BE4E

STDF

## Workshop Presentation Title

# Three Dimensional Modelling of Cairo Citadel

Prepared By

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# Presentation Contents

1- Introduction

2- Cairo Citadel Scanning

3- Citadel and Soil Properties

4- Numerical Modelling of Cairo Citadel

5- Cairo Citadel analysis (static and dynamic)

6- ViBa effect

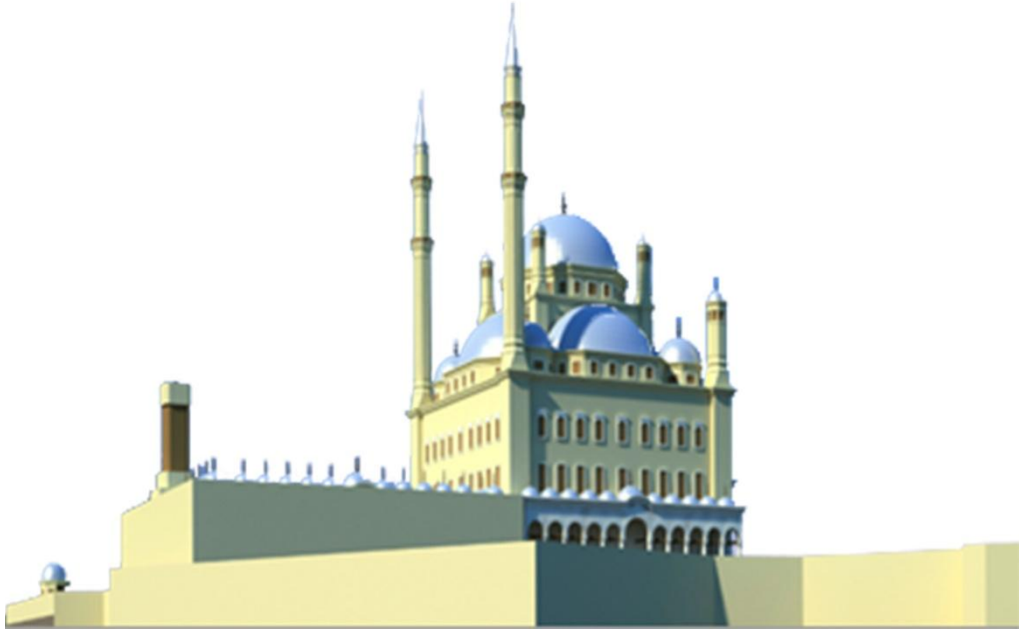
7- Summaries and Conclusions

An inside picture for the Cairo Citadel

# 1- Introduction

## 1.1 Aim of the presentation

- Illustrating the steps of creating a three dimensional model of Cairo Citadel
- Demonstrating the static and dynamic response of the Citadel
- Illustrating the effect of using Vibrating Barriers (ViBa) on the dynamic response of the Citadel



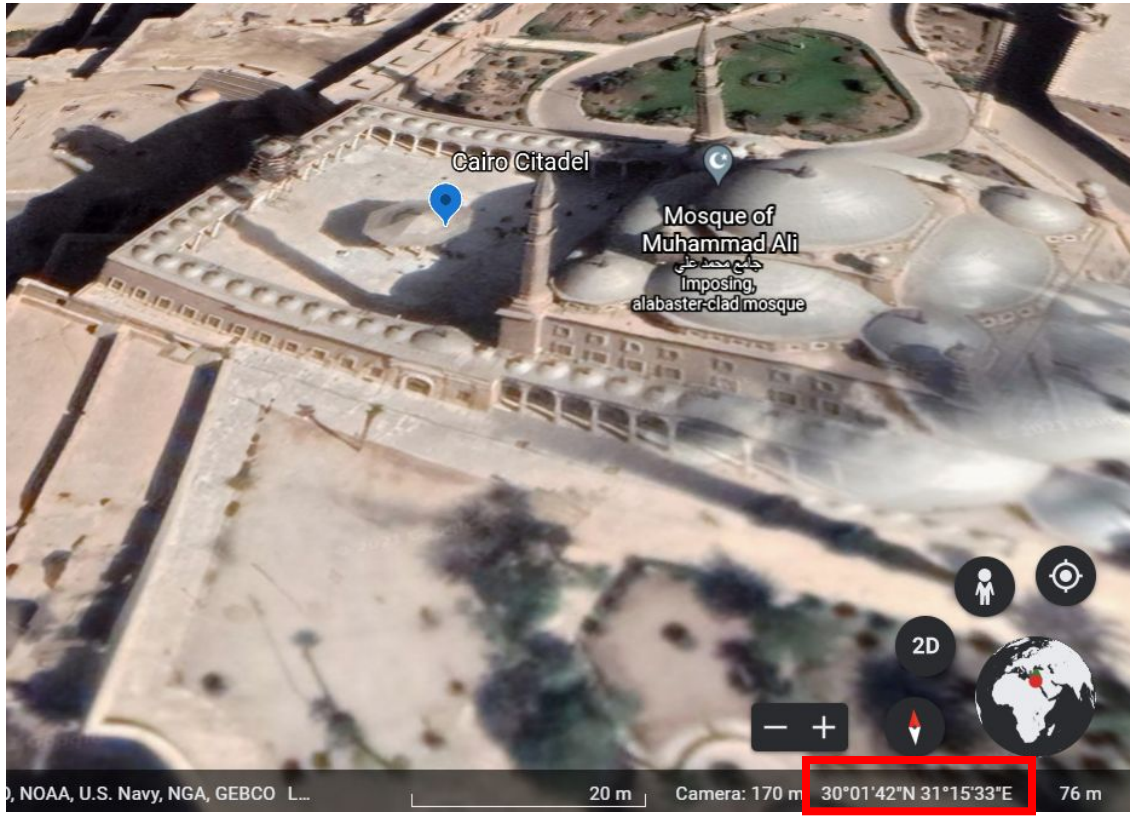
## 1.2 Why 3D numerical modelling of Cairo Citadel is important

- Cairo Citadel is one of the most important monuments in Egypt
- Complexity of the Citadel geometry
- Difficulty of performing dynamic analysis for the Citadel Especially in the existence of ViBa

# 2- Cairo Citadel Scanning

## 2.1 Cairo Citadel Location

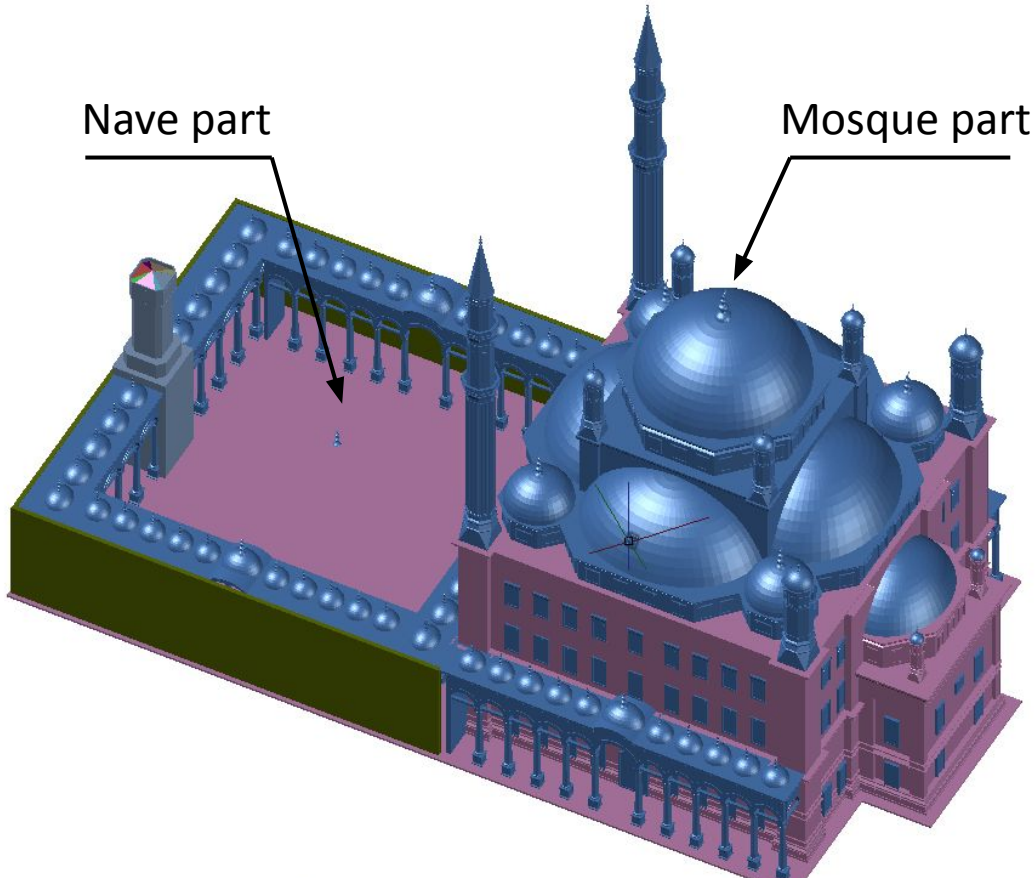
Cairo Citadel is located in Al-Mokattam area, which is at the coordinates of 30 degrees North and 31.15 degrees East.




Google earth snapshot for Cairo Citadel

## 2.2 Cairo Citadel Parts

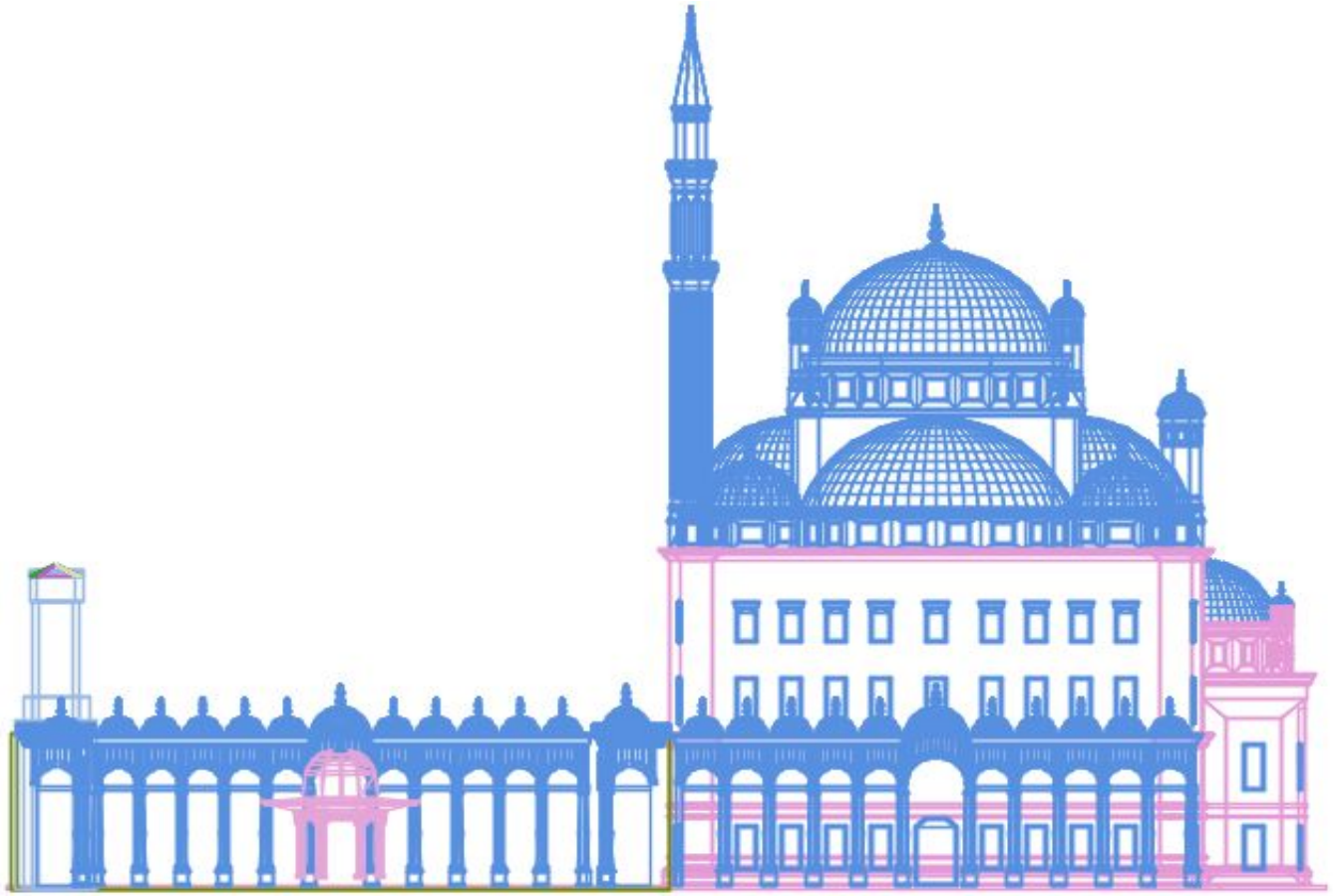
The Citadel Consists of two parts; the Mosque and the nave



