Documentation of the current state of the southern elevation of the temple of Our Lady of Candelaria: application of photogrammetry as an auxiliary technique for data acquisition

Isaías Edén Vizcaíno-Hernández, Miguel Angel Soto-Zamora, Alejandro Acosta-Collazo, Rubén Alfonso López-Doncel

Resumen: A survey of the Temple of Our Lady of Candelaria in Villa Purificación, Jalisco, Mexico, was conducted with the objective of creating a architectural representation that includes the identification of materials and their deterioration. Digital photogrammetry was used to take organized photographs using a handheld camera and a drone. The result was a point cloud that was used to develop architectural drawings in CAD software, obtaining relevant information on dimensions and materials. Based on this, color mapping was performed on the south facade of the temple to identify different materials and lesions. It is considered that the implementation of photogrammetry resulted in a reliable and useful technique, although it has some drawbacks that can be detailed later with the same photographic collection. The contextualization of the environment revealed possible causes of deterioration related to humidity in a semi-humid tropical environment, for example: bulky elements such as buttresses generate periods of sun and shade, reducing the evaporation of humidity necessary for the proliferation of organisms.

Palabras clave: photogrammetry, building materials, historical heritage, deterioration, architectural representation

Documentación del estado actual del alzado sur del templo de Nuestra Señora de la Candelaria: aplicación de la fotogrametría como técnica auxiliar para la obtención de datos

Abstract: Se realizó un levantamiento del Templo de Nuestra Señora de la Candelaria en Villa Purificación, Jalisco, México, con el objetivo de crear una representación arquitectónica que incluyera la identificación de materiales y su deterioro. Se empleó la fotogrametría digital, capturando fotografías ordenadas con una cámara de mano y un dron. El resultado fue una nube de puntos utilizada para desarrollar dibujos arquitectónicos en software CAD, obteniendo información relevante sobre dimensiones y materiales. Sobre de ello se realizó un mapeo de colores en la fachada sur del templo para identificar diferentes materiales y lesiones. Se considera que la implementación de fotogrametría resultó en una técnica confiable y útil, aunque presenta algunos inconvenientes que pueden detallarse posteriormente con la misma colección fotográfica. La contextualización del entorno reveló posibles causas de deterioros relacionados con la humedad en un ambiente tropical semi húmedo, por ejemplo: elementos abultados como los contrafuertes generan lapsos de sol y sombra disminuyendo la evaporación de la humedad necesaria para la proliferación de organismos.

Keywords: fotogrametría, materiales de construcción, patrimonio histórico, deterioro, representación arquitectónica

Documentação do estado atual do alçado sul do templo de Nossa Senhora da Candelária: aplicação da fotogrametria como técnica auxiliar para aquisição de dados

Resumo: Foi realizado um levantamento do Templo de Nossa Senhora da Candelária, em Villa Purificación, Jalisco, México, com o objetivo de criar uma representação arquitetónica que inclua a identificação dos materiais e do seu estado de deterioração. Utilizou-se a fotogrametria digital para captar fotografias organizadas com uma câmara portátil e um drone. O resultado foi uma nuvem de pontos utilizada para desenvolver desenhos arquitetónicos em software CAD, obtendo informações relevantes sobre dimensões e materiais. Com base nestes dados, foi realizado um mapeamento cromático da fachada sul do templo para identificar diferentes materiais e danos. Considera-se que a implementação da fotogrametria resultou numa técnica fiável e útil, embora apresente algumas limitações que podem ser detalhadas posteriormente com o mesmo conjunto fotográfico. A contextualização do ambiente revelou possíveis causas de deterioração relacionadas com a humidade num clima tropical semi húmido; por exemplo, elementos volumosos como contrafortes geram períodos de sol e sombra, reduzindo a evaporação da humidade necessária à proliferação de organismos.

Palavras-chave: fotogrametria, materiais de construção, património histórico, deterioração, representação arquitetónica

Introduction

Starting from the importance and society's right to preserve assets with historical, artistic, cultural, and/or architectural value due to the existing identity link between them (Taller 2014: 11), the need to document their current state is addressed. Documentation is recognized as a fundamental activity in conservation, acting as an information base that progressively collects significant data on history, architectural appearance, material characteristics, damage records, modifications, and other aspects, including use and interaction with society (Balandrano 2024). The main purpose of this database for future generations and those involved in subsequent interventions or research, aiming to improve decision-making and ensure, as much as possible, the longevity and authenticity of built heritage (Nieto *et al*. 2009: 238; Villegas *et al.* 2014: 2).

Located in the municipality of Villa Purificación, Jalisco, Mexico, the Temple of Our Lady of Candelaria (TOLC) [Figure 1], is a structure built between the late 16th and early 17th centuries. Because of its historical significance, it has been declared a Historical Monument under the registration number I-0011500836 (INAH 2022). Their architectural plan has a longitudinal east-west orientation, obtaining greater solar radiation to the south [Figura 1:F]; composed of a pair of bell towers on either side of the access to the main nave, the north side has a chapel and the south side consists of various buttresses and an inscribed sacristy, its structural elements are mainly made of masonry, made with a combination of stone and baked red brick, agglomerated with lime mortar. While some facades are plastered and painted [Figure 1:A, B], The south facade has exposed materials where deterioration can be observed, which is estimated to be mainly due to weathering processes, among which the following could be highlighted: the presence of humidity that invades the buildings through mechanisms such as capillarity, condensation, infiltration, filtration, accidental or due to use (Casas 2018: 42); solar exposure that generates thermal expansion and contraction in the materials; among other environmental factors. Resulting in progressive deterioration, which can be found defined in the ICOMOS Glossary: cracking and deformation, peeling or flaking, induction of failures due to loss of material, discoloration and deposits, and biological colonization (ICOMOS 2008: 2). As a result, the south facade of temple has an aged appearance [Figure 1:C], characteristic of historic buildings that have endured prolonged exposure to environmental conditions and lack of maintenance.

Today, various techniques are available to document the physical characteristics of buildings and their current state, including manual surveys, topographic equipment, LiDAR systems, photogrammetry, or laser scanning (Li *et al.* 2023: 2; Pepe *et al.* 2023: 5720; Pérez S. *et al.* 2023: 27). The information obtained can be used to create 2D architectural representations, which remain important because of their simplicity and accessibility to a variety of professionals in the conservation field. These architectural representations are commonly used to illustrate different materials, lesions or features identified by shading and hatching (Andaluz *et al.* 1994: 147; Arriaga *et al.* 2017: 39).

