Cosmic Rays Pavilion: Candela's First Experimental Hypars - Analysis of Current

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Abstract. The Cosmic Ray Pavilion is a double-curved concrete shell built in 1951 located in the National Autonomous University of Mexico, by the Spanish architect Félix Candela Outeriño, according to the Master Plan of the University City, which is currently listed as Heritage Culture of Humanity. The Cosmic Ray Pavilion was a project designed as a construction-machine, since its objective was not to be inhabited, but to house a series of equipment that would oversee monitoring cosmic radiation, and for its operation a surface with a minimum thickness of 15mm in its centre (where the machine would be positioned), which was constructively difficult for the technological advances of the time. (1951). Over time, the use of the space was modified, the original structure was altered, and adequate maintenance was not carried out on the envelope, which has caused the deterioration of the property. The evolution of the design proposal, the technical details of its execution and the challenges of the construction system were studied to know the current situation of the concrete shell through non-invasive techniques. The results obtained from the study of the structure of the Pavilion contrast with the information from the archive of the National Autonomous University of Mexico. The importance of non-invasive analysis methods in construction systems is discussed, to know the current situation of buildings, and generate intervention strategies that preserve the built heritage of humanity.

Keywords: Non-destructive analyse · Heritage concrete buildings · Concrete evaluation · Architectural envelopes

1 Introduction

The Cosmic Ray Pavilion (Fig. 1) is located on the campus of the National Autonomous University of Mexico, in Mexico City and is one of the most iconic structures built as part of the original master plan for the university campus. The structure was designed and built in 1952 by the Spanish architect Félix Candela using a double curvature hyperbolic paraboloid of reinforced concrete. Currently (2023) the pavilion is 71 years old, and it is estimated that the useful life of the concrete is around 50 to 100 years, and this depends on periodic maintenance and repair. But the pavilion has undergone changes in its structure that have altered its initial condition and perhaps has caused deterioration of the building, for this reason it is important to know what the changes have been in its construction system and propose action plans for its preservation. And conservation.

Y. Endo and T. Hanazato (Eds.): SAHC 2023, RILEM Bookseries 46, pp. 950–958, 2024.
https://doi.org/10.1007/978-3-031-39450-8_77

Fig. 1. Cosmic Ray Pavilion. Photo taken by the authors.

The analysis process consisted of a series of steps, one of which focused on collecting the information contained in the structural memory (1), which mentions that the material used was a mixture of reinforced concrete with a resistance of f' c = 100 kg/cm^2 and a steel grid with a diameter of ¼´´ @20 cm was placed in both directions. He mentions that steel was theoretically unnecessary, due to the low stresses in the shell, but was included to control cracking in the concrete due to temperature effects. The proportions of the concrete mix were 1:2:3 (one part cement, two sand and three gravel), with a coarse aggregate of 0.6 cm maximum size, poured manually and with a wooden formwork which functioned as a temporary bearing element.

Fig. 2. Pavilion interiors. Photo taken by the authors.

The shell reached 5.50 m above the base concrete platform, with a thickness of 1.5 cm in the highest part of the roof, which increases towards the bottom of the shell reaching a thickness of 5 cm to create a beam, edge running from end to end at the base of the shell. (1) The problem identified is the modification of the original structure due to the lack of maintenance and inadequate intervention practices. And due to the heritage category of the property, invasive techniques cannot be used for the study.

The purpose of this work is to study the current characteristics of the pavilion in contrast to the design proposed more than 70 years ago. It is important to mention that the Cosmic Ray Pavilion is part of the set of buildings included in the UNESCO World Heritage Site since 2007. Therefore, the analysis can only be carried out in certain areas (Fig. 2). Non-destructive techniques were applied to combine various analysis techniques that can be used individually or jointly to evaluate the integrity and properties of a material, a component, or a construction system.

2 Materials and Methods

To carry out the diagnosis of the reinforced concrete shell, an analysis method was built that integrates non-destructive techniques that allow the information to be treated jointly and thus reduce the uncertainty of the results. Implementing tools, as well as equipment from the Laboratory of Materials and Structural Systems of the Faculty of Architecture and the Postgraduate Degree in Architecture of the UNAM, a process was designed to start with the cleaning, identification and reading of information in the following order:

The first activity consisted of carrying out the cleaning of the work areas, as well as removing the coatings that the element had to carry out a better reading of the instruments used for the analysis. The sections in which permission was granted to be able to carry out the analysis by means of non-destructive tests were determined. The work areas were called north, south, east, and west sections with a work section by quadrants of 100 × 100 cm (Fig. 3).

