LA JOYA EARTHEN PYRAMID AFTER HURRICANE KARL, SEPTEMBER 2010, ON THE GULF COAST OF MEXICO

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Theme 1: Latin-American Earthen Architecture at Risk: Earthquakes, Rain and Flood Damage
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Abstract

In this paper we analyze the damage a Category 3 hurricane inflicted on a 200-700 AD pyramid located on the coastal plain 6 km inland from the Gulf of Mexico in a humid tropical environment. The evaluation is part of an ongoing preservation program. On the one hand, we report the good performance of a protection strategy consisting of a geotextile covered with an earthen sacrificial layer with very low proportions of vinyl polymers and a silane-siloxane water repellent. On the other hand, we analyze the deterioration and collapse of a section of building fill, caused by the hurricane itself, but also by the heavy rains and afterwards the severe drying period that followed the event. We also evaluate factors of mineral composition of building sediments, rain impact, wind direction, and intrusive vegetation. Based on the evaluation we consider alternatives for the preservation of archaeological earthen architecture in cases of hurricane impact.

1. INTRODUCTION

On September 17, 2010, a Category 3 hurricane, Karl, hit the archaeological site of La Joya, located a mere 6 km inland on the tropical coastal plains of Central Veracruz, Mexico. This paper reviews the damage inflicted on the façade of the earthen pyramid, which has been undergoing a process of preservation since 2009 following its discovery in May 2008. The conservation program is experimental, as there are no antecedents for preserving exposed all-earthen architecture in humid tropical conditions in Mexico. In general, the architectural remnant survived well, except for the collapse of part of the building fill, probably caused by the growth of vegetation. To substantiate this diagnosis, this paper will present a synthesis of (a) the regional climatic and geological conditions, (b) the pyramid´s construction sequence, (c) the preservation process, including a geotextile cover and a sacrificial layer of clay with hydrofugants, partly consolidated with vinyl polymers, (d) the site-monitoring program, (e) the impact of the hurricane, and (f) the assessment of damages. The conclusion is that in contexts of high rainfall, allowing weeds to grow and develop roots through geotextiles is counterproductive, and leads to increased differential humidity that may provoke collapse of unconsolidated fills. Recommendations for preservation include the consolidation of the sacrificial layer and the strict control of root and water penetration beyond the geotextile cover.

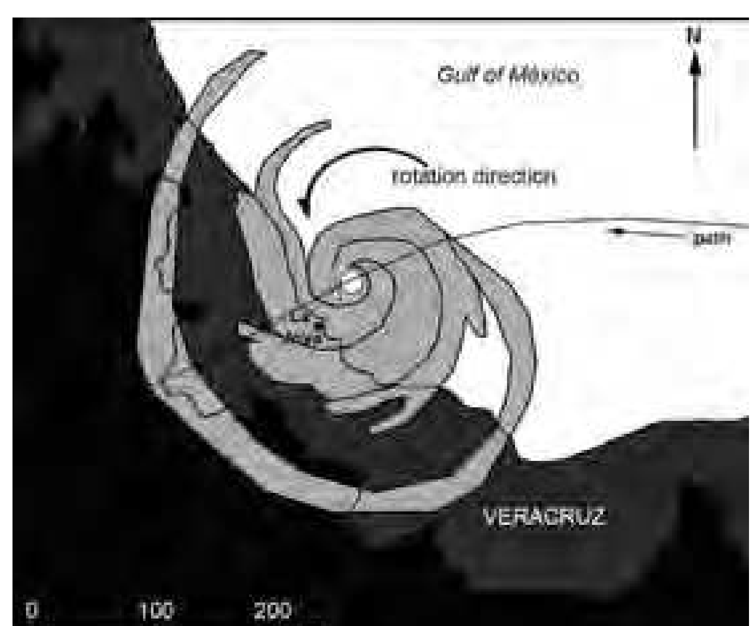

Fig.1 Location of La Joya on the Gulf coast, with respect to Karl's landfall point; inset: location of map area on outline of Mexico (credits: redrawn from Stewart, 2011)

Fig.2 Map of La Joya, with central compound surrounded by a system of ponds. Inset: location of site within the State of Veracruz (credits: Annick Daneels)

