# REHAB 2017

## Proceedings of the 3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures


**Edited by**

**Rogério Amoêda**
**Sérgio Lira**
**Cristina Pinheiro**



green lines institute
for sustainable development

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on Preservation, Maintenance and Rehabilitation
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*Braga, Portugal*
*14-16 June*

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# Foreword

*REHAB 2017 - 3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures* aimed to proceed with the discussion on built heritage and the preservation of its legacy that was established in the previous editions of the event. The importance of conservation of historical constructions (built landscape, urban fabrics, buildings, and engineering works) are of utmost importance to preserve the cultural references of a community and was deeply discussed in March 2014, in Tomar, and July 2015, in Porto.

Under the main topics of discussion, subjects of preservation and rehabilitation methodologies and technologies, as well as the importance of the economic and social impacts of preservation practices were covered as the main leading guidelines for the conference debate. Furthermore, different communities' scales (local, regional, national or even worldwide) and authenticity interpretation raise different questions and approaches, and therefore different solutions that are worthily to study, to compare and to experience. The sustainability approach was covered once more, highlighting the importance of the commitment between heritage preservation and technical requirements related to its occupancy and use, such as energy efficiency or materials recovery. Inclusivity was also an important aspect to be discussed as public historical sites and buildings need to be adapted to receive different kind of visitors (children, elderly or handicapped persons) and to establish an adequacy with the perceiving of the physical environment and information contents.

A new chapter was included in this edition of *REHAB 2017* and Earthen Buildings were brought into a particular approach highlighting the complexity of their preservation, maintenance and rehabilitation. Earthen buildings techniques are in many cases of a great importance for local economies and access to housing.

Authors submitting papers to *REHAB 2017* were encouraged to address one of the above mentioned topics of the Conference by providing evidence on past experience and ongoing research work. As a result, *REHAB 2017* welcomed a significant number of papers and presentations addressing field work and case studies but also theoretical approaches to historical buildings preservation and conservation. As in past editions of this Conference, *REHAB 2017* also gave stage to early stage researchers and students willing to share the results of their research projects, namely post-graduation projects and doctoral projects. *REHAB 2017* received a significant number of such proposals the quality of which was confirmed during double-blind review.

We would like to express our gratefulness to all the partners of this edition of *REHAB* who joined the effort to make a significant Conference. Our special word or recognition to the Ministry of Culture – Regional Directorate of Culture North, Museum D. Diogo de Sousa, Monastery of Tibães, Instituto da Habitação e Reabilitação Urbana, Portuguese Order of Architects, Portuguese Order of Engineers North, Association Centro da Terra and Projecto ReVer of the Unversity of Minho. As media partners of the event we would like to thank *Construção Magazine*.

Last but not least, a special word of recognition to the Municipality of Braga that assisted the Organising Committee in all manners.

The Organising Committee also expresses its gratitude to all Members of the Scientific Committee who reviewed the papers and made suggestions that improved the quality of individual work and the over-all quality of the event.

The Editors

Rogério Amoêda
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# Chapter 1

*Technologies for inspection and monitoring of buildings performance and pathologies*

# Mobile Mapping and laser scanner to interrelate the city and its heritage: the Roman Circus of Tarragona

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ABSTRACT: Historic urban centers have a very specific problem, with very large demands in relation to documenting their heritage elements. Not only for its typological diversity and extent, but also by the need to determine the interactions established between the different elements, especially the dialogue between the modern city and the historic towns. We present here the experience of the Roman circus of Tarragona, which occupies four hectares of the historic center of the city, where we have used the "*Backpack*", the Mobile Mapping solution installed on a backpack from Leica-Geosystems. This system allows access –and therefore the documentation– of areas which are only accessible on foot, as well as underground and inside buildings.

