ENGLISH VERSION

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ARCHITECTURAL RESTORATION OF LUIS MENÉNDEZ-PIDAL, ARCHITECT OF THE PRIMERA ZONA

Luis Menéndez-Pidal was one of the leading restorers of Spanish heritage buildings in the last century, and particularly during Franco's regime. From the start of his professional career in 1920 until 1975, the year he died, he worked through political change and different social circumstances, at a time of unrest and a crucial period for the current discipline of architectural restoration. In the 55 years of his professional career, Luis Menéndez-Pidal restored some 200 buildings in his different posts in the Administration, but mostly as Conservation Architect of Monuments of the First Zone (1941-75), during which time he refurbished the most important works in the provinces of Asturias, León, Zamora, La Coruña, Lugo, Orense and Pontevedra. The study of his work and his intellectual evolution is therefore an excellent tool with which to approach the restoration of monuments in this long and fundamental period in architectural restoration in Spain.

Education and methodological development

Due to the many different influences that accompanied Menéndez-Pidal's cultural and methodological development, together with the changing historic circumstances that took place during his professional life (1920-75), it is impossible to classify his restoration criteria within any particular trend. The ideological stance we can deduce from his writings and acts is extremely meaningful, showing him to be an heir of Viollet le Duc's "neomedievalist rationalism", added to an eclectic education loaded with different references, all of which were present in architectural restoration in Spain at the beginning of the twentieth century, such as "archaeological", "scientific" or even "romantic" interpretations. Menéndez-Pidal's training combined the two great lines of thought about architectural restoration in vogue at the turn of the century: the "preservationist" and the "restorationist" schools, defended respectively by Leopoldo Torres Balbás and Vicente Lampérez y Romea. The interesting debate that took place at the start of the last century between the supporters of the "stylistic" discourse (Lampérez) and "scientific" renovators (Balbás) was the culture broth in which the young architect started his career.
His next reference was to be the historian Manuel Gómez Moreno, who proposed Menéndez-Pidal for the restoration of Santa Maria del Naranco or the Palace of Ramiro I in Oviedo (1929-36). This important personage acted as his tutor for these works and, more importantly, the method they developed together had a great influence on his posterior development. Gómez Moreno and Menéndez-Pidal defended the restitution of Santa María del Naranco to its "original state", which was to be brought to light by means of a methodology based on archaeological and historical research. Archaeological, because both professionals performed archaeological research on the fabrics of the building, concealed under multiple historical additions. And historical, because they consulted all sorts of scientifically authenticated historic documentation that helped get to the bottom of the sought after "original state" of the building (such as the didactic lithographs made by Pacerisa in 1856). The archaeological interpretation of the building and the search for its initial state by studying the remains conserved and the historic documentation was learnt by our architect at the time and was to become a constant feature of his methodological development. However, the responsibility of his first project in Asturias put Menéndez-Pidal in a delicate position of compromise between his more "modern" renovating proposals and the need to obtain satisfactory formal results. In many aspects, the restoration of Santa María del Naranco lacked the "scientific" rigour of his first projects (Nieva and Guadalupe), since he rejected outright Boito's idea of differentiating added fabrics or elements from the original ones and prioritised the overall appearance of the building. Preference for the plastic understanding of the work took precedence, for the first time, over respect for its material truth and historic alterations, which, with the passage of time, was to be an invariable aspect of his method, with few exceptions.
Another early project, before the Civil War, was the restoration of the Monastery of Guadalupe (Cáceres). He was commissioned to restore this important and conflictive monument by the direct mediation of Vicente Lampérez, who reserved for his ex-student at the university a challenge that would show him what he was really capable of achieving. Menéndez-Pidal was the conservation architect of the monument for 51 years. The importance of this monument, not only at the early stages but throughout his career (1923-75), was vital for this architect. The complicated task of caring for it provided Menéndez-Pidal with the best possible lesson, which he later applied on the many occasions that arose, either in the early days, in repairing the damage caused by the Civil War on the Cantabrian coast or from his post as the head of the First Zone. The extensive work on the Monastery of Guadalupe, which lasted almost as long as his professional trajectory, is the best example to show the ideas and evolution of his particular restoration methodology. From the first years, where respect for the monument, reference to his academic period and the principles of "modernity" were more noteworthy, to the last reports, where confidence in his position in the Spanish cultural milieu and the assurance that he would continue to be the sole conservation architect of the monument, led him to take excessive risks. All of this puts before us an evolution that pursued the "idea of the building" as his ultimate goal, which materialised little by little over the years. The ultimate goal that consisted, as we shall see, in recuperating the "authenticity" of the work, although this involved rebuilding or replacing the missing parts,

sometimes following an "archaeological" and sometimes a "stylistic" method. His continuous care of the building and his search for "originality" led him to address the architectural integrity of the whole site from a revisionist viewpoint.
After his first trip to Italy in the mid thirties, a new influence was added to those already in existence. In Italy he saw many viable alternatives to the "stylistic" method, among which we can include the exemplary archaeological restoration works performed by Giuseppe Valadier, which had anticipated the "scientific" discourse and modern theses about the restoration of monuments defended by Boito. He also discovered the work of Antonio Muñoz, who had developed an interventionist archaeological method in the twenties similar to the one adopted by our architect years later. Also an heir to Luca Beltrami's "historic" method, Muñoz created with his interventions an archaeological profile that Menéndez-Pidal shared. The recomposition of buildings by stylistic confrontations that sought the "ideal model" on the basis of true scientific elements as the result of historical and archaeological research was an argument common to them both. Our architect saw the examples of Santa Sabina (1914-19), San Giorgio al Velabro (1923-26) or Santa Balbina (1927-29) and added them to his cultural baggage. Besides, Muñoz's intervention on the Basilica of Santa Sabina bore a clear similarity to what Fortunato Selgas ands Lampérez had done on San Julián de Prados (Oviedo, 1912-15), dubbed "flawless" by the critics at the time, and was highly considered by our architect and taken as a reference to add to his education.

The Civil War
The eclectic and learning period of his first years was followed by profound changes and sad events in the national panorama of architectural restoration. The uprisings in Asturias (1934) and the Civil War (1936-39) were a time of ideological regression of the concepts learnt towards positions that had already become outdated during the Second Republic. These changes were the result of extensive damage to the heritage and, among other things, the new administrative and political organisation that arose after the war. The pressing need to tackle postwar reconstruction brought about a hurried renovation of the rigorous "modern" principles in vogue at the time; in this context, Menéndez-Pidal, like all the other professionals who worked on postwar reconstruction, saw from his own experience that the "scientific method" of the 1931 Athens Charter was inapplicable in many of the cases that required repairs. The systematic destruction of the monumental heritage suffered by Spain in the Civil War, just like Europe in World War II, had a crucial effect on the transformation of the general restoration concepts in the 20th century.
The following stage in Menéndez-Pidal's intellectual and methodological development took place during the Civil War. His firm support of the national side allowed him to act on the conservation of the architectural heritage under military law. But it was his appointment as Representative of the Informative Reconstruction Board when the north front fell (October, 1937) along with Pedro Muguruza that brought him in contact with the monuments in the area of Cantabria that had a definitive effect on his development. The war years were complex, troubled times that conditioned the methodology of our young architect. But that did not mean it was a less rich phase in his training, as the number and importance of the monuments he was put in charge of provided him with excellent preparation for the difficult postwar years ahead. Many interventions were made by the Service during the war and immediately afterwards. A large number of little Asturian churches were selected between 1938 and 1941 and put under the care of Menéndez-Pidal, who drew up emergency projects and performed the most essential works to safeguard the constructional and structural integrity of the buildings. This was the case of the churches of San Julián de Prados, San Salvador de Fuentes, San Salvador de Priesca, San Andrés de Bedriñana, San Juan de Amandi and San Pedro de Nora, among others; drastically affected by the damage suffered, the reconstruction meant that the "modern" postulates of his early career were replaced by more interventionist methods to ensure the recuperation of the monument. However, in his recent post at the service of the newborn regime, Menéndez-Pidal suffered a retrocession in his methodology and firmly recuperated obsolete concepts of "structural integrity" and "unity of style" in the recuperation of the damaged heritage. The "reconstruction" was seen by the new institutions as an indisputable objective, which in many cases included a "stylistic" revision of its morphology. Besides, like in the rest of the cities affected by World War II, the destruction served as an excuse for Menéndez-Pidal to correct or improve defects or erroneous items according to a positivist (and in many cases a "stylistic") posture, with a view to restoring the building to a better state. His interventions, with some exceptions, remained on the margin of the denouncement of the historic fact of destruction, and the "artistic value" and monumentality of the building were the most important factors to take into account, ignoring the responsible "scientific" denouncement of destruction. On the other hand, the training of traditional professional building experts involved in the reconstruction of these examples during the terrible years of the Civil War was to become one of its most solid values; the archaeological fidelity of the procedures guaranteed his interventions on the structural continuity of the buildings. Menéndez-Pidal's commitment to the new regime was acknowledged by the department of Regiones Devastadas (Ravaged Regions) and he was commissioned the most important projects along the Cantabrian coast over the next few years, even before the end of the war. The first project for the new Administration was the reconstruction of the Holy Chamber of Oviedo cathedral (1938-42), which is a token of the importance the capital Asturias was gaining because of its outstanding role of "Resistance". Of all the monuments rehabilitated, the reconstruction of the

Holy Chamber was the one that best reflected the attitude adopted by Menéndez-Pidal in those years; the reconstruction was supported by the institutions as a way of erasing the destruction caused in the past and the establishment of a “New Order”. The “artistic value” was given precedence over any other “scientific” issue and the conservation of the historic fact of destruction was an insignificant, dispensable argument. So the double political and propagandistic strategy involved in the reconstruction was clearly stated and Menéndez-Pidal was obliged to ignore the more “scientific” reconstruction proposed by his colleague Alejandro Ferrant and address the problem from an “archaeological” viewpoint that would restore the building as closely as possible to the formal image and built materiality. Similar criteria were adopted in the reconstruction of the Gothic tower of Oviedo cathedral (1938-53). Mutilated by artillery during the war, Regiones Devastadas ordered it to be integrally reconstructed. The tower was restored to its former state by an equally archaeological process that, apart from repairing the damage caused by bombs and artillery, rectified some earlier interventions that, in Menéndez-Pidal’s opinion, from a corrective, revisionist viewpoint, were poor.

The Postwar Period. Conservation Architect of Monuments of the First Zone.

At the end of the war, Menéndez-Pidal’s career flourished under the new regime. When he was appointed Conservation Architect of Monuments of the Service for the Defence of the National Artistic Heritage, after a brief spell as Commissioner (1939-41), he set out on a new phase in his professional trajectory, which was to be characterised by repairs to the damage caused during the war, as well as looking after the abundant heritage in the First Zone, the largest of the national territory, comprising the provinces of Asturias, León, Zamora, La Coruña, Lugo, Orense and Pontevedra. The new attributions of his post permitted and required him to address an enormous number of monuments in a very extensive geographic area, which provided him with knowledge about the most varied monuments, styles, building methods, etc., which gave a definitive slant to his methodology. Recognition of his task was further reinforced by his continued work on the Monastery of Guadalupe, abandoned during the war until 1942, which was a veritable exception within the strict administrative structures of the regime, reserved to very few professionals.

In his new post, Menéndez-Pidal not only acquired greater responsibility on heritage but exceptional freedom to act as an architectural restorer in those years. From then on, his projects were conceived and developed according to his own criteria, requiring only the approval of his “superiors” to put them into practice. Nevertheless, it was a freedom of action limited by “service” to the ideals of the regime and by the maintenance of the criteria that had been followed in the reconstructions performed in the years immediately after the war. Therefore there was no such thing as renovation, and much less any reference to the modern restoration school in Europe; the ostracism our country underwent conditioned the assimilation of the postulates imposed by the institutions. Both Menéndez-Pidal and other architects performing the restoration of monuments in Spain had to do their work during those years without any knowledge of what was happening in other countries affected by World War II and forgetting the experience gleaned in earlier times because it went against the national cause. His responsibility at the head of the First Zone opened up a broad horizon of interventions before him, where the economic and technical precariousness of the first years of the regime limited his tasks to the most necessary repairs. These usually affected the roofs, which guaranteed the physical integrity of the structure. The scarcity of material means and the lack of modern technologies forced him to base his interventions on what he had learnt of traditional building methods, which meant he avoided using unsuitable modern solutions that were common practice in other countries and had a very negative effect on the integrity of the fabrics.

The archaeological fidelity in the restoration techniques, limited by the absence of means, was a positive argument to be found in many of his early works as the head of the Service. This was the case of his interventions on pre-Roman Asturian buildings, where his constructional contributions were based on an archaeological interpretation of the well conserved models, as we can see from his reconstruction of the church of San Salvador in Priesca (1942), Santo Adriano de Tuñón (1946-48) or San Pedro de Nora (1940, 1952); the following years, after these first restorations had been completed, he undertook less conservative, more invasive and traumatic repair works, which allowed him to advance in his own particular “idea of a building”. Furthermore, the first works on the rest of monuments in the First Zone were the most urgent repairs to safeguard the physical integrity of the architecture (with projects limited by the fractioning of several dossiers and a scant budget), as in the church of the Santa María la Nueva monastery (Lugo, 1946-53), the church of Santa Eulalia de Bóveda (Lugo, 1953) or the collegiate church of Sar (La Coruña, 1946-51), for example; other monuments were saved from imminent ruin thanks to the repairs performed in his first years, like the monastery of Santa María de Osera (Orense, 1949-60). In Zamora, the intervention on the cathedral (1942-66) was the example that best illustrated the consolidation of his deductive archaeological intervention method. Here he addressed the restitution of the most singular architectural features comprising its Byzantine cimborio and its stone roofs, which our architect rediscovered and restored to their original state. This interest in archaeology was also patent in the intervention on the cathedral of Santiago de Compostela (La Coruña, 1941-42, 1945-61), where his work consisted practically exclusively in investigating the archaeological substratum, apart from the usual repair works. Similar archaeological tasks were performed in many other examples, the most outstanding of which were his interventions on the collegiate church in Toro (Zamora, 1942-57), the cathedral of Tuy (Pontevedra, 1942), the towers of the Oeste in Catoira (Pontevedra, 1944-56) or of Santa María la Mayor church (Pontevedra, 1946-53). More modern methods were used, however, in the intervention on the church of Santa María Del Campo (La Coruña, 1945-50), where he solved the serious structural problems in the vaults by means of an interesting process of research and analysis.

According as the postwar repair works were completed, new ideas about the monumental heritage gradually began to arise. Thus, one of the qualities that our architect most appreciated was the image of the building in its surroundings, whether natural or urban. This landscape was conceived, in many cases, with the same aesthetic intention as the building itself. An "appropriate" setting was achieved by overcoming any sort of contamination or by manipulating the natural landscape at will. In pursuit of this exterior perception, quite a few clearing works were performed, following "stylistic" theories and ignoring the important historic role played by additions. In spite of the fact that he was familiar with the contributions of Giovanonni, Menéndez-Pidal always defended the removal of whatever historic alterations he considered "annoying", and preferred to recover the authentic appearance of the monument rather than maintaining its historic veracity. In this process he manipulated and in many cases isolated the surroundings to achieve perfection, as in the clearing of the church of Santa María del Naranco (Asturias, 1929-34), Santo Adriano de Tuñón (Asturias, 1946), where he "amputated" the south portico, or San Martín de Castañeda (Zamora, 1946-63).

In the Monastery of Guadalupe, the first phase of works for National Education was the start of the restoration of the whole complex (1942-75). After the first "modern" interventions, that is. The works carried out prior to 1936, the confidence the Administration had in our architect permitted him to plan his works over time. His work on the monastery was influenced by the pursuit of the pristine state of the building, where the alcove behind the altar, the antechapel and Our Lady's throne (1942-44, 1953, 1957-58) were monumentalised and conceived as the most outstanding elements inside the building by Menéndez-Pidal.

Final Stage. Ideological Turning Point. The end of autarchy and Menéndez-Pidal's appointment to San Fernando Fine Arts Academy in 1956 was a turning point in his ideas and methodological evolution. This last period, characterised by the conclusion of the postwar reconstruction, opened up a new panorama that set aside mere repair works to embark upon personal reconsiderations based on the experience gleaned that were to materialise in the years that followed.

His discourse upon entering the Academy was an ideological compilation of his many personal experiences along with the assimilation of the different European currents in the discipline of restoration, which was our architect's first and only incursion into the field of theory. He had previously contributed merely with unimportant data about the criteria or procedures he applied to his projects (1954). With the title "The Architect and his Work in the Care of Monuments" (1956), this document constituted a thorough account of the different influences that he had assimilated, from the doctrines of Viollet le Duc to Ruskin, Beltrami, Boito and Giovanonni, combined with his own personal experience; Menéndez-Pidal produced a real ideological, didactic and eclectic compendium, in an attempt to introduce and stir up the stunted debate about restoration that was taking place in Spain at that time. Of all his writings and publications, it is undeniably his most updated and interesting document, as it contains and lays before us his perfect knowledge of the history of the discipline. His appointment to the Academy was the acknowledgement of the brilliant career of a figure who had performed the restoration of some of the most outstanding buildings in the postwar years in Spain as an institutional instrument of the regime. Paradoxically, Menéndez-Pidal's ideological stance in 1956 coincided with the start of his most invasive period on heritage. The interesting concepts he had stated in the Academy gave way to positions that are hardly defensible when compared to those he spoke up for in his pragmatic opening speech. These years saw the most unjustified, arbitrary interventions of his career. "Stylistic" and reformist attitudes overshadowed with increasing clarity his early "modern" stance. They were years of contrast, where the fact that he continued to be in charge of the maintenance of monuments permitted him to take unjustified risks, more and more evident as he got older. It was the moment to put into practice the particular "idea of the building" that our architect had for each concrete case, and which in many of them he implemented and carried through to the end. As in earlier periods, but now more clearly, the concepts of "historical veracity" or "authenticity" were replaced by "formal value" and the plastic qualities of the work, often falling into "stylistic" excesses and historicist picturesqueness, so common, on the other hand, in the final years of Francoism. Menéndez-Pidal was aware that these were the last years he would devote to heritage, and saw his interventions as the final, definitive result of the building's life.

In this way he kept up the same methods and procedures he had used at his earlier stage, but applied them more radically and adamantly. His prominent position in the technical competency of the First Zone, coupled with the increase in funds, allowed him to take risks he had been unable to take in earlier years. For example, the continuation of the works on San Salvador de Valdedios (Asturias, 1953-72) gave rise to the dubious construction in his later years of the side chapel in the north, a perfect replica of the south one. Without any documented archaeological remains, its reconstruction turned into a formalist exercise of "completion" of the monument, based exclusively on the most obvious "stylistic" postulates. Arbitrary reconstructions found in the continuation of his intervention on the church of San Pedro de Nora (Asturias,

1952-64), where in the last years he reformulated its architectural reality by building a new freestanding narthex (1958), transferring the Santullano archetype and thus reducing the possible morphological differences in this small family. Nevertheless, his most dubious intervention was the building of a new freestanding bell tower (1963) on nonexistent foundations, which altered even more the outline of the monument and its relationship with the landscape.
The restoration of León cathedral (1948-71) showed an equally revisionist attitude; he dismantled and reassembled its south gable (1961). In San Isidro de León (1958-74), the interest aroused by the church and its crypt as a tourist attraction encouraged him to make a "stylistic" recomposition of the interior when turning it into a museum. The same thing happened with the convent of San Francisco in Lugo (1951-69), adapted into a provincial fine arts museum. But the most surprising work of his late period was the complete reconstruction of the church of Santa María de Bendones (Asturias, 1958-71), on top of questionable archaeological remains. This intervention was the most controversial and risky work of his whole professional life and perhaps the best example of the excesses of his particular archaeological methodology.
Furthermore, in this last period there was a great deal of systematic clearing of buildings in pursuit of formal "authenticity" (in spite of the criticism of this practice he had made in his speech); thus the church of Santiago Peñalba (León, 1949-71) was cleared of the traditional houses that surrounded it, and he also systematically cleared the walls of León (1962-72), Zamora (1956-75) or Lugo (1949-63).
Menéndez-Pidal continued to practise his methodology in the same historical and archaeological manner that he had used in his previous works; however, in his final years, he clearly introduced new technologies, which were adopted with the sole condition that they would not be noticed. The priority he granted to "aspect" rather than archaeological fidelity made him turn original structural and constructional parts into modern contrivances with new materials alien to the nature of the building and introduce harmful structural conditions in spite of scrupulously respecting its exterior appearance. In this way he differed from the constructional rationalism of the "historico archaeological" method he had used at earlier stages, and, either out of convenience or a mere desire to be modern, he adopted the most unfortunate postulates of the "scientific method". In this last period he had roofs and fabrics refurbished and structures reinforced with strange supposedly modern solutions that introduced unknown and often incompatible variables, like the reinforced concrete slabs that were placed on the intrados of vaults to ensure stability, but which endangered the structural system. This unlikely panacea was applied in the second phase of Horta church (Zamora, 1960-68), among others. Structural excesses were performed, like the tie beams in the vaults in the church of San Rosendo de Celanova (Orense, 1963-66), concealed in the intrados. A similar system was used in the chapel of Osera Monastery (Orense, 1958-60). In the same line of procedures, the chancel of the church of Acebeiro Monastery (Pontevedra, 1959-63) was consolidated with a traumatic reinforced concrete beam, which makes the whole building rigid and alters its structural behaviour.
In the Monastery of Guadalupe, the increase of funds our architect received after his 1962 report opened up a new path, where the planning of more important interventions led to the formalist revision of his architecture and the pursuit of his "idea of a monument", which materialised in the years that followed until his death in 1975.

Conclusions

As can be deduced from looking over his professional career and his different periods defending heritage, Menéndez-Pidal's methodological experiments were always supported by his intervention methods, the result of his particular view of architectural restoration. Forged in his first years and consolidated with repairs to the disasters of the war and the knowledge, acquired through his own experience, of the impracticability of the "scientific" discourse, his deductive method became his most solid basis, stronger than any ideological convictions. Menéndez-Pidal's method was founded on a historical and archaeological investigation to discover the original state of the building by an analytico deductive process. The data found in his observations and investigations were compared with the information deduced from similar examples (usually submitted to certain common laws) in search of the most truthful and convincing historical phase for the restoration. It was a method understood from a double strategic viewpoint, scientific and artistic: scientific insofar as it depended upon his historical and archaeological research (and interpretations), and artistic insofar as the final result had to have an aesthetic coherence capable of communicating its plasticity. Thus the lost or damaged elements could be replaced by identical or even better ones, more "authentic", in pursuit of the "original state".
Menéndez-Pidal always put the legitimacy of the "restoration" as a necessary step to restore the lost "integrity" of the building above fashions and trends and strove to guarantee its survival. But it was always an intervention kept within certain limits, marked by his own deductions, in many cases obviating historical fidelity and therefore documentary value, which often caused him to incur in a "historical falsehood". The experience of the aftermath of the war made him see the concept of "artistic value" as a priority, beyond the "historical" value, anticipating the ideas brought up years later by Cesare Brandi, with his "theory of restoration" and the contribution of "critical restoration" after World War II. However, his historicism and archaeological pursuit of the "original state" prevented him from falling into the excesses of modernity in "distinguishing the new from the old"; on the contrary, he always sought a logical, rigorous and beautiful link with the past. Continuity in the choice of material so as not to alter the formal and chromatic qualities of the ensemble was a constant feature of his methodology. And in this way, if imitation was

permitted in order not to clash with the original building, reconstructions were justified, according to Menéndez-Pidal, in exceptional cases such as war or collapse. Overcoming the traumatic events of the Civil War had made him believe wholeheartedly in this opinion, which might seem risky but which was necessary in the postwar interventions. A token of this is the Holy Chamber of Oviedo cathedral (1938-42) or the tower of San Tirso de Sahagún in León (1949-72), both of which were completely replaced "down to the slightest detail" by a scientific and archaeological process. Although these works may be justified, other cases, such as the reconstruction of the ruins of Santa María de Bendones in Oviedo (1958-71) or the bell towers of San Pedro de Nora (1952-64) aroused serious misgivings about the wisdom of his method. So there was a broad field of experimentation between the different sensibilities that existed in Menéndez-Pidal's evolution that he explored in his interventions. His skill resided in his ability not to stick to a single criterion but to take advantage of all fruitful and relevant ideas, understood as accumulative or alternative but not exclusive. In spite of the interpretative excesses to be found in many of his interventions on monuments, particularly in his last period, we must not underestimate the many fortunate works we owe to his personal way of understanding restoration. Perhaps the most transcendental criticism is the mistake he made, quite common at the time, in seeing his intervention as an isolated and definitive act on the history of the monument. Many of his interventions attempted to restore the work to a complete, perfect and closed state, in some cases with the typical discriminations of modern practice, but in many others, with the licences contemplated in his own personal methodology. The conviction of his views and his profound knowledge of the monuments made him see himself as capable of restoring the building to its former splendour, without understanding his true role as a link in the long chain of people who care for each one.

