IDM UID
899Y3S

VERSION CREATED ON / VERSION / STATUS
21 Dec 2022 / 1.3 / Approved

EXTERNAL REFERENCE / VERSION

Technical Specifications (In-Cash Procurement)

Technical Specification for Tokamak Complex Finite Element Modeling

This document specifies the requirements for the provision of a Tokamak Complex (TKC) finite element model to the ITER Integrated Analysis Section (IEA). The implementation of the task is linked to the Long Term Process implementation of the TF 65 as for the related Design Plan ITER_D_5E4WUY v1.3.

Table of Contents

1 Purpose

This document specifies the requirements for the provision of a Tokamak Complex (TKC) finite element model to the ITER Integrated Analysis Section (IEA).

2 Scope

2.1 The ITER Project

The ITER project aims to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes and to gain the knowledge necessary for the design of the next stage device.

The ITER project is organized as an international research and development project jointly funded by its seven Members; the European Union (represented by EURATOM), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA.

ITER is being constructed in Europe, at Cadarache in southern France, which is also the location of the headquarters of the ITER Organization (IO).

During ITER construction, most of its components will be supplied "in-kind" by the ITER Members. These in-kind contributions are being managed through a Domestic Agency (one per ITER Member) located within the Member's own territory.

The working language of the ITER Project is English.

More details about the Project Organization, The Domestic Agencies, the IO location and other different aspects of the Organization are available on the website: www.iter.org.

2.2 Scope of the Task

The purpose of this contract is to provide an ANSYS database including the Finite Element (FE) model of the Tokamak Complex (TKC) to the Integrated Analysis Section (IEA) of ITER Organization (IO). Details about provided input, methodology, technical requirements and expected output are reported in the following section 6.

The task will include the implementation of a FE model of the TKC starting from the 3D CAD models provided, using the software ANSYS Mechanical APDL or Workbench and the modelling rules described in section 6. The delivery will include the FE database, the description report of the model in line with the Instructions [1] and all the scripts, files and work step descriptions needed to replicate the work independently.

The task shall be implemented by the Contractor off the IO work site, with visits on-site for meetings as and when necessary and requested by IO.

The task is only related to FE modelling, so no FE analyses are foreseen, except the ones needed for the verification of the FE model in line with [1].

3 Definitions

CAD	Computer-Aid Design
CRO	Contractor Responsible Officer, i.e. the IO staff person accountable for the full-cycle contract performance
Contractor	The legal entity resulting the selected tenderer of the Call for Expertise related to this contract.
FE	Finite Element
ID	Identifier
IDM	ITER Document Management (system)
IO	ITER Organization
KoM	Kick of Meeting
SQEP	Suitably Qualified and Experienced Personnel
TKC	Tokamak Complex

Table 1 – Definitions.

For a complete list of ITER abbreviations see: ITER Abbreviations (ITER_D_2MU6W5).

4 References

[1] Instructions for Structural Analyses. ITER_D_35BVV3 v4.0.

[2] TKC Structural Analysis for Mass Evolution Control – Basis of Design: FE Model Mesh. ITER_D_899JAT v1.0.

[3] Instructions for the Storage of Analysis Models. ITER_D_U34WF3 v2.0.

[4] Order dated 7 February 2012 relating to the general technical regulations applicable to INB – EN. ITER_D_7M2YKF v1.7.

[5] Provisions for Implementation of the Generic Safety Requirements by the External Actors/Interveners. ITER_D_SBSTBM v2.2.

5 Estimated Duration

The task shall start only after the signature of the contract. One ANSYS FE modeling expert from the selected economic operator will be devoted full-time to this analysis activity until the contract is complete. The total duration starting from the Kick-off Meeting (KoM) is 6 months.

6 Work Description

6.1 Tokamak Complex

The Tokamak Complex comprises the concrete buildings listed below and highlighted in Figure 1:

- Building 11 (B11): is the Tokamak Building, and it contains the Tokamak machine. The building provides the necessary access to the Tokamak machine that is required for operation, maintenance and amendments to the configuration that are required to support the ITER research programme. On top of it, the Crane Hall is covered by a roof steel frame.
- Building 14 (B14): is the Tritium Building, and contains the equipment for the fuel cycle process. It is a chemical process building that handles and controls the “fuel” that is to be

used, and the “exhaust” that is produced during the operation of ITER. Certain areas in the Tritium building also contribute to servicing the Tokamak, notably the extension of the Tokamak cooling water system vault. As well, it houses the Tritium confinement system for the Tokamak and Tritium Buildings.

- Building 74 (B74): is the Diagnostic Building. The main function of the Diagnostic Building is to house the various diagnostic systems that are used by ITER to monitor and control the plasma. Building 74 also supports elements of the coil power system to the magnets.

Furthermore, it is part of the Tokamak Compex also the concrete structure 19 (B19), i.e. the Seismic Isolation Basemat. The purpose of the Isolation Basemat is to support plinths and anti-seismic bearings. The CAD 3D model of the TKS is shown in Figure 2.

Figure 1 – ITER Site Layout with Tokamak Complex highlighted.

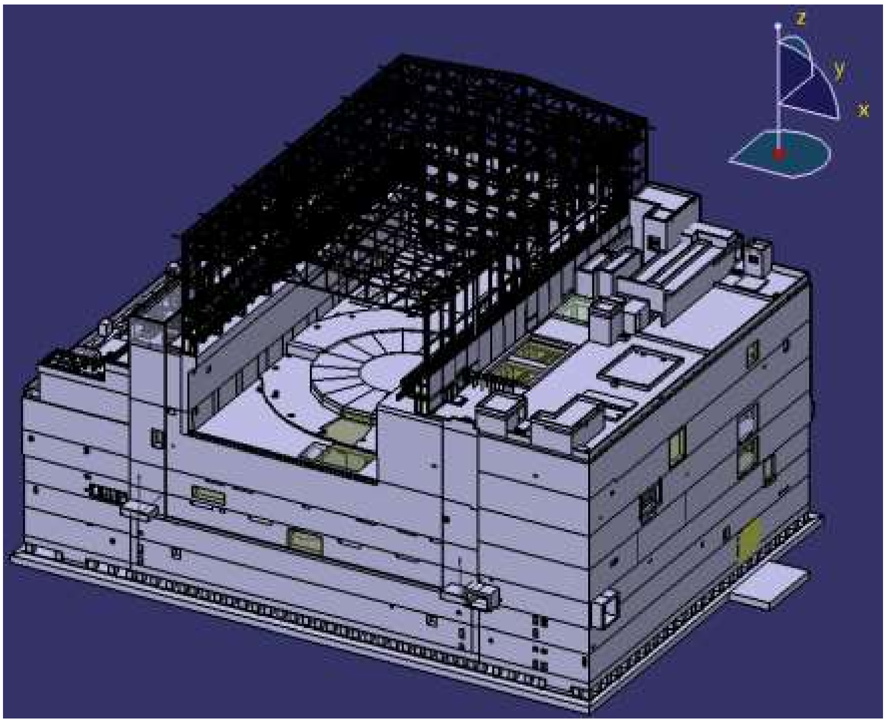

Figure 2 – Tokamak Complex 3D CAD Model.

6.2 Reference Input

The work shall consist in the implementation of a FE shell/beam model of the TKC starting from the 3D CAD models provided by IO. The 3D CAD models will be provided at the KoM in step format or any other format preferred by the Contractor, and they will include all the primary concrete elements of the Tokamak Complex and the Crane Hall steel frame.

The following two references shall be also considered as input for the task:

- BoD [2], where the main modelling rules are described, see section 6.3 below.
- Instructions for Structural Analyses [1], where the content of the report, the verifications of the model to be carried out and the type and format of the expected ANSYS output are described, see section 6.4 below.
- Instructions for the Storage of Analysis Models [3], reporting the procedure for the storage of the analysis files.

6.3 Modeling Methodology and Requirements

The Tokamak Complex concrete body has an envelope dimension of roughly 120 m by 74 m in plant and 55 m of height. It will be part of the modelling:

- The 1.5 m thick lower basemat, to be modelled through SHELL181 quadrilateral elements at the actual top surface of the slab.
- The plinths between the lower basemat and the upper basemat (B2 slab), to be modelled through BEAM188 elements at the axis of the actual elements.
- All slabs, perimetral walls and internal walls between B2 and R1 (roof), to be modelled through SHELL181 quadrilateral elements at the middle of the actual slab and wall thickness.
- All internal columns and beams between B2 and R1, to be modelled through BEAM188 elements at the axis of the actual elements.
- The Crane Hall steel frame, to be modelled through BEAM188 elements at the axis of the actual elements, including section Offset wherever appropriate and assigning the proper section geometry.

For information only, extracts from the CMM of all buildings and levels are reported in section 15 below. The final CMM versions provided at the KoM may be different from what shown here, however eventual differences would not have any relevant impact on the consistency of the task.

In some areas, the distinction between concrete walls and columns may not be straightforward. The Contractor will propose case by case the most suitable approach that will be discussed at the monitoring progress meeting (see section 11).

Here the main rules for modelling and meshing:

- The geometry of slabs, walls, beams and columns shall be generated through ANSYS LINEs and AREAs. Once meshed, the link between geometry and finite elements shall be kept (i.e., in ANSYS language, finite elements shall not be DETACHED from LINEs and AREAs).
- Openings in walls and slabs shall be ignored if the longer edge is equal or smaller than 0.5 m. Otherwise, they will be modelled through specific AREAS and included in a specific element ANSYS AREA COMPONENT (CM command).
- The areas included inside the physical intersection between slabs and walls and slabs and columns shall be modeled through specific AREAS whose depth shall be equal to the actual physical intersection one, see Figure 3 and Figure 4.

More details shall be found in the BoD [2]. Any eventual criticism coming up during the implementation of the task shall be discussed at the monitoring progress meeting (see section 11).

