The Cathedral of Mexico and the Metropolitan Sacrarium

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Fig. 1. Restoration being carried out on the West Tower.

0027-0776/83/04/0255-09$03.00

The Cathedral of Mexico and the Metropolitan Sacrarium are without any doubt the most important works constructed in Mexico during Colonial times. The first cathedral was built between 1524 and 1532 by Martin de Sepulveda, master mason and builder, as a modest design with a basilican plan in which monoliths from Aztec temples were reused. Completed by Friar Juan de Zumarraga, this small structure in which the details revealed the Andalusian taste of its builders, was demolished in 1625 because it was considered too modest to match the flourishing opulence and power of the capital city of New Spain.

The project and construction of what was intended to be the definitive Cathedral was initiated in 1562 as a seven-bay building with an east–west orientation; but in 1570 the plan was modified by Claudio de Arciniega to a north-south orientation. The chapels were under construction by 1585, and by 1615 the walls had reached half their height and eight arches had been closed. The interior was completed about 1667 but the towers had to wait until 1791. The work was completed by Manuel Tolsa who modified the upper part of the central bay of the main facade and added the surmounting clock and figures in 1810 during Mexico's struggle for independence. The neighbouring Sacrarium, a masterpiece of Mexican Baroque design, was constructed by Lorenzo Rodriguez between 1759 and 1768. The two buildings are integrated in a harmonious monumental

FIG. 2. General view of the Cathedral and the Sacrarium.

group (*Fig. 2*) which is the summary of all the architectural styles found in Mexico in the heart of the great city's historic centre.[1]

From the very beginning of the construction of the Cathedral and the Sacrarium, structural problems had to be faced because of the characteristics of the subsoil. These problems only increased later; the monuments began to sink because of the growth of the city and the need to extract water from the subsoil. The original builders had attempted to meet the situation by using wooden piles 3 metres long and 20–30 cm in diameter, which were placed at intervals of 60 cm. Afterwards, the ground was levelled. On top of the palisade was laid a 2 metre wide masonry footing and then 3 metre deep masonry beams to support the columns. The foundation of the Sacrarium followed the same pattern, but it was less strong. Consequently there was differential settlement and the columns and walls collapsed gradually; the worst subsidence occurred in 1970 when the adjacent subway was under construction.

The preparation of the programme for the new foundation, the new structure and the restoration of the Cathedral took two years, during which time surveys of soil mechanics and the structural performance of the building were carried out. Four piezometric stations were installed to observe the hydrostatic pressures, and variations in the level of the water table were registered. Unaltered samples of the subsoil were obtained and later analysed in the laboratory. At the same time levels were taken at regular periods at different points within the buildings, so as to establish the movement of the structures and the subsoil. Comparison of these readings with those taken in 1934 indicated the different subsidences over a forty year period.

Work on the new foundation was begun in 1937 by the Government in cooperation with the Church authorities. Primarily this consisted of freeing the foundation of the weight of the fillings, and to this end a system of concrete beams and slabs was built. This did not solve the subsidence problem, but it decreased the load, stiffened the original beams and unified (as much as was then possible) the transmission of the load by means of the concrete slab. However, the subsidence continued. In 1937 it was intended to stiffen the foundation of the Sacrarium by means of steel beams placed on the original masonry fill of the foundation. This system was combined with a series of timber and concrete piles; but in 1973, when the most recent work were started, it was found that the upper parts of the timber had rotted because of the lowering of the water table. The seriousness of this problem is indicated by the fact that during the last century the central zone of Mexico City has sunk 8 metres. The Independence Monument, built in 1910 on a traditional pile system, confirms that during a 70 year period there has been a subsidence of 3 metres which has produced an impression that the monument has risen by this amount.

