



# The City Walls of Dubrovnik

by Miljenko Žabčić; Picture: Gerald Loacker

**Geographica d.o.o. recently completed a major project which included scanning and comprehensive documentation of the almost 2 km long city walls of Dubrovnik in the very south of Croatia for the "Society of Friends of Dubrovnik's Cultural Heritage", a group of engaged citizens. The medieval city, nicknamed "the Pearl of the Adriatic", is on the UNESCO list of World Heritage Sites. Purpose of the four year project was to fully document the current state of the city walls and fortresses for future improvements and in order to preserve their current state for upcoming generations.**

The "Society of Friends of Dubrovnik's Cultural Heritage" (Društvo prijatelja dubrovačke starine) approached Geographica d.o.o. in 2004, as Dubrovnik's city walls hadn't ever been completely documented before. 3D laser scanning was selected as the best method. The documentation included scanning, modeling, and drawing and will be used for multiple purposes such as everyday maintenance, legal requirements, interior design for functionality improvements, cost estimate calculations for various work, study of the object in terms of its origin, and building stages.

The town fortifications, ramparts, and towers outside the walls were built, reinforced, and reconstructed in the period from the 12<sup>th</sup> to the second half of the 17<sup>th</sup> century. A number of engineers were involved in these works – well known names such as Nicifor Ranjina in 1319, Michelozzo di Bartholomeo in 1461–1464, Juraj Dalmatinac or George the Dalmatian in 1465–1466, Paskoje Milicevic in 1466–1516, and Antonio Ferramolino in 1538.

The main wall is 1'940m long (following the ring-corridor), 4–6 m wide on the mainland side and between 1.5 and 5 m wide on the sea side. It is up to 25 m high in parts. The wall was reinforced by three circular and 14 quadrangular towers, five bastions (bulwarks), two angular fortifications, and a large fortress called Sveti Ivan (St. John). Among the towers, the most monumental is the circular tower of Minceta, on the north-western corner of the ramparts. The reinforcement, along the main wall on the mainland side, includes one larger and nine smaller semicircular bastions, and the casemate fortress Bokar, the oldest preserved fortress of its kind in Europe.

## **Very dense scan data**

Since one of the products to be achieved with the scan data were plane drawings of the current state of the walls, including drawings of the wall's struc-

ture, scans had to be very dense. Therefore all the walls were scanned with a resolution of under 1 cm, usually around 5–8mm, depending of the shape of the stones. Only the interiors of the fortresses were scanned with a resolution of 2.5 cm. The scan data is a very important part of the final product because it will be used in the future for precise measurements in the process of preservation.

### 3D model as simplified representation

A 3D model was created as a simplified representation of the walls and fortresses but it contained all main construction elements of the walls. It is used for general planning in various projects, fast overview of parts of interest, calculations of quantity and expenses in preservation works and presentations.

The model was created in two steps. The first step was edge extraction, done with Leica Cyclone Software by converting the edges of scan data into lines and polylines. The second step was the generation of surfaces from the extracted edges. Surfaces were generated in a CAD environment to ensure the whole model is suitable for a wide range of applications and users.

### Plane drawings as documentation of the current state

Generating the plane drawings was the most demanding and time-consuming part of the project.

According to Croatian laws of preservation of cultural heritage this documentation has to be prepared for plot with a scale factor of 1:50 and must include ground views, horizontal, and vertical sections and facade (elevation) views with stone structure. Every drawing has to be dimensioned with plane and height dimensions.

Drawings were created in a CAD environment using Leica CloudWorks for AutoCAD. These drawings are very detailed and contain all the segments of the walls including drawings of every individual stone. The number of required drawings was not defined at the project beginning. There have to be enough to represent every part of the walls and every segment of its construction. In case of disaster it must be possible to completely reconstruct the walls according to this documentation. Such drawings are also used for detailed planning in preservation and restoration, studying the walls' history and phases of building, everyday preservation works in the field, and various other tasks. ■

#### About the author:

Miljenko Žabčić is a surveying engineer and director of Geographica d.o.o. in Split, Croatia. Geographica d.o.o., founded in 1999, employs 12 experts covering the fields of geodesy, architecture, construction, and archaeology. The company was the first in Croatia to start using 3D laser scanning technology in 2003.

## City Walls of Dubrovnik

**Total perimeter (including both sides of the walls):** 4'300 m

**Total scanned area:** 120'000 m<sup>2</sup>

**Scanning time:** 240 days (1 scanner, 2 operators)

**Products:** Leica HDS2500, Leica ScanStation

**Total project time:** 4 years with two persons in the field and three persons in the office

