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## STRUCTURAL CONDITIONS REPORT IN TAMBO COLORADO, AN INCA SETTLEMENT IN PERU

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**Abstract.** *Tambo Colorado is the most preserved archeological sites in Peru even do it is located in Pisco valley, the most active seismic zone in Peru. This site was built by the Incas, completely with adobe in 1470 B.C. and is the only archaeological site with polychrome painting in all its walls.*

*The earth structures in Tambo Colorado have different kind of damages that have affected its stability and have affected significantly its performance during earthquakes events. Our objective was to make a complete condition assessment on the site. It was diagnosed 3300 square meters, for this porpoise, was used the plane drawn in 1901 by Max Uhle, a german researcher. In Uhle's plane the building is formed by 66 enclosures were we can find courtyards, rooms and passage way. By using this plan we have tried to organize tasks, to facilitate the identification of architectural spaces and to appraise the excellent work done by Uhle over a hundred years ago.*

*The pathologies assessment results reports that: 35% of the walls are cracked by in-plane shear, 37% have partial loss of the wall and 34% of the walls show cracks in sections. All these damages represent the structural condition in which the archaeological site is, and demonstrates the need for corrective actions in the short term that would reduce the risk archaeological structures loss.*

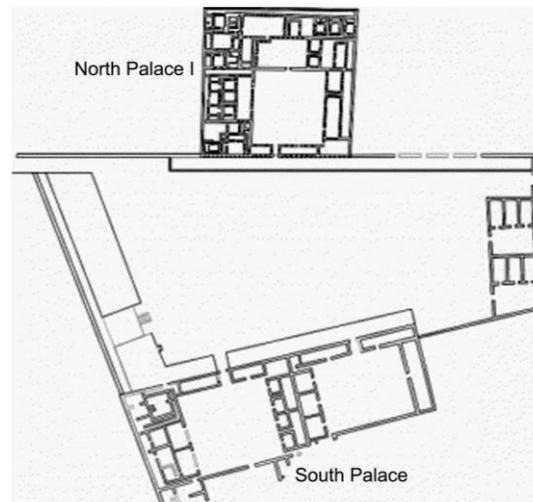
*Because the archaeological structures have suffered extensive damages that have endangered the site integrity, it is very possible that in case of a severe earthquake, many of the structures will collapse which is a serious risk not just for the site but for researchers and visitors. This is disturbing since the last Pisco earthquake was in 2007, and got level 8 on the Richter scale and IX on the Mercalli scale.*

## 1 INTRODUCTION

Tambo Colorado is located on the right bank of the Pisco valley 35 km from the city of Pisco at the south coast of Peru (Fig. 1). This site is also called Pucallacta or Pucahuasi which means "red house" in Quechua; it was built by the Pachacutec Inca at the end of 14th century and was occupied till 1532. This site is historically important because is the first settlement that the Incas built in the coast while coming down from highlands to coast. Because of that, Tambo Colorado shows an impressive Inca architecture, represented on the uses of trapezoidal niches, colorful wall painting and local influence represented by use of laddered friezes and cornices. Despite its historical value, Tambo Colorado has not been properly protected and is currently exposed to different factors that affect its conservation; no proposals have been made to solve conservations problem. Considering Tambo Colorado's importance, the seismic risk of the area where located and environmental affectation, the Tambo Colorado research and conservation project has proposed a transdisciplinary methodology that embraces structural conservation assessment finishes conservation assessment, archaeometry analysis, photogrammetric recording and graffiti recording. The area that has been worked is the North Palace I, and is the most complex and decorated of the site, and supposed to be the area were the Inca family lived (Fig. 1). The result of all this analysis and research allowed us to get a completed and detailed knowledge of the site.



1- © Projet de Recherche Tambo Colorado (PRTC, 2014)



2- Uhle in Protzen J., 2010

Figure 1. Tambo Colorado location in the Inca empire map (1) and the archaeological complex plane with the North Palace I (2), where the project was focused.

