A PROPOSED APPROACH FOR STABILIZING VERDANT CONCRETE OF *STAIRWAY TO THE SKY*, *LAS POZAS*, MEXICO

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In memory of Omar Salinas Garay

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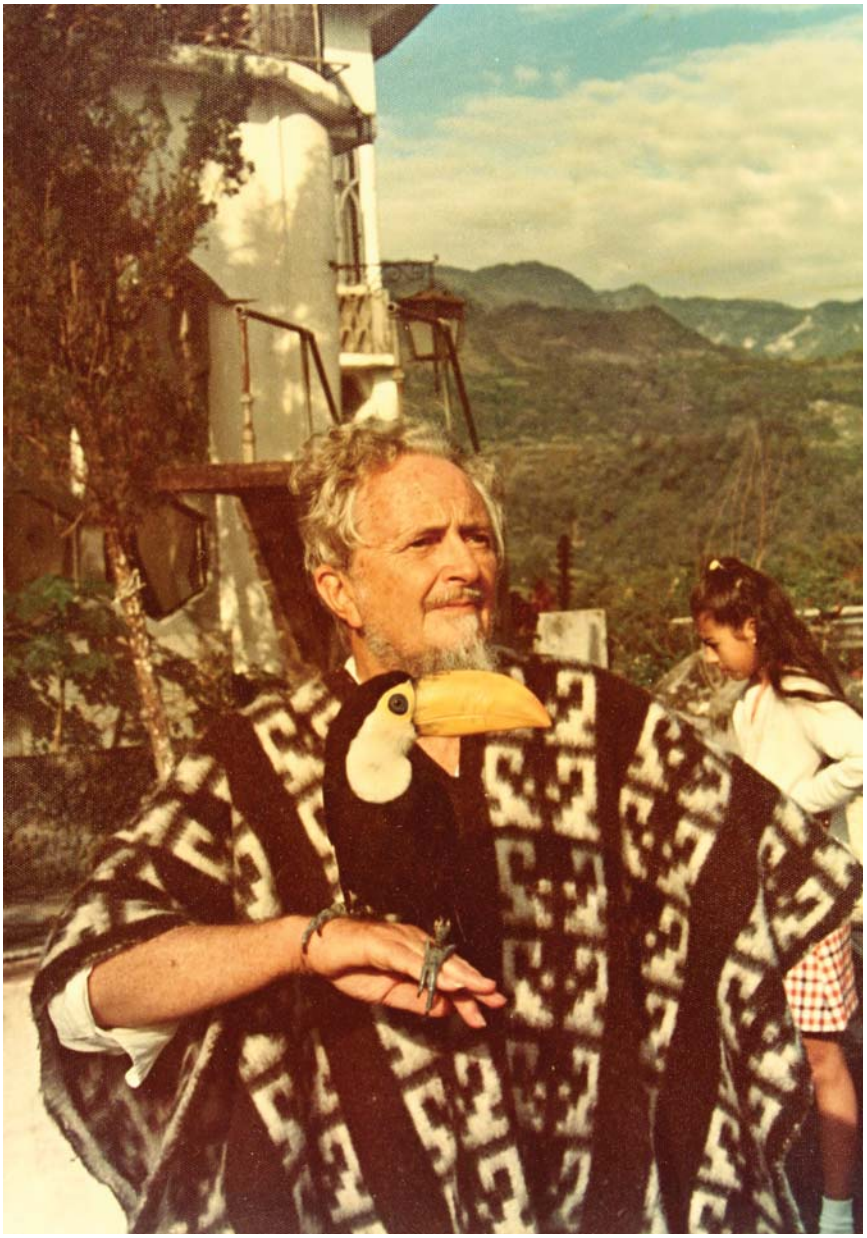

Edward James, ca. 1980

Xilitla, Mexico

Source: Edward James Archive (EJA), West Dean College

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LIST OF ACRONYMS AND ABBREVIATIONS

MEXICO:

CAICH Consejo de Ancianos Indígenas de la Cultura *Huasteca* / Indigenous Elder and Cultural Council of the *Huasteca*

CONAIN Confederación Nacional de Pueblos Indígenas / National Confederation of Indigenous Peoples

CONABIO Comisión Nacional para el Conocimiento y Liso de la Biodiversidad / The National Commission for the Knowledge and Use of Biodiversity

CONACULTA Consejo Nacional para la Cultural y las Artes / National Council for Culture and the Arts

CONAPO Consejo Nacional de la Población / National Population Council

CONAFOR Comisión Nacional Forestral / National Forestry Commission

CONAGUA Comisión Nacional de Agua / National Water Commission

CONANP Comisión Nacional de Áreas Naturales Protegidas / National Commission of Protected Natural Areas

CONEVAL Consejo Nacional de Evaluación / The National Council for the Evaluation of Social Development Policy

FX Fondo Xilita / The Xilitla Foundation

INAH Instituto Nacional de Antropología e Historia / National Institute of History and Anthropology

INAFED Instituto Nacional para el Federalismo y el Desarrollo Municipal / National Institute for Federalism and Municipal Development

INEGI Instituto Nacional de Estadistica y Geografía / National Institute of Statistics and Geography

INBA Instituto Nacional de Bellas Artes / National Fine Arts Institute

LGEEPA Ley General del Equilibrio y la Protección al Ambiente / The General Law of Ecological Equilibrium and Environmental Protection

PEHF Fundación Pedro y Elena Hernandez / Pedro and Elena Hernandez Foundation

SECULT La Secretaría de Cultura / Secretary of Culture

SEMARNAT Secretario de Medio Ambiente y Recursos Naturales / Secretary of Environment and Natural Resources

OTHER:

ASTM American Society for Testing and Materials (ASTM International)

EJA Edward James Archive

EJF Edward James Foundation

MAB Man and the Biosphere Program of UNESCO

WMF World Monuments Fund

UNESCO United Nations Educational, Scientific and Cultural Organization

INTRODUCTION

Between 1948 and 1984, Edward James built over two hundred concrete sculptures and large-scale architectural structures at his residence in the Mexican jungle, *Las Pozas* (pronounced *poh-sas*). Inspired by the verdant landscape that surrounded him, James integrated concrete architectural sculptures into nature, creating an assemblage of fantastical structures over the span of four decades. Whether James first conceptualized *Las Pozas* as one project is unclear; in reality, it evolved naturally, from an orchid garden into a sculpture garden, and later, years after his death, into a world-renowned heritage site.

Before his death, James did not communicate his wishes for the future preservation or presentation of *Las Pozas* to the public. Recently, however, James's intentions have become the topic of many discussions as the site's current owners prepare a long-term conservation plan. Central to the conservation of *Las Pozas* is the paradoxical relationship between the structures and environment—trees canopy concrete, atmospheric moisture is abundant and threatens material integrity; and yet a visual symbiosis is also formed between James's works and nature, revealing an unusual beauty as the plant life becomes one with the concrete.

At *Las Pozas*, it is the coalescence of nature and art that has become valued by many who have visited the site. This thesis sets forth an approach that seeks to find a common ground between maintaining the decayed appearance of a reinforced concrete structure known as *Stairway to the Sky*, while preserving the material integrity of its sculptural concrete—a complicated task in the warm, humid environment of Mexico's Huasteca (*was-tek-a*) region. Public opinion regarding the

2004-2006 cleaning of San Agustín Temple in the town of Xilitla (*he-leet-la*), located approximately two kilometers from *Las Pozas*, supports this approach. After the church's cleaning (a project funded by CONACULTA, Mexico's National Council for Culture and the Arts), white plaster walls were revealed after centuries of impurities had collected on its surface. San Agustín Temple's "new" appearance was widely rejected by the local community, who had only known the church the way it looked before. Perhaps Xilitlans, living in a fecund climate, inherently knew that its cleaned appearance was transient and nature would eventually recapture the structure, thus following John Ruskin's belief that a building's "glory is in its Age," and age, therefore, is unveiled over time through visible physical changes. In this climate, the resilience and persistence of the natural environment challenge conventional approaches to building conservation, which attempt to leave a building looking 'new.' Therefore, the objectives for the conservation of *Stairway to the Sky*, and in the large sense, *Las Pozas*—must actively balance between continuous stabilization and preventive conservation, or, in other words, saving the very thing that may also be a threat.

ORGANIZATION OF CHAPTERS

The first three chapters provide an overview of *Las Pozas* and its historical, environmental, and social contexts, as well as an architectural description of *Stairway to the Sky* and its location at the site. Contextual background is followed by a discussion of the significance of *Stairway to Sky* that will guide the proposed conservation approach for the structure. The remaining chapters identify extrinsic and intrinsic threats associated with reinforced concrete in warm-humid/humid subtropical climates.[1] Chapter 6 addresses biodeterioration of concrete, where biogrowth is both valued and acts as a potential threat. Finally, proposed strategies for the preventive conservation and stabilization of the concrete will be presented in Chapter 7.

METHODOLOGY

Site Visit and Preliminary Observations

The study began with a site visit from May - July 2010. During this period, a visual examination of *Stairway to the Sky* and various structures was performed in situ. Recording techniques employed were: field notes, photographic documentation, measurement, and drawing, as well as RILEM water absorption tests[2] to gain a general

1 The Köppen climate classification system identifies Xilitla as part of a *humid subtropical/ temperate with dry winters and hot summers climate zone* (Cfa). ANSI/ASHRAE/IESNA standards state that Xililtla is located in a *warm-humid* (3A) climatic region. The ANSI/ASHRAE/IESNA system is employed throughout this thesis, and *Chapter 3: Context* provides a thorough account of Xilitla's climatic patterns.

2 Test method employed was "Water absorption under low pressure (pipe method)" Test No. 11.4, RILEM Commission 25-PEM (1980).

understanding of material behavior.

Interviews and Archival Research

Interviews and informal conversations with current *Las Pozas* staff and various stakeholders provided valuable insight for this thesis, while the Edward James Archive (EJA) at West Dean College supplied historic photographs and documents related to Edward James's period in Mexico. Building plans and architectural drawings for *Stairway to the Sky* were unavailable, so this thesis relied heavily on interviews with *Las Pozas* staff to learn about construction methods and materials previously employed at the site, as well as current practices for concrete repairs. Several of the workers consulted were involved in the original construction of *Las Pozas* and provided curious anecdotes about Edward James, which, regrettably, were unable to make their way into this thesis.

Selection of Case Study: Stairway to the Sky

The structures at *Las Pozas* vary in design, construction practices, concrete materials, and prevalence of microclimates. Therefore, only one structure was chosen as the focus of this study: *Stairway to the Sky*. This structure is perhaps the most iconic of all of James's works at *Las Pozas*, and was chosen to illustrate common issues regarding concrete deterioration at the site. It is important to note that *Stairway to the Sky* was chosen as a case study after the 2010 site visit. Consequently, the field survey, although successful in realizing the structure's current conditions, lacked the detailed focus that a traditional condition survey would have entailed. Nevertheless, this remarkable structure encompasses the many challenges and conservation issues presented at *Las Pozas* as a whole.

Evaluation of Conditions

Although an understanding of a building's history, which includes construction methods and materials, environmental conditions, and previous uses, is central to any condition assessment, an alternative approach was needed to adapt to the minimal information available on the structure. This thesis provides a summary of conditions based on observations gathered during a 2010 site visit, and recommendations for future analyses needed to implement the proposed conservation approach for the structure.

Biogrowth

While macro- and microorganisms are character-defining, surficial traits of the concrete structures at *Las Pozas*, post-construction, these organisms are potential mechanisms for subsequent pathologies and deterioration, such as reinforcement corrosion. In order to understand the relationship between *Stairway to the Sky* and the plant life that has colonized its concrete surface, biogrowth was chosen as the primary focus of Chapter 6. An analysis of biodeterioration of concrete in warm-humid climates thereby provides a better understanding of the dynamic interaction between the material and the environment so that recommendations for the management of biogrowth can be provided.

Preventive Conservation Strategies for Stairway to the Sky

Various threats to material and structural integrity are presented in Chapter 5, followed by proposed strategies that address these threats in Chapter 7. Issues regarding human and environmental threats (i.e. reinforcement corrosion, vandalism, inappropriate maintenance or repair) are included in this discussion and preventive solutions provided in the final chapter. The approach is based on a conservation philosophy that was determined after evaluating the significance of the structure in Chapter 4.

DELIMITATIONS

Developing a Conservation Approach for Stairway to the Sky

Stairway to the Sky is non-functional structure that is not considered traditional architecture. However, it strongly suggests the need for a traditional building conservation approach because it embodies many of the same issues as a building: it must resist loads, survive in the environment, and fulfill its aesthetic intent. Even though it evokes both architecture and sculpture, it must be treated as a building for the purpose of its conservation.

James's Intent

Two themes were central to the theoretical development of a conservation approach for *Stairway to the Sky*: values associated with the structure and the artist's intent. James's intentions regarding the preservation (or non-preservation) of *Las Pozas* remained unknown at the conclusion of this study, so values were evaluated to formulate a conservation approach that was speculative of the artist's intent, and considerate of the structure's current context and use.

Previous Analysis

Recommendations provided in Chapter 7 focus on one structure: *Stairway to the Sky*, and are based solely on a visual examination performed in situ. Scientific analyses were not included in the assessment and therefore conditions have not been explored analytically or quantitatively, resulting in the need for future analyses, which are provided in the same chapter.

Climatic Data

Environmental data was collected from the Mexican National Institute of

Statistics and Geography (INEGI). The *Huastecan* environment is highly variable, exhibiting numerous microclimates and changes in vegetation. Therefore, the climatic data presented in the study may not be fully representative of the environmental conditions presented at *Stairway to the Sky*.

TERMINOLOGY

Spanish terms

English translations and pronunciations of Spanish terms are provided throughout the text. English-Spanish translations of some structures frequently encountered throughout this thesis are provided below:

Casa de los Tres Pisos que Podrian Ser Cinco - Three Story House that Might be Five

Casa Original de Edward James - Edward James's House

Escaleras al Cielo - Stairway to the Sky

Palacio Bambu - Bamboo Palace

The Site

The term "site" is used to refer to the entire property of *Las Pozas* that is currently under the ownership and management of the Pedro and Elena Hernandez Foundation (PEHF) and its subsidiary, Fondo Xilitla (FX). The site is defined by approximately seventy acres of land and contains most of James's original 200+ concrete sculptures, including *Stairway to the Sky, Bamboo Palace*, and *House of Three Stories that Might be Five*. *Las Pozas* is defined by legal parameters, yet stewardship and maintenance also distinguishes it from neighboring properties that include original James structures.

LITERATURE REVIEW

Conservation at Las Pozas

For many years after James's death, *Las Pozas* remained virtually unchanged. Having spent his childhood at *Las Pozas* and present during its construction, Kako Gastelum (son of Plutarco Gastelum, James's best friend in Xilitla) kept the site similar to the way his "Uncle Edward" had left it, performing routine maintenance as needed until he sold *Las Pozas* in 2007. Regarding conservation projects at the site, Los Angeles-based structural engineer Bud Goldstone[3] and a team of conservators surveyed *Las Pozas* for a ten-day period in 1998, documenting actual numbers of sculptures,[4] measuring cracks, and observing conditions of concrete surfaces. Goldstone's team produced an *Architectural & Engineering Report* in 1999, sponsored by SPACES, a California-based non-profit agency dedicated to preserving arts and cultural environments.[5] The *A & E* Report is the only conservation study to have been documented at the site before Gastelum sold *Las Pozas*, and it provides a seven-phase conservation program that was never implemented.

Edward James

A relatively small body of work is available on *Las Pozas*. Various biographies focus on Edward James's role as an art collector, but only briefly discuss his period in Mexico, which constituted nearly four decades of his life. However, several works were particularly useful in providing historical accounts of Edward James and *Las*

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3 Bud Goldstone was one of the leading figures behind a movement that saved Simon Rodia's Watts Towers from being torn down in the 1960s. When the city of Los Angeles claimed the towers were not structurally sound and threatened to tear them down, Goldstone performed tests to ensure their stability. Edward James was also involved in the movement by providing financial backing. In 1990, the Watts Towers were designated a US National Historic Landmark.

4 The exact number of concrete sculptures at *Las Pozas* is disputable. Because Goldstone's team performed a field survey documenting individual concrete structures, the 200+ concrete structures referred to in this study are taken from Goldstone's *A & E Report*.

5 http://www.spacesgallery.org.

Pozas. In English, Margaret Hooks's *Surreal Eden: Edward James and Las Pozas,* provides a comprehensive history of the artist's early life and extended period in Xilitla, while Mexican historian Xavier Guzman Urbiola's has written various works in Spanish, focusing primarily on James's period in Mexico. Sharon Kusunoki, leading Edward James scholar and Head of Galleries, Archives, House and Collections at the Edward James Archive at West Dean College, will publish a comprehensive anthology of Edward James's correspondence in 2012, which may provide deeper insight into the creator of *Las Pozas*.

Avery Danziger's 1995 documentary, *Edward James: Builder of Dreams* is an invaluable source that shares interviews with Edward James at West Dean and *Las Pozas*. Additionally, current owners of the site, the Pedro and Elena Hernandez Foundation, recently filmed a short documentary that shares oral histories from many of the workers who built *Las Pozas*. Because *Las Pozas* is a heritage site of the recent past, many Xilitans hold living memories of Edward James, and their stories were valuable sources for this thesis.

The Huasteca Potosina, Mexico

Las Pozas is located in the striking *Huasteca* region of central-northeast Mexico. Despite its immense cultural and ecological diversity, the *Huasteca* is one of the country's little-known regions with few studies available in English. Anthropologist Kristina Tiedje spent nearly a decade working with *Huastecan* indigenous communities—the Teenek, the Nahua, and Xi'Oi, and offers one of few bodies of work on the diverse ethnography of this region. Much of Tiedje's work focuses on the communities surrounding Xilitla (the municipality where *Las Pozas* is located) and addresses issues relevant to the site, such as encroaching development resulting from increased tourism on lands considered sacred to many *Huastecan* indigenous peoples.

Biodeterioration of Concrete

The twentieth century saw an increase in the use of concrete as the building material of choice due to its low cost, presumed durability, resistance to fire, and ability to cast large, monolithic forms. After crack formations related to alkali-aggregate reaction rapidly spread in the Hoover Dam (1931-1936) shortly after it was constructed, materials scientists and engineers began to systematically explore concrete properties to better understand concrete's limitations in performance and durability. [6] This resulted in the creation of design and construction standards to prevent common problems associated with the deterioration of concrete, such as ASR. Biodeterioration of concrete, however, is a phenomenon that received little attention until the 1960s, when the investigation of microbial attack in concrete sewer pipes identified a new vulnerability in this ubiquitous building material. Results from these earlier studies are limited in their application to cultural heritage, since high concentrations of sulfates and hydrogen sulfide gas (H_2S) are typically encountered in enclosed environments such as wastewater pipes. Recently, the field of heritage conservation has seen an increase in research into biodeterioration of concrete,[7] but the wide range of possible organisms, climates, and concrete mixes complicates the application of results from these studies to the specifics of a structure at *Las Pozas*.

6 De Puy, G. W. "Petrographic Investigations of Concrete and Concrete Aggregates at the Bureau of Reclamation." *Petrography Applied to Concrete and Concrete Aggregates, ASTM STP 1061*. Bernard Erlin and David Stark, Eds. (Philadelphia: American Society for Testing and Materials, 1990), 32.

7 For comprehensive publications on biodeterioration of cultural heritage materials, see the Getty Conservation Institute's *Biodeterioration of Stone in Tropical Environments* (1999) and *Plant Biology for Cultural Heritage: Biodeterioration and Conservation* (2009).