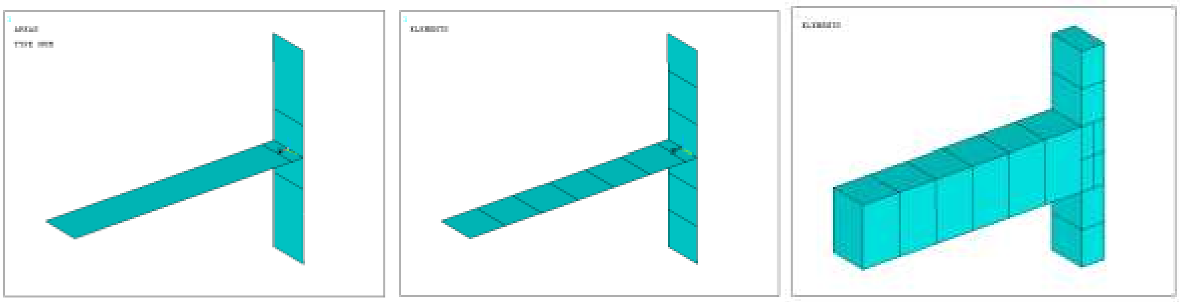

Figure 3 – Example: 1 m strip of wall/slab intersection – From the left: size of ANSYS AREAS at the intersection between slab and walls; SHELL181 element mesh; extruded view of SHELL181 element mesh.

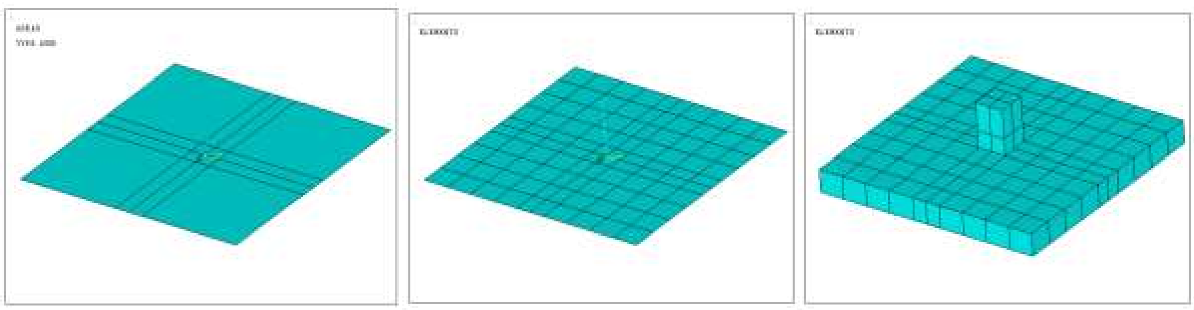

Figure 4 – Example: column/slab intersection – From the left: size of ANSYS AREAS at the intersection between slab and walls; SHELL181 element mesh; extruded view of SHELL181 element mesh.

ANSYS AREAS and LINES shall be grouped in ANSYS COMPONENTS (CM command) as for the following criteria:

- All AREAs representing the floor, the ceiling or a wall of a certain room, shall be grouped in the component B*XX*-R*YYYY*-*ZZZZ*, where:
  - *XX* = building number (19, 11, 14 or 74)
  - *YYYY* = room ID
  - *ZZZZ* = SLAB, CEILING or wall ID (W*NNN*)

  The wall and room IDs shall be provided in the BoD [2] through general arrangement drawings for each level and building. The TKC includes about 700 rooms and 1100 different wall IDs.
- All LINEs representing the columns in a certain room, shall be grouped in the component B*XX*-R*YYYY*-*ZZZZ*, where:
  - *XX* = building number (19, 11, 14 or 74)
  - *YYYY* = room ID
  - *ZZZZ* = column ID (C*NNN*)

  The column IDs shall be provided in the BoD [2] through general arrangement drawings for each level and building. The TKC includes about 400 different column IDs.
- All AREAs and LINEs representing the slabs, beams or columns shall be grouped based on the related material. In particular, the following materials shall be identified:
  - Normal Concrete C30/37
  - Normal Concrete C40/50
  - Heavy Concrete C40/50
  - Heavy Borated Concrete C40/50
  - Normal Concrete C90/105
  - Structural Steel

  The material layout shall be provided in the BoD [2] through general arrangement drawings for each level and building.
- All AREAs representing slabs and walls shall be grouped based on the related reinforcement layout. The identification of the different areas will be done by IO. The areas to be grouped shall be specified in the BoD [2] through general arrangement drawings for each level and building.

6.4 Report Quality and Model Verification

FE model and description report shall be prepared in full agreement with the Instructions [1]. The description report shall be written following the template in [1]. The references for geometry and material properties shall be provided by IO and reported in the description report. The FE model shall be fully verified following the requirements in [1], in particular:

- The total mass, centre of gravity, and second moments of inertia shall be documented and compared to the values in the CMM provided in the BoD [2] for each level of each building. Significant differences have to be explained.
- A gravity load check shall be implemented and documented, applying only gravity acceleration to the FE model and checkin whether the reaction forces on the constraints of the FE model correspond to the weight of the FE model, and whether the distribution of the reaction forces is roughly consistent with the centre of gravity of the FE model.
- Consistency between the geometry in the CMM and in the FE model shall be checked overlapping the plots of the CAD and FE models for each level of each building, in order to demonstrate that the axis of slabs, walls, columns and beams are in the expected location.

All the analysis files including FE models and spreadsheets shall be stored in the ITER analysis database following the instructions and requirements in [1] and [3], i.e. they shall include all files necessary to build the reported FE model from scratch (e.g. including macros & spreadsheets), be linked to the analysis report, with their metadata filled properly, shall be stored in a sensible and organized folder of IO's Analysis Model Database, shall be in a ready-to-run state, shall be commented/organized to be clearly and unambiguously understandable by a third party. Proper storage formats shall be used, i.e. that privileges robustness and exhaustiveness.

See [1] for the full set of analysis requirements.

7 Responsibilities

7.1 ITER Organization Responsibilities

IO shall assign a Responsible Officer to work as the sole Contractor interface. The IO CRO is the Integrated Engineering Analysis Section Leader or a person delegated by him.

The IO CRO shall organize the Kick of Meeting during which all necessary inputs shall be provided and described to the Contractor.

The IO CRO shall be responsible for ensuring that deliverables are checked against requirements, including quality and schedule.

IO shall make available to the Contractor all technical data and documents which the Contractor requires to carry out its obligations pursuant to this specification in a timely manner.

7.2 Contractor's Responsibilities

The Contractor shall ensure that he complies with the provisions of the contract. In particular:

- The Contractor shall provide one ANSYS FE modelling expert to perform the tasks listed in this contract. This expert shall not work on the ITER site, being all the tasks to be implemented at the Contractor's facilities, with the only exception for visits on-site for meetings as and when necessary and requested by IO. All information technology equipment and software licenses are borne by the Contractor.
- The Contractor shall ensure that the expert assigned to create the deliverables of this contract is Suitably Qualified and Experienced Personnel (SQEP).
- The Contractor shall guarantee that all input information provided to perform the task remain property of IO and shall not be used for any other activity than the ones specified by this contract and the IO CRO.
- All output created by the Contractor under this contract becomes the sole property of IO. This includes any macros and software used to create models and run analyses, including pre- and post-processing.
- The Contractor shall be in charge of the training & coaching of all its resources.
- The contractor shall work in accordance with the QA plan approved by IO.
- The contractor shall perform the activities accordingly to this specification taking into account all relevant additional documents and IO processes into account (hand books, export control, intellectual properties, etc.).
- If assigned tasks are not clear, the Contractor shall request clarification as soon as possible from the IO CRO.
- The Contractor shall inform the IO CRO as soon as possible of any event which leads to deviation in content or due date of the delivery of a task.

Prior to the start of work, the Contractor shall gather and review the input technical information provided to it by IO at the Kick of Meeting for completeness and consistency, and shall advise the IO representative of any deficiencies it may find. The Contractor shall not be responsible for errors in the input technical information which could not be reasonably detected during such review.

8 List of deliverables and due dates

One ANSYS FE modelling expert from the Contractor will be devoted full-time to this analysis activity until the contract is complete; the contract duration is expected to be six months. The expert will perform his duty for the majority of the time off site, except for visits on-site for meetings as and when necessary and requested by IO.

The Contractor shall provide the full package of generated ANSYS files and the related description report in line with the requirements reported in section 6. The language used for the report shall be English.

The task shall be considered completed after IO has approved the description report including all ANSYS files in the ITER Document Management system (IDM).

A draft version of the description report and related files shall be also issued three months after the KoM, to allow IO to check the correct implementation of requirements and formats, and to provide corrective indications for the final deliveries.

One week after the KoM, the Contractor is requested to provide a detailed schedule with the sub-task defined in order to get the task properly finalized on time. This schedule shall be updated weekly (see section 11).

The deadlines for the deliverables accepted by IO are as follows:

Deliverable No. (D#)	Deliverable	Due Date
D1	Draft FE Model Description report including ANSYS files developed until then	T0 + 1 week
D2	Draft FE Model Description report including ANSYS files developed until then	T0 + 3 months
D3	First version of final FE Model Description report including all ANSYS files	T0 + 5 months
D4	Second version of final FE Model Description report including all ANSYS files, incorporating all comments from I	T0 + 6 months

*T0 is the date of the Kick of Meeting to be held within 1 week after the signature of the Contract.

9 Acceptance Criteria

Reports and ANSYS files shall be provided as for the schedule in previous section 8. All deliverables shall be uploaded to the IO IDM system where they will be reviewed as arranged by the IO RO.

The form of deliverables is according to the formalized request by the IO CRO. Any deviations, if not previously agreed, may lead to the deliverable being refused.