Biographical note:
Luis Menéndez-Pidal was born in Pajares del Puerto (Asturias) in 1893. He studied at the School of Architecture in Madrid, where he graduated in 1918 with the second highest mark of his promotion. There he received his first influences in the world of restoration, from two projects professors, Vicente Lampérez and Leopoldo Torres Balbás. Both architects stirred up the then languishing debate about the restoration of monuments in Spain, holding opposite positions that were very enriching for the education of our man. His final dedication to the field of architectural restoration took place in 1923, when he was commissioned by the Ministry of Public Instruction and Fine Arts to restore the Monastery of Guadalupe in the province of Cáceres. Even before the Francoist period, he was given another project that was to set him even more solidly on this path, this time in Asturias: the restoration of the pre-Roman monument Santa María del Naranco (the Palace of Ramiro I) in 1929, a token of the success of his work. Gómez Moreno's intercession was a key factor in his receiving this commission and was the cause of the clear "historical" and "archaeological" influence he assimilated during the project. After the uprisings in Asturias, the outbreak of the Civil War surprised him in Madrid. His political inclination towards the nationalist side put his life in peril several times. During this time, Luis Menéndez-Pidal had the militarised post of Agent of the Service of Artistic Recuperation, dedicated to saving the country's badly damaged artistic heritage. In December 1937, by the direct indications of Pedro Muguruza Otaño, he was appointed Representative of the Informative Board of Reconstruction by San Fernando Fine Arts Academy, and he held this position until the end of the war.
This appointment involved looking after the monuments in the Cantabrian Zone, and in particular Asturias, during the Civil War, and this connection continued to exist until the end of his days. Around that time, Luis Menéndez-Pidal was in charge of the protection and repairs of many monuments that received sufficient attention to stop them falling into rack and ruin; among others, it is worth mentioning especially the continuation of the reconstruction of the Holy Chamber, which had been destroyed in 1934 during the uprising, and whose reconstruction had initially been organised by Gómez Moreno and Alejandro Ferrant. His appointment to this new job in 1938 meant he would impose his own ideas and methods until its conclusion some years later. The end of the war (1939) saw the start of frenzied activity to save the damaged heritage; and Regiones Devastadas included Luis Menéndez-Pidal among its select architects for its double strategy of reconstruction and propaganda. Now living in Madrid, he was made Commissioner of the Cantabrian Zone that same 1939, which meant he continued the tasks he had undertaken during the war. In his new post he carried out the vast and profuse task of reconstructing and repairing the monuments "adopted" by the Service. Among the monuments selected by Regiones Devastadas and placed under the care of our architect were: Oviedo cathedral (where the spectacular reconstruction of the spire was performed), Covadonga Sanctuary (where the Cave was totally reconstructed), the collegiate church of Arbás, in León, and countless little Asturian churches (Santa María de Villaviciosa, San Julián de Prados, San Salvador de Fuentes, San Salvador de Priesca, San Pedro de Nora, Santo Adriano de Tuñón and others), which received vital urgent repairs that conserved their architecture under the economic hardships of the time.
After the war, he presented several works at exhibitions in Spain and abroad and got to know European cultures by travelling around Italy, France, Belgium, Portugal and Germany. It was from Italy and France that he extracted the greatest influences in the field of architectural restoration. There he discovered the "scientific" debate that was going on at the time and the influence of the 1931 Athens Charter, and at the same time he studied the works and doctrines of Viollet le

Duc, Camillo Boito and Gustavo Giovanonni.
Back in Spain, at the National Fine Arts Exhibition in 1941, his work received the recognition of the new political institutions with the First National Medal for Architecture as an award for his seventeen years' work on the restoration of the Monastery of Guadalupe. That same year he was appointed Monument Conservation Architect of the Service for the Defence of the National Artistic Heritage, and he was put in charge of the First Zone (comprising the provinces of Asturias, León, Zamora, La Coruña, Lugo, Orense and Pontevedra). He held this post until the end of his days. He took over the post from Alejandro Ferrant, who, less favoured by the institutions, was put in charge of the Cantabrian Zone. Besides, our architect continued to oversee the restoration of the Monastery of Guadalupe, which he had begun before the Civil War and on which he continued to work extensively for the rest of his life. In his new post, he was in charge of all the monuments in the First Zone, whose conservation depended exclusively on his criterion. His privileges included absolute autonomy in deciding which monuments to work on and how, and in distributing the funds assigned to the service as he saw fit. His freedom to act and plan was absolute and so were the works he performed on the architectural heritage.
During those years, Menéndez-Pidal had control of the most important monuments in this large area, among which it is worth mentioning especially: the cathedrals of Oviedo, Zamora, León. Santiago, Mondoñedo and Tuy; the monasteries of Carracedo, Montederramo, San Martín de Castañeda, Ribas de Sil, Osera; the churches of Santiago de Peñalba, San Miguel de Escalada, Santa María del Campo and the pre-Roman churches in Asturias, to mention but a few of the buildings he restored during that time.
Apart from his busy professional agenda, his great capacity for work permitted him to produce some publications about his personal experience and research into the monuments he worked on, a token of which are the well known works "Destrucciones habidas durante…" (1941), "Notas sobre la reconstrucción de la Cámara Santa" (1941) or "Los monumentos de Asturias, su aprecio y restauración desde el pasado siglo" (1954). His tireless activity and permanent connection to his native Asturias was first acknowledged when he was appointed a member of the Institute of Asturian Studies in 1951. With a monograph about Covadonga Cave, he explained the restoration of that site and at the same time reinforced the double religious and artistic criterion he had kept in mind while restoring it, as in most of the works he performed.
However, his definitive recognition in the national cultural milieu was his appointment to the Royal Fine Arts Academy of San Fernando in 1956 (with medal number ten, under the direct sponsorship of Pedro Muguruza). His well known and widely publicised speech "El Arquitecto y su obra en el cuidado de los monumentos" contained his ideological and methodological convictions about restoration and demonstrates his perfect knowledge of the modern debate about restoration.
Our architect continued to look after the monuments in the First Zone and to restore the Monastery of Guadalupe during the final stages of his professional career from his privileged position in the national panorama, operating with greater and greater freedom on the monuments and with a clearly interventionist evolution as he approached the end of his career, assuming risks he had avoided in his early years. So his life went on, dedicated exclusively to taking care of his monuments until he had a serious accident in 1973. It was on one of his countless visits to the works, this time on the church of Santiago de Peñalba in the Valle del Silencio in León. A few months later he died, on Friday 28th February 1975. He was buried at the collegiate church in Arabs (León), one of his most dearly beloved monuments, thus following the medieval custom and his devout spirit. There he lies, in a monumental tomb that he had himself prepared years before.
Luis Menéndez-Pidal was a cultivated man and a great scholar of the History of Architecture and Art. Both disciplines provided him with the necessary basis to act in his work with the self assurance that he always showed. Methodical and vehement, his strong character was the cause of constant attention to "his monuments" and won him more than one opposer to his doctrine, often giving rise to friction and obliging him to defend his position. He was greatly admired as an architect at the time. Apart from political ideals or adhesions, always debatable, his staunch intervention principles and his confidence in his "method" provide us with what we consider a perfect tool to study a fundamental period in architectural restoration in Spain, often rejected because it is scarcely known. Menéndez-Pidal's restorations, in this context, provide a great deal of information about the period during which they took place (from the reign of Alfonso XIII, during the Second Republic and throughout Franco's regime). In a word, Menéndez-Pidal devoted his life to looking after his monuments, with monastic dedication, as he said himself: "…since God did not bless me with children, he made me dedicate myself with absolute abnegation to the monuments that are my offspring" (1974).

Fernando Vegas & Camilla Mileto

RAFAEL GUASTAVINO: A HISTORY OF ARCHITECTURE FROM BEHIND THE SCENE

There have been some absolutely transcendental builders, engineers and even architects in the history of architecture whose names are unfairly concealed behind the names of the main architects of projects for different circumstances. A Spanish proverb says that credit is not always given where credit is due. This has been so for some time now: let us mention the importance in Walter Gropius' work of the architect Adolf Meyer until his untimely death in 1928; or the British Maxwell Fry in both Gropius' work in England and Le Corbusier's plan for Chandigahr; Pierre Jeanneret's human touch in his cousin's

oeuvre; the importance of the engineer Komendant in all of Louis Kahn's work; the irreplaceable presence of Félix Candela as a designer of works that paradoxically do not bear his name; or Ove Arup's fundamental in furthering the careers of many architects, like Berthold Lubetkin, among many other examples. The case of Rafael Guastavino Senior and Junior is similar. Their influence and direct contribution to the history of architecture both in Spain and the United States is not accompanied by the recognition that has so far been given their work.
Rafael Guastavino Moreno (1842-1908) was born in the city of Valencia and moved to Barcelona in 1981, where he studied to be a master builder and was not long in developing a professional career as an architect and builder of both residential and industrial projects. From the outset, his architecture was characterised by an extensive use of thin masonry vaults in combination with the new cement mortars that at first he had sent from England. This system was better than the traditional vault, limited by hydrosensitive gypsum and slow setting lime, thanks to the waterproof quick setting cement mortar. The stability and resistance of this cement mortar made it possible to increase the diameter of these vaults whose thrust could be absorbed by inserting metal beams.
In 1882, at the height of his professional career in Barcelona and during a crisis in his marriage, he decided to emigrate to the United States with his younger son, then ten years of age. After a time of economic and cultural hardship, he gave up his category of major architect and devoted himself to being a builder along the East Coast of the country, thanks to his collaboration with famous architects like McKim, Mead & White, Bertram Goodhue, Ralph Adams Cram, Cass Gilbert, Henry Hornbostel, Carrère & Hastings and Warren & Wetmore, among many others. St the end of his career, even Frank Lloyd Wright was on the verge of hiring his company to cover one of his typical architectural spaces. His building system of timbrel vaults was the result of the need to create representative spaces in public buildings at the time, endowing them with structural resistance and making them fireproof, and was also economical. Before he was even eighteen, his son Rafael Guastavino Expósito (1872-1950) became more and more involved in the management of the business, with the invaluable help of the accountant Blodgett, who introduced a certain amount of order in the anarchy of the company's papers and accounts. He took over the management so easily that, when his father died after partial retirement in 1908, the clients did not notice any change in the services rendered by the company. What is more, Rafael Guastavino Junior modernised and updated the company by creating as many patents as his father had before him, especially as regards the acoustics of the firm's famous vaults.
After twenty years of great prosperity, commissions began to wane in the nineteen thirties because of the new styles, materials and building methods that were gradually becoming popular in architecture. This was the inexorable announcement of the end of the company, which closed down in 1962, twelve years after the death of Rafael Guastavino Junior.

Examples of buildings erected by the Guastavino Company

Of the thirty buildings that Rafael Guastavino designed and constructed in Catalonia, scarcely ten or so remain standing today, the most outstanding of which because of the good state of conservation are the factory of Batlló Hermanos (today the Diputación Provincial and an Industrial School) and the Teatro La Massa in Vilassar de Dalt. The rest of the residential buildings have been seriously altered in several interventions in the past.
In the United States Guastavino and his son erected nearly a thousand buildings or part of them in 28 different states, along with about ten in Canada. Unlike his work in Spain, many of them are churches of different religions and important public buildings. From a long list of extraordinary buildings the following deserve special mention: different lecture rooms, academies, colleges and chapels of the universities of California, Chicago, Columbia, Cornell, Harvard, New York, Pittsburgh, Virginia, West Point and Yale, among many others; some twenty or so schools; about forty banks, including the Federal Reserve Bank in New York; city councils or municipal buildings in Binghamton, Buffalo, Cleveland, Plattsburg, Detroit and government buildings in Washington, Nebraska, New York, Charleston; almost two hundred temples, synagogues and churches, among them the cathedral of St John the Divine in New York; a dozen hotels, sixteen courthouses and some ten public libraries, including the ones in Boston and Washington; fifteen museums, the Metropolitan in New York, among others; over twenty hospitals, one of which is Mount Sinai, also in New York; sixty mausoleums and commemorative monuments; some thirty railway stations, including the famous Grand Central and Pennsylvania in New York, and those of Chicago, Buffalo, Detroit, Houston and Toronto; sixty residential buildings, mainly in New York; theatres, religious seminaries, stables, post offices, private clubs, spas, offices, garages, planetariums, elaborate staircases, etc.

The Guastavino stock

The figure of Rafael Guastavino Senior, born the same year as another great builder, François Hennebique, arose as a result of the combination of several factors: his familiarity with traditional timbrel vaulting thanks to his family background in his childhood and youth, both applied to monumental and vernacular architecture; his interest in structural research encouraged by Professor Juan Torrás i Guardiola, an excellent master of several generations of architects; his deep knowledge of building materials, and particularly mortars, ceramics and iron, as a result of his early work experience and later research; his knowledge of the history of architecture and building and his extraordinary skill at marketing and publicity, which explains the rapid success he enjoyed both in Barcelona and the United States after starting from scratch.

Rafael Guastavino Junior inherited from his father his knowledge of materials, techniques and structures for the perfected construction of thin walled vaulting and some of his commercial skill. He opened up new lines of research and application of vaults with his patents of ceramic tiles, artificial stone and gypsum with acoustic properties, which prolonged the life of the company even when the crisis arising from the introduction of new industrial building procedures or materials like concrete arrived on the scene.

Contribution to the history of architecture

Their contribution to Catalan architecture in particular by means of the Batlló factory, built entirely with timbrel vaults for prevention against fire can be clearly seen in the popularity of this technique among the Moderniste architects of the next generation, who were shown this industrial building as a paradigm when they were still studying architecture. Their contribution to Spanish architecture occurred indirectly through other figures who knew him personally or who knew all about him from his work, as is the case of the architects Mariano Belmás Estrada or Luis Moya Blanco, respectively.
His magnificent contribution to the construction of the city, the public space and the architectural identity of the United States by means of the thousand or so buildings he erected in America (over 300 of them on the island of Manhattan) is recorded in the article by Mar Loren Méndez published on these pages. We can state without a shadow of a doubt that the character of many of the emblematic spaces in Manhattan is due to this Valencian architect's skill in building vaults.

Issues pending investigation

Such an important architect does not suddenly appear from nowhere but is the fruit of his own expertise linked to a certain education and context.
Investigation into the background, context, training and the melting pot of Rafael Guastavino Moreno still requires to be delved into in order to understand this phenomenon in the history of architecture.
The files of the Guastavino Co. that Professor George R. Collins bought from the company when it was in the wind up process, safely guarded in the Avery Library at Columbia University, New York, represent a mere fraction of the information the company possessed. Research into each building under restoration individually is bringing to light a great deal of information to add to what we already know.
The extraordinary quality and composition of the mortars in Guastavino's works is still a mystery in spite of the attempts made so far to discover the secret of the mixtures, aggregates and procedures used. Greater knowledge of these details will not only allow us to evaluate his technical contribution but also to carry out more discerning and sensitive repairs on his vaulted spaces.
Finally, although he worked mainly in Spain and the United States, Guastavino's work can be found in twelve countries all over the world.
In might be especially interesting to examine the buildings he erected in Mexico, which, it seems, are scantly documented and partly unknown, after his courtship of and second marriage to the Mexican Francisca Ramírez.
As regards this point, it would be worth delving into the system of commercial promotion that led to such remarkable success.

Presentation of articles in Loggia

In this issue of Loggia, Arquitectura & Restauración, three articles on different examples and aspects of the restoration of Guastavino's works are presented. The article by Mar Loren Méndez provides an overview of Guastavino's work in New York from the impact he made on the city to the first preliminary studies related to research and restoration works, some of which she analyses and examines in context. Of special interest is the section on the evolution of the company's intervention on acoustic vaults, comprising attitudes that go from the complete obliteration of their auditory properties to the painstaking conservation of their acoustic appearance and qualities.
Charles di Santo's article tells us about the experience of restoring the vaults of Queensboro Bridge in Manhattan, a really interesting case because of the number of stresses to which it was subjected and because of the simple, respectful and elegant solutions applied, some bordering on pure genius. Robert Silman's article evaluates the excellent behaviour of these vaulted structures in fires, thanks to his experience in restoring several buildings by this architect and in particular the famous vaults of the Oyster Bar in Grand Central Station in New York, with interesting references to the tests of structural resistance and fireproof capacity that Guastavino commissioned over a hundred years ago.
We trust that this little introduction to Guastavino and Co. and their buildings in New York, thanks to the secrets discovered in these preliminary studies and restoration projects, contributes to the appreciation of this extraordinary architect and the substantiation of his work in the history of architecture, always in need of new interpretations.

M. Mar Loren M.

WORK PERFORMED BY THE GUASTAVINO COMPANY IN NEW YORK. CONDITIONS & RESTORATION TODAY

This article offers, in the first place, some ideas about the contribution of the Guastavino Company to the History of US Architecture, from the viewpoint of the conception of thin masonry structures to generate public space with architecture of urban dimension. From this viewpoint, which complements the more general reading of his role in the transference and modernisation of a specific building method like timbrel vaulting, we can understand the importance of his work today, when it is undergoing a gradual protection and restoration process, which began in the sixties and became more generalised in the nineties.
The pragmatic resources of the American system have been

implemented and a line of research has commenced for the specific purpose of restoring and rehabilitating the Company's buildings in the United States. Furthermore, the almost universal ignorance of the timbrel vaulting system in the US combined with the way the profession is considered there have brought about a tendency towards specialisation, so that both the diagnosis and restoration of the Company's buildings have been left to a small group of enterprises in this sector. Finally, the durability and solidity of the Guastavino vaults have aroused great admiration and involved an approach of almost blind faith in their quality in their restoration and interventions that were mostly limited to general diagnoses or epidermal replacement of the vaults.

Brief notes about Guastavino's contribution to the american city

Since he began to work in Barcelona in the second half of the 19th century, Rafael Guastavino i Moreno dedicated himself to the renovation of architecture, and members of the generation that followed like Dominic i Montaner described him as an "artist with exceptional skill" whose architecture was "revolutionary". His move to the United States in 1881, his constitution of a building company, his modernisation of the vault system and his entrepreneurial endeavours led to something more than a technological development; they were the first stable and recognisable item in the modern American city that chronologically and formally coincided with the historic city.

The Company's greatest creative and productive moment, 1890-1940, was simultaneous with a fundamental period in the development of the United States as a nation, with a widespread pursuit of "Americanism" accompanied by in depth changes in the democratic paradigm. By participating in the great buildings of the time, he signalised, with his geometry, tectonics, scale and technology, a new concept of public space excavated in his architecture, conferring upon the interior of buildings a new urban dimension.

The Modern Metropolis/The Historic North American City/Vaults as Generators of Public Space

The US nation had founded its bases on Jefferson's 18th century rural myth. Intellectuals and activists as important as Thoreau or Poe saw the city as a kind of cancerous growth. This anti urban conception was opposed in the industrial US of the 19th century, where the city was the perfect medium for the more aggressive capitalist system. Its reticular implantation in the territory sought no other end than the efficient distribution and control of private property. The result is the provisional city, criticised by Henry James on his return from Europe; a city with no history and with no time for history. This nostalgic perception reflected the reality of the US metropolis, immersed in a continuous cycle of destruction and reinvention. New York is undoubtedly the paradigm of the city as a productive medium. Its 1811 Plan foresaw the filling of the whole reticle, with the exception of the central square that was later occupied by Central Park, affirming that free space was not necessary for total functional optimisation. The limited effectiveness of the reticle became critical and the first draught of the metropolitan plan in the early 20th century contained the academic ideas of the City Beautiful movement. Besides identifying its functional shortcomings, the plan represented a new commitment to the public by proposing the incorporation of spaces for collective activity into the urban weft. However, the pressure of private property impeded the insertion of public spaces such as parks or boulevards. Since this public space could not be built into the city reticle, it was excavated in the centre of the buildings and this is where the Guastavino Company made its great contribution. The large vaulted spaces built by the Company are really authentic public spaces in the North American city, unfailingly identified with the contemporary city, which for the first time attempts to become a historic city. The Company's participation in the qualification of these spaces became generalised in each and every chapter of the building of the city, which is after all the construction of its identity.

A large percentage of these buildings made by the Guastavino Company have today been catalogued and refurbished, thanks to the efforts of citizens and institutions to conserve what they consider their Heritage, their historical and architectural identity. These architectures form part of the historic memory and in time have become the principal landmarks that Americans and foreigners recognise as a fragment of the very definition of the USA. The gradual process of discovery, appreciation, cataloguing and restoration of their works have opened up a line of research in the US focused on understanding these constructions in order to repair them.

American pragmatism.
Restoration as a major line of research

The Americans were undeniably the first to carry out monographic studies into the Guastavino Company. So far the study of the Guastavinos has focused on the discipline of Construction regarding their role in the systemising of vault building. The 1968 article by George R. Collins is an essential referent of all the current monographic texts, the only precedent being the article published in 1901 by Peter B. Wright about the Guastavino Company in a specialised building magazine.

Columbia University is at the head of this research, under the directorship of Professor George R. Collins, thanks to the fact that it possesses the collection of material of the Guastavino Company it purchased before it closed down in the sixties, combined today with the Avery Library's Guastavino Collins Collection. The fact that the US is at the head of this research is for heritage reasons: since the seventies buildings of fundamental importance in the American architectural world have required repairs and happen to have been built by the Guastavino Company. Theodore Prudon's informative article opened up this line of research in 1989.

