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# PRELIMINARY DATA OF CFD MODELING TO ASSESS THE VENTILATION IN AN ARCHAEOLOGICAL BUILDING

***MODELIZACIÓN MEDIANTE CFD DE PARA EVALUAR LA VENTILACIÓN EN UN EDIFICIO ARQUEOLÓGICO, DATOS PRELIMINARES.***

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**Abstract:**

The present study addresses the influences of wind flow structure, as an important factor responsible of material damage (erosion contributing) on "Casa di Diana" Mithraeum, a roman building (130 A.D.) sited on Ostia Antica (archaeological site, Rome – Italy), through the Computational Fluid Dynamics (CFD) simulations and direct measurements for its verification and validation (V&V). In this preliminary work, we present results relating to 3D reconstruction (geometry of the entire building) and the mesh importing on Fluent software. In general, the data check confirms, with ±10%, a good agreement (model) between the numerical solutions and direct measurements data by portable sensor. For this, the model proposed could be applied on similar cases, buildings characterised by different "boundary conditions", to predict without direct measurements, the air movement in these ventilated spaces.

**Key words:** computational fluid dynamics (CFD), ventilation, archaeological site, preventive conservation, 3D reconstruction

**Resumen:**

El presente estudio aborda la influencia de la acción del viento en la estructura puesto que dicha acción es un factor relevante y responsable del daño material (contribuye en la erosión) del mítreo de la "Casa de Diana", un edificio romano (130 A.C.) situado en Ostia Antica (sitio arqueológico, Roma, Italia), mediante las simulaciones de la dinámica de fluidos computacional y las mediciones de campo para su verificación y validación (V&V). En este trabajo preliminar, se presentan los resultados de un reconstrucción 3D (geometría del edificio entero) y del mallado importado al software Fluent. En general, la inspección de los datos confirma, con ±10%, un buen ajuste (modelo) de las soluciones numéricas y de las mediciones de campo adquiridas mediante un sensor portátil. Para ello, el modelo propuesto puede ser aplicado en casos similares, edificios caracterizados por diferentes condiciones de contorno, para predecir sin las mediciones de campo el movimiento del aire en estos espacios ventilados.

**Palabras clave:** dinámica de fluidos computacional (DFC), ventilación, sitio arqueológico**,** conservación preventiva, reconstrucción 3D

## 1. Introduction

The study on evaluation of historical buildings indoor conditions is constantly increasing, especially in terms of the adequacy of natural microclimate (D'Agostino and Congedo 2014) and to enjoy the works art by visitors (psycho-physical wellness) (Corgnati and Perino 2013). The effect of ventilation strategies on the microclimate was used to investigate also indoor environment, like crypt (D' Agostino *et al.* 2013), place under harsh climatic conditions.

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A three dimensional (3D) computational fluid dynamics (CFD) model and direct measurements for verification and validation (V&V) of CFD has been developed to assess the ventilation issues of an historic building sited in Ostia Antica (archaeological site, Rome – Italy) in order to assess the influence of wind in terms of material building conservation (erosion and faciliting evaporation processes) that suffer of several problems (Scatigno *et al.* 2016a, Scatigno *et al.* 2016b), and to evaluate the air quality (exchange air).

The aim of the study was to find a solution able to provide a proper microclimate for the conservation of the building, studying the airflows and developing in a future a global plan for conserving and protecting the site.

The preliminary results show a good agreement (model) between the numerical solutions and direct measurements data by portable sensor.

The direct measurements give the punctually information on air movement, the CFD simulation, on the contrary, allows to offer illustrative graphic screens and precise values in the full indoor space of the archaeological site.

The prediction model, offers the whole knowledge of the "real" air ventilation with a "virtual" method.

For all of this, the model proposed could be applied on similar cases, buildings characterised by different "boundary conditions", to predict without recourse to direct measurements, the air movement in these ventilated spaces.

## 2. Methodology

### 2.1. Building description

The Casa di Diana *Mithraeum*, made of bricks and pozzolanic mortar (wall-building materials), is comprised of two inter-communicating rooms (*pre-Mithraeum* and *Mithraeum*) and several openings (windows and main door) which expose small areas to sunlight and outer air. Despite, being defined as such structurally comparable to a semi-confined environment, really the framework presents a very characteristic microclimate, similarly to a hypogeum (Scatigno *et al.* 2016a). No ventilation systems are found, thus the ventilation is natural and comes from several openings, especially from one window, sited at west side (*pre-Mithraeum* room), of significant dimensions (1.48x1.16m).

### 2.2. CFD techniques

CFD techniques consist of the solution of a set of partial differential equations. These equations are the equation of continuity, the conservation of momentum (or Navier-Stokes Law) and the energy. Equation 1 integrates these equations in a single equation:

$$\frac{\partial}{\partial t}(\rho\varphi) + div(\rho\vec{u}\varphi - \Gamma_\varphi grad\varphi) = S_\varphi \quad (1)$$

Where:

ρ = the density of the fluid (air)

φ = the variable of interest

t = the time

$\vec{u}$ = the velocity vector

$\Gamma\varphi$ = the diffusion coefficient of φ

$S\varphi$ = the source term of φ

In this work, from the different CFD commercial software, we have chosen ANSYS FLUENT and GAMBIT (the pre-processor of Fluent). In this way, ANSYS FLUENT has been already used for the study of the ventilation in different types of buildings (Flaga-Maryanczyk *et al.* 2014, Xu *et al.* 2013).