IO will review the report and the ANSYS files, checking consistency with inputs and requirements in [1] and [2], providing to the Contractor a commented version of the deliverables 15 working days after the delivery if they are not compliant with some of the requirements advised in this technical specification; otherwise they will be accepted.

The process of acceptance is driven by the IO internal process of approval. Until this process is completed, modifications can be requested. The IO approval process involves all the interfacing system concerned.

In case of non-compliance / conformity of a deliverable or a set of deliverables, the contractor shall correct them and re-submit them for review and acceptance. Resubmission shall be at contractor's cost.

The Contract will be considered completed after the IO has accepted the last deliverable.

Note that reviewing deliverables imposes an overhead on ITER. To keep this overhead to a minimum, the deliverables shall be of high quality. This includes good use of English in any documentation produced. If deliverables are of unacceptably low quality, or there are delays in the submission of deliverables, IO reserves the right to terminate the contract.

10 Specific requirements and conditions

The official language of the ITER project is English. Therefore all input and output documentation relevant for this Contract shall be in English. The Contractor shall ensure that all the professionals in charge of the Contract have an adequate knowledge of English, to allow easy communication and adequate drafting of technical documentation. This requirement also applies to the Contractor's staff participating to meetings with the ITER Organization.

The work may require the presence of the Contractor's personnel at the site of the ITER Organization, Cadarache, 13115 St Paul-lez-Durance, France, for a short time, for the purpose of meetings and data gathering.

For all deliverables submitted in electronic format the Contractor shall ensure that the release of the software used to produce the deliverable shall be the same as that adopted by the ITER Organization.

11 Work Monitoring / Meeting Schedule

A kick-off meeting shall be arranged on the IO site at the beginning of the task.

Progress meetings shall be organised by IO as necessary to monitor the progress in the work. The progress meeting shall be mainly by videoconference, except for visits on-site as and when necessary and requested by IO.

The Contractor has to implement and maintain a detailed schedule including sub-task launched and planned in order to get the task properly finalized on time. This schedule should be permanently available.

The Contractor shall provide a weekly report of its activities highlighting in particular:

- Update of the detailed schedule
- Possible issues
- Possible proposals for improvements

12 Delivery time breakdown

See section 8.

13 Quality Assurance (QA) requirements

The organisation conducting these activities should have an ITER approved QA Program or an ISO 9001 accredited quality system.

The general requirements are detailed in ITER Procurement Quality Requirements (ITER_D_22MFG4).

Prior to commencement of the task, a Quality Plan must be submitted for IO approval giving evidence of the above and describing the organisation for this task; the skill of workers involved in the study; any anticipated sub-contractors; and giving details of who will be the independent checker of the activities (see Procurement Requirements for Producing a Quality Plan (ITER_D_22MFMW)).

Documentation developed as the result of this task shall be retained by the performer of the task or the DA organization for a minimum of 5 years and then may be discarded at the direction of the IO. The use of computer software to perform a safety basis task activity such as analysis and/or modelling, etc. shall be reviewed and approved by the IO prior to its use, in accordance with Quality Assurance for ITER Safety Codes (ITER_D_258LKL).

14 Safety requirements

ITER is a Nuclear Facility identified in France by the number-INB-174 ("Installation Nucléaire de Base").

For Protection Important Components and in particular Safety Important Class components (SIC), the French Nuclear Regulation must be observed, in application of the Article 14 of the ITER Agreement.

In such case the Suppliers and Subcontractors must be informed that:

- The Order 7th February 2012 applies to all the components important for the protection (PIC) and the activities important for the protection (PIA).
- The compliance with the INB-order must be demonstrated in the chain of external contractors.
- In application of article II.2.5.4 of the Order 7th February 2012, contracted activities for supervision purposes are also subject to a supervision done by the Nuclear Operator.

For the Protection Important Components, structures and systems of the nuclear facility, and Protection Important Activities the contractor shall ensure that a specific management system is implemented for his own activities and for the activities done by any Supplier and Subcontractor following the requirements of the Order 7th February 2012 [4].

In application of the article 2.2.1 of the INB Order [4], the document [5] defines generic safety requirements to be implemented by all external actors in order to satisfy the requirements of the INB Order.

15 Appendix – CMM Models

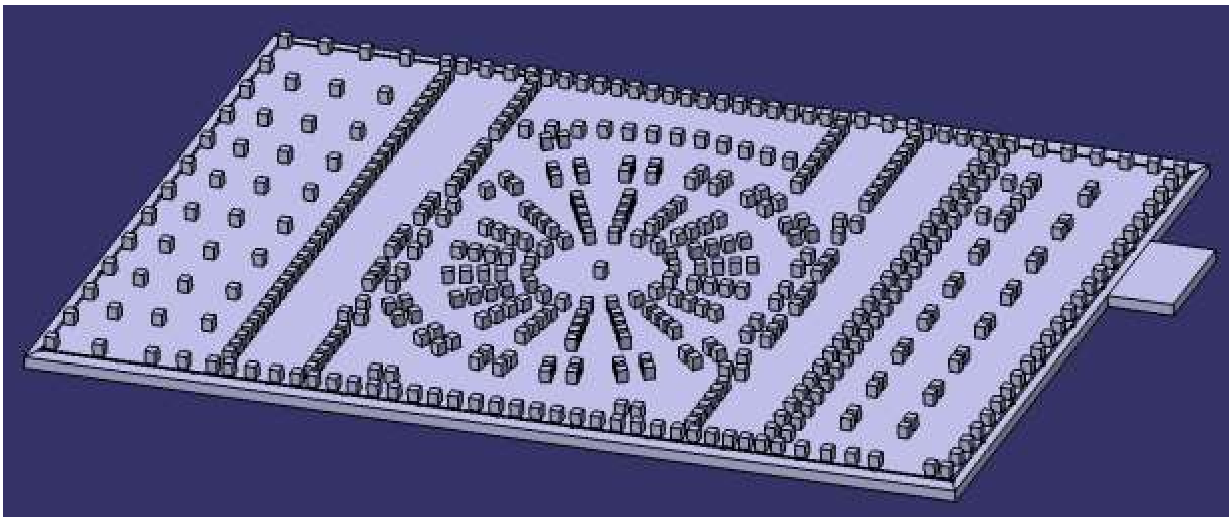

Figure 5 – B19 CMM – Lower Basemat and Plinths

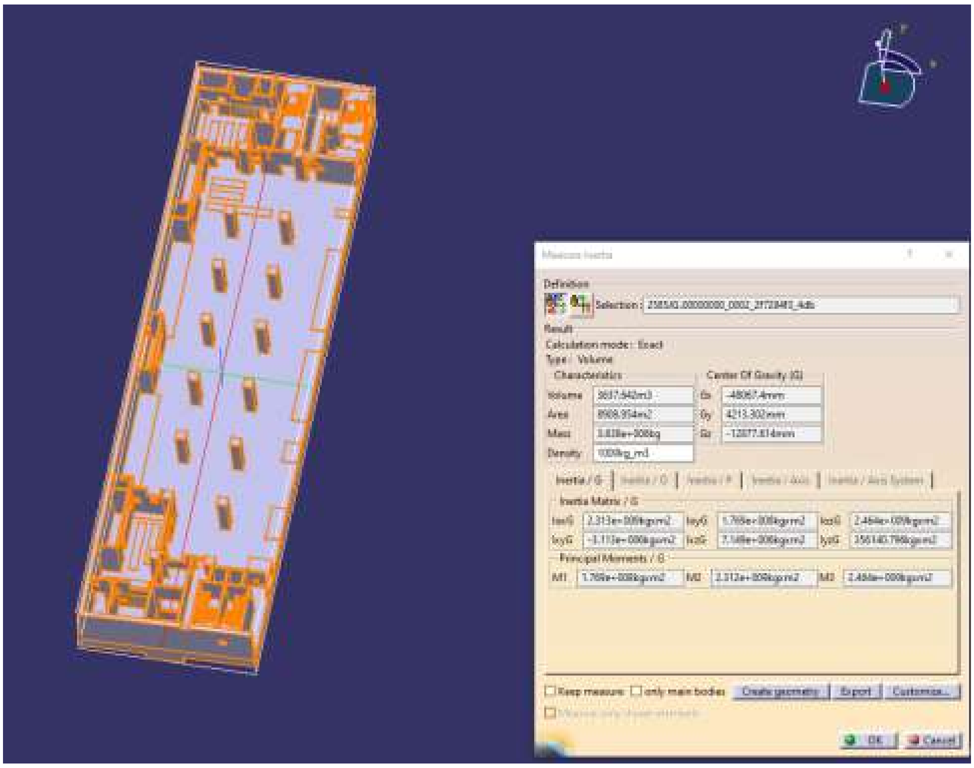

Figure 6 – B74 CMM - Level B2.