Before deciding on the new foundation project for the Cathedral,

[1] See *Desarrollo Urbano en Mexico: Restauracion Monumentos Nationales*, Mexico 1982, 268ff; Kubler, G., Soria, M., *Art and Architecture in Spain and Portugal and their American Dominions 1500 to 1800, Harmondsworth 1959*, 70, 73ff.

several alternatives were examined. The system of *pilotes de control* designed by Manuel Gonzalez Flores was chosen, and in accordance with this it was decided to transmit 25 per cent of the weight of the Cathedral and 50 per cent of the Sacrarium to the firm stratum. The piles were placed gently without vibration at a depth of 38–40 metres, using oil-pneumatic jacks. 383 piles were used in the Cathedral and 133 in the Sacrarium. The loads were transmitted from the structure to the piles by means of dies designed in accordance with their function. The piles and foundation dies may be tested with an overload after they have been placed in position; each pile transmits a load of 100 tons to the stratum. The work in the Cathedral was executed in two phases to avoid interrupting the religious services. In the Sacrarium it was necessary to build a hollow, rigid foundation case consisting of a concrete slab and beams, which was placed under the fill of the original foundation in order to transmit the load evenly to the new slab and piles.

In restoring the vaults, the cracks in the *extrados* and *intrados* were located and their direction and magnitude were recorded in plans, diagrams and tables. The brickwork was then removed, revealing the flaws that did not appear on the surface, and the structural continuity in

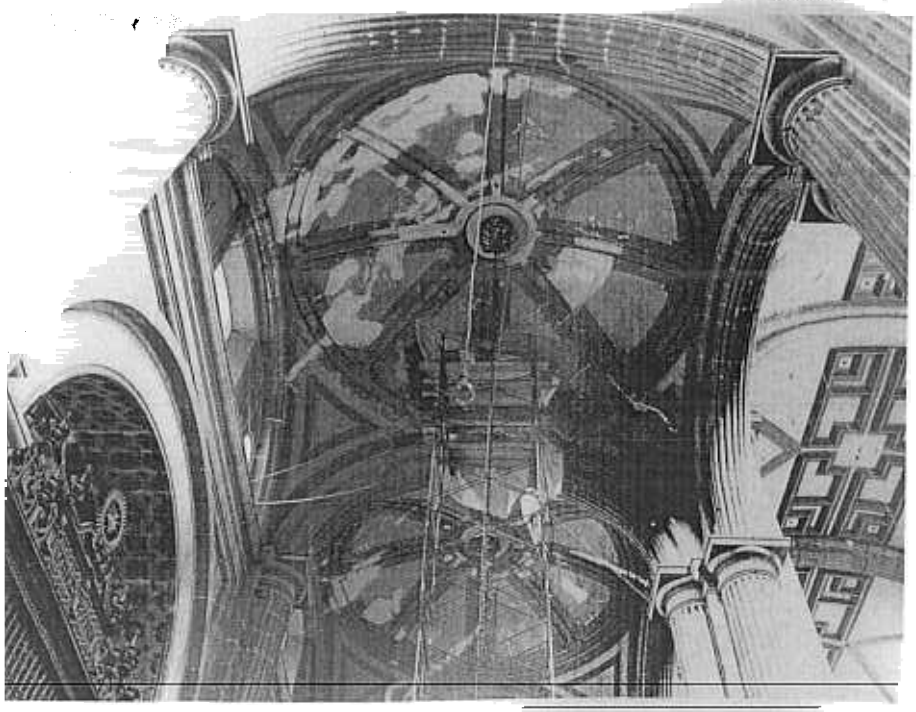


FIG. 3. Consolidation of the structure of the arch and injection under pressure into the fissures found in the side nave.