The second step consisted of detecting the reinforcing steel and its location, for this part of the process the Proceq Profometer 200 model was used, which is a detector of metallic elements that is mainly used for the location of reinforcing steel (Fig. 4). In this identification process, the concrete coating that surrounds the steel was not detected to determine the degree of exposure.

To estimate the resistance of the concrete and as a third step, the technique called sclerometry was used using the Proceq SilverSchmidt 8200 Type L equipment. To analyze the rebound number, the ASTM C805/C805M-13A (2) and NMX-C standards were used. -192-ONNCCE-2018 (3). To determine the relationship between the resistance and the rebound index, it was necessary to construct a sampling of control specimens to be evaluated at simple axial compression and relate the resistances found with the detected rebound indexes. The sclerometer requires that the surface be previously prepared with respect to standard (2) since any other element that covers the envelope would affect the taking of readings (Fig. 5).

As the next stage, the analysis for the determination of the ultrasonic pulse velocity was implemented. This non-destructive technique allows knowing the properties of concrete and other materials through the propagation of ultrasonic waves. The intention of carrying out this experimentation is to complement and expand the information

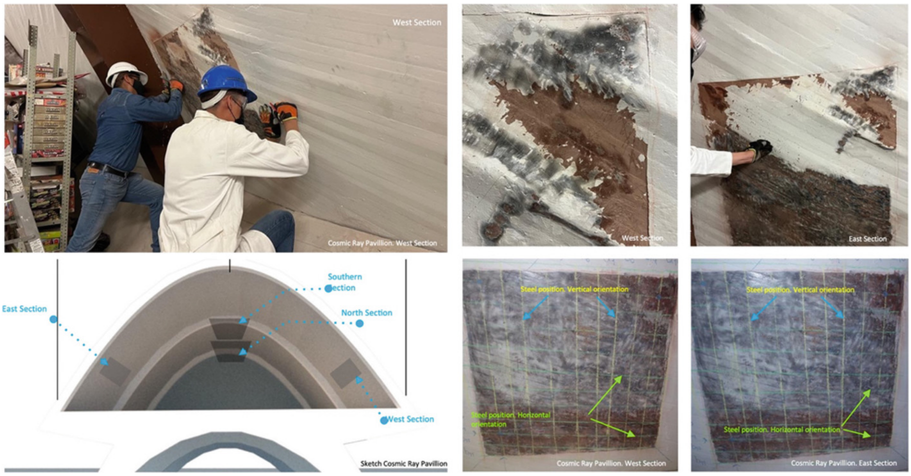

Fig. 3. Pavilion interiors. Preparation of the work area Photo taken by the authors

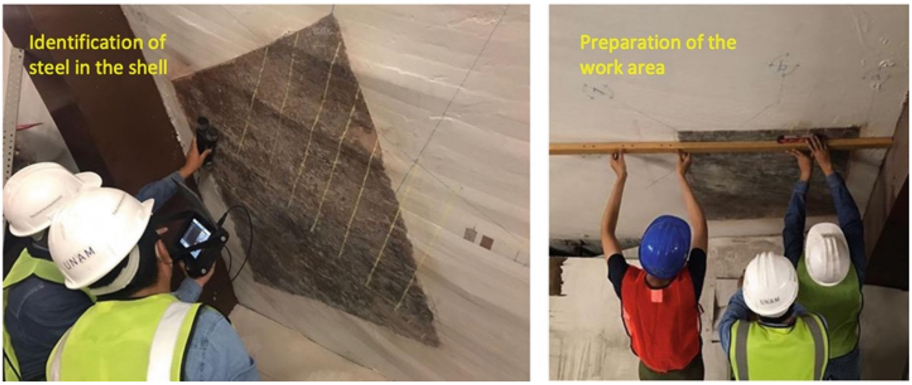

Fig. 4. Identification and location of the reinforcement area. Photo taken by the authors.

obtained by sclerometry, correlating the resistance and homogeneity of the concrete, obtaining a diagnosis with more information to establish a result with a lower percentage of uncertainty. This section was carried out as established by the ASTM C597-03 (4) and NMX-C-275-ONNCCE-2004 (5) standards (Fig. 6).