## 1 INTRODUCTION

The Roman circus of Tarraco is an archaeological site located in an exceptional context: under the historical Center of Tarragona city (Catalonia, Spain).This type of building was generally built outside the romanwalls. In Tarraco, its clear relationship with the *ConciliumProuinciae* of the ancient capital of province *HispaniaeCiterior* caused this anomalous location. In this way the urbanistic scenery was created according the imperial propagandistic scheme developed at the city of Rome: Apolo Temple, portico of the Danaides and circus Maximus.

Since 2000 the Circus is one of the monuments included in UNESCO World Heritage list. Its level of conservation and its implementation in the present-day city is an anomalous case in architectural and urban heritage. The historical evolution of Tarragona and the solidity of construction materials used in this Circus, *opus caementicium* and *opus quadratum*, have made this area a protagonist inseparable in the urban development of present historical centre. For these reasons, the Circus represents both architectural and museographic reality that is present in the everyday life of people of Tarragona and the visitors. It's a tourist attraction but also a challenge of understanding and a sign of identity of the society of Tarragona.

In relation to urban archaeology, almost always emergency or preventive actions, this building has been the subject of numerous archaeological excavations. Despite its importance, it still does not have an integral high quality project of management or unified technical documentation. Consequently, variable technical documentation is available to us, because the participation of different professionals, companies of archaeology and methodologies have

produced a heterogeneous results. On the other hand, the Tarragona city council does not have enough accurate technical information that allows them to manage the conservation of the archaeological remains with the maintenance task of current urban infrastructures.

In this context the collaboration between the Catalan Institute of Classical Archaeology and the Technical School of Architecture of the Rovira and Virgili University should be located (Solà*et al.*, 2014). The documentation and technical analysis, within the framework of Archaeology of Architecture, has been carried out by an interdisciplinary team of archaeologists andarchitects, who have applied the Mass Data Capture Systems. It has been done for the purpose of obtain a digital documentation in three dimensions of the morphology of the Circus, and integrate their remains in the whole contemporary city planimetry (Fig. 1).


Figure 1. Orthophotoand archeological plane of the Roman circus of Tarragona. The itinerary of Pegasus Backpack is indicated by white lines.

## 2 HISTORICAL AND HISTORIOGRAPHIC CONTEXT

The Circus of Tarraco was built at the end of first century and remained in use until the end of fifth century. During the tumultuous fifth century Tarraco was the last capital of Hispania occupied by the Roman Empire (Macias *et. al.*, 2010; Macias &Rodà, 2015). This explains Circus longevity in the context of political and ideological transformation of Late Antiquity. From the Visigoth period the *arena* of the Circus was compartmentalized in private households, as well as the vaults that supported its grandstands. In the historical context of Al-Andalus, between VIII$^{th}$ - XII$^{th}$, the city was sparsely inhabited and remained without any collective management institution. From the XIIth century the emerging Catalan Nation began the reoccupation of the city. Between XII$^{th}$ - XIV$^{th}$ the Circus was the Suburb and in its north side the first medieval wall of the city was constructed. The late middle Ages population growth

caused the construction of another wall in XIV$^{th}$ century. This was on the south side of the Circus. After this time the Circus was the object of an urbanization process that generated the urban landscape that has been substantially maintained until today.

The first historical engravings show us the layout of streets that are still used today, and the Renaissance descriptions of Lluís Pons d'Icart already reflects the coexistence between the evidences of the Circus and the inhabitants of its time. The city of Tarragona was declared Historical Artistic Site in the year 1966 and currently has a high level of protection. The area of the Circus is an attractive tourist point of Historical Centre that houses a museum complex – Circ/Pretori- which had reached 169,203 visitors in year 2015.

Figure 2. Data capturing process at Roman Circus.

In relation to graphical documentation, the professional activity of the decade of the 80's of last century produced the first archaeological planimetry. These were basically plans or elevationsand, progressively, the first efforts to contextualize the findings in the current urban setting emerged. Thus, we should note the first scientific monograph of the Circus made in the sector of the vault of Saint Ermenegild; plus occasional publications made by the Workshop-School of Archeology of Tarragona and Archaeological Service of *RoviraiVirgili* University (bibliographical compendiumin Macias *et al*., 2007). All these works attempts to link and place archaeological remains in the urban plannig of the three monumental terraces of Imperial complex of the roman acropolis.

