and the plebeians to Sant Narcis, the Comuna prison. The works to turn the building into a prison involved closing off areas inside the towers, on the first floor of the central part and the entrances from the city side (image 3). The descriptions of the Towers permit us to realise what an unsuitable prison they must have made. There were two rooms on the ground floor: the Cañeta, which could hold about 25 prisoners, and the Cubo. On the first floor the church with two chapels was on the left, and it was later no longer used for worship and turned into the San José cell. In the central part, the vestibule, where visitors went and the Campana cell. In the right hand tower was the Comuna room, where the only latrines were situated. A large hall was made lower, and the vault was used to make dungeons. Between the dungeons and the keystone, another little dungeon was made to isolate the prisoners in church: the Saleta. On the top floor were the Peñón and San Vicente cells. Between these was a cell for young boys (los Chicos) and the infirmary.

We can easily imagine that attempts were made to have this awful prison closed down, if not because of its disgraceful conditions (at certain times it housed over three hundred prisoners), because of the lack of security and hygiene or out of mere civil decorum. However, there it remained for more than three centuries.

Restoration of the Serranos Gate between 1870 and 1936

In 1887 it was decided to do away with the prison and the last prisoners were moved out in March 1888. Shortly afterwards restoration works were started on the monument under the supervision of the chief municipal architect, beginning with the demolition of the works made to turn the monument into a prison and continued with the cleaning of the walls and the reconstruction of the decorative elements.

In January 1893, the Council asked the San Carlos Academy to advise them about how to continue the restoration works. The Opinion, drawn up by Academy members A. Martorell, J. Calvo, J. E. Serrano y Morales and L. Tramoyeres Blasco, was an authentic restoration programme. After valuing the works already performed, they drew up a list of the things still to be done to "restore the monument to its former splendour and original purity as a most remarkable artistic conception". The works they recommended consisted, in the first place, of putting back the moat and completely isolating the monument and then rebuilding the portcullis gallery by removing the vault that closed it off while respecting the pendentives; replacing the lintel of the door between the central terrace and the second floor of the left tower; putting back the apron of the barbican, after consolidating and restoring the corbels and vaults; eliminating the rectangular windows and rebuilding the loopholes; completing the cleaning of the inner walls; continuing the restoration of the corbels of the ogival vaults; cleaning the outer walls with lye; replacing the arches on the exterior surface of the central building; and finally, they advised that the outer staircase against the wall of the left tower be respected.

It is interesting to note the interest they took in the way the walls should be cleaned so as not to lose the old appearance of the stone. Both the Academy's Opinion and the Municipal Committee give precise instructions about how the works should be carried out: the millstone hammer was to be used as little as possible, all the stone on the monument was not to be chipped and lye was to be used wherever possible "in order to conserve the patina of time" (image 4).

That same year master José Aixà e Íñigo, who had been overseeing the works on the Lonja and the Towers, was appointed municipal artistic restorer, and from that time forward he managed all the works on the ornamentation. The works continued slowly, and the problem of the outer staircase, whose originality was doubtful, had still not been solved. In 1914 its restoration as an original element of the monument was approved and that same year the works project drawn up by chief architect F. Aymamí and by Aixà was submitted to the Academy. So it was done, and was completed in 1917 with the installation of the upper gate designed by Aixà (image 5).

In March 1931 the works were declared completed and that same year the Serranos Towers were named a National Artistic Historic Monument, one of the first buildings in the city to be so appointed, together with the Cathedral, the Lonja, the Cuarte Towers, the Diputación and the Chapel of Santo Domingo.

During the Civil War the Towers were not damaged and the basements were used by the Department of Fine Arts to store works belonging to the National Treasure and Valencia Museum. For this purpose a concrete vault was built inside and later knocked down again, a project drawn up by the architect José Vahamonde.

PRELIMINARY STUDY

The methodology followed to draw up the preliminary study is that usually recognised for the examination of a historico-architectonic building with the logical adjustments for this specific case, that is to say: the title of the commission limits the scope of action to works for the maintenance, conservation and cleaning of the interior and exterior surfaces, vaults and pavements and the timber and metallic elements that make up the monument.

Stages of the Preliminary Study

1. The first approach to the monument was through careful direct examination of the building (image 6). The aim was to get to know the building little by little by observing it, taking photographs and comparing the different parts of it with each other and with other similar buildings. After this first contact with the object of study, it was decided what lines to follow more deeply and what investigation to carry out according to the characteristics of the monument.

2. The historical study linked to the project for the conservation of the Serranos Towers was set up not only as a cognitive study in its own right but as an investigation to support the rest of the preliminary study and help take decisions. The study, therefore, concentrated particularly on identifying the monument's building stages. For this reason, the historical study was made in two parts: the documentary study (a study of the indirect documents) of written documents, engravings, drawings, photographs and historic plans, and the stratigraphic wall analysis as a reading of the traces left by time on the walls of the building (direct document).

The documentary study yielded a table of the many facts that told the history of the building and helped understand the numerous traces that could be seen on its walls. The historico-documentary study was carried out by following the division between the three major periods through which the building has passed. An expert historian in the subject was in charge of each part: Amadeo Serra Desfilis saw to the building period; José Luis Cervera Torrejón, the period it was used as a prison; and Carmen Blázquez Izquierdo, the restoration works between the late 19th and the early 20th century. Besides, an archive investigation was carried out with a view to finding, especially, documentation concerning the restoration works practised on the building. Daniel Benito Goerlich and Ignasi Corresa Martín drew up this "diary".

The historico-documentary study was complemented by a direct study of the masonry of the monument by means of the wall stratigraphic analysis. The main aim of this type of analysis consists of identifying the building periods by means of observing and documenting legible historical facts directly in the building. In this sense, it can be considered to be part of the historical study, where the materials to be studied are not written documents, engravings or photographs but a building. A complementary objective to the study of the building periods is the documentation of the materials and building techniques used. Finally, it is very important to emphasise the possibility this type of analysis provides to get to know the historical traces of the building and consequently to proceed to its conservation in a restoration project.

3. The glyptographic study. A fundamental part of the direct study of the masonry of the Serranos Towers was the glyptographic study. Glyptography is the science that studies glyptographic marks or signs that appear carved on the ashlars used to make buildings. The presence of marks is associated with the stonecutter's trade.

In Europe, and especially in France, professional builders' associations (franc maçons) began to function in the 13th century, and their objective was to protect the monopoly of building procedures and to make them known, as well as fraternity and charity. In the builders' guild there existed the trade of stonecutter, also mentioned in medieval documentation as stone carver, mason and quarryman. Their trade consisted of smoothing, carving and polishing blocks of stone to make ashlars. Once the ashlar had been polished, they put a sign or mark on it.

The greatest difficulty in studying glyptographic signs is knowing how to interpret them correctly. The most trustworthy conjectures forwarded by scholars of this subject is that there are two groups of marks with different functions: on the one hand, one set of marks could be the trademark of a stonecutter or workshop to identify the work for the purpose of retribution and, on the other hand, another set of marks would be to indicate how the ashlar should be placed in the wall, depending on the position of the mark.

All the surfaces of the Serranos Towers were carefully examined, both inside and out and in the vaults, using the scaffolding of the works to get a close-up view of each of the ashlars. In the walls of the towers some 3,000 marks were found (images 7 and 8). However, it must be pointed out that the interventions on the towers, particularly in the early 20th century, must have erased a large number of marks due to the use of the millstone hammer for the cleaning of the walls.

All the marks identified were entered on the plans with a number and the exact location where the mark was found. Seventy-five different types of mark were found altogether, and a specific card was used for each type with a photograph, a scale drawing and the number of pieces identified in each section.

4. The graphic documentation and the metrico-dimensional study of the monument was considered to be a crucial operation in getting to know the building and,

therefore, the most extensive and detailed metric and morphological information and the maximum reliability and precision had to be guaranteed. For this reason, photogrammetric charts of the interior and exterior of the building were drawn up (images from 9 to 12).
At the same time a hand-drawn map was made with two main aims: on the one hand, to provide complementary diagrams to the photogrammetric maps to represent the ground plans of the building and a study of the architectural ensemble; on the other hand, the preparation of an exhaustive inventory of the decorative pieces of cut stone in the monument (images 13 and 14).
The information in the inventory was set out on a set of cards, one for each decorative piece, with the identification of the piece and its location in the towers, a photograph and a diagram with several views.

5. The study of the materials and their degradation. A study of the materials of which the building is made and the degradation phenomena to be found in them is very important to get to know a monument like the Serranos Towers but, above all, to define the conservation interventions on it properly. In the case of the towers, to begin with a visual examination of the materials and their degradation was made so as to have an overview of the different cases in existence. Only then, when a series of different types of materials had been visually identified, were specific laboratory tests performed on them in cases where it was considered advisable or necessary.
All the facts observed in the materials and their degradation were entered on thematic maps, that is, specific plans of different themes, which altogether provide a complete picture of the monument's situation. The thematic plans were made by using photogrammetric mapping procedures to note down the points observed in situ. Besides, both the materials and the degradations visually identified could be verified by laboratory tests that permitted a greater level of precision in the maps. For each of the materials and the degradation phenomena identified, a descriptive card was made, on which the name of the material or the degradation phenomenon was noted, with a photograph and an indication of the corresponding laboratory test to make it easier to compare the image with the physico-chemical features. In this way, the intention was to establish a direct connection between the visual observation and the graphic legends on the thematic maps.
Apart from the visual observation, a series of laboratory tests were carried out, and they permitted an exact classification of both the materials and the degradation phenomena identified while the thematic maps were being drawn up (images 15 and 16).
a. The characterisation of the types of stone (lithotypes) was carried out by means of petrographic testing of thin chips. Once the samples had been suitably prepared, a petrographic description was made by a binocular polarisation microscope. This type of stone analysis yields: composition, classification, texture, porosity, superficial state, valuation of the sample. The characterisation of the stone type was completed by means of a series of physical type tests: determination of porosity, superficial porosity, apparent density, natural humidity, degree of saturation, real density (real specific weight), absorption, compression resistance. Besides, a series of chemical tests were carried out to determine the components: silica, sulphate, magnesium carbonate and calcium carbonate. Four major types appeared in the characterisation study, each with a series of subtypes possibly due to the fact that the stones came from different quarries. The four main types identified in the towers are: calcareous tufa or travertine, compact calcareous tufa, biogenic type carbonated rock and dendritic or sandy limestone.
b. A series of degradation phenomena was initially identified through visual observation of the walls. Most of the phenomena identified depend on the action of atmospheric agents (erosion, washing, patina), the presence of vegetation (biological attack, erosion due to vegetable action) or the nature of the stone itself (alveolar erosion) so that very little can be done apart from a simple protective action. Nevertheless, there are other types of phenomena like black crust, a result of pollution, and saline efflorescence, a result of the movements of water inside the stone that bring soluble salts with them. These degradations need a more detailed study, since the substances present in these deposits can act differently depending on the type of substance. As a result, due to requirements of the diagnosis process, it was necessary to know the components of the black crusts and the salts present in the efflorescence. Samples were taken and both an x-ray diffraction test and a series of chemical tests were performed (Carbonate, Nitrate, Nitrite, Iron Oxide, Sulphate, Oxalate, Phosphate).
c. For the characterisation of the mortars, samples of the visually identified types were taken and a granulometric test was performed on each of them. Furthermore, the following chemical essays were carried out on both the original sample and the thick and thin parts previously found: carbonate content, sulphate content, silica content.
In the Serranos Towers, five major groups of mortars have been identified, with a series of subgroups according to the different doses they contain: lime mortar, lime and cement mortar, lime, cement and gypsum mortar, cement and gypsum mortar and cement mortar. A study of the degradation of the mortars was carried out on each wall of the towers: four different phenomena were identified, from the loss of material to chipping, erosion and blisters.