FIGURE 1: VIEW OF *STAIRWAY TO THE SKY* LOOKING EAST. THE FORMERLY WHITE CONCRETE STRUCTURE NOW DISPLAYS A MYRIAD OF BIOLOGICAL ORGANISMS ON ITS SURFACE, CHALLENGING TRADITIONAL APPROACHES TO THE CONSERVATION OF CONCRETE. *SOURCE: AUTHOR, 2010.*

CHAPTER 2 | HISTORY AND STEWARDSHIP OF *LAS POZAS*

EDWARD JAMES'S EARLY LIFE

Named after his godfather, King Edward VII of England, Edward James (1907-1984) was born into an English family of immense wealth and aristocracy. James and his four older sisters lived at the family's 300-room mansion and 6,400-acre estate at West Dean, located in West Sussex, England. In Danziger's documentary, *Edward James: Builder of Dreams*, James describes reverting to his imagination as a child, creating fantasy worlds where he would entertain himself for hours on end. In a later interview, James describes his mother as indifferent to him following his father's death in 1912, and that she did not support his pursuit of creative inclinations, claiming her son should "cut out music and writing poetry and concentrate on his university degree and his future at West Dean and Parliament."[1]

In 1929, James's mother died, leaving to him West Dean and various properties in England and France. James wrote poetry from the age of 15,[2] and with the money from his inheritance he founded the James Press to publish his own works, including *The Bones of My Hand*, as well as the first book of poetry written by Oxford friend John Betjeman,[3] who later became the country's Poet Laureate. In 1931, Edward James married ballet dancer Tilly Losch but their marriage was short-lived, ending contentiously in 1934. Before their divorce, however, he backed George Balanchine's ballet company, Les Ballets, and commissioned a ballet for Losch to dance, *Seven*

1 Evelyn James letter to Mr. MacKenzie, September 11, 1927. Source: Sharon Kusunoki, "Breaking Canons." *A Surreal Life: Edward James*, Nicola Coleby, ed. (London, The Royal Pavillion Libraries and Museums, Brighton and Hove/Philip Wilson,1998), 23.
2 *Ibid. 23.*
3 *Ibid. 23.*

Deadly Sins, written by Bertolt Brecht and Kurt Weill.[4]

During the 1930s, James began collecting art and supported the careers of young painters such as Rene Magritte and Salvador Dali. James appeared in various Magritte works, such as *Edward James in Front of 'On the Threshold of Liberty'* (1937) and *The Pleasure Principle* (1937). At one of his inherited properties, Monkton House, James collaborated with Dali, Elsa Shiaparelli, and Kit Nicholson, among others, to remodel the country house into a Surrealist mansion. He painted the building lavender and painted hanging curtains from the exterior windowsills. In 1939, James collaborated again with Dali on the "Dream of Venus," a multi-media installation with live performances. The work was later presented at the New York World's Fair, causing a commotion when some actresses performed fully unclothed.

By the time he was thirty, Edward James had acquired the most extensive collection of Surrealist art in the world.[5] In the late 1930s, James left New York for Los Angeles, where he bought a home and lived among the city's prominent musicians, actors, writer, and artists, such as Igor Stravinsky, Aldous Huxley and Ruth Ford.[6] By 1944, James left Los Angeles for Mexico, traveling with Roland MacKenzie to Mexico City. On the drive south, after crossing the U.S. border, the two men stopped in Ciudad Valles in the *Huasteca* region, where an orchid gardener told him of a beautiful town known as Xilitla, located an hour south in the *Huasteca Potosina*. Months later, James returned to the *Huasteca*, this time with Plutarco Gastelum, a postal worker in Cuernavaca. James offered Gastelum money to leave his job and guide him around Mexico, and this initial job led to a close friendship that would last for the remainder of their lives. Gastelum would marry Marina Llamazares, a young

4 http://www.kennedy-center.org/explorer/artists/?entity_id=3510&source_type=A
5 Kusunoki, "Breaking Canons" *A Surreal Life: Edward James*, 21.
6 Hooks, Margaret. *Surreal Eden: Edward James and Las Pozas*. (New York: Princeton Architectural Press, 2007), 37.

woman from Xilitla, and have four children who would become James's adopted family in Mexico.

EDWARD JAMES AND *LAS POZAS*

James had fallen in love with *Rancho La Conchita* (La Conchita Ranch), the former land of a general from the Mexican Revolution named Coronel Castillo.[7] The site was a former coffee plantation located a short distance from the mountain town of Xilitla, and defined by lush vegetation, a river, waterfalls, and natural pools (or *pozas*). Unable to buy land in Mexico as an English citizen, James persuaded Gastelum to purchase *La Conchita* in 1948, acquiring a total of seventy-five acres by March of the following year.[8] The two men built small cabins near the summit of the hillside and lived there for a short time until Gastelum purchased Colonel Castillo's former house in central Xilitla.[9] James remained at *La Conchita* and hired local workers to build a house of concrete, brick, and bamboo, known today as Edward James's House, or *La Casa Original de Edward James*.

When James was not in England, California, or traveling, he lived in his jungle cabin for months on end. There, he would write poetry and tend his orchid garden, which had grown to nearly 20,000 specimens by 1960.[10] James commissioned workers from town to build stone pathways that facilitated movement through the property, and build stone walls to fence in his "pet" deer. While traveling, James often brought exotic plants and animals back to *Las Pozas* with him and built cages for his growing animal collection, which included boa constrictors, ducks and flamingos. On the ground floor of this house, he later commissioned Spanish sculptor Jose

7 The largest waterfall at *Las Pozas*, *Cascada del General,* is named after the property's previous owner, Colonel Castillo.
8 Hooks, *Surreal Eden*, 52.
9 *El Castillo* remains in the Gastelum family today. Its current use is as a Guest House and restaurant.
10 Kusunoki, "Breaking Canons," *A Surreal Life: Edward James,* 30.

FIGURE 2: VIEW LOOKING NORTHWEST OF JAMES'S EARLY LARGE-SCALE CONSTRUCTIONS AT *LAS POZAS*. THE *CINEMA,* AND ITS THIRD STORY, *STAIRWAY TO THE SKY,* SIT IN THE FOREGROUND AND *EDWARD JAMES'S HOUSE* IS LOCATED BEHIND IT. *SOURCE: EJA, WEST DEAN COLLEGE.*

Horna, husband of photographer Kati Horna, to build a cage for a boa constrictor, which is known today as *Jaula de las Boas*.

By 1962, James had made a small impact on the landscape with various pathways and corrals. A rare snowfall in Xilitla that year killed James's orchids, leaving him devastated. James vowed to build with concrete "something more permanent that would not be killed by 'freak' weather."[11] The 1960s marked the period when James fully immersed himself with building in concrete at *Las Pozas*. He emulated the *Huastecan* landscape with concrete sculptures of flowers, plants and mushrooms, and experimented with small and large-scale constructions. James had not expected he would become a builder, stating, "I knew nothing about engineering, so I had to use twice the amount of reinforcing steel necessary in order to ensure they will stand up…and I didn't know I had the capability of being an architect."[12] Nonetheless, he continued building, increasing the pace at which he commissioned structures throughout the landscape.

Jose Aguilar, a master carpenter from the town of Pinal de Amoles in the neighboring *Sierra Gorda* region, played a significant role in constructing *Las Pozas*. Margaret Hooks explains that James greatly respected Jose Aguilar and the two frequently collaborated to make James's unusual designs come to life. James stated, "I drew rather clumsy sketches…the great thing is having found Don Jose" in Danziger's documentary. It is questionable whether James would have been able to accomplish as much as he did without Jose Aguilar's help, since the wooden formwork used to pour concrete required months of labor and a team of skilled craftsmen, led by

11 Danziger, *Edward James: Builder of Dreams*, DVD (Xilitla, Mexico: Top Drawer Productions, 1995).

12 *Ibid*. In a telephone interview with British architect John Warren, a former friend of Edward James, James's building methods were discussed. Warren stated that Edward James had contacted him several times to discuss building with concrete. He said that James was particularly interested in discussing pH value and concrete, as well as building with pre-stressed concrete. While this does not necessarily indicate that James employed these construction methods at Las Pozas, it displays his interest in building construction (albeit for architectural sculptures that were made to perform as buildings).

Aguilar, to carve curvilinear pieces of wood into large, sculptural surfaces.

People who knew James describe his deep love of nature-- one worker's account explains that James did not tear down a single tree while building *Las Pozas*.[13] Leonora Carrington, who maintained a close friendship with James during his period in Mexico, stated that he "related in a very marvelous and special way to animals… he had learned the great art of treating animals as intelligent beings and that we were not necessarily superior to animals."[14] James's love of nature was central to his creating *Las Pozas* and is evident that he did not want his works to impose on the landscape, but rather be incorporated into it.

Plutarco and Marina Gastelum were responsible for the continuous construction of *Las Pozas*, as they managed workers, ordered materials, and oversaw construction while James was away. Their son, Plutarco "Kako" Gastelum has discussed the incredible work that was required to oversee such a large project and at times the immensity of the work distressed his parents.[15] By the 1970s, James had employed over 150 workmen at *Las Pozas*—a significant number for the small community. Xilitlans frequently solicited work from James and Gastelum, as construction at the site provided consistent pay, which was difficult to come by in the impoverished Mexican town.[16]

James spent over $5 million dollars to build *Las Pozas*. In order to raise enough money, he auctioned off part of his collection of Surrealist paintings.[17] Construction

13 Forthcoming documentary, Pedro and Elena Hernandez Foundation, 2010.
14 *Builder of Dreams*, 1995.
15 Forthcoming documentary, PEHF, 2010.
16 PEHF's documentary contains interviews with workmen who describe the great desire Xilitlans had to work at *Las Pozas*, frequently soliciting work, even if there was no work available.
17 Sharon Kusunoki states that at Edward James's death, he owned the single most extensive collection of Surrealist art, including paintings by Marcel Duchamp, Leonora Carrington, Rene Magritte, Picasso, Max Ernst, Paul Klee, Joan Miró, (Source: Kusunoki, "Breaking Canons," 25). Additionally, James left numerous suitcases in a storage unit in Los Angeles filled with hundreds of pieces of tissue paper that enveloped personal letters and paintings, including Dali's *Tristan and Isolde* (1941) and *Paranoic Face* (1935). The collection of James's belongings—purposely disorganized by James before his death—is found in the Edward James Archive at West

continued after Marina Gastelum's death in 1983, until 1984, when news of James's death brought an immediate halt to construction at *Las Pozas*, leaving numerous unfinished works standing in the forest. James had expressed that if he died in Mexico he wanted to be buried behind the waterfall at *Las Pozas*, but he died in Italy, and his body was buried at his former home at West Dean.

LAS POZAS AFTER EDWARD JAMES

James bequeathed *Las Pozas* to Kako Gastelum, in his mid-twenties at the time. Throughout the 1980s, the young Gastelum lived at the site and employed many of the same workers who had built *Las Pozas* to perform regular maintenance (concrete repairs, cutting branches). Gradually, visitors arrived at the site after learning of a sculptural garden hidden in the jungle outside of Xilitla. The concrete structures weathered as moss, algae, and lichen colonized on the formerly white and pigmented surfaces. As the site's upkeep became a financial burden for Gastelum, he officially opened *Las Pozas* to the public in 1994. He also sold various parcels of land—some containing original James sculptures. Today, there is a clear distinction between the properties that remained a part of *Las Pozas* and those that were sold. One property located across the street from *Las Pozas* is visible upon arriving at the site, but remains behind a fence and closed to the public. It contains a later structure and series of sculptures known as *Homage to Max Ernst*, which have been painted bright colors that starkly contrast the pigmented structures inside of *Las Pozas*, whose colors have faded over time. The structure has also received little maintenance and today, many of the *Homage to Max Ernst'*s thin sculptural columns display 0.5 –

Dean College today. To read about James's unusual disarrangement of belongings from his past, see Kusunoki's "Making the Illogical Logical: The organization of the Edward James Archive," an essay from *A Surreal Life: Edward James*, Nicola Coleby, ed. (1998).

1 inch wide cracks that run vertically along the columns (some over three feet in length). Another property located to the western border of *Las Pozas* contains a separate entrance where admission is paid. This property is not a part of the site, but it contains one James structure covered with graffiti.

The 1990s marked a period when the site remained relatively unknown but slowly increased in popularity among certain communities, particularly artists and travelers. A 1995 article in the *New York Times* describes *Las Pozas* with “a small snack bar stand near the entrance, with bathrooms nearby. Nobody collected admission. Only three other cars were there.”[18] On a local level, members of the community had long frequented the site’s pools. By Mexican law, waterways are considered federal property, and citizens have been allowed free entrance to the natural pools at *Las Pozas*. By 2006, the site was named a “State Cultural Heritage Site” in San Luis Potosi. Simultaneously, the two-kilometer distance between *Las Pozas* and Xilitla, previously undeveloped, began to see more houses and businesses, as local entrepreneurs began to capitalize on tourism at the site. Today, this area continues to grow and offers cafés and accommodation to tourists, as well as recreational activities such as zip-lining and hiking.

Increasingly concerned with the heavy maintenance required to care for *Las Pozas*, Gastelum sold his inheritance in 2007 to the Pedro and Elena Hernandez Foundation (PEHF), a non-profit organization based in Mexico City whose mission statement is: “To conserve, restore, and protect the environment, seeking equilibrium between human beings and our surroundings.”[19] PEHF created a partnership with Mexico’s largest cement manufacturing company, CEMEX, and the government of

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18 Myerson, Allen R. (1995, February 19) “Fantasy Garden in Mexico’s Jungle” *New York Times* (1923-Current File), XX16. Retrieved March 28, 2011, from ProQuest Historical Newspapers The New York Times (1851-2007). (Document ID: 122918162).

19 Fundación Pedro y Elena Hernández, A.C. http://www.pedroyelena.org/.

San Luis Potosí, to form the Xilitla Foundation, or Fondo Xilitla (FX) as a subsidiary for conservation efforts at *Las Pozas*. FX is led by a board consisting of Barbara and Roberto Hernández Ramirez, directors of the Pedro and Elena Hernandez Foundation, Kako Gastelum, and more than thirty members, including historians, architects, and various professionals concerned with the site's preservation. FX has managed *Las Pozas* since 2008.

PRESERVATION EFFORTS AT *LAS POZAS*

Fondo Xilitla's preservation efforts include nominating *Las Pozas* a national "Artistic Monument," to the Mexican National Fine Arts Institute (INBA), the entity that recognizes significant monuments in Mexico built after 1800. Currently, *Las Pozas* awaits the INBA designation. FX also nominated *Las Pozas* to UNESCO's World Heritage List, and although it has not been designated a "World Heritage Site," *Las Pozas* remains on the "Tentative List" since 2009.[20] Following these nominations, the World Monuments Fund named *Las Pozas* to its 2010 "Watch List" of endangered heritage sites, bringing further attention to the site's preservation needs.

As a state-designated cultural heritage property, *Las Pozas* currently remains under the protection of the state of San Luis Potosi. As such, FX must consult municipal government, the state's Secretary of Culture (Secretaría de Cultura) for authorization for projects at the site.[21] Further approval will be required from the INBA when *Las Pozas* is designated a national Artistic Monument.[22] Nonetheless,

20 *Las Pozas* was nominated under criteria i, "a masterpiece of human creative genius" and criteria iii, bearing "a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared." Source: http://whc.unesco.org/en/criteria.

21 For more information about state law guiding *Las Pozas* projects, see *Periodico Oficial del Estado Libre y Soberano de San Luis Potosi*, 18 Nov. 2006.

22 Article 36 of Mexico's Federal Law on Archaeological, Artistic, and Historical Monuments and Monument Zones (*Ley Federal Sobre Monumentos Arqueologicos, Artisticos, Historicos, y Zona Monumentales*)

this has not slowed restoration projects from taking place at the site and Fondo Xilitla has spearheaded various projects since 2008. Of these projects, the restoration of Edward James's former bedroom returned the space to its original appearance when James occupied it. The project included uncovering original Edward James poetry on the bedroom walls after it had been altered by the room's later inhabitants, the replacement of interior wood, and the restoration of Jose Horna's *Jaula de las Boas*. By 2011, the project was near completion. In summer 2010, PEHF teamed up with students from several Mexican universities to initiate a documentation project of the following structures: the *Three Story House that Might be Five, Edward James's House,* and *Stairway to the Sky*. Students created measured architectural drawings, obtained GPS coordinates and distances between various structures using a Total Station, and performed surveys of the landscape for future reforestation projects. Finally, hydrological analyses were performed to prepare for the implementation of a proposed wastewater management program.

CONCLUSION

Brought up under the strict social structure of England's aristocracy, James's personal life, driven by art and creative inclinations, naturally conflicted with the social expectations set before him by his birthright. Yet art was central to Edward James's life, and after his mother's death he wrote poetry, experimented with interior and architectural design at Monkton House, and spent the last four decades of his life building *Las Pozas*. In 1941, James wrote in a letter to actress Ruth Ford:

> "So I sum up my point of view in relation to inherited fortune by saying that money seemed to me to have been given to spend…but

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states that monuments built between the 1500 and 1900 are designated "historic monuments" and correspond to INAH. Article 33 states that monuments built after 1900 correspond to INBA. Once *Las Pozas* is designated an Artistic Monument, projects will require approval from INBA.

> I wasn't going to give it away to some uncreative institution called a charity. I felt that I could do more to alter the face of the world, more to usher in that new world by spending it in my own way—in particular by fostering any and all creative spirits I could meet with, who had something individually to contribute to the building of that more vivid and more living future…Moreover, I could see hardly anyone who supported the sort of stairways to imagination which seemed to me to be so vital and necessary to the spiritual potency of the future."[23]

James was conscious of the difficulties of making a living as an artist and promoted his idea of the "spiritual potency of the future" by founding West Dean College, an educational institution dedicated to preserving traditional crafts and trades. Although James was not particularly respected as an artist or a poet during his lifetime, his legacy at *Las Pozas* displays his remarkable artistic vision. The site's multiple nominations by UNESCO and INBA, and designation as a "State Cultural Heritage Zone" in San Luis Potosi, support this notion by displaying its recognition by local and global audiences. The following chapter will provide the contextual background of the site in its environmental and social context, including its role as a cultural heritage site in Xilitla today.

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23 Edward James letter to Ruth Ford, 1941. Kusunoki, "Making the Illogical Logical: the organization of the Edward James Archive" *A Surreal Life: Edward James*, 31.

CHAPTER 3 | CONTEXTS OF THE *HUASTECA* AND *LAS POZAS*

INTRODUCTION

Mexico possesses a remarkable collection of natural and cultural resources,[1] but it also faces many challenges regarding their management and protection. The conservation of a heritage site requires an understanding of the temporal and physical contexts and uses that have shaped it over time. Context is defined by environmental, climatic, technological, economic, and social forces, which become part of the intrinsic character of the site.[2] These qualities can be as significant as physical fabric, particularly in the case of *Las Pozas*. This chapter will present the context of *Las Pozas* and its environs by describing the external factors that have influenced the site over time. This begins with the environmental and social contexts, followed by a description of the site and other factors, such as tourism, that continue to shape the site.

ENVIRONMENTAL CONTEXT

The municipality of Xilitla is positioned between Latitude 21° 31′ and 21° N and Longitude 98° 51′ and 99° 09′ W amid the Sierra Madre Oriental Mountains of

1 Comprised of 31 states and a population of over 112,000,000 people, the United Mexican States, or *Estados Unidos Mexicanos*, encompasses a diverse cultural and natural heritage. Mayan temples and Baroque churches, tropical rainforests and arid deserts, and over 60 national languages define the Mexican landscape, while it also ranks third in the world for biodiversity. (Source: Valdez, *Wildlife Conservation and Management in Mexico*, 270). *Las Pozas* is located in central-northeastern Mexico in the *Huasteca* (named after the Mesoamerican Huastec peoples), a region that extends across the states of San Luis Potosi, Puebla, Veracruz, and Hidalgo. The *Huasteca* is characterized by diverse cultures—mestizo, Nahua, Teenek, and Xi'Oi, as well as a myriad of rivers, waterfalls, caves, lush vegetation, and subtropical climate that distinguish it from other Mexican regions.

2 Henry, Michael, *Context and Use* (Los Angeles, J. Paul Getty Trust, 2003): 1.

Mexico.[3] Xilitla is part of the greater *Huasteca Potosina* region (literally, the *Huasteca* of San Luis Potosi), positioned in the southeastern portion of the state where the states of Queretaro, Hidalgo, and Veracruz converge. Characterized by dramatic topographic changes and altitudes between 196 – 8,530 feet (60 - 2,600 m) above sea level,[4] Xilitla exhibits high levels of relative humidity and warm temperatures resulting from masses of water vapor carried in from the Gulf of Mexico, located approximately 200 kilometers away. Additionally, it lies at a junction of hot-humid and warm-humid climate zones, resulting in irregular climatic patterns and changes in vegetation.[5]

The town of Xilitla (population 50,064)[6] hosts a warm-humid climate with mild temperatures averaging 72° F (22° C). High temperatures may reach up to 102.2° F (39° C), while low temperatures rarely drop to freezing.[7] Microclimates are present throughout the area, and fluctuations in temperature and atmospheric moisture are dependent on factors such as altitude or proximity to water sources. Xilitla experiences wet and dry seasons, with yearly precipitation ranging from 39.4 - 122 inches (1000 - 3100 mm).[8] During the wet season, the region's rivers are fast flowing and serve as vital water sources to local communities. Major rivers running through the municipality are the Tancuilín River, running southeast to Matalpa, and the Huichihuayán River, running to the northeast towards Axtla de Terrazas and

3 "Prontuario de informacion geografica munipal de los Estados Unidos Mexicanos: Xilitla, San Luis Potosi, Clave geoestadistica 24054" (2009).
4 *Ibid.*
5 Pineda-Martinez L.F. et al., 134. Pineda-Martinez examines the *Huasteca*'s climatic variability and touches on the shortcomings of previous climatic classifications based solely on precipitation data. The authors explain that the region's physiography (influenced by topographic changes in the Sierra Madre Oriental Mountains and the resulting orographic shade effect) affects atmospheric circulation, creating a "spatially complex climatology" that is variable throughout the region. While Xilitla is categorized as "warm-humid," it also displays bioclimatic differences in various parts of the municipality through changes in vegetation. Overall, Xilitla's climate complies with its current Köppen climatic categorization as "humid subtropical," but an awareness of the climatic variability of this region should be kept in mind.
6 INEGI, 2005.
7 Weather data collected from 2005 describes the lowest temperature in Xilitla was 37.4° F (3° C). INAFED, 2005.
8 INEGI, 2009.