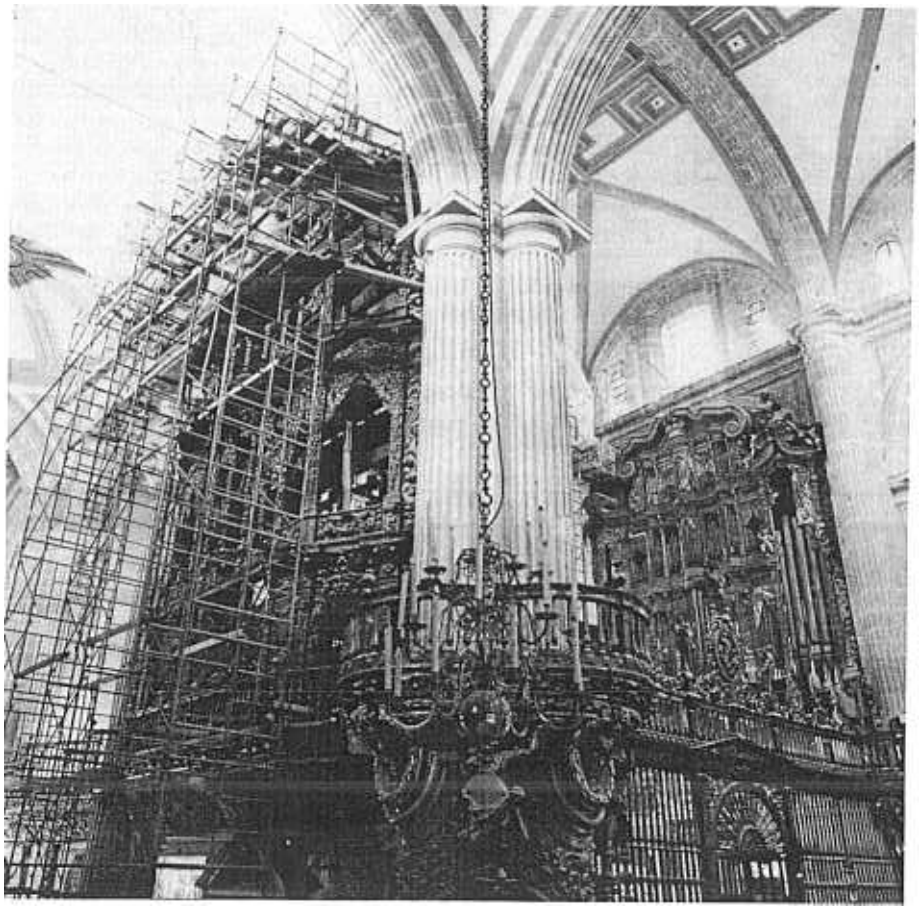


FIG. 4. The restoration of the pipe organ; work in progress on the Spanish organ constructed in 1695.

the vaults was reestablished. The cracks were filled with injections of mortars prepared with expander additives (*Fig. 3*). Since 1977 the buildings have been stabilized, and periodic measurements are taken in order to diversify the transmissions of load to the stratum if necessary; this allows the possibility of controlling the settlement and subsidence of this important group of monuments.

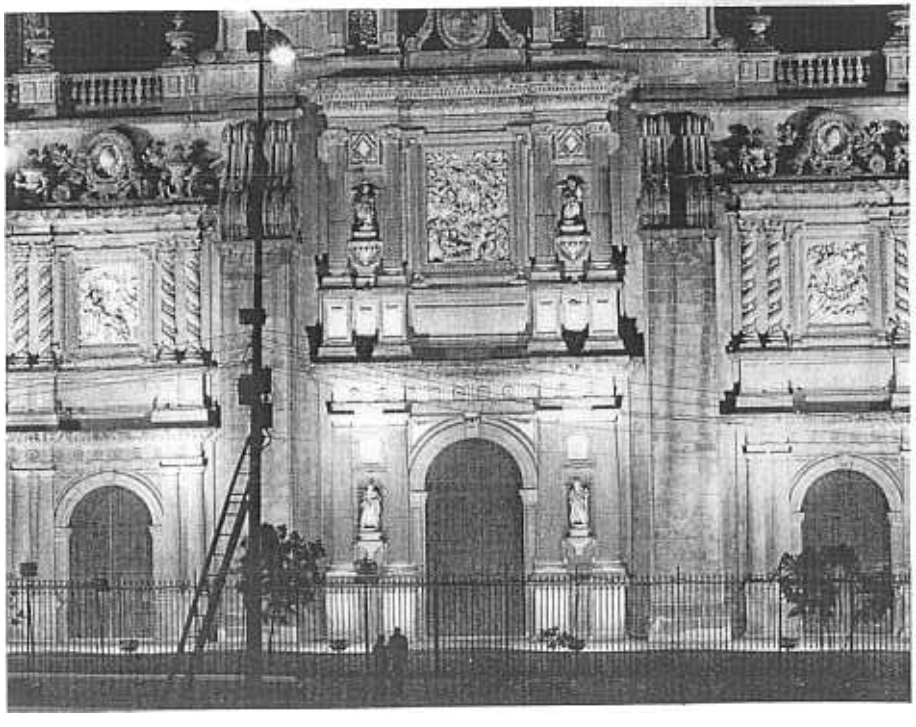
When work began, the electrical installation in the Cathedral and the Sacrarium was in very bad condition. Much of it was surface wiring, and it was so dangerous that it caused a serious fire in 1967 which destroyed part of the Cathedral's historical and artistic wealth. Approximately 80 per cent of Jeronimo de Balbas's Altar of Forgiveness, forty-seven of the