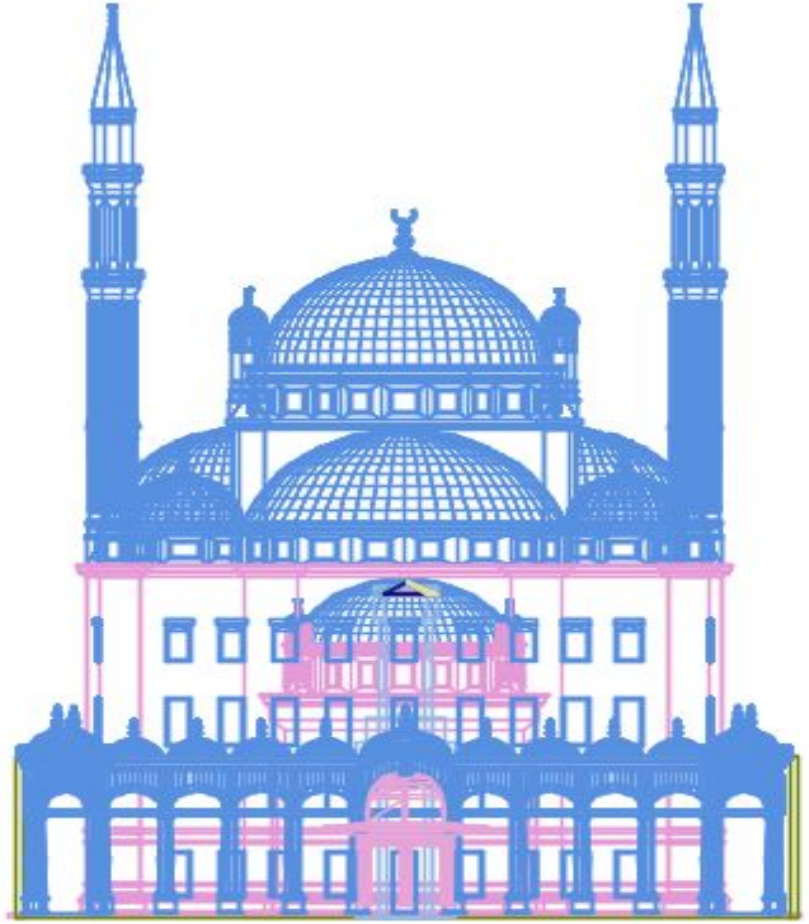

Cairo Citadel 3D model

# 2- Cairo Citadel Scanning

## 2.3 Cairo Citadel views



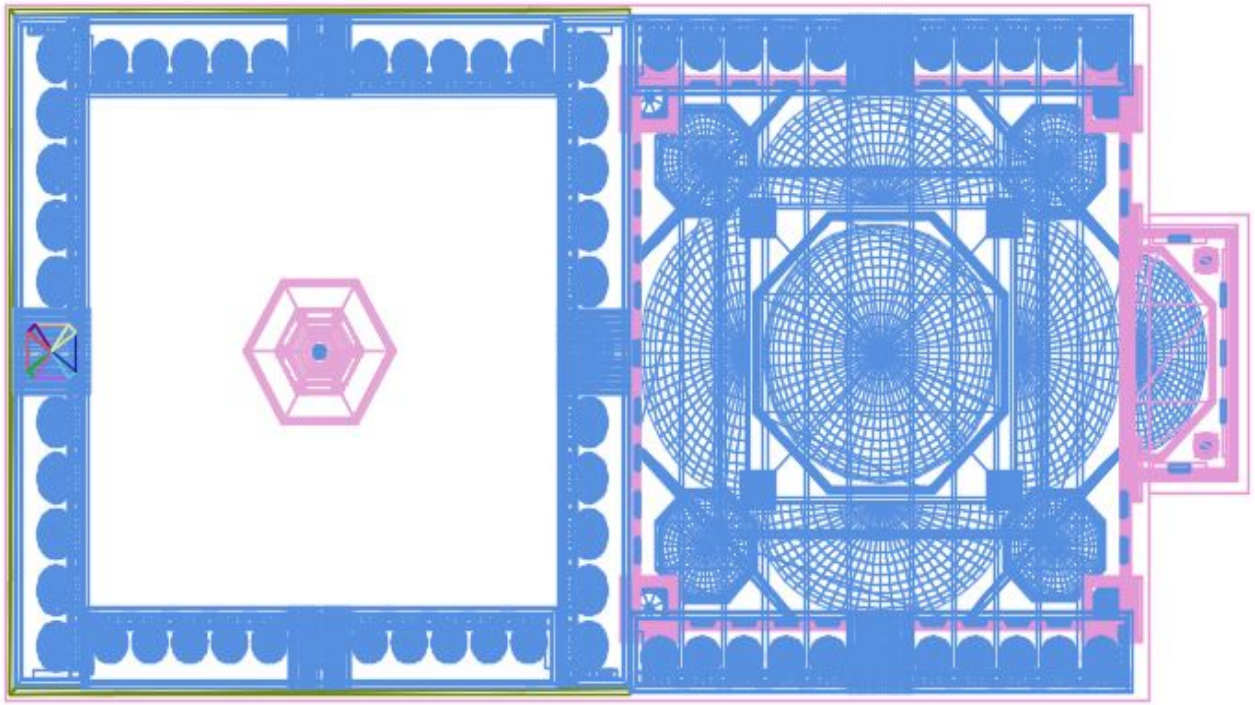
Vertical View in the long direction (North-Dir.)



Vertical View in the short direction (East-Dir.)

