UNIVERSITÀ DEGLI STUDI DI PADOVA

CIVIL, ENVIRONMENTAL AND ARCHITECTURAL ENGINEERING

ICEA

Understanding industrial archaeology: The case of a cooling tower

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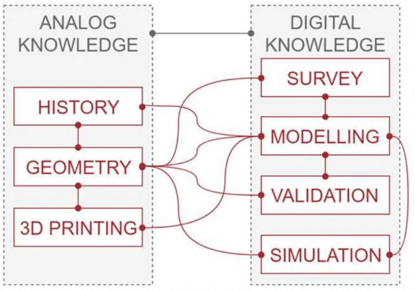
COMPREHENSIVE KNOWLEDGE FRAMEWORK

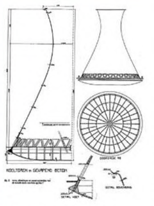


Abstract: The research presents an innovative methodology for studying industrial archaeology buildings, focusing on the cases of concrete cooling towers. The integrated approach combines the opportunity deriving from analog and digital instruments, with the aim of developing a comprehensive knowledge frame on the constructions and their context during and after their operating period. Therefore, a workflow moves from historical and archival research to conduct an in-depth study of the generative geometries in order to understand the static and fluid-dynamic behaviours of the buildings. The introduction of digital survey techniques (aerial and terrestrial laser scanning), three-dimensional information modelling (BIM) and computational analysis tools allows the management of a multidisciplinary framework ensuring data integration, high levels of precision and monitoring capacity through the whole process. A case study analyses the Vetrocoke cooling tower, built in Porto Marghera (Venice) in 1937 and recently converted in a space for cultural dissemination and events.

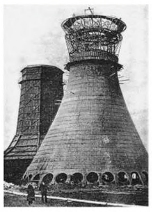
The construction of a comprehensive knowledge framework passes through the use of analog and digital tools. In order to be effective, each tool should play its role in the process with a view to the relationships with the others. All the phases of work are therefore connected in order to define an interoperable network of information.

ANALOG

HISTORY



F. Van Iterson and G. Kuypers (1917) Patent for a concrete cooling tower.

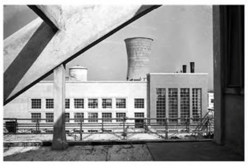


First hyperbolic tower. Emma mines, Herleen (Netherlands).

First cooling towers had rectangular plans and were built in wood, steel or masonry. From the beginning of the 20th century, engineers tried cylindric cooling towers made of concrete and started the search for the optimal geometry. F. van Iterson and G. Kuypers developed a new solution: the hyperbolic tower, realizing the perfect match between form and function. The double curvature gave high structural strength, improved aerodynamic and grew the air draught.

The Porto Marghera (Venice, IT) industrial area was born in 1917. The Vetrocoke cooling tower was built in 1937 from a project designed by the Société des réfrigerants hyperboliques (Paris).

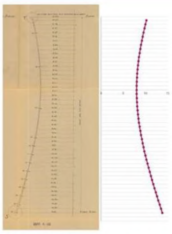
Aerial view of the industrial plants of Montecatini and Vetrocoke.



One of the Vetrocoke sheds, with the cooling tower on the background (1940).

GEOMETRY

The rotation of an hyperbole around one of its principal axes generates a quadric surface whose name is hyperboloid of one sheet.

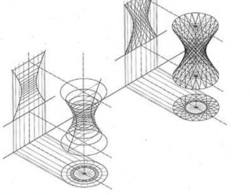


The 47 coordinates that, in the original project (1937), describe the generative of the surface.

The generative formula:

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

$$\frac{x^2}{63.96} - \frac{y^2}{454.32} = 1$$

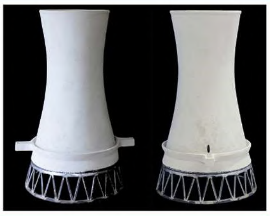


The generative geometry of the hyperboloid determines its properties and applications. The same surface can be interpreted in two ways, revealing hyperboles in vertical planes and circumferences in the horizontal ones, or straight lines sloped in two symmetric directions.