fifty-nine choir stalls by Juan de Rojas (1695), and a painting of the Apocalypse by Juan Correa were lost. The organ cases were seriously damaged, and the flutes and trumpets melted (*Fig. 4*).[2] The choirmaster's desk, brought from Manila in 1762, was partly destroyed, and so were the ivory figures decorating it. The flames destroyed the painting on the main cupola and severely damaged the upper part of the altarpiece made by Jeronimo de Balbas for the Capilla de los Reyes (1718–36) which was in the presbytery at the time. A completely new system has now been installed, including a substation fed by one single branch capable of taking a load of 960 kw. Separate switchboards have been provided for the different parts of the Cathedral and placed under the control of individual members of staff. The external lighting has also been reconsidered, in order to show the architectural quality to its greatest advantage (*Fig. 5*).

During the course of this project, one of the principal aims has been to preserve unaltered the appearance of the monuments. Since the structural system used in the restoration of the foundations necessitated excavations which disclosed important archaeological objects, a strict control of those

[2] The monumental organs, one built in 1695 in Spain by Jorge de Sema and the other in New Spain in 1735 by Jose de Nasarre, have been completely restored while respecting their musical properties. The technical restoration from a musical standpoint was undertaken by Flentrop B.V. de Zaandam, Holland under the supervision of Dr Kirk A.Flentrop. The restoration of the mechanism and pipework and the carving of the cases was done by Mexican craftsmen.

FIG. 5. Testing the external lighting of the main facade.



found has been applied from the beginning. This consisted of an accurate recording of all archaeological material, either pre-Hispanic or Colonial, and of the stratum level at which they were found. Architectural surveys, three-dimensional recording, and photographs have been employed as appropriate.

The building which adjoins the Cathedral and is occupied by the Curia was constructed in 1859–69, but it presented serious structural problems because of poor foundations. Differential settlement had occurred and there was extensive cracking. The first aim was to stabilize the building by shoring the walls and inserting a steel grid foundation to provide rigidity before placing control piles in position. So that the structure of the Curia could be independent of the Cathedral, joints have been constructed in the foundation and the walls. The original floor has been replaced by a reinforced concrete slab over the existing framing which had already received earlier treatment, and a reinforced concrete slab was also inserted at roof level; both these were connected to frames built into the masonary walls. The Curia will now serve two functions: the ground floor will be used for temporary exhibits; and the upper for meetings and conferences. Other rooms may be adapted to house some of the Cathedral's collection of works of art.

Finally, the conservation of this important group of monuments is dealing with the decayed stone of the west tower (*Fig. 1*). Environmental pollution and lack of maintenance have caused serious deterioration to the carved masonry, some of which has been restored, consolidated or replaced according to its condition. Copies of the sculptures on the upper part of the tower have been made, so that they may be placed in position some time in the future, if and when that becomes necessary. By such means it is hoped to assure the future conservation of Mexico City's most important monuments.