This article deals with the implementation of digital photogrammetry as an auxiliary technique to carry out the

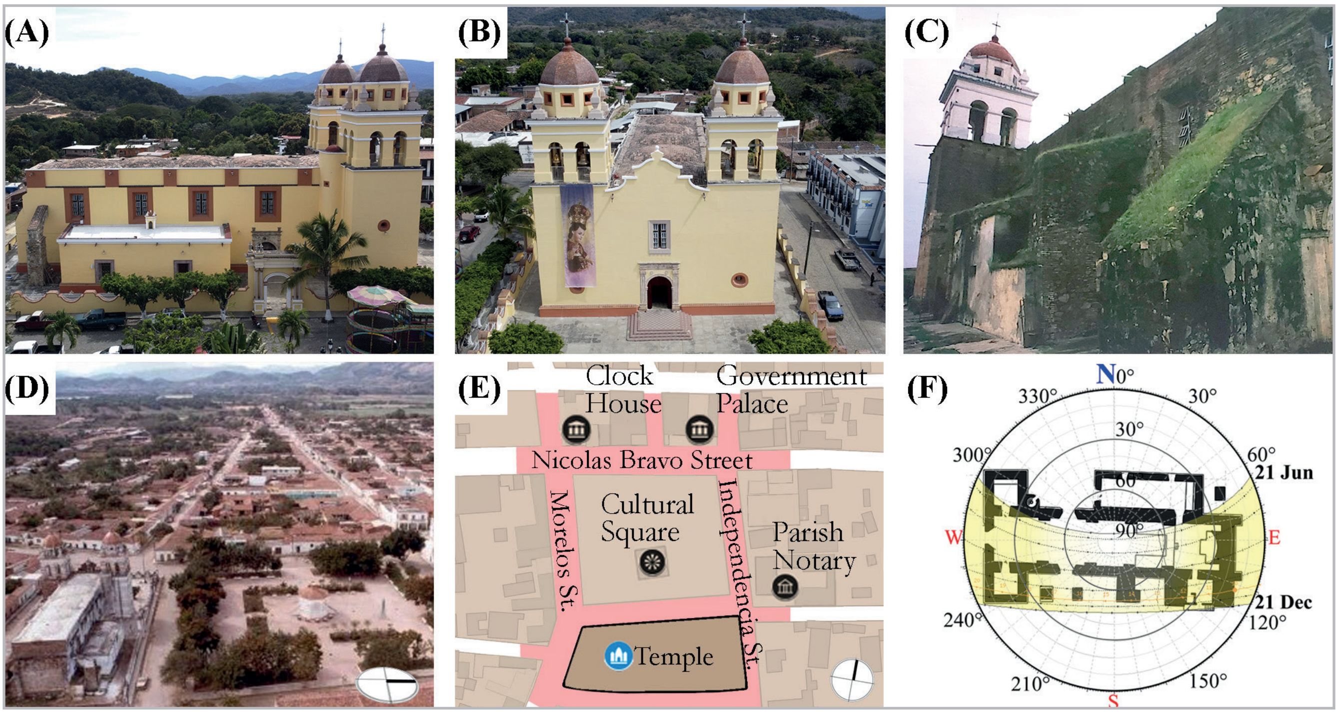

Figure 1.- A) North facade, (B) main west facade, (C) south facade, appearance in 2004 (Ascencio *et al.* 2004). (D) The town of Villa Purificación in 2000 (Jalisco 2023), (E) original urban layout (Google 2023), (F) ground floor (SunEarthTools 2023)

data collection required for the development of architectural drawings, describing the location of materials and the presence of some lesions through mapping techniques. It describes the procedure required to obtain photographs, the scaling process within photogrammetry, and how this information is used for processing in 2D computer-aided design (CAD) applications.

Historical context of the Temple

The town of Villa de la Purificación has kept its name since it was founded in 1533 by Juan Fernández de Híjar, who acted on the orders of Nuño Beltrán de Guzmán to annex these lands to New Galicia under the Spanish Crown. The settlement follows an urban layout that partially corresponds to the orders of Charles V, who described five main avenues that lead to the central plaza, administrative palaces, the royal house and the temple, all located in isolated plots [Figure 1:E]. The plaza serves as a convergence point for the avenues, facilitating the distribution of pedestrians. It also indicates the placement of the temple on a raised platform above the surrounding streets to highlight its hierarchy and divert rainwater. (Regalado 2008: 88).

Since colonial times, these areas have been known for their marked contrasts between the dry and wet seasons [Figure 2:A, B]. For example, the explorers' letters describe vast dry plains and brown hills due to the exposed soil and leafless tree trunks. This description proved inconvenient for the first occupying battalions, who arrived at a place of dense vegetation, pests, and overflowing rivers, causing these initial incursions to be withdrawn. (Regalado 2008: 103; Torales and Lazos 2016: 28). Today, these types of ecosystems are recognized as semi-humid, deciduous forests, typical of the tropics. Thus, in this site the average annual temperature is 24.1°C, with average maximum and minimum temperatures of 35.0°C and 13.7°C, respectively; as well as an average annual precipitation is 1,282 mm^3 (IIEG 2023).

Geological context

The geological description of this town places it on an alluvial deposit of sedimentary rock. The valley is bordered by different geological formations: To the north, the mountain system of the Sierra Madre Occidental, composed mainly of intrusive igneous rocks such as granite-granodiorite; to the east, hybrid igneous formations between tuffs and andesites; to the south, the alluvium continues with some islands of different sedimentary conglomerates; and to the west, there is a region of extrusive igneous formations of andesite, along with an extension of sedimentary conglomerates between shales and sandstones (SGM 2023), see [Figure 2:C].

Characterization of temple materials

It is known that the study of pathologies in buildings and their manifestations in the form of degradation require comprehensive multidisciplinary studies. This article deals in a cursory manner with the relationship between the properties of the materials of the temple and the injuries present in it, since it is known that the physical properties such as density, porosity and absorption of stone materials are directly related to their compressive strength and durability (Raheem 2019: 143). (Raheem 2019: 143). Therefore, the characterization of some materials that make up the TOLC was developed by studying some fragments of detached stones. Their origin is recognized by visual similarities with the stones of the building, such as color, texture and oxidation (the stones have an orange surface).

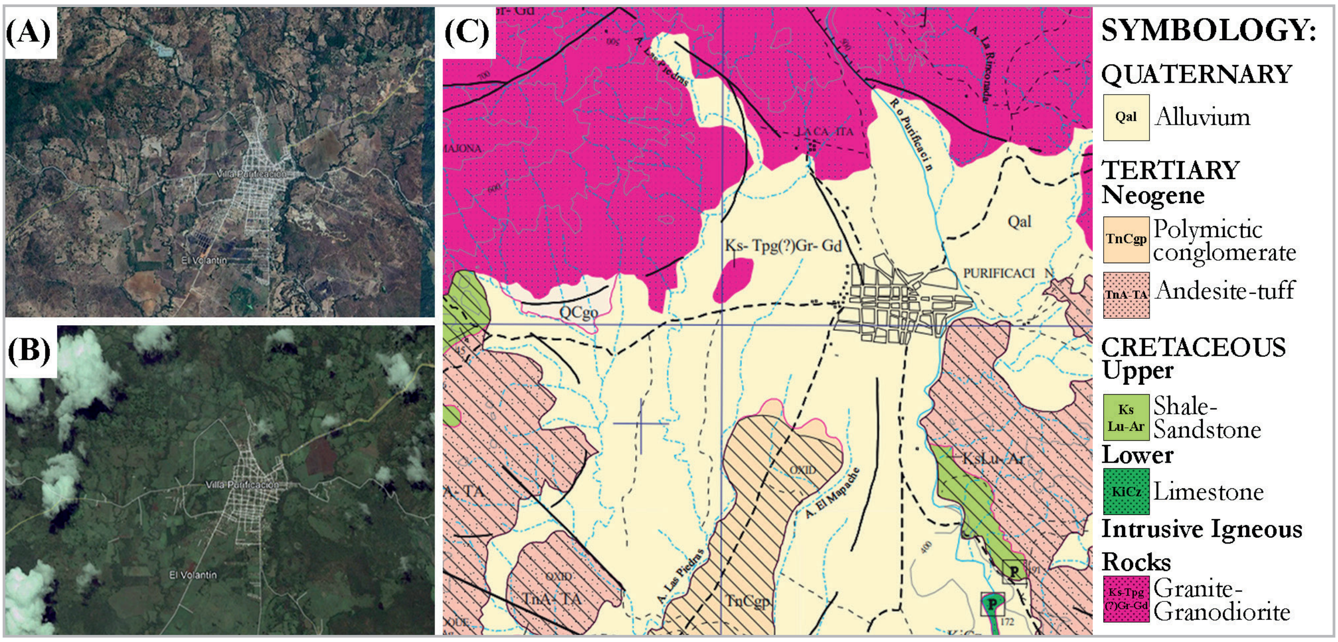

Figure 2.- Contrasts between: (A) dry season (B) rainy season (Google, 2023). (C) Geological map excerpt (SGM 2023)