6. The study of the climate. The climate must be taken into account as one of the causes that determine the intensity of the alteration due to physical, chemical and/or biological processes when studying the state of conservation of a monument that is exposed to the elements. These processes and their intensity are closely related to both the climate and the atmospheric quality of the area where the monument is located, in such a way that the climate acts as a regulator of these processes.
In fact, when the climate is studied apropos of the state of conservation of a monument, it is interesting to find out: the intensity of the alteration processes, their duration throughout the year, the existence of freeze-thaw cycles and the time of the year when they are at their most intense, the existence of salt solubility-crystallisation and the time of year when it are at its most intense (images 18 and 19), the dominant winds (image 17) and the dominant winds on rainy days. All these factors were studied to determine what surfaces suffer greater abrasion and on what surfaces sediments accumulate.

7. The biodeterioration study. Everyone knows the damage living beings can cause to the stones of buildings and monuments. The mechanism is based on the ecological necessity to colonise new surroundings. To achieve this, lichens have adapted in preparing the ground and are considered ecological pioneers. These are the starting points of a succession that will bring about the formation of vegetable soil on the rock to permit superior plants to colonise there.
The phytosociolgical method was used to determine the relative amounts of biotypes present in the Serranos Towers. This study yielded that: lichens colonise the battlements, cornices and water draining areas, places where there is enough humidity and its action is basically chemical with substances capable of chelating the existing cations both in the crystals in the rock and the amorphous cementing substance; bryophytes, represented by two mosses, with a slight presence on the monument (image 20), are located in hollows in the stone that accumulate sediment and detritus and in the joints that are in poor condition; superior plants, also in small quantities and located in joints in poor condition and installation areas where soil has accumulated; as regards animals, perches and nests of pigeons and doves have been observed on cornices and corners of the ornamented parts, and the uric and phosphoric acid in their excrement cause pulverisation of the surface layer and an accumulation of detritus where nitrophilic moss will grow.

8. The study of the doors. The doors and gate of the towers are made up of two large pieces that swing on hinges fitted into stone hinge poles. They are made of pinewood, with dovetailed planks and a frame. They are reinforced with metal fittings: lock pieces, bolts and nails, all made of iron.
A detailed study was made of the degree of deterioration of each door, and several causes were found. As everyone knows, wood is affected by changes in temperature, humidity and sunlight (ultraviolet rays). Continual exposition to these factors causes timber material to degenerate. Successive shrinking and expanding of wood fibres leads to the formation of cracks, grooves and discolouring, forms of deterioration that existed to a greater or lesser degree on these doors. The areas that remained damp for the longest time were affected by blue-staining fungus. This type of rot does not, in principle, affect the mechanical properties of timber, but it does stain and deface it.

9. The study of the metal fittings. The term metal fittings includes all the metallic elements currently to be found on the Serranos Towers: railings and protections; metallic objects on the doors; the door between the stairs going from the middle left-hand nave to the central terrace; the gate closing the Serranos Towers, made up of round bars decorated with roses and ogival arches on the lower part, repeated in the centre and with a double row of ogival arches at the top. The study of the metal pieces, made by means of an inventory and a pathology study, led to the conclusion that these elements were basically affected by two degradation phenomena caused by the environment: lack of paint layer and oxidation.

10. The polychromy study. During the study of the Serranos Towers remains of old polychromy were found on the stone in the area around the keystones in the inside naves (images 21 and 22). These remains are traces of the original finish consisting of layers of colour and gold that must have made the rooms look very different from what we can see today. Besides, they are the only traces left after the different interventions, the last of which were performed between 1890 and 1915.
In the case of the Serranos Towers, the polychromy that formed the border was covered over on two occasions with plaster and paint to renew the surfaces and these coats were later removed and the remains were scraped during the last intervention of 1890-1915. An exhaustive study was made to document these traces of polychromy. A global examination of the surface, cleaning tests and chemical analyses permitted their origin to be established and a reconstruction of their appearance to be made. These data and the historic documentation made it possible to make a chronological hypothesis.
The following were the analysis techniques applied to about 15 microsamples in all in order to study the superposition of the layers of paint, identify the pigments, agglutinants and substances used: optical microscopy; selective microchemical tests; selective coloration tests; infrared spectroscopy by Fourier transform; electronic scanning microscopy; gas chromatography / mass spectrometry. The results of the tests defined the original

procedure. The polychromy and the gold were applied over a primer of drying oil, a very appropriate technique for stone. The agglutinant in the pigment is also a drying oil, so we can speak of a greasy oil procedure. The golden areas are covered with gold leaf with a bole base. The pigments used are white lead, azurite, vermilion, minium, verdigris, soils and black charcoal (images 23 and 24).

11. GeoRadar test. The GeoRadar technique has been used and developed since the nineteen fifties for high resolution surface investigations of the subsoil or certain fields in geology, engineering, mining and glaciology. In a short span of time, GeoRadar has become a multidisciplinary prospective tool of great resolution for depths ranging from a few centimetres to dozens of metres (up to 50 metres), and is now used in very diverse areas: civil engineering, geology, archaeology, natural resources, hydrology, environmental studies, heritage, etc.

This technique was used in the Serranos Towers with three main objectives: to discover the location and layout of a possible dungeon in the right-hand hall on the ground floor, the determination of possible damp zones, the building structure of the foundations and the building structure of the walls.

The use of GeoRadar successfully achieved the objectives set out initially without causing any sort of damage and without needing to perforate the building elements of the Serranos Towers monument. On the one hand, it was discovered that there was no hole that might have been used as an underground dungeon and, on the other hand, that there was not a great deal of damp in the building (image 25). In fact a few limited areas of damp were located in the foundations, possibly due to leaking drains, while the walls were found to be free from damp.

In the structure study, both the foundations and the perimetral walls were identified. The foundations consist of the following layers: the pavement area, where a first area can be distinguished corresponding to the pavement, between 0 and 0.75 m deep, and a second consisting of a compacted horizon, from 0.75 to 1 m deep; next comes an area of stones, corresponding to an irregular construction level, between 1 and 1.75 m deep; an area of compacted earth or improved soil, situated between 1.75 and 6 m deep; and finally the natural ground, from 6 m down. In the wall study, it was possible to affirm that the wall is made up of two exterior stone surfaces, which can be identified as two compact zones and a central part with a different consistency, which corresponds to the nucleus of the wall.

12. The construction study. To complete the information obtained about the characteristics of the subsoil by applying the GeoRadar technique on the two lower naves of the Serranos Towers, it was decided to make a geotechnical examination of the subsoil, with the extraction of a continuous sample (image 26) at the centre of the lower nave on the right hand side.

The comparative study of the results obtained, on the one hand, by the GeoRadar technique and, on the other, by mechanical sounding permits us to describe the construction system used by Pere Balaguer to build the Serranos Towers.

The construction works started by flattening the natural ground, whose depth we can situate definitely about 8 metres under the present pavement of the lower nave on the right, which we shall consider from now on as zero point. Then the ground was improved with a few inches of compacted earth stabilised with lime, on top of which layers of pebble gravel were laid, improved with lime and fines to a height of 6.2 metres underneath the current pavement.

From this point, the foundations of the two towers were changed and the first three rows, with a height of about 80 cm, were built with straight ashlars and the inside space was filled with alternating layers of earth and gravel mostly consisting of pebbles. From here, about 5.35 m to about 1.35 m below pavement level, the slope was begun with large ashlars 30 m high on average, whose outer surface was carved with an inclination of about 53º, and the interior space was again filled with alternative layers of soil and gravel, with layers of lime conglomerate and pebble gravel mixed in. From 1.20 m, a special preparation with a new lime concrete plinth and large pebbles can be observed, on which there now lies a pavement of 10 cm stone slabs.

The use of prospecting technique using GeoRadar in the study of the composition of the walls also allows us to state that the walls of the Serranos Towers, of variable thickness, were made with two external surfaces of limestone ashlars in the shape of parallelepipeds between 22 and 25 cm wide, the remaining parameters being variable, albeit with very slight differences, placed on lime mortar and timber wedges in many cases, with a minor filling at the vertical joints, with a filling of lime concrete containing a great deal of gravel, mostly consisting of pebbles, between the two surfaces.

13. Cleaning tests. The link between the diagnosis study and the project includes an important item that consists of performing a cleaning test. In fact, after studying the building with all its geometric, decorative, historical, etc. features and analysing its materials and the degradation phenomena present, the first intervention criteria were established.

In this particular case, Valencia Council had commissioned the Cleaning, Conservation and Protection of the Serranos Towers. Thus, from the outset, the team drawing up the preliminary survey was determined to intervene on the towers as little as possible, that is to say, to act only where necessary and as gently as possible in order to guarantee the protection of the building and respect its materials, patinas and historical traces. In this sense, several cleaning tests were performed as the last chapter in the diagnosis and a basis for the elaboration of the project.

It must be taken into account that each stone and each type of stone reacts differently to a certain type of treatment according to its degradation. Depending on the type of stone (more or less compact, more or less resistant, etc.) and the type of degradation (alteration or degradation, level of incidence and persistence, etc.), a series of tests were performed with different cleaning methods.

On the walls that were only dirty, methods with low pressure spouts of water (at different temperatures and with different pressure) and sprays of water were tried (image 27); on the walls that had a greater amount of dirt or black crust, methods using the projection of dry and damp soft aggregates (powdered glass, glass microspheres, nutshells, etc.) and the damp projection of a homogeneous mixture of water and aggregate were tested (images 28 and 29); on the decorative pieces, different applications of chemical compresses were tried out.

For each of the tests a specific card was filled in with the description of the technique used, the objectives, a photograph of the surface before and after application and a macrophotograph that would make it possible to control possible damage caused by the cleaning and conclusions. The decisions taken for the project were based on the results of these tests and the criteria established beforehand.

PROJECT & WORKS

Project

The very title of the project: "Maintenance, Conservation and Cleaning of the Serranos Towers", limits the scope of action to works related to the cleaning and conservation of the interior and exterior wall surfaces, vaults and pavements, along with the timber and metal elements that form the monument of the Serranos Towers.

The justification of the solutions adopted in the project (image 30) is determined by the intervention criteria established as a consequence of the studies carried out during the diagnosis phase and the tests performed in situ on several walls before the project was drawn up. In the preliminary study, all the lithotypes that make up the huge stonework of the masonry in the Serranos Towers were identified as was the type of deterioration they had suffered from the passage of time, contaminating agents, climatic variations, biological attacks, etc.