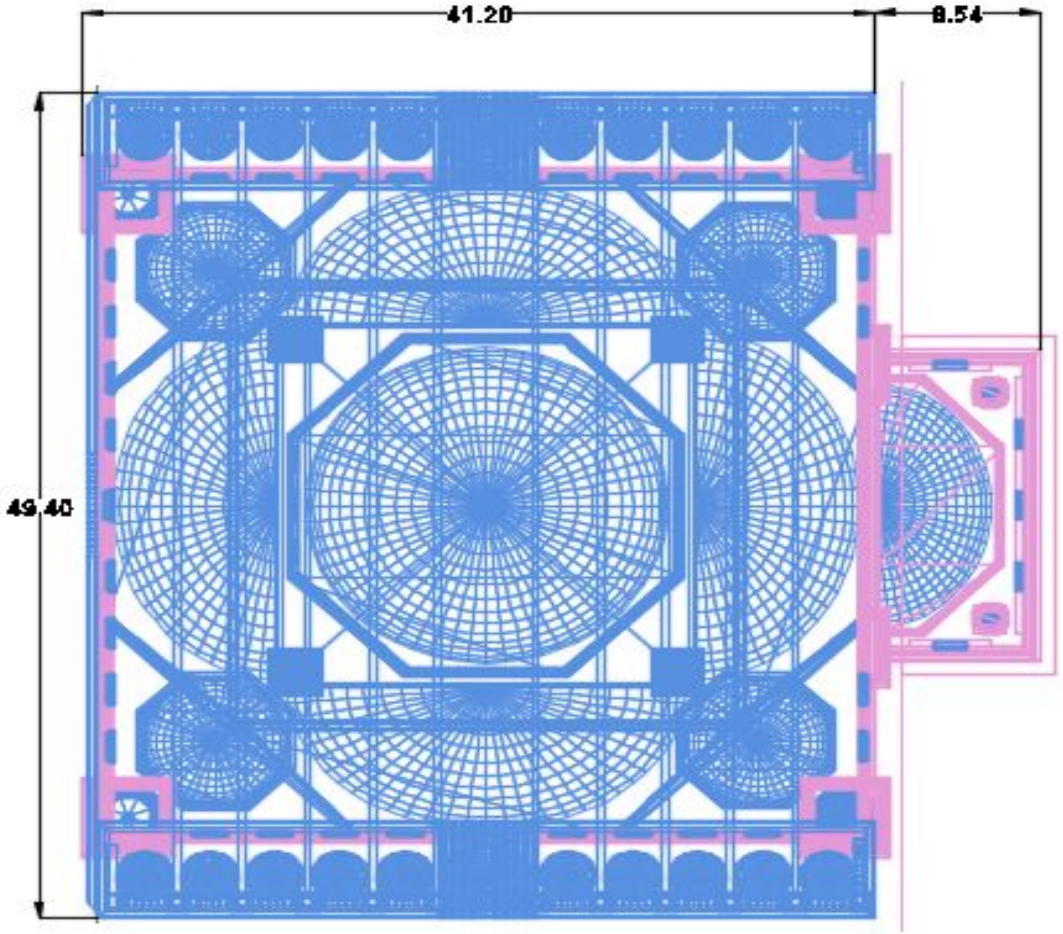
# 2- Cairo Citadel Scanning

## 2.3 Cairo Citadel views



Horizontal Plane of the Citadel

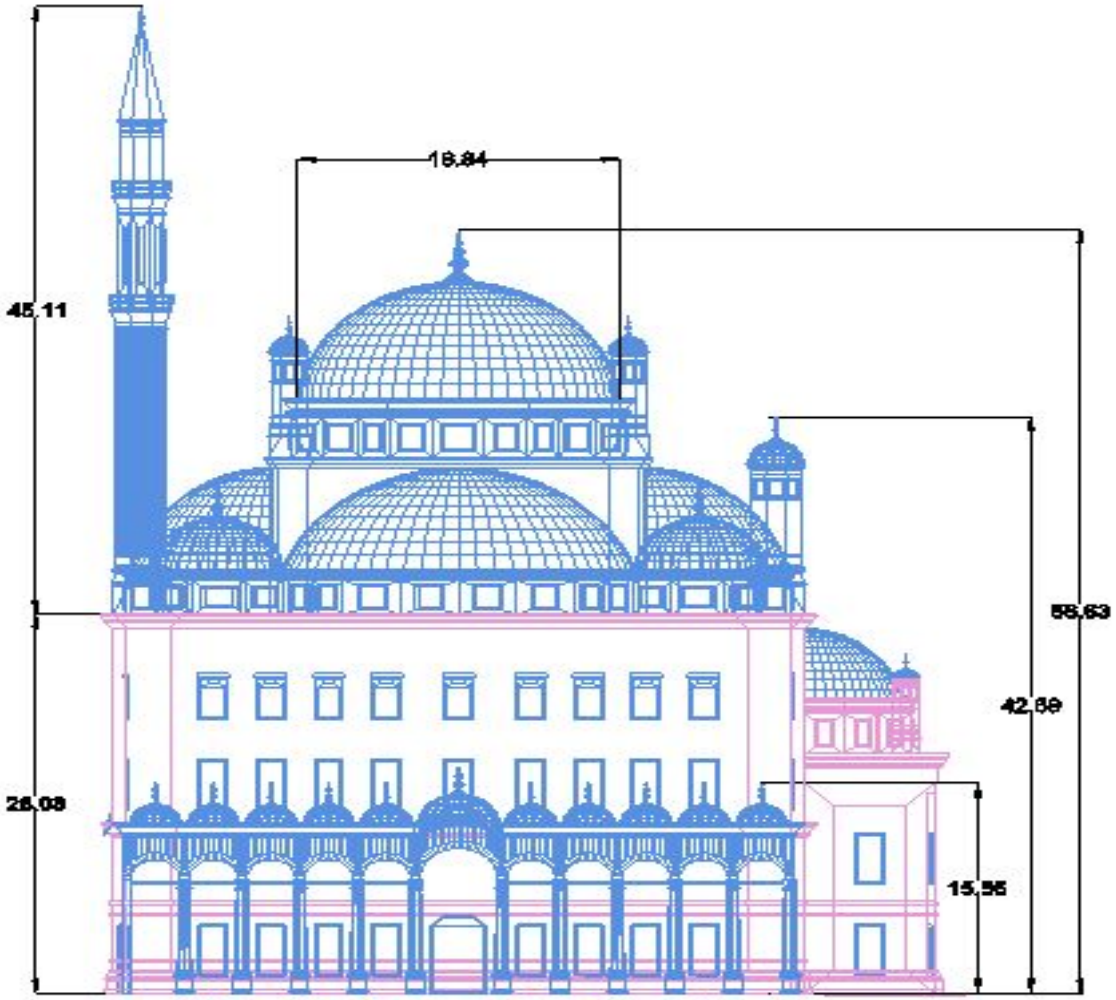
## 2.4 Cairo Citadel Dimensions



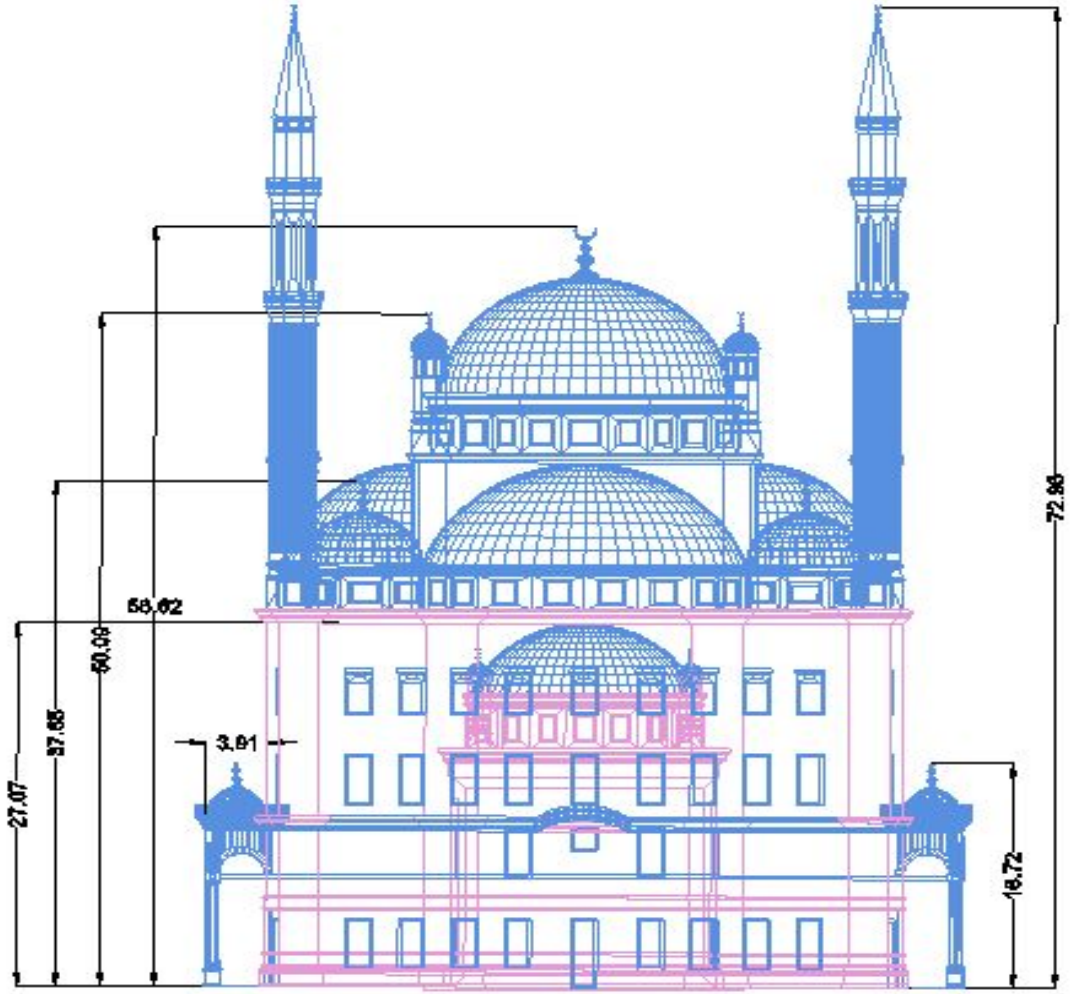

Horizontal Plane Dimensions of the mosque

# 2- Cairo Citadel Scanning

## 2.4 Cairo Citadel Dimensions



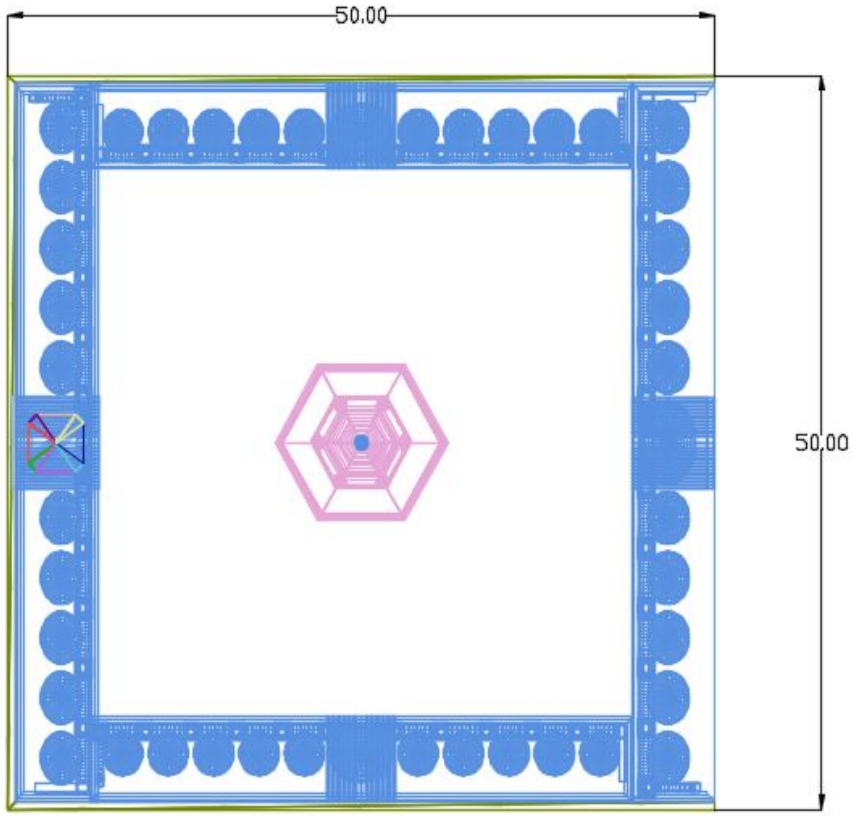

Elevation Dimensions of the mosque (North-Dir.)



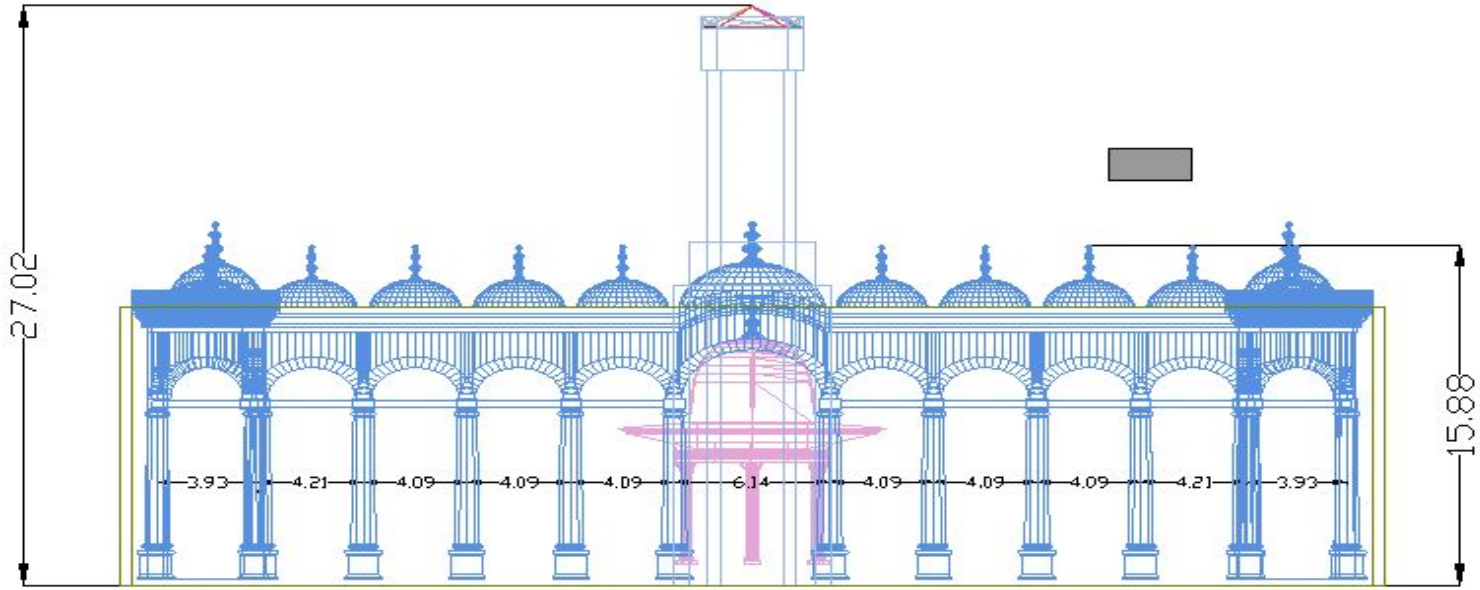

Elevation Dimensions of the mosque (East-Dir.)

# 2- Cairo Citadel Scanning

## 2.4 Cairo Citadel Dimensions




Horizontal Plane Dimensions of the Nave

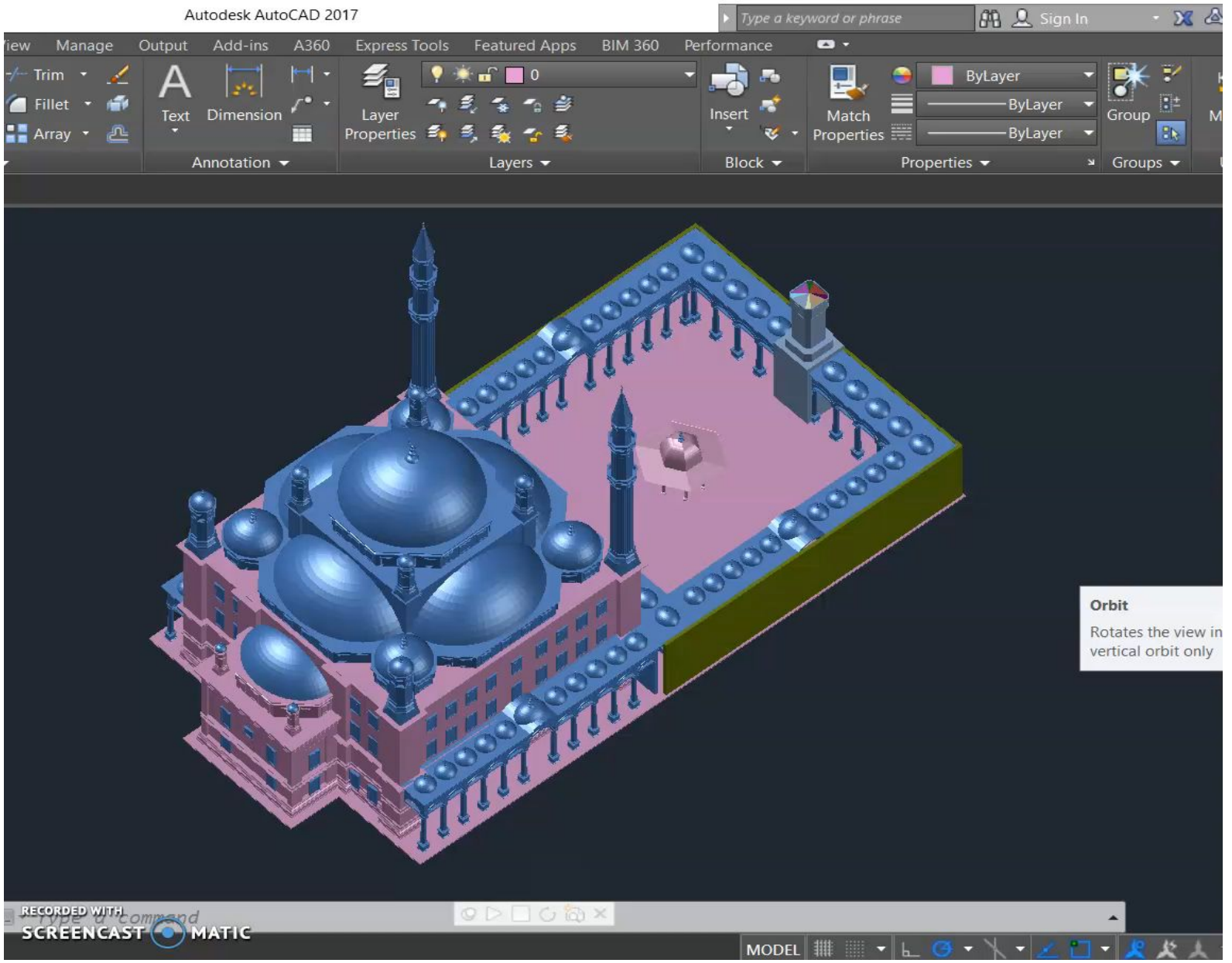



Elevation Dimensions of the Nave

# 2- Cairo Citadel Scanning

## 2.5 Cairo Citadel 3D digital model

- A digital 3D model of the Cairo Citadel was created in AutoCAD program to be imported in the structural analysis programs
- All elements of the Cairo Citadel in the AutoCAD Program were drawn as 3D-Face elements




Video for the AutoCAD model of the Cairo Citadel

# 3- Citadel and Soil Properties

## 3.1 Mechanical properties of the Citadel

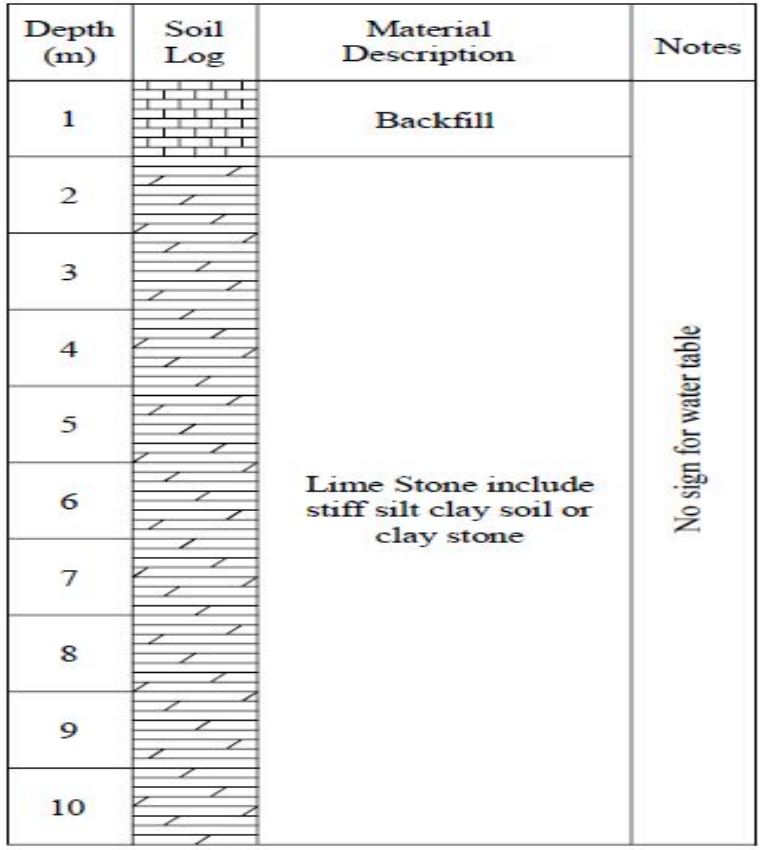
Samples from the stones inside the site were tested in the lab for determining the properties of the materials used in building the Citadel.

Mechanical properties of Citadel material (Limestone)

| Value | Property |
|---|---|
| kg/m3 2700 | Density |
| GPa 47 | Elastic modulus |
| 0.2 | Poisson's ratio |

## 3.2 Mechanical properties of the Soil

Borehole with a depth of 10 meters were dug to determine the properties of the soil in citadel area.