The Architectural Heritage Service of Catalan Goverment had simultaneously commissioned the architect Salvador Tarragó, Polytechnical University of Catalonia, the first complete topographical survey of the remains of the Circus. This documentation, elaborated from the cadastral urban map, included the visible remains in private buildings. This work was carried out at 1: 100 scale (Tarragó, 1993). Finally, the development of the Tarraco Archaeological Planimetry project (2004-2007, Macias *et al*., 2007) allowed us the establishment of a network of topographic bases through GPS and according to the system of the Catalan Cartographic Institute.

Finally, the availability of archaeological plans and sections along with the new digital technologies of image processing and vectorial drawing, allowed us the elaboration of the first pedagogical and diffusion proposals based on three-dimensional reconstructions (Macias *et al*., 2005). At the same time, this research has shownthat the digital proposal requires an accurate technical documentation for the validation of archaeological hypothesis. If we do not do this, it will be difficult to distinguish between reconstructive hypotheses and pedagogical proposals. Thus, we highlight a line of research based fundamentally on the development of three-dimensional applications from pre-existing “traditional documentation” (Mar et *al*., 2015).

## 3 METHODOLOGY

Pegasus BackPack (http://leica-geosystems.com/products/mobile-sensor-platforms/capture-platforms/leica-pegasus-backpack) is the trademark of *Mobile Mapping* system (wearable, portable by a person while walking) marketed by Leica company from the end of 2015. The *Mobile Mapping* is a bulk data capture system characterized by its multiple types of sensors, and particularly by the fact that the receiving antenna is moving. It derives directly from LIDAR systems, which merge laser scanning technology and radar, and must carry motion sensors that allow to calculate and correct the drift of the antenna as it moves between laser emission and the reception of its bounce.

Figure 3. Scanning of *Trinquet Vell* street and three-dimensional reconstruction.

In a standard laser scan, relative positioning of a point to the device is determined by time of flight (or wavelength changing) of the laser pulse from being sent until it returns, together with the vertical and horizontal angles of the transmitter at the time of sending the beam. Obviously, if the device undergoes a displacement both the distance and the angle of return vary, thus giving a false reading. In order to solve it different devices are installed: INS (Inertial Navigation Measurement Unit), DMI (Distance Measurament Indicators), or IMU (Inertial Measurament Unit), that combines accelerometers and gyroscope to measure and report on the speed and direction of a moving object. With these sensors are calculated both the drift and the speed of movement, allowing to correctly position the reading points. If a GPS is added the survey can also be georeferenced.

At the beginning of the century, mobile reference systems supplemented with data capture sensors began to be designed (Mackenzie 2001); initially they were only photographic cameras. Quickly were mounted on motor vehicles to take advantage of its odometer and the known diameter of the wheels, which allowed to easily calculate the movement drift. The best known example is, undoubtedly, Google's *street view* (https://www.google.com/streetview/), which since 2007 has allowed this company to intensively perform spherical photographs in different parts of the world.