As a fifth stage to determine the integrity of the concrete and inquire about the thickness of the concrete shell in the upper part, the Echo ultrasonic pulse technique was used with a Proceq brand equipment, Pundit Array 250 model. The technique consists of place the equipment on the surface and emit ultrasonic pulses to obtain a tomography of the study area. This technique presents one of the greatest difficulties of interpretation, since if some anomalies are found, they will block other anomalies due to the existing coating. The inner surface of the shell was analyzed to look at the reinforcing steel inside to determine how far the steel is from the liner and in some cases if it is exposed or very close to the bottom shell bed.

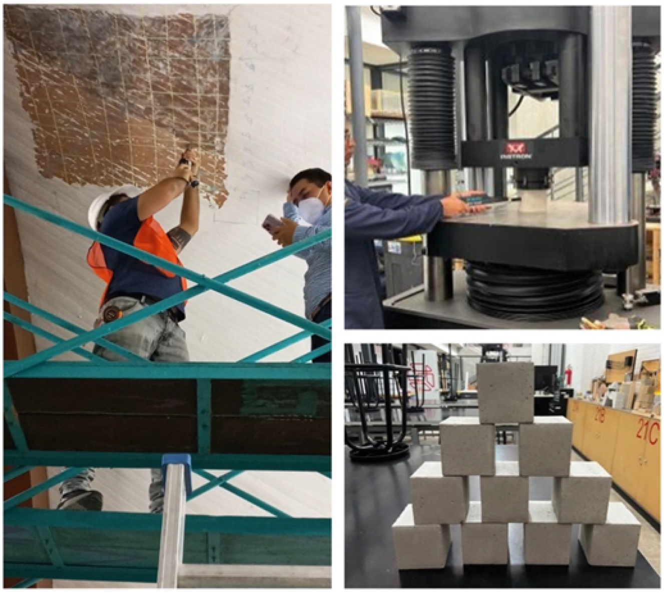

Fig. 5. Clerometry analysis. Photo taken by the authors.

Fig. 6. Analysis to determine ultrasonic pulse. Photo taken by the authors.

3 Analysis and Discussion of Results

At the conclusion of the analyzes according to the four techniques implemented, the following is described below:

Regarding the determination of the rebound index using the device known as a sclerometer, we can observe that in the southern section and the northern section, according to the Guidebook on non-destructive testing of concrete structures (5), they present areas of cracks and porosity (red areas) which means that there is high carbonation, as well as corrosion and cracking showing degradation in the concrete mix, therefore, there is a decrease in adherence in the aggregates affecting their durability. This shows in Fig. 7 where the two sections are located, and the red-orange shading represents areas where the concrete has the previously mentioned deficiencies.

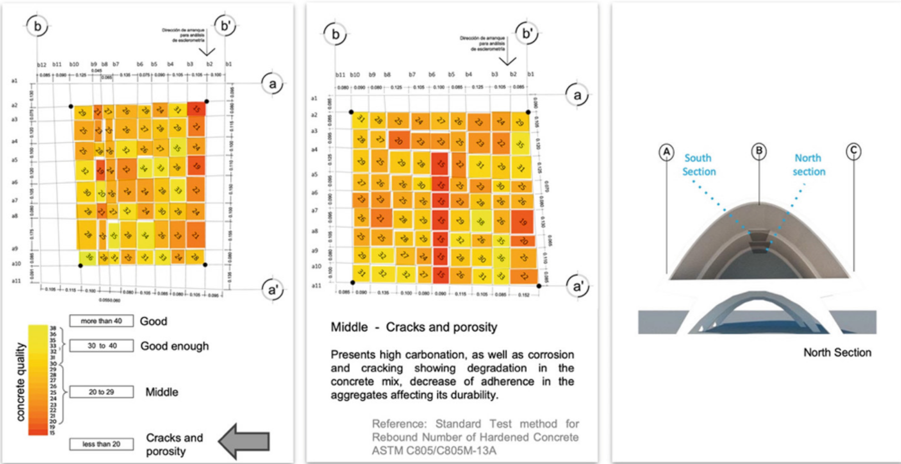

Fig. 7. Concrete Strength and Uniformity Testing Using Rebound. North and South Section. Made by the authors.