The main objectives of the cleaning were: a gradual and progressive, non-aggressive cleaning process, measured according to the requirements of each case, the conservation of the reddish colour of the stone, maximum respect for the patina of time in such a way that it would be compatible with the monument's conservation requirements.

Due to the great variety of stone types and kinds of deterioration, the project included the use of different cleaning processes adapted to each particular case. In this way, cleaning methods with water preheated at 60º and low pressure were considered (for cases where the level of dirt was still under control and the stone was free from black crust), methods with a damp jet at low pressure (for fairly thick layers of black crust), methods with a dry jet (in areas where water could affect the future conservation of the stone or where salts or biodeterioration were present), hand cleaning methods with soft bristle brushes (where there were vegetable microorganisms) and chemical cleaning methods (in the case of cut stone or areas where the stone was covered with black crust).

After the cleaning works the need to apply waterproofing to the whole monument by applying a concentration of oligomeric alkylcoxyloxans was considered. The preliminary study and close visual inspection from the scaffolding made it possible to affirm that it was only necessary to apply a consolidating agent before cleaning in the few areas where there were ashlars made out of sandy limestone with a high degree of erosion. Similarly, the same treatment was adopted for the sculpted pieces located under the modillions supporting the vaults of the parapet walk and the base of the ribs.

As we mentioned above, the tests performed showed that five types of mortar had been used: lime, lime and cement, cement and gypsum, lime, cement and gypsum and cement. Furthermore, the state of degradation of the mortars was examined and areas with no mortar or loosened joints were detected.

It was considered necessary to remove the joints with adhesion problems and the joints that were made with cement mortars and those that contained gypsum, because of the possible formation of salts that might affect the conservation of the stone.

For all the timber and iron elements, it was decided to follow only a cleaning and conservation process, without making any additions or replacements. In the same line of intervention, it was determined to carry out a prior cleaning by aspiration and consolidation of the existing pigments on the polychromy of the vaults and to apply a specially prepared waterproof layer afterwards on the vaults with synthetic stripper and a plastic coat to protect the paint during the cleaning process. Once the vaults had been cleaned, this protection was removed and the parts stuck to the stone surface were eliminated.

The works

a. Cleaning with dry microjet

This type of cleaning is used on all the surfaces looking onto the river from the parapet walk upwards. The use of a

dry system instead of the usual damp system was adopted because of the abundant presence of clayey elements that could have reacted to damp (image 31). The cleaning with dry microjet was performed with 0.2 to 0.3 mm glass microspheres at a pressure of between 0.5 and 1 bar.
At the same time, the ashlars where lichens had been detected were dry cleaned by hand with soft bristle brushes and then cleaned with the dry microjet system avoiding the use of water that might resuscitate the vegetable microorganisms.

b. Cleaning with the projection of damp aggregate

The damp aggregate projection system used admits three variations: the type of abrasive (silica, powdered glass, glass microspheres, etc.), pressure (in no case over 2 kg/cm2) and the possibility of varying the volume of water or abrasive depending on the type of stone to be cleaned and its state of conservation. Therefore it is a system that adapts perfectly to different situations and allows a graduated cleaning process according to the needs in each case.
This method was used in all the areas that had black crust or a degree of dirt that could not be cleaned satisfactorily with a jet of water (image 32).
To avoid the problem of salt migration and settlement on the surface, demineralised water was used for cleaning surfaces with saline efflorescence. The other surfaces were cleaned by damp or rinsing systems with water taken from the mains that had previously been decalcified. The reason a decalcifier was installed for the cleaning utensils was because of the large amount of lime in the water in Valencia that could have remained on the surface after the rinsing necessary after the cleaning process had been completed.
Parts of the protection canvas were removed during cleaning to see the results obtained.

c. Work on the joints

As a general norm, all the joints with problems of fixation to the masonry were eliminated and the joints made of cement mortar were also removed and those containing gypsum, particularly the mortars made of cement, lime and gypsum, were very carefully eliminated by mechanical means and the lips were chiselled by hand. This was necessary because of the degradation phenomena to be found in the joints depending on the composition (reaction of tricalcium aluminate in the mortar containing cement, hydration of the anhydride in the mortar containing gypsum...). Scraping was performed in some cases after cleaning, since the crust made it impossible to detect the layout of the joints.
After making some tests with manual and mechanical methods, the surface was scratched by means of a mechanical system. This mechanical system consists of a little compressing hammer with a point attached and lateral pieces to prevent it from penetrating too deeply. Besides, the work pressure was reduced to a maximum of 2.5 kg/cm2. This tool made it possible to control and measure the scraping procedure much more precisely than scraping by hand (image 33).
During the preliminary survey, the original lime mortar was identified and appropriate composition tests were carried out to replace it at the joints from which it had been removed. However, a commercial make of lime mortar with a similar composition to the original was found and used for replacing the joints. It is a lime mortar that comes in sacks with a 1:4 proportion and a 1/1 relationship of silica sand and lime sand.
As regards the type of jointing used, after eliminating the protruding joints, which were known to date from the 1888-1917 period, and since this type of joint facilitates the accumulation of dust and contamination (causing serious deterioration), “concave flattened jointing” was used so as to prevent retention of water and consequently biodeterioration, the settling of dust and the formation of black crust.

d. Consolidation

In the preliminary study, all the lithotypes contained in the enormous stone mass of the Serranos Towers’ walls and the types of deterioration they had suffered over the years, the contaminating agents, climatic variations, biodeterioration, etc., were identified.
According to the criteria defined in the project based on this study, a consolidator was applied in areas where ashlars or cut stones of calcarenite type, whose composition (over 30% silica) and the degradation phenomena, had suffered a serious loss of their cementing content. Thus both interior and exterior modillions, high reliefs and all the ornamented parts were consolidated (image 34), taking it into account that preconsolidation had to be carried out on all these elements before beginning the chemical and mechanical cleaning process because of their softness. In the preconsolidation and the consolidation processes, a compound of ethylic esters of silicic acid and oligomeric polyxyloxans was used, dissolved in mineral turpentine to optimise absorption right through to the healthy nucleus of the stone. The ethylic esters react and turn into silica gel and ethylic alcohol.
Where necessary, consolidation was performed on ashlars. This was done on ashlars situated on the battlements of the central part of the north facade. The product was applied to a totally dry surface and was not waterproofed until several weeks later, since it takes that amount of time to complete its reaction. The traces of painting from the last day of the Spanish Civil War on the surface of the central body in the south facade that looks on to the Plaza de los Fueros were also consolidated.

e. Waterproofing

A waterproofing treatment was applied to the whole stone surface, but in no case was it applied until the surface was completely dry (it must be noted that the cleaning method adopted was damp, especially in the inner naves, which greatly affected the timing of the works). The order of application was logically determined by the assembly and disassembly of the scaffolding, in other words, from east to west, first on the north facade and then on the south. The naves also followed the order of the assembly of the scaffolding. The ornamented parts were not waterproofed because the consolidating agent applied by the restorers contains a water repellent component. The same applies to the decorative elements and sculpted pieces like the exterior and interior modillions, high reliefs, etc.
As a general method, two coats of the product were applied with a roller, because even though this system involved wasting a great deal of the product, it guaranteed that the waterproofing agent would penetrate the surface better.

f. Perimetral band

Two types of work were performed on the perimetral band: on the one hand the upper strip and, on the other, the ornamental elements (sculpted stone) on it.
To guarantee the watertightness of the element and to prevent rainwater from staying on the perimetral band, after cleaning a sloping surface was applied to it with hydraulic cement mortar modified with polymers especially conceived for the restoration and/or imitation of natural stone. This product ensured excellent hardness and cohesion, perfect adherence to the support and, above all, guaranteed that the element would be perfectly impermeable. On the other hand, the restorers began to clean the sculpted pieces on the band with chemical and mechanical systems (images 35 and 36). To finish, the whole surface was waterproofed.

g. Timberwork

The only timberwork on the Serranos Towers is the different doors, laid out as follows: four on the ground floor (the main entrance underneath the arch, the two leading into the downstairs rooms and one into the toilets built in the nineteen eighties); two on the first floor (the entrance door designed by Master Aixà and the door into the left-hand room on the first floor, which was made in 1985 under the supervision of municipal architect Emilio Rieta); one on the second floor (leading into the high room on the right, whose construction date is not known, although the graffiti made before the Civil War in 1936 makes it possible to date it earlier).
All the wooden elements were cleaned, eliminating the dust and environmental dirt, and all holes, cracks and slits were sealed with water putty, a bactericide and fungicide was applied (Bondex base) and maintenance was completed with matt Bondex finish.

h. Metal elements

All the metal elements on the Serranos Towers date at least from the works made by Master Aixà and the principal municipal architects between 1893 and 1917. Two types of works were performed: on the one hand, on the railings of the monument and the metal fittings on the timberwork and, on the other, on the surrounding railings.
In general the metal was treated with a metal varnish after cleaning with a metal brush, applying a single coat until the surface was saturated to avoid the shine that would appear by applying a second coat over the existing protective film. This criterion was also applied to the metal pieces on the timberwork (nails, iron fittings, locks, bolts, etc.) and metal fittings.

i. Pavements

Only the pavements of the upper terraces were treated, and the works were limited to cleaning. The pavement on the terraces and the parapet walk was made of lime mortar, about 10 cm of it was scraped down and a new pavement made of mortar made with a hydraulic bonding agent was spread over it due to its properties of permeability to steam. A grouting of lime was applied as a finish and to conceal the joints that had appeared on the pavement made on several different days.
Since the tests performed on the existing pavement on the central terrace during the preliminary study showed that it was made of slabs 10 cm thick jointed with mortar, which, if removed, would make it practically impossible to recover the slabs, it was merely cleaned with a damp microjet and the gaps were later filled in with lime mortar. The same system was used to clean the pavement of the rooms (made of Alcublas stone).

j.Protection from pigeons

Instead of other systems that involve greater expense, maintenance and a larger amount of items (batteries in the case of an electric system), it was decided to apply a system of polycarbonate strips and stainless steel spikes. This method was adopted because it was not very expensive, it was easy to install, required no maintenance and was less visible than other methods. Therefore an anti-bird system made up of strips of extra polycarbonate (resistant to ultraviolet rays) with 302 stainless steel spikes 1.3 mm in diameter and 11 cm high with a wavelength of 25 cm was applied along all the moulding around the monument about half-way up.

l. Works on the moat

Work on the moat was included among the complementary tasks to the cleaning, maintenance and conservation project. After removing the rubble, it was cleaned by hand, and weeds, stones and other waste materials were eliminated. After levelling it slightly and thanks to the fact that the type of soil did not require to be compacted, a waterproof sheet (image 37) was placed on it and a layer of 2/3 cm of inert gravel the same

reddish colour as the ashlars was placed on top of it (image 38).

Maintenance Scheme

In order to preserve what is to be maintained properly, it is necessary to be familiar with the causes of the damage and the characteristics of the material to be used as protection so as to act as efficaciously as possible.

In the case of stone, the action of weathering over the years brings about deterioration phenomena like erosion, breakage or microvegetation. In the last century, contaminating agents have joined atmospheric agents in contributing to a faster degradation of stone materials because of the formation of black crust.