In the nineties the growing need the US felt to understand Guastavino's building systems in order to repair them gave rise to academic studies in postgraduate programmes at American universities, what is known as "Master Theses", addressed above all at constructing a corpus of knowledge for restoration professionals. In 1992 Anne K. Milkovich was working at Pennsylvania University about aspects of durability and conservation of several buildings the Company had built in Philadelphia. In 1995 Kain M. Link drew up a more thorough study at Oregon University that focused on the analysis of restoration works following the case study method. The author speaks about the almost total ignorance of the timbrel vault and her main aim is to provide knowledge for professionals performing restoration works on any of the Guastavino buildings. She begins by speaking about aspects like reversibility in the restoration of Guastavino buildings although her final conclusions are of a general nature and not specifically about the vault system. That same year Richard Pounds proposed a detailed study of acoustic materials and Daniel R. Lane of the mortars used. The latter addresses a subject of major interest for restoration: the complexity of the materials used by the Company in its mortars, revealing the presence of gels, several additives and even the use of lime mortars in certain works. Professionals like Robert Silman, from Robert Silman Associates, an engineering consultancy firm that has intervened in the diagnosis and repair of many Guastavino buildings, confirms the Guastavinos' use of "secret ingredients" in their mortars that still have not been identified today and that Stilman wittily compares to Coca-Cola because of the care taken keep its ingredients secret

In 1999, due to the growing interest in the Guastavinos' work, Columbia University held the first series of professional and pragmatic monographic lectures. The sponsor, New York Landmarks Conservancy, is an organisation whose objective is the restoration and conservation of New York's architectural landmarks, and therefore the contents of the lectures were technical and delivered by professionals who have worked in the restoration of Guastavino buildings in the United States completed by others, where aspects of a general nature such as the acoustic materials or the behaviour of the structures during earthquakes are analysed. The lectures were published in the monographic issue of the American magazine The Association for Preservation Technology Bulletin (APT Bulletin).

It is true that the work of Rafael Guastavino i Moreno is known in Spain thanks to the studies on cohesive building carried out in the nineteen sixties and seventies, with the uninterrupted production of authors like Belmás, Goday and Maya Blanco, who appreciated concepts like structural simplicity and constructive clarity in his work. Nevertheless, these authors did not write specific monographic studies about his work and it was not until 2001 that the first exhibition was held with the first monographic text about the Company's production. The contents, however, are rather academic and do not address the specific field of restoration.

It was not until December 2004 that a specific section on "the Restoration of Rafael Guastavino's vaults in New York" was included in the 27th edition of the Course on the Intervention on Architectural Heritage by Barcelona Council, directed by the Professor of Architectural Constructions José Luis González. The author of this article shall provide an overview of the importance of Guastavino's work in the history of US architecture and the restoration of his work. Charles DiSanto explains his intervention on Queensboro Bridge and Kent Diebolt, from the firm Vertical Access, who is an expert on the works to be restored, explains his deep involvement in the diagnosis of the vaults. Finally, in June 2005 a seminar on restoration of architectural works was held in New York and contact was made with the people most involved in the recuperation and diagnosis of Guastavino's work and a large number of buildings were visited, some of which are currently being restored.

Restoration of Guastavino vaults. The case of New York

An approach to the restoration process of Guastavino's works

Both authors and professionals in the field of restoration in the US coincide in three fundamental aspects to understand the way to approach Guastavino vaults.

1. In the first place, they all agree as to the ignorance that exists regarding the building system used. The Guastavino Company kept it quite secret, and the fact that other companies could not use the system because of patent regulations hindered its diffusion, and, besides, it did not belong within their building tradition. Richard Pieper went so far as to describe it as an "esoteric historic construction technology" among other voices that cry out for specialisation in the specific field of the Guastavino vault.

In the nineties there emerged a small group of professionals in the sector involved in restoration works whose companies are now often linked with the Guastavino Company.

Such is the case of Robert Silman, considered the greatest expert in the structural diagnosis of the Company's works. Although his vast experience in this discipline permits him to establish general guidelines, he himself admits he has no objective tools for calculating the behaviour of Guastavino vaults. In the process of his structural analysis, he describes two actions:

a) Those that attempt to calculate the load that a vault is capable of resisting according to its geometry and thickness at different points. In a lecture delivered 22nd June in New York, he stated that at the present time there is no mathematical model to allow this nor a specific line of research, as these would be theoretical studies that the clients are not as yet willing to promote.

b) The second and more common action focuses on studying the degree of stability and safety of a structure after it has suffered some specific damage. Robert Silman admits he does not know how to analyse Guastavino vaults and says he depends on his intuition and a blind faith in the system. This total confidence in these constructions leads him to the conclusion that the professional should aim to restore the structure to its original state, alleging, "if they have proven stable, resistant and solid for around a century, they will be able to resist another hundred years if we restore them to their original state". It is a rather disconcerting statement, for if

one does not know how seriously an agent has affected the structure, one can hardly restore it to its original state and much less predict the lifespan of the structure if it is restored to that state.
2. Faith in the Guastavino Company's work is the second aspect about which the professionals involved in restoration hold a unanimous view. Without exception, they express their total faith in its architectures, praising the high quality of these constructions as regards structural resistance, solidity and durability.
James Rhodes, an architect from Preservation Design in New York and involved in the restoration of different works of the Guastavino Company for twenty years as an architect of the firm Beyer, Blinder & Belle, said that the Guastavinos undoubtedly had a better understanding of building than American architects and engineers today. This expert in restoration underscores their dominion of material and geometry in works of high quality and great sophistication where the structural system was at the same time a decorative system.
Thanks to this unanimous faith in Guastavino's work, the tests of loadbearing and fireproofing made by the New York Department of Building, to which the Company submitted its products in April 1897, are used in the diagnosis of restoration works today. Robert Silman's firm concluded that the vaults of the Oyster Bar at the Grand Central Terminal were still stable and resistant after the fire that broke out in 1997 based on the Company's tests. It was also concluded that the loss of the first layer of tiles was not a consequence of the loss of resistance or stability but a result of the contrast in temperature between the extreme heat of the fire and the water used to extinguish it and the pressure of the water. This conclusion was not reached after performing a stress test on the vaults over the Oyster Bar but again on the basis of the results of the Company's tests, where the vaults also lost the first layer of ceramic tiles in the fire, although when stress tests were later carried out it was found that the loadbearing capacity of the vaults remained undiminished. Therefore 1800 pieces were replaced in the Oyster Bar on the consideration that the vaults themselves were structurally stable. Some of the pieces that came loose were reused, although those directly damaged by the fire had to be replaced with new ones. In short, the diagnosis and repair works were limited to checking which pieces had come unstuck from the second layer –in the next section we shall see what this analysis consisted in– and then removing and substituting them. The structure was not subjected to a structural analysis or repair works. The same applies to most of the restoration works on Guastavino vaults, where, thanks to the great solidity and durability of the system and the confidence it arouses, only superficial repairs have been carried out.
This is also the case of the main hall of the Immigration Centre on Ellis Island, where Guastavino replaced the interior of the ceiling of the vestibule after it collapsed in 1916, although the original roof was respected. Guastavino covered the inside with rectangular groined vaults of different width alternating with those that define the entry of light, thus achieving surfaces of different curvature and creating gradients in the luminosity of the space. This building was closed for over thirty years, since 1954. Because of its historic importance in the construction of the identity of the American people –over 40% of Americans are genealogically connected to the immigrants who went through Ellis Island– it was made part of the National Monument of the Statue of Liberty in 1965. From 1986 to 1990 it was rehabilitated as the Immigration Museum. The building was in a very poor state of repair and due to the total loss of insulation in the roofs and walls, it was literally wet, and particularly in the main hall water was leaking through the Guastavino vaults onto the floor. Again it was a case of a construction built by the Company subjected to external agents derived from pathologies located in other elements of the building. After drying the building with pressurised air for 15 months, the vaults were diagnosed. It is surprising to note that the structural diagnosis carried out after suffering such serious damage was limited once again to a mechanical analysis by hitting the pieces in the first layer with a pneumatic hammer. The results confirmed the reputation of Guastavino vaults, for the restoration consisted in substituting 17 ceramic pieces out of the 28,282 that form this impressive dome.
In the nineties the hall built by the Guastavinos was expressly catalogued, since it was considered the most representative element of the original building although it had been built at a later date. It is interesting to note that even though it is the largest space, it was decided not to use it to exhibit material: The Guastavinos' structure and the historical value of this important building that witnessed the formation of the nation is thus the major exhibition piece.
3. In the third place and as is becoming evident from the works quoted, everyone agrees that the causes of the deterioration of the structures are almost entirely due to agents that have nothing to do with the vaults. Therefore, their dilapidation is not related to an error of calculation, bad building methods or the poor quality of the materials used. External agents such as fire, water or vibrations have put the Company's constructions to the test. Even in extreme conditions, the vaults and domes built by the Guastavino Company are still amazingly long lasting and solid. Kent Diebolt, from the firm Vertical Access, emphasises the magnificent state of the Guastavino structures after years of total neglect. In these cases it is external agents that have caused deterioration in the vaults, and they have resisted magnificently even in such extreme conditions.
In the specific case of the vaults that the Company built under Queensboro Bridge, the deep cracks and extensive loss of material are due to the vibrations caused by traffic from the principal metal structure of the bridge and rusting and water infiltration. Even so, in a lecture about the restoration of the structure delivered by his firm, Walter B. Melvin, Charles DiSanto said the solidity of the vaults, which have suffered external agents for years, was surprising and it is unlikely that any

other sort of structure would have withstood similar conditions.
In the case of the Battery Maritime Building, cracks have been detected in the vault built by the company in the loggia located on the first floor. Daniel Lane, an architect of the firm Pokorny & Associates, explained that these cracks are due to the differential subsidence of the building. The vault can be seen to have suffered slight damage at the corner where the main structure, also metallic in this case, has descended and the vault in this case has conserved its rigidity and remained in place, although it no longer rests on the structure.

The most suspect material: Acoustic material in a religious space. Light and shade in the products patented by the Company.

The acoustic products patented by the Company after the nineteen twenties are the most often doubted proposal and as a result the most often subjected to restoration works specifically addressed at altering the characteristics of the product offered by the Company. Although patent 464,563 Cohesive Ceiling Floor is a token of Rafael Guastavino i Moreno's concern about the acoustic qualities of his materials, it was his son Rafael Guastavino i Expósito, with the collaboration of Wallace Clement Sabine, who patented and manufactured materials that substantially altered the acoustic behaviour of the architectural space. Indeed the Company's use of acoustic materials became generalised for the interior of churches and it was the architect Ralph Adams Cram who convinced Guastavino to improve the absorption coefficient and thus reduce reverberation inside ecclesiastic spaces. It was this architect who commissioned Sabine to measure the absorption coefficients in the chapel of the military academy West Point, built by the Guastavino Company in 1911.
After manufacturing and installing experimental material in the First Baptist Church in Pittsburgh and thanks to two years' research with Sabine, the Company patented the Rumford Acoustic Tile in 1914. This was a ceramic tile that had six times more absorption power than any masonry or ceramic construction of the period thanks to the porosity it acquired during the manufacturing process. Made of clay, feldspar and vegetable soil (which allowed pores to form when burnt), it was very good at absorbing sounds in the frequency band of the spoken voice (500-2000). However, it was not very profitable to manufacture it because of the lack of homogeneity and quality achieved in its production. Two years later they patented a new product, Akoustolith Cast Stone. This was not a ceramic material but portland cement mixed with sand and ground brick or stone with a grain similar in size to sand and water. The graded porosity achieved in its manufacture permitted it to absorb a very broad band of tones and frequencies, a decisive factor for the product's market success. In this way, the Company offered an solution integrated into the constructive process, which did not make the work much more expensive since the same pieces that have a structural and aesthetic function were now endowed with acoustic properties as well.
However, in spite of the success the products enjoyed in the first decades of the 20th century, these materials actually prepared the liturgical space in the best possible manner for the spoken word although they drastically impaired their behaviour for music. Indeed by indiscriminately increasing the power of acoustic absorption, nuances and sonorous continuity disappear and, in other words, the ideal equilibrium between the spoken word and music is not achieved. Although in the mid 20th century it began to be crucial for churches to have good acoustics for musical interpretations and the first interventions were carried out on Guastavino's work, it was not until the seventies that congregations started to use their temples as concert halls either for charity performances or celebrations of the community or a institution. Saint Thomas Church on Fifth Avenue, designed by the firm Cram with Ferguson and Goodhue in 1914, for which a very interesting asymmetrical solution is applied to a little site on a corner, underwent a rather aggressive intervention in the seventies, in which 100% of the Rumford acoustic tiles were sealed with a solution of Kyanize Clear Latex Sealer (L-0560). The pores of the Rumford pieces used both in the vertical surfaces and the vault covering the church considerably increased the reverberation time of the architectural space, thus resulting in greater quality for the music played there although it lost quality somewhat for the spoken word. Besides, this material gave a shiny finish to the surface, so that it looks almost metallic when illuminated, changed its texture completely and provided a rather unfortunate overall effect that has still not been resolved.
In the Church of Heavenly Rest, also on Fifth Avenue, although a little further to the north, it was also decided to change the acoustic conditions, but in this case a detailed study of the acoustic behaviour and the materials to use was carried out beforehand. Although the acoustic study was performed in the late seventies, the restoration works carried out by Allen, Harbinson & Associates took place in the nineties, and by that time sensitisation had taken place regarding the need to respect the original building in such interventions. In this case, Klepper Marshall King Associates Ltd., acoustics experts who had worked on quite a few places where the Guastavino Company had installed their products, first analysed the acoustic behaviour of the church. Their advice was to seal 75% of the Akoustolith acoustic pieces in the church. This measure was meant to solve two problems: on the one hand, to make the space suitable for musical and choral events, diminishing the absorption of medium and high frequency sounds, but also to achieve greater equilibrium and homogeneity in the sonorous distribution of the whole church. In fact, in the tests performed, there were found to be differences of up to 9 decibels in different places in the interior.
This intervention also included a thorough study and at first it was concluded that a coat of L-0560 could be followed by a coat of Kyanize L-0561 to make it matt again. However, its use was banned before the works were

performed because it was toxic during application. In 1994 the firm ProSoCo, specialised in cleaning, restoring and protecting buildings, carried out tests with different materials because there was no specific product for the Church of Heavenly Rest's problem at the time. After performing the tests, it was decided to use a product normally employed on exteriors to prevent leaking, also made of latex. Three undiluted coats were applied and the acoustics was improved without altering the texture and matt appearance of the Akoustolith.

Nevertheless, other religious communities still give priority to the spoken word in their churches without any electronic installation. Such is the case of the Jewish congregation, the vertical surfaces of whose main place of worship, the Emanu El Temple, were covered with Akoustolith tiles. In this case, the Akoustolith does not attempt to imitate stone, and although the basis of the material is portland cement, both the format and the colour should have a ceramic appearance. The pieces are about 50 cm tall to accentuate the verticality of the space. The pieces were made in more than ten different shades. Here the architecture firm Kohn, Butler & Stein collaborated with the Guastavino Company again to emphasise the verticality of the temple by placing the pieces at a gradient with the paler colours at the bottom and the darker at the top. After every four pieces, golden strips also made by the Company were inserted to emphasise this effect and to enhance the appearance.

This temple is now undergoing global restoration works worth 25 million dollars directed by the firm Preservation Design, founded by the architect James Rhodes. In the case of the Akoustolith tiles, the community underscores this material's great capacity from an acoustic point of view and has no intention of modifying its characteristics. Far from it: when considering cleaning them, they were afraid that the use of any product containing detergent or even water might damage the colour, texture or porosity of the tiles and therefore their capacity for acoustic absorption. For that reason, James Rhodes himself states the cleaning was done dry and entirely by hand, one piece at a time, with very hard sponges called wishab imported from Germany. The total surface covered with Akoustolith is 350 square metres. In one hour a worker can clean 10 square metres using seven wishabs.

Diagnosis and characterisation of the Company's constructions.

Given the ignorance concerning Guastavino's work, the diagnosis phase was a key moment in the intervention on their constructions. The analyses made for the diagnosis of the Guastavino vaults to discover their state of repair are of three types:

1. Visual analysis. Only a visual analysis is possible in areas of difficult access. Video cameras are used to monitor these large surfaces.

Due to the great expense of installing scaffolding, the workers were suspended from the vault. To this end, it is necessary to perforate the structure in certain places. This technique has been generally applied in Guastavino's works and specifically it was the firm Vertical Access that used this system on many of the restoration works like, for example, Saint Thomas Church. Only in Saint Paul's Chapel at Columbia University did they use an elevating apparatus to avoid these perforations.

2. Mechanical analysis. This consists in striking each of the pieces with a pneumatic hammer and analysing the state of the vaults on the basis of the acoustic data collected. It is a diagnosis system that has been generally adopted and is applied almost systematically on all the Guastavino works that need to be diagnosed, whether they are to be restored or not.

A vault that has lost consistency between the different layers of pieces –whether they are ceramic or cement based, as in the case of the Akoustolith tile– and the mortar made of portland cement will be segregated from each other and the space between them will absorb the acoustic energy. The energy reflected will be less and the sound obtained will be more "blurred" and less clear. If, on the contrary, the vaults are in a perfect state of repair and the adherence between the layers is perfect, the energy reflected will be greater than that absorbed and the sound obtained will be clear and pure.

The interpretation of the data obtained is made by four specialists, who listen to the sound and evaluate the state of the vaults. Therefore, the process is not objective, since it depends on the auditive capacity of the four people, with all the problems that this involves.

3. This system is a variation of the previous one. It also consists in striking the pieces and analysing the acoustic data obtained. However, with this technique, the data are analysed by a receiver, which transmits them to a computer, calculating the degree of deterioration and segregation of the different layers in an objective analysis of the sound absorbed and reflected by the vault.

This is really an adaptation of a diagnosis technique for sheets of concrete in brick covered vaults. Kelly Streeter wrote her engineering master's thesis in this field, evaluating problems in concrete sheets according to their response to ultrasounds. At the present time the Vertical Access company is adapting these concrete evaluation techniques to Guastavino constructions. Apart from converting this ultrasound diagnosis method into objective studies, it was a solution for vaults that could not be accessed from below. It also permits the diagnosis to be made from above, since most vaults can be accessed from above. This is the case, for example, of the diagnosis made on the Battery Maritime Building, where this system was applied. The vaults can be reached from above and this makes it possible to receive the acoustic signal easily. In this case, except for the fragment affected by the subsidence of the building mentioned above, the vault in is a good state of repair and is not delaminated.

In contrast, in the diagnosis made on the domes of the Federal Reserve Bank in the nineties, this technique led to the conclusion that there was almost total segregation of the first layer, in this case made of Akoustolith tiles, from the rest of the structure. This is very unusual, as

they are not brick lined vaults but a metal structure holding a plaster base to which a sheet of merely ornamental Akoustolith tiles was attached. In any case, the ultrasound system made it possible to diagnose that this sheet had come loose from the substructure and its stability was seriously endangered, so a conglomerating product was injected to adhere it and guarantee the safety of the pieces.
This ultrasound technique opens up a very interesting field of study to get to know the characteristics of vaults, and discover the number of sheets in a vault at each point of its geometry. The amount of sound reflected is thus inversely proportional to the number of sheets; the more layers, the more acoustic energy is absorbed and therefore the less sound is reflected. This technique has been applied in Saint Thomas Church and has located the use of two, three, six and eight layers, whose greatest thickness is at the springing points.

Patrimonial considerations in restoration works

Finally, all the agents involved are unanimous in emphasising the patrimonial value of the Guastavinos' work in American architecture. Its cataloguing and protection has also influenced the approach to architecture, avoiding aggressive interventions and controlling them by means of institutions like the New York City Landmarks Preservation Commission, which since the nineties has been imposing reversible rehabilitation techniques as far as possible and called for respect and the use of the Company's original building methods and materials.
To illustrate this change of attitude towards rehabilitation, it is very useful to compare different restoration works performed at different times. In the restoration performed by Beyer, Blinder and Belle on the canopy over the taxi entrance at Grand Central Station, the brick covered vaults served as a sort of framework resolved with metal beams. The rusting of the beams and the ensuing dilatation compressed the vaults and they broke along the line of the keystone. The Guastavino vaults were replaced completely reproducing the geometry of the vaults with concrete reinforced with fibreglass and then lining this shell with ceramic tiles. It is therefore a rather aggressive intervention where the form and the texture have been conserved but the building system has not. This sort of intervention would not be possible today, as the New York City Landmarks Preservation Commission has established much more respectful and stricter criteria for conservation in the last few years. In the restoration of the vaults under Queensboro Bridge, these vaults were in very poor condition with huge cracks caused by vibrations from the main structure of the bridge. However, the initial work was totally respected and reversible repairs were practised with flexible joints in the cracks keeping the original structure and permitting the movement of the structure so as not to transmit this stress to other parts of the vaults.
Only one of the vaults had to be replaced because the main metal structure of the bridge was literally piercing the vault causing the obvious problems of direct transmission of vibrations and damage caused by the dilatation of the rusted structure and more serious problems of damp. To this end, the original brick lined vault technique was used with the only difference that stainless steel reinforcements were added. The introduction of metal reinforcements was common practice for the Guastavino Company and even specifically mentioned in their patents. In this case, however, it seems the Company was responsible for this pathology due to an error in the calculation of the vault's geometry.
Within the most orthodox line of restoration promoted by the New York City Landmarks Preservation Commission and supported by professionals in the field of restoration with profound respect and admiration for Guastavino's work, the mortars used in the works are analysed and reproduced today. In the restoration of the Oyster Bar in Grand Central Station in New York after the fire that broke out in 1997 mentioned above, Robert Silman analysed the composition of the original mortar and reproduced it. It was a 1:1:6 mixed mortar used to replace the pieces of the first layer and latex was added instead of an unknown substance detected but not identified as part of the mortar. The shape and size of the joints is also a faithful reproduction of the original solution, where the joint was T-shaped in order to increase its thickness. In this work, the Commission even went so far as to propose reproducing the original furniture installed when it was built at the turn of the century, although they later rejected the idea. They also controlled the illumination system and the materials that were to be used. Although the Company had used 12 different shades, in the negotiations with the owners due to the great expense of reproducing it exactly, it was agreed to reduce it to three shades.
In the restoration of the Battery Maritime Building, the idea of replacing the fragment of the vault affected by subsidence was discarded, as the objective of the architects Pokorny & Associates is to show the utmost respect not only for the original solution but also for the original vault built by the Company. For this reason, now that it is under restoration, they are thinking of building a concrete framework in the space between the roof and the vaults from which to hang the last 15 metres of the vault in order to unload the weight and prevent it from further deformation and cracks.
St Paul's Chapel at Columbia University, however, is undergoing serious loss of pieces from the first layer. St Paul's is considered the jewel in the crown of the pieces made by Guastavino in New York, for in this work the Company's products were mostly used. In this case, Kent Diebolt says the pieces that have fallen belong to parts of the church where they were located at a later date, that is, after building the vaults and domes, and that they are therefore not structural pieces but merely decorative. There are serious doubts in the restoration milieu about whether the layer of bricks was installed

first as shuttering or last as a decorative finish.
Like in the restoration of the Battery Maritime Building, it has been suggested that each and every one of the pieces considered decorative in St Paul's should be replaced by new ones, which should be installed with a mechanical method of pressure screws without any mortar. Although this proposal is being studied, it is surprising since it goes against the respect for heritage we spoke of above, especially in a work like St Paul's. Considered the paradigm of the Guastavino Company's work, where the use of a building method and ceramic materials was crucial for the architectural formalisation of the edifice. This loss of material is accompanied by the appearance of cracks in segmental arches located at the sides whose origin is unknown at the moment. The first step is always to guarantee the safety of the structure so metal pieces have been inserted to correct the lack of cohesion of the vault caused by the crack, even though the cause of these pathologies is as yet unknown.
Concluding with this case of the pathologies found in St Paul's Chapel, we can see that according as diagnosis and restoration works are being carried out on Guastavino works in New York, a group of experts in these works has been consolidated (again we find Vertical Access, Robert Silman in the diagnosis phase) and although they themselves still insist they know very little about the building methods, their professional career is now undeniably associated with the Guastavino Company and the restoration of its works.