## 2 OBJECTIVES

Our main purpose is to develop interdisciplinary research to provide the necessary tools to conserve the materiality and significance of the site. In the first work season (October 2013), our objectives are focused on developing a suitable condition assessment of the site, specifically in one of the most significant area which is known as North Palace I (Fig. 2), area that highlights for its colorful wall painting and architectonic display (Wolgang, 1999). Other objective is to characterize the wall painting pigments, to record one of the areas using 3D photo modeling and finally to make graffiti record in each wall.



Figure 2. Tambo Colorado - North Palace I (© PRTC, 2013)

## 3 METHODOLOGY

Transdisciplinary methodology is the most important aspect of the project. Indeed, the monument has been to consider as a unit, and to attend all its issues it has been used multi-protocol methodology, combining archeology, archaeometry, and structural and finishes conservation.

At field three teams were conformed: condition assessment (structural and finishes) team, archaeometry, and graffiti recording team.

All the team work walk together through the 66 rooms of North Palace I, area that has been choose for its condition, color display and architectonic complexity. By using a plan of the site (Uhle 1901 in Protzen J., 2010), were marked the walls that needed to be preserve urgently, these chooses were done according to a list of priority where the structural damages were consider the most important issue, followed by the presence of wall painting and lastly the presence of significant graffiti (with possibility of colonial date). Letter "A" was used for the most damaged wall and B, C, and D for the walls less damaged or in-teresting (Fig. 3).

This procedure will allow us to compile the necessary data for each aspect, in all rooms of this area and then to compile enough information for a complete diagnosis of the site.

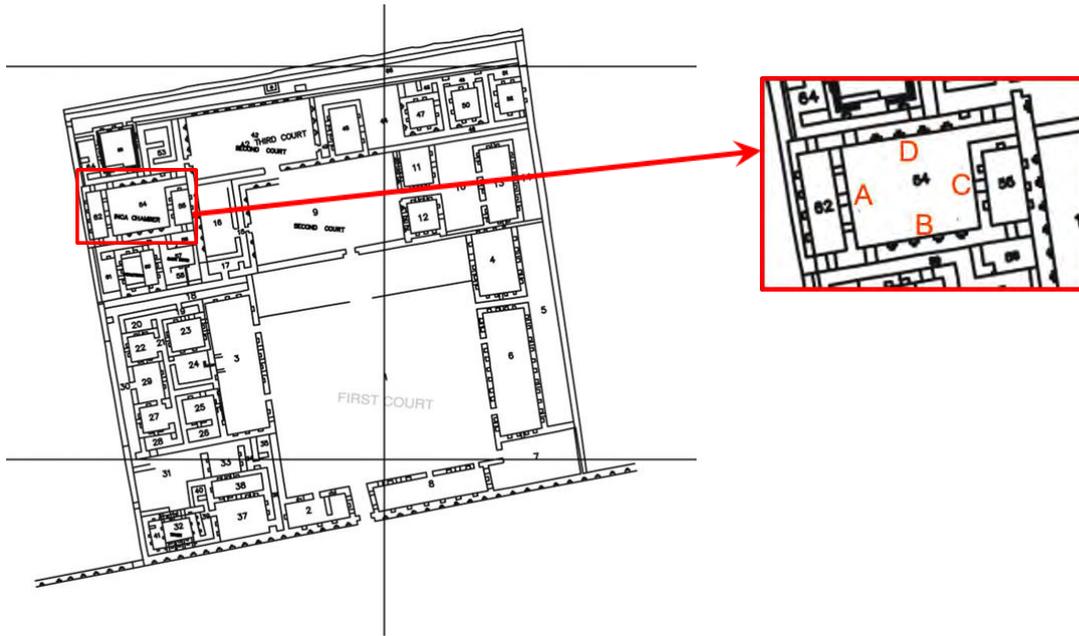


Figure 3. North Palace I (according to Uhle 1901), it shows the letters code system for each wall of the rooms according to damage level. Letter A indicates the wall that needs priority intervention.

### 3.1 Structural Condition assessment

The architectonic complex North Palace I, was built completely with adobe masonry. These adobes have a quadrangular shape and heterogeneous measures, there is no archaeological evidence about the adobes production, but it's possible to establish the use of molds on manufacture (Fig. 4). The walls width is between 65 and 95 cm, and has from 2.40 to 3.00 m heights. Most of the walls' bases were made with stones; the rooms have remarkable niches presence, as well as windows and trapezoidal entries.