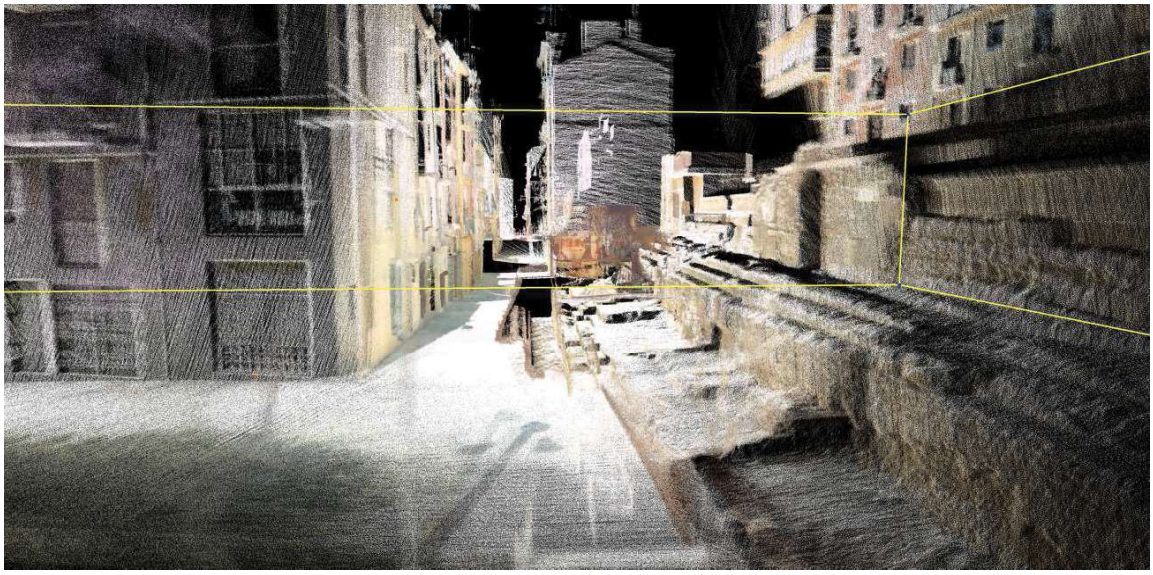

Figure 4. *Trinquet Vell* street: remains of the grandstands.

The sensitivity improving of the IMU, along with the gradual reduction of its dimensions, allowed, in the second decade of the present century, to replace the main sensor by a laser scanner. It is necessary to take into account that these devices reach centimetric or subcentimetric precisions, and therefore systems of navigation of a similar precision are necessary to obtain surveys with a minimum rigor.

The first company to market a *Mobile Mapping* with laser sensor was TOPCON, the year 2009, with its IP-S2 (http://www.topconcare.com/en/hardware/mobile-mapping/ip-s2/), equipped with a dual frequency GNSS, a Honeywell IMU, and a 360º photographic camera. It could carry from 1 to 5 linear laser scanners. Soon other companies such as Trimble, Mitsubishi or Optech started selling similar products. Leica marketed its model, the Pegasus, in 2014 (http://leica-geosystems.com/products/mobile-sensor-platforms/capture-platforms/leica-pegasus_two). All of these devices were mounted on wheeled vehicles.

In the year 2015 appeared a remarkable novelty with the Pegasus BackPack, which was the first system of Mobile Mapping that dispensed with the use of the odometer, and therefore could be carried inside a backpack. This allowed the possibility to carry out moving surveys in areas where it would be difficult or impossible to circulate by a wheeled vehicle.

The Backpack is oriented thanks to a triple channel GNSS (GPS and Glonass) that is reinforced by an IMU with a drift of 20mm RMS every 10 seconds that is activated when GNSS signal fails or is insufficient. It has two planar laser scanner profilers that can register 600,000 points per second with a useful range up to 50m. One of them is the one who does the reading, while the other serves as a support when the IMU is activated by creating areas of overlap that help to correct drift. It is complemented by four 4MP photographic cameras that cover a 360º x 200º visual area. With all this, a spherical photographic image of the entire route is obtained, besides the point cloud of the documented area.

Its accuracy is determined mainly by the quality of the GPS signal. Under optimal conditions, its nominal value is 5cm, but the experience we have done indicate a real precision between 5 and 12cm. Obviously, the precision suffers from the moment the GNNS signal is lost and the IMU comes into operation: we have to remember that the IMU has a drift of about 20mm every 10 seconds. This limitation can be partially overcome thanks to the software of data processing, as it incorporates the continuous recording of the points generated by the second laser scanner, allowing to adjust the overlap of the partial point clouds. If some control points with known coordinates are added, the working accuracy (regardless of whether the GNNS is active or not) is below 10cm.

