

World Tunnel Congress & Exhibition



ITA - AITES General Assembly and World Tunnel Congress

**TUNNELS AND UNDERGROUND CITIES: ENGINEERING
AND INNOVATION MEET ARCHAEOLOGY, ARCHITECTURE AND ART**



Società Italiana Gallerie
Italian Tunnelling Society



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TUNNELS AND UNDERGROUND CITIES:
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Innovation in underground engineering, materials and equipment

Integrated functional metro station design using BIM tools

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Presenting author: Christian Pallaria

 **GEODATA**
UNDERGROUND SOLUTIONS



I'm here for...

1. Presenting our **Istanbul Metro Line project** developed with a “full BIM approach” using **computational design tools**
2. A quick presentation of **our last experiences in BIM for Tunneling**

Istanbul

- Istanbul is a megalopolis with **over than 14 million of inhabitants**, characterized by a mixture of historical and modern urbanization, often uncontrolled, and natural constraints.
- **The morphology of Istanbul**, heavily hilly and with the Bosphorus that separates the Eastern and Western sides, adds greater complexity to these challenges.
- Large investment plan that consists in building, by 2023 (**100th celebration of the founding of the Turkish Republic**), a new metropolitan railway network, **covering the metropolitan area of about 500 km.**



Railway Metro Lines in Istanbul

Within this ambitious investment plan, Geodata has been involved in the development of four subway projects

Metro Line	Lenght	Stations	Design Stage
Dudullu-Bostanci	14 Km	13	Final and Construction Design
Ümraniye-Ataşehir-Göztepe	13 Km	11	Final Design
Kirazli-Halkali	9,6 Km	9	Final and Construction Design
Gayrettepe – İstanbul Yeni Havalimani	37 Km	10	Detail design revision and Construction Design

All abovementioned projects have been done with a “full BIM approach”, from the alignment up to stations design, considering also temporary and permanent structures.

BEP and stakeholders cooperation

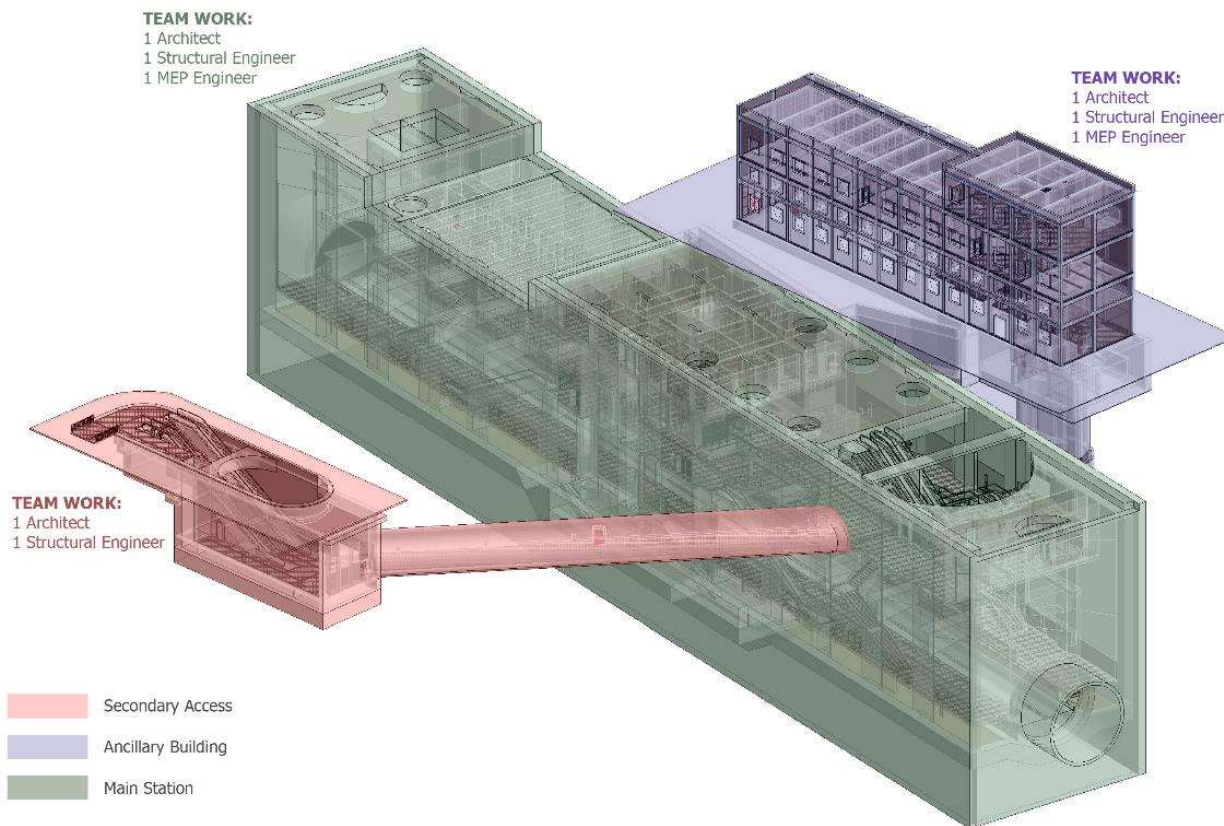
The BEP (BIM Execution Plan) defined the rules of how to use BIM in the entire project (within Geodata and with other stakeholders)