2. REGIONAL CLIMATIC AND GEOMORPHOLOGICAL CONDITIONS

La Joya is located 19°04'00''N 96°09'00''W (in UTM Zone 14 799799E 2110514N), at 7 m above sea-level at the confluence of the Jamapa and Cotaxtla Rivers, 6 km from the actual coastline as the crow flies. Part of the coastal lowlands, it stands on top of a paleo-dune, completely surrounded by fluvial sediments eroded from the neovolcanic mountain range dominated by the Pico de Orizaba, Mexico's highest peak. This situation makes for a geological profile dominated by sands and smectite, a highly expansive clay. This very deep sediment layer serves as a cushion absorbing most tectonic movements: the strong earthquakes in Orizaba (1973) and Mexico City (1985) had only minor impact on the lowlands. The climate at the site is tropical savannah Aw, on the limit between Aw1 and Aw2, characterized by predominant summer rainfalls between 1,500 and 2,000 mm annually, and gale-force winds in the winter. Wetter conditions prevail towards Southern Veracruz, where 2,000 to 4,000 mm of rain are common (García, 1970). Hurricanes in this area are rare. Before Karl, only two hit the South-Central Veracruz region in the twentieth century, in 1950 and in 1933, both of Category 2 (Gómez Ramirez, 2006). Thus Karl's Category 3 impact is highly significant to evaluate the efficacy of the preservation strategies applied to the pyramid.

Hurricane Karl is the strongest hurricane on record in the Southern Gulf of Mexico, with maximum winds of 110 knots (204 km/h); at landfall, at the point 19.3°N 96.2°W, the wind speed was still 100 knots (185 km/h) (Stewart, 2011). This is 30 km to the north of La Joya, leaving the site exactly on the edge of the eye of the hurricane, where winds are the strongest. Total rain in the nearby city of Veracruz was reported as 9.21 inches or 234 mm (Stewart, 2011), or 253.75 mm between September 17 and 18, 2010 at the Ylan Ylang weather station located 19.15 W 96.11 N, 10 km to the north of the archaeological site (Servicio Meteorológico Nacional, 2010). The heavy rainfall on the mountainside caused an exceptional flood on the coast, but this did not affect the archaeological site because it was protected by the pre-Columbian drainage system, consisting of connected water reservoirs that conduct excess water back towards the river by a northeastern drainage canal.

3. LA JOYA AND THE GULF COAST TRADITION OF EARTHEN ARCHITECTURE

The heavy summer rainfall and abrasive winter gales characteristic of the Central and Southern Veracruz coastal plains would seem adverse for earthen architecture. Yet this region is home to a millenary tradition, originating with the Olmecs, of monumental architectural complexes built of earth, including ball courts, pyramids, and palaces with porticoed rooms and balustraded staircases, sunken patios and large enclosed plazas, all conforming to the classical Mesoamerican architectural canons. This tradition has only recently been defined, with the oldest examples

Fig.3 Above: pyramid's substructure west façade when excavated in May 2008. Below: reconstruction (credits: photo and excavation data by Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History, 2008; hypothetical reconstruction by Giovanna Liberotti, 2010)

only probed through test-pits and not exposed or systematically analyzed as to their constructive techniques; these cases, in San Lorenzo and La Venta, were reburied for their preservation (Cyphers et al., 2006; González-Lauck, 1997; Gillespie, 2008).

La Joya is exceptional in this respect, as due to extensive damage by brick makers only 5% of three of the mounds remain (Fig. 2, extant portions shown in black), exposing large profiles of superimposed buildings and allowing the definition of the building sequence and the analysis of construction techniques. The oldest building is the North Platform, apparently starting as a palatial complex enclosed by a perimeter wall, radiocarbon-dated to 400-100 BCE (Daneels, 2008a, 2011). An enclosed plaza complex framed by the Pyramid and the North and East Platforms, including a first version of the water-pond enclosure, arises by 200 CE, in the early part of what is called the Classic period in Mesoamerica. The complex had several renovations, the last one about 800/900 CE, with the site apparently abandoned by 1000 CE. The intervention at the site was done originally as a rescue operation, with no restoration contemplated. But the discovery in May 2008 of the pyramid's substructure led to the decision to attempt the preservation of the extant remains of its west façade.