	Weight (grams)			Apparent density	Matrix density	Absorption	Porosity
Sample	**dry**	**saturated**	**submerged 19° C**	**cm^3**	**cm^3**	**%**	**%**
PC-1	68.21	71.51	45.19	2.588	2.963	4.84%	12.54%
PC-2	37.29	39.49	25.21	2.608	3.087	5.90%	15.41%
PC-3	42.61	43.31	26.37	2.512	2.624	1.64%	4.13%
PC-4	51.19	53.76	34.19	2.612	3.152	5.02%	13.13%
PC-5	403.17	406.68	259.68	2.739	2.810	0.87%	2.39%
PC-6	321.94	323.95	199.48	2.583	2.629	0.62%	1.61%
LD-7	372.96	461.37	234.58	1.645	2.695	23.70%	38.98%
LD-8	385.44	485.71	237.54	1.553	2.606	26.01%	40.40%

Table 1.- Physical properties of materials

Three different types of igneous rock were identified among the recovered stone samples. In addition, two pieces of fired red brick, currently produced in the region, were included. It is assumed that they can be considered representative due to their similarity in origin and production materials.

To begin the physical studies, it is necessary to cut the samples into regular quadrangular prisms, using some bench saws. These specimens receive the following names: Orange Stone (PC-1 and PC-2), Black Granite (PC-3 and PC-4), Gray Granite (PC-5 and PC-6), and Brick (LD-7 and LD-8). Activities include:

1. Determination of the dry weight obtained by drying the samples for 24 hours at a minimum temperature of 60°C [Figure 3:B].

2. Recording the saturated weight, obtained by soaking the samples in distilled water for 24 hours and then superficially drying them [Figure 3:A].

3. Submerged weight, obtained by suspending the samples from a balance and immersing them in a container of distilled water at room temperature.

These data are used to calculate apparent density, matrix density, absorption and porosity. (López *et al.* 2018; UDELAP 2023: 28), see [Table 1].

Representation of the current state

To represent the current situation of the TOLC, the objective was set to carry out a survey using digital photogrammetry to obtain vertical views that will serve as the basis for the development of a 2D architectural representation using CAD applications. This elevation view is useful for delineating the materials and deterioration of the building.

It is understood that photogrammetry is based on the principle of structure from motion (Locher *et al.* 2018: 1). This concept suggests that three-dimensionality is interpreted from at least two planar images with significant overlap between them. In this way, passive triangulation can be used to determine the location of points in a digital environment. It is estimated that both photogrammetry and laser scanning began to be used in large-scale historic monument documentation projects around the year 2000 (Levoy *et al.* 2000: 1).

Photogrammetry has gradually improved due to the increasing processing power of computers, and is now considered a competitive technique due to the automation that emerged around 2010 (Janvier *et al.* 2016: 354). This has led to the recognition of photogrammetry by the International Council on Monuments and Sites (ICOMOS) (Tamayo N. *et al.* 2010: 2; Korro *et al.* 2023: 24). It is also recognized by different authors as a technique for the architectural documentation of historical elements (Medina Carrillo 2014: 4), and as an aid in identifying lesions (Sánchez L. and Soto Z. 2021: 89).

Although photogrammetry has achieved improvements in its automation, allowing anyone with minimal training to digitize a real element, it is considered that a good photographic survey, as well as a good choice of the moment of capture, can lead to better results and even reduce the processing time within specialized photogrammetry software.

Materials and methods

Prior to the collection of the necessary photographs for the modeling by photogrammetry, some preliminary planning activities are considered essential, which consist of:

1. Identifying the site, taking into account the existing obstacles (Figure 4) and the hours of sunlight. This helps to determine the photographic acquisition circuits that can be applied. In addition, a schedule was defined for the photographic captures near sunrise, when

natural lighting is favorable, avoiding high contrasts, reflections from direct solar radiation and lens flares in the background.

2. To confirm the scale of the resulting model, some markers were placed [Figure 4]. Their positions were later determined using the UTM Zone 13N (WGS84) coordinate system, with X, Y, and Z values obtained from topographic instruments.

1	2180304.223000	541822.532000	440.611000
2	2180280.392000	541787.039000	439.868000
3	2180280.557000	541793.899000	439.830000
4	2180282.170000	541828.163000	440.275000

Table 2.- Referenced markers (X, Y, Z). UTM Zone 13N, WGS84

Given the obstacles previously identified, it was decided to carry out different photographic surveys according to the instruments available:

1. Ground Survey [Figure 5:A] Since the entire building perimeter is accessible on foot, this survey was conducted manually using a Samsung Galaxy S10e smartphone with a 12-megapixel (MP) camera, f/2.4 aperture, dual-pixel autofocus, and optical image stabilization. The device captured JPG images at 3024 × 4032 pixels and 72 dpi. During the survey, photos were taken in circles at different levels to obtain images perpendicular to the facade. Three circuit levels were completed: two with the camera perpendicular to the building and a final level tilted ±45° upward to avoid capturing the sky.

2. Aerial survey [Figure 5:B] For this process, a DJI Mini 2 aircraft was used with a 12 MP camera, f/2.8 aperture,

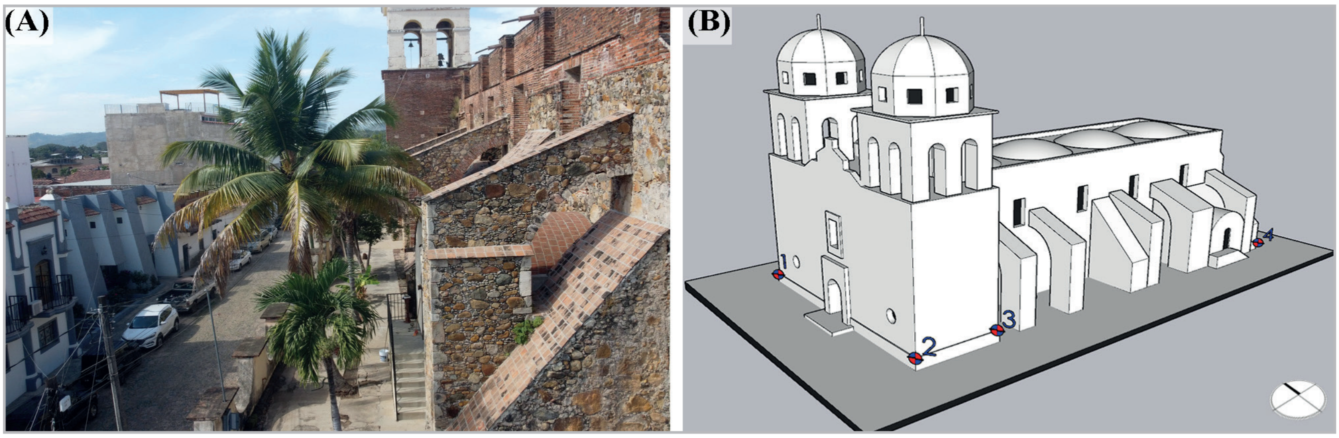

Figure 4.- (A) Identification of obstacles: aerial wiring and vegetation. (B) Location of markers in the temple.