In Tarragona a route of about 2650 linear meters was made, which allowed to cover all the area of interest (https://youtu.be/z_i_YPjML9M ). It was performed, including the previous and final calibration work, in about 3 hours (Figs. 3-4). The average distance to the nearest point has

always been between the meter and the 4 meters. The final model has about 580 million points, with a density that varies greatly depending on the height of the facades, since the number of registered points decreases as the distance from the Backack increases.

## 4 CONCLUSIONS

This new skill, combined with in-depth historical and archaeological knowledge, has allowed us to interconnect the architectonic heritage preserved in the ancient roman circus area. At the same time, we can determinate the constructive interactions between the different elements with a great precision in the details. In addition, in special interest places, we have linked the mapping's point cloud with others previously obtained from traditional laser scanner, more precise and perfected.

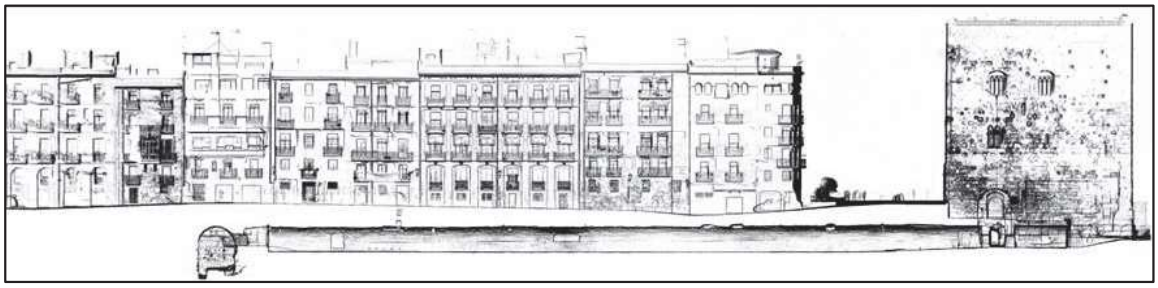

Figure 5. *Enrajolat* street: facade and remains of its subsoil.

But the main advantages is the graphic documentation of large areas in minimal time, and de fact that this system allows access –and therefore the documentation– of areas which are only accessible on foot, as well as underground and inside buildings. We have obtained an indiscriminately documentation of several historical remains, both exterior and indoors.

And not just architectonical remains have been documented with Backpack. This work, however, made it possible to capture every step of all the streets and facades of the old town of Tarragona, which are inserted in the area occupied by the roman Circus. The use of this unique reality capture solution also facilitated the graphic integration of the contemporary and ancient architecture of the city into one single workflow (Fig. 5). From the roman wall of IIth BC from the latest building edified. Therefore, the graphic documentation allows a diachronic dialogue between architectural elements in the historic center, the result of different protagonists and how these ancient constructions have developed and transformed Tarragona's history and its urban plans.

For these reasons, the survey transcends our traditional technical needs and the resulting documentation allow us afford new educational resources and control and management tools of a city, that is superimposed on a building included in the UNESCO World Heritage list.

Figure 6. Three-dimensional models host in Sketchfab platform: modern city (https://skfb.ly/66Sys).