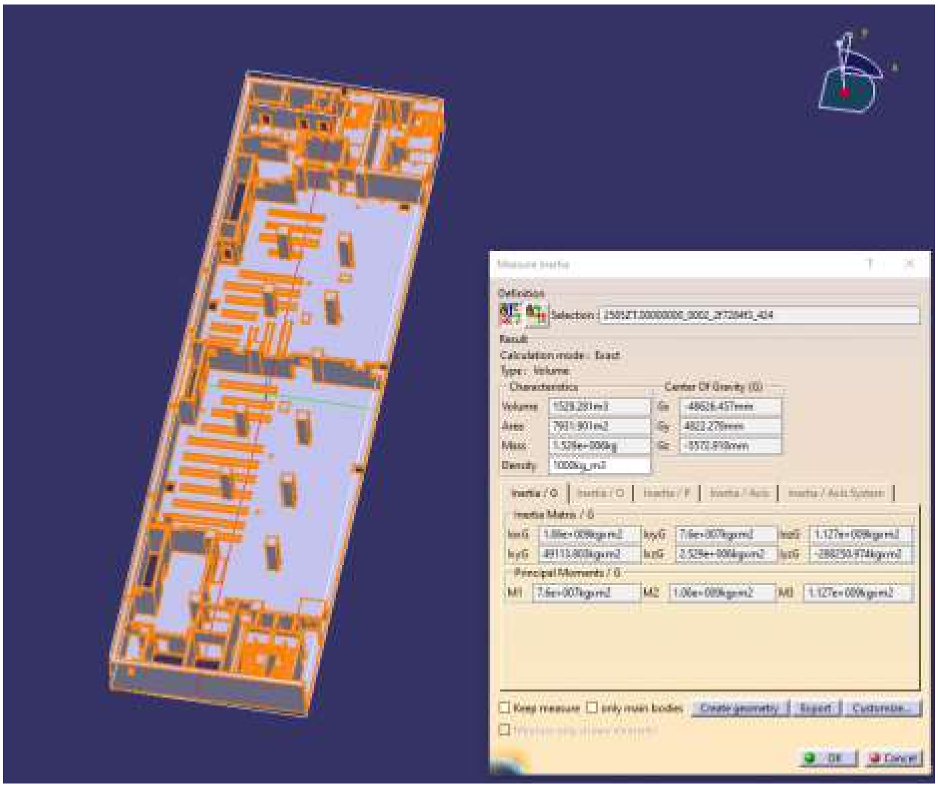

Figure 7 – B74 CMM - Level B1.

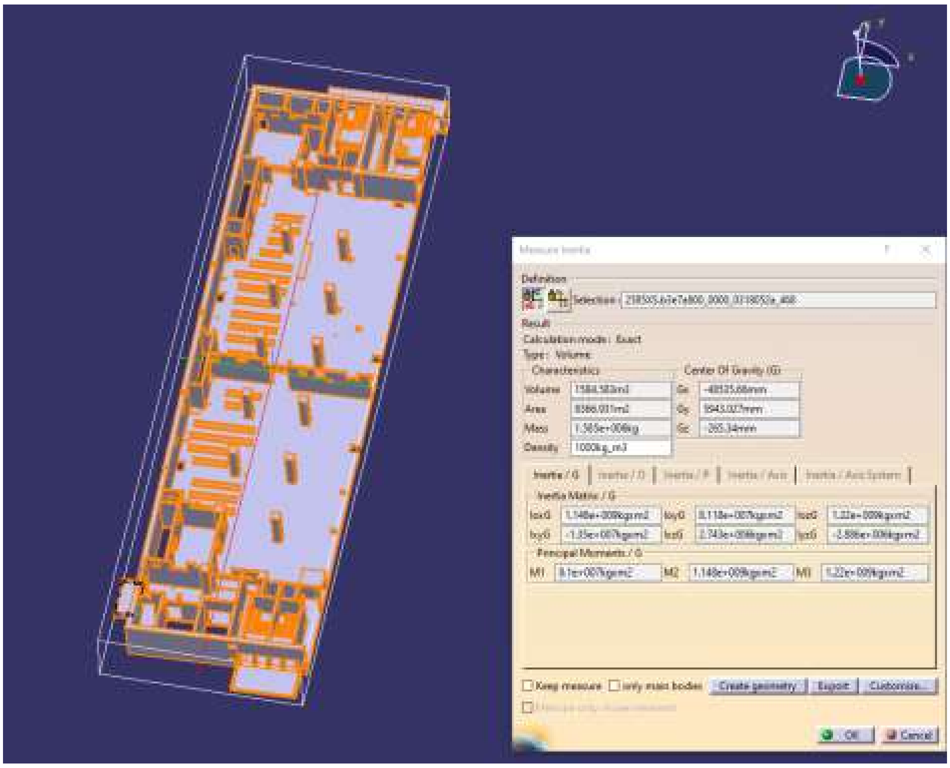

Figure 8 – B74 CMM - Level L1.

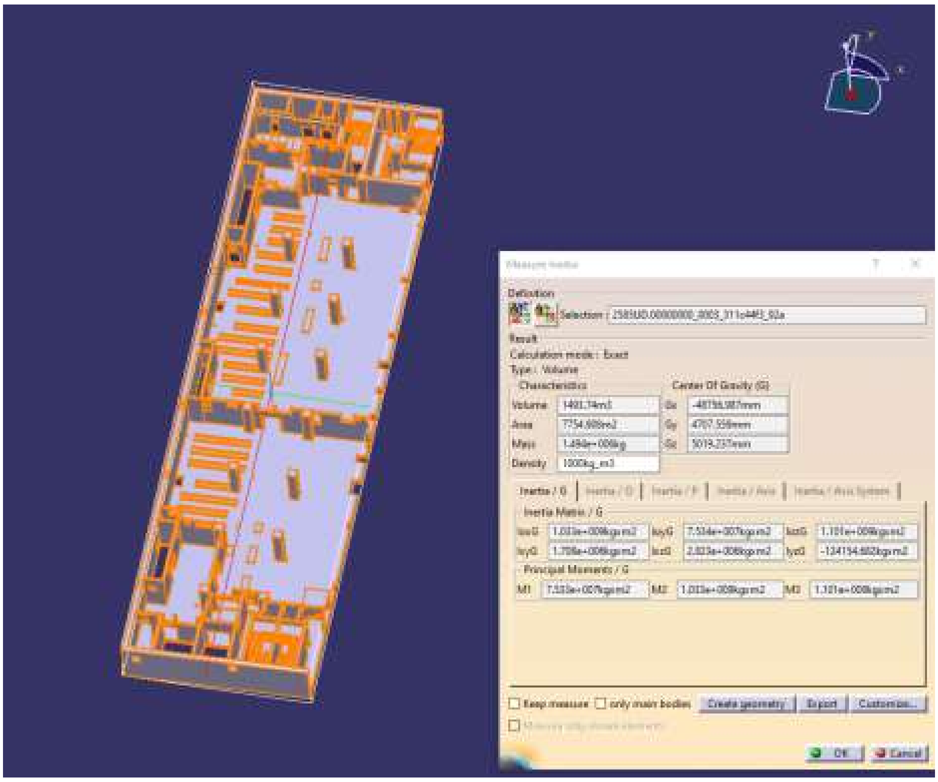

Figure 9 – B74 CMM - Level L2.

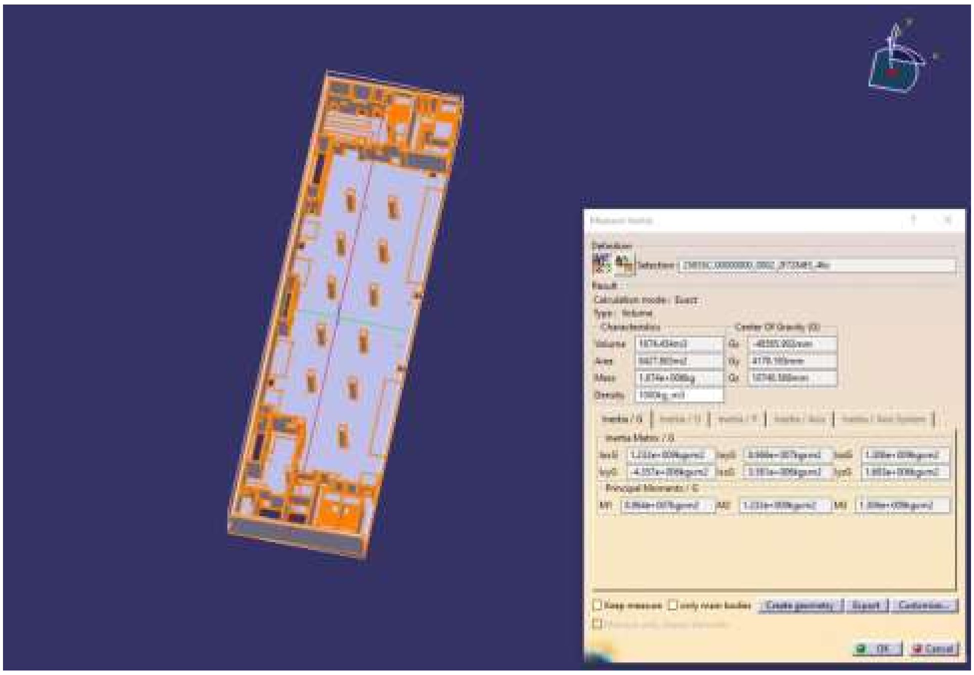

Figure 10 – B74 CMM - Level L3.

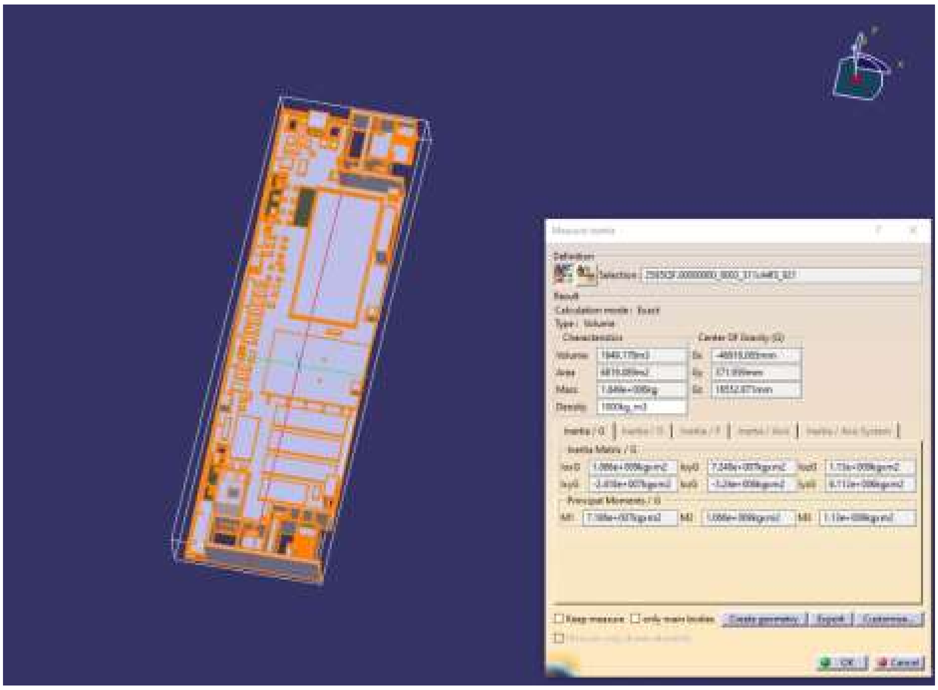

Figure 11 – B74 CMM - Level L4.