The main problem was that there was no a standard classifiers imposed from the Client. **There are no any recommendations, standards or guidelines for tunneling.**

The BEP defined also rules to generate a federated model, that consists of linking different disciplines, in particular:

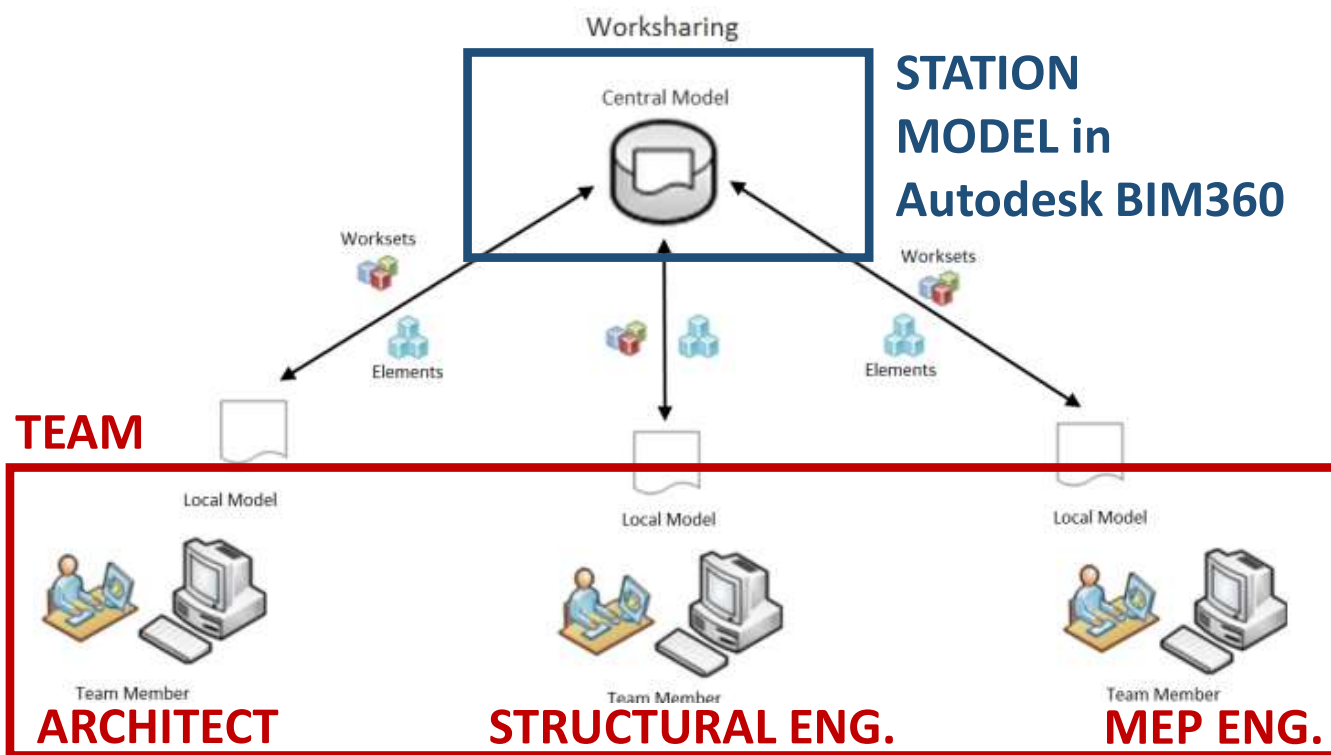
- **Functional/Architectural model**
- **Structural model**
- **MEP model**