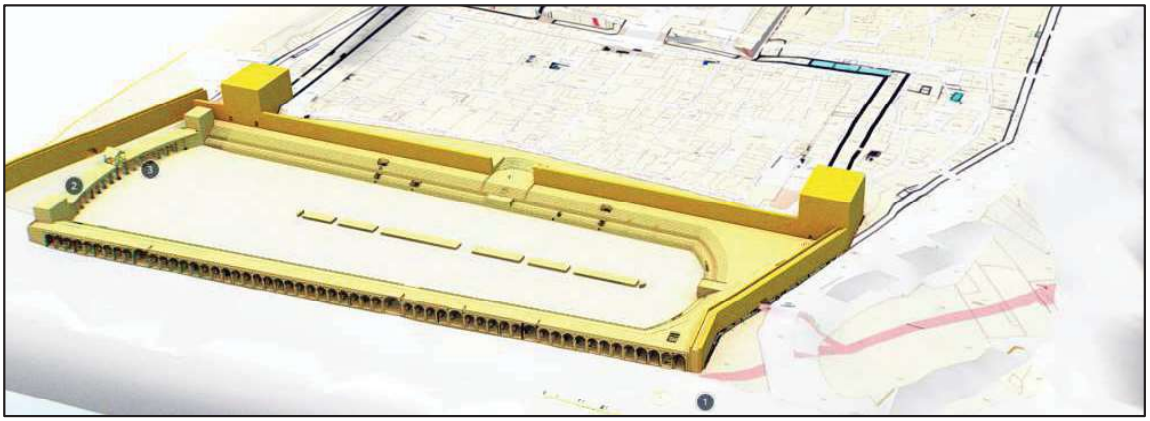

Figure 7. Three-dimensional models host in Sketchfab platform: Roman circus model. (https://skfb.ly/66YMw).

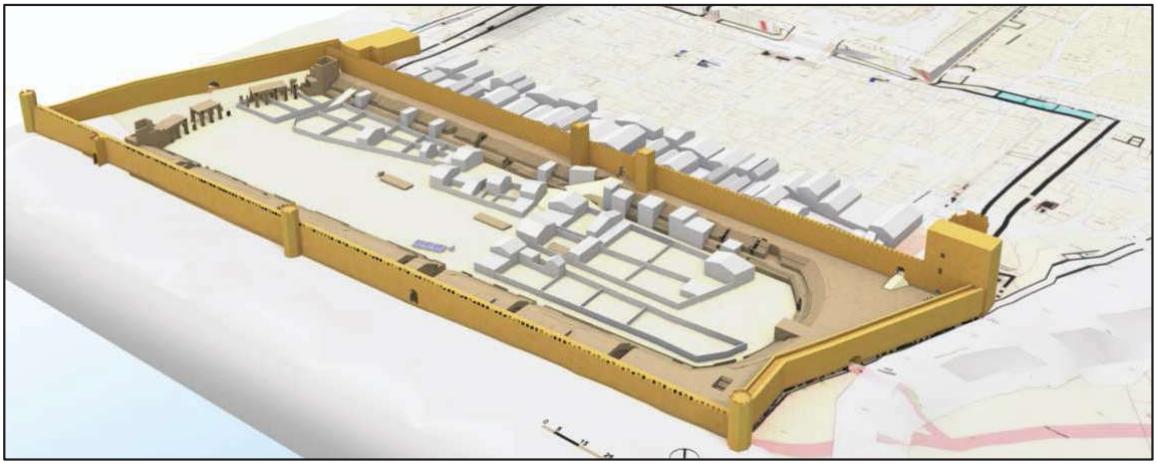

Figure 8. Three-dimensional models host in Sketchfab platform: medieval walls (https://skfb.ly/6oXAq).

Finally, 3D documentation of roman Circus allowed archaeologists at ICAC and architecture at ETSA to develop several activities:

- Historical urban studies. In this case between the roman building and medieval walls superimposed.
- Archaeological research mixing all the remains in a single three-dimensional graphic documentation.
- Cadastral plans and a heritage management system, with a particular focus on the effects of urban infrastructure: sewer, etc.
- Pedagogy and museography of the historical heritage.Recently, with the aim of explain currently urbanism like a result of specific historical development, a large part of documentation has been organized in three historical layouts, after which dimensional models can be consulted. Our collection of Circus three-dimensional models host in Sketchfab platform serves as an example of future possibilities of this technology: 3D model (https://skfb.ly/66YMw), medieval walls (https://skfb.ly/6oXAq) and modern city (https://skfb.ly/66Sys) (Figs. 6-8).

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Furthermore, different communities' scales (local, regional, national or even worldwide) and authenticity interpretation raise different questions and approaches, and therefore different solutions that are worthily to study, to compare and to experience.

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