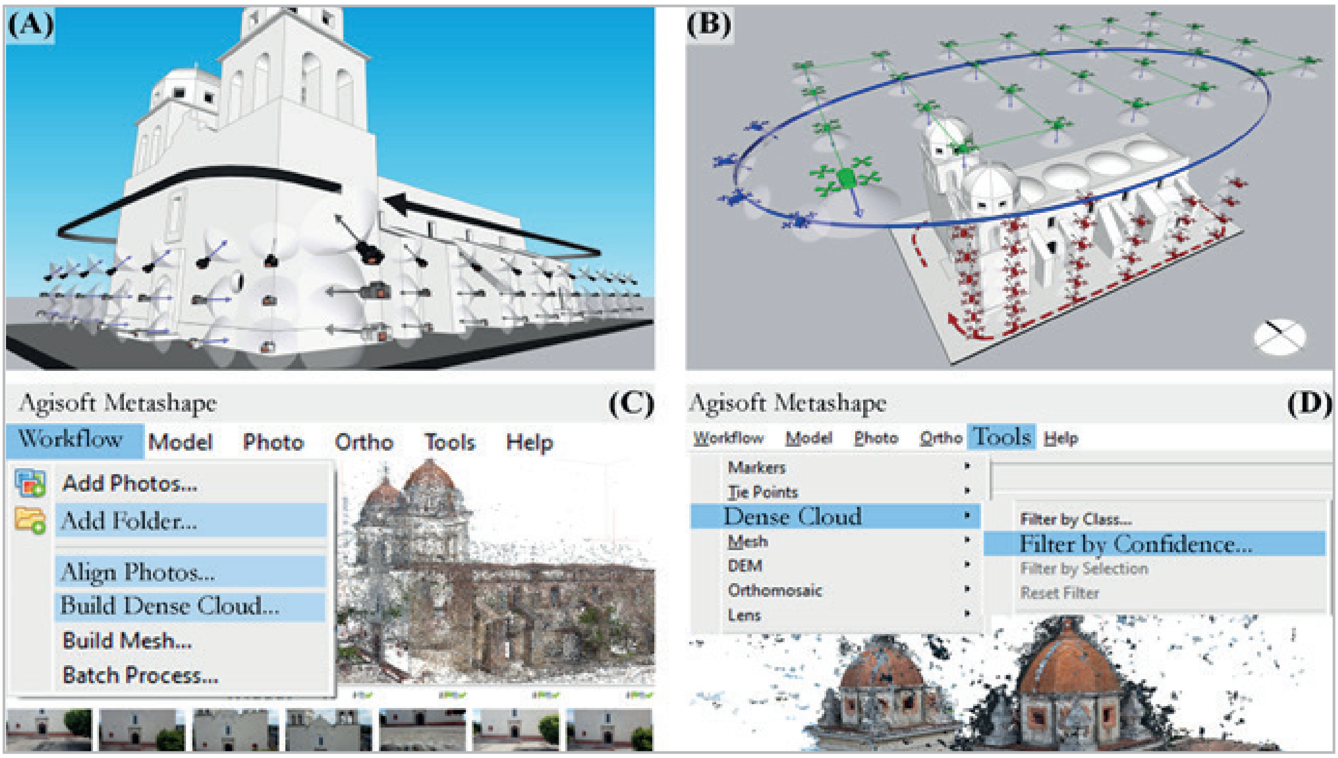

Figure 5. (A) Ground loops for photogrammetric surveys (B) Routes and airborne loops for photogrammetric surveys. (C) Workflow in photogrammetry software. (D) Point cloud cleaning.

obtaining images of 4000 x 2250 pixels and a resolution of 72 dpi; this drone was controlled by the DJI_fly application (DJI 2023) for free flights and DH_mobile (D.H. 2023) for scheduled flights. Considering the presence of obstacles that could interfere with the aircraft, three types of captures were implemented: 1) Column-like captures, where the aircraft was deployed in accessible areas to obtain images perpendicular to the facade from the ground up to the maximum height, repeating this process around the perimeter (red); 2) helical circles, overcoming the height of cables and trees, performing circles with a camera tilt angle between 30° and 60° downwards (blue); 3) snake flight, taking perpendicular photos of the building's floor plan along a planned route, maintaining a constant height and following a snake-like or zigzag trajectory (green).

Digital photogrammetric processing was performed using Agisoft Metashape software (Agisoft 2020), with a total of 857 photographs and four referenced markers. The modeling within the software followed an intuitive workflow (Figueroa C. and Pacheco M. 2016: 35; Vizcaíno and Soto 2018: 111; Sánchez L. and Soto Z. 2021: 64). Basically, the steps followed for this process included: adding photos to the software, photo alignment (highest accuracy, 40,000 key points and 4,000 tie points), optimizing cameras alignment (using referenced markers), to obtain a sparse point cloud of 604,091 points, subsequently creating a dense point cloud (medium quality and mild filtering), to obtain a total of 16,861,508 points [Figure 5:C], and finally, cleaning points in the dense cloud, supported by selection tools, confidence level selection or color selection [Figure 5:D].

Figure 6.- Clean point cloud, within the SketchUp software, perpendicular views: (A) south elevation view and (B) rooftop plan.

At the end of the photogrammetric activities, a dense point cloud with colors is obtained which, due to its density, can be visualized as a 3D model. This point cloud can be viewed in a specific software where, thanks to the manipulation of the camera, it is possible to align the object of study perpendicularly [Figure 6]. Unlike a traditional photograph, these visualizations do not have perspective distortions or vanishing points; this allows direct drawing on them, allowing scaled and proportional dimensions, even for elements that are difficult to access due to their height. In this way, the desired architectural representations are achieved.

The software used was SketchUp Studio (Trimble 2023) which implements an internal extension called essentials that allows the base program to visualize the point cloud in this 3D environment. This is done to maintain the scale of the image seen from the point cloud. Thus, most of the drawing is done directly in SketchUp and the images are saved in a perpendicular view to finalize the details in AutoCAD (Autodesk 2021), a program specialized in 2D digital drawing, which facilitates the representation of textures, hatching, line thickness, transparencies, among other predefined elements.

Mapping of materials and deterioration

As part of the objective of this article, the development of a mapping technique is proposed. This technique involves drawing with shading or hatching, which allows the communication of specific characteristics through the inclusion of a list of symbols. The aim is to help understand the distribution and delineation of material changes and the presence of various deterioration.