The eastern section is very similar to the southern and northern ones, since there are findings of cracks and porosity, while the western section does not show deterioration as present as in the previously described sections (Fig. 8). The western section, according to its rebound index, presents a chemical deterioration due to poor hydration of the mixture, which promotes the formation of soluble compounds and a loss of mass and mechanical resistance, all this according to Guidebook on non -destructive testing of concrete structures (Fig. 8).

Regarding the analysis carried out on the eastern section, since it sought to relate and corroborate the data found by sclerometry through the speed of the ultrasonic pulse, we found something very similar since in the lower part of the images composed of colors and the lower part Right, it is observed according to the pulse velocities obtained, (Fig. 9) that there is currently a low quality or deficient concrete since the material may be too permeable with capillary channels. This is due to the excess water with which the mixture was applied at the time of its preparation, which leads to the creation of a large number of open porosities (Fig. 10).

As the fourth technique implemented, the Echo ultrasonic pulse technique was used, the purpose of establishing this method is to search and find with the least possible uncertainty the thickness of the concrete shell in the upper part. With the ultrasound pulse, possible delaminations, lack of vibration, internal cracks and cavities were detected. The important thing to highlight is that when implementing this technique it was shown that what was reported in the structural memory does not coincide with the current state since the thickness at the top is between 2.7 and 3.3 cm, contrary to what is written where

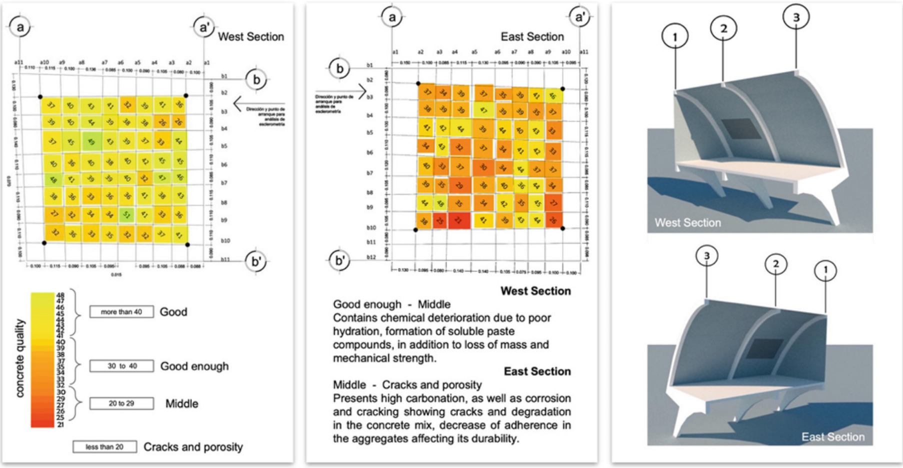

Fig. 8. Concrete Strength and Uniformity Testing Using Rebound. West and East. Made by the authors.

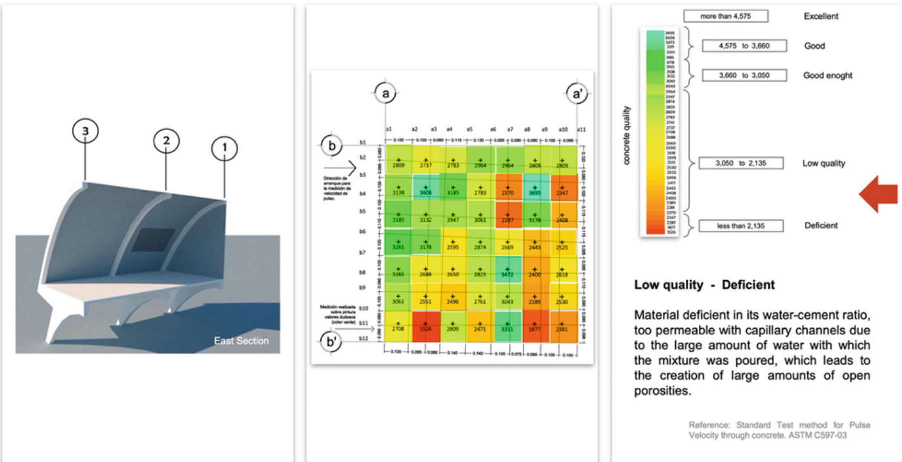

Fig. 9. Analysis using ultrasound pulse velocity. East Section. Made by the authors.

reports a thickness of 1.5 cm. At the ends of the shell, the thickness ranges from 5.4 to 06.6 cm, which is close to what is described in the structural memory. It is worth mentioning that the percentage of error is around 10%, and it was taken into account to present these results (Fig. 11).