Architectural and functional design



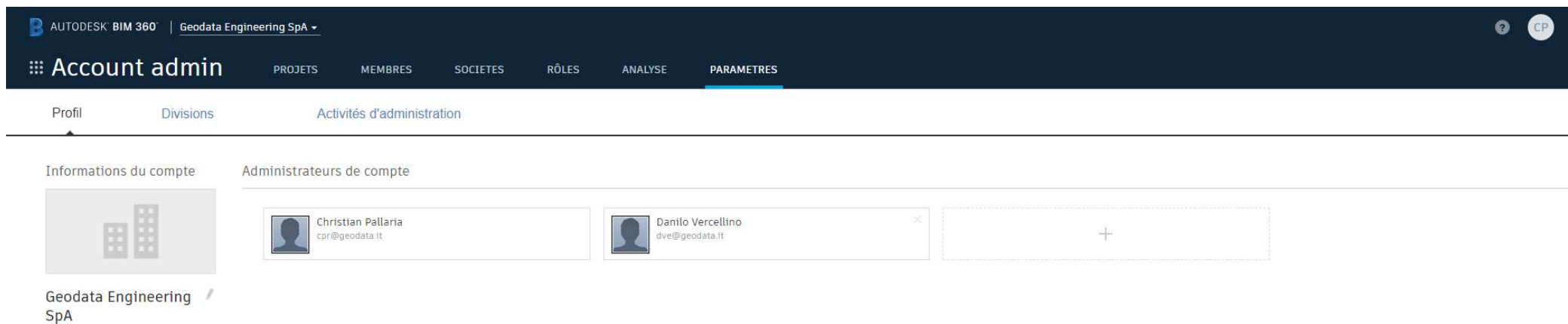
The use of the BIM approach has improved for the design management both within Geodata and towards other Stakeholders. In particular, it has been extremely useful for **sharing the same model simultaneously with structural, architectural and MEP designers.**