Materials and methods

Once the architectural elevation for the mappings is obtained, the features to be represented are delineated:

1. Material mapping: Three main types of materials were identified on the facade: exposed stone masonry, exposed brick masonry, and coatings with varying degrees of wear.

2. Deterioration Mapping: Following the glossary of deteriorations for stone elements proposed by ICOMOS, six categories of alterations were identified on the building: cracks and deformations; detachments and flakes; failure inductions; discolorations and deposits; biological colonizations; and restorations.

Both types of mappings were represented using AutoCAD software(Autodesk, 2022), for its tools to define regions (polyline) and shading (hatching). The mappings were based on the results of the perpendicular view obtained from the dense point cloud. A higher level of detail was achieved by consulting and corroborating the collection of images taken during the photographic study.

Results and discussion

—Materials characterization

Considering the igneous origin of the stones present in the Temple of La Candelaria and the geological environment of Villa Purificación, where there is a greater presence of igneous rocks in the mountainous formations to the north, it is proposed that these rocks could have been transported downhill by rainwater channels [Figure 7:A], from where they were extracted for use in the construction of the temple walls. This could be explained by the condition of the stones, which have rounded or smoothed edges [Figure 7:B], a common characteristic of rocks that have been carried or eroded by water currents.

The physical characterization of the recovered materials, presented in Table 1, shows that the stones used in the

Figure 7.- (A) Pluvial causes. (B) Rounded-edged stones on the second buttress in front of the gate. (C) First buttress behind the tower, damage mainly to bricks and mortar.

temple walls mostly have low absorption (less than 6%) and porosity (between 1.6% and 15.4%). In contrast, the bricks have an absorption of more than 23.7% and a porosity of more than 38.9%. Following the assertions of other authors who establish a relationship between the durability of a material and its porosity (Raheem 2019: 143), it can be estimated that materials such as bricks and mortar will have a lower durability compared to the igneous rocks that make up this historical structure, being more affected by deterioration [Figure 7:C].

Architectural representation of the current state

The photogrammetric survey has allowed the development of an architectural representation in plan [Figure 8:B] and elevation [Figure 8:A], facilitating proportional and scale drawing. This has allowed the extraction of relevant information about the configuration and shape of the temple. For example, it can be seen that the layout of the towers is not perpendicular to the layout of the main nave; they differ by two degrees from the longitudinal axis of the main nave. Given the scale of the temple, this is not visible to the naked eye and is difficult to detect through manual surveying. In addition, the technique has made it easier to capture the geometry of tall, elevated, or hard-to-reach elements without the need for sophisticated equipment, tools, or additional lifting gear.

Regarding the architectural representation in specialized CAD software (Autodesk 2022), the ease of discretizing repetitive materials is noteworthy, such as the arrangement

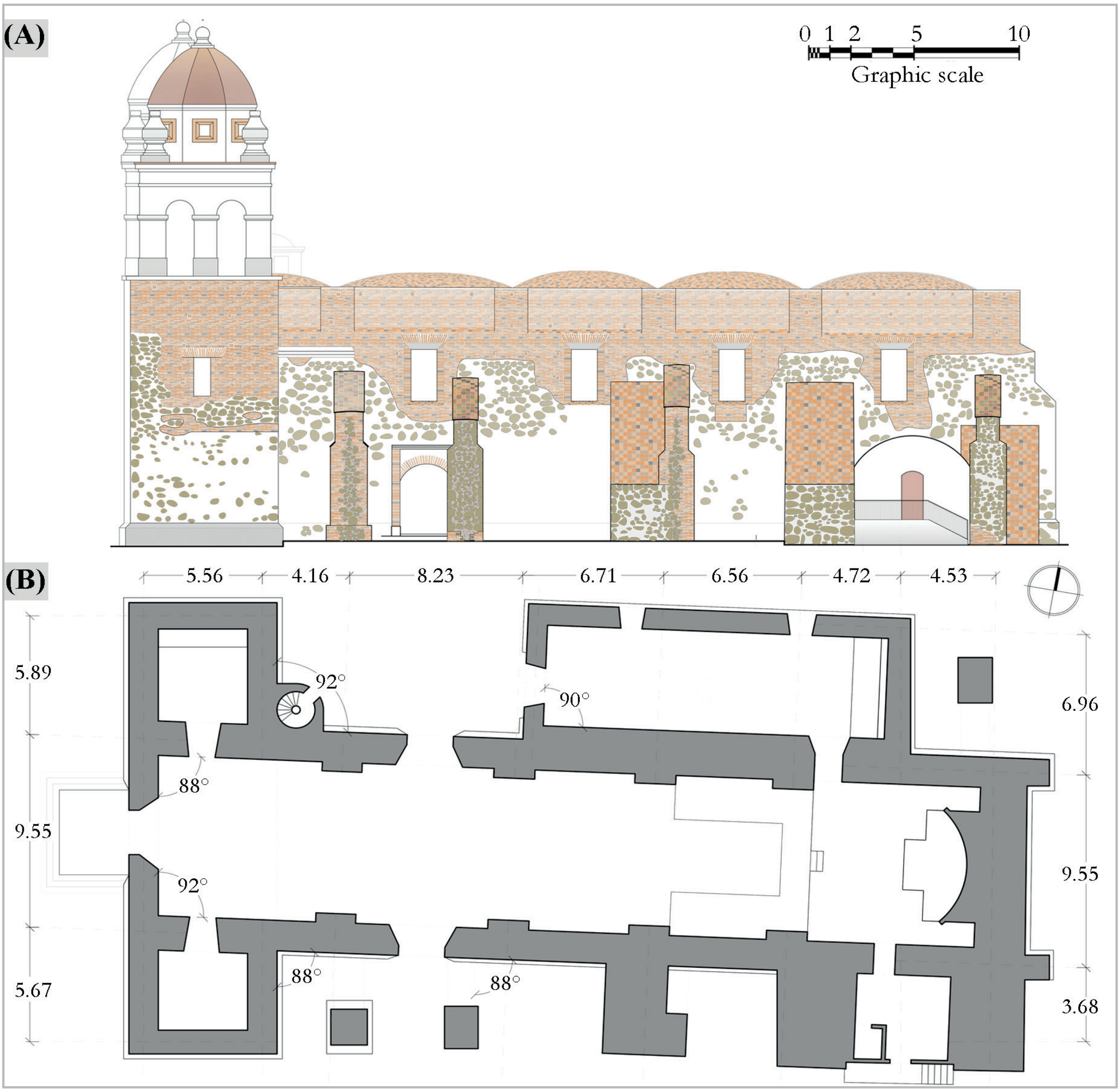

Figure 8.- Architectural representation: (A) elevation view and (B) ground floor.

of bricks in continuous walls and the distribution of square tiles on the buttress roofs, using functions available for replicating drawings as textures in regions (Superhatch) or by representing repetitive linear drawings (Array) to define the edges of bricks at corners, as in the tower, windows, and buttresses.

Mapping of the materials and deterioration present

The demarcation of the materials shows that the walls are constructed mainly with stone masonry up to the level of the windows, where a material change is generally seen in the diagonals, giving way to the continuity of the walls with fired red brick masonry that extends from the windows to the roofs. Brick is also found enclosing some buttresses. In addition, square brick tiles are present on the roofs, both on the roofs and on the buttresses. Finally, remnants of plaster or render are observed in the middle of the nave and at the base of the tower, while new plaster is seen in the sacristy and the bell tower [Figure 9:A].