Figure 4. Details of the masonry of the archaeological site (© PRTC, 2013).

Through almost 450 years, the south center Peruvian zone has suffered more than 17 telluric movements, with intensities that arise between VII and IX type on the Mercalli scale (MM). The last Pisco earthquake reached 7.0 ML Richter, VII MN was the largest scale ever recorded in central Peru region in the last 100 years (Tavera, Bernal and Salas, 2007). The Getty Conservation Institute reported this seism got a VII (MM) on Tambo Colorado area, and about the damages caused, reported: “diagonal cracking between adobe block and mortar. Vertical cracking at the junction of perpendicular walls, among others, was observed” (The Getty Conservation Institute, 2011). In the report they couldn't find any structural condition antecedents or data before 2007, for this reason the 2013 record is the first one on its kind and it will be used to monitor the site structural condition on the future.

The adobes used on walls construction have different sizes, and were made with molds. There are adobes 52 cm long, the mortar between each adobe is 2-5 cm and they don't have vegetal fibers or any other additive. The walls' bases are usually built with stones and mortar, and their height is variable.

The moorage used on masonry has influence on walls stability. There are some areas where it can be seen that the adobes are put along the wall crossing through wall faces, and in the next level the adobes are put along the wall, this advantage the walls resistance.

The width-high ratio, for most of the walls lies between 1:3 and 1:4 ranges, which allow these structures have adequate strength and rigidity, the measurement described ensures in most cases a pattern, detecting an established proportion used by manufacturers.

There are evidences of reinforced walls placed at the base of the walls, one located in the tower (“Torreón” rooms 32 and 41, Fig. 9) and another in the enclosure 65, both chambers have evidence of a second level, both have part of its structure in stone but are not fully constructed in this material, and finally both reinforcements have the same cross section 75 x 160 cm.

Currently no rooms have ceilings, however can be seen traces of the beams that were used in the roof structure, it is possible that roofs contribute to earthquake-resistance.

In order to achieve a proper condition diagnosis it was identified the structural problems that currently affects the site, for this porpoise, it was used a glossary in which was identified the main problems in walls of the North Palace I. Subsequently an inventory was made in order to establish the recurrence of these conditions in each of the enclosures. This inventory was made by visual inspection wall by wall; in total we have verified 250 walls faces in the 66 rooms.

Finally it was made a map of the vulnerable areas with walls or wall segments that have serious collapse risk and that its fall could represent a serious risk to visitors, this plane also allowed us to establish that visitors access from the patios to the enclosures should be restricted in order to safeguard the integrity of the people and the building.

#### **4 RESULTS**

The Tambo Colorado earth structures have different pathologies that have affected its stability and have influence greatly their performance against earthquake forces; the walls have a series of injuries that have affected many different ways, conditioning its architectural conservation (Fig. 5).

<b>Structural problems in the North Hall 1 of Tambo Colorado</b>	
Cracks in access vain.	Horizontal cracks.
Diagonal crack in corner.	Partial loss of the wall.
Vertical crack in the plane of the wall.	Loss lintels.
Local instability of wall segment.	Biological damage / vandalism agents.
Damage at the walls intersection.	Loss of the corner of the wall.
Rolling out of the plane of the wall.	Drastic loss of the wall section.
Cracks in-plane shear.	Widespread cracks.
Relative displacement between walls.	Cracks in the cross section of the wall.
Damage to the base of the wall.	Total loss of walls.

Figure 5. Pathologies affecting walls structure of the archaeological site.

The pathologies records results show that: 35% of the walls have cracks in-plane shear, 37% have partial loss and 34% of the walls have cracks in the cross section. These pathologies show the archaeological site serious condition and demonstrate that is necessary to take corrective actions to reduce in short-term the risk of loss of the structures of the archaeological site (Fig. 6).