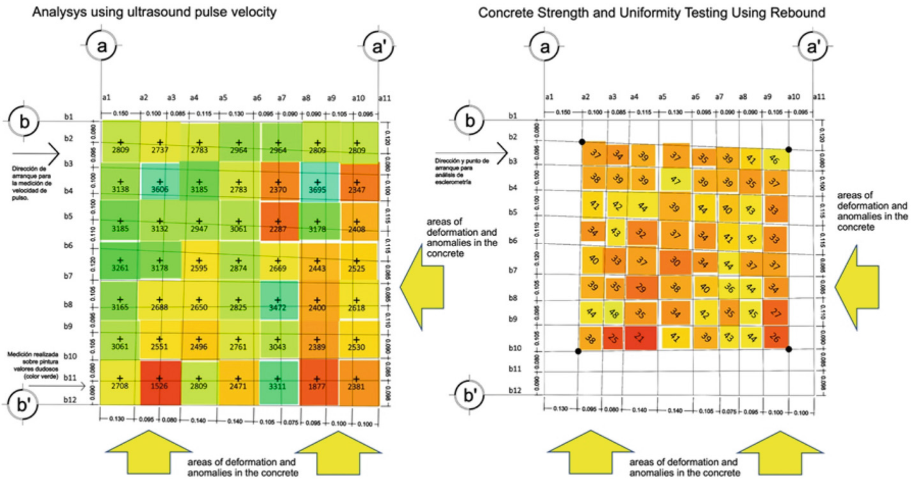

Fig. 10. Comparison of sclerometry techniques and ultrasonic pulse velocity. Made by the authors.

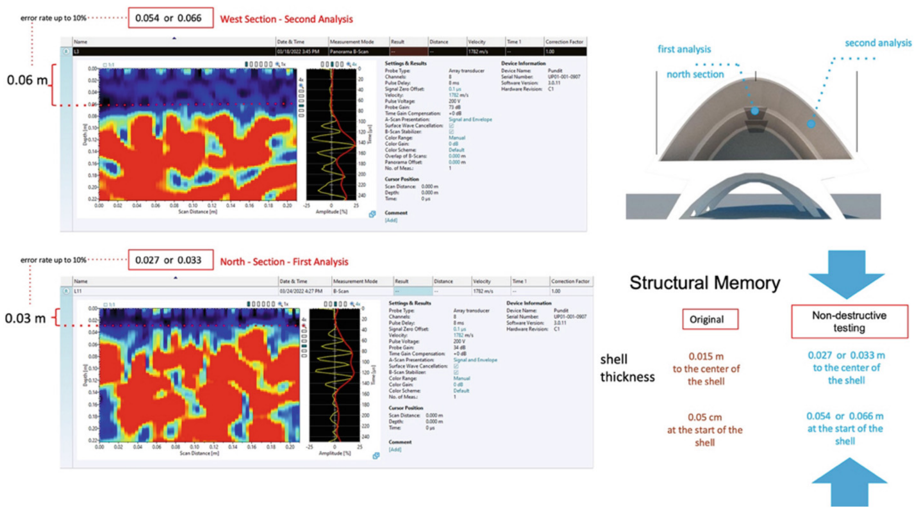

Fig. 11. Analysis by the ultrasonic pulse Echo, Made by the authors.

4 Conclusions

In the center section of the shell and at the ends, the analysis showed a detachment of the bottom layer of concrete coating. The resistance of the concrete in the shell is not optimal, thus, it is mandatory to establish a maintenance technique that will allow to keep it in the best conditions possible.

It is necessary to expand the analysis area to determine if the shell presents greater physical and mechanical deformations. If it's possible, contrast the results with semi-destructive techniques to be able to carry out chemical analyses, thus deepening the study of its deterioration processes and learning how to carry out more adequate maintenance and restoration projects.

After the February-March 2022 non-destructive test it was clear that the building needed further studying, expanding the examination area to include not only the shells (upper structure), but also the slab and pillars (lower structure). Moreover, after collecting all the data a complete restoration project seemed evident.

Acknowledgments. To the Laboratory of Materials and Structural Systems of the Faculty of Architecture of the National Autonomous University of Mexico for the facilities in the development of the study. To the Postgraduate in Architecture for providing non-destructive testing equipment.

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