Charles DiSanto

RESTORATION OF THE QUEENSBORO BRIDGE GUASTAVINO TILE VAULTS: A CASE STUDY

The Queensboro Bridge, built between 1901 and 1909, was designed to carry horse, trolley, and elevated train traffic between Manhattan and Queens following the consolidation of the Greater City of New York from the five boroughs in 1898. Prior traffic between the two boroughs was limited to ferry boats, and it was expected that the bridge would facilitate the exploitation of cheaper land in Queens for light industry and manufacturing.
In keeping with the city's desire to celebrate the civic grandeur of such significant transportation improvements, the designers of the bridge, engineer Gustav Lindenthal and architect Henry H. Hornbostel, embellished the state of the art technical and engineering aspects of the structure with architectural grace and sensitivity to detail. Nowhere are these intentions better realized than in the soaring vaults of the Bridgemarket space below the roadway of the Manhattan approach.
The vaulted Bridgemarket was conceived as a sheltered public market that would occupy the otherwise unutilized area below the Manhattan approach to the Queensboro Bridge. The space was originally open to the street, but in 1916 it was enclosed with large, steel sash windows. The Bridgemarket closed in the 1930s and fell into disrepair. Traffic increased on at the roadway above, and moisture leaked through the bridge deck. The Bridgemarket was designated a New York City Landmark in 1974, and the restoration is expected to be complete before 2000.

The Manhattan Approach and Guastavino Vaulting
The Manhattan approach extends from Second Avenue at 59th Street eastward to the Manhattan anchor pier near York Avenue and includes road and pedestrian ramps, massive load bearing granite side walls, and four distinct areas of Guastavino tile vaulting. Of these areas, the Bridgemarket space, between First Avenue and the Manhattan anchor pier, is the largest (at approximately 32,000 sq. ft.) and most prominent (fig. 1).
The vaults at the First Avenue over pass, sign shop/maintenance area (12 bays), and trolley entrance kiosk make up the balance of the Guastavino fabric at the site. In total, approximately 60,000 sq. ft. of exposed vaulted ceiling graces the underside of the bridge road way. There are no less than five primary geometric forms of vaulting: spherical, modified spherical (at shop area), segmented elliptical, straight barrel, and curving barrel.
All vaults are finished in the signature Guastavino herringbone pattern of ribbed, glazed face tile (6 in. by 12 in. by 3/4 in.), with two or three layers of larger red backup tile. The whole is cohesively bound in a cement mortar matrix of approximately 4-1/2 in. over all thickness. The thickness of the vaults varies from two layers of backup (plus face tile) at the top of the dome to as much as nine layers at the rib spring point. While the four bays of the First Avenue vaulting rest on granite clad arched girders that span 120 ft. across the street, most of the spherical vaulting is stiffened and supported by built up tile ribs, which in turn rest on shelf angles at the terracotta clad, structural steel lattice columns (fig. 2). These columns continue past the vaults to support the roadway of the Manhattan approach.
The spherical vaults at the Bridge market area are truncated from a 22 ft. radius dome with a 5 ft. rise over a 30-ft. by 30 ft. bay dimension. There are 34 such vaults. The remaining two bays at the east end near the Manhattan anchor pier were modified in the original design by the removal of a central column to allow for an uninterrupted view of the central area of the abutment. The resultant vaulting extends across two bays and is terminated at the free edge by an elliptical rib supporting four radiating, triangular vault sections ("pie vaults"). When viewed together, these vaults approximate the shape of a half dome (fig. 3).

Program and Project Requirements
Because the Queensboro Bridge and Manhattan approach are designated as city landmarks, all work on any aspect of the bridge requires the review and approval of the Landmarks Preservation Commission. The New York City Department of Transportation's Bureau of Bridges administers and maintains the bridge and thus assumed the role of the

owner. The firm of Walter B. Melvin, Architect, was engaged as a consultant to Steinman Engineering in 1992 to survey, design, and specify repairs to the architectural elements of the Manhattan approach, including a new pedestrian access ramp, and to shepherd the work through the city agency review process, including the landmarks approvals.
The architect's mandate was to satisfy the pragmatic concerns of the Department of Transportation with respect to structural repairs, replacement of lost material, and stabilization of existing fabric, while retaining the basic architectural features of the spaces and materials involved. The project was primarily conceived of as a structural stabilization but was approached from a preservation perspective.

Survey and Observed Conditions

General conditions of vaulting, ribs, and columns throughout all areas of Guastavino construction were significantly deteriorated at the initiation of the project in 1992. In 1993, survey work began of all vaulted areas, as well as the 56 terracotta clad structural columns at the Bridgemarket and sign shop areas. Investigative work included a two pronged approach of field survey work and related materials research. All vaults and columns were inspected from the ground and (where necessary) from personnel lift (boom) equipment. In addition, all vault areas were accessed and inspected from above to identify relevant top surface and roadway conditions. At the same time, original construction drawings were studied, and lab testing was performed on selected core drill samples of the vault construction to ascertain properties of constituent materials.
The field survey information was gathered and recorded on individual vault-plan diagrams, showing the typical herringbone tiles and perimeter ribs of a 30 ft. by 30 ft. bay. Visible areas of efflorescence, deteriorated pointing, spalling, tile delamination, cracking, and lost material were identified, quantified, and recorded on the survey sheets. These sheets were later compiled to assemble overall reconstruction plans of the vault areas.
Research included materials testing of tile and mortar. Face tiles were found to have an average compressive strength of 6530 psi and absorption of about 9% (24-hour soak). Backup tile tested at 3750 psi and 8% absorption. Both tiles were acceptable under ASTM C62, severe weather grade. Mortar was characterized as ASTM Type N, with no evidence of sulfate attack. The original pointing mortar was determined to be ASTM Type S. Review of original drawings provided important insights into the intended construction details and configurations, particularly with respect to the relationship between vaults and the bridge roadway superstructure.
The deterioration of the vaults is attributed to three primary causes: water infiltration and its effects, thermal movement of the structural frame of the bridge (superstructure), and vibration stresses carried from the roadway to the vault construction.
Water infiltration from the roadway above, particularly at perimeter areas and poorly maintained movement joints, resulted in direct saturation of vault masonry, corrosion of shelf supports (lifting the shell and ribs at the spring point), accumulation of salts, and freeze/thaw damage. The geometry of the vaults was such that water ran to the column (low point) areas from the top side of the dome section, causing displacement of terra cotta column cladding due to the expansive forces of corrosion and freezing on the internal lattice columns. Clearly, any restoration effort needed to address this primary concern.
Another source of damage to the vaults arose from the significant influence of the bridge superstructure. Columns and beams supporting the roadway above the vaults transfer thermal and vibration stresses to the thin shell tile vaulting, which in some areas encase the column cross bracing (these conditions were observed physically from the top side of the vaults during periods of moderate to heavy traffic flow). The moisture infiltration and thermal and vibration stresses combined with years of deferred maintenance to create the deteriorated conditions noted during the survey phase.(figs. 4, 5).

General Repair Approach and Methodology

The restoration program identified the extent of the problematic conditions of the vaults and sought to effect repairs that would meet the following challenges:
Salvage and retain as much original, sound material as practically possible.
Utilize repair and replacement materials that are compatible with original components and physical properties.
Prevent future deterioration of vault and column elements where possible by the inclusion of water and drainage controls and soft joint repairs.
Utilize modern materials and approaches where observations indicated inherent difficulties in the original design.
The repair and restoration of the Guastavino vaults at the Queensboro Bridge included the employment of both traditional and modern materials and methods. These modern materials included stainless steel rods (fig. 7), flexible sealants, and polyurethane waterproofing systems. All other materials utilized in the restoration were traditional terra cotta and mortar based components.
Repair categories are shown in Table 1. The initial field survey established primary reconstruction, crack locations, and broad areas of efflorescence and suspected tile delamination. Once the vault areas were cleaned from below, an additional level of repair was identified based on field criteria established for use by the city's inspection engineers. Criteria included the following physical characteristic observations: sounding with a wooden or acrylic mallet, identification of the quantity and distribution of crazing and cracks at the tile glaze, and resistance of mortar to knife edge probing. This criteria utilized simple field tests applied on a tile by tile basis and resulted in additional and more detailed quantification of face tile and pointing mortar replacement. It was extremely important to perform a hands on inspection of each tile to identify these types of repairs.

Waterproofing and Control of Moisture Infiltration

In April 1995 the Graciano Corporation was awarded the contract for vault and column restoration at the Queensboro Bridge. Prior to the execution of any repairs to the vaults or columns, the control of ongoing water infiltration from the roadway above was established as a priority. Although major repairs to the roadway greatly reduced the infiltration, it was expected to persist to some degree. The top surface of all vault areas was first coated with a compatible cementitious waterproofing material (Thoro seal foundation coating) to seal small cracks and minimize absorption of occasional moisture into the vault masonry. The low point collection areas (at the columns) were built up with lightweight concrete to create a new low point and divert water away from the steel columns (fig. 8). A flanged scupper tube was installed at this location and stripped in with a polyurethane water proofing membrane throughout the collection area. The scupper drain tube extended throughout the vault tile at this new low point, which avoided damage to the more significant column terra cotta, while also penetrating the vault at an area of thinner cross section. The membrane waterproofing material was brush applied to the vaults, the steel cross bracing, and the lightweight concrete fill at the low point basin.

Once the waterproofing and scupper drainage effort was in place and functional, work could begin on the tile vault and column repairs. In order to replace damaged terracotta cladding units at the columns, ribs at adjacent vaults required shoring (figs. 6, 9). In all, over eight hundred terracotta cladding units were replaced, along with repairs and resetting of several hundred salvaged units. Boston Valley Terra Cotta fabricated the reproduction units. Some terracotta column cladding was removed entirely and reset to address general displacement due to corrosion of the structural steel column. Exposed steel was scraped, primed, and painted with rust inhibitive paint.

Crack Repairs and Movement Accommodation

The forces that caused tension cracking through the vault construction were assumed to be only partially related to moisture infiltration. Stresses due to thermal and vibration movement of the bridge superstructure remain unchanged, and it was determined that a solid repair to such cracks would raise the risk of future recurrence. 1 The challenge was to strengthen the joint in a flexible manner and replace the broken face tile while allowing future movement to occur in the stress crack areas. The detail developed for this repair made use of a flexible reinforcing rod and a special, slotted face tile that was not bonded to the backup vault material. Flexibility in the rod itself was achieved by a bent configuration that would allow elongation without a full transfer of stresses into the masonry at the embedded rod ends.

The slots in the special face tile allowed for a "suspended" installation, and tile was free to move relative to the backup vault materials. The back face of the slotted tile was not scored to receive mortar and was covered with a bond breaker sheet prior to installation. Sealant was injected in the crack area of the shell (between backup tile) and was applied along the herringbone joint of the special face tile in the manner of a traditional soft joint. The result was a stitched seam that accommodates movement and remains virtually indistinguishable from the adjacent pointed joints. Cracks at some face tile that did not extend through the thickness of the vault were also sealed with this material.

Rebuilding of vault sections where significant loss had occurred was accomplished in a straightforward and traditional manner utilizing reproduction tile and mortar that matched the physical properties of the original, along with stainless steel reinforcing rods at the perimeter of the reconstruction area (figs. 11, 12). Full tiles were replaced at both top and bottom layers.

The repointing work utilized mortar of identical composition and color and included the distinctive "raised profile" joint so commonly found in Guastavino's herringbone design. This joint, which accentuated the lines of adjoining tiles while presenting a uniform width, was tooled by the contractor using custom site built striking tools.

Conclusion

For over fifty years, the soaring vaults and elegant columns of the Bridgemarket were hidden from the public eye and allowed to deteriorate without meaning ful repair. Significant failures of mortar, tile, and vault and rib construction were apparent throughout. Still, the Guastavino vaulting has withstood the elements, the abuses, and the longterm neglect with relative success. There are few, if any, comparable construction systems that can be exposed to such conditions of environmental and structural stress, including excessive water infiltration, cracking, and loss of material, and still be considered restorable. This fact alone is a tribute to the superior qualities of the design and execution of the Guastavino vaulting (figs. 13, 14, 15).

The repair and restoration program sought to accommodate the difficult environment of the Manhattan approach while maintaining a sensitivity to its unique architectural qualities. The repairs were grounded in an established scientific base, but in the tradition of much of Guastavino's work also relied on instinct and experience with the behavior of other masonry construction. The completed restoration has retained significant original character while introducing changes that should prevent future deterioration. Time will reveal the effectiveness of the decisions made today.

Robert Silman

STRUCTURAL REPAIRS TO FIRE DAMAGED GUASTAVINO TILE VAULTS AT GRAND CENTRAL TERMINAL'S OYSTER BAR

Structural repairs to the fire damaged Guastavino vaults at the Oyster Bar in Grand Central Terminal presented several interesting challenges (figs. 1, 2). Guastavino restorations are always challenging because of their minimal use of material in structurally simple yet elegant solutions. Still, from churches (St. John the Divine and St. Bartholomew's in New York City) to college buildings (at Barnard and Columbia) to industrial buildings (a printing plant in New London, Connecticut, now converted to housing), Robert Silman Associates has experienced how remarkably these vaulted structures accept repairs and adapt to new uses and modifications.

Oyster Bar Vaults: A Description

The main vaults at the Oyster Bar are configured from a part of a sphere, which is then forced into a square by cutting vertical chunks off the sphere to form a four sided shape (fig. 3). Rather than directing all of the load from the vault into the pendentives in each corner, the Guastavinos trimmed the curved openings on the four sides with very substantial, wide tile arches that carried a good portion of the vault load. The loads from the vaults and the arches were delivered to the steel columns of the main Grand Central Terminal building (fig. 4). The history of the Oyster Bar and the description of the original system, as well as the damage caused by the fire, is described elsewhere in this issue.

The vaults of the Oyster Bar were constructed for the most part of three layers of tiles, one being the glazed face layer and the other two consisting of red terra cotta. All were bonded together with high strength portland cement mortar along their edges, as well as between the layers (the parge coat). At the pendentives it was customary for the Guastavinos to use several more layers of tile; however, Robert Silman Associates did not probe these locations, and thus the number of layers of tile actually used there is uncertain.

Many face tiles had fallen off during the fire. This may be attributed to two causes, most probably acting together. The first was thermal shock caused by a rapid heating and concurrent expansion of the tiles, followed by a rapid cooling when water from the fire hoses was sprayed on the ceiling, which likely generated sufficient movement and stress to cause the bond in the mortar parge joint to fail. Additionally, there was sufficient stress from the force of the fire hose stream against the tiles to knock them off. In no case was damage to the red clay backup tiles or the mortar joints observed.

Structural Assessment of Fire Damage

The first assignment from the owner of the Oyster Bar was to determine the safety of the remaining portions of the vaults immediately following the fire, so as to allow clean up and repair operations to begin immediately but without subjecting the workers to any danger.

First, an acrylic faced mallet was used to tap each remaining face tile to determine if it was loose, a technique that had been developed in the examination of the Ellis Island Registry Room ceiling some ten years ago. This procedure identified entire fields of loose face tiles, as well as isolated individual tiles with insufficient bond. All loose tiles were removed immediately (fig. 6).

However, when an isolated tile was shown by sounding to be loose and was subsequently removed, all of the surrounding tiles became destabilized, with loss of bond detected upon resounding.

The face tiles had formed an independent vault of their own, one tile thick, which, once disturbed, lost its vault like capability to behave like a shell and failed. Thus it became apparent that the most prudent approach was to remove all the face tiles in the most heavily damaged bays.

As part of the safety analysis, the remaining red clay tile vault was observed to determine whether it was structurally adequate without the presence of the face tiles. It was noted that the central portion of each vault emanating from the crown was constructed of only two layers of red clay backup tile and one layer of beige glazed finish tile. Further observation revealed that the vaults were not load bearing – that is, they did not support the load of the terminal floor above, which was basically carried by steel I beams with independent shallow tile barrel vaults (fig. 5). Finally, it was apparent that the finished glazed tile ceiling had been applied to the underside of the red clay tile vaults after they were completed, which was the best way to achieve a clean, uniform herringbone pattern and the only way to apply the final mortar bead to the exposed surface of the tile joints. The major evidence that the finished tile was applied last came from the observation that mortar dabs held the tiles in place rather than a fully parged collar joint. With this information in hand, it was determined that the original red clay tile vaults had been self supporting prior to the initial installation of the finished tile; absent any observed distress, they were still adequate to remain as free standing vaults.

A structural analysis of the vaults would have been a time consuming and expensive exercise that was not considered necessary. Instead, it was determined that since the vaults had behaved satisfactorily for 84 years, and there was no observable damage to the backup tile or mortar, there was no reason why the face tile should not simply be replaced and the vaults returned to service. This is an important principle in a structural engineering evaluation of an existing system.

Mathematical analyses of shell structures whose configuration is similar to these vaults show that very high bending stresses occur in the pendentives and adjacent to the cut edges of the vaults where they meet the tile arches; a two tilethick unreinforced masonry vault would be a very poor structure to resist these theoretical bending stresses. There is no documentary evidence that the Guastavinos used sophisticated mathematical analyses; indeed, the mathematical analysis of shells was not developed until the 1930s.

The Guastavinos relied upon load tests to prove that their vaults were more than adequate to stand up to the required loadings. The two most interesting load tests are thoroughly documented in the Guastavino archives1. These two tests were actually fire and water tests of a single vault, constructed in a manner similar to that used in the Oyster Bar, with plan dimensions of 11 ft. by 14 ft (fig. 7). The first test was conducted on a vault whose general thickness from the crown down was three tiles, with a superimposed load of 150 pounds per square foot (psf). The temperature under the vault was taken up to more than 2000° F. (fig. 8) and held for four hours. Then, the underside was observed, and

water was sprayed on. The water caused the lowest layer of tiles to fall off completely, much as in the Oyster Bar fire. After the fire test was concluded, the vault was loaded to 600 psf (fig. 10). No cracks were observed, and the deflections measured before, during, and after the fire were well within the range of acceptable. In fact, under the 600 psf load, the incremental increase in deflection was only 0.195 in. or 1/677 of the span – a remarkably low number that indicates an extraordinarily stiff structural system. Two weeks later the fire test was repeated on the same structure, but first a new layer of tile was installed from the underside to replace the layer that had failed in the first test. This application was similar to that in the Oyster Bar. Under the sustained load of 150 psf the vault performed very well during the second fire test, with the lowest layer of tiles falling once again when subjected to the hose stream. At the conclusion of the second test, the slab was loaded with 450 psf, resulting in a deflection reading of 0.18 in. (V733).
The intensity and duration of the Oyster Bar fire was not nearly as much as the 1897 test vault, and there was no superimposed load on it. Nevertheless, the behavior of the lowest layer of tiles in the Oyster Bar closely paralleled the original fire test. The fact that the basic structural integrity of the vault was not impaired by the fire allowed an effective, efficient repair to be executed (fig. 9).

Salvador Vila Ferrer

RESTORATION OF THE GOTHIC VAULT IN THE APSE OF VALENCIA CATHEDRAL

The project

The discovery of the Renaissance paintings that were concealed behind the Baroque vault in the main chapel of the cathedral was followed by the process for their recovery. Their existence was a known fact; books about the fabric said they were in very poor condition, but nothing was known about their quality. During the restoration of the Baroque work in the chapel by Carmen Pérez's team, through a little hole in the Baroque vault the first sight of the frescoes painted by Francesco Pagano and Paolo de San Leocadio in 1477 commissioned by Rodrigo de Borgia appeared, at the same time as the architectural context where they were located, and their state of conservation was seen (fig. 2). The paintings were found not only to decorate the Gothic vault but also the Gothic interior panels and the windows, also hidden behind the vault and the Baroque windows made in 1687 at the orders of the architect Juan Bautista Castiel based on a project drawn up by Martínez De Urrana (fig. 3).
A few months earlier, we had completed the reconstruction of the stellar Gothic vault in the Chapter Room of La Valldigna Monastery, attributed to Pere Comte and of similar dimensions, also commissioned by Rodrigo de Borgia when he was the abbot of the monastery. Perhaps for that reason, the Heritage Section of the Valencian Culture Department entrusted me with the task of studying the condition of the two vaults in the cathedral to facilitate the restoration of the Renaissance paintings if that was the decision finally adopted. Meanwhile the restorers of the chapel gleaned more and more information about the state of the paintings and at the same time experts from all over the world drew up reports about their quality.
On 20th December 2004, from a scaffold erected nineteen metres above the ground I had my first glimpse of the Renaissance frescoes. Although I am not an expert in painting, their beauty impressed me deeply and I wondered what had been the reason to conceal such great paintings (fig. 1). The answer had to come from art historians and the explanation would surely be found in the ecclesiastic Counter Reformation, when everything connected with the Borgia pope, Alexander VI, was covered over. The space that remained between the two vaults was only thirty centimetres at the keystone (fig. 4) and a little over a metre near the facades (fig. 5). The segments of the vault came down as far as the springing points, about eight metres lower. Therefore it was extremely difficult to get into the space to restore the paintings. According to the opinion expressed in the reports about work safety that were requested and as we discovered in practice during the months the restoration of the frescoes was carried out, it was not possible to do so from the chamber.
So, if the paintings were to be saved, there was no choice but to dismantle the Baroque vault to reach them in safety to apply the necessary treatment.
Fortunately, the supporting structure in the Baroque vault the was the Gothic ashlar ribs made by Arnaldi Vitalis in the second half of the 13th century at the orders of Bishop Andrés de Abalat and, of course, the walls enclosing the apse. Pérez Castiel had adjusted himself to these structures by placing lunettes at the five windows of the vault, three octagons and two half octagons springing from the Gothic structural keystone, which is still in place, and eliminating part of Gothic decoration, which was lost forever (fig. 6).
Judging from the metre high excrements that filled the space between the two vaults, doves had been nesting on the fabric of the chamber formed by the extrados of the curved lintel of each of the Baroque windows for centuries. These brick fabrics of the lintel and jambs were not joined to the Gothic ashlar fabric or the archivolts of the windows, which rose freely to the Gothic vault until the Gothic arch. The Renaissance paintings on the Gothic windows and walls, although they were in very poor condition, could be seen here, and this decoration was expected to be found in the parts hidden behind the Baroque windows as far as the sill, as was discovered in a probe made at the base (fig. 7).
The quality of the materials of the decoration containing the whole Baroque repertoire from the base of the presbytery to the keystone through the ribs was poorer above the eleven metre cornice. Above this height, marble was no longer used, but all the windows, cornices and ribs were covered with imitation marble and gilt paint. This lavish decoration made us suspect that it would be impossible to remove the Baroque decoration on the ribs, which

also, logically, bore Renaissance paintings, as we could see from the chamber. The springing point of the Baroque ribs from the interior walls would have required chases to be made in the Gothic ashlar fabric, which would indeed have seriously impaired the Renaissance decoration at the top.
The works involved in freeing the archivolts of the Gothic windows with the Renaissance paintings would be just as difficult, since the Baroque lintels crossed all the thickness of the walls to the exterior, affecting the façade, where the height of the Gothic windows was reduced almost by half, because the sloping roof with curved tiles added to the 19th century ambulatory also interfered, and the sloping canopies at the level of the exterior Baroque lintels on each of the windows (fig. 9).
With all these important formal features in the ensemble, and always with a view to try and recuperate the Renaissance decorated surface, we began to prepare the project. All the structural, constructional and ornamental difficulties that had to be solved were aggravated by problems relating to the justification of the intervention according to the 1998 text and the 2004 amended version of the Valencian Cultural Heritage Law in force at the time.
Valencia cathedral is a monument that was appointed an Asset of Cultural Interest in 1932. All its parts, even though they date from different periods and are superimposed on top of the original fabrics, are equally protected by this law. But naturally the law also obliges us to preserve concealed elements of recognised value. The conditions for the intervention in the event that parts of the monument must be removed to guarantee the survival of other important parts are double: the parts removed must be documented and the procedure must be reversible.
The project was carried out under these premises, and was shown to the relevant professionals from the Culture Department during development. There was never consensus among all those supervising it, although those who were against the project did not suggest an alternative solution for the consolidation and restoration of the Renaissance frescoes.
It was quite a challenge to draw up the project. Apart from the problems inherent in working on a monument like Valencia cathedral, it was necessary to show the maximum respect for all the layers of architecture that appeared so as to combine them in the best possible manner, at least until the Baroque cladding was returned to the main part of the church.
However, throughout its history, Valencia cathedral had already been through similar situations of superposition. Conrad Rudolph's Baroque door (fig. 10), which could also have been built by Pérez Castiel, although he was not commissioned to perform the work, is a token of this. The Obra Nova, made by Miquel Porcar according to Gaspar Gregori's design (1566), was the most important work on the exterior of the cathedral in Renaissance style. Gilabert's classical intervention between the 18th and 19th century left traces of arches, above all in the transept under the cimborio leading into the chapels in the lateral aisles (fig. 11). Many chapels share solutions in different styles, as is the case in most cathedrals.
Even so, Valencia cathedral is basically a Gothic construction, where the height of the centre aisle and the two side aisles is practically the same and its original decoration is in keeping with Cistercian simplicity (fig. 12). The volumetry of the chancel with an ambulatory and apse chapels, the portals and the large size of the Miguelete bell tower or the old Chapter Room, today the Chapel of the Holy Chalice, and above all the impressive cimborio, all dating from the 14th and 15th centuries, are a token of this (fig. 13). Back in 1961 this was the opinion of the architect Segura de Lago when the process of removing the NeoClassical decoration began, to reveal the Gothic interior we can see today. Similarly the original flat roofs on the main nave and the side aisles, over the cimborio and the apse, which had been covered over with a most unsuitable sloping curved tile roof, were recovered. The original flat roofs of the Chapter Room, the ambulatory and the apse chapels still had to be retrieved.
Taking into account the most important facts of the background described above, the project commissioned by the public foundation of the Generalitat Valenciana La Llum de les Imatges was completed on 25th April 2005. This project included the definition and justification of all the works required for the restoration of the Renaissance paintings on the vault, the interior walls over the cornice and over the Gothic windows. The jambs and lintels of the Baroque windows were not to be dismantled and the decoration on the Gothic ribs was to be left intact.
In general terms, the intervention would consist in breaking two solid brick segments with their plaster ornamental elements (fig. 16) and dismantling the wooden boss of the Baroque keystone (fig. 8), restoring the roof of the apse and the five exterior facades, clearing the five Gothic windows and removing the sheds over them (fig. 14) and recovering the original flat roof over the ambulatory (fig. 15). Finally, the illumination of the inside and the outside of the apse had to be adjusted.