A. Giordano (1999). Cupole volte e altre superfici. La genesi e la forma. Utet, Turin.

3D PRINTING

The BIM model is eventually used to create a scaled representation as large-format 3D printing (scale 1:25). From a structural perspective, scaling the dimensions of the hyperboloidic wall brings to an "unprintable" building due to the excessive thinness. A structural simulation on the scaled model was performed in order to predict the optimal thickness of the printed tower. The result is now exposed in a exhibition hall on the ground floor of the tower.



Images of the model realized in collaboration with Desamanera.

DIGITAL

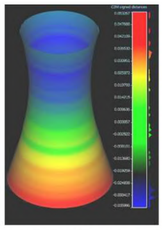
SURVEY

The LiDAR point cloud

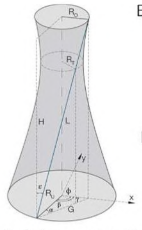
A digital survey acquired with the LiDAR (Light Detection and Ranging) technique is the representation of all the points constituting a solid object, with their x, y and z cooditates and their color properties. The result is a point cloud: a accurate digital copy of the artifact. The digital survey, acquired by arch. Umberto Pavanello, allowed to determine all the geometric parameters of the cooling tower and to compare the original projects with the as built. The resulting shell has a variable thickness between 10 and 35 cm, which is the outcome of an optimal shape design.

The comparison between the executive project and the real constuction highligts an impressive precision in the realization, with a maximum deviation of 5 cm, noticeable on the basement of the cooling tower.

SW used:
Leica Cyclone



Analysis of deviation between the projects and the as built.

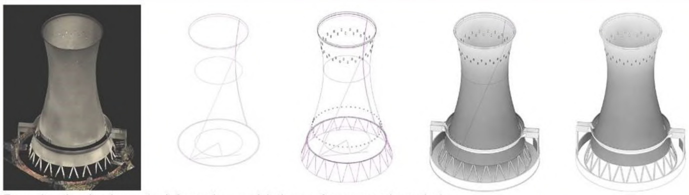


Costitutive parameters of the Vetrocoke cooling tower.

External surface
R_U: 13.96 m
R_O: 10.18 m
R_T: 8.10 m
β: 91.7°
H: 50.2 m

Internal surface
R_U: 13.55 m
R_O: 9.87 m
β: 90°
H: 50.2 m

MODELLING



From the cloud point to the informative model, throug the geometric analysis

The informative and parametric model (BIM) was designed starting from the point cloud. To allow a close link with the generative geometry, the use of Visual Programming Language (VPL) scripts was included in the process. This permits high levels of control and guarantees the achievement of a precise representation, able to support analyses and simulations by changing the shape of the hyperboloid.

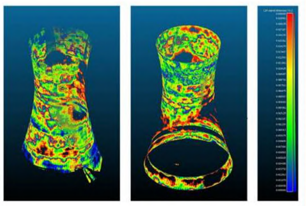
SW used:
Autodesk Revit
Autodesk Dynamo

The VPL script in the Dynamo environment.

VALIDATION

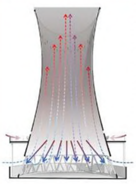
The comparison between the digital survey and the BIM model estrablishes high levels of compliance. The test, made for both the internal and external surface, shows a maximum deviation of 3 cm. This outcome validates the model and allows its inclusion within a virtuous process of data modelling aimed at the achievement of a knowledge frame on the cooling tower.

SW used:
Cloud Compare



Comparison between the point cloud and the model. Internal and external surface.

SIMULATION

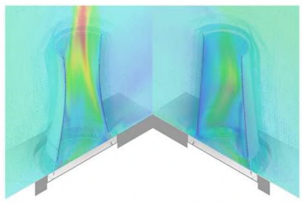


Scheme of the functioning of a cooling tower.

In a cooling tower the hot water to be cooled encounter the air and it is partially transformed into steam. This is pushed upward thanks to the difference of temperature between the base and the top of the tower. The cooled water is then collected in the lower tank, ready to be reused within the industrial plants. In this physical process, the geometry of the tower can deeply affect the performances of the system. The shape of the building is therefore asked to follow optimization criteria.

CFD (Computational Fluid Dynamics) simulations, confirmed that the hyperbolic profile is the optimal configuration for the functioning of a cooling tower, by increasing the air velocity inside the tower with respect to cilindric or truncated cone alternatives. In the figure on the right, colors shifted to red represent higher air speeds.

SW used:
Vento
Autodesk CFD



Air speed in the CFD simulation performed with Vento. Hyperbolic and truncated cone configuration.

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