Since olden times, whitewash or a fine lime mortar finish has been applied with a brush to protect the stone from direct contact with atmospheric agents apart from reinforcing, consolidating and adorning it with the addition of pigments and, above all, sheltering it from water and its effects.

These protection treatments no doubt used in the late 14th century when the Serranos Towers were built required periodical maintenance works that were most definitely abandoned after the first hundred years. At present, the traces of these protective coats have almost completely disappeared, so it would not be wise to apply them today because they would bring about a very great change in the consolidated image of the monument.

Therefore, in order to avoid the damage caused by contamination and damp, waterproof chemical products are used nowadays because they prevent water from entering into the pores of the stone and causing its rapid degradation without altering the appearance of the monument. However, these products last for a limited length of time, like the systems used long ago, and require periodical maintenance works to guarantee their efficacy. Guaranteeing the efficacy of the protection treatment prevents degradation phenomena from occurring again and avoids the need for further important restoration works. The programme of periodical inspection of the monument by specialised technicians is an essential aspect in the maintenance of historic buildings. These controls at regular intervals whose frequency is determined by the nature of the monument must be documented and the results filed. Furthermore, a coordinated programme drawn up prior to the necessary maintenance works makes it possible to avoid more important interventions and carry out timely and successful repair works at a lower cost.

During the works performed on the Serranos Towers, absorption tests were made (Kaarstens test tube) on different areas of the walls (image 39) before and after waterproofing to check the success of the treatment. Thanks to these tests at well documented and easy to reach places, the same method can be used to check the possible loss of efficacy of the waterproof layer and the need to replace it.

Apart from this possibility of verifying the needs according to the variations of the absorption test time, a maintenance plan has been drawn up on the basis of the theoretical properties of the treatment and the influence of weathering on the monument. A periodical renovation programme of the waterproof treatment has been elaborated (every year, every five or every ten years), depending on the physical features of the monument and the influence of weathering in each of its specific areas (image 40). The periodicity can be modified, however, according to the comparative tests made with the Kaarstens test tube method programmed to verify the water repellent qualities of the waterproofed surface.

Camilla Mileto

MATERIAL HISTORY OF THE SERRANOS TOWERS

At the same time as the documentary historical study was carried out, a direct study of the masonry was made by means of the Stratigraphic Analysis method. This method is based on the observation and documentation of any type of sign found in the walls of a building connected with the stages of its construction. A stratigraphic reading of the walls has made it possible to find the material traces of the interventions mentioned in the documentary studies performed and enabled each one of them to be identified directly on the monument.

The Serranos Towers are made of ashlar masonry, walls of two rows of ashlars fixed with mortar and with a filling between that may have been made of a lime concrete. Ashlar masonry, by its very nature, consists of a large number of ashlars without any direct physical relationship between them. In this case, the relationship between two ashlars is established by means of the mortar that joins them, so if the mortar is contemporaneous to the ashlars, they can be considered a single stratigraphic unit. On the contrary, in the event that the mortar is posterior to the two ashlars, they cannot be deemed contemporaneous and must be treated as two different stratigraphic units. In the latter case, however, it is important to try to establish a relationship between the two ashlars, which is only possible by trying to compare their physical characteristics by means of a typological process.

In the specific case of the Serranos Towers, the intention was to characterise the ashlars by observing the type of stone, the presence of layers of plaster and the level of degradation and surface carving, as well as by recording the presence of stonecutters' marks. All these data are compared with the material characteristic analysis performed during the Preliminary Survey. All the data gathered, with their variables, are compared, generating several types of ashlars, so it can be established from the outset whether the ashlars are contemporaneous or not. The relationships of older/newer are established afterwards: on the one hand, through the observation of conventional stratigraphic relationships (covers/is covered by, cuts/is cut by, rests/is rested on, fills/is filled by); on the other hand, through chronotypological relationships. Several types are established for the mortars also, deduced likewise from the tests carried out during the Preliminary Survey, which are related to each other according to stratigraphic relationships of contemporaneous, earlier or later.

The information collected, both stratigraphic and typological, is recorded in some plans of stratigraphic reading (photo 1) and on a series of descriptive cards for each unit. At the end of the information gathering phase, a hypothesis was forwarded regarding the monument's building periods, a relative chronology, where each part of the building was identified only as earlier, later or contemporaneous with the other parts. Not until a later stage was this relative chronology compared to the historic records of the documentary study so as to associate a dating hypothesis with each part of the building.

HYPOTHESIS OF THE SERRANOS TOWERS BUILDING PERIODS

By means of a direct study of the masonry of the Serranos Towers it was possible to locate a series of interventions corresponding to the four periods identified by the historico-documentary survey: a first period that corresponds to the construction of the Towers (1392-1398) and all the period until it was made into a prison in 1586; a second period corresponding to the time the building was used as a prison (from 1586 to 1887); a third period corresponding to the different restoration works carried out between the late 19th century and the early 20th (1888-1930); and a fourth period covering the works carried out in the second half of the 20th century.

On the north facade most of the masonry corresponds to the construction period (1392-98), although a series of interventions were carried out later (photograph 7). On many of the ashlars in the north facade and the lateral facades stonecutters' marks can still be detected, which somehow certify their originality (photograph 2). Most of the masonry, especially the areas most exposed to the east, has taken on a peculiar reddish tinge over the years due to the natural oxidation of the stone from the sea breeze (photograph 3). In fact both the reddish ashlars and the whiter ones at the top, all made of calcareous tufa, belong to the original masonry of the building.

A series of interventions were made at the end of the 19th century with a view to restoring the building to its original splendour. All the windows that had been opened up in the masonry when the building was used as a prison were closed and replaced by the old loopholes (photograph 4). Of the two doors in the two side walls, the one in the east side was completely rebuilt (photograph 5) and the one in the west was restored. The modillions and the vaults supporting the parapet walk were conserved, but the decorative elements on which the modillions rest were restored by mortising and refashioning the pieces (photograph 6).

In the same way the south facade can be considered to belong to the Gothic period of the towers' construction (photograph 10). However, many more works were performed here than on the north facade, both during the reconstruction works between the late 19th and early 20th century and more recently, in the nineteen eighties. One of the most important interventions carried out on the south facade is undoubtedly the reconstruction of the large staircase leading from the ground floor to the west side of the first floor. After a great deal of polemic about its authenticity, the staircase, partly destroyed during the prison period, was rebuilt between 1915 and 1917, and the existing parts were reused.

Another very important intervention on the facade was performed on the gargoyles at the same period. Under the direction of the architect Emilio Rieta, the four gargoyles on the south facade were rebuilt and replaced (photograph 8), reproducing the figures already reproduced by the sculptor Aixà at the beginning of the 20th century.

During the cleaning and consolidating process carried out in 2001, three different layers of mortar were identified corresponding to the three construction stages of the facade walls (photograph 9): a very compact whitish lime mortar corresponding to the Gothic period of the towers; a sand-coloured lime and cement mortar from the rebuilding works at the start of the 20th century; and a cement mortar corresponding to the mortising work in the eighties.

An outstanding feature of the image of the Serranos Towers is the magnificent tracery on the facade facing the river on a blind arcade crowning the main door of the central building. The surface with the decorative tracery has a series of characteristics that differentiate it from the rest of the towers' masonry, and a detailed study was performed on each part of it.

On direct study, three different types of stone and five types of surface treatment or stone carving were detected, apart from the documentation of the presence of stonecutters' marks. The combination of these two parameters yielded nine different types of ashlars. Once the different types present in the tracery had been identified, the next step was to relate each of them with a

precise building or intervention stage. Apart from observing the stratigraphic relationships found in the mortar joints between one stone and the next, the study was based on the comparison of the historic pictures and the current condition.
The combination of observing the material features and comparing the building with the historic photographs made it possible to identify precisely the original parts still conserved and the parts that had been replaced during the restoration works. These findings were summed up in a plan where different colours are used for the different periods according to the code used for the other surfaces of the monument (photograph 12).
There is no doubt that most of the blind arches and the upper tracery were replaced during the 19th century restoration works. Only two pieces of the original Gothic tracery remain at the two ends of the top part, made of calcareous tufa covered by a layer of red (photograph 11), which suggests that all the tracery was once covered by a red layer, which can almost certainly be said to be the original Gothic colour. Dendritic (or sandy) limestone pieces possibly carved by tracing the original ones substituted the rest of the tracery in the late 19th century. Two pinnacles decorated with a series of stylised vegetable motifs stand at each end of the tracery surface. These two elements underwent a series of important substitution interventions with a precise jointing technique that exactly reproduced the pieces and the insertion of the graft (photograph 13).
It was more difficult to identify the substitution of the blind arches in the lower part of the wall because the ashlars bear many types of stone and surface carving. After carefully studying and observing each ashlar and identifying the types, it was possible to forward a hypothesis of the interventions.
The cleaning of the tracery during the last intervention made it possible to appreciate the difference between the original and the replaced parts of the central panel of the portal and particularly the original decorative elements because of their strong red colour as opposed to the whitish shade of the replaced items.
Important changes were practised on the interior naves, which are seven in all, in 1586, when the towers were turned into a prison. During the three centuries the towers were used as a prison, many changes were made, especially on the inside. When the prisoners were moved from the Serranos Towers to the new San Agustín prison in 1888, great restoration works were started to return the building to its former splendour. At that time not only were the facades of the towers restored but the interior spaces were freed, cleaned and rebuilt.
The cleaning of the inside was performed by an indiscriminate use of the hammer that completely transformed the surface of the original walls, eliminating the carving and the stonecutters' marks in many cases. Besides the ashlars replaced inside are cut by millstone hammer and stonecutter's hammer, so that it is much more difficult to identify them from their interior surface with respect to the exterior. For that reason, on the inside it was necessary to observe particularly the type of mortar used at the joints, since the late 19th century interventions and those of the nineteen eighties can be distinguished by the use of mortars made of lime and cement, cement and gypsum or cement only, instead of the original lime mortars.

Some last reflections

The study of the masonry carried out by the stratigraphic method made it possible to discover a series of data concerning the history of the building of the towers and the modifications it underwent over the years.
It is worth emphasising that the stratigraphic study was complemented and enriched by all the other sections of the preliminary study carried out at the same time. In the first place, the historico-documentary study yielded a great deal of information that, in many cases, was confirmed by the direct study of the masonry, besides making it possible to date the building stages found in the stratigraphic study. In the second place, the study of the materials and their deterioration provided a large amount of information that made it possible to relate the materiality with the chronology of the interventions.
On the other hand, it must be pointed out that during the course of the works, apart from the chance to examine the surfaces closely, the steps taken in the intervention and the work requirements permitted the discovery of details and points of special interest that could be documented and taken into consideration. The cleaning operations have also permitted a closer examination of certain details that would otherwise have gone unnoticed beneath the dirt.
Finally, we would like to add that the stratigraphic study was never intended to be conclusive or final, but has merely been another contribution to the material survey of the monument, and will be complemented, contradicted or confirmed in the future by further research.