Regarding the mapping of deterioration on the temple, the surfaces with biological colonizations, discolorations and deposits are the most obvious. These colonizations may be responsible for the superficial erosion caused by their roots or the appearance of discolorations and deposits due to the decomposition of organisms (Casas 2018:

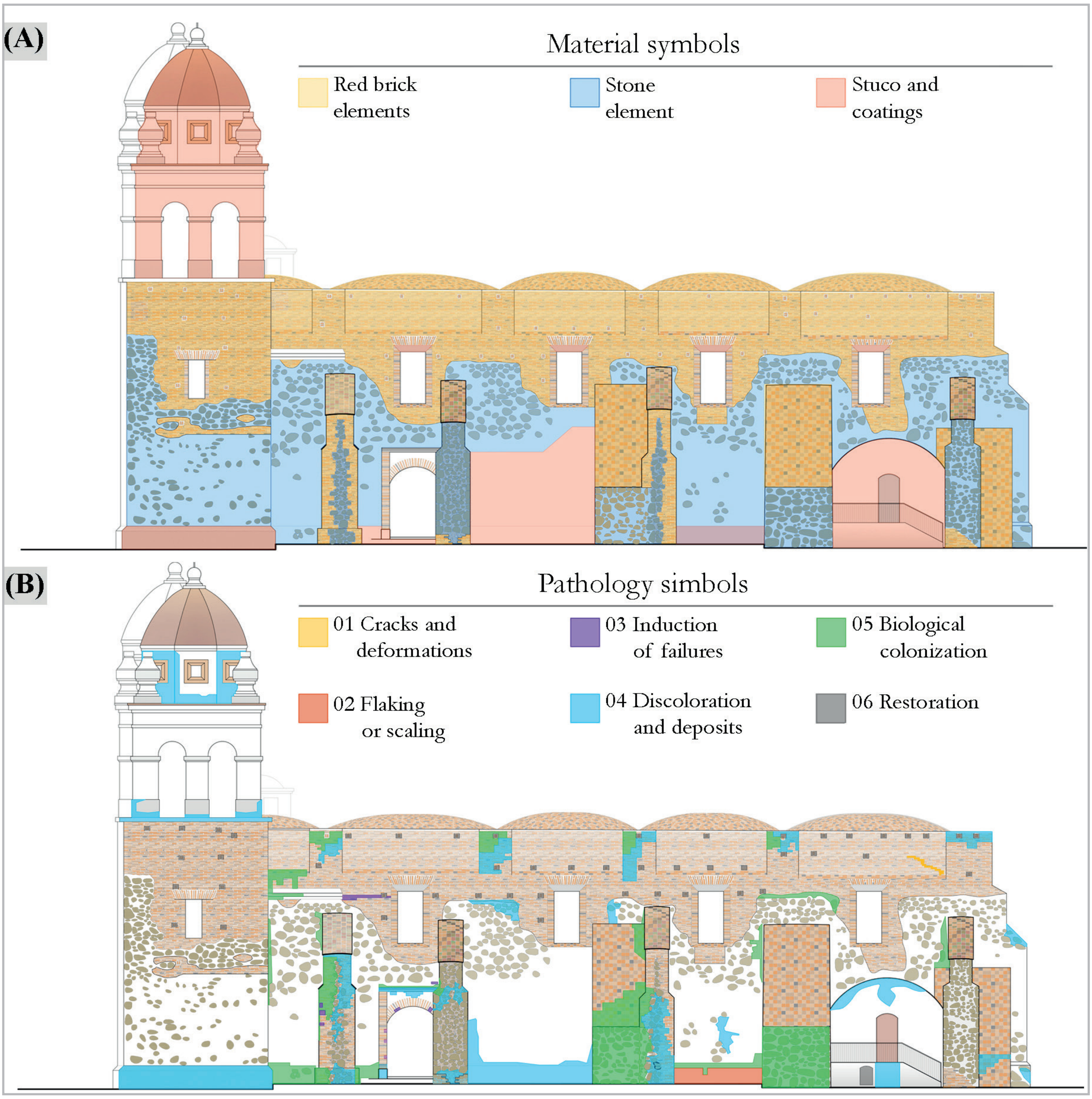

Figure 9.- Mappings on the architectural elevation: (A) Materials and (B) Deterioration

58). Although the constant sunlight on the south facade should be unfavorable for these biological colonisations, the invasive species have managed to settle in the porous materials of the temple, mainly in areas that experience periods of sun and shade. These conditions are found between the tower and one of the buttresses, and on the tile-covered buttresses that are in the shade of the trees. Finally, there are small areas of material loss, mainly bricks, and a crack in the upper right corner [Figure 9:B].

Conclusions

The Temple of Our Lady of Candelaria is a historic building with an age of at least 400 years since its construction. Therefore, it is expected to find accumulated deterioration due to simple weathering, which affects all buildings. In addition, the temple is located in a tropical environment where there are significant contrasts between rainy and dry seasons, which favors the development of lesions due to changes and migration of moisture (saturation and drying).

Regarding the analysis of the temple's materials, it has allowed the identification of significant differences in terms of porosity and absorption, suggesting a greater durability of the stone compared to bricks and mortar. This finding leads to the consideration that some mortar joints may have been lost or eroded over time, which would explain the presence of "rajuela" [Figure 9:B] a repair or construction system that involves embedding small fragments of brick, tile and/or stone in the construction joints. It is believed that this method was used to fill the gaps created by the loss of mortar, and in some cases, the lack of mortar allowed entire pieces to detach. It is therefore considered likely that these missing materials were replaced with bricks or rajuela. This may explain the bricks present in the lower areas of the buttresses and the horizontal band of bricks in the tower.

Regarding the architectural representation of the TOLC, the photogrammetry technique is considered suitable for developing this type of representation. The supporting image obtained from the point cloud retains enough information to produce a drawing of considerable quality, preserving details of shapes, dimensions and colors that were favorable during the interpretation and development of the architectural drawing. It is worth mentioning that due to the dimensions of the building, there may be differences and discretization of information regarding its smaller elements, such as canopies, projections, gargoyles, recesses, and others. However, the technique has some advantages, such as the fact that, being a virtual model, dimensions can be obtained from it without the need for an exhaustive survey of the building.

The current state of the southern facade and the documentation of existing deterioration, it can be generally seen that there is a concentration of alterations at the base, possibly due to capillary humidity or rainwater filtration (Serna *et al.* 2016: 28; Casas 2018: 45); There are also elevated areas where the geometry is complex (bell tower), horizontal (marquees) or close to the gargoyles, where it is estimated that environmental and meteorological conditions provide humidity (Speri *et al.* 2017: 157), in n general, this moisture should be easily lost on the south facade that has the greatest solar incidence, but due to the geometry of the building that generates shadows on itself, this humidity can remain longer in those elements with low solar radiation, favoring the development of biological colonization [Figure 7:C]. Knowledge of the physical properties of the materials helps to reinforce these conclusions, since in these porous materials with high absorption, such as bricks and mortar, there is a proliferation of plants, mosses and possibly microorganisms (ICOMOS 2008: 64; Berenguel Paredes 2014: 96); Furthermore, these same materials are eroded, perhaps by roots, efflorescence, and particle transport, causing undermining that would facilitate the detachment of other materials, such as stones or bricks. On the other hand, the stones, which are denser and less porous, are affected only by patina stains and superficial oxidation of their minerals.