FIGURE 3: THE SEMIARID LANDSCAPE OF THE *SIERRA GORDA,* AND THE SIERRA MADRE ORIENTAL MOUNTAINS FROM AFAR. APPROACHING THE *HUASTECA* FROM THE SOUTHWESTERN *SIERRA GORDA,* THE REGION'S CLIMATE AND VEGETATION DRAMATICALLY CHANGE FROM SEMIARID TO SUBTROPICAL. *SOURCE: MEMO FLORES, 2008. HTTP://WWW.MEMOFLORES.COM/BLOG/LA-HUASTECA-*

FIGURE 4: VIEW OF XILITLA'S CENTRAL PLAZA FROM SAN AGUSTIN TEMPLE. *SOURCE: EKATARINA DONOVA, 2011.*

Huehuetlán.[9] Xilitla belongs to the Panúco hydrologic region, with sub-drainage basins characterized by the Axtla River (78.3%) and subterranean drainage (21.7%), which combine into the greater Moctezuma River (78.3%) and Tamuín River (21.7%) drainage basin.[10] Geological surveys describe Xilitla's surface and subsurface as composed of sedimentary rock from the Cretaceous Period (98.9%), characterized by limestone (88.2%), limestone-shale (9.9%), shale (1%), and alluvial soil (0.8%).[11] Soil type is divided between Leptosol (79.1%) and Luvisol (20.9%).[12]

To the north of Xilitla are the municipalities of Axtla de Terrazas, Aquismón and Huehuetlán of San Luis Potosí. Eastern municipalities include Axtla de Terrazas and Matalpa of Hidalgo and Querétaro. The state of Querétaro is situated to the western boundary of the municipality, while Hidalgo and Queretaro lie to south. The *Sierra Gorda* region, a UNSECO Biosphere Reserve, also lies in Queretaro, providing 385,000 hectares of protected forest and sparsely populated communities between Xilitla and larger cities located to south and west (i.e. Mexico City, Puebla, Guadalajara).

The *Huasteca* is a region of considerable ecological importance and biodiversity is threatened by new development and agricultural practices.[13] Mexican federal legislation did little to ensure environmental protection until the General Law of Ecological Equilibrium and Environmental Protection, or *Ley General del Equilibrio y la Protección al Ambiente* (LGEEPA) was passed in 1988. A 1996 amendment to LGEEPA supported sustainable development and established natural reserves to

9 Prontuario de informacion geografica munipal de los Estados Unidos Mexicanos: Xilitla, San Luis Potosi, Clave geoestadistica 24054" (2009).
10 *Ibid.*
11 *Ibid.*
12 *Ibid.*
13 Clearing and burning forested areas for agricultural use is a subject that has been discussed by Tiedje. See Kristina Tiedje "People, place and politics in the *Huasteca*, Mexico" (2005), "Situating the Corn-Child: Articulating Animism and Conservation from a Nahua Perspective" (2008).

protect biodiversity, however it continues to hold states independently responsible for implementing environmental protection procedures. Consequently, some states suffer from continuous environmental degradation while others states have become more progressive in their laws. Neighboring state Queretaro has led the country by funding programs such as *Sierra Gorda* Conservation Alliance, an entity concerned with protecting biodiversity by promoting reforestation projects throughout the *Sierra Gorda*.[14]

SOCIAL CONTEXT

Xilitla means "land of the snails" in Nahuatl, one of the region's predominant languages.[15] Nahuatl is primarily spoken in rural villages surrounding Xilitla, while Spanish is spoken in town. The municipal town of Xilitla is one of the largest municipalities in the *Huasteca* Potosina with 245 localities. Many are considered highly or extremely marginalized;[16] in 1995, 83% of Xilitla's population lacked drainage or toilets and 75% were reported using firewood for cooking,[17] making Xilitla one of Mexico's most impoverished municipalities. Today, Xilitla remains an agrarian community with unique cultural traditions. Yet there is a disjuncture between the increasingly modernized town center and rural communities situated in the

14 The *Sierra Gorda* is similar to the *Huasteca* in that it contains unique ecological and cultural resources, both of which are define each regional landscape. The *Sierra Gorda* Biosphere Reserve was designated by UNESCO's Man and the Biosphere Program (MAB) in 2001 and the Franciscan Missions (a group of five 18th century Franciscan mission churches) were designated UNESCO World Heritage Sites in 2003. The *Sierra Gorda* is managed by Grúpo Ecológico *Sierra Gorda* (GESG) and Mexico's National Commission of Protected Natural Areas (CONANP), and carries partnerships with a multitude of local, national and international agencies such as UNESCO, Joya del Cielo AC, Bosque Sustentable AC, and Grúpo Ecológico *Sierra Gorda*. In terms of ecological conservation, reforestation, and community development, the *Sierra Gorda* programs serves as successful models [Sources: http://www.sierragorda.net/; http://whc.unesco.org/en/list/1079].

15 In 1990, Nahuatl was spoken by 179,000 inhabitants; Xi'Oi was spoken by 20,000; Teenek with 110,400. Source: Tiedje, "People, place and politics in the *Huasteca*, Mexico," *Anthropology Today*, 14.

16 INEGI, 1995.

17 Tiedje, "Gender and Ethnic Identity in Rural Grassroots Development: An Outlook from the Huasteca Potosina, Mexico," 264.

surrounding hillsides. Xilitla's economy relies primarily on agricultural production, but tourism provides additional sources of revenue.

The *Huasteca* hosts a remarkable display of cultural and natural resources that are valued by local populations. Heritage sites include Tamtok, a Mesoamerican Huastec archaeological ruin, and *Las Pozas*. The *Huastecan* landscape also holds a spiritual value to many of the region's inhabitants. Mountains, caves, lakes, rivers, trees, rocks, and other natural features are vital to the spiritual beliefs and religious ceremonies of various indigenous cultures living in Mexico today. In the *Huasteca*, sacred geographic features include the *La Silleta* (or Huitzmalotepetl in Nahuatl) mountain, which forms a triangle on the landscape with the Fertility and Wind caves, which are believed to be the birthplace of indigenous peoples.[18]

TOURISM IN THE *HUASTECA*

Few people travel to the *Huasteca* with the sole intent to visit *Las Pozas*. Natural sites such as Golondrinas Cave (*Cueva de las Golondrinas*) and the 344-foot (150 m) Tamul Waterfall (*Cascada de Tamul*) are popular destinations for ecotourism. Nonetheless, *Las Pozas* has inadvertently shaped Xilitla since the end of the twentieth century, with new development around *Las Pozas* accommodating growing tourism. The opening of *Las Pozas* to the public in the 1990s marked a new era as a cultural heritage site, generating development around the rural mountain community. In Xililta's town center, numerous historic mud brick and wood buildings were replaced with newer structures.

Anthropologist Kristina Tiedje states that ecotourism is a threat to sacred natural

18 Tiedje, "People, place and politics in the *Huasteca*, Mexico," *Anthropology Today*: 15.

sites located near Xilitla and throughout the *Huasteca*.[19] Since the 1990s, Mexican legislation protects sacred landscapes by designation as a "natural-sacred site." The designation process allows the state control of natural-sacred sites, contributing to the protection of many religious and ceremonial places worshipped by indigenous peoples, particularly those practicing animistic religions. However, development, tourism, and the exploitation of natural resources threaten the sacred landscape, which extends beyond Xilitla and the Sierra Madre mountains of the *Huasteca*. Recently, a road planned connecting Xilitla to Aquismón was to pass directly through the pilgrimage path to a ceremonial cave until the Indigenous Elders Council of the *Huasteca* (CIUCH) was able to stop the road's construction.[20]

SITE DESCRIPTION

Two roads connect Xilitla's town center to *Las Pozas* (21˚23′40″ N latitude and 98˚59′47″ W longitude). It takes approximately twenty minutes to walk to *Las Pozas* from town, and less than ten minutes to arrive by taxi, bus, or car, and the distance between the site and the town center is enough to provide a sense of solitude and tranquility during the low season, when fewer visitors frequent the site. Upon arriving at *Las Pozas*, the first visible monument is *Stairway to the Sky*. It stands as a striking three–story concrete structure projecting out from the forest that lies behind it. Inside the entrance gate to *Las Pozas* and beyond *Stairway to the Sky*, more than two hundred concrete structures, ranging from smaller sculptures to large-scale architectural forms are dispersed throughout thirty hectares of subtropical forest. The Huichihuayán River runs along the western border, carrying with it a series of waterfalls that descend the steep hillside. At the base of each waterfall are tranquil

19 *Ibid.*
20 *Ibid.*

FIGURE 5: NATURAL POOLS, OR *POZAS,* AND EDWARD JAMES'S UNFINISHED CONCRETE SCULPTURES. *SOURCE: AUTHOR, 2010.*

FIGURE 6: CONCRETE GOTHIC ARCHES INTEGRATED INTO THE JUNGLE. *SOURCE: AUTHOR, 2010.*

natural pools where visitors and Xilitlans frequently swim. Around these natural pools, James constructed stone and concrete walls and sculptures, designed for functional reasons (i.e. to direct the water flow) and also for purely aesthetic reasons (i.e. concrete columns 'supporting' a stone cliff). A series of stone and concrete paths wind through the site, leading visitors to 'stumble upon' unusual concrete sculptures.

Visitors move through pathways that outline the contours of the landscape. Occasionally, these paths diverge, allowing visitors to create their own route through the jungle. Most of James's works are concentrated in a four-hectare area located between the site entrance, the river, and the steep hillside, known as the "structural zone." Larger structures exhibit Surrealistic names like *Three Story House that Might be Five, Palace of the Ducks, Bamboo Palace*, and the *Cinema*. Ascending the steep hillside, smaller sculptures covered in plant growth are hidden in the landscape, often away from designated paths. These works receive less maintenance due to their location away from the structural zone, and provide a stark contrast to the maintained structures below. These two areas of the site exhibit alternative presentations of the site—one landscaped and maintained, and the other, fully immersed into the jungle.

Various cabins built during the late 1970s and early 1980s are also dispersed throughout *Las Pozas*. These cabins served a functional purpose—to house James's guests, and later, various persons living at the site. These cabins were previously rented to visitors, a practice that has been eliminated since 2008. Today, landscaped gardens have replaced much of the dense vegetation that once grew abundantly throughout *Las Pozas*, which serves both to protect the structures and provide a more controlled appearance to the feral landscape. When James and Gastelum purchased the property, coffee plants, one of Xilitla's staple agricultural products, grew in abundance on the landscape, but today coffee plants are only encountered far away from the structural zone.

STAIRWAY TO THE SKY

Stairway to the Sky is the name given to the third story of a structure known as the *Cinema*. The building was constructed in various campaigns during the 1960s, and historic photographs indicate that *Stairway to the Sky* was built during the last campaign. James had originally planned this three-story reinforced concrete and hollow brick structure to be seven stories tall,[21] but for unknown reasons did not complete this design. Like many of the structures at *Las Pozas*, the original design or idea changed, either because James changed his mind or simply added on to, or subtracted from, the original design.

The *Stairway to the Sky* is composed entirely of cast-in-place reinforced concrete. It is open-air and stands without tree cover, receiving ample sunlight throughout the day. The structure contains two monumental columns with winding stairs that ascend towards the sky and unite several meters above the pavement, thus giving the structure its name: *Stairway to the Sky*. Along the perimeter of the structure, six slender columns with flower-like concrete features have been placed only for their aesthetic effect. Another mid-air concrete pathway hangs several meters from the ground, and unites *Stairway to the Sky* with *Edward James's House*. This permits access to the third stories of each structure without the need to descend the stairs. Overall, *Stairway to the Sky*'s unusual design combined with the interactive experience of climbing and descending the stairs that actually lead to the sky, makes it an exemplary display of the unusual structures at *Las Pozas*.

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21 Danziger, *Builder of Dreams*. In an interview from Danziger's documentary, James discusses his intentions for *Stairway to the Sky*, claiming he was going to make it seven stories tall. Kako Gastelum also discusses the structure, stating that James wanted to use the third story to house monkeys.

CONCLUSION

Las Pozas is situated amid the *Huasteca Potosina*, one of Mexico's most picturesque and biologically diverse regions, but also one of its lesser known. The landscape is central to spiritual beliefs of many of the region's inhabitants, as well as Xilitla's local economy, which relies primarily on subsistence farming and agricultural activity. Edward James was attracted to the region's natural beauty and settled in Xilitla in 1948, creating *Las Pozas* over the course of four decades. Today, *Las Pozas* is often referred to as "Xilitla," which is telling of the town's enigmatic character. The changes that the site brings to the town, notably with tourism and development, suggest additional threats to the natural environment, as well as gradual changes in Xilitla's cultural and built environments resulting from globalization. Regional growth is not addressed in Chapter 5 since it is not directly related to the specifics of a conservation approach for *Stairway to the Sky*, but it is part of a broader context in which heritage tourism may adversely affect the ecological and cultural landscape. Nevertheless, it should be taken into consideration if site managers create a comprehensive conservation plan for *Las Pozas*, since the site's integrity is also dependent on external factors, such as ecological and cultural diversity.

Xilitla is also situated in a climatic region of great variability. Its geographic location amid the Sierra Madre Oriental mountain range, and 150 miles from the Gulf of Mexico, results in changes in vegetation and microclimates that are influenced by factors such as elevation, wind, and air masses moving in from the Gulf. Xilitla's warm-humid climate provides substantial yearly rainfall influenced by wet and dry seasons, and consistently high levels of relative humidity that contribute to the area's fertile environment. Climate unquestionably affects James's works at *Las Pozas*, and remote areas of the site exhibit concrete sculptures covered in plant growth. Whereas this may be perceived as a hazard to the works and incite the immediate removal of biogrowth, in reality, the combination of polychromatic biological organisms and concrete creates an alluring aesthetic that is uncharacteristic of concrete. The following chapter will explore this phenomenon and explain how the convergence of nature and concrete sculptures is central to the artistic and environmental significance of *Las Pozas*.

CHAPTER 4 | PROPOSED VALUES AND SIGNIFICANCE

VALUES AND HERITAGE CONSERVATION

With regard to built heritage, values are quite simply: any trait that is associated with the significance of a place. Values attributed to heritage places are the tangible and intangible qualities that become defined by the dynamic interaction between the site and its encompassing environment. This means a place holds different associations with various audiences; for instance, a heritage place can play a vital role in an ecosystem and support life forms that grow on top of it, or it can be a center for recreational, spiritual, or social activities. Conservation practices and site management plans can positively or adversely affect valued attributes (i.e. physical appearance or use), and in order to protect the very things that make a place significant, it is necessary to evaluate its significance and develop a conservation approach that respects values.

A conservation plan, then, is built upon an understanding of the evolution of the site and the numerous factors that have shaped it over time. This may include changes in social, environmental and legal contexts, presentation or 'display' (i.e. how a building or site is perceived, or how interventions may have changed one's perception of it), and how it is experienced through movement and sensory factors. Additionally, a conservation plan should work in accord with the environment (if the environment cannot be controlled) to manage appearance, ensure durability and function, and seek a balance between what is desired and what can be achieved.

In this chapter, a values-based approach will propose the significance of *Stairway to the Sky*. Departing from the common method of listing all associated values (i.e. social, economic, and historic), the following analysis focuses primarily on the structure's artistic and environmental values. This is done to express the uniqueness of this individual structure within the context of many works, and ultimately, one body of work (*Las Pozas*). The chapter ends with a 'Statement of Significance,' which serves as a guide to subsequent discussions about the conservation approach applied to *Stairway to the Sky*.

ARTISTIC VALUE

Edward James's evolution as an artist can be seen as one walks through *Las Pozas*. This is not done chronologically (in fact, no chronology of James's structures has been created to date), but spontaneously. Each visitor may walk a unique route and experience the disarray of plant-covered sculptures differently, and yet, their arrangement in the jungle creates a unified whole. It is a place created from multiple components, both natural and manmade, and its outstanding assemblage makes it one of the twentieth century's great artistic achievements.

Edward James looked to the world around him for design ideas for his sculptures at *Las Pozas*. Though he incorporated both decorative familiar symbols, such as the Fleur-de-lis coat of arms or Modernist geometric shapes, and architecturally familiar features, such as Classical Doric columns and gothic arches, he made them his own. James incorporated groin vaulting, which is used as a support for a roofing system, into a freestanding concrete sculpture with no architecturally functional purpose. He also integrated concrete buttresses into his designs to support a wall that needs no lateral support, and he shaped them as human legs. Edward James referenced the world of function and duration, and appropriated it. The *Three Story House that*

Might be Five could be mistaken for a building explicitly influenced by mid-twentieth century Modern architecture if it was enveloped with four walls, but instead, it is open to the jungle. James's architectural interests in style, time and duration, and a glimpse into his thought process and inspiration are revealed in this comment about a colorful flower-like fountain he built and how he perceived his works to transform with time:

> "….La Plaza de San Eduardo"…. is just a glade in the forest where four paths meet and which Plutarco had paved, during my absence in England five years ago—that first fountain in the Plazuela is more stark in its forms, more 20th Century. This second version takes the shapes of foliage and the effect becomes more baroque. I think that in Architecture there is bound to be a swing of the pendulum, a development toward the more elaborate, a reaction against the purely stark and rectilinear. The trend away from Bauhaus steel cubes, like chromium plated and glass matchboxes, began with the last works of Le Corbusier—specifically those he designed for Pakistan; earlier it was already noticeable in his famous chapel dans les Montaignes des Voges where the masses are rounded and curved, instead of following square angles. So I like to think that my second fountain (here in the making) is the 21st Century in style, whereas Fountain Number One was just 'modern.'"[1]

James progressed through the landscape at *Las Pozas*, building and adding onto structures for nearly three decades. Using concrete as his medium, he emulated the *Huastecan* flora and fauna by building sculptures of flowers, bamboo, mushrooms, and snakes. He also conveyed his sense of humor in original forms such as a concrete record player that was immersed into a natural pool, and an arch that was formed into the shape of the Queen of England's ring. Though he was guided by his imagination and inspired by familiar symbols, shapes, architectural elements, and nature, he was

1 EJA, West Dean College.

also influenced by post-modern thought and spent time reflecting on past artistic styles and how he would deliberately further develop sculptures through his own processing of time and perception.

James placed his works in the feral landscape, and in the process, avoided cutting down trees, but he did not live to see its full immersion into the jungle. Even after his death, the site continued to evolve as nature took over, this time representing an unexpected, yet beautiful assimilation of the natural environment and James's works. Based on his love of nature, it is likely he would be pleased with the appearance of his concrete structures today, however, he did not clearly state that he wanted *Las Pozas* to 'return to nature.'

The *Cinema* represents one of the most remarkable of the many architectural sculptures that make up *Las Pozas*. The interactive experience of ascending the stairs to view the open sky perhaps served a similar function as some Mayan temples in that it provided a prime location to view the sky, or it may have been created merely for aesthetic purposes. Either way, James envisioned architectural sculptures through his observations of concrete as a building material with endless sculptural capabilities. Concrete allowed him create a monumental structure that evoked a building, but in fact was not, and instead served to support two massive and four slender columns with flower-like formations at their peak, and a stairway that ascended into mid-air. Jose Aguilar's artistry and vision as a woodworker also played an important role in the construction of *Stairway to the Sky*, ultimately allowing James to realize his designs in concrete. Aguilar carried out each wooden concrete formwork with incredible precision and complexity, taking months to carve thousands of curvilinear pieces of wood as the molds for James's unique sculptures. Aguilar's reputation as a craftsman in the *Huasteca* was unparalleled at the time,[2] and without his contribution it is

2 Hooks, *Surreal Eden*, 88. Many of Jose Aguilar's wooden forms can be found today at *El*

possible that *Stairway to the Sky* may not have been executed. Altogether, the two men formed a collaborative team of artist and craftsman, which allowed the *Cinema* and *Stairway to the Sky* to later be erected by an additional team of workers.