Résumé

Ces monuments sont certainment les plus importants de l'époque coloniale à Mexico. Conçu en 1562, le plan de la cathédrale actuelle est le résultat de modifications datant de 1570. Quant à l'intérieur, il fut achevé en 1667 mais les tours ne furent élevées qu'en 1791. Le Sacrarium voisin, chef-d'œuvre de style baroque mexicain fut construit entre 1759 et 1768. Ces constructions que se trouvent au coeur du centre historique de la célèbre cité sont à elles seules le résumé de tous les styles d'architecture représentés à Mexico.

Dès son début, la construction présenta des problèmes de structure dûs à la mauvaise qualité du sous-sol, problèmes qui ne firent que s'aggraver avec l'extension de la ville et l'abaissement du niveau de la nappe phréatique. L'effondrement le plus grave advint en 1970 lors de la construction du métro tout près de là. Dès 1937, de nouvelles fondations furent commencées par le gouvernement avec l'aide des autorités ecclésiastiques. Il s'agissait essentiellement d'alléger le poids à supporter; le problème de l'affaissement n'en fut pas résolu pour autant mais les piliers de fondation originaux furent renforcés et la charge fut réduite et mieux répartie grâce à une nouvelle dalle de béton.

En 1973, au début des travaux les plus récents, on découvrit que les parties supérieures des anciennes piles de bois avaient pourri du fait de l'abaissement du niveau de la nappe phréatique—un grave problème à Mexico où la zone centrale s'est affaissée de huit mètres

au cours du siècle dernier. Après l'étude de plusieurs alternatives le système de pilotes de contrôle, inventé par Manuel Gonzalez Flores, fut adopté et il fut décidé de transmettre le quart du poids de la Cathédrale et la moitié du poids du Sacrarium à la première couche solide du sous-sol. Pour ce faire, 383 piles pour la Cathédrale et 133 pour le Sacrarium furent enfoncées, avec grand soin pour éviter les vibrations, à une profonder de 38–40 mètres. Les charges furent transmises par des dés à raison de 100 tonnes par pile. Pour les fondations du Sacrarium, il s'avéra nécessaire de construire un cadre rigide fait d'une dalle et de poutres de béton, cadre qui fut placé sous le remplissage des fondations originales afin de transmettre à la nouvelle dalle et aux nouvelles piles une charge équilibrée.

Lors de la restauration des voûtes, les fissures furent repérées et répertoriées. Les parements de briques furent enlevés, rélévant des défauts qui n'apparaissaient pas en surface; ils furent réparés et la continuité structurale de la voûte rétablie. Depuis 1977 ces bâtiments ont été stabilisés; des mesures de contrôle sont faites périodiquement afin de modifier la transmission de la charge si cela s'avérait nécessaire. Mais en 1967 un important incendie (dû à l'état défectueux du circuit électrique) détruisit une partie du trésor artistique et historique de la Cathédrale. Tout le système électrique a été refait et il comprend maintenant un central et des interruoteurs sîparés pour les différentes parties du bâtiment.

Quant au bâtiment jouxtant la Cathédrale et occupé par la Curie, il fut construit en 1859–69 mais lui aussi présenta des problèmes de fondations. Sa stabilisation irrégulière donna naissance à de nombreuses fissures; aussi cette construction a-t-elle été rendue indépendante de la Cathédrale par l'insertion de joints dans les fondations et dans les murs. Le plancher a été remplacé par une dalle de béton armé reposant sur la cadre original; une autre dalle fut ajoutée au niveau du toit et reliée à la première par une charpente insérée dans la maçonnerie des murs.

En dernier lieu, la conservation de cet important groupe de monuments inclut la restauration, la consolidation ou le remplacement des pierres de la tour Ouest. Des copies des sculptures de la partie supérieure de la tour ont été exécutées et elles seront mises en place plus tard si cela devient nécessaire.

Tous ces travaux devraient assurer la sauvegarde future des plus importants monuments de Mexico.