Jesús Pita de Aguinaga

RESTORATION OF THE SCULPTURAL ELEMENTS OF THE SERRANOS TOWERS. VALENCIA

The Serranos Towers, originally known as the "Serranos Gate", used to be the defence of the main entrance into the old walled city of Valencia. The appearance and architectonic presence of the building today is very similar to when it was first built in the 14th century. However, we can see certain changes caused by the different uses to which it has been put as a public building and the different fashions that affected several details of its external and internal configuration.
The greatest alterations on the Serranos Towers were practised when it was used as a prison after 1586 and as a result of the restoration works started in the 19th century, between 1890 and 1901.
A series of changes directly affecting the sculptural elements associated with their architectonic configuration were made when the fortress was turned into a prison. Windows were opened to provide better ventilation, the central wall over the entrance gate, amongst others, was broken, which affected the tracery and presumably eliminated the original royal bell located over the entrance arch, which appears in the texts of the contract. The fascia that ran around the towers was also broken. The horizontal division of some of the interior rooms and the closing of bays facing into the city destroyed or seriously damaged the sculptural corbels.
Most of the sculptural elements that can be seen today were made during the great refurbishment works carried out when the building stopped being used as a prison, and date from the period going from 1893 to 1901, under the architects Antonio Martorell and José Calvo and the art director José Aixa.
During these works, the interior corbels were restored in the first place, followed by the supports of the barbican and finally the tracery and sculptural high reliefs on the principal facade. The works consisted of replacing the pieces that were in poor condition with others inspired on the originals or on good ornamental models of the time. The documentation available does not specify who made them, or the workshops that participated in the restoration of the different sculptural elements, but there are great differences among the different pieces. A detailed approximate chronology of the different processes carried out on each of the elements will be defined below.
The last restoration works on record were directed by the municipal architect Emilio Rieta (1981-88) and as regards the sculptural elements, the major works were the replacement of the gargoyles, the keystones of the central nave and an arch on the parapet.
The current intervention, performed in 2001, the subject matter of and reason for this article, basically consisted of a conservation process. To perform this, cleaning, consolidation and protection procedures were used. During the cleaning phase, the layers of pollution and dirt that were altering the stone material were gradually removed, always prioritising both the original finishes and those applied in the later interventions mentioned above, provided that they did not affect the conservation of the stone material.
Each of the sculptural elements was given specific treatment. Not all these sculptural elements are coetaneous, as we shall explain below. They can be classified under the following headings (image 1):
- Supports of the barbican: these are the sculpted elements of the corbels of the barbican.
- Tracery: central panel over the entrance arch with decorative forms typical of Gothic art.
- Fascia: the moulding that runs around the whole building about one third of the way up.
- Sculptural high reliefs: the three sculptural plaques situated on the main facade.
- Commemorative plaques: two marble bas-reliefs situated on the main facade.
- Interior corbels: decorative elements that crown the springing point of the ribs of the fan vaulting in the rooms.
During the refurbishment process, some elements and segments of stone material and the original finish that had survived the passage of time and the different interventions were identified. This permitted us to study the original finish.

STUDY OF THE FINISHES

While cleaning was taking place, the dirt accumulated on the stone was removed little by little and coloured areas were discovered. These were not continual, but only remains, and were usually located in sheltered areas.
According as the cleaning works of the different elements advanced, samples were taken and classified in order to analyse and interpret data afterwards. The results of this study allowed us to define two types of finish on the stone, described below:
Original Finish (photographs 2 and 3)
This finish is on the original stone material and consists of gypsum and natural soils rich in iron oxide, which gives it a reddish hue, going from red ochre to orange depending on the degree of alteration. Given the hardness and insolubility of the material, it can be deduced that it was a plaster made up mainly of anhydrite or anhydrous calcium sulphate obtained by firing at high temperatures. This last detail could not be verified analytically because of the scarcity of the original material conserved.
The thickness of the plaster varies and an intermediate layer of lime and sand has been found in places between the stone and the finish, used in the joints and to cover the irregularities of the Travertino stone.
The remains found are scarce and scattered in different areas. Specifically, samples can be obtained in the: tracery, supports of the barbican, fascia and exterior surfaces. The layout of the remains and the uniformity of the procedure, demonstrated analytically, allow us to conclude that the outside of the towers was completely covered. On the other hand, the absence of this finish on the substituted

stone and its presence only on the original, without any intermediate layer or sediment, would confirm the fact that it is the original finish. Its mission would be to protect and enhance the stone material.
Precisely in different restoration works performed in the last few decades, it has been possible to verify the existence of old plaster finishes of different types, as in the remains found in Palencia cathedral, the western portico of Oviedo cathedral, the Pórtico de la Gloria and the Puerta Santa of Santiago cathedral, the Portada del Perdón of Seville cathedral, the cloister of the monastery of Santo Domingo de Silos and many others.
Restoration Finish (1893-1901) (photographs 4 and 5)
It is composed of gypsum, soils with very little iron oxide and oxalates. In this case, the traces of organic material (oxalates) probably stem from some mucilage added to the mixture to improve its characteristics. The initial organic substance could not be determined, although to judge from the particles found, the original compound might be a polysaccharide like those in gum arabic. This natural gum is recorded as an agglutinant of fillers or putty in restoration manuals of the period.
The finish is dark coloured and it was applied so as to match the replaced elements with the rest of the surface, and it was even applied on original stone whose initial finish was very damaged or missing.

DESCRIPTION OF THE SCULPTURAL ELEMENTS

1. Support Points of the Barbican (photographs 6 and 7)
The barbican running around the towers and the central volume of the gate is supported by inverted pyramids and tiered corbels crowned with a sculpted element.
These elements are laid out as follows: the four large supports in the shape of an inverted pyramid are located at the outsides of the towers flanking the central building. Their vertex is ornamented with figures and the trunks bear a mixture of plain mouldings and vegetable patterns. There are ten of the tiered corbels on each tower and two on the central wall, twenty-two altogether. Their last ashlar is adorned with a sculpted vegetable motif.
In the current restoration works it was discovered that only three of the tiered corbels were originals, a human figure on one of the large pyramidal supports and segments of the frets and mouldings on them. These pieces or segments are made out of calcareous tufa and conserve traces of the original finish (photograph 8).
Most of the remains of ornamentation date from the restoration works performed approximately between 1895 and 1900, when the original stone was mortised and the different decorative motifs were replaced with calcarenite stone.
Differences have also been observed among the replaced elements, both in the degree of compacting of the calcarenite stone and in the finish. The sculptural elements on the western tower are made of a very compact stone with more careful and varied carving; the central parts are not very well compacted and have no texture. This would suggest stone from a different quarry or workshop, because according to the historic documentation, the eastern tower was restored first. Traces of plaster applied to enhance the surface have been detected on the replaced stone material.
On the other hand, regarding the iconographic programme, it is surprising to note the coincides regarding the total number of support points of the barbican, their layout and the number of characters represented on them.
Regarding the total number of supports, 26, it coincides with the number of God in Hebrew IHVN. Regarding the number of characters, there are three on every large support (3 x 4), which means 12 figures altogether, a number that is given great importance in the Bible and Christian religion: there are twelve tribes of Israel, twelve apostles and twelve doors in celestial Jerusalem.
Regarding the layout, the large supports are placed like sentries, two looking at the old walls, no longer in existence today, and the other two facing the gate into the city.

2. Tracery
The face of the entrance gate is ornamented with a blind arch with tracery at the top and flanked by pinnacles. Inspired on the original Gothic decoration, the ensemble is a replacement from the period between 1893-1901 approximately (photograph 9). During the restoration works some original elements were identified, and are represented on the plan of original elements. Some bear remains of the original finish. (photograph 10). The replacement is made up of a systematic placing of plaques configuring the different decorative motifs. Some very altered traces of finish were found on the surface and in reserve wash areas.

3. Fascia (photograph 11)
Approximately one third of the way up the monument there is a decorated moulding running around the whole building. This moulding is made out of calcareous tufa and the concave part of it is decorated with vague vegetable motifs. Its decorative form is the same as the moulding at the start of the last volume of El Miguelete tower in Valencia cathedral, also designed by Pere Balaguer. It is mostly original and, although some areas and elements have been replaced, it is not easy to identify them with the naked eye because of the degree of erosion and the use of calcareous tufa in the replacement.

4. Sculptural High Reliefs
On the central wall over the entrance arch, three sculpted elements can be seen: in the centre, the emblem of the royal family and at each side the coat of arms of the city held by angels. These pieces were made and put in place between 1895 and 1901, during the intervention directed by José Aixa, and the latter date appears beside the royal seal. The stone used to make them is calcarenite.
These pieces cannot be said to be an exact replica of the original ones. However, on analysing the texts included in the "historic study of the diagnosis document" we found the contract for Marzal de Sas (1394) to paint the royal seal over the gate between the stone angels.
By examining engravings and photographs of different periods, pictures of the royal seal could not be found at any time, because when the towers were turned into a prison in 1586, a bay was opened in this place to put in a window.
As regards the city's crests, the angels holding them only appear in an engraving dating from 1671, since in a photograph taken in 1835 only a shield can be seen on either side and in another taken in 1870, only a volume can be seen. In the refurbishment works directed by José Aixa, the model for the design of the crest was probably taken from the engraving illustrating Juan Dorca's article titled "The Serranos Towers" (1671, the Archive of Valencian Art). The author of this text was a member of the restoring committee. The design of the royal seal was probably based on the heraldic seal of the royal gate of Poblet and the crest of Pedro the Ceremonious conserved in the Valencia Fine Arts Museum, and which used to decorate the no longer standing Xerea Gate.

5. Commemorative Plaques
On the main facade and on both sides of the entrance arch there are two marble plaques. On the right hand side, there is a commemorative plaque dedicated to Luis Boliche Compañ erected in 1931. It is a bas relief with a figure and an inscription. It is separate from the wall, anchored to it and figuratively supported by two small corbels.
On the left hand side, there is a marble plaque with the legend: "CIUDAD DE VALENCIA CAPITAL DE PROVINCIA PUERTA DE SERRANOS" (Valencia City Provincial Capital Serranos Gate). There is no documentation about the placing of this plaque, but it could be from a date similar to the one described above to judge from its degree of deterioration. It may have been used to replace another one bearing similar information. It is built into the wall.

6. Interior Corbels (photographs 14 and 15)
These are in the naves inside the towers and crown the ribs. They depict vegetable motifs, animals and a single one has a human form. The vegetable decorations are: acanthus leaves, oak leaves with acorns, vine leaves and ivy. The following are some of the animal motifs: a lion, an eagle, a bat and others difficult to define because of their fantastic appearance. The human motif is a face peering out from among the acanthus and ivy leaves.
STATE OF REPAIR

Exterior
Like all monuments situated outdoors in a city, the main cause of deterioration is meteorological elements, in other words, a combination of the climate and pollution.
Human action has had a lesser influence and in the case of the towers is limited to mechanical damage caused by vandalism, war and the different purposes for which the building was used. Among the atmospheric agents, the combination of rainwater and pollution produce very damaging effects on stone due to the creation of acidulate water that initiates carbonation, sulphatation and nitrification processes. So they create a black crust that defaces and erodes the stone underneath it.
In the first place, the intensity of this mechanism is closely related to the orientation of the surface because of the direction of the dominant winds on rainy days, as can be clearly seen on the sculptural elements on the barbican supports, whose black crust was thicker and harder depending on what surface they were located on (photograph 12). Compass rose with the dominant winds on rainy days and the intensity of the expected damage to the surfaces.
In the graphic we can see the dominant winds on rainy days and at the bottom the expected levels of intensity of the mechanism associated to rainwater. All the supports on the surfaces marked in dark blue had a fairly hard black crust between 2 and 3 cm thick. However, there was only a very fine layer on some areas of the parts marked in light blue.
In the second place, the intensity level is also determined by the nature of the stone, so that the calcarenite used in the restoration works performed at the end of the 19th and beginning of the 20th century situated on the NW-NE arch of the eastern tower were in a worse state of repair than the original calcareous tufa stone in the same arch of the western tower.