The works

The works began on 13th September 2005, and priority was granted to dismantling the vault so that restorers could start work as soon as possible on the paintings and interior wall surfaces. It was important to decide how to cut the material based on the knowledge gleaned while studying to prepare the project. For this purpose, the company hired to do the work set up a small scale replica of the vault with the same type of segments and lunettes in their studio. Samples of brick were taken to specialised companies to try out cutting systems with laser beams and high pressure water. These are machines that can make clean cuts with both these procedures for trials, but in this case specific machinery had to be designed to work on the scaffolding. The high pressure water method was discarded first. The large dimensions to be cut

made it unsuitable for working inside the cathedral, as well as expensive, because it required the manufacture of special pieces to cut the fabric that could be used by a mason on the curved surface. The laser apparatus, even though it was more precise and easy to handle (we must not forget it is used in surgery as well as industry). Also required a specific design to work so high up, although it was less unwieldy and lighter than the water machine, was more complicated and expensive to make. However, in both cases the long manufacture and adjustment period of high risk equipment because there was no way of knowing how it would operate beforehand made us insist on using traditional cutting methods.
At the same time, different traditional machines were tried out on the replica of the vault, such as circular or electric saws. The conditions we demanded were the following: under no circumstances must they damage the paintings either because of their size or their handling; no more than one centimetre should be lost in the cut; the cut should be perfectly clean and not scatter particles onto the paintings. The radial system was the fastest, but produced more dust and noise and was less accurate. The electric saw was slower, but produced less dust and noise and was easier to apply to all the little joints in the vault with its decorated plasterwork. This method was finally chosen and used for the works.
The first thing that was dismantled was the polychrome Baroque keystone that was held in place by a vertical iron brace, which went through the original Gothic keystone and the vault through a hole bored in the structural ashlar fabric. The brace went up to the ceiling and was attached to an exterior truncated pyramidal brick fabric, placed on top of the roof by metal crossbars. The Gothic keystone, made from a polygonal ashlar which is still intact, has paint on the sides and is chipped on the bottom, and its decoration disappeared when the Baroque keystone was installed. The dismantling of the Baroque boss revealed new Renaissance paintings around the Gothic keystone, its section of original stone and the remains of polychrome also dating from the Renaissance period, because on the space that concealed the Baroque keystone the decoration of the ribs we found over the interior cornice had not been completed (fig. 18).
The solid brick Baroque vault, placed flat with one or two layers and decorated with stencils, was dismantled from top to bottom by breaking pieces about fifty centimetres high for the undecorated surfaces (fig. 17). In the case of the parts with plasterwork, larger in size and anchored to the vault by means of metal nails, the pieces cut were larger and the cuts attempted not to interfere with the most important parts of the decoration. This system of cutting had been provided for in the plans of the project, made on the topographic maps that had been drawn up by taking over ten thousand points from the Baroque vault and a large number of photographs. The cutting of the vault was reconsidered and the new design was drawn on the tracing paper protecting the whole surface. Dismantling was carried out in alternative octagons with their corresponding lunettes and it took three months to complete the whole operation, resulting in a total of three hundred and fifty six pieces, which were stored in the crypt of the chapel of Moncada seminary, duly protected and labelled.
After making sure that the fabric of the Gothic vault was the same as the other vaults in the cathedral (because as it was the oldest, it might have been built of stone like the vault over the east transept leading to the Romanesque door), the most important cracks that did not allow the restorers to do their work were repaired. The fabric, which is a single layer of header bond bricks thirty centimetres thick, was not seriously cracked and the existing chinks followed the stereotomy of the brick fabric with loss of lime mortar in the joints.
It was also important to make sure that the roof of the apse over the Gothic vault of the cathedral with the Renaissance paintings was completely waterproof. For that purpose, tests were first performed to find out the state of the fabrics and their composition. We found it was a flat brick roof, repaired in the second half of the 20th century, with wire netting and waterproof treatment, but the framework had begun to rust and there were holes in the sheets of asphalt (fig. 19). A similar solution was applied to the entire surface. Taking special care around the edges, to make sure the waterproof treatment reached the perimetrical coping, which it had not before. The truncated pyramidal fabric necessary to hold the pin to which the Baroque keystone was attached was reconstructed (fig. 20), leaving the hole running through it, but closing it with a glass cover, so that now light goes through all the fabrics and when visitors look at the Gothic keystone from the centre of the apse they can see right through it (fig. 21).
Cracks in the five facades of the apse were repaired and sealed, and the chinks in the ashlars were filled with mixed lime mortar that were coloured according to the place they were located. Missing parts of the ashlars were replaced in areas where stone was a working element of a wall or an arch, and mortar was used to repair superficial breakages that were a testimony of historic interventions (fig. 22), such as, for example, the chases made to fix the sloping tiled roof of the ambulatory.
As we said above, the Renaissance paintings not only covered the Gothic segments of the vault but also the five interior panels and the archivolts of the Gothic windows. The support work for the restoration of the paintings on all these surfaces began by clearing the Baroque additions that covered the frescoes around the Gothic windows. We needed to find a solution that would make the remaining parts of the Baroque bays compatible with the recuperation of the Gothic bays. But this gave rise to a problem in inserting the five Baroque stained glass windows that the chapter wanted to conserve. These were logically smaller than the Gothic space. To solve this problem, a new stained glass window was designed that would occupy the Gothic bays instead of the Baroque windows. For the new design, 13th century Cistercian windows were used as a reference, considering that

they might be similar to the original ones. Specifically the windows at Eberbach in France were used, simplifying their complex composition but maintaining the geometric solutions of interlacing circles and their plain colour scheme (fig. 23). Before installing each complete window, protected on the outside with a safety glass to protect it from ultraviolet rays, the exterior archivolt of each Gothic window were restored (fig. 24).

In order to clear the Gothic windows on the outside, it was necessary to eliminate the 19th century sloping tiled roof over the ambulatory, which came almost half way up to them forming a little courtyard (fig. 25). To build this 19th century roof, at least two rows of ashlars, the perimetrical coping and the supporting corbels had been removed from the ambulatory façade (fig. 26). The original Gothic roof was underneath the partitions, in a very poor state of repair and with traces of several repairs. There were remains of brick and mortar paving that made us think the original might have rested on a bed of lime mortar (fig. 27). It was decided to give the roof a solid brick cladding like the rest of the cathedral already restored. It was necessary to discover the dimensions and height of the perimetrical coping. We were lucky enough to find the mark of the original coping at both ends where it joined the walls, which provided us with the dimensions and level of the pieces we had to make and their exact location. Ashlars were made out of stone from a quarry in Montesa, and fashioned the moulding of the coping and the lower corbels with a plain piece, because we were not quite sure of their formal configuration (fig. 28).

It was rather more complicated to make a decision about the crowns of the buttresses at the sides of the ambulatory façade that end in large cantilevered gargoyles supported by ashlar pillars at each end (fig. 30). These buttresses, truncated because of the insertion of the sloping roof, made us think that there might have been flying buttresses that served to drain water from the roof of the main nave, like on all the other lateral aisles of the cathedral (fig. 29).

Again it was by chance that during the restoration of the walls of the apse façade we discovered ceramic leaders inside them near each corner, which originally served to drain water from the roof of the apse. On assuming that there were no flying buttresses, the missing volume was reconstructed over the buttresses of the ambulatory (fig. 31). Finally the pipes underneath these buttresses and the gargoyles were restored so that they would fulfil the purpose for which they were created, to drain the roof, which also collects rainwater from the apse, which in turn collects water from part of the cimborio and the transept aisles.

Inside work on the surfaces of the interior facades continued, repairing the breakages caused by inserting the Baroque lunettes in the Gothic ashlars. Repairs were made with the support mortars the painting restorers requested so as to restore the greatest possible painted surface. The only thing left was the mark of the interior capitals crowned with the little interior columns of the Gothic windows, which had been demolished when the Baroque vault was built, probably similar to the windows that still exist in the transept (fig. 34).

The last intervention consisted in providing a suitable lighting system for the interior and exterior of the apse. In the interior, it was decided to install a Led illumination system with multiple lights and cylinders, which would be completely innocuous for the valuable frescoes. The layout of the lamps allows visitors to see the Baroque remains of the vault with a soft, warm, filtered light. The paintings on the segments are illuminated by unfiltered lights, more cold and natural, emphasising the starry sky where the angel musicians singing to the Virgin Mary are located, which was originally at the Gothic keystone and removed when the Baroque vault was built (fig. 33). The exterior illumination of the apse is provided by spotlights at the centre of each façade with halogen bulbs that enhance the architecture of this part of the cathedral.

On 19th and 20th January 2007, an international symposium of experts was held in Valencia, to discuss the future of the Renaissance frescoes on the Gothic vault of the cathedral. The conclusion reached was that the dismantling of the Baroque vault and the restoration of the paintings had been impeccable, and that, due to the importance of the frescoes of angels for the world at large, they should be left visible to be admired and studied in future. A report by the Heritage Department dated 29th December 2006 finally authorised the removal of the Baroque vault from the apse of Valencia cathedral and ordered that the disassembled elements be conserved.

The architectural intervention has served, as expected, to restore the Renaissance frescoes that were concealed by the Baroque vault and partly by the Baroque windows. But the process required has also served to enhance the value of part of the chancel of the cathedral and to discover many things previously unknown that should be taken into account in future interventions. If possible, the relationship between the architectonic space and its surroundings must be as sincere and coherent as it was designed to be almost seven hundred years ago and it is our obligation to retrieve, preserve and divulge it for future generations (fig. 32).

Francisco Juan

...AND THE ANGELS EXTINGUISHED THE STAR OF THE BAROQUE

In June 2004, during restoration works on the main chapel of Valencia cathedral, the frescoes painted by the Italian artists Paolo de San Leocadio and Francesco Pagano on the vault of the Gothic presbytery between 1472 and 1481 were revealed conserved underneath the current Baroque vault. They were found to be in a better state of repair than might be expected.

The paintings, exquisitely executed, and very beautiful, are believed to be the first manifestation of Renaissance art in the Iberian Peninsula. Their principal motif is a choir of twelve angel musicians placed in a circle around the altar. The importance and transcendence

of this discovery was enormous, and was unanimously acclaimed both in academic circles and among experts and intellectuals who showed interest in the subject.
Outside these circles, there was an extra point that aroused people's enthusiasm: the frescoes had been concealed for over three hundred years. Nobody had seen them in all that time. The last Valencians to see them, many generations before, were still under the jurisdiction of the Austrian monarchs. Since then, oblivion, an ingredient added by the atmosphere of mystery sought by best sellers today, which filled people with expectations that were crucial to the eventual outcome. And the "culprit" of this punishment, the reason for the oblivion and concealment of these magnificent paintings, was still standing: the Baroque vault over the main altar. A rich, complex space that became an awkward obstacle after the paintings were discovered. For that reason it deserves special attention now.

The Baroque works

The works for the "refurbishment, cladding and finishing of the main part of Valencia cathedral" was the first definitive architecture to be created in the Kingdom of Valencia in the magnificent spirit of Baroque ornamentation. The contract dates from 17th February 1671, and the works consisted in many plain and mottled marble architectures associated to the preceding festive celebrations (fig. 2). It is the principal sample of Valencian Baroque vernacular architecture. And this is not surprising, for the presbytery of the cathedral was the symbolic and representative heart of the diocese, the nucleus from which the aesthetics of the new post-Counterreformation spirit was to spread, seeking an image that would bring the people together and with which they could identify, so that they would feel they were a single, renovated community.
This Baroque work was not made so much with the intention of concealing the previous architecture under a mere cladding as of generating a new space. It was architecture in every sense of the word. The new structure was included within the original Gothic space with a technical and compositional complexity that was a token of the skill of the craftsmen of the time. This refurbishment, like most of the works carried out during the Baroque period, sought a deliberate integration, which materialised in what some authors have described as "complex totalities", with the capacity to articulate but not decompose.
It has many remarkable merits. The skill in applying the architectural order on the polygonal design of the Gothic presbytery, with giant pilasters in the corners, placed at an angle and running along the entablature to the large cornice; the novelty of the successful double bodied portal shaped motifs set in the classical porticoes on each side (fig. 3); their composition with a central bay and a tiered lintel, flanked by solemn Solomonic columns crowned with scallop shaped moulding in the form of split fastigiums and the upper level with a shrine adorned with beautiful marble reliefs flanked by pilasters in the shape of truncated inverted pyramids and crowned with a curved pediment; the impeccable execution in black Alcublas stone, Tortosa mottled marble and the best marble available in the kingdom; and all decorated with an exquisite gold covered ornamental repertoire.
And although these values are not to be underestimated, they would be no more than a luxurious finish if it were not for the happy solution of the "modern style" cloenda or timbrel vault. It is precisely the octagonal vault with lunettes that closes, or rather used to close the chapel that characterises the new space and endows this work with the category of architecture (fig. 4). Without it, this fabric would be no different from some altarpieces or certain ephemeral monuments of the time except for the nobility and luxury of the materials. The vault alone makes this fine cladding of false fabric the first real Baroque architecture in Valencia. Because it is the cloenda that generates the space. It gives it meaning and resolves the crowning of all the lower part with surprising coherence and at the same time it fits into the existing ogival vault brilliantly. Its geometry comes from the Gothic, transforming it with great skill into a new modern spatiality, covering the deep rampant ogives with smooth, gently curved surfaces. The lunettes and the ribs spring from the vertices of the octagon, in continuity with the pilasters, form a half star and finish in a voluminous gilt bossed central keystone, which closes the ensemble.
The result is one of the most harmonious spaces in the history of Valencian architecture. Conceived as a splendid majestic background for the longitudinal axis of the central nave, beyond the luminous vertical axis of the cimborio, it became the symbolic destination of all the spiritual paths of the diocese. And its effect was enhanced by the fact that it was extraordinarily concentrated in the presbytery and did not spread to the rest of the Gothic temple; a clear example of these "complex totalities", easily articulated but impossible to decompose. The work, typical of its time, manifested (and still manifests) the extraordinary vitality of the Valencian society during the Baroque period, a token of the skilful execution of all the crafts connected with architecture. It expresses the ostentation of the skilled workers, and is a valuable testimony of the direct individual work of the best craftsmen of the time. Following the plan and at the orders of the obrer de vila (master builder) Juan Pérez Castiel, there were stonemasons (like Juan Escrivá or Bartolomé Mir), sculptors (like José Artigues or Tomás Sancho), wood carvers (like Sebastián Martínez), carpenters (like Felipe Coral), gilders (like Gaspar Asensi or José Caudí) and painters (like Pablo Pontons), all remarkably skilled at fine tasks.
The new chapel was highly regarded, and became a major reference. This first crucial initiative embarked upon under the Archbishop's authority was followed by most of the towns in the area, giving rise to what was no doubt the most important refurbishment enterprises undertaken in our land in the last few centuries. One by one the towns "modernised" their parish churches. Taking the cathedral chapel as a model, and at the request of the people, the Gothic structures of the churches were

covered in Baroque style and thus the temples adjusted to the new aesthetics, generating new spaces with extremely elaborate ornamentation.
The success of this space was so great that, in spite of posterior fashions that repudiated exuberance and rich ornamentation, the main chapel has continued to be Baroque for over three hundred years. After a century of its life, academicism, which kept such strict control over artistic aesthetics and, in its institutional orthodoxy and uniformising, centralist and censoring attitude, embarked upon a "crusade" against Baroque excess, maintained intact and in place Pérez Castiel's chapel. Even though in 1774 Antonio Gilabert started to refurbish the whole interior of the cathedral, adapting it to the new aesthetics of "real architecture" in NeoClassical style. In the 20th century, Rationalism, positivist, abstract and not at all fond of ostentation and pomp, respected the Baroque style. And not even in the thorough refurbishment work performed on the cathedral in the nineteen seventies, whose result was the current restored Gothic appearance of the cathedral, did anybody dare interfere with the magnificent architecture of the central altar. We can then add another merit to this architecture: the credit due to all survivors.
However, in the individualistic and pragmatic world today, lacking in authorities and hierarchies, the chancel of the cathedral has a serious shortcoming: it is an "addition" not to the liking of the general public. Few aesthetic terms have such pejorative connotations today as "Baroque", generally applied to fussy and overelaborate elements. And it is logical that this should have come about since our society has been educated in the methods and principles inherited from enlightened Modernity. Accustomed as we are to the positivist tradition, as R. Venturi pointed out, we lack the mental agility (not to mention the attitudinal agility) to understand the magnificence, complexities and subtleties of the Baroque tradition. And however much we say that the appreciation of our heritage must never be a matter of taste (what was popular yesterday may be unpopular today, and vice versa), the fact is that the cultural heritage belongs to those that partake of it. And here, we must admit, Baroque architecture is at a disadvantage.

The dilemma

We find ourselves, therefore, faced with two magnificent artistic manifestations with great patrimonial value inside the same architectural structure. It turns out that one of them was concealing the other and the intention, for reasonable and legitimate considerations, was to make it possible to see and appreciate them both. A serious dilemma with a difficult solution. And at the same time, an exciting project, both because of the extraordinary value of the works themselves and the unusual complex situation. As a strategy, it would have been prudent and wise to try to prevent rivalry between the works. Ideas about restoration that were sustained in the past and involved putting certain periods above others are now totally outmoded. Our laws say that none of the historic sequences of a monument is dispensable, for they are all testimonies of its complex cultural expression. So each of the parts of a building, whatever period it may date from, is part of our heritage and therefore deserves to be preserved. But at times it is not so easy to be judicious and objective. Soon after the paintings were discovered, the press brought out tendentious headlines saying, "The Baroque vault of the cathedral to be taken down" or "The Archbishop's see and the local authorities have decided to take down the Baroque vault in the cathedral to display the frescoes". And in this way, maybe without meaning to (but without trying not to either), people were induced to take sides for one or other of the works of art, and even to express preference for one particular solution. As though there were a conflict, the citizens became divided between those in favour of the frescoes (much more numerous) and the defenders of the Baroque vault, an awkward situation which did little to favour a wise, well pondered decision.
In view of this dilemma, the initial idea should take into account the following: Can the two works remain together in the same place in such a way that both can be contemplated and admired without seriously impairing either of them? It seems undeniable that a satisfactory, viable, affirmative answer to a proposal of this type would have given rise to an efficacious, successful solution that would have made everybody happy. But the question was never brought up, because it was considered impracticable. The Renaissance frescoes were irremediably confronted with the Baroque vault. The affirmation of one of them implied the negation of the other, and vice versa. And nevertheless I am convinced there was (and still is) a positive answer in this respectful, committed line. However delicate and complicated the process might have been, it would have been worth doing it, because obviously we would never have come up with an easy, "commonplace" solution. On the contrary, it would have taken time, the generous, effective intellectual contribution of expert institutions and individuals, refusal to dismiss outright new fangled systems and techniques, a great deal of imagination and serious and rigorous methods of research and experimentation.
The cathedral chapter did not make things easy either. Wary because of recent experiences of the same type, they did not want to hear of "research" or "experimentation" in such an important place as the main chapel of the cathedral. They were not even willing to prolong the duration of the works already initiated any more than necessary because of the inconvenience they were causing (workers, scaffolding, noise, dust and dirt). And logically, they wanted an agile, diligent result. In general it is not wise to rush through any intervention on a cultural asset (with the exception of urgent emergency repairs). In this complex case, where there seemed to be no objective reason that would justify urgent action, there was no need to rush. But unfortunately the timeframe involved in political decisions today is not measured by the same yardstick as the timeframe for works of art. And these frescoes are a good example of this fact: they were

painted over five centuries ago, have been concealed from human eyes for over three hundred years, and they were supposed to be "unveiled" in a few months.

The solutions

Under these circumstances, the only viable solution seemed to be to formulate proposals that would be easy to understand and execute. A reasonable option would have been to finish the cleaning and restoration works already under way on the Baroque work (sponsored by the Department of Culture, Education and Sport of the Generalitat Valenciana) according to schedule, and simply provide faithful, comprehensive documentation of the real state of the frescoes so that they could later be reproduced in detail somewhere else. For example, in a replica of the original Gothic presbytery of the cathedral built for that purpose. In this way the paintings would have been safeguarded in keeping with the recommendations of all restoration charters and under the laws protecting heritage, and both architectures would have been preserved (the Gothic in the frescoes and the Baroque covering them) in the same way as they have reached us today. Besides, with this solution, both artistic manifestations could have been admired in their natural surroundings (the frescoes, or rather their reproduction, in a replica of the medieval chapel, and the Baroque space, complete and unitary, in the chancel of the cathedral), which would undoubtedly have increased their value. And it would also have been easy to offer the visitors both a distant vision of the angel paintings in their architectural space (from below, at altar level) and provide the means to see them in detail (from two or three metres away), a real privilege that would have allowed them to appreciate first hand their great beauty and skilful workmanship. It would even have been advantageous to preserve the original paintings in their dark chamber, controlling them hygrothermally. It would not have mattered that the paintings be overilluminated or overexploited from a museistic point of view, because they would only be a replica of the original ones. In this sense, with the logical differences, it would have been an operation a little like what was done in the Altamira Caves. But the principal advantage of this solution would have been respect. No door would have been closed. Everything would have been conserved in its original place, which would have given time to think things over slowly and calmly in search of a definitive intervention.