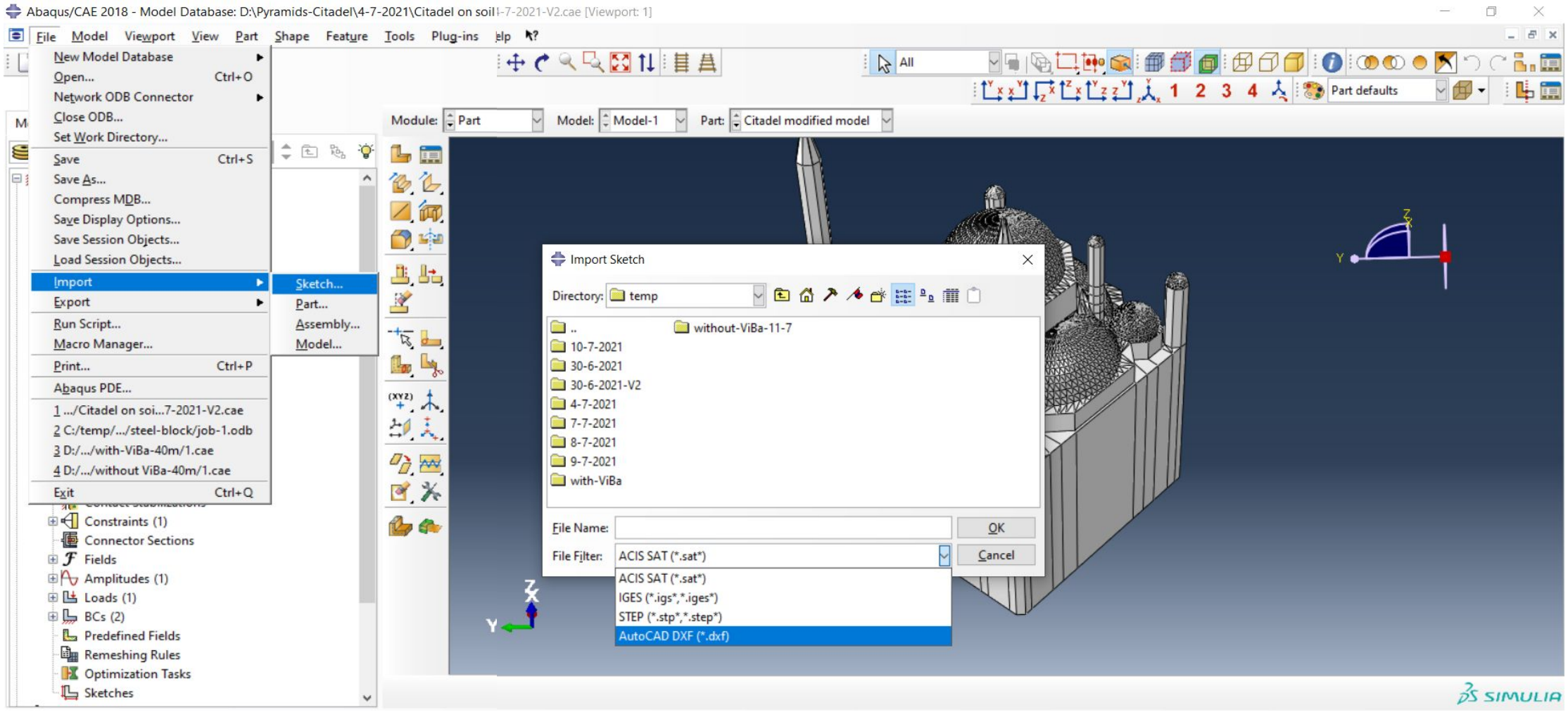



Soil profile

# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.1 Modelling of the Citadel (mosque part)

Importing the DXF file to Abqus



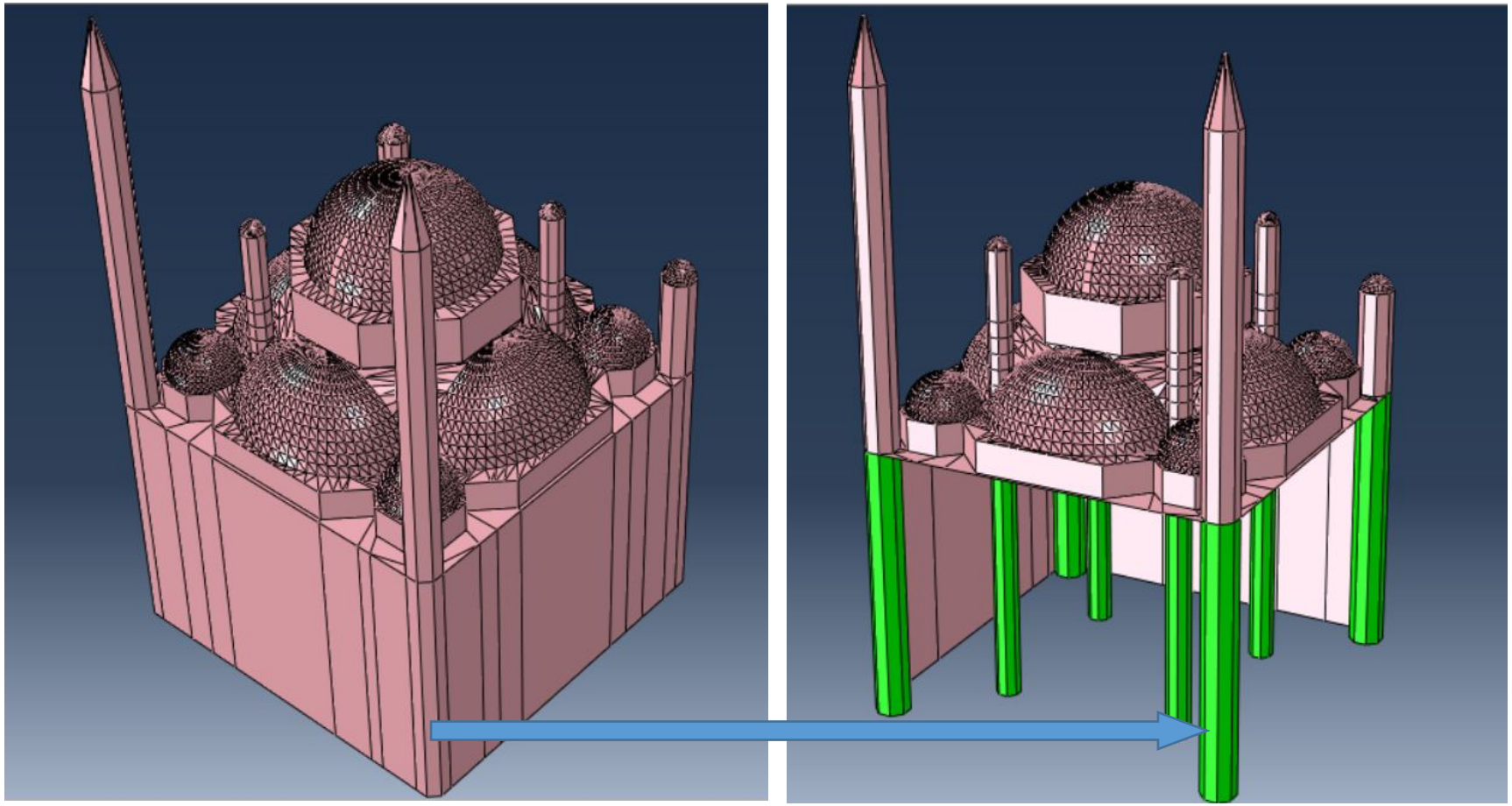

Steps of importing the DXF file

# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.1 Modelling of the Citadel (mosque part)

**Citadel element types**

- Domes and wall elements are shell elements of type S4R: 4-node linear thin or thick shell element
- Columns are solid elements of type C3D8R: 8-node linear brick element

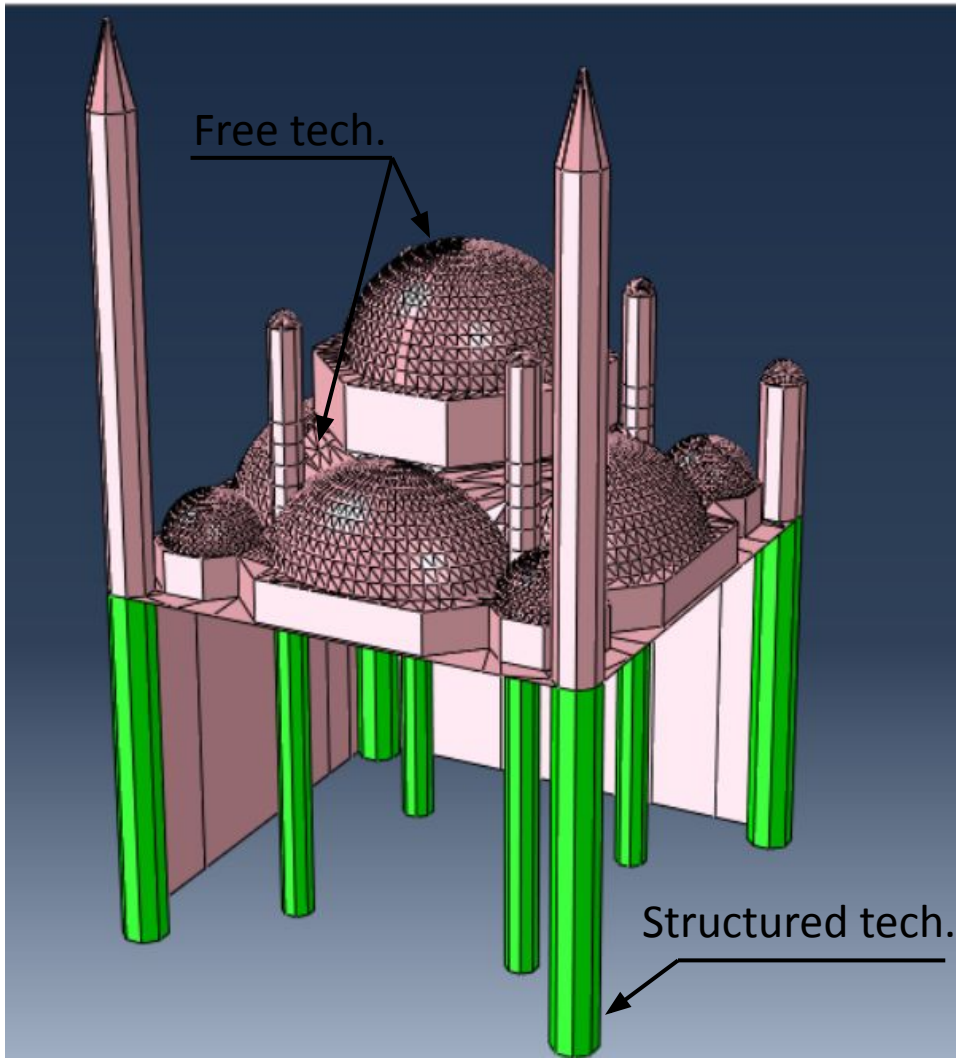


Converting the shell elements to solid elements

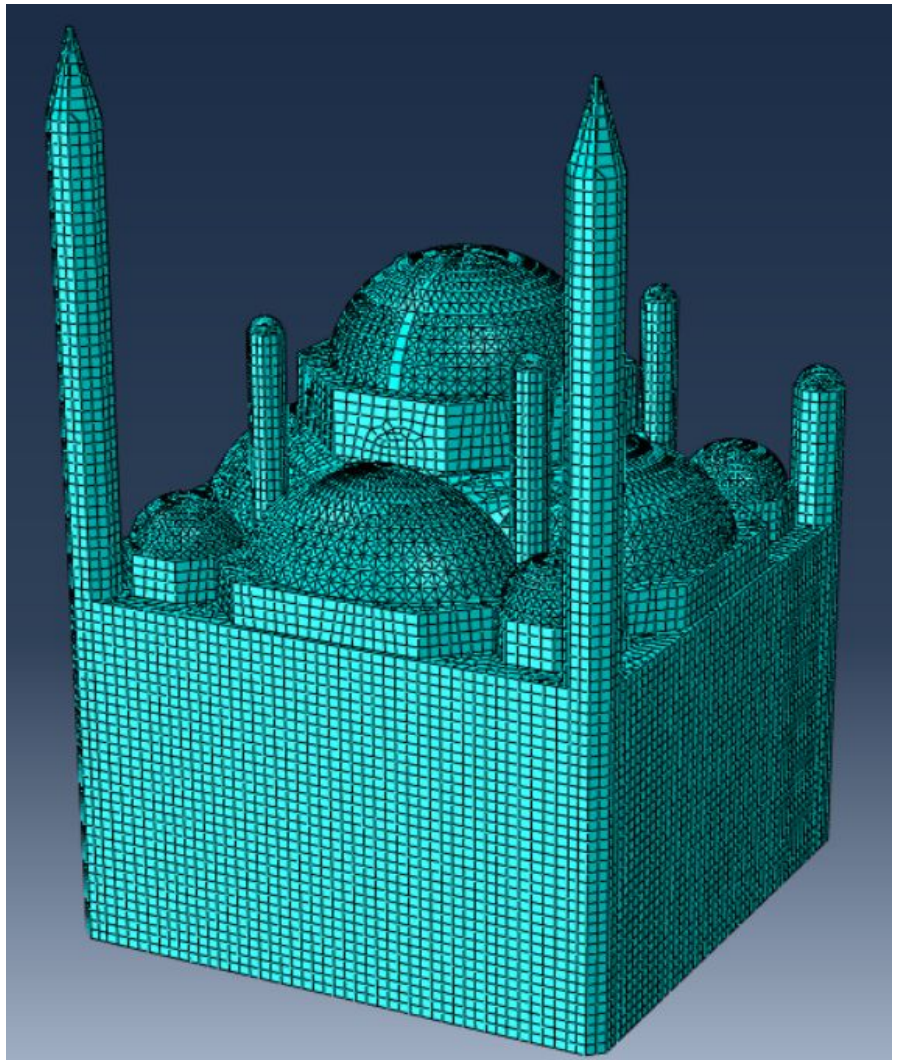
# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.1 Modelling of the Citadel (mosque part)