Interaction and interface in a teamwork



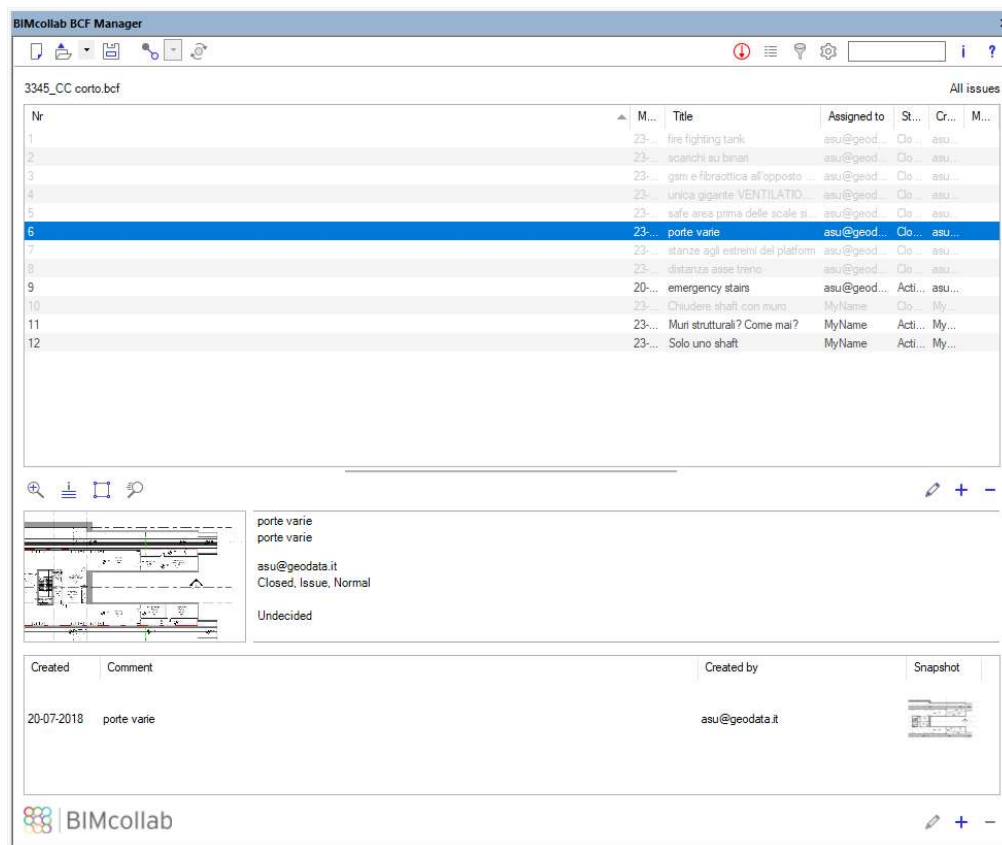
The interaction and the interface with all the other related disciplines, structural design, MEP design, architectural finishes, is a must. The greater the interaction between the disciplines is and the minors the negative impacts are during the construction phase.

Autodesk BIM360 for stakeholder collaboration



Autodesk BIM360 was used at the construction level, in order to give a full access of the design documentation to all stakeholders, with **different access rules** according to the user. Everyone was able to insert comments, even uploading images **directly from the station sites**. All this allowed a **simultaneous coordination between stakeholders**, especially between the Construction Supervision, the Contractor and the designers.

BCF (BIM Collaboration Format)



For the design phases, the BCF format was used to check errors, to make “issues and changes report” and to keep track of all the changes requested, made or rejected.