The life of the structure after it was completed by Aguilar and James provides an added value that may not have been anticipated by Edward James. As time passes, *Stairway to the Sky* continues to transform as nature reclaims it. Like Robert Smithson's *Spiral Jetty*, it is a work placed into an environment and intended to be a part of its natural setting, but with an uncertain future as nature takes over. This raises the theoretical question of the future of an artwork after the artist has died, especially when nature was, in some way, a significant component of the work. As a concrete architectural sculpture placed into a humid jungle, *Stairway to the Sky* cannot be isolated from its environmental context—deterioration will inevitably occur. Yet deterioration, which is suggested by plant growth and uneven, eroded concrete surfaces, has also created an aesthetic that has become valued and character defining. Concrete, combined with lichens, moss, and black fungal organisms have become a part of the structure, while insects, plants, and the jungle's acoustic sounds contribute to the sensory experience of the natural environment.

The combination of James's dynamic and evolving design process and Aguilar's masterful craftsmanship methods, along with the overall 'disorder' of a jungle environment at *Las Pozas* resulted in the creation of an enigmatic place. Each construction at *Las Pozas* tells a story, but it is not necessary to know the full story to experience the reflection and containment of time that each construction whispers while wandering through the site.

Castillo Restaurant in Xilitla. However, hundreds of forms were used to build *Las Pozas*, and thus remain in storage where they are subject to dark and humid environmental conditions that favor rot and biodeterioration. The craftsmanship involved in creating the *Las Pozas* formwork is remarkable and their conservation merits attention.

FIGURE 7: A POLYCHROMATIC CEMENT SURFACE EXPOSED AFTER CLEANING.
SOURCE: AUTHOR, 2010.

FIGURE 8: VARIOUS SPECIES OF BIOLOGICAL ORGANISMS COLONIZING BLUE PIGMENTED STAIRS OF THE *THREE STORY HOUSE THAT MIGHT BE FIVE*. ALTHOUGH SOME SPECIES MAY THREATEN MATERIAL INTEGRITY, THEY PROVIDE AN AESTHETIC THAT IS CHARACTERISTIC OF JAMES'S WORKS AT *LAS*

ENVIRONMENTAL VALUE

Most of James's works are situated within a 2.5 acre area among the seventy acres that make up *Las Pozas*. Lush, subtropical vegetation, a river, waterfalls, pools and steep terrain provide an aesthetic value to the landscape and sensory experiences that are central to the work. Xilitla's distinctive flora includes orchids, ferns, bamboo, coffee, rosewood, royal poncianas, and numerous species of fruit trees (e.g. lychee, passion fruit, orange, and blackberry). The landscape does not terminate with the site's legal boundaries, but is connected to the broader *Huastecan* landscape, characterized by lagoons, rivers, waterfalls, and caves. Nature is a significant component of the site, providing multi-sensory experiences, but its integrity is reliant on ecologically diversity and environmental protection. Xilitla, and to a larger extent, the *Huasteca*, is remote from major industrial and urban centers, which greatly supports the region's ecological diversity. This has also contributed to the safeguarding of cultural constructions of nature, displayed in the spiritual beliefs of many of the region's indigenous inhabitants who worship natural features of the landscape, such as caves and mountains. Because the natural environment is ecologically, culturally and spiritually valued, it is implied that *Las Pozas*—as a product of man and nature, embodies multiple associations within the natural and cultural landscape.

The centricity of nature has long since been a part of Xilitla, and Edward James was undeniably aware of this after arriving in 1948. Numerous accounts describe James as person who was deeply connected to nature and this is implied at *Las Pozas*, since his vision was to integrate his works into nature. It is in this particular environment that James grew as an artist, possibly inspired by solitude, or the simple fact that he was surrounded by a beautiful landscape. Regardless, James created a great artistic work in a place that had inspired him, and today, many can experience the union of the two at *Las Pozas*.

STATEMENT OF SIGNIFICANCE

Las Pozas is a place where nature and constructed works converge in a living, organic artistic expression. At *Las Pozas*, Edward James created multiple works that stand on their own merits individually, however when combined with nature, they form an interdependent whole. As the site ages, plants envelope the concrete sculptures and they slowly become integrated into the natural environment. *Stairway to the Sky*'s aesthetic value becomes enhanced by plant growth, suggesting the structure will eventually attain a unified and harmonic appearance with its surroundings. The union of art, architecture, craft and nature defines *Las Pozas* and *Stairway to the Sky*, resulting in a unique work that stands without precedent.

CONCLUSION

Stairway to the Sky is one of many remarkable structures that represent Edward James's artistic vision at *Las Pozas*. As part of a larger body of work, the structure's preservation is needed to retain the significance of the larger body of work—*Las Pozas*—which is an integration of manmade forms and nature. *Stairway to the Sky* has always been a part of its natural environment, and although time has altered its appearance, it remains the work of Edward James. Nonetheless, multiple environmental and human factors continue to threaten *Stairway to the Sky*, and the following chapter will identify these threats so that conservation strategies can be proposed.

CHAPTER 5 | PAST, PRESENT AND POTENTIAL RISKS AND THREATS

The current physical condition of *Stairway to the Sky* is attributed to the building's construction materials and methods, as well as its context and use.[1] This may include acts of vandalism, inappropriate interventions or maintenance routines, weather events, environmental agents, and visitation. A listing of environmental and climatic threats to material and structural integrity is provided, followed by human threats posed by staff and visitors. All of the below listed threats have been identified as previous threats or potential intrinsic and extrinsic threats.

EXTRINSIC THREATS: ENVIRONMENTAL

Weather Events

Major storms (i.e. hurricanes, tropical storms) from the Gulf of Mexico making landfall in southern Tamaulipas and northern Veracruz become threats as they move into the *Huasteca*. These storms can bring heavy or prolonged periods of rainfall and high winds, increasing threats from mudslides, landslides, and/or falling branches and trees. Twenty-six tropical storms and hurricanes passed within 100 miles from Xilitla since 1948, the most severe storms being two Category 5 hurricanes occurring in 1955 (Hurricane Janet) and 2007 (Hurricane Dean).[2] At *Las Pozas*, mudslides and landslides result from the uneven positioning of soil along bedding planes, which are characterized by sedimentary strata that shift during wet and dry seasons.[3] After

1 Henry, *Context and Use: A Technical Note,* 1.
2 http://csc.noaa.gov/hurricanes/#.
3 Guzman and Holmes, *Master Plan: La Conchita, Xilitla, San Luis Potosi: Priority issues and responses* (2008).

periods of heavy rainfall, the soil is subject to movement, carrying rocks and soil along inclined surfaces. Because the *Cinema* is situated on a relatively level terrain, it is less susceptible to the threat of landslides and mudslides than other structures at *Las Pozas*.[4] The *Stairway to the Sky*, however, remains exposed to trees and plants that pose major threats in the event of a storm.

Vegetation

Historic photographs show dense foliage previously surrounding the structure. This suggests that branches may have fallen and caused damage that has since been repaired. Currently, however, much of the surrounding vegetation has been removed and trees hover near the surface. In the event of a major storm, their proximity may become problematic, but in comparison to other structures at *Las Pozas*, falling branches and trees are less threatening to *Stairway to the Sky*.

Sunlight

While trees and vegetation shade most structures at *Las Pozas*, there is minimal tree cover surrounding *Stairway to the Sky*, which allows the structure to receive more sunlight exposure than most structures at the site. Strongest sun exposure occurs during afternoon hours when the sun moves across the structure; this is relevant to wetting and drying cycles, particularly to the drying of moist areas. Altitude also affects sun exposure, which is decidedly stronger in the high altitudes of the Sierra Madre Oriental Mountains than in lower lying coastal areas.

Water run-off

Water run-off distributes high concentrations of water to some surfaces. In

4 Structures located on the hillside are more susceptible to the threat of landslides/mudslides. In 1988, the impact of a mudslide into the side of the *Three Story House that Might be Five* caused severe structural damage and the building's subsequent closure to the public.

some cases, this may increase the risk of biological colonization or reinforcement corrosion. Water run-off is a particular concern in areas of insufficient cover, where the distance between the reinforcement and surface is minimal and water penetration may accelerate reinforcement corrosion. Unlike other structures at *Las Pozas*, plants do not hang directly over *Stairway to the Sky*, but it is possible that water run-off from trees, plants and architectural elements present water run-off onto surfaces with higher concentrations of biogrowth, or eroded surfaces.

Biodeterioration

The presence of biogrowth has become a character-defining trait of *Las Pozas*, enriching the appearance of concrete structures with a multitude of life forms of various textures, shapes and colors. However, biogrowth may act as a deterioration mechanism and threaten material integrity by excreting deleterious chemicals, organic substances or causing mechanical damage. Biogrowth may occur in areas where organic pigments were used (i.e. pigmented cement coatings), or in areas where sunlight, oxygen, moisture, and nutrients provide the sufficient conditions for survival. Additional factors such as orientation of the substrate may also contribute to biological colonization. Inappropriate techniques have been employed at *Las Pozas* for the removal of biogrowth, which will be discussed in the following section. This complex issue will be explored in the following chapter to determine possibilities for its removal or non-removal.

Freeze-thaw Damage

When temperatures drop below freezing, water located within concrete pores solidifies and expands in volume and causes mechanical distress to outlying areas. Micro-cracks, cracks, spalls, exposed aggregate are just a few damaging effects resulting from freeze-thaw cycles.

Atmospheric Moisture

The entry of water vapor through cracks, voids and pores of the material may lead to reinforcement corrosion and provide moist environments for biological colonization. This becomes possible as adsorbed water vapor concentrates in pores leading to saturation with liquid water. Atmospheric moisture is abundant at *Las Pozas*, suggesting moisture penetration is a dominant threat to concrete durability by enabling either corrosion of reinforcement or by sustaining biogrowth.

EXTRINSIC THREATS: HUMAN

Surface Cleaning

Site workers cleaned buildings and sculptures with wire and plastic-bristled brushes. The process included dry scrubbing a surface with a brush, then using water to wash away dirt or vegetation. If a surface required further cleaning, workers repeated this procedure until the film or vegetation or debris was fully removed.[5] Abrasive actions can be destructive by removing fragments of the material and cause subsequent problems such as increased porosity and permeability of the material. If wire brushes are used, iron particles can remain on the surface and cause rust staining. Overall, increased porosity and permeability is associated with increasing the risk of concrete deterioration and reinforcement corrosion by providing new or larger openings for external deleterious substances such as chloride ions, sulfates, atmospheric moisture, water, biodeteriogens, and other substances.

5 Interview with Angel Martinez, June 2010. Site worker Ángel Martinez was interviewed about the cleaning process used observed using wire-bristled and plastic-bristled brushes to remove biological growth from the concrete pavement adjoining Edward James's residence.

Also, improperly executed concrete patches (i.e. the repair is not well bonded to the surface, poor materials were used, removal of deteriorated concrete did not take place)[6] may allow the ingress of water and contribute to reinforcement corrosion if the patch does not adhere to the surface. Finally, uprooting higher plants may cause successive damage and larger surface cracks, such as accelerated reinforcement corrosion, chloride ingress, or microbial colonization within newly formed cracks.

Overloading, Impact and Vibration from Visitation

Visitation is a threat if a structure is overloaded with live loads, or impact loads; the most significant source of live load and impact loads are from visitors. In 2009, the average number of daily visitors at *Las Pozas* was 248, yet up to 3,200 people[7] visited the site in one day during high season.[8] The load capacity of *Stairway to the Sky* has not been determined by analysis or testing, so the visitor load on the structure cannot be managed. *Stairway to the Sky* exhibits seemingly delicate elements—reinforced concrete cantilevered stair treads that ascend from the structure into mid air, and stairs that wind around the columns. Currently, signage directs visitors to refrain from climbing delicate structures in large groups, and guides enforce the site's rules as they lead tours. The question of structural stability and visitor safety remains a concern since structural appraisals have not been recently been performed on various structures.

Vandalism, Graffiti, and Litter

Acts of vandalism include graffiti and looting, as well as intentional and

6 United States Department of the Interior, *Concrete Repair Guide*, 4.

7 Liñan, Zaira, email message to author, September 7, 2010. In 2009, the lowest number of visitors at *Las Pozas* was 12. However, Liñan said that it is uncommon to see so few visitors in one day. The highest number of visitors at the site occurred during *Semana Santa*, or Easter week, of April 2010.

8 In Mexico, The "high season" occurs during *Semana Santa* and in the summer from July until September. These numbers do not include members of the local community, who are allowed free entrance to the *Las Pozas*.

unintentional acts of physical destruction on the buildings and sculptures. Site management prohibits visitor entry after 5 p.m., employs security guards to patrol the main entrance, and has erected wire fabric fences topped with barbed along the main road. This strategy prevents easy access to the site after-hours but it does not deter vandals from entering from the site's northwestern boundaries (near the peak of the hillside) or by jumping fences. In spite of the pervious site boundaries after hours, no severe acts of physical destruction have occurred from vandals entering the site illegally.

Visitors also pose greater threats by deviating from designated pathways. This is exemplified by damage inflicted to the iconic sculpture, *Plutarco's hands*, which was recently broken after a visitor encroached on it. The sculpture has since been restored, and plants were placed in front of it to deter access by unauthorized routes.

Poaching

Native plant species are an integral component of the landscape at *Las Pozas*, and visitors threaten environmental integrity by removing flora and fauna from their natural habitat. Plant poaching is currently addressed with signage, but nevertheless it remains a threat since staff surveillance is not possible in all areas of the site.

INTRINSIC THREATS: QUALITY OF MATERIALS

Quality of materials will affect concrete performance. Materials are those that contain impurities (i.e. water, aggregates contaminated with chlorides, organic materials, or aggregate prone to alkali-aggregate reactivity may adversely affect longevity. Attributes of the aggregate, such as size, shape, gradation and surface texture, affects material performance.[9]

INTRINSIC THREATS: CONCRETE MIX DESIGN

Poor design techniques

Improper cement/water and aggregate/binder ratios in the mixture may affect properties such as tensile strength, porosity, permeability, and drying shrinkage. Concrete of high porosity and high permeability facilitates the ingress of water and chloride ions, and in some cases, biodeteriogens. The inclusion of pigments in cement mixtures may also affect the aggregate/binder ratio, or attract biodeteriogens if an organic pigment was used. A white parge coat is visible on most surfaces of *Stairway to the Sky*, most likely derived from an inorganic pigment or acrylic paint, yet the source of James's cement mixtures remains unknown. High water to cement ratio results in a porous material more vulnerable to chloride ingress and carbonation, and poor cover is also a significant factor linked to concrete durability.[10]

Construction Methods and Quality Control

Stairway to the Sky was cast-in-place during the 1960s; according to one worker[11] involved in construction at *Las Pozas*, materials were mixed in situ and the concrete was placed into wooden formwork. Pine and mora (*Mora excelsa* and *M. gonggrijpii*) wood was used to create the formwork,[12] which was composed of thin pieces of wood nailed together. If openings were present in the formwork, this may have

9 Graves, Robin E. "Grading, Shape, and Surface Texture." *Significance of Tests and Properties of Concrete and Concrete-Making Materials,* 337.
10 Macdonald, Susan, *Concrete Building Pathology*, 146-47.
11 Worker Angel Martinez explained construction practices during an interview in June 2010.
12 One staff member at *Las Pozas* explained that most of Jose Aguilar's formwork was constructed of pine (pino) and (mora) woods.

affected the curing process after the concrete was placed, causing cracking or drying shrinkage to occur in areas where hydration was disrupted by leakage of water from the mix.[13] Also, it is necessary for formwork to be left in place for enough time to allow hydration to take place.[14] Quality control would ensure proper mixing, placement and curing of concrete, however it is unknown if appropriate construction methods were employed in the construction of *Stairway to the Sky*. Finally, quality control would have taken into consideration environmental conditions during construction.

REINFORCEMENT CORROSION

Reinforcement corrosion is perhaps the most significant pathology that affects concrete durability and performance, and environmental conditions may present a number of factors that enable corrosion. Carbonation, is a leading factor in corrosion, is caused by the penetration of atmospheric carbon dioxide (CO_2), while chloride attack results from the ingress of chloride ions from cast-in salts or the environment.[15] Moisture and oxygen lead to corrosion of the steel reinforcement, causing volumetric expansion of the steel and spalling of the concrete to occur.[16] Once reinforcement corrosion has occurred, treatment options are limited due to long-term effects of this pathology.

Carbonation

Carbonation occurs when atmospheric carbon dioxide penetrates concrete and reacts with water stored in the pores of the material to form carbonic acid. This substance reacts with calcium dioxide and other alkaline hydroxides to lower the alkalinity concrete, which ordinarily have a pH of 12-13. When the pH level of

13 Macdonald, *Concrete Building Pathology*, 4-5.
14 *Ibid. 5.*
15 MacDonald, *Concrete Building Pathology*, 143-144.
16 *Ibid. 144.*

concrete drops below 11, the steel's passive layer is broken down and the steel becomes susceptible to corrosion. This electrochemical reaction causes the reinforcement bar to oxidize and expand, resulting in cracking or spalling of the concrete. Visible signs of reinforcement corrosion are the presence of small and large cracks, spalls, the latter resulting in exposure of the corroded rebar. Carbonation is accelerated in environments with high levels of carbon dioxide and frequent wet/dry cycles, in concrete with low cement content, and in areas with low protective concrete cover over reinforcement.[17] Sufficient cover is needed to prolong the penetration of CO_2 in concrete, and multiple areas of *Stairway to the Sky* display an exposed, corroded rebar where areas of low cover have spalled and detached.

Chloride Attack

Chloride attack occurs when chloride ions are introduced into concrete through water penetration, or are already present in the material if salts were present in the original mixture or calcium chloride was used as an accelerator.[18] When chloride ions reach the reinforcement they will break down the metal's passive layer and cause corrosion of the reinforcement to occur, resulting in the oxidation and expansion of the steel. The ingress of chloride ions due to marine environments is unlikely due to Xilitla's remote location from the Gulf of Mexico (approximately 200 kilometers), however, cast-in salts or calcium chloride accelerators may have been used in the construction of *Stairway to the Sky*.

Sulfate Attack

Sulfate attack occurs when sulfates of calcium, sodium, potassium, and aluminum are introduced into the material through the soil, groundwater, or

17 *Ibid.* 144.
18 *Ibid.* 144.

fresh water.[19] This is a destructive process, as the calcium hydroxide and calcium aluminates found in the concrete are attacked by the sulfates. Wet/dry cycles cause salts to form at the surface of the concrete, resulting in the spalling of the surface material. Another major source of sulfate attack is atmospheric pollution, which does not appear to be a great threat due to Xilitla's small size. However, *Stairway to the Sky* is located directly at the front entrance to the site, and thus experiences greater exposure to atmospheric pollutants (i.e. SO_2) from automobiles than the more remotely located sculptures.

Alkali-silica reaction (ASR)

Petrographers did not fully understand the dangers of alkali-silica reactivity in concrete until the late 1960s and early 1970s,[20] suggesting the possibility of ASR at *Stairway to the Sky*. Hydroxyl ions in the cement can react with silica ions from the aggregate to cause an alkali-silica reaction (ASR). Aggregate that is alkali-reactive occur with various sandstones, quartz wacke, greywacke, agrillite, limestones with chalcedony, or sands with chalcedonic chert.[21] ASR is typically identified by the visible cracking patterns that occur from the expansion of the concrete material, or by the alkali silica gel viewed under magnification with an optical microscope. ASR is one of the most discernible conditions in concrete in situ, but was not observed in the visual examination of *Stairway to the Sky*. This does not exclude its potential as a deterioration mechanism. Liquid water, water vapor, chloride ions, and other deleterious substances can enter through crack formations resulting from ASR.

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19 MacDonald, *Concrete Building Pathology*, 149.

20 Stark, David. "Alkali-Silica Reactions in Concrete." *Significance of Tests and Properties of Concrete and Concrete Materials*, 365.