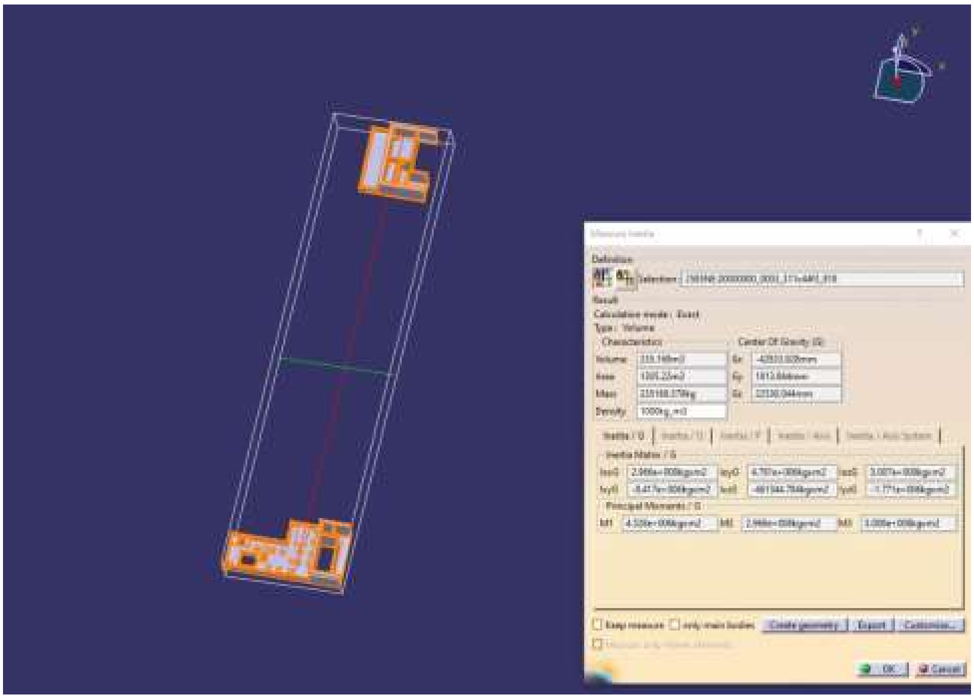

Figure 12 – B74 CMM - Level L5.

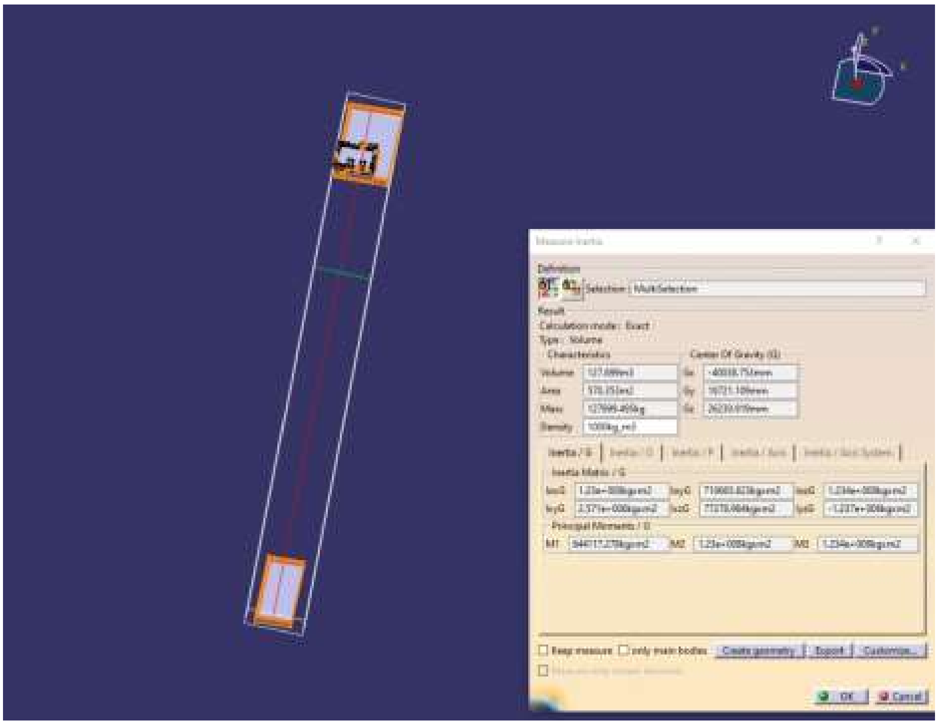

Figure 13 – B74 CMM - Level R1/R2.

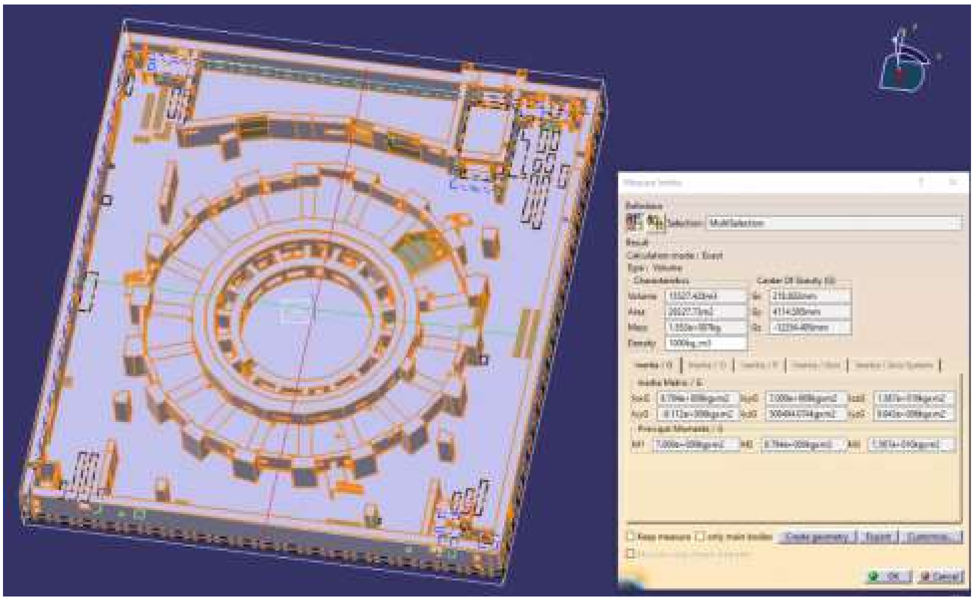

Figure 14 – B11 CMM - Level B2.

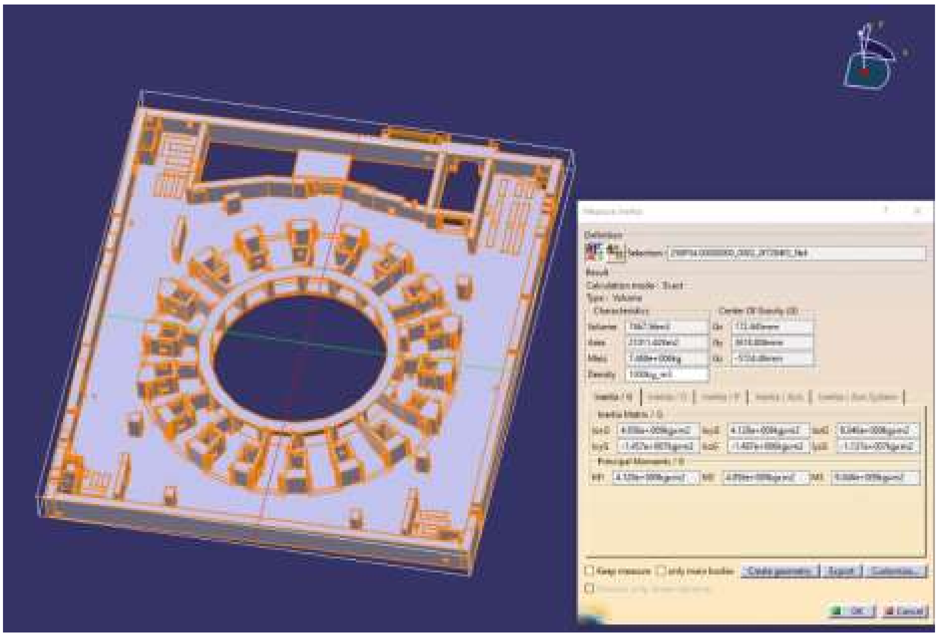

Figure 15 – B11 CMM - Level B1.