**Mesh technique**




Elements with structured and free mesh techniques



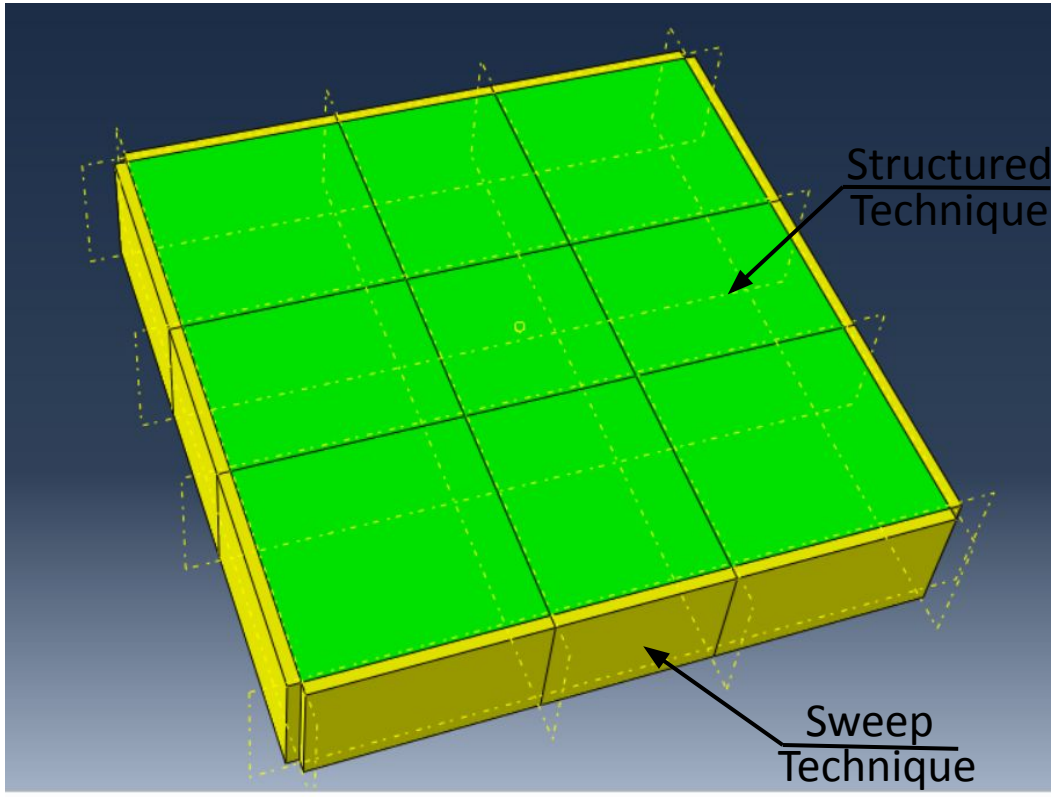
The overall Citadel (mosque part) mesh

# 4- Numerical Modelling of Cairo Citadel Using Abaqus

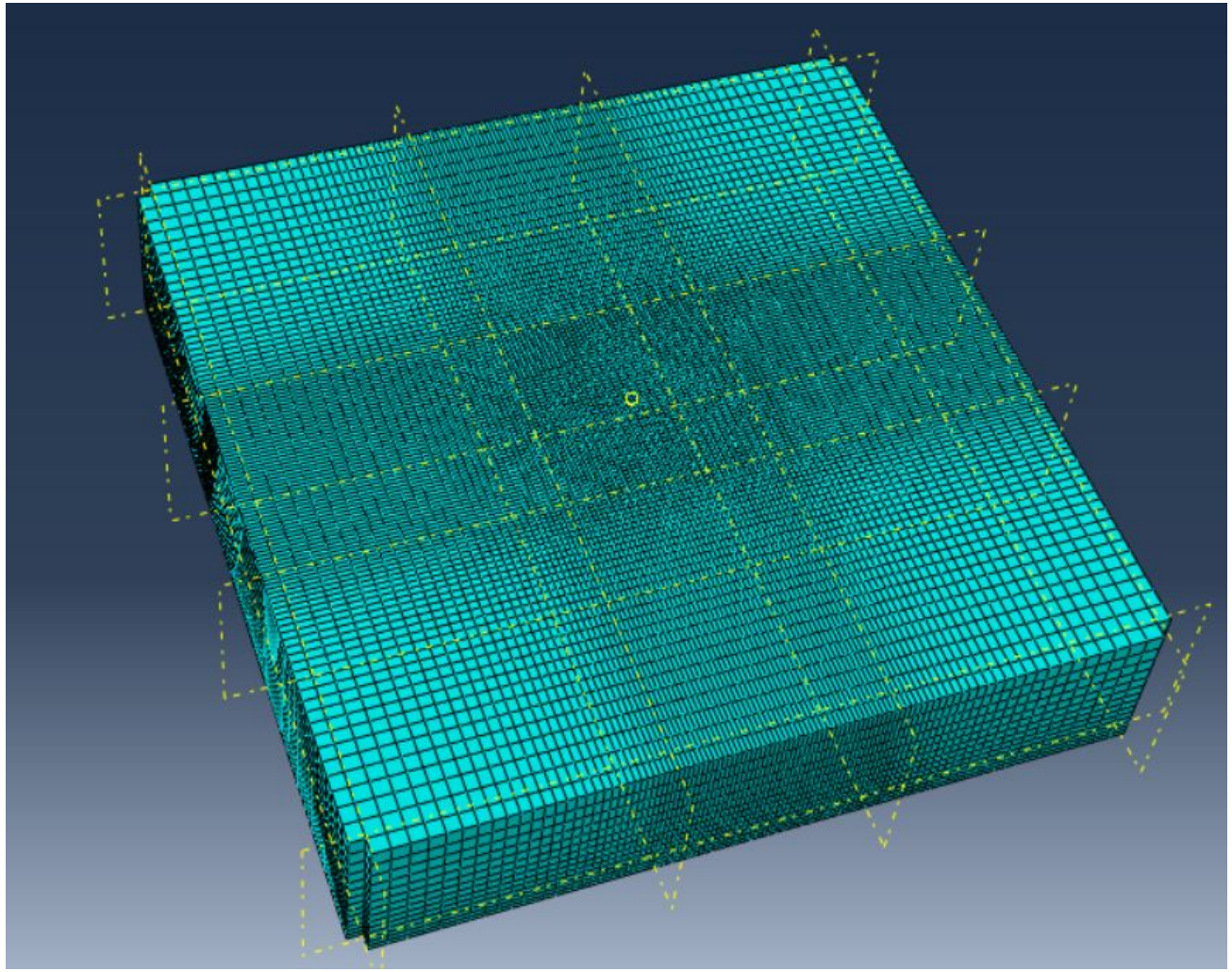
## 4.2 Modelling of the Soil

**Soil Dimensions , element types and mesh technique**

- Soil Dimension = 250x250x40m
- Green blocks are solid elements of type C3D8R: 8-node linear brick element
- Yellow Blocks are semi-infinite of type CIN3D8




Soil mesh technique

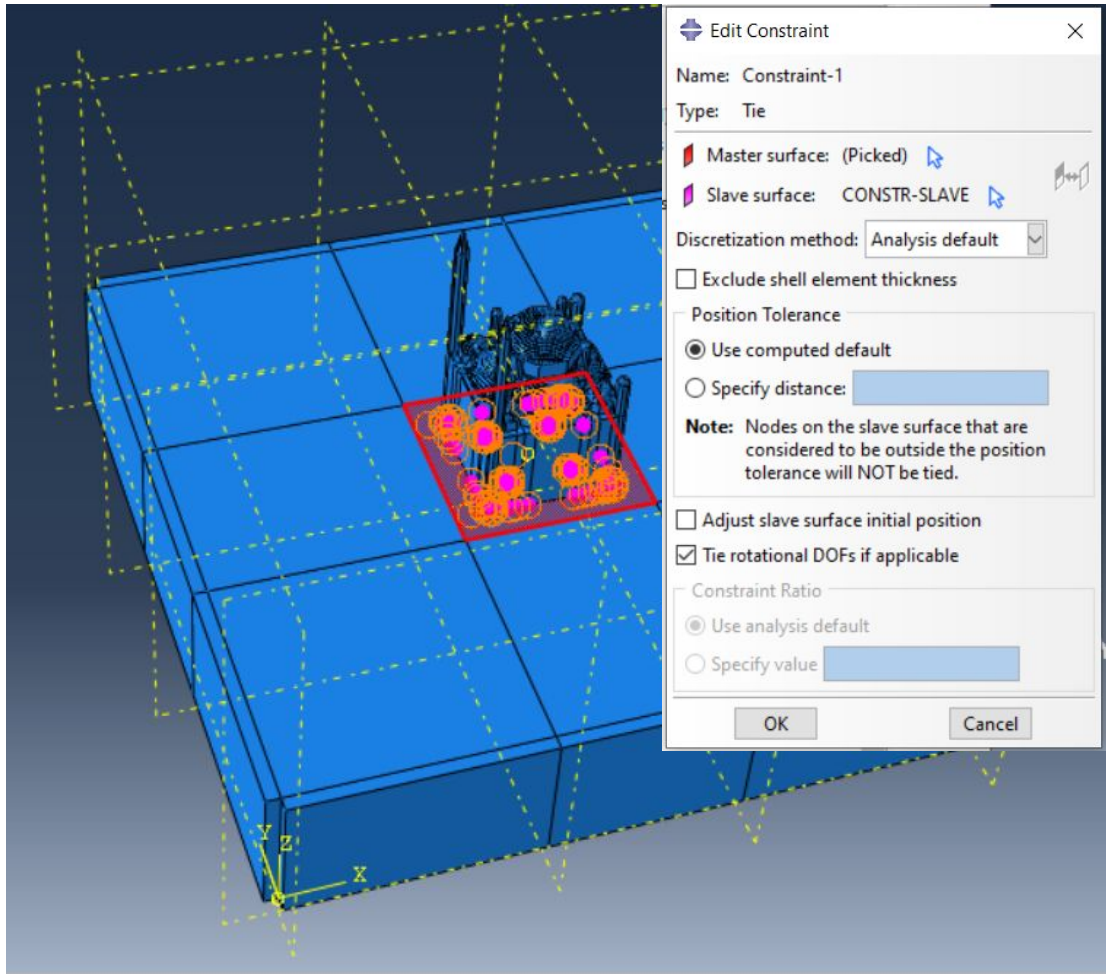


Soil overall mesh

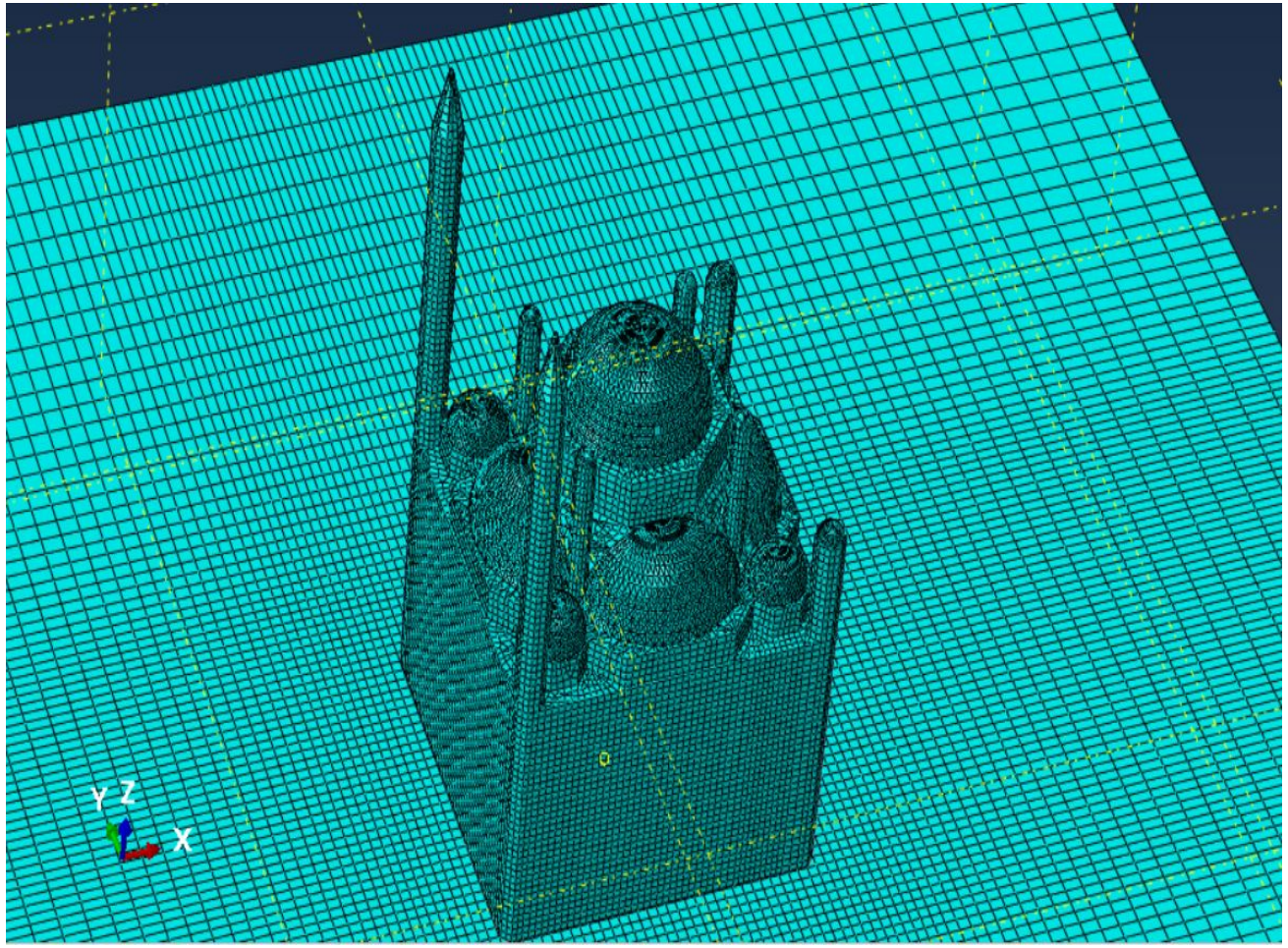
# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.2 Modelling of the Soil