21 Rogers, C. A. "Petrographic Examination of Aggregate and Concrete in Ontario," *Petrography Applied to Concrete and Concrete Aggregates, ASTM STP 1061*, 6.

CURRENT CONDITIONS OF *STAIRWAY TO THE SKY*

A preliminary reconnaissance level survey of *Stairway to the Sky* was performed from June-July 2010. Survey techniques included visual examination, written notes and photographic documentation, as well as RILEM permeability tests.[22] The overall objective of the survey was to gain a preliminary understanding of the physical conditions of the concrete structure after approximately forty years in service.

Description of Materials and Construction Methods

Stairway to the Sky is composed entirely of reinforced concrete. A parge coat was applied to exposed concrete surfaces with the exception of the floor. The structure exhibits two colossal columns, also composed of reinforced concrete, with a white parge coat applied in a textured pattern to the steps. Two smaller freestanding columns were constructed at the same time as the larger columns, and four slender columns appear to have been added at a later date.

Observed Conditions at Stairway to the Sky [See Appendix E: Conditions Glossary]

- Biological Colonization

In areas that receive less sunlight (primarily in shaded areas underneath the stairs) the presence of biogrowth is prominent, colonizing the surface of the material and subsurface concrete pores.23 Lichens and algae are present on this structure, yet the most ubiquitous biological form is black fungal. This type appears to colonize areas that are shaded for longer periods in the day.

- Cracking

22 Test method employed was "Water absorption under low pressure (pipe method)" Test No. 11.4, RILEM Commission 25-PEM (1980).

23 This was observed in many areas at *Stairway to the Sky* and occurs most prominently with black fungal growth. The presence of black fungal biogrowth is evident inside of the material's pores.

FIGURE 9: VOIDS, CRACKING, AND EXPOSED AGGREGATE ARE REVEALED ON THE WEST COLUMN, *STAIRWAY TO THE SKY*. *SOURCE: AUTHOR, 2010.*

FIGURE 10: IMPRESSIONS OF FORMWORK ON THE MONUMENTAL COLUMNS OF *STAIRWAY TO THE SKY*. *SOURCE: AUTHOR, 2010.*

Microcracks and cracks are ubiquitous on both exposed concrete and parged surfaces. Numerous craze cracks are present on the stairs, and of notable interest is a widespread cracking pattern on the east column. Causes of cracking are unknown, and may be resultant of drying shrinkage, loading, or internal pressure caused by reinforcement corrosion.

- Deteriorated Parge

The parge has deteriorated or flaked off in some areas and exposed concrete surfaces have been revealed.

- Exposed Aggregate

Weathered concrete surfaces are ubiquitous on the structure resulting on loss of surficial cement paste and exposure of aggregate in multiple areas.

- Leaching

The east column displays what appears to be a calcareous deposit leaching from a joint, suggesting water exodus from the crack, or from a previous repair.

- Reinforcement Corrosion

Reinforcement corrosion is visible in areas of insufficient cover where the concrete has spalled, revealing corroded reinforcement bars. This occasionally occurs on edges of cantilevered stair treads, where less than half an inch of cover was revealed by detached spalls. This supports the notion that insufficient cover is problematic in the structure.

- Repairs

Multiple concrete repairs are visible throughout the structure. Repairs colors range from white to grey cements.

- Spalling

Spalling is evident on the vertical, rear edges of numerous stair treads. In these areas, insufficient cover appears to have been placed over the reinforcement bars. Numerous areas on the larger and smaller columns also display attached and detached spalls.

- Staining and Discolorations

Black staining occurs on both parged and exposed concrete surfaces, and is probably biological. Other discolorations of orange, brown and yellow colors are present on various columns, however, no discolorations were detected on the exposed concrete ground.

- Voids

Numerous voids were detected throughout the structure. At least two voids measured approximately two inches in diameter on each column.

CHAPTER 6 | BIODETERIORATION OF CONCRETE AT *STAIRWAY TO THE SKY*

Xilitla's warm-humid climate provides a congenial environment for biological activity on a variety of surfaces at *Las Pozas*. Commonly referred to as biogrowth, these organisms are considered deteriogens when they cause the mechanical, chemical, or aesthetic deterioration of a substrate. The pervasiveness of biogrowth on concrete at *Las Pozas* raises many questions about its destructive potential, however, without identification of a species by a biologist, only generalizations are presented in this thesis.

Despite the wide range of literature available on biodeterioration of cultural heritage materials, it is also recognized that inadequate research limits our understanding of the many species of biodeteriogens that are encountered on historic structures.[1] Furthermore, laboratory analyses are not always representative of the climatic and biological conditions a building may experience in situ. While preventive measures are frequently implemented to control RH, temperature, ventilation, and pest control in interior environments, addressing microbial colonization in exterior environments is far more complicated. The investigation of biodeterioration requires the identification and/or analysis of the following components: the species of organism, mineral constituents and microstructure of the substrate, environmental conditions, and behavior of the species over a given period of time. At *Las Pozas*, this process is essential for every structure that is to be preserved due to the prevalence of microclimates and variability of concrete mixtures. With the exception of higher plants, which are clearly deteriogens due to the irreversible mechanical damage they induce on concrete surfaces, the role that micro-biogrowth plays at the

1 Biodeterioration of cultural heritage materials is commonly analyzed in controlled laboratories with simulated environmental conditions. While this has revealed a great deal about the destructive potential of various biodeteriogens, it is recognized that knowledge of certain biodeteriogens is needed. (Sources: Cassar 2001, Urzi and De Leo 2001, Herrera and Videla 2004, Caneva et al. 2008).

Stairway to the Sky requires a closer examination. While biological colonization may be responsible for the physical and/or chemical deterioration of the structure, it is possible that repeated removal of biogrowth, with consequential damage to the concrete substrate, is damaging to the concrete in the long term since the biogrowth will recolonize the substrate within a short period after removal.

This chapter will examine various organisms associated with biodeterioration of concrete in warm and hot humid environments, and explore their implications at *Stairway to the Sky*. The predominant species observed colonizing the structure—green algal, black fungal and lichens, are not entirely representative of the myriad of organisms encountered at *Las Pozas*. Therefore, biogrowth should be approached as it relates to an individual structure constructed from unique materials and experiencing varying environmental conditions.

BIODETERIORATION IN WARM-HUMID ENVIRONMENTS: AN OVERVIEW

Biodeterioration is defined by H. J. Hueck as "any undesirable change in the properties of a material caused by the vital activities of organisms."[2] The process occurs when an organism colonizes a substrate, which acts as a food source or physical support, and subsequently physically and/or chemically alters it. Characterized by macroorganisms (i.e. higher plants, birds, insects, lichens, mosses, algae), and microorganisms (i.e. bacteria, cyanobacteria, fungi), biogrowth is visible when it colonizes the surface of the material (epilithic), or when concealed within the material's pores (endolithic).

Both micro and macroorganisms may cause physical and/or chemical damage of a substrate. Mechanical damage results from the growth or movement of an organism's structural parts (i.e. roots, hyphae, rhizines, rhizoids) as they cause

2 Caneva, Guilia et al. *Plant Biology for Cultural Heritage: Biodeterioration and Conservation*, (Los Angeles: The Getty Conservation Institute, 2008), 15.

microcracks, cracks, and in more severe cases, spalling of the substrate. Various organisms use the pores of a material or irregular surfaces for anchorage, while others form biofilms that allow them to adhere to a substrate. Chemical deterioration occurs from the inorganic and organic acids released in the metabolic processes of organisms. These byproducts can break down the stable composition of a substrate material and cause deterioration. Finally, biogrowth is not only associated with altering the physical composition of the material, but it can change the appearance of a building by staining its surface with the production of biogenic pigments.[3]

Organisms are also divided into two categories based on their ability to produce their own food. Heterotrophs consume and decompose the organic elements of a substrate, while autotrophs require other sources for their survival, such as sunlight and carbon.[4] Both autotrophs and heterotrophs can live autonomously or in a community, however it is rare to find microorganisms living in isolation.[5] At *Las Pozas*, it is not uncommon to find a variety of organisms colonizing a surface, some surviving off of another organism and/or its byproducts, or simply consuming nutrients present in the substrate material. In addition to the nutrients required for their survival, organisms operate under environmental conditions that vary according to each species. Listed below are specific environmental factors that support microbial activity in warm-humid environments.

Water and Atmospheric Moisture

Moist environments sustain numerous species of microorganisms. At *Las Pozas*, high levels of relative humidity, rainfall, water run-off and capillary rise from moisture retained in soil are possible sources of liquid water and water vapor penetration into concrete materials. In the case of capillary rise from the soil, this

3 Crispim and Gaylarde, *Cyanobacteria and Biodeterioration,* 1.

4 Microorganisms such as algae and cyanobacteria require a carbon source, which is derived from carbon dioxide in the atmosphere, and sunlight to carry out photosynthesis. In addition to water, hospitable environmental conditions, sunlight, and a carbon source, photosynthetic autotrophic organisms only need these elements to survive (Source: Gaylarde, 344).

5 Caneva et al. *Plant Biology for Cultural Heritage,* 65.

FIGURE 11: BLACK FUNGAL BIOGROWTH COLONIZE SHADED SURFACES OF *STAIRWAY TO THE SKY*. *SOURCE: AUTHOR, 2010.*

FIGURE 12: THE STRUCTURE'S CURRENT APPEARANCE AFTER DECADES OF EXPOSURE TO THE DAMP *HUASTECAN* ENVIRONMENT. *SOURCE: AUTHOR, 2010.*

may facilitate the entry of microorganisms living in the soil into the material. Liquid water may collect in the concrete pores after rainfall, and adsorbed water vapor may become liquid water in pores if environmental conditions (i.e. temperature and prevalence of atmospheric moisture) are favorable. Numerous studies show that high relative humidity levels, generally between 60-98% (typical of warm and hot-humid environments) best support the biodeterioration of concrete,[6] and therefore high relative humidity levels at *Las Pozas* and high levels of precipitation support the moist conditions needed to support various species of organisms.

Sunlight

Sunlight is needed to carry out photosynthesis for higher plants and various species of bacteria and fungi, however, it may also be beneficial in preventing biological colonization by evaporating damp surfaces at a faster rate. At *Las Pozas*, organisms mostly colonize areas where sunlight exposure is minimal, yet some structures display biological colonization on concrete surfaces that are regularly exposed to sunlight during the day. *Stairway to the Sky* displays biogrowth in both shaded and sunny surfaces, however it is more prominent on surfaces shielded from sunlight (e.g. under the stair treads, or on areas of columns that are shaded for long periods).

Warm temperatures

Although some species develop coping mechanisms that allow them to survive in the absence of water or great fluctuations in temperature, most thrive in environments with warm temperatures.[7] Warm-humid environments are ideal for microbes since freezing temperatures may kill cells, which are primarily composed of water.

Wind

6 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials,* 358.
7 Caneva et al, *Plant Biology for Cultural Heritage*, 142.

Wind may cool the surface temperature of a material if the air temperature is lower than the temperature of the material, or, if moisture in the material evaporates (evaporative cooling). Wind may also transport spores that encourage biological colonization on other surfaces.[8]

Atmospheric pollution

Harmful atmospheric pollutants expose materials to toxic substances such as carbon monoxide (CO), nitrogen oxides (NO_2), and sulfur dioxides (SO_2).. Pollution can be introduced into the material after it is absorbed by some organisms, such as lichens, and accelerate deterioration.

Nutrients available in the material

Materials are often subject to biodeterioration based on their chemical constituents. With the exception of autotrophic microorganisms and various macroorganisms that find nutrients elsewhere, the material serves as a mineral source for many organisms. The constituents of concrete, for example, include calcium, aluminum, and silicon components that act as nutrients for organisms such as nitrifying bacteria.[9] The metabolic processes resulting from the consumption of a substance can subsequently alter the stable composition and cause deterioration.

Surface typology

Porosity and surface texture are important attributes that allow many organisms to find anchorage on a substrate. Both macroorganisms and microorganisms benefit from irregular surfaces, as they are able to insert their structural parts into the pores or other irregularities of the material with greater ease. In the case of microorganisms, porous and irregular surfaces are also preferable for the formation of biofilms.[10]

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8 Caneva et al, *Plant Biology for Cultural Heritage,* 49.

9 Gaylarde, "Microbial impact on building materials: an overview." *Materials and Structures* 36 (June 2003): 344.

10 Caneva et al. *Plant Biology for Cultural Heritage,* 19.

BIODETERIORATION OF CONCRETE

Concrete composition and susceptibility to biodeterioration

To determine the susceptibility of concrete to biodeterioration, an understanding of the composition of the material, which includes its petrographic structure, chemical makeup, and mineralogical properties, must be established. Concrete is composed of a mixture of binders (portland cement, natural cements, and possibly lime or fly ash), fine and coarse aggregates (e.g. sand, stones), and water. Sometimes an additive, such as gypsum, is used to slow the hydration of the mixture. The type of aggregate determines a portion of the mineralogical composition of the concrete. Common aggregate contains quartz, micas, and feldspars, indicating a predominance of silica, potassium, sodium, and/or calcium. The use of Portland cement, pulverized fly ash, or blast-furnace slag as an aggregate will also affect the chemical makeup of the concrete mixture, introducing even greater quantities of the same minerals, as well as alumina, iron, and/or gypsum.[11]

Although a variety of substances are used in concrete, calcium, silicon, and aluminum are primary constituents, and are assumed components in this evaluation. Portland cement, which is repeatedly cited as a component used in the construction of *Las Pozas*,[12] is composed of 20-25% silica, 5-12% iron oxide and alumina, and 60-65% lime in its raw form.[13] When hydrated with water, a complex interaction occurs between the binder and aggregate involving the dissolution of calcium, sodium and potassium hydroxides, forming a solid mass of primarily calcium carbonate ($CaCO_3$).[14] The resulting material will maintain a pH of 12-13.5[15] and provide a high alkaline environment that is hostile to most organisms but protective to the ferrous

11 MacDonald, *Concrete Building Pathology*, 3.

12 Conversations with workers involved in the construction of *Las Pozas* have explained that portland cement was used as a binder. Also, original documents (including notes from the Gastelums and Edward James) from the Edward James Archive at West Dean College confirm cement was used in construction, but do not specify which type.

13 Matero, 2009.

14 MacDonald, *Concrete Building Pathology*, 142.

15 *Ibid.* 142.

reinforcement.[16] However, as the alkalinity of concrete naturally decreases over time, the surface will become more vulnerable to biological colonization. Furthermore, biogrowth is capable of lowering pH levels of concrete after colonizing the material, increasing the threat of reinforcement corrosion.

Susceptibility to mechanical deterioration

The growth and/or movement of organisms can generate mechanical deterioration of concrete by causing micro-cracks and fissures in the concrete surface. This appears to be most destructive at *Las Pozas* due to the colonization of higher plants. By providing new openings for the ingress of water and chloride or other deleterious ions, mechanical deterioration of concrete can be highly destructive and even threaten structural stability (i.e. its load carrying capacity) due to fracture or by accelerating reinforcement corrosion.[17]

New openings in the material become spaces for microorganisms to enter and remain undetected. Some species produce soluble salts in their byproducts, a process which not only causes the chemical deterioration of the material, but also enters the pores when dissolved, recrystalizes, and causes mechanical damage on a micro-level within the concrete's pores.[18]

Susceptibility to chemical deterioration

Concrete is subject to chemical deterioration based on the metabolic processes of an organism as it reacts with the properties of the material. Mineral salts, calcium, aluminum, iron, and silicon, provide nutrients to certain organisms, making it vulnerable to chemical attack.[19] This is referred to as acidolysis, a process that occurs as a reaction between molecules from a substrate and inorganic and organic

16 This excludes "alkalinophilic" organisms, which can survive with pH levels of 9-11. (Source: Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials*, 359).
17 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials*, 359.
18 Kumar and Kumar, *Biodeterioration of Stone in Tropical Environments*, 12.
19 Caneva et al. *Plant Biology for Cultural Heritage,* 16.

acids released by the organism. A new product may occur from this interaction, such as soluble salts, which adsorb within the pores of the material in the presence of atmospheric moisture or water and pose the threat of mechanical deterioration after recrystallization.[20] A number of deleterious substances can occur as byproducts of organisms, which will be further explained based on their relationship to reinforced concrete.

ORGANISMS ASSOCIATED WITH BIODETERIORATION OF CONCRETE

Bacteria

Bacteria thrive under favorable environmental conditions where there is available oxygen and water.[21] One of the most prolific types of bacteria known to affect concrete is of the species Thiobacillus,[22] which are frequently encountered in warm environments and sewers. Thiobacilli are associated with biogenic sulphuric acid corrosion (BSA), a destructive process in which sulphur is converted into sulphuric acid, forming gypsum after reacting with calcium hydroxide (CH) in concrete. Calcium aluminate hydrate (C_3A) may react with the gypsum to form ettringite, which causes volume expansion, internal pressure, and eventual material failure.[23] Over sixty types of bacteria have been linked to the colonization of concrete, many of which require pH levels of 9-9.5 for survival.[24] However, the colonization of concrete by bacteria is often successive, and when one species lowers pH levels with its byproducts and dies, the material is open to the colonization of another species.[25] Bacteria are not only encountered on concrete surfaces, but also within the pores as well after being introduced by means of capillary rise.[26] Bacteria colonize surfaces

20 Caneva et al. *Plant Biology for Cultural Heritage,* 21.
21 *Ibid.* 64-65.
22 Sanchezi-Silva and Rosowsky, *Biodeterioration of Construction Materials,* 360.
23 De Balie, *Microorganisms vs. Stony materials: a love hate relationship*, 2.
24 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials*, 359.
25 *Ibid*. 360.
26 Caneva et al. *Plant Biology for Cultural Heritage,* 132; Sanchez-Silva and Rosowsky, *Biodeterioration*

with an availability of water, oxygen, and appropriate temperatures required by each species.[27] Light is an additional factor that is needed for autotrophic bacteria (e.g. sulphur-oxidizing, nitrifying, hydrogen, iron).[28]

In tropical environments, three species of bacteria have been linked to the biodeterioration of limestone and sandstone—chemoautotrophic sulfur-oxidizing and nitrifying bacteria, heterotrophic bacteria, and photoautotrophic bacteria.29 A comparison of concrete and these stones (based on physical and chemical properties) should be included in the evaluation of bacterial biodeterioration at *Las Pozas* after future analyses are performed. Specific heterotrophic bacteria associated with biodeterioration of concrete are proteolytic, cellulolytic, amylolytic, lipolytic, and dentrifying.[30] Various species of heterotrophic bacteria can change the appearance of the material, or produce chelating biogenic acids.[31] Bacteria linked to the production of nitric and sulfuric acids are nitrifying and sulfur-oxidizing. Nitrifying bacteria solubilize the calcium component of a concrete surface by producing nitric acid, which reacts with calcium to form a soluble calcium nitrate.[32] Sulfur-oxidizing bacteria attack sulfur and produce sulfuric acid, which can lead to the formation of gypsum ($CaSO_4$). According to Sanchez-Silva and Rosowsky, this may act as a "protective" coating if it is not removed,[33] but may also cause mechanical damage if it recrystalizes after entering the pores of the material.[34] Not all bacteria, however, are considered harmful. In some cases, they have been used as mechanisms to protect limestone and cementitious materials, such as in the use of carbonate precipitation for consolidation purposes.[35]

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of Construction Materials, 360.

27 Caneva et al. *Plant Biology for Cultural Heritage,* 65.

28 *Ibid. 65.*

29 Kumar, and Kumar, *Biodeterioration of Stone,* 14.

30 Caneva et al. *Plant Biology for Cultural Heritage,* 64-65.

31 Kumar and Kumar, *Biodeterioration of Stone,* 15.

32 Gaylarde, "Microbial impact on building materials: an overview," *Materials and Structures* (June 2003): 344; Giannantonio et al, "Molecular characterizations of microbial communities fouling painted and unpainted concrete structures," *International Biodeterioration and Biodegradation* (2009): 30.

33 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials,* 360.