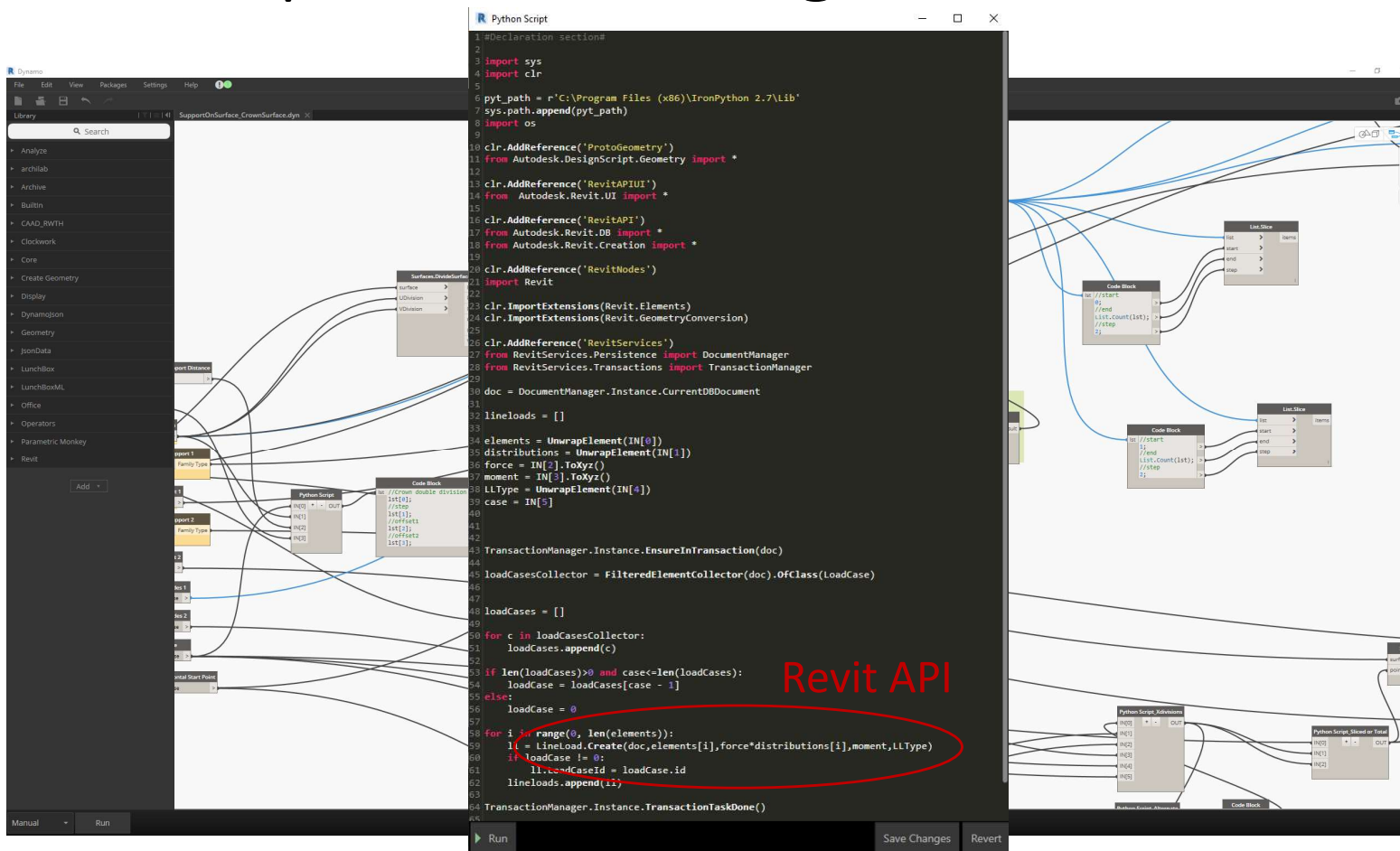
Every Friday a **general coordination meeting** was held between the various disciplines and a **specific report of issues and changes** in BCF format was re-issued.

Computational design consists of applying computational strategies to conventional design processes.

Dynamo is a visual programming language. It consists of standard nodes that allow to do many operations.

When the nodes
doesn't do what you
need, you have to
program your custom
node using Python
programme language

Computational Design



Python is a simple program language object oriented used in many other contexts other than Dynamo.