**Assembling and overall mesh**




Assembling constraints

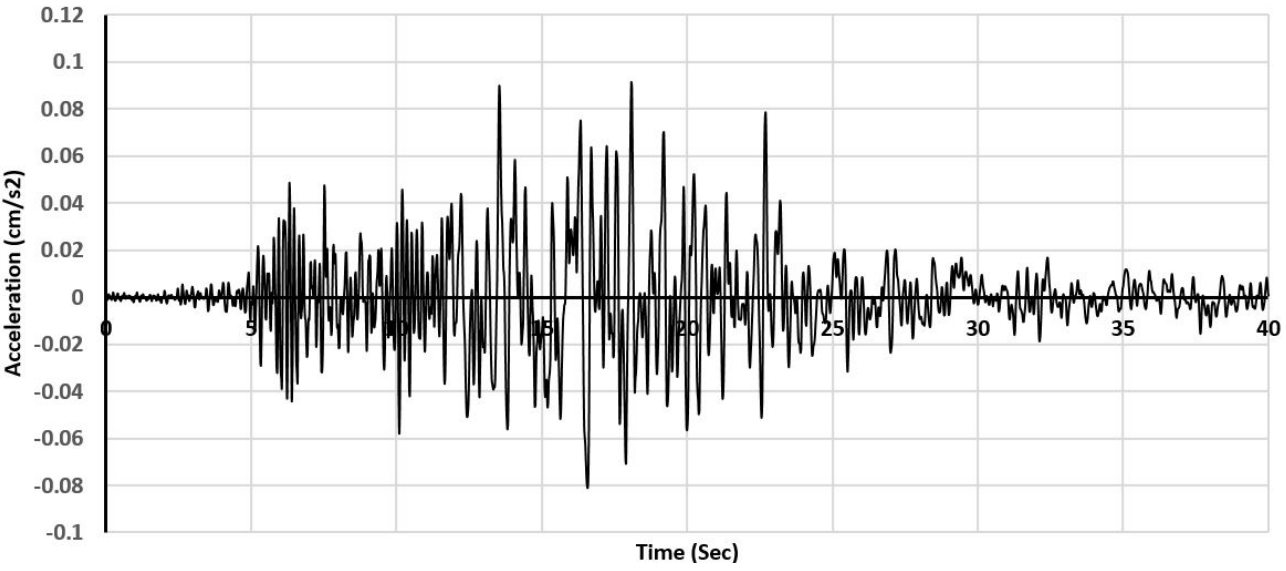


Assembling overall mesh

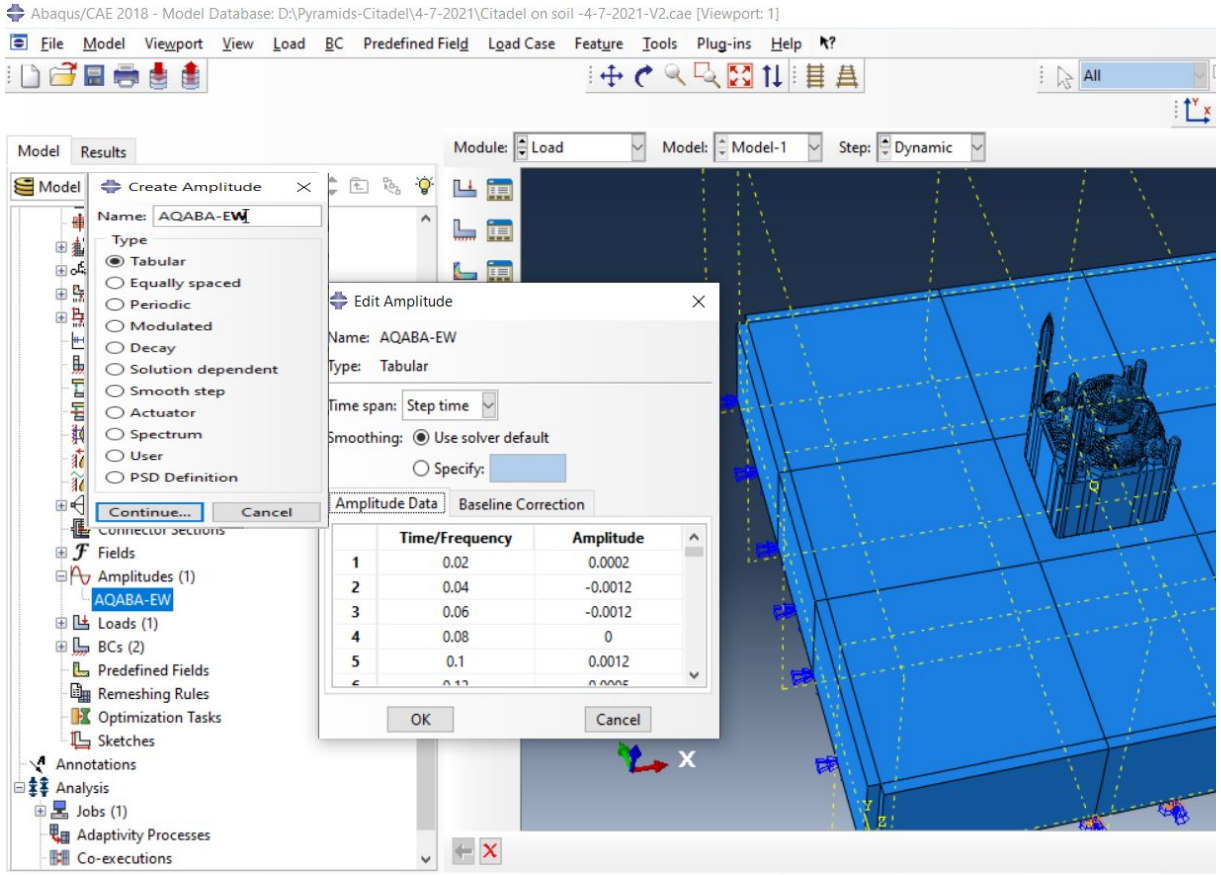
# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.2 Modelling of the Soil

### Dynamic loads




AQABA-EW earthquake record

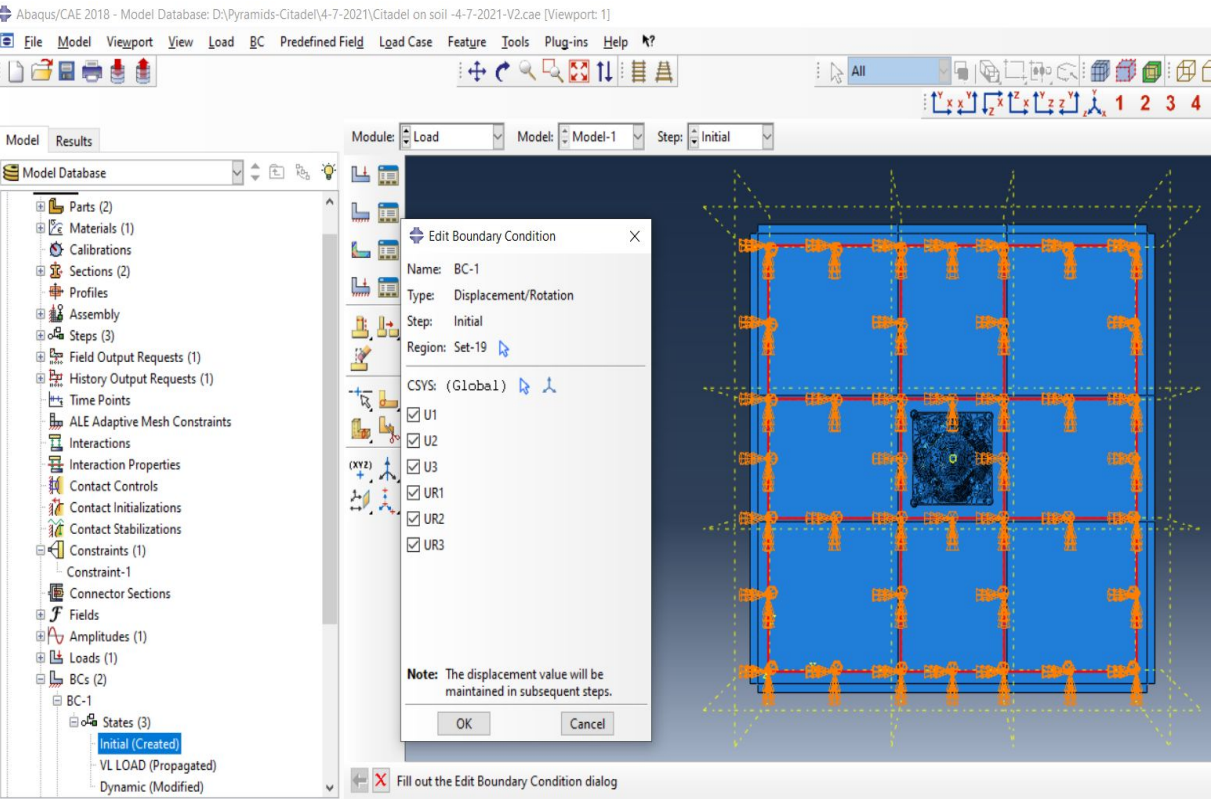



Abaqus AQABA-EW input

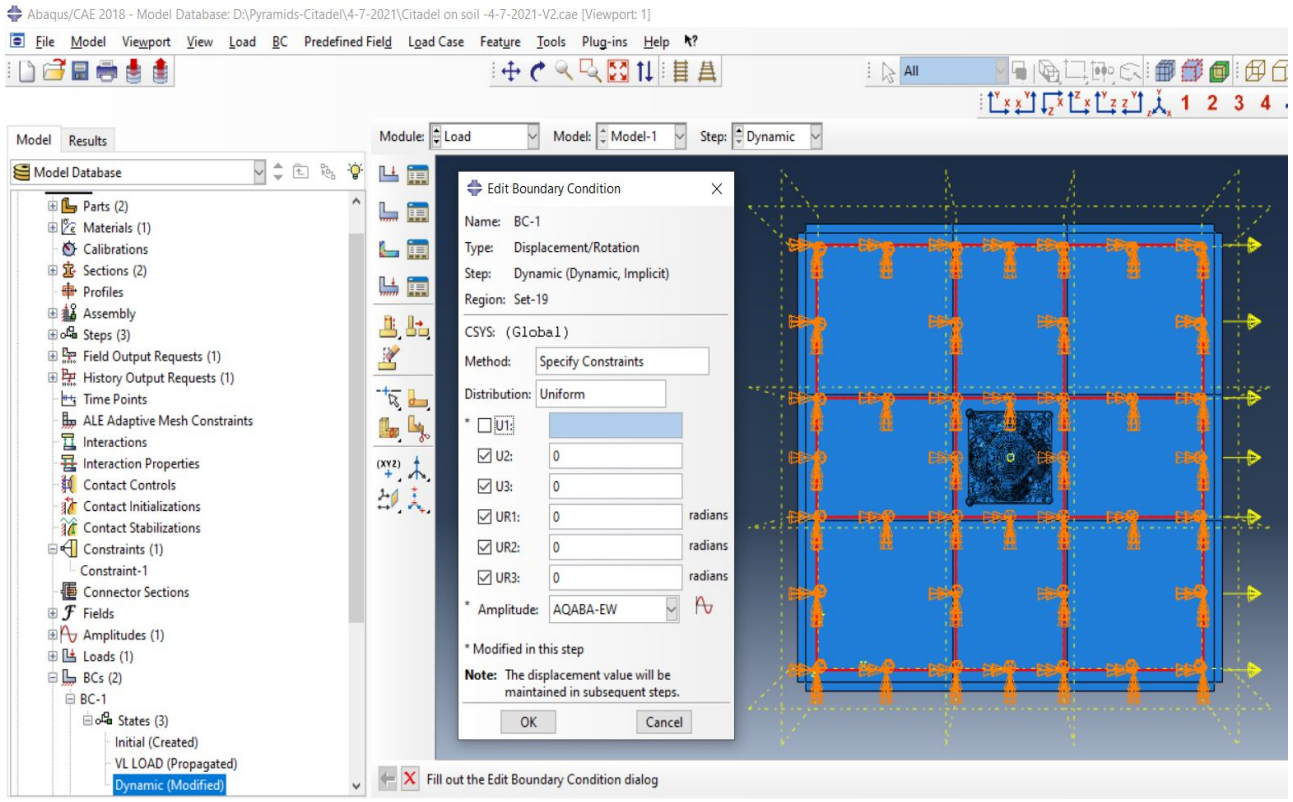
# 4- Numerical Modelling of Cairo Citadel Using Abaqus