Damp Contaminating Pathologies
The most important pathologies that affect the sculptural parts of the Serranos Towers are those caused by atmospheric agents. Because of their location in Valencia, these are damp pathologies due to rainwater, atmospheric humidity and dew combined with the effects of pollution.
As regards this type of pathology and depending on the sorts of deterioration, we can define three main zones:
- *Rainwater zone*: this consists of the surfaces that suffer water runoff and as a result the washing and lixiviation of

the constitutive materials of the stone and sedimented on it (photograph 13). This zone looks clean and in a good state of repair, as no materials are allowed to accumulate. However, constant washing by rainwater acidulated from pollution provokes the loss of cementing materials from the stone, causing loss of volume, pulverisation and lack of surface cohesion. Besides, the finish applied had disappeared. In fact, although the stone is clean, its state of conservation is poor from the viewpoint of cohesion, and it is badly eroded by atmospheric agents.
On the other hand, the jointing coinciding with the rainwater zones had practically disappeared, so water was able to seep inside.
- *Concretion zone:* It occupies between 10 and 15 cm around the above. Damp appears through capillarity and the absence of washing permits the accumulation of compounds coming from pollution. In this way a very hard, insoluble black crust is formed, which gets thicker and thicker with new damp and pollution and degrades the stone beneath by converting the calcite into bicarbonates, bisulfites, sulphates and nitrates that are more soluble, which in extreme cases leads to a loss of volume. The finish applied was missing.
- *Accumulation zone:* Generally situated around the above, it consists of those surfaces that are sheltered from the inclemency of the weather by cornices and volumes. Here pollution dust accumulates as there is no washing, but as there is not a great deal of damp, hardening and the resulting black crust do not appear. However, it is a deposit of soot, smoke and catalysts that will pass on to the concretion zone. There is no problem about cleaning it; the stone is in a good state of conservation and maintains the finish, albeit in a very altered state (photograph 16).
- *Special case:* On the lower cornice of the tracery there is a particular case of damp pathology due to the faulty operation of the flashing which allowed water and detritus to accumulate and form vegetable soil with bryophyte and phanerophyte elements. This accumulation causes pulverisation, loosening and cracking with important loss of volume both at the bottom of ashlars and the lower part of pilasters. The height this damage reached was variable, with a maximum of 20 cm (photographs 17 and 18).

Anthropic Pathologies
This type of pathology caused by human action are not important in the sculptural parts thanks to the height of these zones. Nevertheless, mechanical damage was discovered caused by bullets and other weapons. These appear as rounded hollows that had been repaired in some cases. Many of these impacts were probably produced during the Civil War, although other hypotheses cannot be discarded because of the fact that some of them had been repaired. In summary, the basic deterioration mechanism of Serranos Towers is detailed in the flux diagram. Here the most serious degradation processes regulated by the environment can be seen (photograph 19).
Pollution sediments on the stone surface and the entrance of rainwater favours the appearance of the three zones: rainwater, concretion and accumulation.
Rainwater pools produce phenomena of washing and lixiviation that lead to loosening, erosion and cracking. Water produced by capillarity from the rainwater zone and soot, smoke and catalysts from the accumulation zone bring about the creation of the concretion zone, which is where the black crust is formed with the phenomena of carbonation, nitrification and sulphatation that cause pulverisation, loosening and breakage. In both zones the consequence is the loss of volume and sculpted surface.
The accumulation zone forms deposits of pollution that, combined with the humidity in the environment and the dew, alter the finish causing it to come loose.
Interior Corbels
There are great differences in these corbels depending on their location. The corbels situated beside bays are generally in a worse state of conservation. The ones that are sheltered from whirlwinds, turbulence and draughts formed by the winds from the arch with NW-NE orientations are in noticeably better condition. However, the corbels situated furthest from the bays are in a good state of repair, only bearing dust and environmental dirt.
With these data, three groups have been defined according to their degradation level (photograph 20):
Supports 1, 2, 3, 6 and 9 have a slight black crust and loss of volume on the more exposed cornices. The best state of conservation corresponds to 6 and 9 because they are sheltered from whirlwinds and draughts by the projecting part of the southern side. Numbers 1, 2 and 3, which are on the upper storey, undergo a great deal of washing, which has prevented black crust from forming but caused superficial pulverisation.
Supports 5, 8 and 10 have a full, hard, insoluble black crust with a serious loss of volume in the more exposed areas, both on the cornice and on the sculpted surface. The black crust has corroded the stone material, causing chipping, cracking, deep pulverisation and comminution, much worse in the more exposed areas.
Supports 7 and 4 have lost a great deal of their volume. Number 7 particularly is practically worn away and only the bottom half of 4 remains, so that it is impossible to tell what it represented. The loss of volume in the latter is not only due to atmospheric factors but iron hooks in the interior have caused the stone to break (photograph 21).

INTERVENTION CRITERIA; METHODOLOGY & TREATMENT

After the comprehensive analysis of the state of conservation of the sculptural elements of the Serranos Towers, currently under restoration, as described above, the following intervention was planned and designed.
In the first place, as in all restoration works, the principal aim is to prolong the life of the cultural asset. To that end, it was necessary to act on it and carry out a conservation process that can be summed up in three major lines of action: to perform only whatever interventions were strictly necessary and always justified; to give priority to consolidation treatments and, finally, to combine the knowledge of the materials to be treated, the products and materials available and the conditions of the building as a monument exposed to the inclemency of the weather.
Before applying the different treatments, preliminary tests were carried out and the technical descriptions of the products were examined. Treatment was applied where necessary according to each pathology. It is also worth pointing out that part of the methodology consisted of good understanding and fluid communication between the different work teams, the technical group and management.
The four major treatment areas were: preconsolidation, cleaning, reinstatement and consolidation-protection.

Treatments
a. Preconsolidation
The objective of this treatment was to restore the cohesion of the stone material before proceeding to the application of further treatments. It was carried out by impregnating only the areas that required it with organosilicates.

b. Cleaning
As in all cleaning procedures, the essential purpose was to eliminate the layers of pollution and dirt that altered the stone material and, at the same time, conserve the original and replaced finishes. Furthermore, this treatment facilitates the penetration and application of subsequent treatments. Different techniques or procedures were used, as explained below.
- Cleaning by aspiration: removal of deposits of non-incrusted environmental dirt and detritus.
Soft bristle brushes and an aspirator with power control were used. Application was general.
- Chemical cleaning: removal of sulphates, carbonates and neutralisation of the damaging effects of the layer of pollution.
This was done with a mixture of carboxymethylcellulose, ammonium bicarbonate, sodium bicarbonate, desogen and EDTA. This is applied to the stone, left to act and then brushed and rinsed off carefully with sprayed water. Given the thickness of the layer of pollution on the sculptural elements, three applications were made.
- Mechanical cleaning: removal of the concretions of insoluble pollution.
The remains of black crust that could not be removed by chemical procedures were treated with micromotors, precision miscoabrasimeters or aeroabrasimeters depending on the area to be treated. Carborundum polishing heads were used for the micromotors, the precision microabrasimeter was loaded with a glass microsphere with a diameter of between 70 and 149 microns and the aeroabrasimeter with a glass microsphere with a diameter of between 140 and 350 microns. These were applied where necessary (photograph 22).

c. Reinstatement
The aim of reinstatement was to replace the missing parts necessary for the proper conservation of the monument. This set of treatments consists of: renovation of the jointing, sealing of cracks and chinks and reintegration of volumes in elements that provide shelter: the flashing. It was applied only where necessary.
- Renovation of the jointing: this prevents water from seeping in and erosion of the joints by rainwater.
The rejointing was done in general with lime and sand mortar and, in special cases, where rainwater did the most damage, epoxy mortar.
- Sealing of cracks and chinks: to adhere the areas in danger of coming loose and to prevent the entry of water. Epoxy mortar was applied in deep areas and lime and sand area on the surface.
- Reintegration of volumes: restitution, replacement or reinstatement of the elements that protect the monument and eroded areas.
This reintegration was performed with lime and sand mortar.

d. Consolidation and Protection
Finally, the consolidation and protection phase was implemented as a preventive measure. It prevents the atmospheric agents from acting directly on the stone material. This was done by impregnating the surface with ethylic esters of siliceous acid and oligomeric polysiloxanes. It was applied to all the elements treated (photograph 23).

Antonio Almagro Gorbea

PLANIMETRY OF THE ALCÁZAR OF SEVILLE

In many fields of science, drawing is a means of analysis and a vehicle for expressing our knowledge. Graphic representation is generically applicable to all except immaterial physical reality, but traditionally it has been used specifically in the field of architecture, where it is used both for the analysis and study of what