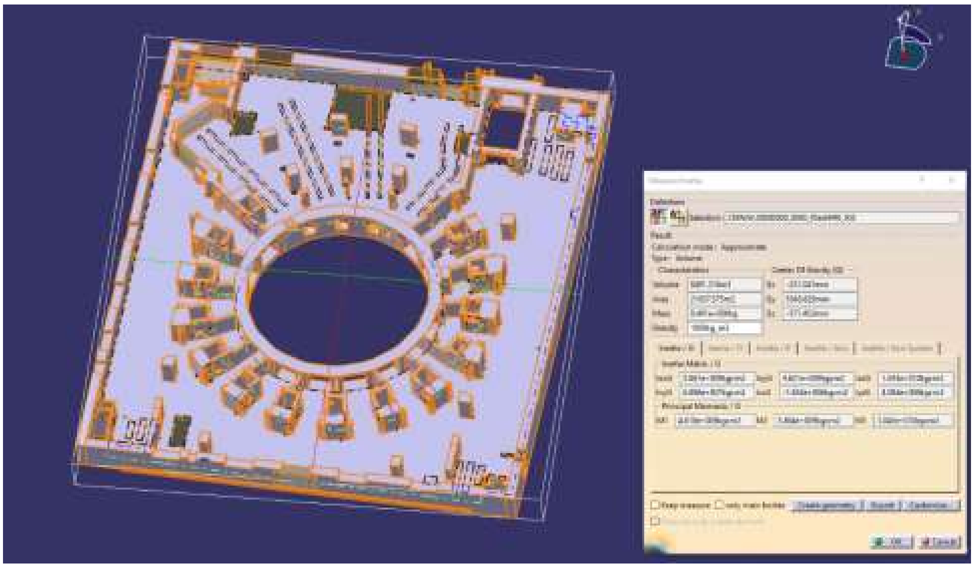

Figure 16 – B11 CMM - Level L1.

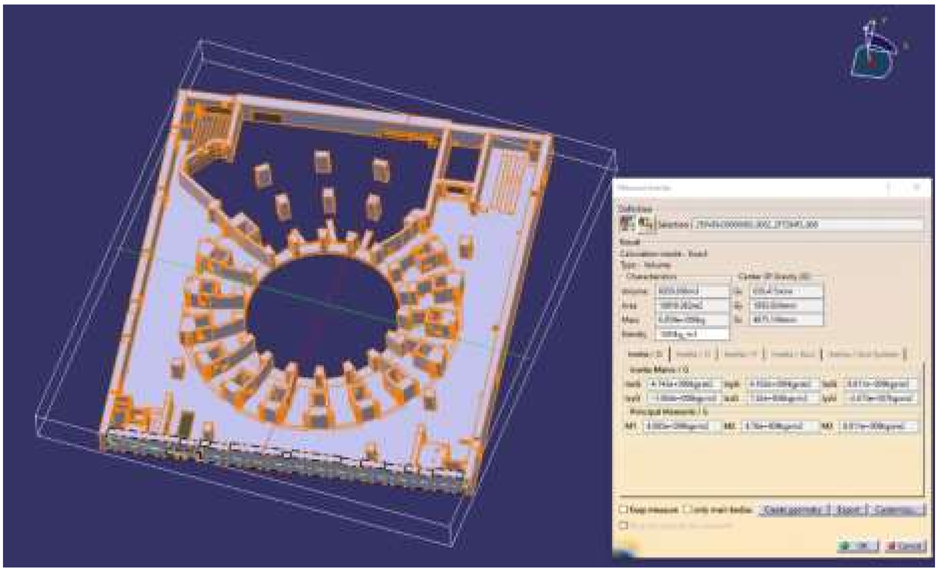

Figure 17 – B11 CMM - Level L2.

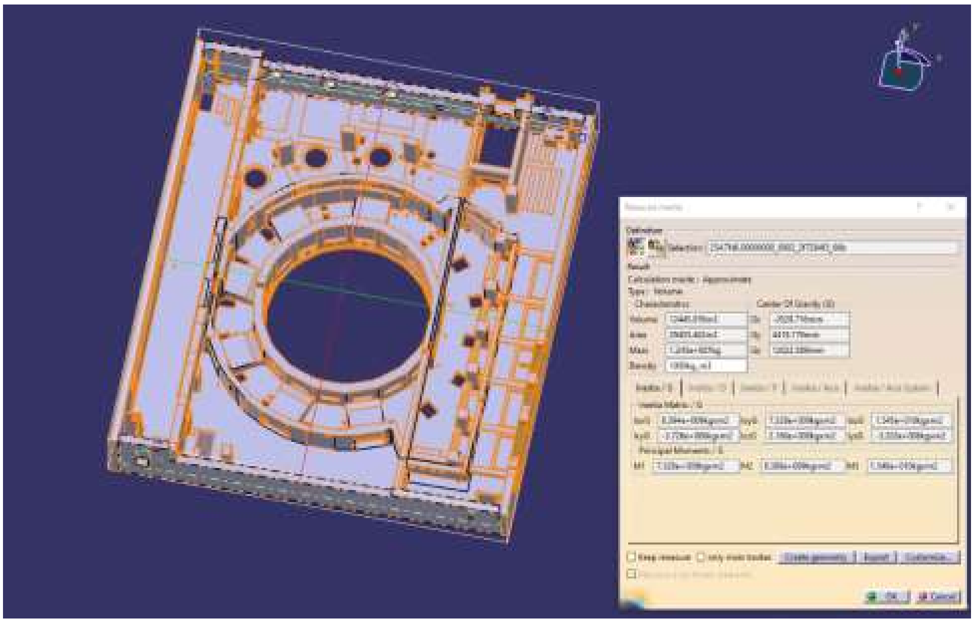

Figure 18 – B11 CMM - Level L3.

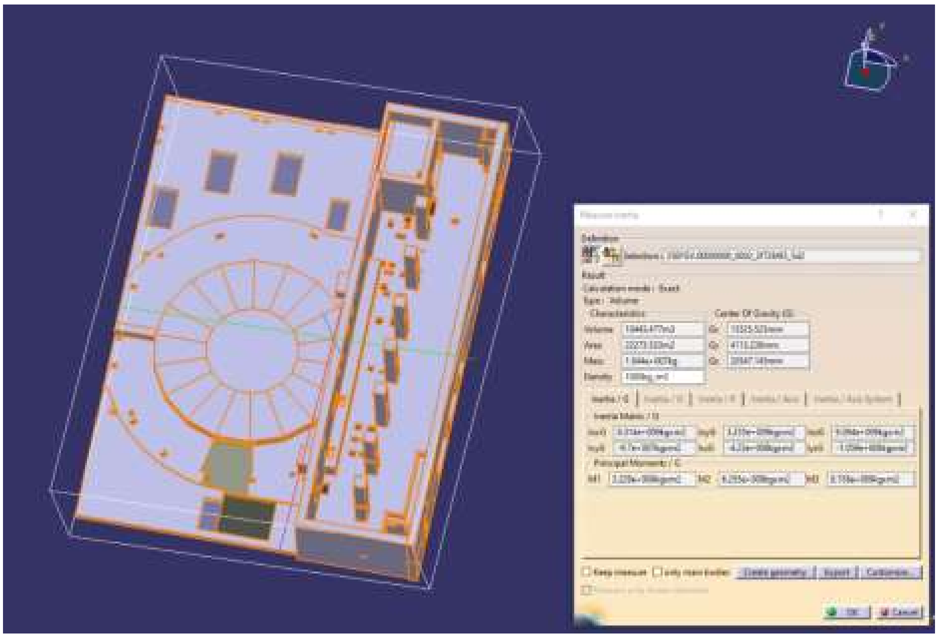

Figure 19 – B11 CMM - Level L4.

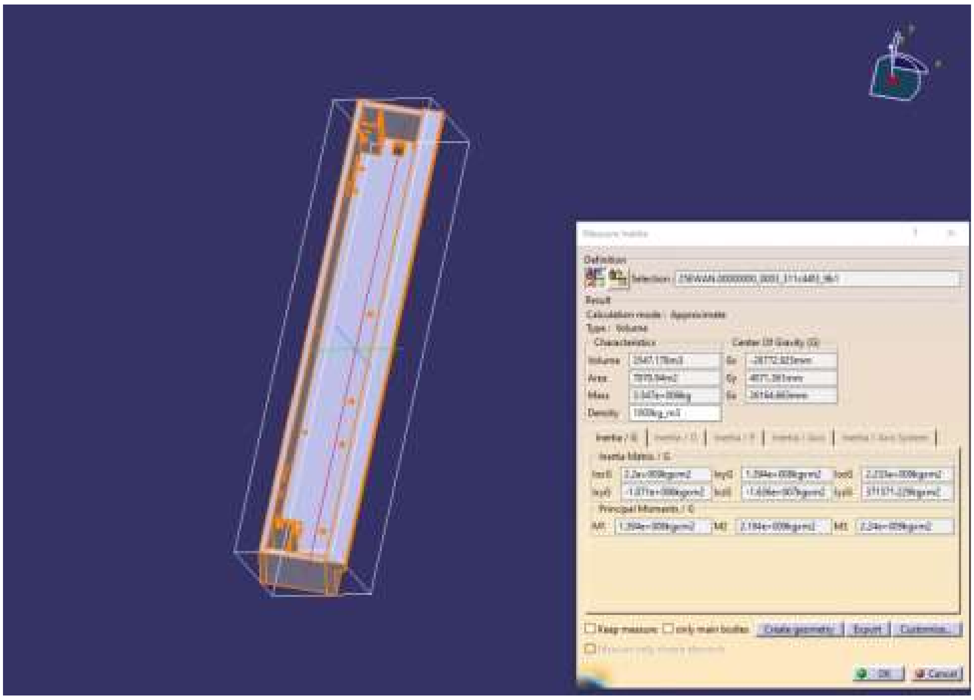

Figure 20 – B11 CMM - Level L5.