## 4.2 Modelling of the Soil

### Boundary Conditions



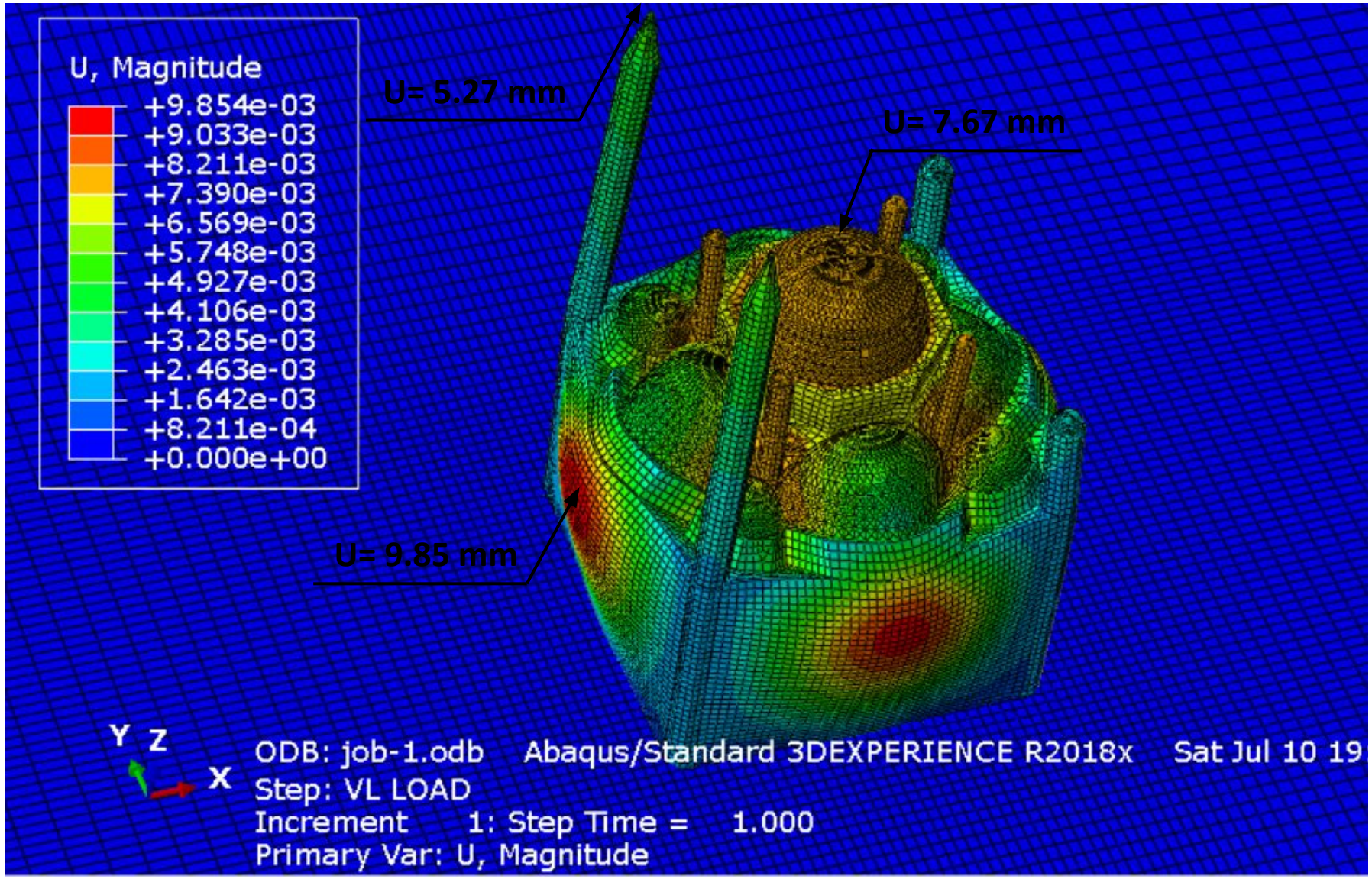

Displacements and rotations BCs (initial step +static step)




Displacements and rotations BCs (dynamic step)