is already built and for the expression of new creations while still at the project phase.
Knowledge is an essential basis to enable us to protect our Heritage properly. Only with an in-depth knowledge of what must be conserved and protected can the proper steps be applied to achieve it. For that reason it is necessary to use proper analysis methods that will permit us to get to know well the property to be preserved. And among these methods, there is no doubt that planimetric surveys are the first to be put into practice because, to make them, we must get to know both the shape and the dimension of the objects, and we can then convey this knowledge, thanks to the representation conventions of general use, in the form of plans, drawings or models.
A well documented building will always have a better chance of surviving the effects of ignorance and negligence and even an unpredictable catastrophe than one that is not well known or badly drawn. Even in the very worst case, it can survive in a fertile memory if we have left suitable documents for its knowledge, study or even its virtual recreation.
Preparing this documentation about our Heritage is no easy task. It is often underestimated as people are not aware of the usefulness of this work, which takes time, means and devotion by professionals well enough qualified in the technical tools to be used and the very essence of the architecture being documented.
However, there are times when the very beauty of what we are analysing can actually be seen in the documents we make, thus helping enhance this commitment. The representation of an intrinsically beautiful architecture will necessarily give rise to beautiful drawings of merit in their own right.
The Seville Alcázar, the oldest royal palace in Europe still used as such, is no doubt one of these cases in which the graphic representation is full of beautiful images that show us the countless stages of its architecture, the fruit of one of the most wonderful artistic symbioses that have ever come about.
Nevertheless, until now there were very few planimetric representations of this site. Until very recently, few monuments in Spain had been suitably studied or documented, giving rise to sufficient, precise plans that provide us with complete scientific knowledge of their physical reality. And we must also point out that some of these studies have been carried out by people trained in other cultural disciplines. The splendid work performed by the Real Academia de San Fernando between 1766 and 1767, when José de Hermosilla, Juan Pedro Artal and Juan de Villanueva were commissioned to draw up plans of the Alhambra in Granada, the cathedral of the same city and the Mosque in Córdoba, was unfortunately an isolated event that was not repeated in time or with other monuments. However, a similar incentive of the Academia that resulted in the drawings of the Alcázar of Segovia made by J. M. Avrial made it possible to reconstruct it after the fire in 1862. In many cases foreign authors like Laborde, Girault de Prangey, Murphy, Owen Jones, etc. performed this task, concentrating on the monuments considered most attractive in their home countries, but of course they only managed to document a tiny fraction of our built Heritage.
It was not until the late 19th century that a large-scale project like the publication of Monumentos Arquitectónicos de España was embarked on. Some of the drawings in it are still a magnificent representation of a large amount of our Heritage that have not yet been surpassed. Only in the last few years have we begun to get plans of buildings made with greater precision, thanks to the improved technical media and, above all, more scientific representation criteria. On many occasions they arise as a result of the interest of the professionals in charge of the restoration of these buildings and, in other cases, the management of this heritage, when, as is sometimes the case, their technical training makes them aware of the need for these documents to exist. But in many cases, these drawings are not widely known because they are not sufficiently publicized. This is a serious drawback, because a plan with sufficient information about a building cannot be greatly reduced for publication without sacrificing a large amount of the data it contains. That is why the case of the recently made planimetry of the Alcázar of Seville is a really special occasion. The Management and Foundation of the Alcázar have not only realized the need to document this unique site properly, thus filling a transcendental gap regarding its knowledge and conservation, but they have promoted its publication in order to allow scholars and lovers of this monument to examine the result of this work, which, in our opinion, is an object of beauty in its own right.
The origin of the drawings now published was a series of commissions made by the Foundation of the Real Alcázar to the School of Arab Studies of the Superior Council of Scientific Research that were formalized with the corresponding agreements of scientific collaboration. In this way it was possible to take advantage of the experience in this type of commissions of the research and auxiliary staff of the School and the equipment and technical instruments they have at their disposal. Beforehand, through the Municipal Department of Urbanism of Seville Council, the Foundation had managed to obtain a ground plan of the site measured with topographic procedures, which included a network of observation stations. This work was carried out by the Seville company Tecnoart. The School of Arab Studies had also been performing documentation tasks, especially the planimetric survey of the roofs of the whole area between the cathedral and the Alcázar by means of aerial photogrammetry. Between 1997 and 1999, they started to draw up sections and elevations of the different parts of the Alcázar in three campaigns using mainly photogrammetric systems, considered the most suitable for this type of work. Photogrammetry permits operation without any sort of auxiliary means (scaffolding, cranes, etc.), with very short periods of field work and with great homogeneity in the precision and the density of the information to be included in the drawings, especially in cases such as the present one, where the decoration has unique features and extraordinary importance.
Places like the Maidens' Courtyard, with its large plaster panels of sekba, or the Ambassadors' Hall, with the half-orange knot decoration, are difficult to measure and represent without resorting to photogrammetric techniques and today's computer-assisted drawing methods which even allow us to create three-dimensional models that can be seen from different angles, with different projections and scales.
For this publication we have chosen to use only the more traditional systems of ground plans, elevations and sections, since they are easier to read.
The plans have been grouped according to areas. In order to be able to consult and locate them more easily, we have included an index-plan with the approximate position of the section lines and numbers for the corresponding plates. The numbers in circles refer to general or local plans. Needless to say, the planimetry offered here does not cover the whole Alcázar, but the most outstanding parts and elements from an architectonic and artistic viewpoint. It provides good knowledge and adequate data about the most important structures, which must serve as the basis for complementary documentary work to be carried out in the future in the course of ordinary conservation and maintenance of the monument.
The work has been done with semi-metric Rollei 6006 metric and Hasselblad SWC cameras, the latter converted into semi-metric at the School of Arab Studies. For the measuring of the control points, Wild T1000 and TCR303 tachymeters were used, the latter with a laser distanciometer. Restitution was performed with Leica SD2000 and AdamMPS2 restitutors. For some detailed jobs, a calibrated digital Kodak DC200 camera and the VSD digital restitution system of AGH University in Cracow were used. All the drawings were digitally made with the AutoCADv14 programme. For publication, they have been converted directly to post script format.

Arturo Martínez Boquera and Adolfo Alonso Durá

TECHNIQUES FOR THE DIAGNOSIS OF THE STRUCTURAL BEHAVIOUR OF HISTORIC BUILDINGS. ANALYSIS OF THE DOME OF SAN MIGUEL DE LOS REYES IN VALENCIA

The use of precise diagnosis techniques for examining a monument is essential before beginning to draw up a rigorous restoration project. Technological investigation is crucial for understanding the truth about material, degradation and its causes, and therefore about possible solutions.
There is no doubt that any method aimed at achieving these ends requires knowledge of intervention theories and techniques that will relate the problem of conservation and restoration with the history of architecture and disciplines connected to the science of building. That is why, in the field of monument consolidation, structural behaviour is a matter of great theoretical and technical complexity that requires evaluation and specific knowledge that has a lot to do with the discipline of architecture.
It is the aim of this research to contribute to the architectural restoration project specific data based on the relationship between the historic evolution of the structural analysis and current techniques concerning the structural behaviour of either brick or stone masonry structures and particularly the vaulted structures and domes that abound in 16th and 17th century architecture, especially in religious buildings.
The dome of the church at the monastery of San Miguel de los Ríos in Valencia (figure 1) can be included within this typology. The Hieronymite monastery is a Herrera-style Renaissance building. The church was designed by Alonso de Covarrubias in 1546 with false stellar vaults on round arches, actually spherical, decorated with plaster ribs. It is worth mentioning the fact that the buttresses have been eliminated from the last two chapels at each side of the nave, creating a space that is a pseudo-cross vault and thus in the shape of a Latin cross that cannot be discerned from the outside.
The dome was constructed during the rebuilding works in the first half of the 17th century on the site of the old medieval church of the Cistercian monastery San Bernardo de la Huerta. Although in the text of the project the building of a dome at the centre of this

transept is not specifically mentioned, Alonso de Covarrubias probably had this type of roof in mind, because it was the solution adopted in buildings with similar characteristics during the Renaissance.
The works on the church really began in 1601, with interventions by Juan de Cambra, and they continued until 1604. They then stopped until 1623, when Pedro Ambuesa took over. Most of the current church was built during this second phase. However, the roof was not made by this second architect because he died in 1632, and was replaced by Martín de Orinda, the author of the roof of the nave in 1636 and the dome in 1641.
The dome (figure 2) is circular with an interior diameter of 7.70 m in the rise. It is a minimum of 30 cm thick and rests on a drum 5.70 m high and 70 cm thick. It has a lantern 8 m high with an interior diameter of 2.40 m.
Having described the dome, we shall now describe the different diagnosis techniques used to analyse its structural behaviour.
In the last few decades, the structural calculation procedures developed by Continuous Medium Mechanics have provided a very powerful tool for the analysis of more and more complex structures. These procedures have an enormous load of numeric calculation, whose practical use is only possible under computer platforms of certain capacity and strength.
Within Continuous Medium Mechanics, the Finite Elements Method (FEM) is the one that has undergone the greatest development. Its application in structural mechanics is based on the theory of elasticity and energetic theorems. This method makes it possible to analyse a great variety of structural forms as regards their geometric arrangement and the materials used. It requires a topological definition of the structure (geometric shape and dimensions) and of the mechanical parameters of the materials that constitute it.
In its most immediate formulation, the linear calculation FEM, applied to the project of architectural structures, has turned out to be an extraordinarily useful tool for the technician who has to design, calculate and construct the structures of new buildings. When analysing the state and behaviour of historic structures by applying FEM, the situation is more complex. The special characteristics of these constructions require certain conditions in the application of the analysis for the results to be trustworthy.
In the first place, on beginning an analysis of these structures, it is necessary to take into account the structural conception and methods used in designing and building them. These methods are completely different from those used by the professionals who work on structures. These structures were designed and built with parameters that had nothing to do with concepts such as tension, resistance, deformability, etc, which we now deem essential for the understanding and evaluation of structural behaviour, but were unknown at that time. The materials in vaults and domes are stone masonry or brickwork. In the case of the dome studied in san Miguel de los Reyes, it is brickwork. The main property of these materials is their scant capacity to develop traction tensions. Although quite resistant to compression, they are much less so to traction. Several investigations coincide in attributing brickwork with mechanical values that depend on those established for the base constituent material, which in the case of brickwork can be estimated as between 40 and 50 kg/cm2 compression resistance and 10 or 20 times less for traction resistance, varying between 2 and 5 kg/cm2.
The material's resistance to compression in this type of structure is not usually a decisive factor, since the tensional levels to which the masonry is submitted are usually far below their resistance limit. It is the low resistance to traction that determines their stability, which depends on their shape and size, so that the adjustment between the design of the vault and the position of the pressure lines or surfaces determines the traction level. They are structures that resist because of their shape rather than the material they are made of, provided that it maintains its mechanical properties without degradation.
It is this traction that causes the different degrees of cracking in masonry, from slight cracking, which does not affect the structural stability of the piece, to serious cracking, which can cause it to collapse. We could say that cracks are inevitable in masonry and that they do not necessarily mean that the structure is endangered, although they can have a negative influence on other elements, such as plasters, frescoes, paintwork, etc.
It is very interesting to know the different interventions that may have been performed on these structures over the years because, if there have been undated, insufficiently documented or unknown alterations in the geometry, repairs or replacement of material, this can cause a great deal of uncertainty, because there is no way of knowing the tensional change that may have taken place.
The movements brought about by the settlement of the foundations tend to change the directrix of the design of vaults and domes. The state of tensional equilibrium of these structures is very sensitive to this geometric variation, and it is very difficult to calculate the numeric values of these tensions. On the other hand, they are structures with a very high degree of adaptability to the different geometries resulting from these movements: within certain bounds of variation, there are many possible positions of equilibrium which make the construction stable, even though a great deal of cracking may appear.
For all these reasons, the evaluation criteria based on the extreme states that involve verifying the $\sigma_u \geq \sigma_d$ condition, that is to say, the values of the calculation tensions are lower than the material exhaustion tensions, must be used with suitable caution.

Analysis levels

The structural analysis of historic constructions can be approached from two different, complementary viewpoints:
a) as a theoretical study to understand the mechanics and behaviour of these constructions better.
b) as part of the conservation-restoration process of the monument in question.
Today there are several structural analysis techniques based on different theories (elastic, rigid-plastic, elastic-plastic, etc.) that attempt to evaluate the tension level, the collapse load or the degree of safety of structures. At the present time one cannot aspire to have a single method to solve all cases in general, because of the great variability of masonry and typologies and their peculiarities. It is necessary, then, to use several techniques to complement the study.
For this purpose, several analysis techniques are described below, detailing their field of application and the degree of reliability of their results.