CFD software also requires some Boundary Conditions (BC) to perform the CFD simulations. In this vein, and using the suitable sensors, the pressure and the air velocity at the windows, doors and holes were measured as well as the temperatures at the walls, floor and air. By different BCs and meshed, CFD simulations were performed. In this work, the standard k-ε turbulence model and wall functions were used in all these computations (D'Agostino and Congedo, 2014). Unfortunately, the numerical results are obtained from a limited number of cases, i.e., these measured inputs determined by the meteorology of the day of the field experiments.

### 2.3. Field measurements

In order to verify the model, the direct measurements were performed in only one day with non-extreme meteorological conditions (in March of 2016) with one sensor moved in different points to map the area, considering the more ventilated area (near to openings: principal entrance, windows) and the centre of two rooms (within other four central points).

## 3. Preliminary results

The "Casa di Diana" *Mithraeum* presents a complex geometry. The building is built on two different levels, due to the presence of structures like the altar and "*podiae*", seats for the Romans that assisted the sacrificial ritual of the killing the bull, which are about seventy centimeters above the pedestrian level.

For this, the geometry phase was conducted with special attention.

The Figure 1 and 2 show the phases of geometry building through the GAMBIT. The Figure 3 shows the next phase, the importation into FLUENT.

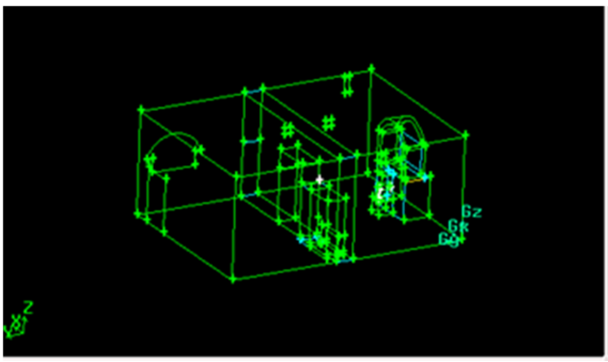

**Figure 1:** Phases of geometry building (point cloud), made by Gambit software

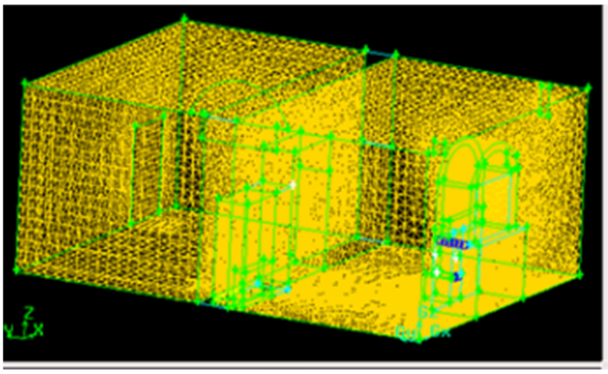

**Figure 2:** Phases of geometry building (meshes) made by Gambit software

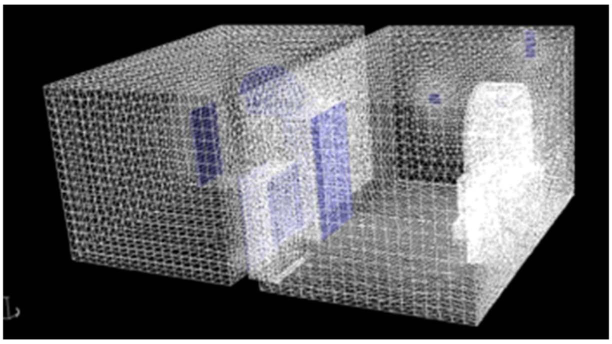

**Figure 3:** Mesh importing in Fluent. The blue areas indicate the openings (main entrance and windows) and the access into two inter-communicating rooms.

At the first view, the ability of the CFD simulations to predict airflow in archaeological site was clear.

A significant difference was found between two rooms. In particular, in a corner area of the *pre-Mithraeum* room, the air valocities change. During the experiment, the airflow rates, which pass through the wholes, is small: no relevant wind gusts are detected during this day as consequence no indoor air velocities changes appear neither in direct measurements with sensors or in CFD results. Of course, seasonal changes and several wind gusts could modify the nature of indoor microclimate of the monument. Next field measurements will be carried out in different seasons and in extreme meteorology to compare results.

## 4. Conclusions

In this preliminary work, we present the results relating to 3D reconstruction (geometry of the entire building) and the preliminary meshes to study the convergence of the results.

Regarding the air monitoring, a preliminary data checking reveal that the indoor air velocity values are in a very low range of values, as consequence the resulted percentage is a very small magnitude. In this vein, the most important question is the good fit in the comparative results (CFD and measurements) and that the trend of results is accomplished.

In general, the data check confirms, with ±10%, a good agreement (model) between the numerical solutions and direct measurements data by portable sensor. In some cases, a more significate difference was found.

This work confirms that CFD modeling can help in a better control of the indoor microclimate of archeological buildings. However, there will be necessary next field measurements in different seasons and in extreme meteorological events as well some measurements and computations including the presence of people in the historical building in order to analyze their influence.

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