34 Kumar and Kumar, *Biodeterioration of Stone,* 14.

35 De Belie, *Microorganisms vs..Stony materials: a love hate relationship*, 3.

Fungi

Fungi are heterotrophic organisms that require organic nutrients for survival.[36] Types of fungi specifically association with biodeterioration of concrete include cladosporium, phoma leveillei, and trichoderma citrinoviride.[37] Fungal colonization can cause varying degrees of deterioration of concrete, which are often dependant on mineral constituents of the material. For example, sand containing Silicon Dioxide (SiO_2) has been linked to rigorous deterioration of cementitious materials with voids of 1 mm observed after only a one and a half year exposure to fungi.[38] Fungal vegetative parts, known as mycelia, are composed of branching hyphae that have been linked to the mechanical deterioration of cementitious materials by penetrating hyphae into portland cement grains.[39] Mineralogical changes have also been associated with fungal colonization of portland cement-based materials, as the organism's byproducts react with calcic constituents (i.e. calcium carbonate, portlandite) or other siliceous products in the material (i.e. quartz, mica).[40]

Lichens

Lichens are ubiquitous on concrete at *Las Pozas*, and were observed primarily colonizing vertical surfaces at *Stairway to the Sky*. There are over 13,000 types of lichens in existence today, many of which survive in extreme environments and can survive long periods without water.[41] Lichens are organisms that live in symbiosis

36 Kumar and Kumar, *Biodeterioration of Stone*, 16.

37 Giannantonio, David J. et al. "Molecular characterizations of microbial communities fouling painted and unpainted concrete structures," *International Biodeterioration and Biodegradation* (2009): 30.

38 Kondratyeva, A., A. A. Gorbushina, and A.I. Boikova, "Biodeterioration of Construction Materials," *Glass, Physics & Chemistry* 22, no. 2 (2006): 255-256. In this laboratory-based experiment, SEM and X-ray analyses were used to observe mineralogical and mechanical deterioration by fungal mycelium on samples of industrial portland cement clinkers with varying chemical properties. No visible changes occurred over short periods of time (2-3 months). However, samples with SiO_2 and were susceptible to fungal deterioration with visible voids of 1 mm after a 1.5 year exposure to fungi. Other hydrated cements without SiO_2 were susceptible to fungal attack after longer periods of time (approximately 2.5 years).

39 Kondratyeva, Gorbushina, and Boikova, "Biodeterioration of Construction Materials," *Glass, Physics & Chemistry (2006)*: 255.

40 *Ibid. 255.*

41 Some species of lichens are pokilohydric, meaning they can survive for periods without water due to their cryptobiosis, or ability to maintain a dormant metabolism. Source: Caneva et al. *Plant Biology for Cultural Heritage*, 80.

with a fungus and either cyanobacteria or chlorophyta.[42] They are categorized as crustose, foliose, fruticose, and squamulose based on their structural form, and more than half of contain a thallus and hyphae (located at the base of the thallus), which allows it to adhere to a substrate. Lichens are one species that have been studied as a potential protective barrier for substrates, such as from driving rain,[43] and recently there has been an increasing concern over their removal as it may accelerate deterioration in some materials.[44]

Algae

Algae need damp conditions, warm temperatures and sunlight.[45] Similar to fungi, algae can penetrate the material's cracks or pores and enlarge the size of an existent micro-crack or crack.[46] Algae are known to colonize irregular surfaces, making a material's surface texture and porosity significant properties in the potential biological colonization of a material.[47] Algae are also believed to prefer alkaline surfaces,[48] and diatom algae are the most common type that colonizes concrete.[49] The species chlorophyceae is associated with biodeterioration of concrete.[50]

Cyanobacteria

Cyanobacteria have been linked to both the physical and chemical deterioration of carbonate rocks,[51] and are also directly linked to the biodeterioration of concrete.[52] They are characterized by a slimy outer layer that adsorbs minerals, such as clay,

42 Kumar and Kumar, *Biodeterioration of Stone*, 20.
43 Caneva et al., *Plant Biology for Cultural Heritage,* 16.
44 Artioli, *Scientific Methods and Cultural Heritage,* 162
45 Kumar and Kumar, *Biodeterioration of Stone*, 18.
46 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials,* 361.
47 Caneva et al., *Plant Biology for Cultural Heritage,* 71.
48 Kumar and Kumar, *Biodeterioration of Stone*, 18.
49 Sanchez-Silva and Rosowsky, *Biodeterioration of Construction Materials,* 360.
50 Giannantonio et al, "Molecular characterizations of microbial communities fouling painted and unpainted concrete structures," *International Biodeterioration and Biodegradation* 63 (2009): 30.
51 Kumar and Kumar, *Biodeterioration of Stone in Tropical Environments,* 15.
52 Giannantonio et al., "Molecular characterizations of microbial communities fouling painted and unpainted concrete structures." *International Biodeterioration and Biodegradation*: 30.

quartz, calcium carbonate, or byproducts of other organisms.[53] Cyanobacteria are also linked to the colonization of bacteria and fungi since they can serve as the nutrient source.[54]

BIODETERIORATION OF CONRETE AT STAIRWAY TO THE SKY

Species previously observed at *Stairway to the Sky* include lichen, as well as black fungal and green algal species. Currently, there is no link between the mineral constituents in the material that may serve as mineral sources for the organisms. It is likely that aggregates in the concrete mixes of different structures at *Las Pozas* will vary since the structures were made during different periods. Some sculptures contain a bluish-colored sedimentary stone, similar to a stone found in the Huichihuayán River running through *Las Pozas*, which suggests stones were sometimes taken from the river, crushed, and used as aggregate in concrete mixtures. On the *Stairway to the Sky*, however, the aggregate is more difficult to observe, and the filler may have been commercially quarried or merely taken from the river. Since the sources of the materials are unknown, analyses of the material's mineral constituents are needed to determine its susceptibility to colonization by various species of fungi, bacteria, cyanobacteria, lichens and algae. Also, evidence of concrete deterioration is seen in the spalls, corroded rebar, and exposed aggregate at *Stairway to the Sky*, suggesting the alkalinity of the material has decreased over time. If this is the case, the concrete may be more vulnerable to biological attack by organisms that survive under conditions of low pH levels, which may exclude most alkalinophilic types from future analyses.

Exposed concrete, surfaces with a parge, and pigmented cement coatings

Stairway to the Sky is comprised of exposed concrete and some surfaces

53 Kumar and Kumar, *Biodeterioration of Stone,* 15.
54 *Ibid,* 16.

contain a parge. Horizontal surfaces of the concrete stair treads display a white parge that was applied in a circular pattern. The columns also contain visible traces of a parge, however, many of the areas are deteriorated and display exposed aggregate. The surface typology of the exposed concrete exhibits a higher porosity than that of the parge that has been applied to the stairs and columns, and displays a greater presence of black fungal growth inside the material pores. This implies that surfaces of a higher porosity (i.e. exposed concrete) are more susceptible to colonization by some species, such as the observed black fungal type. In other areas of the site, different species were detected on concrete sculptures with pigmented cement coatings of low porosities. This suggests the possible presence of organic pigments in the cementitious coating, which may serve as nutrients for various organisms.

Environmental and Climatic Influences

The dense vegetation that surrounded *Stairway to the Sky* while Edward James lived at *Las Pozas* has been removed. This allows the entire structure, and particularly the third story, to remain exposed to wind, driving rain, and sunlight when there is no cloud cover. Vertical and horizontal surfaces are affected differently by each element. Vertical columns are colonized by different species than horizontal surfaces, and shaded areas that receive less sun exposure (i.e. underneath stair treads, west sides of columns) contain higher concentrations of black fungal biogrowth.

Structural design

Stairway to the Sky exhibits multiple alcoves in sculptural elements that become suitable places for birds to nest. This is a result of the design, which provides numerous curvilinear spaces and niches that support the colonization of microorganisms, plants, insects and birds.

METHODS OF ANALYSIS OF BIOGROWTH

The identification of a colonized species begins with an ecological analysis that is performed in situ with an expert. Most higher plants and macroorganisms are identified this way, but microorganisms generally require additional analyses. This begins with sampling the organism, which may be done with a needle, adhesive tape, swab, or microscalpel or scalpel.55 The sample is subsequently taken to a laboratory to be observed under an optical microscope, which allows the species to be identified based on its structural parts (i.e. hyphae, thalli, uni- or multicellular bodies). If further analyses are required, molecular techniques (DNA or RNA extraction), FISH (Fluorescence In Situ Hybridization), chemical and biochemical testing are methods for identifying organisms.[56] Scanning Electron Microscopy (SEM) is a useful analytical tool that has been used for observing the organism as well as the damage caused to the substrate.[57]

IMPLICATIONS OF INTERVENTIONS FOR THE REMOVAL OF BIOGROWTH AT *STAIRWAY TO THE SKY*

Methods of removing biogrowth from cultural heritage materials include: mechanical removal using scalpels, brushes; bioremoval/biocleaning; or chemical removal. A combination of mechanical and chemical removal may be necessary for higher plants. This can be achieved by applying a small amount of a biocide product to the plant and waiting for the effects of the product to take place, then uprooting the dead plant from the concrete surface using a scalpel or tool. After mechanical removal it may be necessary to patch the concrete as a follow-up procedure if cracking has occurred.

The application of biocide products is the most common method employed to kill biological organisms.[58] However, biocides do not remove the organic material

55 Caneva et al, *Plant Biology for Cultural Heritage*, 349-350.
56 *Ibid. 350.*
57 Kondratyeva, et al.. "Biodeterioration of Construction Materials," *Glass, Physics & Chemistry*: 254.
58 Caneva et al, *Plant Biology for Cultural Heritage,* 318.

left behind on the material and require a cleaning product if removal of the stain is desired. Common 'eco-friendly'[59] biocide products such as Cathedral Stone D2 Biological Solution may leave a surface free from microorganisms up to one year but require period reapplication. In a warm-humid environment such as that of *Las Pozas*, organisms may recolonize around six months or earlier and frequent reapplication of a biocide may be needed due to dilution from rainfall. Methods of applying biocide products include brushing and spraying the product onto the colonized surface, then leaving the product to dry. Spraying is most effective for indoor environments and larger surface areas, while brushing has the tendency to be more effective by penetrating deeper into the material.[60] Poultices made of paper pulp, combined with carboxymethyl cellulose are also used for surfaces that require longer contact with the biocide product, but this method would only be effective in smaller concentrated areas. Sometimes more than one campaign of biocide product is needed, and mockups are employed to determine frequency of campaigns needed to kill organisms. Finally, biocides do not ensure that all microorganisms will be killed—some forms of bacteria may become immune to biocide products, thus making them ineffective.[61]

If biocide products are tested and/or utilized at *Las Pozas*, it is important to consider their potentially harmful effects on the environment. Inorganic biocides include hydrogen peroxide, sodium hypochloride, copper salts, Borax, perborate, and although they are considered effective biocide products, they are used less frequently today. Some countries have prohibited the use of tributal tin oxides, methyl bromide, arsenic, prussic acid, and ethylene oxide due to their extreme toxicity.[62] A final consideration with all biocide products is the potential discoloration of the material. To avoid undesirable changes in the aesthetic appearance of the material, products always require testing before they are applied.

59 Even though many biocide products are advertised as environmentally sustainable, they often contain harmful constituents, albeit in minimal quantities.

60 *Ibid.* 321.

61 *Ibid.* 19.

62 *Ibid.* 321.

CONCLUSION

Biogrowth enhances the aesthetic and artistic value of *Stairway to the Sky*. Historic photographs display the continuous presence of biological organisms on the 40+ year-old structure, suggesting the possibility of it remaining in a stable condition and inflicting relatively minimal damage. If this is the case, an approach that involves non-removal would allow biogrowth to remain in place and allow *Stairway to the Sky* to continue its integration into the surrounding environment. Therefore, a program is needed to identify the species of organisms that presently colonize *Stairway to the Sky*, determine their relationship with concrete, and establish necessary measures for removal or non-removal.

While some species may be responsible for the mechanical and/or chemical deterioration of the material, further analyses are needed to identify organisms. The removal of higher plants is recommended due to the mechanical damage that growth and movement inflicts on the substrate, but this must be done in a way that causes minimal damage to the substrate. Also, the removal of microorganisms and various macroorganisms should not take place until they are identified and their potential as biodeteriogens is determined. Mechanical removal methods employed at *Las Pozas* include dry- and wet-scrubbing biogrowth from concrete surfaces, and it is suggested that this practice be suspended due to the physical damage abrasive action inflicts on the substrate. Over time, this method may cause more damage than the physical and/or mechanical damage caused by a biodeteriogen if it is not removed. The following chapter presents a program that identifies colonized species and analyzes their potential to act as a deteriogen to concrete materials. The program will also address additional threats addressed in Chapter 5 and provide recommendations for the preventive maintenance of *Stairway to the Sky*.

CHAPTER 7 | PRELIMINARY OBJECTIVES AND PREVENTIVE CONSERVATION STRATEGIES

CONSERVATION PHILOSOPHY

Natural decay processes inevitably cause materials and structures to change over time. The conservator's role, however, is to manage appearance, durability and function by intervening after deterioration has occurred and/or preventing deterioration from occurring. A desired appearance, then, can be achieved through the implementation of a conservation program that applies a base knowledge of materials to the intrinsic and extrinsic factors causing aesthetic and physical changes to occur. At *Las Pozas*, nature and James's works possess a contradictory relationship—visually, they enhance one another, but as manmade works are, in essence, transient in nature, their degradation is inevitable. Since physical deterioration of *Stairway to the Sky* is undesired and since a verdant or "soiled" appearance is valued, the stabilization of plant growth on the structure is necessary. Therefore, the proposed conservation approach for *Stairway to the Sky* involves minimal intervention, allowing biogrowth to be stabilized at a threshold that ultimately results in maximal retention of original material integrity. Further testing and analysis must inform the proposed program, so that the delicate balance of threat and integrity can be sustained by preventive maintenance. The proposed program addresses the threats to *Stairway to the Sky* and provides strategies to control, stabilize, or ascertain deterioration caused by the various mechanisms explored in Chapter 5.

PRELIMINARY OBJECTIVES

The proposed program and conservation approach for *Stairway to the Sky* provides emergency intervention strategies, and outlines testing and analyses needed to determine future intervention or non-intervention options. The plan seeks to achieve the following objectives:

- Identify threats that require an immediate response. In cases where advanced deterioration may lead to structural failure, repair or replacement may be necessary.
- Determine causes of reinforcement corrosion and concrete deterioration, as well as methods of quantifying rates of deterioration.
- Provide an overview of testing methods (in situ and laboratory) needed to ascertain concrete composition, quality, variability, conditions, and deterioration mechanisms.
- Design an environmental and material monitoring program to correlate environmental conditions to concrete conditions and possible deterioration mechanisms.
- Develop biodeterioration monitoring program to compare the efficacy of removal and non-removal.
- Establish long-term maintenance strategies.
- Develop training program for site staff that includes appropriate maintenance and repair methods for *Stairway to the Sky*.

EMERGENCY INTERVENTIONS

Crack Repairs

Emergency repair methods include repairs to seal openings and cracks that facilitate the ingress of water and other substances. In cases where a detached spall has exposed reinforcement, immediate repair is necessary and requires the removal of failed material and replacement with compatible patching material.

Typical products employed in concrete repairs include epoxies, grouts (which has been used in the past for crack repairs at *Las Pozas*), and polyurethane resin. High quality materials and good workmanship (i.e. mixing, handling) is also a necessity. Color matching concrete repairs maintains a unified appearance of the surface, but due to the overall dissimilarity of the surface of the structure, color matching will achieve a unified appearance of the already soiled concrete surface. Therefore, performance and durability is recommended as a first priority, and color matching is recommended if it complements the appearance of a surface.

Tree Branch Trimming

Weekly inspections of the surrounding environment are performed to detect immediate threats from branches, trees, or other objects that appear unstable in the environment (i.e. nearby structures, architectural elements from *Edward James's House*). If threats are present in the environment, branch trimming is needed. In the case of a forecasted hurricane or tropical storm, it is necessary to carry out a thorough inspection of the surrounding environment beforehand as a preventive measure. While branch trimming is recommended, vegetation removal should be minimal and should not detract from the density of the landscape unless necessary.

Plant Removal

Removing colonized plants from the structure is necessary to avoid further damage inflicted by plant growth. The removal of larger plants involves applying biocide solution to the plant to kill it, followed by careful removal of the plant itself. It is possible that uprooting the plant may cause micro-cracking, cracking, and/or spalling of the concrete surface. In this case, patch repairs are needed to close all openings of the surface. Bird nests should also be removed. If niches in the sculptural columns are recurrent nesting areas, clear netting can be placed around these areas as a preventive measure.

Closure of Fragile Structural Elements

Access to fragile architectural elements, notably the elevated concrete pathways uniting *Stairway to the Sky*'s columns and *Stairway to the Sky* to *Edward James's House*, should be closed from the public as a safety measure. This will prevent accidents from occurring, as well as eliminating live loads due to visitation. Closing the concrete pathways will detract from the visitor 'experience' since the structure was meant to be interacted with, however, the site must also be treated within today's context as a cultural heritage site that receives thousands of visitors a year. A structural assessment should be conducted to identify specific architectural elements at *Stairway to the Sky* that are susceptible to overloading and vibration, and may need to be closed to the public.

Monitoring for water run-off and drainage

Stairway to the Sky should be inspected for areas of heavy water run-off (notably from projecting architectural features and vegetation) or areas where water collects and does not drain from the roof of the structure. These areas may contain eroded parge coatings, exposed aggregate or greater concentrations of biogrowth. *Stairway to the Sky* should be observed both during and after rainfall, and then compared with a visual examination of the structure after it has dried, with a focus on inconsistencies in the material where water collects and does not properly drain, or receives heavier water run-off. Interventions might include the installation of discrete gutters, drains, or creating an artificial slope on the ground to deter water from collecting on these areas. This is followed by an inspection of the efficacy of the intervention to make sure it does not concentrate water run-off onto other architectural features.

IDENTIFYING THE ENABLING FACTORS OF REINFORCEMENT CORROSION

A conditions assessment addresses identifiable conditions and ultimately determines areas where further testing is needed. Conditions observed at *Stairway to the Sky* may be a result of environmental conditions, flaws in design and construction, and/or human threats, however the causative factors these conditions (i.e. cracks, spalls, popouts, corroded rebar) are confirmed after scientific analyses. Listed below are various methods that can be used to determine the causes of reinforcement corrosion, including tests for carbonation, chloride ion content, the presence of sulfates, and ASR. Nondestructive testing methods, although more costly, are preferred due to the minimal damage inflicted on the structure.

Structural Condition Assessment

First, the background information is collected relating to the building's history, including previous uses, design and construction methods, materials, and previous repairs. A condition assessment is then performed in situ to identify nature of loading, material finishes, physical properties, and conditions (i.e. visible signs of deterioration or distortion). Photographic recording of conditions and previous interventions are placed into a "condition glossary" to be used for future reference. Data from the field is then collected and mapped by tracing conditions on plastic sheets overlaid onto photographs or by using Geographic Information Systems (GIS), after which they are examined and linked to potential deterioration mechanisms. Condition mapping is a particularly useful method in identifying deterioration patterns and later correlated to data collected from an environmental monitoring program. Also, nondestructive testing (NDT) is increasingly used today in the appraisal of concrete buildings. NDT methods are preferred because they do not require the removal of materials, however, they are often expensive and require a skilled practitioner to interpret results. Common nondestructive testing methods include visual inspection, ultrasonic pulse velocity, radiographics (x-ray or gamma ray penetration), and ultrasonic pulse-echo. Ultrasonic pulse velocity is one of the most popular NDT methods used to identify inert concrete pathologies that are unidentifiable with a visual examination.

Petrographic Analysis

Petrographic analyses determine the concrete microstructure, composition, and recognizable changes that have occurred over time, providing a more in-depth analysis of material defects that a structural appraisal does not address. Petrographic analyses involve the visual examination of the microstructure and typology of the sample under a light optical microscope by a petrographer; it is common to find the microscopic analysis accompanied by additional analytical methods such as scanning electron microscopy (SEM), x-ray diffraction (XRD), and "wet" chemical analyses. A petrographic analysis is the first recommended procedure needed for *Stairway to the Sky* to determine what type of concrete material is present and the conditions is currently is subjected to, ultimately determining the presence of ASR, water/cement ratio, and quality of aggregate used in the original mix. The petrographic analysis is comprised of the following procedures:

I. *Sampling*. Samples must be taken from the structure to bring to a laboratory for a petrographic analysis to be performed. Three core samples, approximately 10 cm in diameter by 20 cm in depth are recommended.[1]

II. *Thin sections*. A petrographer creates thin sections from concrete samples. Thin sections should be polished to 25-26 μm, and left un-coverslipped.

III. *Petrographic Examination*. Thin sections are observed for visible signs of deterioration, as well as observations of mineralogical composition. Alkali-silica reaction is usually identifiable with a microscopic analysis due to the silica formations within the material cracks.[2]

In Situ Testing Methods for Carbonation and Chloride Attack.