Nevertheless, in view of the way things were going, we must admit that this alternative would have caused a certain amount of frustration. From the citizens' point of view, renouncing the discovery of the original frescoes would have been tantamount to disappointment since it was the desire of the majority to see the real paintings in their proper place. This drawback could have been lessened with a lengthy, didactic explanation of the arguments in favour of this solution, although it would have required a great deal more decision and political determination…

The objection raised by some restorers was better founded: the frescoes, although they were not in bad repair, required urgent, in depth restoration. It seems that the need was so great that if they were not restored in a reasonable length of time (they said months), their integrity would be endangered. There was no objection to this point. Above all else, the safety of the paintings should prevail. However, this is where the largest number of discrepancies arose. For those in charge of the works, the paintings could only be properly restored if the Baroque vault that concealed them were removed beforehand. There was no other viable solution. So this was done without any misgivings. The Baroque vault was removed after dividing it up into many pieces. But you do not have to be an architect or an expert to realise that this action would profoundly damage the Baroque work. Its "complex" unity was broken, thus ruining a fundamental element: precisely the one that, with great coherence, closed and generated the brilliant architectural space. And there is no need to say that the preservation of this architecture and every part of it, as an asset of cultural interest, should also have been guaranteed. Especially if there was a viable alternative. Probably much more expensive, slow, difficult and risky, but another alterative after all and therefore worth taking into account.

The formula chosen to evade these "architectural" misgivings was the "reversibility" of the process. A controversial concept that lacks a unanimous definition when applied to our architectural heritage. Some sustain that in architecture, given today's technology, everything is reversible if the proper media are applied. A nefarious way of interpreting its meaning, because in such a case the concept itself would be pointless. At the other extreme we find those who hold that nothing is reversible, because if it were, it would be anything but architecture because of its ephemeral nature. And until an agreement is reached, our laws impose a diffuse precept on interventions with contributions that are not original. Of course this prescription attempts above all to establish a strategy guaranteeing the preservation of the "authenticity" of the building: everything new that is added on must be designed and executed in such a way that it can be removed in the future without damaging the original work. And this is precisely what was not done with Pérez Castiel's vault. To start with, it was brick lined cloendas, clad with gypsums and plasters, that were neither designed nor fashioned to be "dismantled". Therefore it was not "reversible". In the second place, they were themselves original pieces whose authenticity should be preserved. And in the third place, its real value as testimony of a traditional way of covering architectural spaces with masonry methods was lost forever by cutting it up with a saw or laser beams. By reassembling those pieces in their original place, the original appearance would never be achieved. At the back, they would be all seams and scars. So the idea of "reversibility" is not applicable in these works, however much they insist that it is so.

Once the vault was removed and the frescoes were successfully and

brilliantly restored, a "board of experts" pronounced their decision that the paintings should be left uncovered. And under the circumstances, there is no doubt that that was the best thing to do at that point. But nothing was said about their opinion of the Baroque space. Of course they had no opportunity to see it whole. When the experts set their eyes on it, the presbytery was filled with scaffolding (fig. 5). This permitted them to see the paintings close up; of course it was the best way to do so, but at the same time it prevented them from seeing the overall effect and consequently from judging and thinking over the global result of their decision. The important thing were San Leocadio's angels. The Baroque chapel did not matter. And it is precisely from below, without scaffolding, that we see the angels today, irremediably inserted in the ambit of the exuberant central chapel.
And as a few of us feared, the most questionable part of the whole intervention resides, without a doubt, in the result. The angel musicians, sunk in the ogives, are foreshortened behind the brilliant rocaille ribs that frame them. Set among gold ornaments, they lose their pre eminence. Besides, located as they are in an unsuitable place very different from the sober medieval chapel for which they were designed, they are seriously adulterated (fig. 6). In the vault, without the lunettes and the bossed keystone, the ribs look sad, lacking the references that gave them meaning. The presbytery space, with Baroque walls, Gothic vaults and Renaissance paintings, is incoherent and disconcerting. An invented space that never existed before, incapable of provoking the evocative emotion of works that come from our past. A solution does away with the vitality transmitted by its authenticity, turning the chancel unto a sort of museum of itself (fig. 7). Because restoring and unveiling the frescoes, even though it might have been advisable, should not have been the only task undertaken. An identifiable architectural purpose, a project, was lacking, an integral idea that would have guided the process and oriented the decisions.
There is still hope that things will not be left for posterity as disappointing as they stand today. Hope that the matter may not be considered settled. Hope that once people's wishes have been fulfilled, the dilemma will move away from the public eye and can be reconsidered slowly and calmly. Hope that the Baroque space may be recuperated (including the vault), albeit with different elements, lighter and easier to dismantle. In this way perhaps the Baroque chapel and the Renaissance frescoes may finally exist together. The former in the usual way, recovering its central role in the chancel of the cathedral and the latter exhibited on certain special occasions, which would help preserve them and maintain enthusiasm about them. Not everything has been lost (except the Baroque cloendas, today little more than a well packed pile of glorious rubble). All that is required is the will, commitment and high mindedness of the people who have the power to make decisions. We must not forget that interventions like this one depend on a few, but can give pleasure to many.

Enrique Rabasa

PRINCIPLES AND CONSTRUCTION OF GROINED VAULTS

As part of an editorial project of the Centro de Oficios in León, a school where stonemasonry is taught, among other subjects, I managed to build a groined vault with tiercerons and five keystones and three metre spans, with the intention of demonstrating the Gothic system and building methods. The experiment posed certain unforeseen problems, and served to confirm something we already knew, or thought we knew, about the construction of groined vaults.
The model used was a drawing found on one of the pages of a manuscript by Hernán Ruiz (1558-60) (fig. 1). We have other drawings, in treatises or collections of designs, explaining the form of groined vaults made between the 16th and 18th century. Almost all of them have a four pointed star on a square plan, that is, a design of ogives or diagonals, joints (ribs linking the secondary keystones to the principal one) and liernes (fig. 2). A drawing by Philibert De l'Orme (1567) shows the width and side of the ribs, and the same applies to those found in a book by Vandelvira (1575-80), in the notes by an unknown author signed by Alonso de Guardia (c. 1600) and in a treatise by the Majorcan master stonemason Joseph Gelabert (1653). These three Spaniards appear in figure 3 with Hernán Ruiz. Although Hernán Ruiz does not provide any data about profiles, it is possible to make a rough calculation based on the diameters of the keystones. In the case of Gelabert's five keystone chapels, the thickness of the members, although possible, suggests a rather small vault. From other details that would take us away from the subject, Gelabert can be confirmed as a late follower of the medieval tradition, which came down to him somewhat deformed. However, the manuscript signed by Alonso de Guardia is a totally improbable design, as it obtains the templets of the ribs' intrados, which would be a reasonable practice for the voussoirs of a spherical vault but unnecessary in a groined vault; besides, it is evident that given the thickness of the arches it would have been preferable to reject the ribcladding system and build it with ashlars. Vandelvira's design is complicated with a couple of circles and joints of the ribs without keystones, like De l'Orme's.
That is why it was decided to use Hernán Ruiz's more general and conceptually original design as a model, as it was also feasible. Nevertheless, when making our vault we altered somewhat the dimensions of the secondary keystones to avoid excessively horizontal joints. The problem of the interlocking of the ribs at the spring, arranging them at different points and not just equidistant from the corner, as the drawing by Hernán Ruiz seems to suggest.

Principles

The treatises mentioned above coincide in simplifying the explanation by using

the four pointed star as a model. But Gothic ribbed vaults are not limited to these simple vaults with tiercerons and variations of them, but, as is evident, they can be extremely complex in form. On the other hand, they respond to very different traditions depending on the different nationalities: German reticular vaults, English fan vaults, more classical French vaults or the plurality of Spanish vaults provide a very broad range.
However, the principles are common to all of them; and when I say principles, a term very often used by classical French authors of building history, Choisy or Viollet le Duc, I mean, as they do, the way of approaching building, the overall design and the detail, in relation with a conception of space and the role of the designs control it uses the term Principle or Principles with several different meanings. Some of them are similar to our usual meaning, as when we speak about physical laws, when we establish these laws as elements or principles, that is, the beginning of a reflection that gives rise to a way of acting, or when we refer to the more moral issue concerning sticking to certain principles. In many parts in the texts by Choisy and Viollet the term "principle" could be replaced by "postulate", "premise", "cause", "basis", "rule" or "regulation"; but the most common word used to replace it tends to be "idea". It is an idea or conception about a material possibility. It is not, therefore, the idea that guides the project because of similarity with something exterior, the idea of doing something as though it were something, or organising the ensemble in a general way, which must be resolved by building skill and experience in layout. It is, on the contrary, the idea of a feasible configuration, which can be developed in many ways, which refers to the reality of equilibrium, the way of manufacturing and assembling and the geometric link that the design makes possible and whose efficacy will determine whether it deserves to be developed further.
In Choisy's Histoire de l'architecture the evolutional developments of some principles, the series of Greek temples or Gothic cathedrals are outstanding. But the text contracts and loses brilliance when explaining how, since the 16th century, building is subordinated to the wish to obtain previously conceived forms, spheres, cylinders, cones, of classical elements and their intersections, that do not immediately appear as the result of reflections about building.
This other approach to the project, the conception of (classical) form and the technical resolution of the problems that come up has given rise to episodes of interest in the history of construction. Renaissance forms were resolved in Italy with masonry, but in France and Spain what are apparently the same surfaces are obtained as intrados of complex bonding of stone carved voussoirs. This implies an effort in the spatial conception of the pieces, the development of the surfaces and the graphic obtainment of dimensions to be applied to the carving process, which reached its peak in the 18th century when this knowledge and these procedures were given the name stereotomy.
However, let us return to the principles of the groined vault. It is a volumetric, spatial object, controlled nonetheless by two dimensional designs of round arches on vertical planes. The verticality of the members even of the decoration and the reference of these members to the horizontal projection, to the plan, direct the design of the large lines, they are its principles. There is no abstract homogenous space such as we are used to conceiving, but a network of material references where we can speak of perpend, rather than vertical, and level instead of horizontal, as was to occur in literature concerning building techniques until a very late date.
The rules for the design of Gothic ribbed vaults are few and they are not watertight. The horizontal projection is a mesh; by raising its nodes –what we call keystones– vertically, to a suitable height, this mesh adapts to the volumetric form desired. In this spatial elevation, the segments that unite the nodes become ribs and these ribs, to begin with, are merely round arches over vertical planes. The aim of this sort of inverted projection of the plan towards the space can be very diverse. In the simplest cases, it is a question of locating the keystones in such a way that the longitudinal or transversal section of the vault –the rampant– acquires a more or less rounded shape or the relative elevation of the highest parts is reasonable. In the second half of the 16th century this was done so expertly that the alteration of the profile of the ribs became a game or a show. Finally it was possible to adapt the reticle to any previously conceived form; so stars were grouped to form a single vault or the mesh was adapted to s classical shape. (The latter is what was done to achieve, for example, the spherical, groined vault over a hexagonal plan, which illustrates the article by Benjamín Ibarra that appears in this same magazine.)
As the ribs are arches over vertical planes, their joints, intersections of vertical planes, are vertical axes. The keystones are therefore developed vertically –with exceptions that prove the rule. And the ribbing corresponds vertically to the plan, which appears materially during the process, as we shall see.

The Design

In the simple case we mention, the design is limited to coordinating four types of arch. The ogives or transepts are semicircular, as is usual. The four perimetrical arches –groined or bonded according to their location in the building– are pointed arches with a more or less high keystone. The tiercerons are obliged to project vertically and rise to the height of the secondary keystones. The ligatures join these secondary keystones with the central one, which they reach horizontally. We shall leave the details of the design and the alternatives and decisions for the publication mentioned, but it is clear that some basic knowledge of flat geometry is enough to fulfil this coordination of arches over vertical planes (fig. 4).
The design the vault requires is a schematic plan and the elevations of each of the ribs, which are only round arches that must be properly designed to link two given points. That is sufficient to make the pieces. The medieval

builder did not know, nor did he need to know, how to make a cross section of the vault such as we can find in a 19th century treatise (fig. 5).
Indeed the ribs are arches made out of voussoirs, and to make them it is sufficient to know the curvature or profile or section. Formal problems, which today we would call stereotomic, concentrate at the toothing and the keystones, that is, at the places where the ribs meet or intersect with each other. We can summarise here the way to carve unique pieces, whose details we have described elsewhere. The pieces of the toothing, which are separated by horizontal beds, are carved according to the upper and lower flat sections, which are marked directly on the stone, without any more requirement than to know the plan, the profiles of the ribs and the distance between them at each level, which can be obtained from the design of the separate elevation of each rib (fig. 6). And the keystone pieces are carved (fig. 7) according to an operation surface, as the English archaeologist Willis called it in the mid 19th century, the horizontal plane of the intrados, which contains the designs, the directions of the ribs of the plan; to locate the couplings leaving the keystone and joining the normal voussoirs of the ribs, only one piece of information had to be added: the inclination of the rib when it reaches the keystone, which can also be obtained obviously in the design of the elevations.
So the general design of the vault is reduced to the plan and the height of the keystones. The plan, the reticle, is quite random –in Spain there are enormous differences in the drawings– and the height of the nodes of this mesh is also chosen freely to a certain extent. If we add to these initial decisions the design of the profiles of the ribs, there are no other general variables. The way these elements are combined in the ceiling and the construction is so evident that anyone who has to make this type of vault today will use the same methods as a medieval builder.
The design is made up of flat elements; the possibility of using the resources of descriptive geometry or computer graphic models will make it possible to foresee the resulting appearance and better explain to the workers the forms sought, but this is really only interesting for us, inexperienced designers and stone carvers who have never before come up against the problem. If a 16th century stonemason had had similar means, perhaps he would have used other building methods, but if he decided to go on making groined vaults his methods would not have been very different even if he had had such means. Detailed drawings of the rib design, that is, of the simple elevations we mentioned, have not been conserved and there are very few horizontal projections. This is probably so because the drawings were made on provisional surfaces of the apparatus holding the centering. But there are some drawings that reproduce this process. In the one that appears in Hernán Ruiz's notebook, the ribs are represented by the curve of the centering. The same applies to many others. However, in De l'Orme's drawing for an estimate for the vaults of the parish church in Priego (Cuenca), in Gelabert's and in some German drawings, all the outline of the rib can be seen, that is, the line of the intrados too.
It makes sense to show only the line of the intrados, as it is a necessary and sufficient guide to carve the pieces and the line common to the arch and its centering. In the vault at León, however, we decided it was wise to draw the parallel line of the ext5rados also. On designing the profiles of the ribs, the ogives were given a greater thickness than the tiercerons and the ligature, as a result, it was necessary to make sure the several surfaces of the intrados of the ribs that reached the same keystone were on a level with each other, so as to guarantee correct support for the surface of the vault cladding. Attending to this simply involves making sure the height of the intrados of the rib at the keystone is a few centimetres higher or lower; but there can be no possible confusion if the whole edge of the rib is drawn, which explains why this was common practice in some of the representatives mentioned. When we speak of the edge and the intrados, we do not take into account, naturally, the added mortice and tenon the rib can offer to be inserted into the vault.

The Detail

Having mentioned the design of the profiles, it is worth explaining what criteria we have followed to make the templets. There is little information available about this matter, since it is not easy to obtain an exact map of these sections from the ground, and during restoration works, data collection is not always performed. But in general, besides the schemes that attach the rib to a rectangular shape, there are many others that have reeding and keel moulding following a convex concave convex shape, therefore with a central projecting part, which allows support on the centering and lateral roll moulding that may simplify the task of raising it manually or with pincers (fig. 12). Apart from the formal design, which followed this criterion, the profiles had to be dimensioned according to their function in the vault. In this respect, the only written document that gives any clue about the original uses is the one quoting the words of Rodrigo Gil de Hontalón in Simón García's manuscript. The edges of the ribs are established there and even the weight of the keystones, depending on their location and the width of the vault. Applying these proportions to ours, three metres wide, we obtained such thin edges that it would have been very difficult to carve them out of stone and, if they had been, with exceptional craftsmanship, the vault would have looked like a maquette and not a real groined vault, like so many that exist with these dimensions. Consequentially, it was clear that the proportions stipulated by Rodrigo Gil were intended for the usual width of large church naves, and not so much for the cloisters.
Once the pieces had been designed, they were fashioned by students from the Centre over several years, because the work had to be alternated with other tasks that would guarantee thorough training in stonemasonry. In any case, it took many hours of work, of painstaking carving of mouldings perfectly executed. In this detail perhaps, paradoxically, this

vault differs from those it aspires to imitate. If we look closely at the ribs of the original vaults, we can see a certain amount of tolerance regarding the craftsmanship, understandable if we are sure no one can get close enough to see them clearly. We could even say that the imperfections give some life to the stonework. In contrast, in neo Gothic vaults and in the one in León, the execution is impeccable, not only due to their short lifespan or good state of repair, and although it is desirable from the viewpoint of learning the trade, it distinguishes them clearly from those made according to Gothic tradition.
The shaping of a mould always starts with an approximation where the curves of the profile are replaced by straight lines; first a mortised piece is carved and the edges are fashioned until they become rounded (fig. 14). To verify the correct carving of the mouldings in this vault, especially in the toothing, it may be sufficient to use a curved truss or ruler with the curvature of the rib as a guide. But it is true that, strictly speaking, this truss would only fit perfectly in one place (fig. 15). If the truss follows the curve of the intrados designed, in theory it would only have to be applied at the central line of the rib profile. That is why the workers from the Centro de los Oficios have added other references, like the design of more profound curves with different radiuses, special gauges and countertemplets used to check the roundness of the mouldings (figs. 16, 17). As a result, the workmanship is perfect.
According to the degree of strictness regarding this sort of detail, it may seem difficult to control the shape completely. We said above that the possibility of having computer images of the result sought does not substantially change the design necessary to do the work. But it is true that the stonemason who has a computer model may be obliged to deal with details the Gothic builder would not have noticed.
However, the geometrical conception of the general lines is, as we have seen, relatively simple. Much more than what is required by the dismantling of classical stereotomy that was developed with more and more complexity until the 19th century, and that always attempted to determine the precise shape of the pieces. The drawings of groined vaults we have spoken about here are mere sketches, showing the ribbing in some lines, but more a general guideline rather than a specific design; stereotomy, on the contrary, defines the volume of each of the ashlars.

Assembly

To assemble the vault, the text attributed to Rodrigo Gil de Hontañón (fig. 18) was followed. It contains a description that says –and this is one of the clearest parts of a text that is generally not easy to understand– that a horizontal platform "with lots of planks" has to be set up where the toothing meets the vault proper. On it, he adds, the horizontal projection of the ribs is drawn. at the spot where a keystone is to be located a stanchion is placed at a suitable height, and the piece is placed on it, resting on a strut. Trusses are placed between the stanchions to hold the centering of the ribs, and finally the gaps between them are filled with cladding.
This is what we did, setting the platform on a dismountable frame, which for a real vault would be a scaffold reaching down to the floor or resting on the construction described above (fig. 29 and following).
Thus the assembly is conceived with the same principles as the design and the carving, the supremacy of the plan and the vertical correspondence of the elements on it. To summarise, we can say that the design is the spatial projection of the plan of a reticle; that the carving of the toothing and keystones only requires a rough knowledge of that plan and some arches over vertical planes; that it is assembled by setting up the plan and the elements that are just dropped on top of it.
The system is easily conceived, elastic and admits variations. Among the latter, the design of the curved horizontally projecting ribs, which are often elements that are supported (by the segments) and not loadbearing elements, as Rodrigo Gil would say.
We can also find keystones whose axis is not vertical. In some cases the form has been forced to soften a verticality that might clash with the general inclination of the zone. But in many others, the keystone is not really a keystone, a meeting point of ribs, but a decorative broadening of the ribs. Or it receives single curved ribs. (This also occurs in some keystones in the vault of Teposcolula.)
As an extreme exception, we can see that some vaults in Prague disobey all the rules of verticality, offering twisted ribs whose profile has a longitudinal development.
We must add that, before setting up the platform to place out vault, the toothing with all its pieces was solid with a very advanced centre of gravity, so much so that it could easily swing inwards. In a real vault the toothing would be joined to elements of masonry that would prevent this falling forwards. Let us remember, on the other hand, that a filling of rubble and mortar is usually added to the gaps in the intrados on this zone of carved stone.
The initial model had been, as we said above, a design from Hernán Ruiz's notebook. In it, apart from the sketchy drawing of the vault and the map of the ribs, piers were represented at the four corners, probably as a reminder of the problem of stress for didactic purposes. In our case, the volume of stone necessary to reproduce these piers would be excessive, keeping in mind the easy alternative of using perimetrical braces, which can show to what extent the vault is actually thrust. During the removal of the centering, there was no symptom of this thrust –no movements or sounds that suggested thrust– and the braces did not seem to be tenser or to have lost the slight curvature of their own weight. This is not surprising, if the toothing offers a considerable mass in relation to the ribbing and, as we have seen, also tend to push inwards. However, we still have not added the cladding, which will increase the stress. We have left this finish to be added when it is finally located somewhere.
The counteraction, which we have only mentioned at the end, is, nonetheless, a very typical case in Gothic building. For Viollet le Duc, Gothic principles are essentially ways of experimenting with balance. Indeed French cathedrals take

to extremes this reflection, especially developed in the transversal section of churches. However, Gothic architecture as an efficacious, standardised system of building vaults, which is basically the same all over Europe, could not be understood without the particular conception of form and details that we have briefly described here, the principles of its geometry and design.

Benjamín Ibarra Sevilla

RESTORATION OF THE VAULT OF THE OPEN CHAPEL AT TEPOSCOLULA IN OAXACA, MEXICO

For many years, the architectural heritage of Mexico has suffered from neglect and lack of maintenance. Due to the influence of different historic events, today we face the challenge of healing the wounds of some historic buildings and doing whatever is necessary to prevent many others from collapsing. Although ideas about conservation and restoration have changed at the same rate as in other parts of the world, in Mexico the number of patrimonial buildings is greater than the capacity of the institutions to look after them, which can clearly be seen from the state of many convents, open chapels and other buildings that are no longer used. Preservation strategies vary according to the institutions, regions and number of heritage buildings in their care. Oaxaca is one of the richest states in the Republic of Mexico as regards cultural heritage, with a large number of preHispanic structures, town centres, colonial houses, natural sites, ethnic groups, traditions and customs that make it a very interesting place. Between 1994 and 2002 a great effort was made to restore and maintain the most outstanding buildings. Interventions focused on 16th century buildings that were still standing, as a living testimony of the encounter of the Mesoamerican and the European world. In 1995 it was decided to restore the vault of the Open Chapel in Teposcolula to save a building that is often cited as one of the masterpieces of colonial architecture in America. For all of us who participated in these restoration works it was a very unusual and enriching experience; the social and economic situation provided sufficiently suitable conditions to contemplate the possibility of restoring the 12 metre wide vault using the same building methods and materials that were used in the 16th century, that is, carving the stone by hand to replace the ribs and segments that had been lost. The first part of this text describes the research performed by the author, and the intention is to familiarise the readers, in a very simple way, with the basic elements they require to understand the type of building we are dealing with and why it is so important. The second part strives to explain and share the experience of what it meant to reconstruct that vault following the rules of stereotomy and the building process used in the 16th century, an important task in the context of architectural restoration at the end of the 20th century.