Resumen

Sin duda alguna, son éstas las obras más importantes construidas en Méjico durante la época colonial. Iniciada en 1562, la planta de la catedral actual se modificó en 1570. El interior se terminó alrededor de 1667, pero las torres tuvieron que esperar hasta 1791. El vecino Sagrario, obra maestro del barroco mejicano, se construyó entre 1759 y 1768, y los dos edificios forman un resumen de todos los estilos arquitectónicos que se hallan en Méjico, en el corazón del centro histórico de la gran ciudad.

Desde el principio de su construcción hubo que hacer frente a problemas estructurales a causa de las características del subsuelo, problemas que empeoraron más tarde al ir creciendo la ciudad y bajar el nivel del agua. El hundimiento más fuerte tuvo lugar en 1970, cuando se construía el ferrocarril metropolitano adyacente. Ya en 1937 se empezaron las obras de los nuevos cimientos por parte del gobierno y las autoridades de la Iglesia. Principalmente, se trataba de reducir el peso de los cimientos originales, lo cual no resolvió el problema del asentamiento, pero disminuyó las cargas, reforzó las vigas de los cimientos y contribuyó a unificar la transmisión de las cargas por medio de una nueva plancha de hormigón.

Em 1973, cuando se empezaron las obras más recientes, se descubrió que la parte superior de los viejos pilares de madera se había podrido a causa de haber bajado el nivel de las aguas, problema importante en la Ciudad de Méjico, donde el área central se ha hundido 8 metros durante el pasado siglo. Después de haber estudiado diversas alternativas, se escogió el sistema de pilotes de control diseñado por Manuel González Flores, y de acuerdo con esto se decidió transmitir el 25 por centos del peso de la catedral y el 50 por centos del Sagrario al estrato firme. Para la primera, se emplearon 383 pilares, y 133 para el segundo, colocándolos con cuidado y sin vibración a una profundidad de 38–40 metros. Las cargas se transmitieron desde la estructure a los pilares mediante cubos, y cada pilar transmitió una carga de 100 toneladas al estrato. Para el Sagrario fue menester construir una envoltura de cimientos rígida y hueca, formada por una plancha de hormigón y vigas que se colocó bajo el relleno de los antiguos cimientos a fin de transmitir equilibradamente las cargas a la nueva plancha y pilares.

Al restaurar las bóvedas se tomó nota del emplazamiento de las grietas. A continuación, se apartó la obra de ladrillo y quedaron al descubierto los fallos que no aparecían en la superficie, restableciéndose la continuidad estructural de las bóvedas. Desde 1977, se han estabilizado los edificios y periódicamente se toman medidas para variar la transmisión de cargas al estrato, si hace falta; esto hace que se pueda controlar el asentamiento y el hundimiento de este importante grupo de monumentos.

Un grave incendio (ocasionado por el peligroso estado de los cables eléctricos) destruyó parte de la riqueza histórica y artística de la catedral en 1967. Se ha instalado un sistema totalmente nuevo que incluye una subestación y cuadros de control independientes para las diversas partes del edificio.

El edificio unido a la catedral y ocupado por la Curia se construyó en 1859–69, pero presentaba también problemas de cimentación. Había tenido lugar asentamiento múltiple que había ocasionado importantes grietas. Esta estructura ha sido independizada de la catedral construyendo puntos de unión en los cimientos y muros. El suelo original ha sido reemplazado por una plancha de hormigón armado sobre el armazón antiguo, y se ha insertado también una plancha de hormigón armado a nivel del tejado; las dos están unidas a armazones empotradas en la mampostería de los muros.

Por último, los trabajos de conservación de este importante grupo de monumentos están haciendo frente al deterioro de la piedra de la torre oeste. Algunas partes han sido restauradas, consolidadas o reemplazadas, según su estado. Se han hecho copias de las esculturas de la parte superior, a fin de que puedan ser colocadas en su sitio, si hace falta en el futuro. Se espera así tener asegurada la futura conservación de los más importantes monumentos de la Ciudad de Méjico.