It was possible to reconstruct the complete contour of the building as a square, twelve-tiered structure, with four staircases of differing width. Its construction technique is different from the fill-block system of the Late Classic period (Daneels, 2008b), and consists of a nucleus of layers of compacted loamy sand, covered and contained by a thick exterior capping of clayey loam, in which the shape of the building is modeled (tiers, staircases and balustrades). The surface was then covered with a series of at least three 2- to 2.5-cm thick layers of clay facings of well-graded loamy clay with finely chopped grass, probably mixed with an organic agglutinant that had consolidating and hydrofugating properties (but remains so far unidentified), and then strongly compacted. As only an 18-m wide segment of the west façade remains, the northern, eastern and southern contours of the vestige expose the sandy fill.

4. THE PRESERVATION PROCESS AND ITS MONITORING PROGRAM

As indicated above, no case antecedents were available in Mexico for preservation of pre-Columbian earthen architecture

Fig.4 La Joya Pyramid in spring 2010: a. arrow indicates collapse of north retaining wall due to weeds, b. geotextile applied directly to north profile, c. west façade protected by tarpaulins, whereas for the southern sector (on the right) with the new sacrificial layer with vinyl polymer (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

in humid tropical environments. Guided by ICOMOS' general principles of conservation (2003), a fully documented archaeological-excavation report determined the extent and the building techniques of the structure, and samples were obtained of fills, capping layers, and facings to ascertain the mineralogical composition, plasticity, porosity, absorption, compressive strength, and nature of the organic agglutinant, using thin-section petrography, sedimentation analysis, X-Ray Fluorescence and Diffraction, FTIR, and ESM (Daneels and Guerrero Baca, 2011). As an urgent protection measure, conforming to the principles of reversibility and material compatibility, in the spring of 2009, the vestige was covered with a polyester geotextile (non-woven PET 275 gr/m², gray), then faced with a sacrificial layer of clayey loam, and treated with a silane-siloxane hydrofugant aspersion at 1/40 concentration (Wacker SILRES BS 1001A), after constructing retaining walls of raw bricks bedded with mud where needed, and filled in with sand. Profile cuts where whitewashed with lime, to bring out the extent of the original façade.

With bi-monthly control visits and photography, it was possible to systematically document that the summer rains of 2009 deteriorated the sacrificial layer, while the geotextile effectively protected the original structure, as the surface below remained firm. The retaining wall on the north profile collapsed because the weeds that started growing on the ledges percolated

Fig.5 La Joya Pyramid in spring 2009: first preservation experiment: a) retaining walls at the foot of west façade and on the north profile, placing of geotextile and protective layer; b) west façade after preservation; c) north profile after preservation and d) weeds growing through geotextile and sacrificial layer (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

rainwater into the sand fill and weakened the wall. In spring 2010, the debris was cleared and geotextile applied directly to the fill profile. A new experimental layer of increased resistance was developed and tested in the Restoration Laboratory of the Institute of Anthropological Research, and applied only on the southern sector of the façade. It consists of a first thin layer of sand/loam mix in equal proportion, then a second 1.5 cm thick layer of the same sand/loam mix with 1,5% finely chopped Pangola grass (1), 0.8% of vinyl polymer (Wacker VINNAPAS 5044N), and 0.3% of hydrofugant (Wacker SILRES BS Powder D). The cracks that appear in the layer are afterwards sealed with a sand/loam mix with a 5% addition of the same polymer, to insure compatibility and give elasticity to the cover.

5. IMPACT OF HURRICANE KARL AND DAMAGE ASSESSMENT

The 180-km/h winds from Karl hit the pyramid from the south, a direction opposed to the local dominant winter winds. This lessened the impact on the structure, as the wind rode over the wedge-shaped vestige that increases in height and width from south to north. Nevertheless, the tarpaulins where torn off, exposing the surface to the 250 mm of rain. Affecting only a very small part of the façade's edge, part of the original fill of the north profile collapsed, stretching the geotextile to a breaking point. Unknown to us, below the tarpaulins, weeds had started to grow again along the northern edge of the façade.