The open chapel at Teposcolula, Oaxaca
Teposcolula in History

On 2nd February 1526, the first group of Dominicans embarked on a voyage to New Spain, and at the end of June of that year, twelve monks landed at the port of Veracruz. In 1528, two new groups of monks arrived, making twenty four in all. By that time, the monks of the Franciscan order had already occupied the native centres near Mexico City. The Dominicans decided to go south to fulfil their apostolate, because, in fact, "they had no choice". The creation of provinces was the basis of the structure identified by convents and vicarages it controlled and administrated. The convents were usually in cities or in a place where a city was to be built. The vicarages controlled a portion of the territory of the province and were established in accordance with the existing organisation of the regions and the political, social and territorial structure was often respected after negotiations between the Mixteco lords and the viceroys' commissioners.
Several studies agree that the moment of splendour of the Lords of Teposcolula was between the 16th and 17th centuries. Between 1553 and 1559 teachers were appointed at Teposcolula monastery for each of the subjects taught to students of the order. In historic documents, Teposcolula is commonly mentioned as a vicarage, and as such it was recognised in the province. Around 1550, with the Dominicans' work and the wish to create a building that would identify the new urban settlement, the need arose to build the open chapel and atrium to hold religious services. There was sufficient social support to start to construct the ambitious religious complex.

The Atrium – Open Chapel System

In 16th century American religious architecture, it was common to find a structure consisting of an atrium and an open chapel, the result of the combination of different spatial conceptions and different ways of performing religious ceremonies; on the one hand, the use of the open space of the Mesoamerican world, and on the other, the use of covered space of the European world. In the task of christianising the Mesoamerican people, the atrium as an open space played the role of a real temple and the chapel was reserved for the altar, the priests, the choir of singers and the principal parishioners.
The atrium, a constant element in 16th century religious architecture, is a horizontal piece of land usually located at the front of the religious complex and generally enclosed by an "atrial fence" with several entrances. For the different orders the large outdoor space was very useful for their religious activities; worship in the open air was familiar to the American natives and they soon considered it their own. George Kubler mentions the atrium and open chapel system as a token of a broad, generous concept of space, generous and tolerant towards American concepts of space and in keeping with ancient customs of both Christian and native rites (fig. 4).
Don Manuel Toussaint is believed to have been the person who gave the name "Open Chapel" to a type of architectural item that was created in America in the 16th century and he says

that this may be the only possible analogy between the Christian church and the Mesoamerican teocali. In general and in a very simple way, these buildings are an open bay that leads to the atrium through one or several arches. The open chapel was essential when there were few monks and particularly in communities that covered several separate settlements. Later on, some open chapels were turned into the presbyteries of churches, but many others conserved their relationship with the open space. Some examples are still standing in Mexico, and the variety of solutions shows us how freely the matter was dealt with.

The Open Church at Teposcolula

The heritage of the town of San Pedro and San Pablo Teposcolula in the Alta Mixteca region in the state of Oaxaca still possesses the most remarkable of all the open chapels; its design is very beautiful, and suggests an excellent technical and compositional feat for the time, since there is no other building in America with a vault of over 300 tons supported by columns. No doubt it was a well trained European architect with experience in stereotomy who instructed the Mixteco builders. The solution of the building speaks of spatial exploration, and its scale and originality made it a symbol of the town and the religious institution. This building was avant garde in its day. It is now considered a classic. Its composition has transcended fashion, superficiality and mere inventiveness (figs. 5, 6).

Composition of the Building

In an attempt to find the design behind the architecture, some ideas were put forward. The first shows the relationship that exists between the ground plan and the elevation (fig. 8). The second shows that the proportions between the length and width are generated by three hexagons grouped in both the ground plan and the elevation (fig. 9). A third shows the importance of the presbytery, the axis of symmetry towards the centre, which attracts the eye to the place where the altar and the altarpiece stood (fig. 7). To understand its structure, at the north and south ends of the building we find two horizontal planes; the first, at the height of the impost of the vault, whose flat roof forms the terrace, and the second, at the height of the capital of the columns, forming the floor of the choirs. These horizontal planes form the structural core of the building in a transversal direction. On the other hand, there are three vertical planes that run longitudinally from north to south. If we look east, the first corresponds to the façade, the second to the intermediary arches and the third to the solid wall at the back (fig. 10). The most importance space in the building, where the altar stands, is covered by a vault contained in a hexagonal prism; there is a pier at each arris. Underneath, at each side of the prism, there are bays with the main arches; the piers thicken towards the bottom to the impost of the main arches, which in turn rest on columns continuing with the hexagon to the ground (four vertices of the hexagon in freestanding columns and the other two in columns attached to the solid wall at the back) to achieve the desired transparency. On the west façade there are a couple of flying buttresses. In the arch behind, the buttress leans on a rampant arch coming out of the capital shared with the impost of two main arches, and continues in the air towards the north and south respectively on little arches resting on smaller columns (figs. 11, 12). Two buttresses are attached to the wall at the back of the building (fig. 13).

The vault

The vault that originally covered the open altar at Teposcolula, whose reconstruction shall be described below, required that two conditions be complied with:1. that it would cover a 12 metre bay (the impost is 11 metres high)
2. that the weight of the vault be supported by props or columns.

This vault was conceived as a half sphere. The centre of this sphere is at the level of the impost and the length of the radius is the distance from the centre of the vertices of the hexagon. At each vertex there is toothing and the sphere is intersected by the vertical planes of the hexagonal prism. The vault has ribs that work structurally forming three round arches, the diagonals that go from vertex to vertex in the hexagon and an elaborate network of secondary ribs.

All the arches that form the ribs of the vault are generated by vertical sections of the sphere (perpendicular to the plane formed at the impost), with the exception of the double curved ribs that connect the diagonals with the tiercerons forming a more “whimsical” pattern. We shall discuss this type of ribs and their stereotomy below. The position of the keystones in the sphere and the relationship of the ribs with each other is resolved in the flat projection of the vault with a fairly logical series of designs, with the hexagon in which the vault is located as the point of departure, and, in consequence, forming smaller and smaller equilateral triangles inside it, as many as the tip of the pencil permits (fig. 17). At the centre, the circle of the keystone lies within a couple of triangles from this series, and the foliated cross (the symbol of the Dominicans) obtains its geometry from the geometry of the vault, reinforcing the idea of taking the triangles ad infinitum, where the vault has a keystone that in turn has the vault with its keystone inside… and so on (fig. 16). Even though the structural calculations demonstrated that the work on the vault is a self supporting spherical membrane 30 cm thick (the thickness of the segments), the design of the ribs is intended to take the stresses to each vertex, where the columns hold the weight (fig. 14).

The reconstruction of the vault

The deterioration

It is not clear when exactly the deterioration started, but it could have been at the end of the 19th century that the vault began to collapse. In the early nineteen twenties, Manuel Toussaint visited Teposcolula and published a description of the building accompanied by some photographs showing its state at that time. Toussaint’s graphic information shows that the flat roof in the north was no longer there, and the most serious damage was to the south of the altar with the loss of the intermediate arcade that had collapsed along with a third of the vault. The keystone was still in place, held up by some diagonal arches that were still standing. Some ribs and some keystones were still in place. From this time onwards, the vault deteriorated rapidly. As the century went on, large pieces continued to fall, but the rest of the building remained standing. In the second half of the twentieth century, in the publications by J. McAndrews and G. Kubler, we can see some photographs of the building, showing that about 25% of the vault approximately was the only part still standing (fig. 15).

Hypothesis of the deterioration
Based on the photographic material and the structural analysis, the deterioration process was found to be as follows:
- Lack of maintenance in the roofs led to water infiltration, the growth of vegetation, infection by moths and other destructive agents, which brought about the loss of the flat roofs and the floors of the choirs and the collapse of the horizontal planes that connect the walls, which are so important to the structure.
- The intermediate arcades without roofs or choirs are in a very precarious state of repair, as the solid part is at the top and rests all its weight on the columns. During an earthquake (whose date is unknown but it is believed to have been towards the end of the 19th century), the intermediate arcade in the south, which was also a buttress, collapsed. Immediately afterwards, the column, the two main arches resting on it and a third of the vault fell (fig. 21).
- What remained of the vault was not functioning properly from a structural point of view, and pieces went missing throughout the 20th century; by the nineteen nineties only 25% of the vault was left standing (fig. 18).

Interventions in the sixties and seventies
Between 1960 and 1970, interventions that consisted in reconstructing the intermediate arcade and the two main arches were performed. The roofs and the floors of the choirs with their respective beams were also reconstructed. The rest of the vaults were left untouched. There is little information available about these works, but they helped save the building from total destruction.

Preliminary works for recuperation
Before tackling the reconstruction of the vault, a series of preliminary tasks had to be carried out:
1. A wooden staircase was built at the front of the building, in the north, to give access to the roof and the vault during the building process.
2. A steel roof was built with perforated beams, for two purposes:
I. To protect the work area from rain and sunshine.
II. To hang the carved pieces to put them in place in the vault.
3. A wooden scaffold was inserted up to the impost level (11 metres high) for two purposes:
I. To form a perfectly horizontal platform to record the details of the pieces still in existence
II. To support the intrados of the vault and the weight during the building process (scale model in figure 20).
4. A pulley operated by a petrol engine was installed to raise the carved pieces and other material to a height of 17 metres.
5. Sections of arches were cut out of timber. Once they had been assembled, the trusses were placed on the scaffolding platform following the geometry of the ribs of the vault (fig. 19).

Stonework
The stonework was performed in different activities that can be classified as follows:
a) Locating the quarry
The aim was to find the quarry where the material for the building of the 16th century open chapel originally came from. Covering a radius of some 20 km, we visited different sites where we knew there was stone. We finally found the stone 9 km away from the town, very close to what used to be the road to Yanhuitlán. There we found traces of the extraction and large stones that had not been used. The quarry had been unused for about four centuries and we had to open up a road for a lorry to pass through in order to carry the stone to the works.
b) Extraction of the stone
It was necessary to remove a thick layer of vegetation that had grown on it over the years. When the stone was uncovered, we realised it was badly damaged from damp and roots. Once the thick layer had been removed, the stonecutters followed the stratigraphy and the grain of the stone to obtain large blocks. Only 10% of the stone extracted could be used. The quarry was divided into three work zones. When the work rhythm was at its highest point, there were between six and eight people working on each zone. The tools used were picks, crowbars, spades, wheelbarrows, wedges and mallets. Without any other tools, holes were made by hand and gunpowder was inserted to extract the stone. With a few "tricks" the workers moved the rocks, some weighing over a ton, put them on the lorry with the help of a pulley and took them to the atrium in Teposcolula (figs. 22, 23).
c) Stonecutting
The rough stone arrived at the site, where a loggia was built. A team of stoneworkers fashioned the stones piece by piece with a hammer and chisel. It is worth mentioning that no machinery was used. The stereotomy lines had to be followed and the drawings were given to the master stonecutter with the most important measurements.
The stone was "faced" (that is, a flat surface was fashioned) to draw on it the actual projection of the piece. Then the planes between the joints were fashioned. On these planes the section of the moulding was drawn with the aid of a metal templet and the excess was removed from the stone. According to the complexity of the piece, the number of drawings, bevel squares and templets required was greater or lesser. When the rhythm of work was at its peak, more than twenty stonecutters were fashioning pieces for the vault. Depending on the difficulty of the piece, a stonecutter was chosen and a price was set. Every worker had a job he could do and he was paid according to his skill (figs. 24 to 28).
d) Placement
The general strategy was to put all the ribs in place first and then fill in the segments between them. Before placing them, a network of horizontal lines was lain out to mark the axes of the ribs at about eight metres over the impost level, resting on these lines and with a plumb the position of the piece was marked on

the timber intrados according to drawings previously made in the studio, placing their centre and the position of the joints with the other pieces. To raise the cut stone to its place in the vault, the stone was lifted 17 metres high with the mechanical pulley. Once raised, the piece was tied to pulleys, which in turn were fixed to the framework of the ceiling, and the segment of rib was carried through the air and set in place. This operation was called the “Tarzan stunt” by the workers (figs. 29, 30). The piece was put on the intrados, the correct position and verticality was checked by placing a level at one side (as we said above, the geometry of all the arches is generated by vertical sections in the sphere). On some occasions, the stone needed to have one of its sides cut for an exact fit. We always tried to have the piece a little extra large to be able to cut it to size. Depending on the position, complexity and weight of the piece, it took a longer or shorter time to put it in place. Some of them took up to two working days. The team of workers was made up of six or eight skilled workers with their respective assistants.

Waterproofing

In America, timber and tile roofs were not generally used to protect vaults from the rain as they were in most of Europe. In colonial architecture, the extrados was covered with ceramic tiles and the water was channelled to the exterior by means of gargoyles. So this work was performed by covering the extrados with mortar to achieve a spherical surface that was then covered with a plastic waterproof sheet and a layer of previously waterproofed ceramic was set in place with mortar.

Office work

An office was set up in the choir on the north side of the altar, which strangely enough is the only one that can be reached by a staircase inside the wall. All the plans, models and studies required to do the works were drawn up in this office. Practically all the drawings were made by hand on tracing paper. The most interesting part of the work was undoubtedly the stereotomy studies. Even though the drawings speak for themselves, I shall try to give an example to illustrate what this work involved and how it was performed.

Stereotomy

We already said that the diagonal arches and tiercerons are vertical sections of the sphere. The voussoirs that form these arches were fashioned in the ordinary way, although there are sometimes intersections or keystones that make them rather more complex. However, I would like to include here some studies and drawings I made for pieces that I consider of the utmost interest. They are curved ribs that fit into the sphere and are therefore pieces we called “double curve”, although they are not really.

The case of the node of the keystone of the tierceron arch

Several pieces were created here: the keystone and the curved ribs of the tiercerons (fig. 31). These ribs have a different geometric generation from the ordinary voussoirs. In the layout they do not correspond to a clean line in the relationships of the hexagon and their structural function is practically nonexistent, that is, they are merely decorative. No flat projection or elevation of the pieces (parallel or perpendicular to the horizon respectively) provides sufficient information to carve them. In order to obtain the necessary data by means of a drawing it was necessary to use some very simple resources of descriptive geometry. On the other hand, it was essential to use large rocks, because they are very long curved pieces and the moulding becomes deformed due to its position within the sphere.

So it is a single problem that provides the solution for six pieces in the sphere facing the tympanum towards the keystone that I gave the following names to:

- V shaped piece: this stone rests on the keystone of the tympanum and on which lie two low curved ribs and whose circular directrix is on the same plane as the ribs it supports. The rough piece weighed approximately 0.7 cubic metres.
- Low curved ribs: these are four circular directrix pieces that appear in pairs on each side of the V and end at the tiercerons keystone. Because of the development of these pieces, the rough stone had to be more than a cubic metre.
- Tierceron keystone: this is the keystone closest to the impost of the vault. It is another voussoir of the tierceron arches, so the joint and the central axis of the director of the cylinders are facing the centre of the arch formed by creating a vertical section in the sphere, following the line of the arches in the design. The joint with the curved ribs is resolved on the plane where their true shape and magnitude can be seen. The size of the rough stone was over one cubic metre.
- High curved ribs: these are two circular directrix pieces that spring from the tiercerons keystone and meet the diagonal arch. The joint with this arch is directed at the centre, and an extension must be made with the keystone for the pieces to form a joint. The rocks did not need to be over half a cubic metre.

Below I shall attempt to give a brief explanation of the procedure followed in making the drawings from which the projections were obtained to provide the information necessary to understand and fashion the pieces.

1. To tackle the problem, the first step was to make a list of the existing pieces. Their geometry was deduced from the drawings of the elevations in order to make the new pieces similar. The projections of the traces in the ground plan were taken on the horizontal wooden platform and in elevation taking the vertical distance of the platform to each point of the piece selected. Data were also obtained to draw the section of the mould that is “deformed” in relation with the section of the rest of the ribs.
2. The projections for the new pieces were drawn using the old ones as a model. It was necessary to find the real shape and size of the projection in order to have sufficient data to carve them. In order to find the desired projection, a change of plane was drawn parallel to the directrix curve of the piece (about 60º in relation to the horizon). All the other projections were drawn on this last

projection and thus we gleaned the necessary information to shape the pieces (fig. 32).
3. With the V shaped piece it was necessary to obtain the surface that joins the low curved ribs. Some changes of plane and rotations were drawn on the plane formed at the joint between the pieces until the correct shape and size were projected. The mould to cut the templet was obtained. The rest of the piece was determined by the projections obtained from the elevation of the original pieces (fig. 33).
4. To solve the assembly of the tiercerons keystone with the low curved ribs, the projections were drawn up to the line parallel to the directrix of the ribs. Thus a change of plane was performed, approximately 60º with relation to the horizon, to obtain the pieces from the front, that is, the projection plane parallel to the tympanum or, in other words, one side of the hexagon. Then, in another larger scale drawing, the projection parallel to the generatrix of the keystone cylinders (or perpendicular to the directrices) was resolved. In this way we obtain a projection where we can see concentric circles. This is the projection that has sufficient data to provide the stonemasons with the necessary information to draw it on the surface of the stone and carve the piece. Then the projection of the ribs was taken to where the plan coincides with the horizon.
5. For the high curved ribs, the projections of the tiercerons keystone and the pieces at the intersection with the diagonal arch were drawn and a change of plane was made parallel to the circular directrix of these ribs (approximately 45º in relation to the horizon). By drawing all the projections we obtained the proper size of these pieces and it was possible to determine the assembly surfaces of the ribs with the different pieces they touch as far as the place where the plan coincides with the horizon (fig. 38).
6. After resolving the general problems, each particular detail was attended to. For this purpose a drawing and a templet was made for every curved rib and every keystone in the vault. Little details changed from piece to piece. We had to depend on the traces because the original work had little flaws in the design and it was necessary to “adapt” to them to achieve visual continuity in the rib pattern. At the same time, templets were made for every moulding to guarantee continuity and the correct assembly of the pieces.

Charles DiSanto

THE RESTORATION AND REPAIR OF HIGH-RISE APARTMENT BUILDINGS IN NEW YORK CITY

The early part of the 20th Century saw a building boom in New York City that culminated in the late 1920s (predepression era) with the construction of scores of high rise apartment buildings in Manhattan's Upper East Side and Upper West Side neighborhoods. This boom was fueled by a combination of factors: a rise in immigration, the returning of soldiers from the First World War, and a general economic expansion that found its center in New York City, the world's first "Modern Metropolis". Prolific and talented architectural firms such as Rouse & Goldstone, Rosario Candela, J .E. R. Carpenter, and Emery Roth built their reputations designing luxurious residential buildings during this period, which saw the formalization of the skyscraper building type. These "mansions in the sky" combined the refinements of upper class living with a growing industrial approach to housing to produce some of the City's most enduring symbols of wealth and civility the prewar apartment houses that line Central Park, Park Avenue, Riverside Drive, and many of New York's other finer streets and avenues (see illustrations 1, 2 and 13).

Typology
As a building type, there are common architectural elements to these structures which have come to influence our current approach to restoration and repair of these buildings. These include:
- Steel structural frame, usually built to 12 or 15 stories, but sometimes soaring to 30 or more.
- Concrete floor and roof slabs with draped steel mesh or other wire reinforcement.
- Brick exterior walls and parapets, often embellished with extensive terra cotta, stone or cast stone ornament.
- Simpler brick court walls, often constructed of a reflective, or light colored glazed brick.
- Terra cotta and brick back up masonry, solidly bonded to the facing brick.
- Granite bases with Indiana limestone cladding at the lower (two or three) floors.
- Projecting balcony and cornice elements.
- Regular fenestration of wood or steel windows (the latter particularly popular in the Art Deco buildings of the 1920s and early 30s).
- Steel lintels and stone, cast stone or terra cotta sills framing regular masonry openings.
- Modest penthouse construction, usually of lesser quality materials such as terra cotta block and light steel framing with cement (stucco) or sheet metal covering. (Many of these areas were originally designed as laundry, servant or storage spaces.)
- Multiple chimneys (serving apartment fireplaces) stair and elevator bulkheads, and water tank towers constructed on the roof top environment.
- Flat roof and walk on terrace areas (the latter largely developed in response to setback laws established under the 1916 Zoning Resolution to promote daylight at street level).
- Concrete sidewalks, often constructed above vaults at the building's basement level, where building services, boilers, fuel storage, etc. are housed.

Socio-Economic Context
In addition to the common physical attributes associated with the New York City high rise apartment buildings of the age, there are other factors worth considering in a discussion of the circumstances of these buildings. Primary among these is the particular form of ownership and control, which is currently predominant in New York and consists mostly of cooperative corporations. In cooperatives, groups of owners collectively own an apartment

building, and pay for essential services, taxes, energy costs and upkeep through monthly "maintenance" fees. The shares the individual residents (or "shareholders") purchase upon entry correspond to the apportioned value of the particular apartment in which they reside. Most of the day to day management of staff and coordination of professionals (attorneys, accountants, architects) engaged by the building is handled by a management company, but the key decisions are made by an elected Board of Directors.
This system tends to promote greater care and stewardship of the building itself, as resident owners are more likely to protect their investments in a long term manner. (This was not always the case, as the City's financial woes in the 1970's corresponded to a period of deferred maintenance and ill advised short term repairs that left many large buildings in a poor state through the succeeding decade.)

Physical Context
In addition to the social and economic factors, the unique physical environment of New York City must be taken into account in order to understand high rise buildings. The location of New York in the climatological zone of the northeastern United States results in a condition of regular freeze/thaw action, to the detriment of most building materials. Temperature swings in excess of 1000 Fahrenheit (380 C) over a yearly period result in extensive building movement not anticipated or fully appreciated by the original designers of these buildings. Wind driven rain, particularly from the northeast direction, is prevalent in Manhattan, and is particularly potent along the wide avenues, parks, and river drives where large apartment buildings are concentrated. High levels of urban pollution and acid rain as well as excessive vibration (due to subways and underground trains) and wear and tear also serve to deteriorate structures over time. These factors, taken as a whole, create a continuing breakdown of envelope components and materials in buildings, which must be addressed through maintenance, repair and restoration.

Typical Conditions
As most of the classic prewar residential high rise buildings approach 75-100 years of age, the effect of time in the physical context of New York has resulted in a steady stream of restoration, reconstruction and repair activity in the City that has continued essentially unabated since the early 1980s (see illustrations 3, 4, and 5). It was during this time that New York City passed a law requiring owners of all buildings in excess of six stories in height to have regular inspections made of the facades to establish if any unsafe conditions existed. The inspections are focused on those elements of the building envelope which are ubiquitous in the prewar (WWII) high rises, namely the projecting sills, band courses, balconies and cornices which give these same buildings their unique character. (Later structures, particularly from the 1950s and 60s, are much more streamlined and restrained with respect to ornament.) This law (Local Law 10/80, recently revised and renamed Local Law 11/98) has had an enormous impact on the overall public consciousness of the physical condition of high rise facade construction, and has been a boom to architects, engineers and contractors specializing in the area of facade restoration and repair.
Many restorative projects evolve from the required inspections (which must be, in part, conducted from scaffolding in a hands on fashion), and the guidance of professionals is more often sought in connection with facade work than prior to the passing of Local Law 10/80.
In addition to playing an inspection and enforcement role, the City also acts to control the quality of restoration, repair and new construction through the NYC Landmarks Preservation Commission. This agency is responsible for reviewing and approving projects at buildings in designated neighborhoods (as well as significant individual structures), and helps to assure that decision making is in accordance with established guidelines and that modifications are sympathetically carried out.