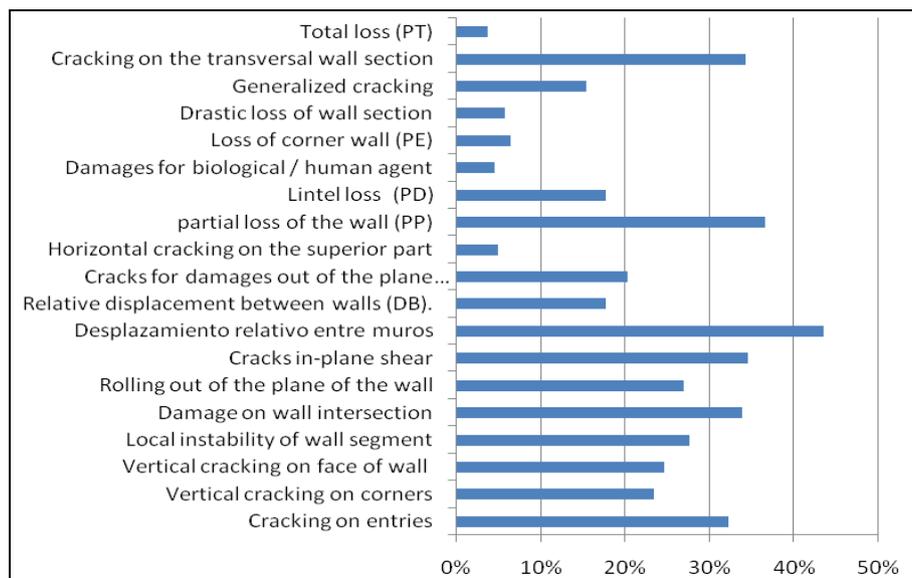


Figure 6. Record of pathologies in Tambo Colorado.





Figure 9. North Palace I vulnerability it shows enclosures with walls in risk of collapse (© PRTC, 2013).

## 5 CONCLUSIONS

The results we got, although are preliminaries, allow us to get a global structural and finishes condition assessment and to propose specific actions to prevent more damages, this proposal consider to begin taking on count the most affected areas.

The methodology has allowed distinguishing structural damages from finishes damages, consequently, a better understanding of the kind of damages and a specific conservation proposal for each case has been developed.

All the data acquired from the condition assessment work, lead us to understand that the area known as the “Torreón” of the North Palace I (rooms 32 and 41) (Fig.10) is the most vulnerable and must be intervened urgently. The photogrammetric survey on this sector gave us the opportunity to record appropriately this area and plan the first stage of our future work.

In the other hand, thanks to the first results of the condition assessment, the authorities of Peruvian Ministry of Culture, based on the vulnerability map, has recently restrict the tourism access to the areas diagnoses as the most damages and with collapse risk. This sets an important step on the site conservation, due to the fact there were no protection action taken before.

The condition assessment work has allow us to plan, in short term the conservation work properly, taking in count the most damages areas, and to complement this work with archaeometric analysis and graffiti record, this information will enrich the knowledge of the murals and the building.