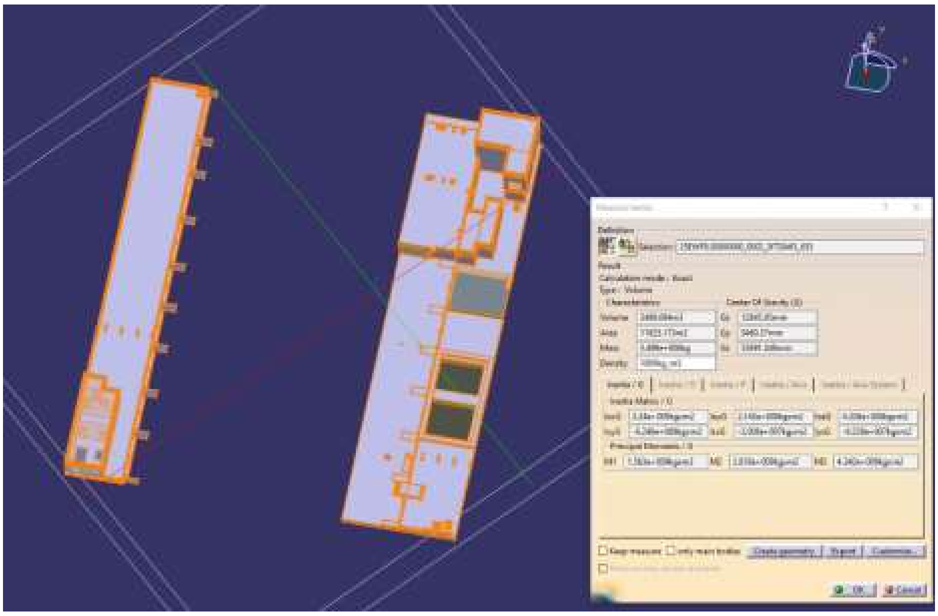

Figure 21 – B11 CMM – Level R1/R2.

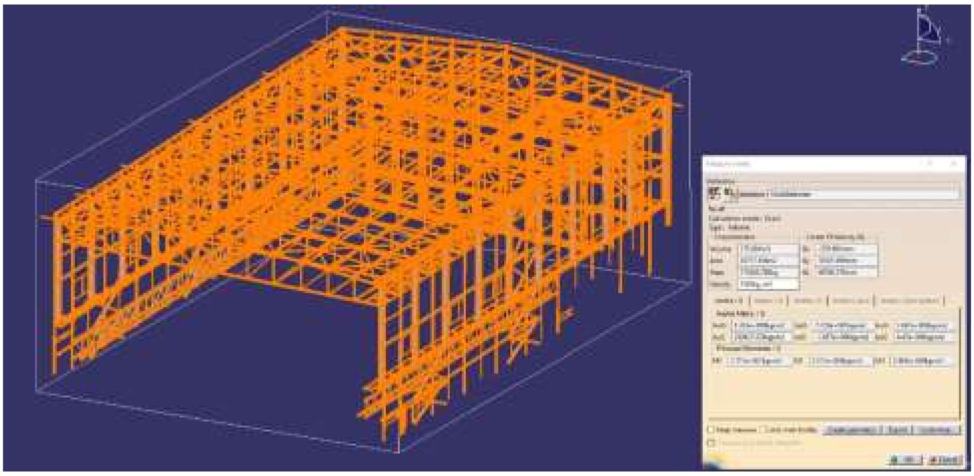

Figure 22 – B11 CMM - Crane Hall Steel Frame.

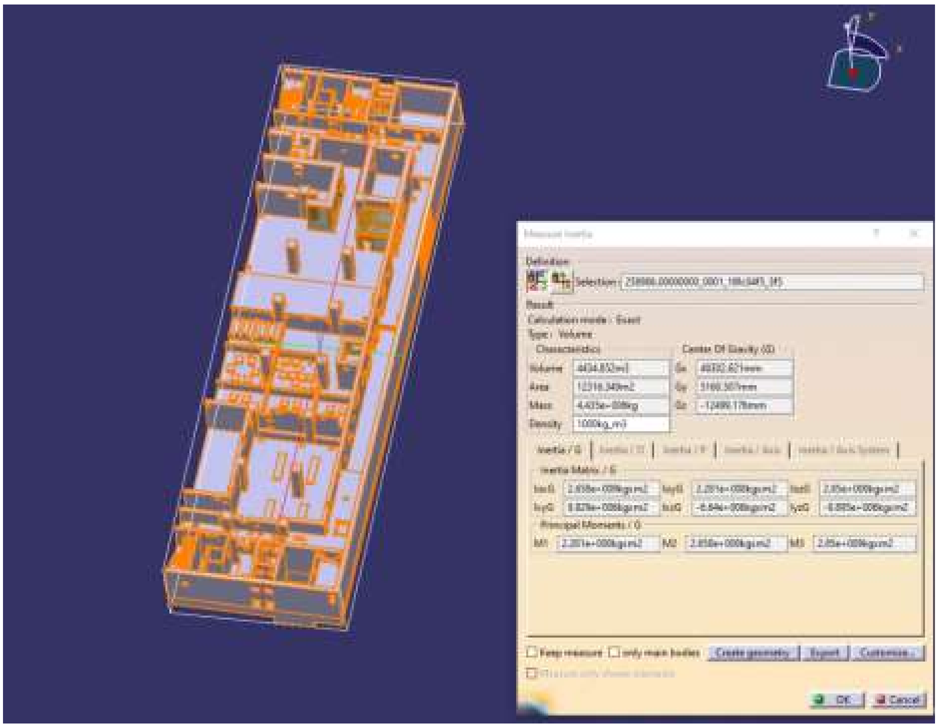

Figure 23 – B14 CMM - Level B2.

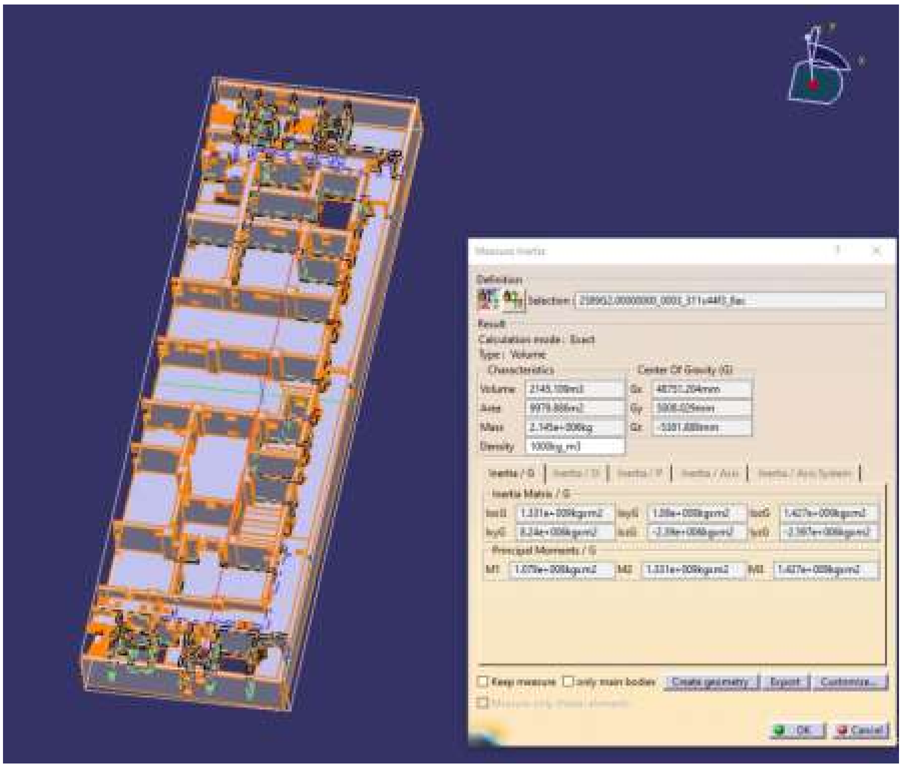

Figure 24 – B14 CMM - Level B1.

Figure 25 – B14 CMM - Level L1.

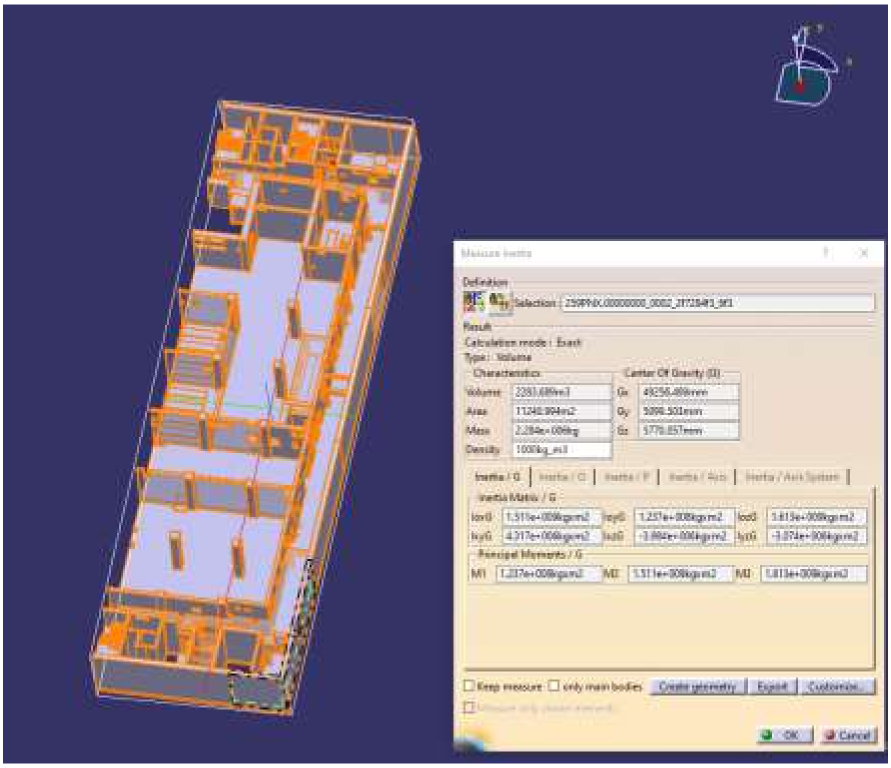

Figure 26 – B14 CMM - Level L2.