A depth of carbonation test determines if carbonation has occurred in the concrete and can be performed in a petrographic analysis or in situ by spraying a freshly exposed concrete surface with a low percentage (approximately 1%) solution of phenolphthalein. If alkaline levels are high, the solution will change a pink color, but if pH levels are low, the solution will not change color; color change should be observed to determine rate of change as well as the movement of the

1 Walker, Hollis N., D. Stephen Lane, and Paul E. Stutzman. *Petrographic Methods of Examining Hardened Concrete: A Petrographic Manua*l, Revised 2004. Revised Manual, (Charlottesville: Virginia Transportation Research Council, 2006): 247

2 Additional tests used to identify ASR in concrete include chemical analyses: ASTM Test Method for Potential Alkali Reactivity (C 227) and ASTM Test Method for Potential Reactivity of Aggregates (C 289). Stark, David, "Alkali-Silica Reactions in Concrete," *Significance of Tests and Properties of Concrete and Concrete Materials:* 367.

solution to carbonation fronts.[3] Methods of treating carbonated concrete include full replacement with new material. Due to the invasive procedure involved in the phenolphthalein analysis, it is recommended that carbonation tests be performed with the core samples taken during the petrographic analysis.

Chloride content must also be measured to determine the presence of chloride ions. Chloride ion content below 0.4% (Chloride Ion Content by Wt. Cement) does not pose a risk to reinforcement corrosion, however between 0.4-1.0% and above 1.0% indicates a high risk of corrosion induced by chloride ions. Testing chloride content may be performed in situ with chloride test kits, or in a laboratory following a testing method (i.e. ASTM C1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration"; ASTM C1152/ C1152M "Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete). In the case that chloride is present, salt extraction is needed and can be achieved through electrochemical chloride extraction, which extracts chloride ions without altering the concrete matrix.

BIODETERIORATION MONITORING

Central to the conservation approach for *Stairway to the Sky* is a biodeterioration monitoring program, which determines options for intervention and/or non-intervention. Historic photographs of *Stairway to the Sky* display the structure colonized by biological growth for decades now, suggesting the perseverance of this condition on the structure and also the possibility that it remains in a stable condition. The objective of the biodeterioration program is to determine which organisms are

3 "Current practice sheet no. 131: Measuring the depth of carbonation," Jan. 2003 http://findarticles.com/p/articles/mi_qa5379/is_200301/ai_n21325892/

present, if they are deleterious to concrete and cementitious materials, and test the efficacy of biocide treatments. If identified species are deleterious, growth rate and penetration into the material must be quantified. Should any biocide treatments be considered for future use, it is important that they are environmentally sustainable and do not contaminate the environment, and they do not support the colonization of another species. The program involves the following testing methods:

1. Species identification

The program begins with the identification of macro and microorganisms, performed in situ with a biological specialist. This is necessary to identify the species present, since the warm-humid *Huastecan* climate fosters a multitude of biological organisms. A visual examination will allow the identification of macroorganisms, however, further testing may be required for microorganisms. Samples should be collected with a clean, sterilized needle, swab, adhesive tape, microscalpel, or scalpel,[4] suspended in paraformaldehyde or glutaraldehyde,[5] and brought to a laboratory, where structural parts are first observed through microscopic analyses. Additional analyses—RNA or DNA extraction, FISH (Fluorescence In Situ Hybridization), or chemical and biochemical testing will be necessary to identify some organisms. The method of analysis used to identify the species must be established before sampling so that the proper sampling technique is employed (i.e. DNA extraction requires a larger samples, which is best achieved with a scalpel).[6] After species are identified, their potential to act as biodeteriogens can be evaluated.

2. Monitoring biodeterioration using scanning electron microscopy (SEM) and X-ray powder diffraction (XRD)

4 Caneva et al, *Plant Biology for Cultural Heritage,* 348-49.
5 *Ibid*. 353.
6 *Ibid*. 348-49.

Species identification should be coordinated with SEM/ XRD analyses of the substrate so that any synergistic aspects between the material's physical and chemical properties and the organism can be identified. Although it is a more costly analytical method, SEM can classify a wide range of surficial traits related to biodeterioration of concrete, including mechanical damage inflicted from the penetration of hyphae and roots into the material surface. Scanning electron microscopes emit a beam of electrons that moves across the material surface in a raster pattern, producing high quality, three-dimensional images of the substrate.[7] X-ray powder diffraction (XRD) is often used in conjunction with SEM when monitoring damage inflicted on concrete from various species of biological organisms, providing a quantitative and qualitative chemical analysis of the substrate. Both analytical techniques are will be used to determine mechanical and chemical damage inflicted on a substrate by biological organisms.[8] The proposed SEM/XRD analysis at *Stairway to the Sky* includes the following procedures:

I. *Sampling*. Biocolonized concrete is sampled from the structure. This might include areas where black fungal biogrowth is ubiquitous, or surfaces colonized by lichen or algae. It is important to sample the biological organism is in contact with the concrete surface, and target a species that has been identified. An added benefit to SEM/ XRD is that small samples will suffice.

II. *SEM and image analysis*. Samples are examined with a scanning electron microscope. High-resolution images are subsequently analyzed for mechanical damage inflicted on the substrate, or colonization within the material pores.

7 Stutzman, Paul E. "Applications of Scanning Electron Microscopy in Cement and Concrete Materials." *Petrography of Cementitious Materials*, 74-75.

8 Ibid. 75; Kondratyeva, "Biodeterioration of Construction Materials," *Glass, Physics & Chemistry*, 254.

III. *XRD analysis*. The use of X-ray analysis will provide a quantitative and qualitative analysis of chemical changes in the sample as it may relate to biodeterioration.

IV. *Documentation of observations*. After SEM/XRD testing methods are performed, results should be documented and kept in a database for future reference. These analyses may be consulted in future biodeterioration monitoring programs executed on *Stairway to the Sky* or other structures.

3. Determining efficacy of biocide products

Biocide products are often, but not always, effective in preventing biocolonization. Selective response to biocide treatments is possible, so a variety of eco-friendly biocides should be tested and predicated on the identification of deleterious species observed in previous analyses. Growth rates are crucial parameters that will determine the efficacy of biocides on deleterious organisms based on method of application, quantity of biocide applied, and frequency of application treatments. If frequent application is needed to deter biological colonization, then non-removal may be the better option. The program will accomplish the following objectives:

- Establish application method of biocides for *Stairway to the Sky*, including number of campaigns needed.
- Determine the efficacy of eco-friendly biocide treatments on different organisms associated with biodeterioration of concrete. Species targeted were identified in Steps 1-2 and are based on mechanical and/or chemical damage inflicted on concrete surfaces.
- Create monitoring program to determine rate of recolonization after biocide

product is applied. This pertains to pilot areas of the structure chosen as illustrative areas of biological colonization.

- Monitor colonization by additional species after biocide treatments are used to target an identified species.

The following methodology will be used to accomplish the abovementioned objectives:

I. *Determine most effective method of application of biocides.*[9]

Areas demonstrating heavy biocolonization are targeted for pilot testing. A durable tape is used to delineate eight one-foot square areas of the concrete surface. Methods of application—spraying and brushing—are tested on separate pilot areas.

Brush application: Four pilot areas are chosen for the brush-application method. An eco-friendly biocide product, such as Cathedral Stone® D/2 Biological Solution is applied to each dry surface with a non-metallic brush. After one application, the product is left 2-5 minutes. A second application of biocide is administered to the surface and left to dry, about 5-10 minutes. The amount of time the biocide is left on the surface must be documented each time. After the second application, a brush and water are used to remove biogrowth from only one of the pilot test areas at this time. Special attention to the removal of granular particles from the concrete surface should be observed at this time since scrubbing action is likely to remove particles of the material. The additional pilot test areas

9 Specifications for D/2 Biocidal solution application were used as a reference for the following program. See Appendix F for a copy of datasheets and specifications for the product.

will receive a third application of biocide, which will be left on the surface for 10 minutes, after which it will be removed with water and a brush. The third pilot test area will receive a third cycle of biocide and the fourth pilot areas will receive a fourth cycle. After all cycles are completed, observations are made on the immediate effects of the treatment.

Application by spraying: A low-pressure washer is needed of psi 300-600 is used for three pilot test areas of the same shape and size. The same procedure will take place as the brush-application method with four pilot test areas, with four cycles applied to the fourth test area.

SEM follow-up analysis: After treatments are applied, it is necessary to view the surface for physical damage inflicted by scrubbing action. SEM can be used to detect visible physical changes to the surface. Small samples are required and taken from the pilot test area. If physical damage has greatly changed the concrete surface, then its is likely that biocide treatments will not be part of biogrowth management strategy.

II. *Efficacy of eco-friendly biocide treatments on different organisms.*

It is necessary to test for the efficacy of biocide treatments on various species of organisms since selective response is possible. The abovementioned procedure will target a predetermined organism that is considered deleterious after SEM/XRD analysis.

III. *Growth rate after biocide product is applied.*

After biocide treatments are applied, the surface must be monitored over an extended period of time to determine growth rate. This is important in determining the frequency of reapplying biocide products and the damage inflicted by scrubbing action. After biocide products are applied, pilot areas must be observed in situ every month visible signs of recolonization. Special attention to colonization by additional species should also take place at this time.

IV. Use of proxies to observe damage.

Due to the invasive damage that would result from sampling *Stairway to the Sky* after biocide treatments, proxies can be used to observe changes that occur to new concrete. This might reflect the conditions a patch repair might experience. Although proxies do not represent the same conditions experienced by the structure because they have not been subjected to the same environmental conditions for extended periods of time, they may provide useful information regarding the damage inflicted to the concrete surface by various organisms. Proxies are left outside if areas inaccessible to the public over the course of one year. It is recommended that more than additional proxies be left for more than one year and observed at a later date. Proxies will not receive biocide treatment and will solely be left exposed to the environment. After one year, they are removed and changes observed.

4. Environmental monitoring

Since the majority of material deterioration problems at *Las Pozas* are probably linked to the environment and presence of water, environmental monitoring is needed to quantify environmental conditions.

I. Installation of weather stations. Weatherproof HOBO Micro Station Data Logger or HOBO U/30 NRC Data Logging Weather Station can be used to collect the following data: relative humidity levels, temperature, rainfall, wind speed, solar radiation, surface temperature, and photosynthetic light.[10] Weather stations are battery-operated and should be installed on locations that best illustrate environmental conditions supporting biological colonization, preferably in close proximity to pilot testing areas. It is imperative that micro stations are inaccessible to the public and are not tampered with. Environmental data is collected over the course of one year, interpreted with HOBOware Pro software, which reads data collected from the weather stations. Data is interpreted to ascertain the presence or absence of various deterioration mechanisms, such as freeze-thaw cycles. The collection of environmental data is particularly useful in the monitoring of biodeterioration by determining RH levels, temperature, wind speed, and wind direction, all of which are attributed to the colonization of various biological organisms.

WEEKLY MONITORING CAMPAIGNS

Regular inspection of the structure is recommended with special attention paid to the colonization of plants and additional threats from the surrounding environment.

10 http://www.onsetcomp.com/

TRAINING PROGRAMS

Repeatedly, heritage sites experience a disjuncture between regular maintenance staff and management, emphasizing the need to inform staff about the appropriate procedures for concrete repair and maintenance. Through workshops and training programs, *Las Pozas* staff will learn about appropriate concrete repair techniques, biogrowth maintenance, and the specifics of good quality workmanship. The positive and negative associations with previous cleaning methods should also be expressed due to the long-term use of these methods.

CONCLUSION

The word most commonly used to describe *Las Pozas* is "magical," and it refers to the intangible qualities that cannot be placed while walking through the site. To many inhabitants of the *Huasteca*, *Las Pozas* sits on a sacred landscape where man and nature coexist, and, as Leonora Carrington stated, where neither is considered to be superior to the other. Physically, *Las Pozas* has come to represent a living relationship between man and nature, and the approach set forth in this thesis aims to preserve the magnificent result of their union.

Unlike most 20th century concrete structures, the visible state of decay of *Stairway to the Sky* does not evoke a sense of loss—on the contrary, the structure's aged appearance reflects beauty that is acquired through natural processes. This challenges conventional notions that concrete should appear flawless, but instead, live in symbiosis with its surrounding environment in a progression that is reflected in the material's verdant and soiled appearance. By recognizing that the resilient *Huastecan* climate will inevitably cause *Stairway to the Sky* to decay over time, an alternative approach to the conservation of the structure was developed in this thesis, presenting a program where managing deterioration mechanisms is used to give concrete materials more longevity in the warm-humid environment.

While this thesis addresses the management of biogrowth colonizing *Stairway to the Sky*, it does not address additional factors that may be incorporated into a conservation plan. As *Las Pozas* receives more attention and receives up to 3,000 visitors per day during the high season, additional concerns, such as preserving ecological diversity, have become a central concern to maintain the site's environmental value. Ecological and cultural diversity— both significant components of Xilitla's landscape, are attributes that enhance the visitor experience at *Las Pozas*. Over recent years, conservation management plans, such as the Getty's *Conservation Plan for Joya de Ceren in El Salvador,* have implemented a multi-disciplinary approach to the conservation of a heritage site, incorporating environmental management and human development components into conservation plans. This strategy supports economic development and heritage stewardship in places that experience an imbalance in wealth, and also recognize that cultural, natural, and built heritage define a landscape, and heritage tourism can serve as a catalyst for change. Revenue generated through heritage tourism may provide opportunities to improve infrastructure, social amenities and environmental protection that otherwise may not have been made available to a local population. Xilitla's largely impoverished population will benefit from *Las Pozas* playing a central role in the community if work opportunities are made possible, as they were during Edward James's lifetime.

Las Pozas may lead other heritage sites by implementing sustainable conservation and environmental management practices, as well as present an innovative approach to the conservation of a 20th century concrete structure. Management strategies adopted since 2007 suggest that *Las Pozas* is poised to lead in developing a comprehensive conservation plan that incorporates building conservation, environmental management, and social sustainability into its program, ultimately recognizing that preserving a heritage place includes the protection of ecological and cultural diversity.

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Edward James Archive (EJA), West Dean College, England

WEBSITES:

Cathedral Stone® Products http://www.cathedralstone.com/

Consejo Nacional para la Cultura y las Artes (CONACULTA) http://www.conaculta.gob.mx/

Comisión Nacional de Áreas Naturales Protegidas (CONANP) http://www.conanp.gob.mx/

Instituto Nacional de Bellas Artes (INBA) http://www.bellasartes.gob.mx/

Instituto Nacional de Estadistica y Geografía (INEGI) http://www.inegi.org.mx/

Instituto Nacional para el Federalismo y el Desarrollo Municipal (INAFED): http://www.inafed.gob.mx/

National Council on Evaluation of Social Development Policy (CONEVAL) http://www.coneval.gob.mx/

Onset Data Loggers http://www.onsetcomp.com/

SPACES http://www.spacesgallery.org/

UNESCO World Heritage Convention http://www.whc.unesco.org/

World Soil Information (ISRIC) http://isric.org/

APPENDIX A | CONTEXT

MAP OF MEXICO AND SAN LUIS POTOSI, LOCATED CENTRAL-NORTHEAST. *SOURCE: HTTP://WWW.WELT-ATLAS.DE/DATENBANK/KARTEN/KARTE-8-115.GIF.*

THE STATE OF SAN LUIS POTOSI AND THE HUASTECA REGION (LEFT). THE MUNICIPALITY OF XILITLA (RIGHT). *SOURCES: HTTP://WWW.VISITASANLUISPOTOSI.COM/UNICO/ELEMENTOS/MUNICIPIOS/M_MAPA57.JPG; HTTP://CRONISTAMASOPO.BLOGSPOT.*

MAP OF THE HUASTECA AND XILITLA. *SOURCE: HTTP://MEXICO.PUEBLOSAMERICA.COM/MAPAS/UHAXUQUITO*

SITE PLAN OF *LAS POZAS*, DISPLAYING SEVENTY-ACRES OF SUBTROPICAL FOREST AND APPROXIMATELY THIRTY-SIX LARGE SCALE STRUCTURES. *SOURCE: MATHEW HOLMES, 2011.*

XILITLA'S SAN AGUSTÍN TEMPLE, BEFORE CLEANING. *SOURCE: HTTP://XILITLAN.BLOGSPOT.COM/2009/03/BLOG-POST.HTML.*

SAN AGUSTÍN TEMPLE AFTER THE 2004-2006 CLEANING CAMPAIGN. *SOURCE: HTTP://HOTELAURORAXILITLA.BLOGSPOT.COM/.*

THE 1,220-FT DROP CAVE KNOWN AS *SOTANO DE LAS GOLONDRINAS* (CAVE OF SWALLOWS) IS LOCATED A THIRTY-MINUTE DRIVE NORTH OF XILITLA. *SOURCE: HTTP://WWW.TURISMOENFOTOS.COM/ITEMS/MEXICO/OTROS/6078_SOTANO-DE-LAS-GOLONDRINAS/*

AERIAL VIEW OF TAMUL WATERFALL, ONE OF THE *HUASTECA*'S GREAT NATURAL TREASURES. *SOURCE: GETTY IMAGES, HTTP://WWW.TIME.COM/TIME/TRAVEL/ARTICLE/0,31542,1930353,00.HTML*

THE NATURAL POOLS AT *LAS POZAS* ARE VISITED REGULARLY BY XILITLANS AND TOURISTS. *SOURCE: AUTHOR, 2010.*

VIEW FROM *STAIRWAY TO THE SKY* LOOKING EAST TOWARDS THE SIERRA MADRE ORIENTAL MOUNTAINS. *SOURCE: AUTHOR, 2010.*

EDWARD JAMES'S FORMER HOME AT WEST DEAN. *SOURCE: AUTHOR, 2011.*

THE COUNTRYSIDE OF WEST SUSSEX WHERE EDWARD JAMES SPENT HIS CHILDHOOD. *SOURCE: AUTHOR, 2011.*

RENE MAGRITTE, EDWARD JAMES IN FRONT OF 'ON THE THRESHOLD OF LIBERTY,' 1937 (GELATIN SILVER PRINT). *SOURCE: THE METROPOLITAN MUSEUM OF ART, HTTP://WWW.ARTSTOR.ORG.*

MONKTON HOUSE, EDWARD JAMES'S FORMER SURREALIST HOME IN ENGLAND. *SOURCE: HTTP://WWW.NYTIMES.COM/2007/04/01/STYLE/TMAGAZINE/04TALK.SURREALISM.T.HTML*

EDWARD JAMES IN MEXICO, CA. 1976. *SOURCE: AVERY DANZIGER, HTTP://WWW.XILITLA.ORG/ PHOTOS.PHP.*

JOSE LUIS AGUILAR'S ELABORATE WOODEN FORMWORK ON DISPLAY AT *EL CASTILLO* IN CENTRAL XILITLA. *SOURCE: AUTHOR, 2010.*

FORMWORK FOR COLUMN CAPITALS, *EL CASTILLO,* CENTRAL XILITLA. *SOURCE: AUTHOR, 2010.*

FORMWORK FOR MASSIVE CONCRETE CAPITAL, *EL CASTILLO,* CENTRAL XILITLA. *SOURCE: AUTHOR, 2010.*

APPENDIX B | HISTORICAL PHOTOGRAPHS

VIEW OF THE *CASCADA DEL GENERAL* (THE GENERAL'S WATERFALL), AROUND THE TIME JAMES PURCHASED *LA CONCHITA* RANCH. *SOURCE: EJA, WEST DEAN COLLEGE.*

PARTIALLY SUBMERGED CONCRETE AND STONE CONSTRUCTIONS. *SOURCE: EJA, WEST DEAN COLLEGE.*

VIEW OF BAMBOO COLUMNS THROUGH *LA CONCHITA'*S DENSE VEGETATION. *SOURCE: EJA, WEST DEAN COLLEGE.*

THE FAST-FLOWING HUICHIHUAYAN RIVER DURING THE WET SEASON. *SOURCE: EJA, WEST DEAN COLLEGE.*

PLUTARCO GASTELUM AT *LAS POZAS*, CA. 1970. *SOURCE: EJA, WEST DEAN COLLEGE.*

BAMBOO PALACE, DATE UNKNOWN. *SOURCE: EJA, WEST DEAN COLLEGE.*

A COLORFUL STONE CONSTRUCTION LOCATED NEAR *CASCADA DEL GENERAL*.
SOURCE: AUTHOR, 2010.