In summary, this historic building, which has existed since the early expansion of the Spanish Empire in what is now known as Villa Purificación, Jalisco, Mexico, presents multiple alterations due to the effects of weathering and lack of maintenance. The description of the current state through the development of a photogrammetric survey has yielded good results, with this technique being a functional complement for architectural drawing and representation. It is suggested that the damage identified on the south facade is largely due to multiple manifestations of humidity, resulting from the combination of porous materials with good absorption, together with a high presence of meteorological humidity and areas of low solar exposure.

References

AGISOFT (2020). *Agisoft Metashape*, (2020) [Software]. [computer program]. https://www.agisoft.com/

ANDALUZ M., N., MARÍN C., C., GISBERT A., J., & REMÓN C., A. (1994). Diagnóstico del deterioro de edificios del Patrimonio Histórico-Artístico del sureste de la provincia de Huesca. *Lucas Mallada: revista de ciencias*, 6: 143–170.

ARRIAGA, DE LA C. J., RAMÍREZ, F. A., & LÓPEZ, D. R. (2017). *Estudio geológico del deterioro de la iglesia El Señor de la Misericordia, Linares, N. L.* [Ingeniería, Universidad Autónoma De Nuevo León]. http://cdigital.dgb.uanl.mx/te/lic/1080312738

AUTODESK. (2021). *Autodesk Meshmixer*, (2021) [Software]. [computer program]. https://meshmixer.com/

AUTODESK. (2022). *AutoCAD 2022* (Versión 2022). [Windows]. https://www.autodesk.mx/products/autocad/free-trial

BALANDRANO, C. A. (2024). *Mediateca.inah*. VIII La arquitectura y el patrimonio edificado. https://mediateca.inah.gob.mx/webapps/publicaciones-digitales/80ANIV_INAH/caps/8/cap_viii.html

BERENGUEL P., A. E. (2014). Patología de la edificación patrimonial en el Centro Histórico de Lima. Humedades, causas y consecuencias. *Universidad Nacional de Ingeniería*, 93–108. https://doi.org/10.21754/devenir.v1i1.239

CASAS, F. L. (2018). Humedades. En *Programa Editorial Universidad del Valle*. Programa Editorial Universidad del Valle. https://doi.org/10.25100/peu.86

D.H. (2023). *DH_mobile* [Android]. https://app.droneharmony.com

DJI. (2023). *DJI fly* (Versión 2023) [Android]. DJY. https://www.dji.com/mx/dji-fly

FIGUEROA C., M., & PACHECO M., J. (2016). *Evaluación y calibración de las técnicas de fotogrametría digital aplicadas a la caracterización geométrica de obras patrimoniales* [Maestría, UAA]. http://bdigital.dgse.uaa.mx:8080/xmlui/handle/11317/658

ICOMOS (with Comité scientifique international Pierre). (2008). *ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns* (English-French version). ICOMOS.
IIEG, I. de I. E. y G. de J. (2023). *Municipios: Villa Purificación*, Carta Municipal, 2019, IIEG. https://iieg.gob.mx/ns/?page_id=135

INAH. (2022, septiembre). Ficha del Catálogo Nacional de Monumentos Históricos Inmuebles número I-0011500836. Consulta Pública del Catálogo Nacional de Monumentos Históricos Inmuebles. https://catalogonacionalmhi.inah.gob.mx/consulta_publica/detalle/27564

JANVIER, R., BRUNETAUD, X., BECK, K., & MUKHTAR, M. (2016). The potential of laser scanning to describe stone degradation. *Science and Art: A Future for Stone,* 353–360. https://www.researchgate.net/profile/Nevin-Aly/publication/308167709_The_Effect_of_Salt_Crystallisation_on_the_Mechanical_Properties_of_Limestone_Statistical_Correlation_between_Non-Destructive_and_Destructive_Techniques/links/57deee2008ae4e6f184c31de/The-Effect-of-Salt-Crystallisation-on-the-Mechanical-Properties-of-Limestone-Statistical-Correlation-between-Non-Destructive-and-Destructive-Techniques.pdf

KORRO, J., ZORNOZA I., A., & VALLE M., J. M. (2023). Documentación de las intervenciones de conservación-restauración del patrimonio arquitectónico: Perspectiva histórica, situación actual y tendencias de futuro. Ge-conservacion, 24(1):21-33 https://doi.org/10.37558/gec.v24i1.1195

LEVOY, M., PULLI, K., CURLESS, B., RUSINKIEWICZ, S., & KOLLER, D. (2000). The Digital Michelangelo Project: 3D Scanning of Large Statues. https://graphics.stanford.edu/papers/dmich-sig00/dmich-sig00-nogamma-comp-low.pdf

LI, Y., ZHAO, L., CHEN, Y., ZHANG, N., FAN, H., & ZHANG, Z. (2023). 3D LiDAR and multi-technology collaboration for preservation of built heritage in China: A review. I*nternational Journal of Applied Earth Observation and Geoinformation,* 116(16). https://doi.org/10.1016/j.jag.2022.103156

LOCHER, A., HAVLENA, M., & VAN GOOL, L. (2018). Progressive Structure from Motion. En V. Ferrari, M. Hebert, C. Sminchisescu, & Y. Weiss (Eds.), *Computer Vision – ECCV 201*8, 11208: 22–38. *Springer International Publishing.* https://doi.org/10.1007/978-3-030-01225-0_2

LÓPEZ, D. R., WEDEKIND, W., AGUILLÓN R., A., DOHRMANN, R., MOLINA, S., LEISER, T., WITTENBORN, A., & SIEGESMUND, S. (2018). Thermal expansion on volcanic tuff rocks used as building stones: Examples from Mexico. *Environmental Earth Sciences*, 77(9): 338. https://doi.org/10.1007/s12665-018-7533-0

MEDINA C., F., JEREMÍAS, P., & GUTIÉRREZ, J. (2014). *La fotogrametría digital como herramienta de trabajo para la toma de datos y catalogación de las iglesias románicas en la comarca de Las Merindades* (Burgos). http://rua.ua.es/dspace/handle/10045/43582

NIETO, M., RIVERO, P., & LOBO, W. (2009). Análisis dinámico lineal de una edificación histórica en San Cristóbal, Estado Táchira. *Ciencia e Ingeniería*, 30(3): 237–246.
PEPE, M., ALFIO, V. S., & COSTANTINO, D. (2023). Assessment of 3D Model for Photogrammetric Purposes Using AI Tools Based on NeRF Algorithm. *Heritage*, 6(8): 5719-5731. https://doi.org/10.3390/heritage6080301

PÉREZ S., M., CRUZ F., P., & RUEDA M. P., A. (2023). Proceso de digitalización de edificios históricos y parametrización de instalaciones. En *Oportunidades que ofrece la tecnología digital para los problemas de documentación, seguimiento, uso y visualización del patrimonio arquitectónico y ambiental* (ReUSO: 25–35). Dykinson S.L. https://www.researchgate.net/publication/375071826_Proceso_de_digitalizacion_de_edificios_historicos_y_parametrizacion_de_instalaciones

RAHEEM, Z. (2019). *Suggested Methods for Determining Water Content Suggested Methods for Determining Water Content, Porosity, Density, Absorption and Related Properties and Swelling and Slake-Durability Index Properties PART 1: SUGGESTED METHODS FOR DETERMINING WATER CONTENT, POROSITY, DENSITY, ABSORPTION AND RELATED PROPERTIES NOTES (i) Mechanical significance of porosity and density data.*

REGALADO, P. A. (2008). *La Fundación de la Villa de la Purificación* (2a ed.). Publicaciones Iberoaméricana y Europa.