Repair Approaches
There are a wide range of typical repairs that one encounters when dealing with high rise structures in Manhattan, a short list of which follows. These repairs represent the most common interventions in response to the conditions described above, and the evolution of these repairs has largely led to the industry standards which are utilized today.
- Parapet reconstruction, including the introduction of new waterproofing membranes and flashings (to protect the interior structure and prevent leaks into the building), vertical and horizontal reinforcement, anchorage and new masonry (see illustrations 7 and 8). These repairs often lead to the reinforcement/replacement of corroded structural steel, which is generally not waterproofed in the original construction.
- Corner reconstruction, particularly as a consequence of vertical cracking due to thermal movement, which in turn promotes infiltration and corrosion of structural steel columns. Such corrosion expands the original steel to 8 or 10 times the original dimension, the force of which displaces the adjacent brick masonry. Newly rebuilt comers are provided with waterproofing, anchorage and renewable soft joint detailing (see illustrations 9 and 10).
- Lintel reconstruction, including the replacement of exposed (ferrous) supporting angles with hot dipped galvanized or stainless steel, as well as waterproofing. (This is the most common source of interior leak damage in buildings of this type.) The waterproofing must extend along the lintel, but critically must turn up at the ends to prevent accumulated water from dropping into the building interior (see illustration 10).
- Replacement of sills, band courses, balconies, cornices and other projecting and decorative elements. These replacements utilize in kind (stone and terra cotta) materials, as well as cast concrete, resin reinforced cement and fiberglass. The need for such customized alternative material has spawned a variety of mid size companies which supply and support the restoration industry today (see illustration 12).
- Replacement or restoration of windows, which must take into consideration aesthetics, performance,

and cost. (In recent years, the additional costs associated with abatement of lead based paint and asbestos containing putty in older windows has resulted in less restoration, as replacement windows are usually cheaper than a proper restoration.) Cooperative buildings have devised a number of strategies to finance, promote and control window replacement, one of which is the development of "master plans", which are preapproved by the building's Board of Directors and the Landmarks agency in the City, and which allow for piecemeal but uniform replacement over time.

- Repointing or renewal of mortar joints, which involves the fairly disruptive process of grinding out the existing mortar with electrical tools, and replacing it with new materials (see illustration 11). This is probably the most common "repair" undertaken in buildings of this type.
- Replacement of roofing, both service areas and "walk on" terraces, with new modified asphalt or resin based systems, with paver or quarry tile overburden, new flashings and drains. Most new roofing systems carry an extended warranty of up to 20 years.
- Replacement of sidewalks and curbs, and waterproofing and structural repair of underlying vaults.

The Construction Process

Many of these necessary repairs are challenging enough on their own, but because the buildings are occupied during the work, these projects become much more difficult. Couple that with the fact that most of the restoration work takes place off moving or fixed scaffolding, and that the contractor is responsible to maintain the watertight integrity of the building envelope, and the challenges multiply (see illustrations 3, 4 and 5).

Despite the challenges, a wide range of exterior restoration contracting companies have evolved to fill a growing market. One time roofing or sheet metal contractors have added masons and stone setters to their crews, and successful bricklayers have learned the particular skills of waterproofing and flashing associated with their trades. The result is, more often than not, that a "restoration contractor" in New York has all the skilled labor to execute a multifaceted and complex envelope repair project, from the initial scaffolding to demolition, waterproofing, masonry installation, sealant, painting, welding, roofing and concrete work. This full service approach may be unique to New York, and is certainly in direct response to the market demands posed by hundreds and hundreds of large cooperative apartment buildings throughout the Metropolitan area. The most successful of these firms are medium (50+ employees) to large (300+ workers) in size, and maintain strong and hierarchical control over the work product through the use of skilled foremen and supervisors, whose daily communication of job issues to both the resident managers (building superintendents) and the project managers in the architect's or engineer's staff ensure proper execution of the work as it evolves.

Conclusions

The particular environment of New York, both historically and presently, has led to a unique set of opportunities with regard to building restoration. High rise apartment buildings constructed in the early 20th Century utilized the finest materials, craftsmanship and design in the context of tremendous urban building activity to create a housing stock well worth preserving. Although the lessons learned and techniques developed during the last 20 years are, in many ways, particular to New York City, there is general application to the wider arena and growing knowledge base of building restoration and repair. These include an appreciation for the importance of understanding materials and the relationship between building components. The need for waterproofing in rebuilt envelope sections is inherently at odds with the original construction in that membranes are bond breakers. One needs to reconcile the separation of exterior and interior construction via waterproofing with the desire to integrate the reconstructed work structurally and mechanically. This is achieved through careful detailing, and a "strong yet flexible" approach to construction. The flexibility not only allows for in field adjustment of newly introduced materials to the existing building fabric, but also assures that the long term effects of thermal movement on the envelope components will be duly accommodated. (The development of the sealants industry, initiated in the 1950s, has been critical in this regard.) The matching of new materials to the existing building is equally important in restoration, and as sensitivity and an appreciation of architectural detail has grown over the past 20 years, so too has the supporting industry of custom reproduction fabrications. It is no longer the norm to strip buildings of their ornament in response to localized failure, as the means now exist to more economically repair and retain these critical components. Finally, the importance of teamwork and communication via the sharing of information among the owners, contractors, fabricators, conservators, architects, and engineers has allowed for a continual and progressive movement towards a fuller understanding of how to treat these buildings successfully.

Case Study - 850 Park Avenue

There is an old saying, "if at first you don't succeed, try, try, try again". At 850 Park Avenue, two repair campaigns were performed to the street facades over a 15 year period. The first managed to address numerous unsafe and deteriorated conditions, but fell short of a full restoration as budget concerns precluded certain "optional" items. The recently completed project more closely returned the building to its initial state of grace, and included the reintroduction of a decorative cornice, removed ca. 1970.

850 Park Avenue is in many respects a typical prewar cooperative luxury apartment building in New York City. Designed in 1913-14 by Rouse & Goldstone, Architects, this 12 story structure at the southwest corner of 77th Street and Park Avenue utilizes terra cotta Italianate detailing to embellish a robust and rustic brick wall design. A variety of band courses, window surrounds, and balcony features serve to

embellish an otherwise reserved facade, and deeply set windows with thick slate sills help lend the building a strength and presence lacking in most modern examples of the residential building type. The brick is both textured in its surface and varied in its hue. Mortar joints are wide and coarse, and produce significant shadow lines.

Although the building is framed in steel, thick masonry walls and the relatively recessed structure belie the conservative nature of the original design, as the evolution towards curtain wall technology was still in its infancy in the early 20th century. Still, the very presence of carbon steel in the building, particularly as it related to support for the projected terra cotta, created problems as the building aged and moved, and poor maintenance contributed to the state of affairs first studied in 1990, following the loss of a portion of a fourth floor terra cotta water table.

The water table at 850 Park Avenue is a continuous projection of bracketed terra cotta situated at the fourth floor of the building. The water table visually defines the building's "base", and also provides a critical water shedding function. Corrosion of internal steel "outrigger" supports and the perimeter angle led to displacement and failure of the terra cotta at the face. Although various alternatives were studied during the initial repair campaign, the building owners opted for a partial repair approach at that time, using precast concrete reproduction units and a leadcoated copper cover to limit future infiltration in the support structure, which was largely retained. (Other terra cotta damage at balcony and window surround areas was similarly replaced with cast concrete reproduction units, which still exist and remain in good condition after 15 years.)

The 1991 project also included some comer reconstruction, slate sill replacement, pointing and cleaning work. Reintroduction of the original cornice design was considered cost prohibitive given the extent and nature of the base project, which consisted largely of "emergency" or unplanned repairs.

In the intervening years, some other exterior projects were undertaken at the building, including court wall repairs, window painting, and penthouse wall cladding. At some point, the protective copper cover at the fourth floor water table was removed and the terra cotta coated with elastomeric paint.

We were reintroduced to the building in 2003 after a Local Law 11 inspection revealed some cracked terra cotta (in areas not previously repaired) and some further deterioration at the water table. Early discussions with the Board confirmed a serious level of commitment to restoration, not just repair, of deteriorated elements. This was partly attributable to the increased value of the property, but also reflected a broader awareness by the owners of the causes and effects of long term deterioration and a greater level of sophistication regarding the expected outcome of such an effort.

There were four main components to the recently completed (January 2005) facade restoration: water table replacement, miscellaneous terra cotta repairs/replacement, brick and mortar replacement (particularly in areas previously repaired with poorly matched materials), and a new cornice.

The idea of reintroducing a cornice created much internal debate among the building owners. On the one hand, the cost to erect new structural steel and new (fiberglass) cornice material, along with a cornice roof and inside wall cladding, was not inconsiderable. On the other hand, the tangible benefits of a water shedding overhang at the top of the building could not be discounted, and experience has borne out the assumption that a lack of such protection served to promote deterioration at the upper floors of larger buildings like 850 Park Avenue. There was also the less tangible but equally compelling rationale to improve the building's appearance, especially in the context of the wide avenue, where most buildings have a consistent height and massing, and where 850 Park was conspicuous within the streetscape by its lack of defined "top" (see illustrations 13 and 15). Many on the Board also felt a higher quality facade restoration would pay dividends in terms of resale value of apartments in the building.

A concern with the overall height of the cornice, for which no original drawings were found, related to the development potential of the penthouse area (currently utilized as service space, but coveted as a possible apartment). It was important to minimize the extent to which existing viewing vantage points would be impacted by the cornice, so the design stressed horizontal projection and detail development over height, while attempting to generally conform to historic photographs (see illustration 20). The design was approved by the Board and the NYC Landmarks Preservation Commission, which has jurisdiction over facade alterations in this historic district. The design also incorporated discrete scaffold cable "sleeves" within the overall construction to allow for hanging scaffolding to be installed without the need to cantilever over the entire cornice.

The water table was completely reconstructed in new, hand pressed terra cotta units on a new stainless steel support system (see illustrations 16). This work was particularly satisfying given not only the previous decision to repair this element, but the proximity of the new material to the street, where its visual benefit and crisp detail can be more fully appreciated.

Higher in the building, precast reproductions were again utilized, although more significant rebuilding included new and salvaged material while allowing for a meaningful waterproofing of concealed structure.

Finally, both brick and mortar were carefully analyzed and painstakingly matched with available replacement materials. In all, five different face brick selections were made and blended according to specified proportions.

All of the work was performed from a fixed pipe scaffold and planking, and white debris netting covered the scaffolding, protecting the public while maintaining a bright environment for the workmen, residents, and neighbors. The work was completed in 12 months at a cost of $1,500,000.

Kent Diebolt and James V. Banta

INDUSTRIAL ROPE ACCESS: SPECIALIZED INVESTIGATIONS OF HISTORIC BUILDINGS IN THE UNITED STATES

Beginning in the 1980s, mainly in France and England, a new approach to accessing different types of vertical structures emerged. This approach, now known as Industrial Rope Access, allows trained technicians safe and ready access to a variety of "extreme" work sites. Industrial Rope Access is currently practiced in countries world wide, including Spain, and has an excellent safety record.

In the United States, the governing bodies active in establishing professional standards for Industrial Rope Access are: SPRAT (Society of Professional Rope Access Technicians), and OSHA (Occupational Safety and Health Association).

Although international standards exist, Industrial Rope Access in the U.S. is still evolving towards certification standards. In the United States, SPRAT is a trade organization that serves the same function as the European IRATA (Industrial Rope Access Trade Organization) and is in the process of creating standardized safe practices and certification for rope access technicians in the U.S. For over 15 years, IRATA has been the organization involved in safety, training, and certification for rope access work in the U.K. and much of Europe.

In Spain, ANVETA (Asociación Nacional del Empresas de Trabajos) plays a role similar to IRATA, establishing guidelines for rope access work, and provides an online listing of accredited companies. Most rope access companies working in Spain carry out maintenance and rehabilitation work such as façade restoration, painting and cleaning.

Approximately 14 years ago, Vertical Access pioneered the use of Industrial Rope Access for inspection and testing of buildings and structures in the United States. Working with architects, engineers, and conservators, Vertical Access provides highly skilled and specialized services during the diagnostic or preconstruction phase of a repair or restoration project.

Compared to the expense of conventional means of hands on inspection via typical scaffolding, Vertical Access provides low cost, innovative solutions for planning building repairs and maintenance. Furthermore, Vertical Access employs an approach that prevents overt physical disruption to the building, a feature that is especially important where delicate architectural components are of concern.

How Industrial Rope Access Works

Industrial Rope Access utilizes lightweight, highly adaptable rigging systems to position workers in hard to reach vertical locations. This field of expertise developed out of techniques used in rock climbing and cave exploration, as well as search and rescue operations that use specialized rope skills.

Industrial Rope Access systems rely on two independently anchored ropes on which technicians are suspended in industry specific climbing and suspension harnesses. One rope is termed the "working line" and the second, redundant "fall protection" line provides fall protection. Chosen for their low stretch properties, rope access companies use static kernmantel ropes as opposed to dynamic ropes that are designed to stretch, particularly under dynamic loads such as might occur when catching a falling climber.

Technicians typically tie off ropes to immovable structural members at the roof, tower, or attic. Rigging and anchors are highly adaptable and always site specific according to the conditions of the work area, building or structure. Technicians use specialized "hands free" descent control devices that facilitate maneuverability and ease in recording information as they descend on the ropes.

A Powerful Tool for Architects and Engineers

Integration of Industrial Rope Access techniques into the initial survey team allows architects and engineers to present more fully developed scopes of work to clients, building owners, and contractors, saving the building or structure owner time and money. Before preparing construction documents, such as conditions reports, drawings, and specifications, it is ideal to have a clear picture of existing conditions and the practical benefits of a hand on investigation should not be underestimated. Erecting scaffolding prior to beginning a repair or restoration project is almost always an ineffective use of valuable time and money when compared to the relative speed and flexibility of performing a rope access investigation during the planning stages. There are other reasons not to erect scaffolding in the preconstruction of discovery phase, such as compromises in building security, diminished aesthetics and potential liability problems arising from designing the wrong scaffold for the work that is ultimately required.

Furthermore, Industrial Rope Access is often the best solution when building size and configuration – or the surrounding landscape/streetscape conditions – inhibit the use of conventional means of inspection and testing. Specific areas that pose access challenges are steeply pitched roofs, spires, domes, steeples, tall parapet or screen walls, and towers.

Vertical Access's on site documentation techniques began with simply making notes on paper. In recent years, however, VA has integrated live feed video, hand held computing devices (i.e. Personal Data Assistants), and tablet computers into a more precise and efficient documentation process. Most importantly, the development of pen based tablet computers has allowed Vertical Access to use AutoCAD as the primary graphic tool for recording existing conditions on site.

While all of the tools used in Vertical Access' annotation system are native to AutoCAD releases 2002 and 2004, some customized features have been designed to further automate the documentation process, including automatic fault length and area calculators and the capability of linking digital photos with data blocks. See our website for more information on the Tablet PC Annotation System (TPAS):

http://vertical-access.com/resources.html.

Safety in the Industrial Rope Access Workplace
Vertical Access strives to maintain the highest regard for health and safety of all persons potentially involved, including employees, clients, building occupants, and pedestrians. To ensure safety for all parties it is often necessary to close streets, sidewalks, entrances, or public spaces surrounding a building or structure. In instances where additional precautions are required, or heavy traffic exists, Vertical Access may also employ security personnel and sidewalk bridges. Furthermore, all Vertical Access technicians are trained in rescue procedures for the rope access environment and a minimum of two employees are always present on site.

Projects
Vertical Access has experience with a wide range of historic and modern building materials and has provided inspection and testing services for a variety of structures. Since 1992, Vertical Access has completed investigations employing these techniques on a wide range of religious, educational, commercial, and government buildings, as well as monuments, sculptures and bridges.

Buffalo City Hall, Buffalo, New York
Architect: George Dietel and John Wade with Sullivan Jones
Date: (completed in 1932)
Owner: City of Buffalo, New York
In collaboration with: DiDonato Associates, Engineers and Richard Pieper, stone consultant
Buffalo City Hall is a massive 29 story steel framed Art Deco building clad in sandstone and limestone with a granite water table and extensive polychromatic terra cotta ornamentation. Vertical Access has been working at Buffalo City Hall since 2002 and plays a major role in creating a baseline documentation of existing conditions, providing temporary stabilization interventions, and assisting in planning for significant future repairs. The existing conditions report Vertical Access provided to the client consisted of 41 annotated AutoCAD elevation drawings, copies of videotape made during the course of the investigation, and more than 500 photographs.
In the summer of 2002, Vertical Access identified and located different types of stone and terra cotta deterioration including spalls, cracks, and exfoliation due to salt fretting. Specific information, such as the size of cracks, was recorded to provide the architects with information as to the magnitude of repairs required. In the interest of public safety, technicians removed potentially hazardous terra cotta and stone during the inspection.
In order to avoid potential conflicts of interest and keep the tasks of contractor and preconstruction investigation separate, Vertical Access typically does not engage in actual repair or restoration work. However, in certain cases such as this, Vertical Access may undertake measures to mitigate hazardous conditions during the planning process of a long term repair or restoration.
Once again, in 2004, Vertical Access returned to Buffalo City Hall to make in situ measurements of individual stones in order to help the architects' prepare detailed, stone by stone drawings for construction documents. Drawings that accurately depict the actual measurements and configuration of existing conditions are valuable and often rare assets when it comes to planning the appropriate intervention methods. Currently, the building awaits government funding for phased façade restoration.

Philadelphia City Hall, Philadelphia, Pennsylvania
Architect: John McArthur
Date: (completed in 1901)
Owner: City of Philadelphia
In collaboration with: Keast & Hood Engineers, for the City of Philadelphia Public Arts Council
In the case of Philadelphia City Hall, Industrial Rope Access was selected as the optimal means of providing as much hands on examination as possible within a limited budget. Vertical Access helped determine and record existing conditions in order to inform the conservation treatment of bronze sculptures located 400' above street level.
Designed by Alexander Milne Calder, grandfather of the famous creator of mobile sculptures, the figurative statues at Philadelphia City Hall weigh 12 to 18 tons and are up to 28 feet tall. Each sculpture or figure group is a hollow bronze casting that has a hatch in the rear. Through these removable panels, Vertical Access was able to perform a thorough inspection of the interior conditions with specific attention to the corroded base plate bolts.A key feature of the investigation was a real time/live video and audio transmission of the conditions to sculpture conservators asked to bid on the treatment methods for the bronzes. With a hand held digital video camera and two way radio contact, Vertical Access technicians could converse with conservators inside the tower while they watched the video. Observation of the live feed video was a significant part of the mandatory on site walk through for all bidders on the work.
This project was an exercise in efficiency and effectiveness. Instead of the great time and expense required to erect scaffolding outside the tower, it took three Vertical Access technicians only four days to accomplish the entire scope of work.

Hanging Flume, Uravan, Colorado
Architect: Thomas B. Barber
Date: 1880s
Owner: United States Bureau of Land Management
In collaboration with: Alpine Archeological Consultants, Inc.; Anthony & Associates, Inc.; Bureau of Land Management; Colorado Preservation , Inc.; Colorado Center for Community Development; Cultural Resource Planning; Jerald Reid; State Historical Fund; Robert Silman Associates, P.C.; Western Colorado Interpretive Association; Photographer Tyler Young
In this remote location, the logistics for safety and communication added to the usual challenges of accessing areas difficult to reach. Located up to hundreds of feet below the main road,

and several hundred feet above Dolores River, the Hanging Flume could not be reached with conventional means of access such as scaffolding, swing staging, man lifts, or even industrial cranes.
Work included documentation of construction details and existing conditions, with a focus on how determining the flume was constructed. Vertical Access also provided logistical support for the entire team, included live feed video, assistance with measurements and observations, Schmidt hammer testing of the rock for surface hardness, and use of a wood densitometer for analysis of the wood integrity. Additionally, Vertical Access provided training, "guiding" and the means for engineers from Robert Silman Associates to inspect the flume structure themselves. These engineers created the sketches and detail drawings while suspended on ropes that are needed to inform decisions about what will be done to preserve and interpret this highly unique and endangered example of mining technology.
Establishing sound anchor points without the usual structural elements to tie off to added a level of complexity to this project. Anchors were created by utilizing existing geologic features or through the installation of redundant steel anchor bolts.
The further challenge of working on such remote ruins rather than a structure in a more urban environment ensured that technicians would be exposed to potentially loose or highly decayed construction materials.

St. Paul's Chapel, New York, New York
Architect: I. N. Phelps Stokes
Date: 1904
Owner: Columbia University
In collaboration with: Robert Silman Associates, PC
Using a 1 lb. acrylic hammers to lightly tap or "sound" masonry materials is a routine part of many Vertical Access investigations, particularly on masonry or terra cotta clad structures. The challenge in hammer sounding Guastavino tiles – as is true for other ceramic construction materials – lies in interpreting the type of noise made upon tapping. Technicians listen for a dull rather than a ringing noise that usually indicates a sound or well attached tile that is not cracked.

Low Library, New York, New York
Architect: McKim, Mead & White
Date: 1903
Owner: Columbia University
In collaboration with: Robert Silman Associates, PC
Vertical Access installed sensors used for remote location monitoring of movement. These sensors, often called "crack monitors" are highly sensitive electronic devices installed at key locations where structural stress is of concern. The data recorded by the sensors is relayed to an on site computer that constantly keeps track of incremental movement over time for the engineers working on the project.

Chrysler Building, New York, New York
Architect: William Van Alen
Date: (completed in 1930)
Owner: Tishman Speyer Properties
In collaboration with: LZA Technology
The 77 story art deco skyscraper is a tour de force in art deco style and was briefly the world's tallest building. The 7 story pinnacle with stainless steel cladding and the gleaming automotive inspired gargoyles and ornaments are juxtaposed atop the more traditional light brick cladding of the steel tower below.
Vertical Access was hired to perform an investigation of the stainless steel spire to determine the cause of increasing water infiltration. The project included flood testing to find locations of the leaks. Flood tests were conducted on the exterior of the building's crown, as technicians sprayed water in specific locations while personnel on the interior verified water penetration.

The Tribune Building, Chicago, Illinois
Architect: Raymond Hood and John Howells
Date: (completed in 1925)
Owner: The Chicago Tribune
In collaboration with: Wiss Janney Elstner Associates, Chicago office
This famous icon of Chicago architecture is a magnificent steel frame structure clad in limestone and built to resemble the Cathedral of Rouen's Butter Tower. Gothic Revival stone elements surround the top of the tower and the base of the building.
Vertical Access performed a critical inspection at the 25th-35th floors of the tower and safely removed potentially hazardous material, such as stone spalls, loose mortar and failed cementitious repairs in over 20 hard to reach locations. Vertical Access provided the client with annotated elevations, electronic AutoCAD drawings, and detailed photographic documentation. Additionally, Vertical Access technicians installed fixed permanent directional anchors to allow future inspection of the buttresses using Industrial Rope Access techniques. This fact represents progressive foresight on the part of the building owner, architect, and engineer and long term acceptance of Industrial Rope Access.

Why Industrial Rope Access?
This review of projects offers a sampling of the variety of solutions Vertical Access has employed in the documentation and testing of existing structures. Due to its flexible and light weight rigging systems, Industrial Rope Access techniques can accommodate an increased survey or testing area while minimizing disruption to building occupants and reducing the physical impact to a structure. In addition to employing these techniques, Vertical Access provides its clients with state of the art technology and unique documentation services. The ultimate goal behind Vertical Access' work is the collection, management, and communication of condition survey data for the design professional, who understands that the precise documentation of existing conditions is fundamental to making informed decisions in maintenance plans and restoration projects.