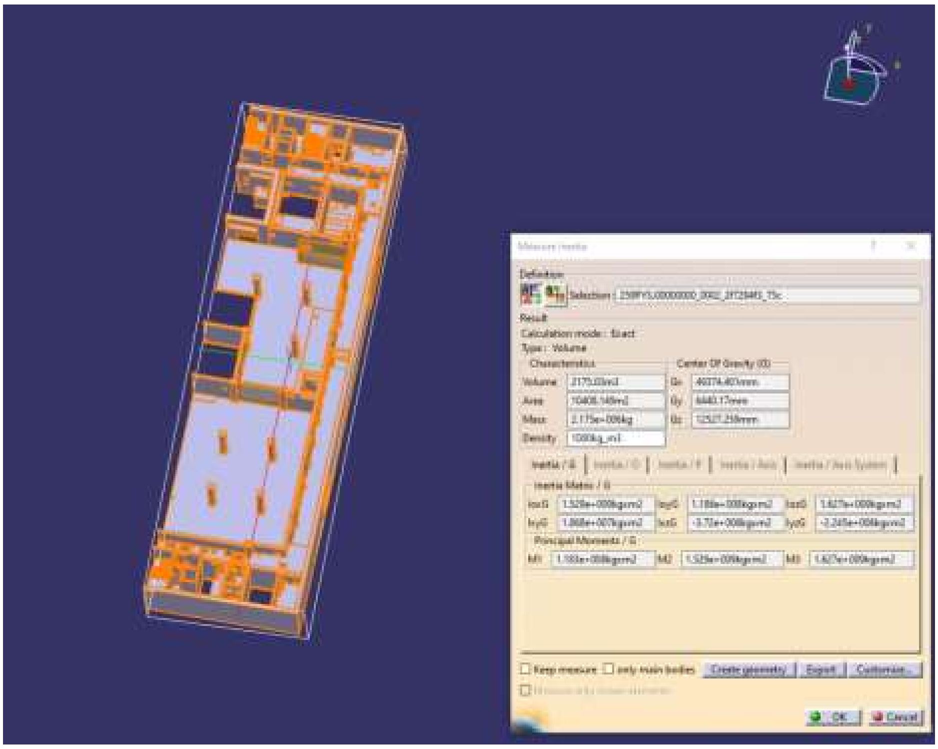

Figure 27 – B14 CMM - Level L3.

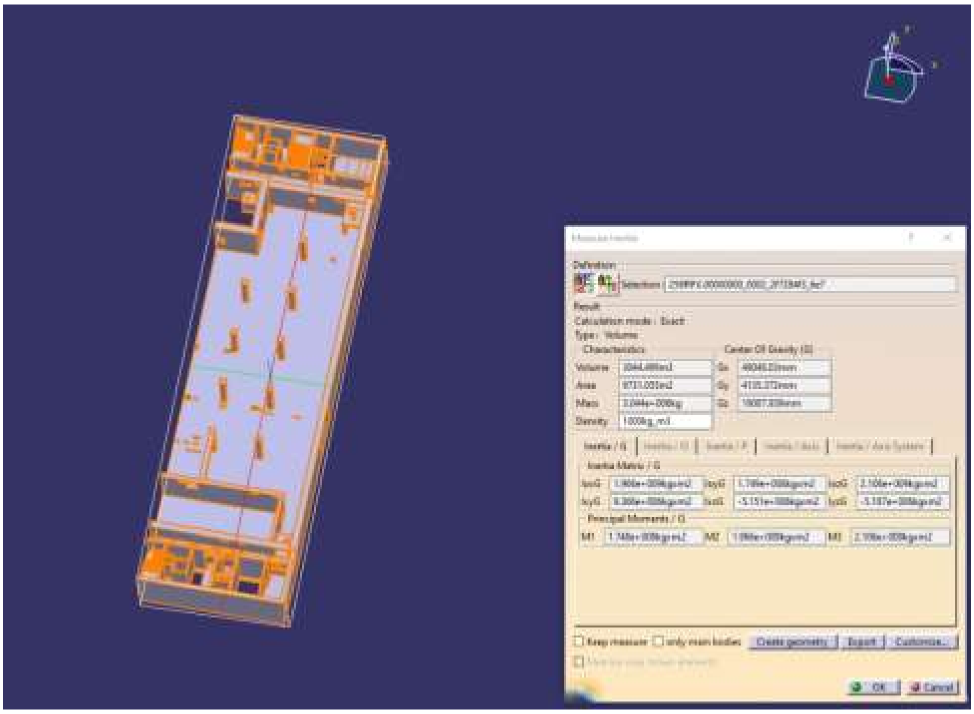

Figure 28 – B14 CMM - Level L4.

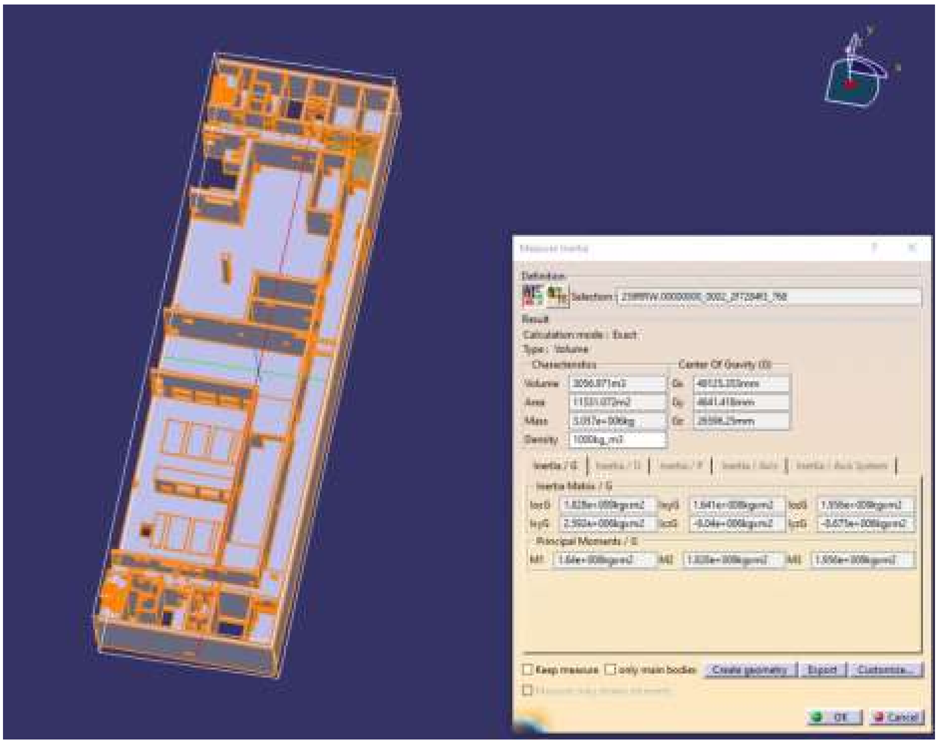

Figure 29 – B14 CMM - Level L5.

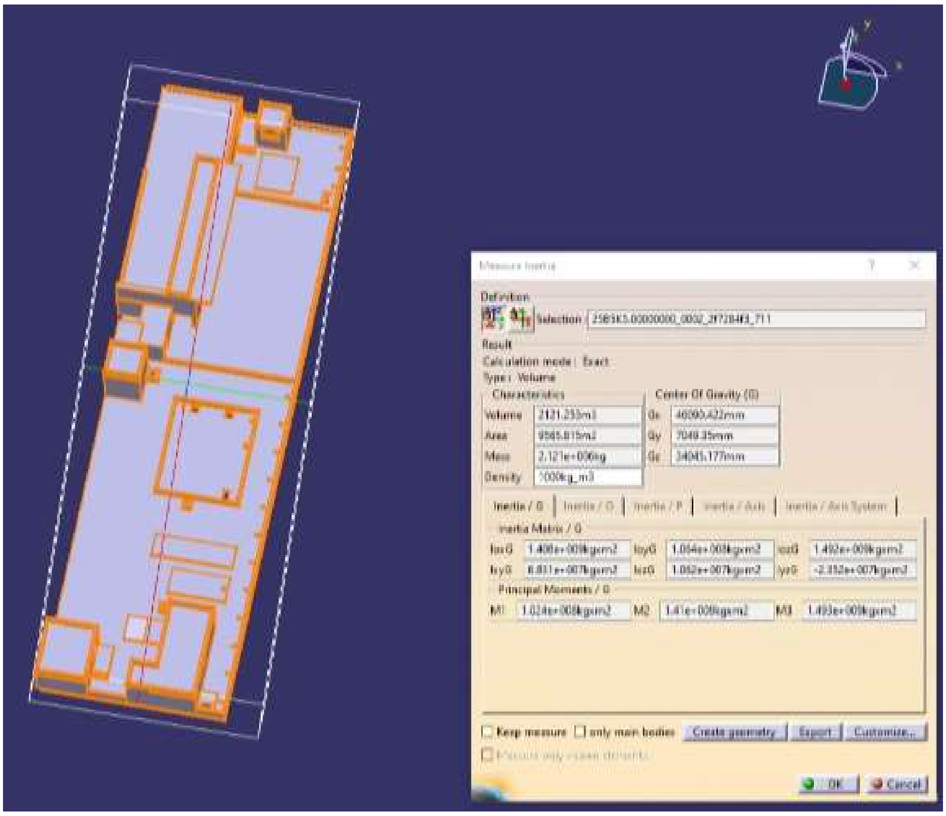

Figure 30 – B14 CMM - Level R1/R2