# 5- Cairo Citadel Analysis

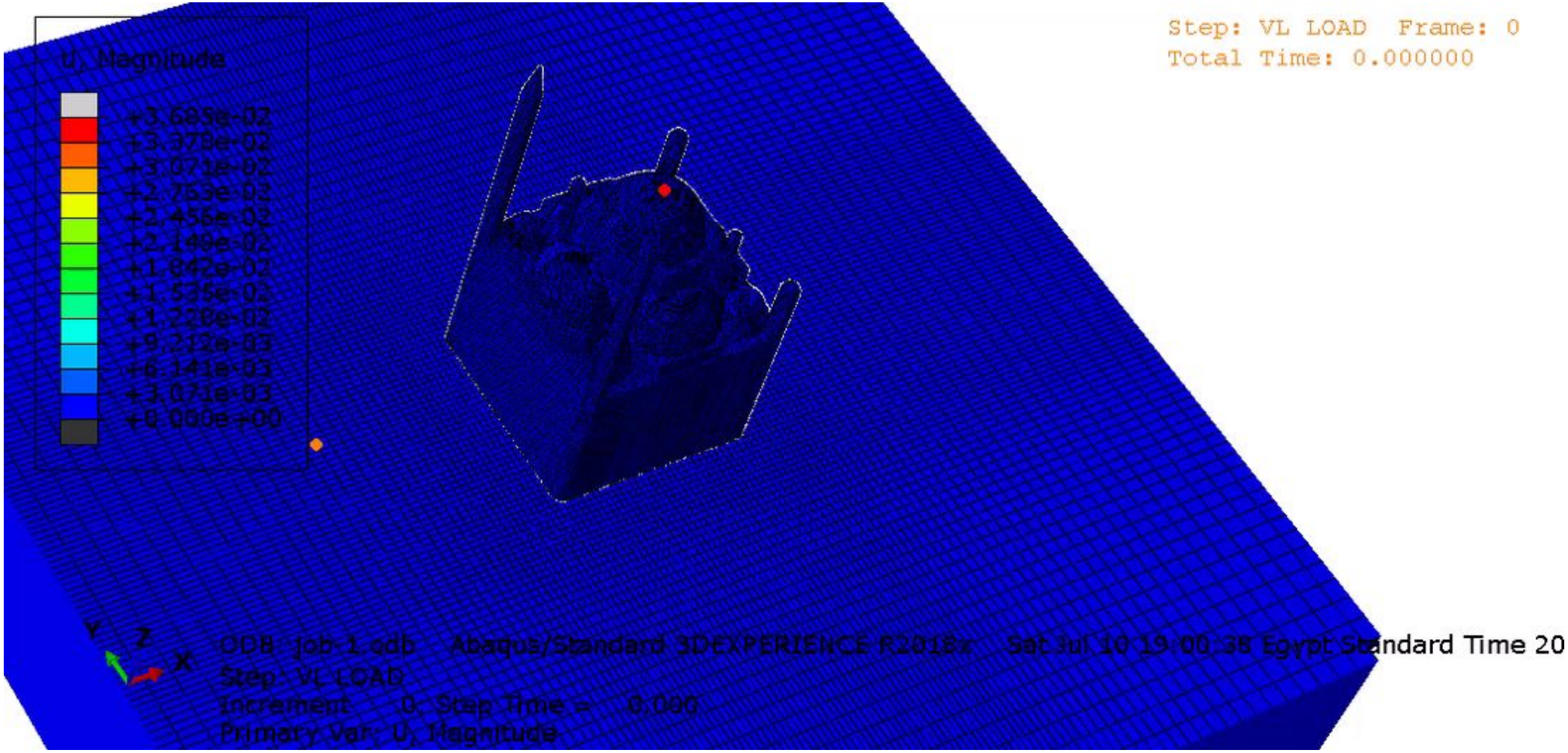
## 5.1 Static response




Static Deformed shape contours for the displacement magnitude

# 5- Cairo Citadel Analysis

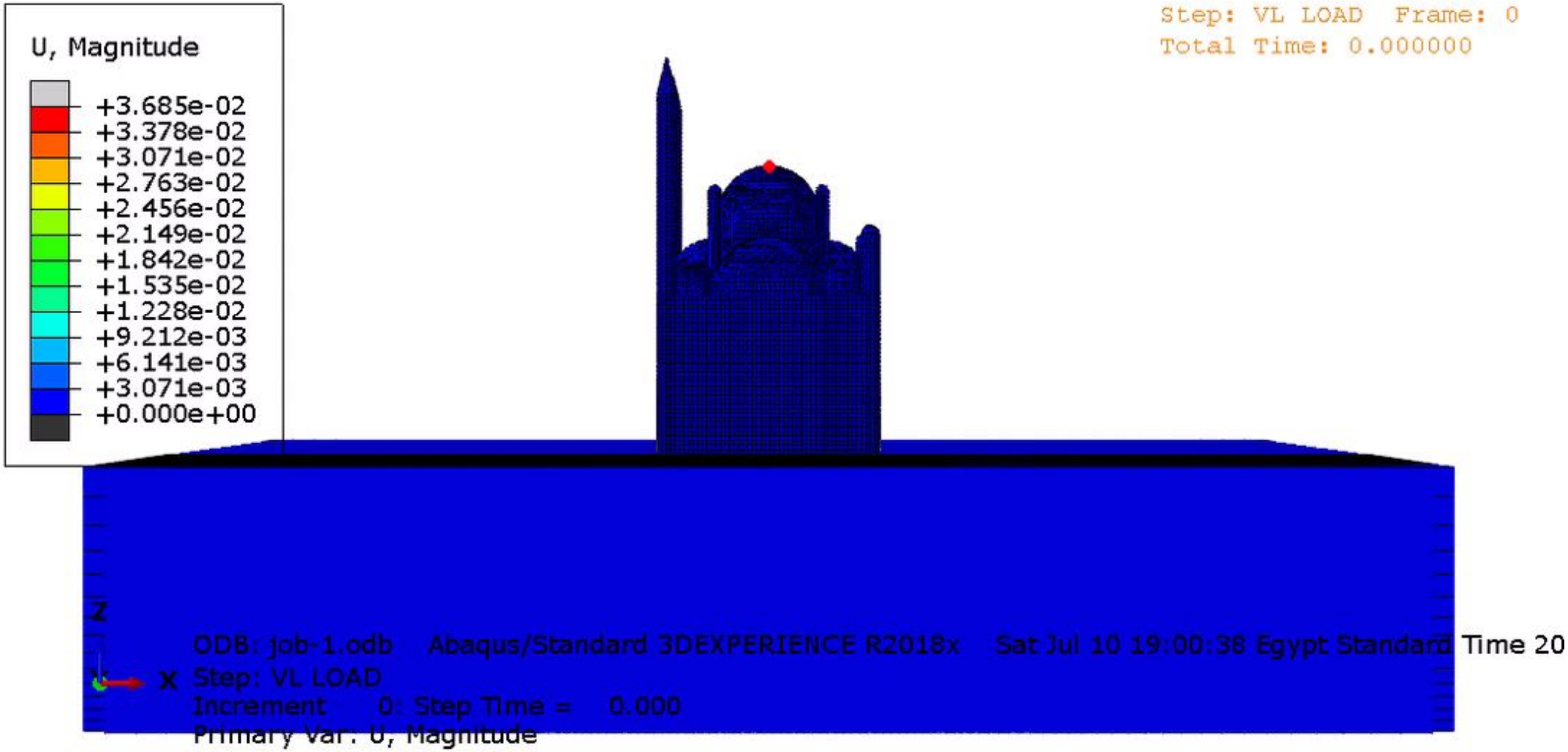
## 5.2 Dynamic response




3D deformed shape contours video for the displacement magnitude

# 5- Cairo Citadel Analysis

## 5.2 Dynamic response

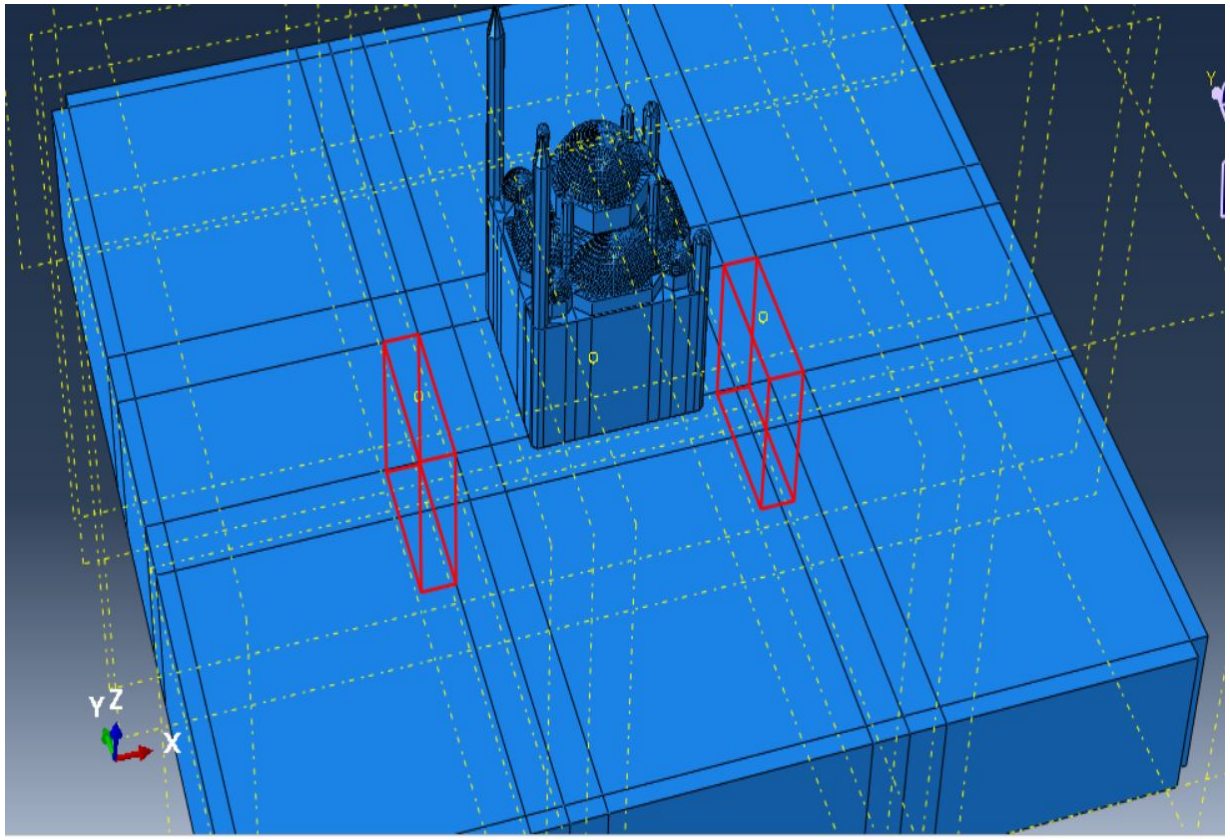



Side view deformed shape contours video for the displacement magnitude

# 6- ViBa Modelling and its Effect

## 6.1 ViBa material and dimensions

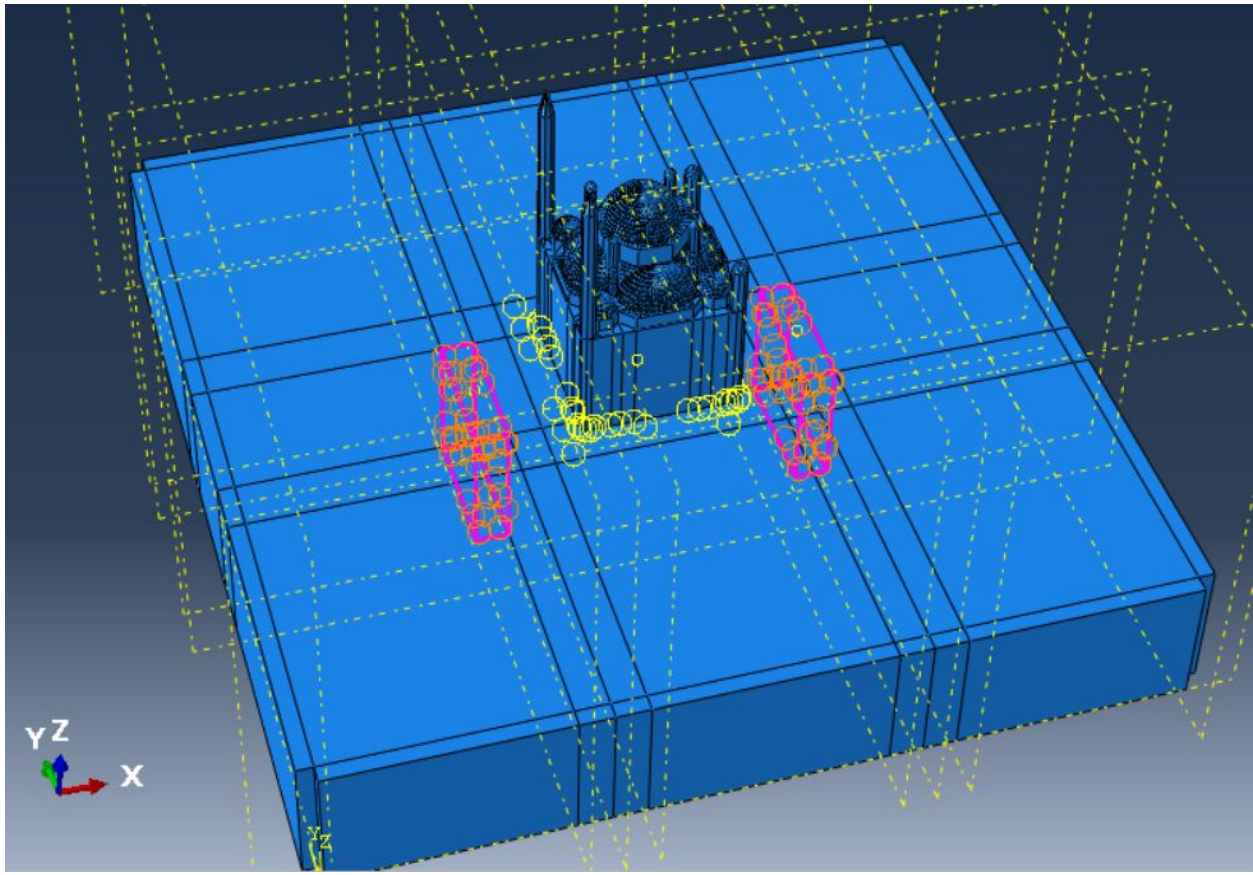
- ❑ The ViBa Blocks materials are assumed to be concrete
- ❑ The ViBa Block weight is assumed to be 0.4 from the Citadel weight and accordingly the ViBa dimensions are 40x10x40m
- ❑ The ViBa is assumed to locate at 15m far from the Citadel
- ❑ The ViBa Blocks materials are assumed to be concrete




3D view of ViBa concrete Blocks (outlined with red color)

## 6.2 ViBa constraints

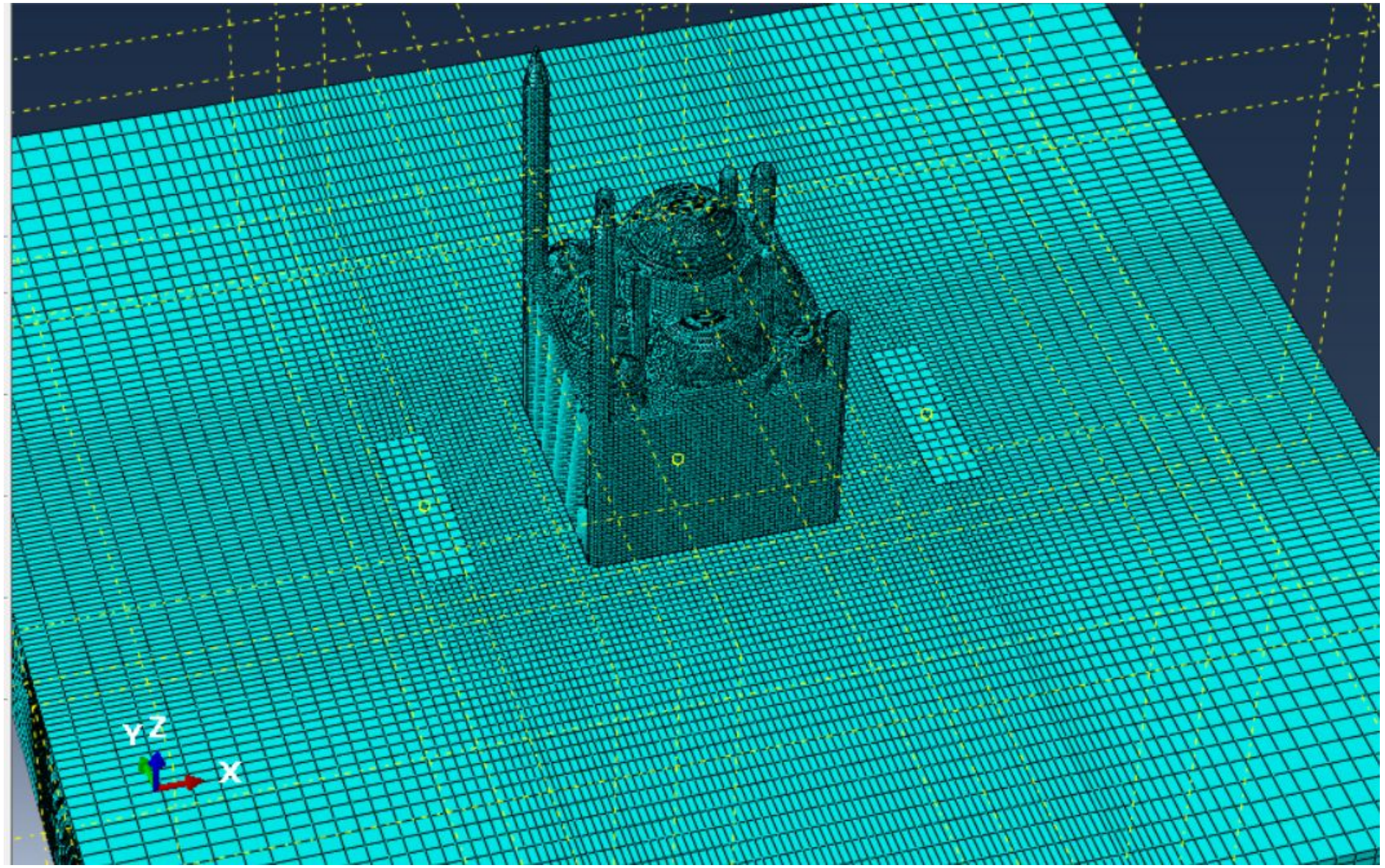
The ViBa sides are tied to the surrounding soil (nodes have the same rotational DOF)




3D view of ViBa constraints

# 6- ViBa Modelling and its Effect

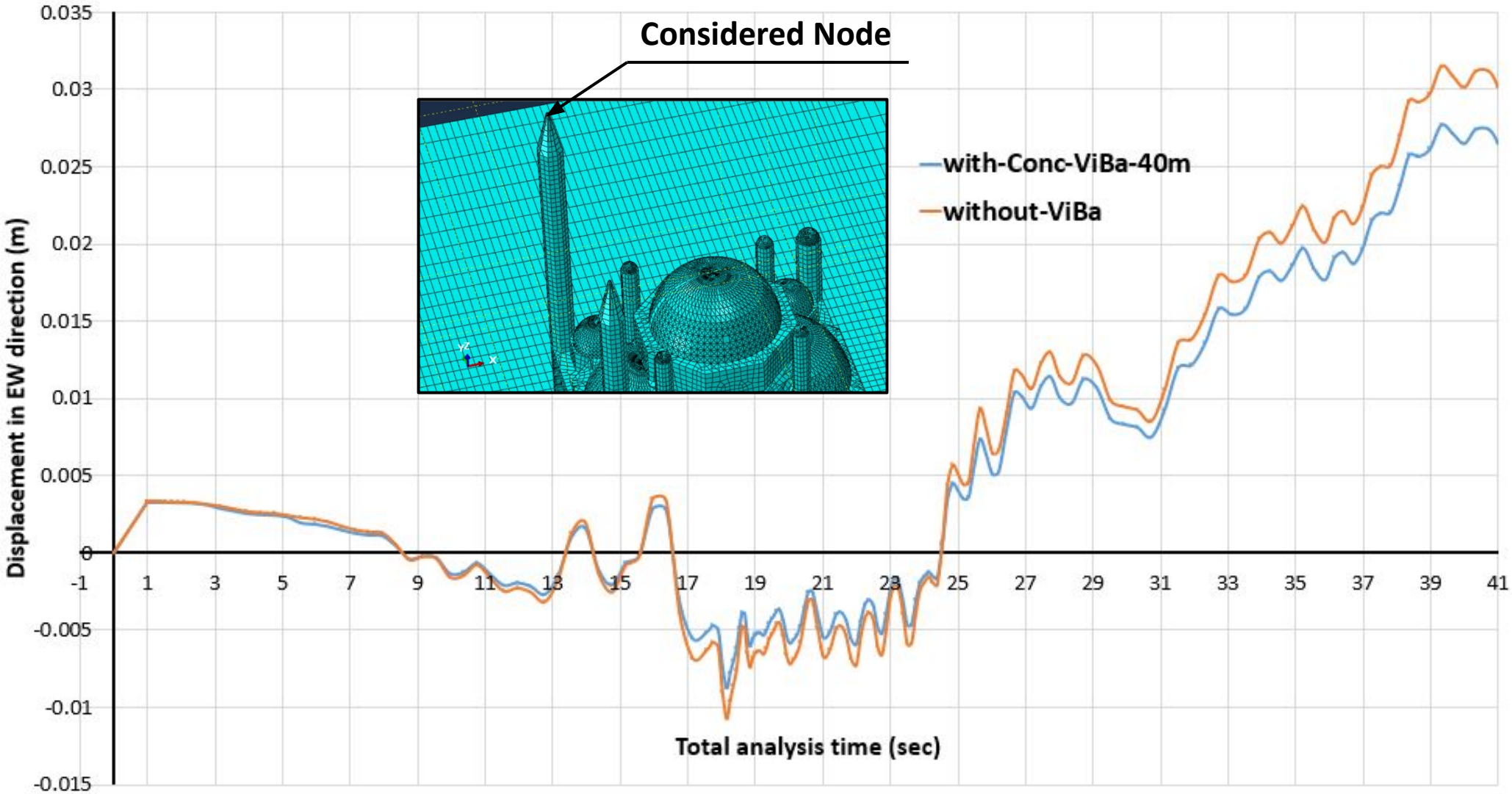
## 6.3 Overall Citadel mesh including the ViBa blocks




3D view for the Citadel overall mesh including the ViBa blocks

# 6- ViBa Modelling and its Effect

## 6.4 Comparison of the dynamic response of the Citadel without and with ViBa




Displacement with time for the highest node of the minaret without and with using ViBa

# 7- Summaries and Conclusions

- A realistic three dimensional scan for the Cairo Citadel was carried out
- A digital 3D model of the Cairo Citadel was created in AutoCAD program
- 3D numerical model of the Cairo Citadel (Mosque part) was created using Abqus
- Static and dynamic analysis of the Cairo Citadel was performed without and with using ViBa
- The dynamic response is mitigated 12 % using ViBa (studied case)
- ViBa will be a promising method to protect Ancient Monuments from earthquakes
- A comprehensive parametric study should be done to study the effect of ViBa weight, material, dimensions, and distance from the Cairo Citadel

# Thank you