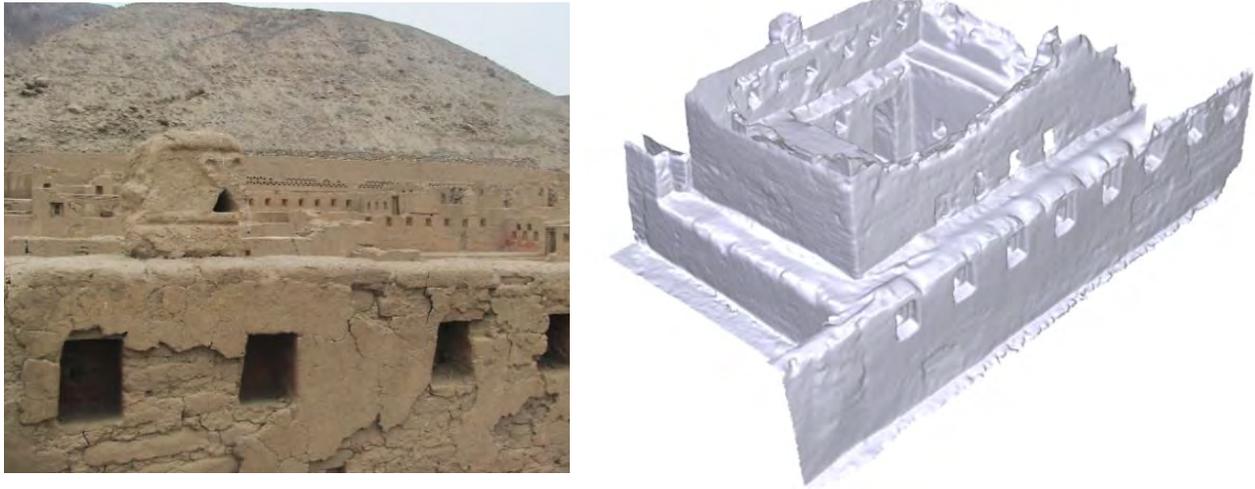


Figure 10. *Torreón* photography and 3D photogrammetry survey. This area was diagnosed as the most damaged, and will be treated priority (© PRTC, 2013).

## REFERENCES

- [1] PROYECTO DE INVESTIGACION TAMBO COLORADO, *Informe Final Temporada 2013*, presentado al Ministerio de Cultura del Perú.
- [2] PACHECO G., WRIGHT V., TORRES PECEROS H., HUAMAN OROS O., 2014, *Tambo Colorado Research and Conservation Project*, Rehab 2014 – Proceedings of the International Conference on Preservation, Maintenance and Rehabilitation of Historic Buildings and Structures, Tomar, Portugal - 19-21 March 2014, p. 1253-1262, Editors: Rogério Amoêda, Sérgio Lira & Cristina Pinheiro, Publisher: Green Lines Institute, Barcelos, Portugal.
- [3] BONAVIA D., 1974, *Pinturas murales prehispánicas*, Ricchata Quellccani, Fondo del Libro del Banco Industrial del Perú, Lima, Perú.
- [4] COOKE L., 2010, *Conservation Approaches to Earthen Architecture in Archaeological Contexts*, British Archaeological Reports (BARS2147), Archaeopress, Oxford, England.
- [5] ENGELS F., 1957, *Early sites in the Pisco Valley of Peru: Tambo Colorado*, *American antiquity* vol. 23, p. 34-45, Society for American Archaeology, Washington DC, USA.

- [6] TAVERA I., BERNAL I. and SALAS H., 2007, *El Sismo de Pisco del 15 de Agosto, 2007*, Departamento de Ica - Perú, INSTITUTO GEOFISICO DEL PERU, Informe Preliminar, Dirección de Sismología - CNDG., Lima, Perú.
- [7] THE GETTY CONSERVATION INSTITUTE, 2011, *Damage Assessment of Historic Earthen Buildings After the August 15, 2007 Pisco, Peru Earthquake*, Los Angeles, US.
- [8] MATERO F. 2011, *Conservation of surface finishes, Fire Temple, Mesa Verde National Park, Colorado*, Interim Report, The Architectural Conservation Laboratory School of Design. University of Pennsylvania, USA.
- [9] MORRIS C., 2004, *Enclosures of Power: The Multiple Spaces of Inka Administrative Palaces*, Ancient Palaces of the New World: Form, Function, and Meaning, p. 299-323, S. Evans y J. Pillsbury Editors, Dumbarton Oaks Research Library and Collection, Washington D.C., USA.
- [10] PROTZEN J., 2010, *El trabajo de Uhle en Tambo Colorado: Una evaluación*, En Kaulicke, P., M. Fischer, Masson P. Wolff G, Eds. Max Uhle (1856-1944), Evaluación de sus investigaciones y obras, Fondo Editorial PUCP, p. 233-252, Lima, Perú.
- [11] PROTZEN J.-P., MORRIS C., 2004, *Los colores de Tambo Colorado: una reevaluación*, Boletín de Arqueología PUCP, n°8, p. 267-276, Departamento de Humanidades de la Pontificia Universidad Católica del Perú, Lima, Perú.
- [12] WOLFGANG W. W., 1999, *Max Uhle, 1856-1944. Pläne archäologischer Stätten im Andengebiet, Planos de sitios arqueológicos en el área andina*, Materialien zur allgemeinen und vergleichenden Archäologie, Bd. 56, Mainz am Rhein, Bundesrepublik Deutschland.