When removing the geotextile, it was possible to observe the presence of more than 1-m deep weed roots in the fracture zones, penetrating the original compacted-earth fill of the building and the modern sandy fill placed in 2009 as part of the raw brick retaining-wall system. The weeds did not grow on the façade itself, but on its northern edge, formerly exposed, where before preservation attempts, an invasion of a sturdy weed existed, identified as Cyperus rotundus L. of the Cyperaceae family. This weed has long rhizomes forming chains of bulbous tubers that developed below the geotextile, and cannot therefore be removed manually without damaging the textile, nor killed with standard glyphosate weed killers. It was first used FAENA forte (Monsanto) in 2009, then Finale Pro 15 (Bayer) in small experimental patches in 2010, at the recommendation of biologist Pablo Torres Soria, consulting specialist of the National Institute of Anthropology and History in Mexico in matters of site preservation. These applications were suspended in view of their inefficacy and the high toxicity of the products. This weed even broke through the polymer-consolidated sacrificial layer, showing that being cut off from sunlight does not affect its vitality. The presence of the roots suggests a repetition of the 2009 scenario: the weed catches the rain and allows it to penetrate along its roots beyond the geotextile, 1- to 2-m deep into

Fig.6 La Joya Pyramid in September 2010, after hurricane Karl: a. west façade with torn tarpaulins, southern sector (on the right) with polymer layer in good condition, b. collapse of north profile fill, arrows indicating weeds and roots, c. detail of weed roots in old crevices, originally filled with sand (credits: Annick Daneels, from project authorized by the Archaeology Council of Mexico's National Institute of Anthropology and History)

the sandy fill of the building itself. The ensuing differential humidity weakens the fill stratum that does not have the clay content and compaction of the capping layer of the façade. The steep incline of the north profile led to an almost vertical slide, in line with the weed-root penetration.

6. CONCLUSION

The experience obtained at La Joya, in normal (2009) and exceptional (2010) meteorological conditions suggests that our preservation strategy is basically effective. The geotextile, while hiding the original vestige from view, does protect it from the heavy summer rains and scouring winter winds, and is a reversible strategy for as long as it takes to develop a treatment that would allow exposure of the original surface. As all the surfaces of the building have an adequate incline, the geotextile captures the rainwater, and gravity drains it to the foot of the building, where it is absorbed by the sandy subsoil. The sacrificial layer consolidated with very low proportions of vinyl polymer and powdered hydrofugant has successfully passed an extremely hard test with the hurricane; it conforms to the requisites of being of equal or lesser resistance than the original surface, of allowing the building to "breathe" and expand and contract with seasonal cycles.

What has become evident is the necessity of avoiding sandy fills when building the retaining walls, as they allow drainage to occur too rapidly and provoke differential humidity that weakens the compaction of the fill. Also, it is very important to continuously monitor weed growth, especially those that have deep root systems that penetrate beneath the geotextile, curtailing its protective action. A strategy to control weed growth needs to be developed, as the usual weed killers have proven ineffective.

In 2011, the pyramid was completely covered with the experimental vinyl-polymer layer on top of the geotextile, after building a stronger retaining wall around the north profile, filled in with layers of loam stabilized with lime, based on the experiments made at the Materials Laboratory of the UAM-Xochimilco (Guerrero and Roux, 2010: 93-94). These are provisional preservation measures while the laboratory analyses proceed both on pre-Columbian samples of facings, in an effort to determine the original organic agglutinant, and on other experimental sacrificial layers using vernacular techniques extant in tropical-rainforest environments in Central America, as well as other, modern components. Bi-monthly monitoring will continue at least until the end of the year, for the duration of the actual project.

As a parallel action, the members of the project work both on community awareness, to promote knowledge about the coastal tradition of earthen architecture and its importance as cultural heritage, and on a feasibility dossier to involve local and state authorities in the creation of a museum that would integrate the maintenance of the pyramid's façade, so far the only exposed monumental example of this splendid architectural tradition on the coastal Gulf plains of Mexico.

Notes

(1) Pangola grass is an African grass species, introduced as pasture in tropical America. It has shallow roots as it reproduces horizontally through a stolon. It was chosen as a mechanical binder in the sacrificial layer because its size is akin to that of the grasses identified in the pre-Columbian samples, and because even if it would grow, the roots would not penetrate the geotextile, as happened with the damaging weed species.

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