Equilibrium Analysis

It consists of establishing the possible equilibrium between the different parts of the structure and the acting loads, involving rigid-plastic behaviour of the material. This is to determine the pressure lines within the design of the masonry; equilibrium is established if this pressure line goes through the inside of the vault or dome. The design of the pressure line can be made by graphical statics or vector analysis.
The authors have developed a computer procedure that, by AutoCad, automatically carries out vector statics operations, calculating and drawing the forces that define the pressure line and the values of the co-barycentric tensions.
In classical mechanics it was considered an essential condition that the pressure line be inside the central nucleus of the element. This guaranteed that there would be no traction in the masonry. Heyman applies plastic calculus theorems to the calculation of the construction, thereby achieving a very versatile method for studying the stability of arches, vaults and domes.
The calculation bases are:
1) The behaviour of the material is considered perfect rigid-plastic. Resistance to traction is null and resistance to compression is high enough for tensions that are exerted on the section to be very much below the material's plasticisation limit. This is true, or at least guarantees safety, in stone masonry and most brick structures.
2) Under these conditions, the cracks that appear in the masonry will provoke tilting when the pressure line is tangent to a surface of the vault, intrados or extrados.
3) Arches are unstable when the number of tilts produced causes a mechanism.
With these bases, stability calculations consist of finding a line of pressures inside the arch or the vault while in equilibrium with the loads. If a design that fulfils this requirement is found, the arch is sure to be stable, however much cracking there may be.
The concept of safety becomes geometric instead of tension resistant, in other words, the degree of safety is the amount of play that the thickness of the wall has on the design of the pressure line. With this procedure, what is sought is not the real line of pressure exerted on the masonry but a possible line that will guarantee stability.
In the case of dome analysis, the same procedure is used applied to a "segment" or sector of the dome and taking into account the pressures according to parallels that determine the possible appearance of cracks in the direction of the meridians, as well as the meridian pressure line, in arches and vaults,.
One advantage of this method is that it is not necessary to know the mechanical properties of the material provided that the conditions stated in the bases of the method are fulfilled. The geometry of the structure must be defined with precision and this requires painstaking data collection of dimensions and constructional arrangements. Figure 3 represents the layout of the pressure lines of a "segment" of the dome of San Miguel de los Reyes, showing evident stability, no serious traction tensions and co-barycentric compression tensions with values around 2 kg/cm^2. With this procedure, the analysis of seismic actions may be carried out considering the gravitational loads acting at an inclination depending on the degree of seismicity.

Analysis by the Finite Element Method

This technique can be used to analyse the whole structure, because it permits an exact model of it as regards geometrical definition by meshes of superficial or volumetric elements that adapt to the form needed.
The method follows the calculation process briefly described below:
The system of equations formed by the global rigidity matrix of the structure and the load vector must be resolved.

$$\vec{F} = |K|\vec{U}$$

To obtain the local rigidity matrix of each of the elements isoparametric formulation is used. The form functions *N'* of the isoparametric element relate the *u'* movement of any point inside the element with the *a'* movement of the end nodes of each element.

$$\vec{u} = \vec{N}\vec{a} = \sum N_i a_i$$

Calculation of unitary deformations of the material depending on the movements of any point of the element:

$$\vec{\varepsilon} = \vec{L}\vec{u} = \sum B_i a_i = \vec{B}\vec{a}$$

in which

$$\vec{B}_i = \vec{L}\vec{N}_i$$

Expression of the relationship between tensions and deformations through the constitutive matrix, elasticity or D flexion:

$$\vec{\sigma} = \vec{D}\vec{\varepsilon} = \vec{D}\vec{B}\vec{a}$$

Application of the Virtual Work Principle to a virtual shift of the nodes and integrating, the local rigidity matrix of the element is obtained:

$$k = \int_V B_i^T D B_j \, dV$$

This expression is resolved by numeric integration using the Gauss-Legendre quadrature. Once the rigidity matrix has been obtained in local axes

$$\vec{f} = |k|\vec{a}$$

the transformation

$$K = R^T |k| R$$

is made to refer it to global axes of the structure

$$\vec{F} = |K|\vec{U}$$

and then each element is assembled in the global matrix.

From the resolution of this system of equations the movements (shifts and twists) of the structure nodes are obtained, and once these are known by means of the rigidity matrix of each bar, the tensions directed at the ends are calculated, in which "a" is the vector of the movements of the end nodes.

$$\vec{f} = |k|\vec{a} - \vec{f}_{emp}$$

In the case of superficial and volumetric finite elements, stress is calculated at the Gauss points used for the quadrature of each element and they are passed to the nodes. These strains are averaged between those corresponding to each element that influences this node. Tensions at the p Gauss points of elements with n nodes are resolved with the expression:

$$(\sigma)_p = \sum_{i=1}^{n} (DB_i)_p \vec{a}_i$$

The calculation process described supposes that the structure is formed by a continuous material with elastic-linear behaviour, these parameters are specified by means of the constitutive matrix D. That is why it is called linear calculation. It requires thorough knowledge of the mechanical properties, a conflictive point, as we pointed out above. This method permits the analysis of any state of actions: gravitational, seismic, aeolian, temperature, imposed deformations (settlement of foundations), etc., resolving the structure's response regarding the state of deformations and tensions. Once these are known, breakage criteria can be applied to determine the failure or damage mode that the structure may suffer and the possible appearance of cracks. Where there is a cracked structure, it is possible to map the cracks by imposing geometric discontinuity at the nodes of the mesh of the elements and analyse the stress deformation state and therefore the stability of the whole structure. Figure 4 shows the map of the cracks of a vault imposing geometric discontinuity at the nodes of the mesh. The mechanical behaviour of masonry is very different from what it is supposed to be in linear calculation. The joints and possible cracks cause a loss of continuity in the material; the mechanical properties depend on the level of tensions applied; there is no linear relationship between tensions and deformations, etc. This enumeration emphasises the fact that linear calculation does not correctly represent the behaviour of historic structures; all that can be expected is an approximation to structural reality, more or less divergent according to the state of the deformations, tensions and degradation of the masonry: the state of the mortars and the pieces that form it. Thence non-linear calculation appears in an attempt to evaluate the behaviour of the structure by including the properties of the material, which are variable. Mapping this variability makes the calculation extraordinarily complex. In the FEM it involves evaluating the constitutive matrix D according to the concepts of plasticity theory and breakage mechanics. This process is necessarily non linear, and therefore repetitive, with the resulting increase in complexity and calculation time. The appearance of cracks in masonry, along with the variation in the tensional and deformational state that they cause, makes the calculation models applied include cracking modes in order to obtain results in accordance with the structural reality under study.

There are basically three non linear calculation procedures for mapping the non linear behaviour of masonry structures, calculating the appearance and evolution of the cracks and the ultimate collapse load. The one used in this research is the one known as the isotropic damage model, incorporated in the CID finite element programme for the study of different historic domes, which is briefly explained below.

Damage map

Damage mechanics is a branch of Continuous Mechanics which introduces microstructural changes in the behaviour of material by means of internal variables. These variables model the influence of material behaviour history on the evolution of tensions. The appearance of cracks and their evolution in time on materials like concrete and rubblework can be described as the trajectories of the different damaged points. If a damage function that correctly represents the response of the material, regarding both compression and traction, is defined, then the non linear behaviour of the masonry can be mapped. Cracking is represented in this case as an effect of local damage, which can be characterised depending on the known parameters of the material and functions that control the evolution of the damage with the successive state of the tensions at each point. In the CID programme an application of the isotropic damage developed in the last decade has been implemented (Hanganu 1997, Oller 1991, Oliver 1990, Oñate 1988). The model used takes into account the three suppositions necessary to map the non linear behaviour of concrete and rubblework correctly: the different behaviour in compression and traction, the degradation of rigidity for mechanical causes (tensional level) and the effect on the response according to the size of the finite element mesh.

Concept of Isotropic Damage

It is considered a point of a material with a certain degree of deterioration. This degradation is represented as gaps in the material. If S is the total surface considered and S' the resistant area (S-S' is the gap surface), the damage variable "d" is defined as:

$$d = \frac{S - \bar{S}}{S} = 1 - \frac{\bar{S}}{S}$$

This index expresses the material's degree of degradation (0<d<1) . Zero represents the undamaged state, whereas the unit represents the total damage to the resistant area.

The relationship between the standard Cauchy tension and the actual tension that acts on the part of the actual resistant section is calculated by the equilibrium condition:

$$N = S\sigma; \qquad N = \bar{S}\bar{\sigma}; \qquad \sigma S = \bar{\sigma}\bar{S}$$

$$\sigma = (1-d)\bar{\sigma} = (1-d)E\varepsilon$$

This scale index is sufficient to represent adequately the behaviour of materials like concrete and brick and stone masonry. The effect it produces on the mechanical behaviour of materials is a reduction of proportional rigidity to (1-d) (figure 6). If this relationship is extended to the total tension vector, one obtains:

$$\begin{vmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{xz} \\ \tau_{yz} \end{vmatrix} = (1-d)|D| \begin{vmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{xz} \\ \gamma_{yz} \end{vmatrix}$$

In which D is the elasticity matrix for an isotropic material. In the reiterative FEM process, the matrix is calculated as:

$$\bar{D} = (1-d)D$$

The scale damage variable is:

$$d = 1 - \frac{r^0}{r}\exp\left\{A\left(1 - \frac{r}{r^0}\right)\right\}$$

The values r, ro, A are obtained as in note number 12. An important advantage in damage formulation is how simple it is to calculate compared to other crack models, as it does not require a special algorithm to integrate the constitutive equations of the elastic plastic models.

Results

When this model is applied to the dome of San Miguel de los Reyes, mapped with volumetric finite elements, figures 7-8, the following results are obtained: the value of the membrane tensions obtained in the dome are very slight, reaching Sx values that vary between –0,082 kg/cm2 (compression) and +0,82 Kg/cm2 (traction) in the direction of the parallels, figure 9, and values between–0,001 kg/cm2 and –2,136 kg/cm2 all compression in the direction of the meridians of the dome, figure 10. With this tensional level, an almost imperceptible index of damage can be gauged, which is the actual situation of the dome, corroborated on applying the calculation by the damage model, as shown in figure 11. The damage model is also useful to calculate the degree of safety of the dome as it permits easy evaluation of the damage index obtained with proportional factors of the gravitational loads to which the structure is subjected. In the dome studied, a damage index of 0,1 begins to be manifest from 5 times its own weight, only on the intrados in figure 12, but more serious damage can be detected in the drum. And for a factor 10 times its own weight, elementary damage can be seen in the extrados, there is damage with an index of up to 0,575 at the union with the drum and damage close to collapse in the gap area of the drum (fig. 13). In summary, making models for the calculation of the domes is very complex, both in the geometrical topological definition and in the characterisation of the properties of the materials. It is necessary to have CAD programmes that permit the work to be done in a reasonable length of time and relatively easily for the detection of possible definition errors. It is not wise to use only one method to resolve all cases in general, because of the great variability of masonry and typologies and their peculiarities. It will be necessary, therefore, to use several techniques that will complement the study. The use of non linear models is essential for this type of structure. The post calculation process also requires a suitable user programme interface that permits graphic and numerical consultation and analysis of the results. Due to the varied uncertainties in the input data, the analysis of a masonry structure requires sensitive studies that make it possible to know the incidence of the possible variations in the input parameters and the results of the calculation.