THE HOUSE WITH A ROOF SHAPED LIKE A WHALE, CA. 1980. *SOURCE: EJA, WEST DEAN COLLEGE.*

THE HOUSE WITH A ROOF SHAPED LIKE A WHALE, TODAY. *SOURCE: AUTHOR, 2010.*

BAMBOO PALACE, CA. 1975. *SOURCE: AUTHOR, 2010.*

BAMBOO PALACE, TODAY. *SOURCE: AUTHOR, 2010.*

CONSTRUCTION OF *STAIRWAY TO THE SKY*. TODAY, THIS LOCATION SERVES AS THE ENTRANCE TO *LAS POZAS*. *SOURCE: EJA, WEST DEAN COLLEGE.*

CONSTRUCTION OF *STAIRWAY TO THE SKY,* CIRCA 1965. *SOURCE: EJA, WEST DEAN COLLEGE.*

VIEW OF *STAIRWAY TO THE SKY* FROM ONE OF TWO ROADS LEADING TO XILITLA. *SOURCE: EJA, WEST DEAN COLLEGE.*

STAIRWAY TO THE SKY BEFORE REMOVAL OF SURROUNDING VEGETATION (CIRCA 2007).
SOURCE: JORGE VERTIZ, HTTP://WWW.XILITLA.ORG/PHOTOS.PHP.

THE CINEMA AND *STAIRWAY TO THE SKY* AS SEEN FROM BELOW (CIRCA 2007). *SOURCE: JORGE VERTIZ, HTTP://WWW.XILITLA.ORG/PHOTOS.PHP.*

STAIRWAY TO THE SKY, CIRCA 2007. *SOURCE: JORGE VERTIZ, HTTP://WWW.XILITLA.ORG/PHOTOS.PHP.*

APPENDIX C | CONTEMPORARY PHOTOGRAPHS

EDWARD JAMES'S FIRST CABIN AT *LAS POZAS,* CONSTRUCTED CIRCA 1948.
SOURCE: AUTHOR, 2010.

PLUTARCO GASTELUM'S CABIN AT *LAS POZAS* (ca. 1948). *SOURCE: AUTHOR, 2010.*

VIEW LOOKING EAST OF A PATIO THAT STANDS ADJACENT TO EDWARD JAMES'S LATER HOUSE. TODAY, THIS STRUCTURE IS KNOWN AS *LA CASA ORIGINAL DE EDWARD JAMES, OR EDWARD JAMES'S HOUSE*. *SOURCE: AUTHOR, 2010.*

A CLOSER LOOK AT THE THIRD STORY OF *EDWARD JAMES'S HOUSE*. ORCHIDS COLONIZE THE CAPITALS OF ITS DECORATIVE COLUMNS. *SOURCE: AUTHOR, 2010.*

THREE STORY HOUSE THAT MIGHT BE FIVE, AS SEEN FROM A PATHWAY THAT WINDS THROUGH THE JUNGLE. *SOURCE: AUTHOR, 2010.*

BAMBOO PALACE'S FULL INTEGRATION INTO THE JUNGLE. *SOURCE: AUTHOR, 2010.*

BLUE PIGMENTED SCULPTURES AND *CASCADA DEL GENERAL* IN THE BACKGROUND. DURING THE WET SEASON, THE RIVER FLOWS THROUGH THIS ROUNDED ARCHWAY. *SOURCE: AUTHOR, 2010.*

ASCENDING THE FLEUR-DE-LIS BRIDGE. *SOURCE: AUTHOR, 2010.*

CONCRETE SCULPTURES OF *PLUTARCO'S HANDS,* RESTORED AFTER DAMAGE INFLICTED BY A TOURIST. *SOURCE: AUTHOR, 2010.*

A CONCRETE PATHWAY DESCENDS THE HILLSIDE. *SOURCE: AUTHOR, 2010.*

DETAIL OF A WELL-PRESERVED FLOOR AT *LAS POZAS*. *SOURCE: AUTHOR, 2010.*

A BLUE PIGMENTED CONCRETE COLUMN JUXTAPOSED WITH A STONE CASTLE-LIKE STRUCTURE. *SOURCE: AUTHOR, 2010.*

EDWARD JAMES'S 'BAROQUE' FOUNTAIN *AT PLAZA SAN EDUARDO*. *SOURCE: AUTHOR, 2010.*

MUSHROOM SCULPTURES NEAR THE SITE ENTRANCE. *SOURCE: AUTHOR, 2010.*

EDWARD JAMES'S CABIN AND JOSE HORNA'S *JAULA DE LAS BOAS* (RESTORED 2010-2011). *SOURCE: AMANDA HOLMES, 2011.*

JAMES'S *HOMAGE TO MAX ERNST,* LOCATED IN FRONT OF *STAIRWAY TO THE SKY,* WAS SOLD TO A PRIVATE OWNER AND REMAINS CLOSED TO THE PUBLIC. *SOURCE: AUTHOR, 2010.*

CRACK FORMATIONS IN A COLUMN OF *HOMAGE TO MAX ERNST* RESULTING FROM LACK OF MAINTENANCE. *SOURCE: AUTHOR, 2010.*

APPENDIX D | CONDITIONS AT STAIRWAY TO THE SKY

*ALL DEFINITIONS TAKEN FROM AMERICAN CONCRETE INSTITUTE'S "GUIDE FOR MAKING A SURVEY OF CONCRETE IN SERVICE" (ACI 201.1R-6) UNLESS NOTED.

CRACKING

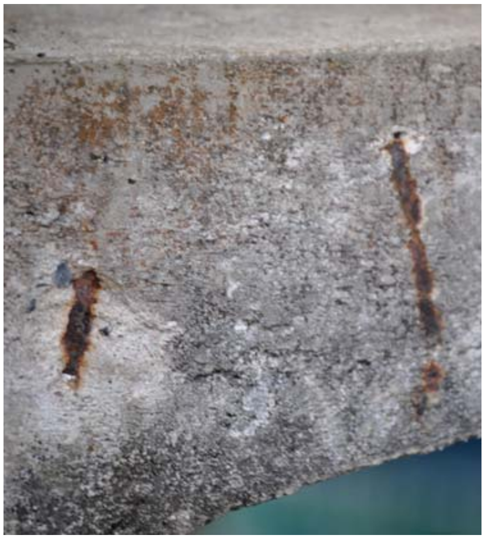
A SERIES OF CRACKS IN CONCRETE NEAR AND ROUGHLY PARALLEL TO JOINTS, EDGES, AND STRUCTURAL CRACKS

PATTERN CRACKING (FINE)

FINE OPENINGS ON CONCRETE SURFACES IN THE FORM OF A PATTERN; RESULTING FROM A DECREASE OF VOLUME NEAR THE SURFACE, OR INCREASE IN VOLUME OF THE MATERIAL BELOW THE SURFACE, OR BOTH

SCALING

LOCAL FLAKING OR PEELING AWAY OF THE NEAR-SURFACE PORTION OF HARDENED CONCRETE OR MORTAR; ALSO OF A LAYER OF METAL



CORROSION

DESTRUCTION OF METAL BY CHEMICAL, ELECTROCHEMICAL, OR ELECTROLYTIC REACTION WITH ITS ENVIRONMENT

SPALL

A FRAGMENT, USUALLY IN THE SHAPE OF A FLAKE, DETACHED FROM A LARGER MASS BY A BLOW, BY THE ACTION OF WEATHER, BY PRESSURE, OR BY EXPANSION WITHIN THE LARGE MASS

POPOUT

THE BREAKING AWAY OF SMALL PORTIONS OF A CONCRETE SURFACE DUE TO LOCALIZED INTERNAL PRESSURE WHICH LEAVES A SHALLOW, TYPICAL CONICAL, DEPRESSION

EROSION

PROGRESSIVE DISINTENGRATION OF A SOLID BY THE ABRASIVE OR CAVITATION ACTION OF GASES, FLUIDS, OR SOLIDS IN MOTION

DISCOLORATION

DEPARTURE OF COLOR FROM THAT WHICH IS NORMAL OR DESIRED

JOINT

A PHYSICAL SEPARATION IN THE CONCRETE, WHETHER PRECAST OR CAST-IN-PLACE, INCLUDING CRACKS IF INTENTIONALLY MADE TO OCCUR AT SPECIFIC LOCATIONS; ALSO THE REGION WHERE STRUCTURAL MEMBERS INTERSECT SUCH AS A BEAM-COLUMN JOINT

APPENDIX E | BIOLOGICAL GROWTH AT *LAS POZAS*

BIODETERIORATION

MECHANICAL, CHEMICAL, OR AESTHETIC DETERIORATION RESULTING FROM THE GROWTH, MOVEMENT, OR METABOLIC PROCESSES OF AN ORGANISM

BIOLOGICAL COLONIZATION BY HIGHER PLANTS

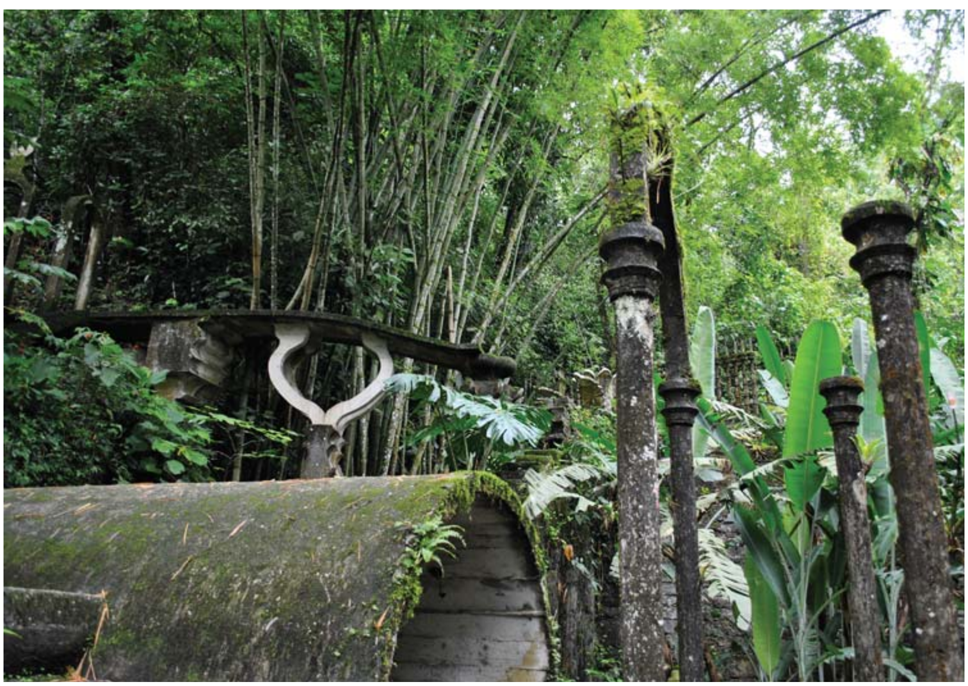
A STRUCTURE IS COLONIZED BY HIGHER PLANTS, I.E. ORCHIDS, SHRUBS; MOVEMENT AND GROWTH CAUSES MECHANICAL DAMAGE OF THE SUBSTRATE

BIOLOGICAL COLONIZATION BY MICROORGANISMS

COLONIZATION OF MICROORGANISMS, I.E. FUNGI, BACTERIA; MAY CAUSE MECHANICAL AND/OR CHEMICAL DETERIORATION OF THE SUBSTRATE

MULTI-COLORED STAIRS, *THREE STORY HOUSE THAT MIGHT BE FIVE*. *SOURCE: AUTHOR, 2010.*

BIOCOLONIZED STONE AND CONCRETE SURFACES, *SECRET GARDEN*. *SOURCE: AUTHOR, 2010.*



VERDANT CONCRETE SCULPTURES AT *LAS POZAS*. *SOURCE: AUTHOR, 2010.*

GOTHIC ARCHES BLANKETED WITH PLANT GROWTH. *SOURCE: AUTHOR, 2010.*

BLACK FUNGAL GROWTH, COLUMN, *EDWARD JAMES'S HOUSE*. *SOURCE: AUTHOR, 2010.*

DETAIL OF STAIR TREAD, *THREE STORY HOUSE THAT MIGHT BE FIVE*. *SOURCE: AUTHOR, 2010.*

DETAIL OF COLUMN BASE, *EDWARD JAMES'S HOUSE*. *SOURCE: AUTHOR, 2010.*

DETAIL OF BUTTRESSING. *SOURCE: AUTHOR, 2010.*

BIOCOLONIZATION OF A COLUMN BY PLANTS AND MACROORGANISMS. *SOURCE: AUTHOR, 2010.*

BIOCOLONIZATION OF CEMENTITIOUS COATINGS. *SOURCE: AUTHOR, 2010.*

COLUMNS INTENDED TO SUSTAIN PLANT LIFE. *Source: author, 2010.*

BIODETERIORATION OF A PAINTED FLEUR-DE-LYS CONCRETE SCULPTURE.
SOURCE: AUTHOR, 2010.

APPENDIX F | MISCELLANEOUS

GUIDELINE FOR WRITING SPECIFICATIONS WHEN USING

D-2 / Biological Solution

Select Relevant Selection

Division 04900-Masonry Restoration and Cleaning

Part 1 – GENERAL

1.1 RELATED DOCUMENTS

A. The Contract Documents shall govern work of this section. Provide materials, labor, equipment, and services necessary to furnish, deliver, and install all work of this section as shown on the drawings, as specified herein, and/or as required by job conditions.

1.2 SUMMARY OF WORK

A. This section includes, but is not limited to, the following:

   a. Removal of biological growth by chemicals from all historic surfaces including smooth and ornamental wood, metal, masonry, concrete, and brick. Mock-ups will determine the best appropriate method.

B. Visual Requirements:

   a. Maintain aesthetic or historic qualities of Project by protecting Work designated to remain.

1.3 REFERENCES

A. Manufacturer's specifications and instructions.

1.4 SUBMITTAL

A. See Section 01300 SUBMITTALS. Submit each item in this Article according to the Conditions of the Contract and Division 1 Specification Sections.

B. Product Data: Submit manufacturer's specifications and installation instructions for products used including finishing materials and methods.

C. Submit manufacturer's technical data sheet for product indicated including recommendations for their application and use.

D. Submit a work plan describing capture, storage, and disposal as required and/or governed by any and all local, state, and/or federal laws, codes, and regulations.

Material Safety Data Sheet: **D/2 BIOLOGICAL SOLUTION**
Version No. 24005 Date of Issue: March 2008 *ANSI-Z400.1-2003 Format*

Section 1: PRODUCT & COMPANY IDENTIFICATION

Product Name: D/2 Biological Solution

Exclusively Distributed By:
Cathedral Stone® Products, Inc.
7266 Park Circle Drive
Hanover, MD 21076
Telephone: 410-782-9150
Fax: 410-782-9155

Manufactured By:
Sunshine Makers, Inc.
15922 Pacific Coast Highway
Huntington Harbour, CA 92649
Telephone: 800-228-0709
Fax: 562-592-3830

Emergency Phone: Chem-Tel 24-Hour Emergency Service: 800-225-3924

Use of Product: D/2 Biological Solution is an easy-to-use liquid that aids in the removal of a broad spectrum of soils. It is designed for use on outdoor sculpture, monuments, decorative fountains, stone, brick, terra cotta, concrete, stucco, and other architectural surfaces.

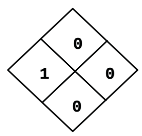
Section 2: HAZARDS IDENTIFICATION

D/2 Biological Solution is a colorless liquid with a very faint detergent-like odor. It is non-flammable, non-combustible, non-explosive, and non-reactive.

Hazard Rating (NFPA/HMIS)

Health = 1*	Reactivity = 0
Fire = 0	Special = 0

* Mild eye irritant, non-mutagenic and non-carcinogenic



Rating Scale

0 = Minimal 1 = Slight 2 = Moderate
3 = Serious 4 = Severe

Eye Contact: Eye Irritant.

Skin Contact: Prolonged skin contact with D/2 Biological Solution may irritate the skin. Repeated daily application to the skin without rinsing, or continuous contact of D/2 Biological Solution on the skin may lead to irritation.

Ingestion: Essentially non-toxic. May cause stomach or intestinal upset if swallowed.

Inhalation: No adverse effects expected under typical use conditions. Adequate ventilation should be present when using D/2 Biological Solution over a prolonged period of time. Open windows or ventilate via fan or other air-moving equipment if necessary. Mucous membranes may become irritated by concentrate mist.

Carcinogens: No ingredients are listed by OSHA, IARC, or NTP as known or suspected carcinogens.

Medical Conditions: No medical conditions are known to be aggravated by exposure to D/2 Biological Solution.

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients	CAS Number	OSHA PEL ACGIH TLV
Surfactants	Proprietary	None established
Wetting Agents	Proprietary	None established
Buffers	Proprietary	None established

Section 4: FIRST AID MEASURES

If in Eyes: Immediately rinse the eye with large quantities of cool water; if present, contact lenses should be removed after 5 minutes of rinsing; continue rinsing 10-15 minutes more. Both upper and lower lids should be lifted to facilitate thorough rinsing.

If on Skin: Minimal effects, if any, from diluted product; rinse skin with water, rinse shoes and launder clothing before reuse. - Reversible reddening may occur in some dermal-sensitive users; thoroughly rinse area.

If Inhaled: Use in well-ventilated area, or use adequate protection from inhaling mist during spray applications. Prolonged exposure of workers to concentrate-mist during spray application may cause mild irritation of nasal passages or throat. If this happens, relocate workers to fresh air.

If Ingested: Give several glasses of milk or water to dilute; do not induce vomiting. If stomach upset occurs, consult physician.

D/2 Biological Solution

D/2 Biological Solution is a safe, easy to use liquid that removes a broad spectrum of biological deposits from hard environmental surfaces. A contact time of only 1 to 2 minutes will loosen most fungal and algal deposits with manual scrubbing and is typically sufficient for excellent results.

Growth of bacteria, fungi, algae, lichens, and mosses contributes significantly to the degradation of many types of construction materials, and can be disfiguring. D/2 can be utilized to control this problem on outdoor sculpture, monuments, decorative fountains, gravestones, and tombs. Biological growth found on some individual building features (such as parapets and zones of ground contact) or materials (such as stucco) can also be treated with D/2, although it is not a general purpose architectural cleaner.

Features and Benefits

- **Fast Acting:** 1 to 2 minute contact time for great results.
- **Keeps Surfaces Clean for a Minimum of 1 year**
- **Safe for Landscape Plantings and Grass**
- **No Detrimental Effects on Masonry**
- **Non-Toxic and Biodegradable:** No special precautions required for handling and storage.

Application Procedures

No Scrub/No Rinse Method

1. Apply D/2 Biological Solution with a brush or pump sprayer to a dry surface. Do not pre-wet the surface. 2. Allow to dry. Repeat if there are heavy biological deposits. D/2 works with the elements and results occur within one week to one month depending on severity of growth and weather conditions. The surface will become cleaner over time as the subsurface biological growth dies and releases.

Immediate Result Method

1. Apply D/2 Biological Solution with a brush, roller or pump sprayer to a dry surface. Do not pre-wet the surface. 2. After waiting 2-5 minutes, scrub surface with a non-metallic, short bristle scrub brush. 3. Allow the undiluted D/2 to remain on the surface 5-10 minutes longer. 4. Apply additional D/2 to maintain a wet surface and continue scrubbing. 5. Rinse with clean water.

<u>Heavy biological deposits</u> should first be loosened using a low pressure washer (300 to 600 psi), or by mechanical scraping using wood or plastic tools. Follow removal with one or more applications of D/2 as stated above. The surface will become cleaner over time as the subsurface biological growth dies and releases.

<u>Light biological deposits</u> may be removed with a D/2 dilution of water from 1:1 to 1:4 parts water by volume. Perform tests to determine effectiveness of various dilutions. Follow testing with application of D/2 as stated above.

Safety Information

D/2 Biological Solution is non-mutagenic, and contains no carcinogenic compounds as defined by NTP, IARC, or OSHA. It is considered essentially non-toxic by swallowing, as it has an oral LD50 of greater than 5.0 g/kg of body weight. No special ventilation is required during use.

Packaging and Coverage

D/2 Biological Solution is available in 32 ounce spray bottle, 1 gallon and 5 gallon containers, and 55 gallon drums.

The area that can be treated with one gallon of D/2 will vary considerably as a function of the nature and extent of biological deposits, as well as the physical characteristics of the surface.

Typical coverage to remove medium deposits will vary from 250 to 350 square feet per gallon.

Cathedral Stone® Products, Inc. 7266 Park Circle Drive, Hanover Maryland 21076
(800) 684-0901 FAX: (410) 782-9155 WEBSITE: www.cathedralstone.com

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