SÁNCHEZ L., A. V., & SOTO Z., M. A. (2021). *Propuesta de una metodología para desarrollar y evaluar técnicas de fotogrametría como herramientas para la realización del mapeo de patologías en elementos patrimoniales* [Maestria, Universidad Autonoma de Aguascalientes]. http://hdl.handle.net/11317/2186

SERNA, M. S., ARAIZA, G. G., & SOTO, Z. M. (2016). *Evaluación de sistemas correctivos para la inhibición capilar en desplante de muros de adobe en edificios patrimoniales* [Maestria, UAA]. http://bdigital.dgse.uaa.mx:8080/xmlui/handle/11317/657

SGM. (2023). *GeoInfoMex—El Banco de Datos del SGM*. https://www.sgm.gob.mx/GeoInfoMexGobMx/#

SPERI, L., FALCHI, L., BALLIANA, E., ZUENA, M., & ZENDRI, E. (2017). Behaviour of brick-NHL render systems in presence of NaCl solution. *Ge-conservación*, 11: 157–164. https://doi.org/10.37558/gec.v11i0.468

SUNEARTHTOOLS. (2023). Outils pour les consommateurs et les concepteurs de l'énergie solaire. https://www.sunearthtools.com/dp/tools/pos_sun.php

TALLER, A. (2014). Derecho a la preservación del patrimonio arquitectónico urbano: Un desafío para las autoridades locales. *Revista Eurolatinoamericana de Derecho Administrativo*, 1(2): 7–37.

TAMAYO N., F., QUESADA R., A. L., & AYÓN A., V. (2010). *Aplicación de la fotogrametría arquitectural digital, en la restauración de edificaciones coloniales del centro histórico de la ciudad de Holguín, Cuba. Un paso superior en la conservación del patrimonio arquitectónico y cultural.* 1: 451–458.

TORALES, A. G. J., & LAZOS, C. E. (2016). *La relación ambiente-cultura en una sociedad ranchera ante el proceso de ganaderización* [ESCUELA NACIONAL DE ANTROPOLOGÍA E HISTORIA]. https://mediateca.inah.gob.mx/islandora_74/islandora/object/tesis%3A3044

TRIMBLE. (2023). *SketchUp*, [Software]. [computer program]. https://www.sketchup.com/

UDELAP. (2023). *Capitulo III: Estudio de mecánica de suelos.* Universidad de las Americas de Puebla. http://catarina.udlap.mx/u_dl_a/tales/documentos/lic/sanchez_m_r/capitulo3.pdf

VILLEGAS, D., CÁMARA, M., & COMPÁN, V. J. (2014). Análisis estructural de la torre del homenaje de la Alhambra de Granada (España). *Informes de la construcción, 66* (Extra 1). https://doi.org/10.3989/ic.13.101

VIZCAÍNO, H. I. E., & SOTO, Z. M. A. (2018). *Propuesta y evaluación de una metodología para la determinación del peso propio en elementos constructivos y ornamentales de edificios patrimoniales empleando fotogrametría digital de corto rango* [Maestría, Universidad Autonoma de Aguascalientes]. http://bdigital.dgse.uaa.mx:8080/xmlui/bitstream/handle/11317/1581/432897.pdf?sequence=1

Author/s

Isaías Edén Vizcaíno-Hernández
edenv15@gmail.com
Universidad Autónoma de Aguascalientes. México
https://orcid.org/0000-0003-1477-4384

Arquitecto por el Instituto Tecnológico de Jalisco en 2015 y Maestro en Ingeniería Civil por la Universidad Autónoma de Aguascalientes en 2018, ha participado en diversas estancias de investigación por la Academia Mexicana de Ciencias, así como en varios congresos dirigidos por la Universidad Autónoma de Aguascalientes y ha publicado algunos artículos en revistas internacionales. Donde su principal línea de investigación esta centrada en el patrimonio histórico, la caracterización de materiales pétreos y la implementación de técnicas indirectas para la representación.

Miguel Angel Soto-Zamora
miguel.soto@edu.uaa.mx
Universidad Autónoma de Aguascalientes. México
https://orcid.org/0000-0003-1399-8001

Ingeniero Civil, Maestro en Ingeniería Civil y Doctor en Ciencias por la Universidad Autónoma de Aguascalientes, Profesor Investigador del Departamento de Ingeniería Civil de la Universidad Autónoma de Aguascalientes con 14 años de antigüedad, Miembro de la Sociedad Española de Historia de la Construcción de 2015 a 2019, Secretario Técnico de la Maestría en Ingeniería Civil 2017 a 2019, 34 tesis y tesinas de Licenciatura Maestría y Doctorado dirigidas.

Alejandro Acosta-Collazo
aacosta@correo.uaa.mx
Universidad Autónoma de Aguascalientes. México
https://orcid.org/0000-0002-8655-2038

Doctorado en Arquitectura por la Universidad Nacional Autónoma de México en 2005; Maestría en Planeamiento Urbano Regional por la Universidad de Guanajuato en 2004; Maestría en Restauración de Sitios y Monumentos por la Universidad de Guanajuato en 1997 y Licenciatura en Arquitectura por la Universidad Autónoma de Aguascalientes en 1993. Tiene una dilatada experiencia como Docente y Profesor Investigador Interino en la Universidad Autónoma de Aguascalientes desde 1999 a 2009. Tiene publicados varios artículos de revista, así como, capítulos de libros. Ha dirigido tesis y participa en proyectos de investigación en torno a temas relacionados con "Estudios sobre la experiencia del entorno", "Urbanidad y patrimonio histórico" y "Urbanidad, movilidad y patrimonio industrial histórico"

Rubén Alfonso López-Doncel
rlopez@uaslp.mx
Instituto de Geología Universidad Autónoma de San Luis Potosí. México
https://orcid.org/0000-0002-7596-8505

Ingeniero Geólogo por la Universidad Autónoma de Nuevo León en Linares, Maestría y Doctorado en la Universidad Técnica de Clausthal, Alemania, con la especialidad en Geología Petrolera. Investigador de Tiempo Completo adscrito al Instituto de Geología de la UASLP. Director del Instituto de Geología de

la UASLP. Ha participado en diversos proyectos nacionales e internacionales, entre los que destacan proyectos en Alemania, Turquía, Sudáfrica, Armenia, Cuba, República Dominicana, Albania, Omán, Jordania entre otros. docencia y asesoría posee al 2023: 38 artículos científicos arbitrados. Asesor de 23 tesis de Licenciatura, 19 tesis de Maestría y 3 de Doctorado y es Miembro del Sistema Nacional de Investigadores nivel 2 (SNII2).

Artículo enviado 04/06/2024
Artículo aceptado el 29/03/2025

https://doi.org/10.37558/gec.v26i1.1316