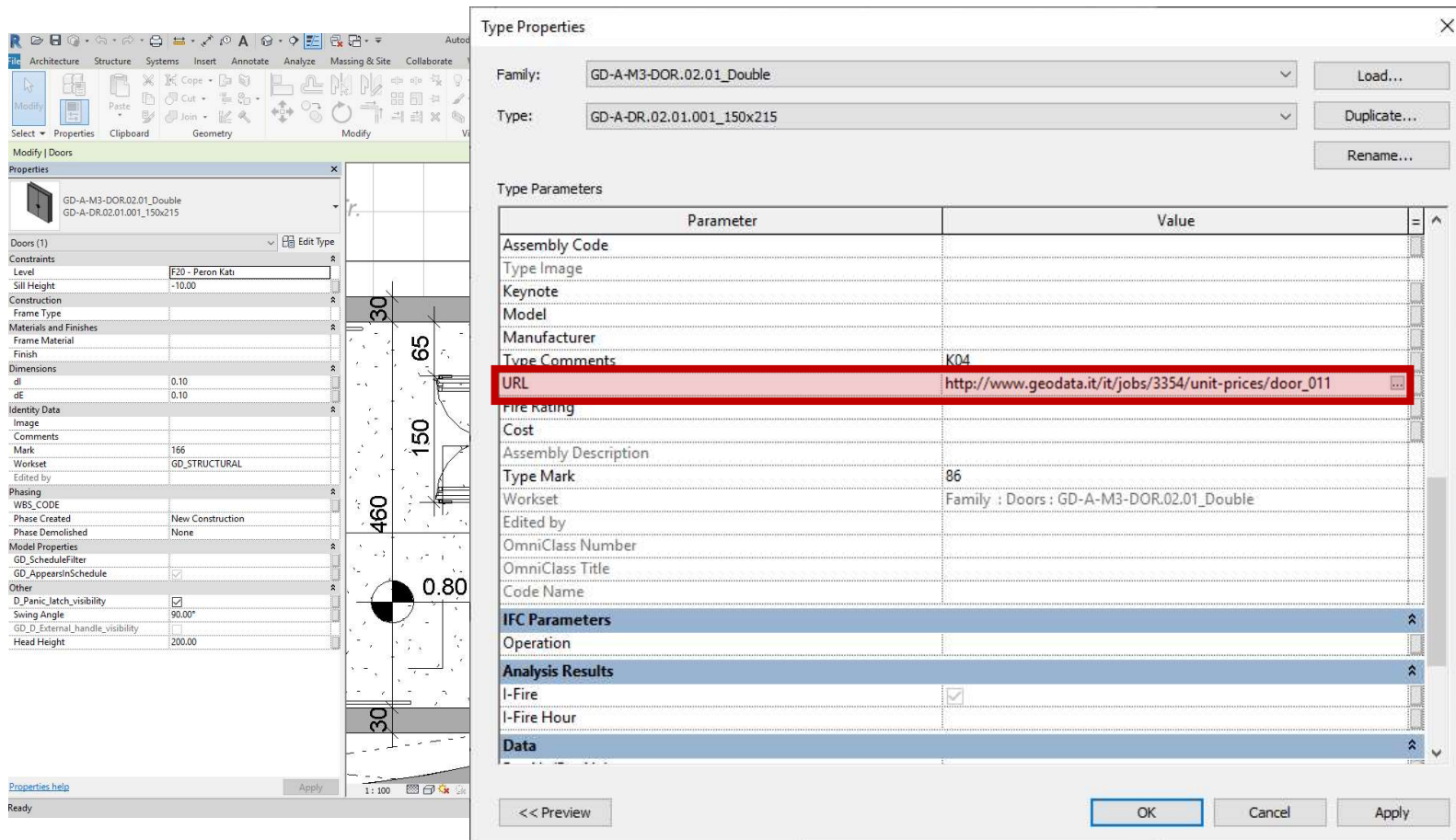
It is useful also for machine learning simulations.

Application of Computational Design

Automated workflow for:

- filling **title blocks** by reading the parameters from the processed list of drawings
- filling **stations room names** according to the coding for each room
- **numbering model elements** (rooms, walls, pillars, slabs, etc ...)
- **writing specific parameters** extrapolated from external database
- **modelling TBM tunnels**
- **modelling NATM tunnels**
- **modelling excavation supports**
- Automated **design of TBM segments** by using a specific tool developed for **Inventor**

Architectural and functional design



The screenshot shows the Revit software interface with a door family type properties dialog open. The dialog includes fields for Family and Type, and a table of Type Parameters. The URL parameter is highlighted in red.

Type Properties

Family: GD-A-M3-DOR.02.01_Double

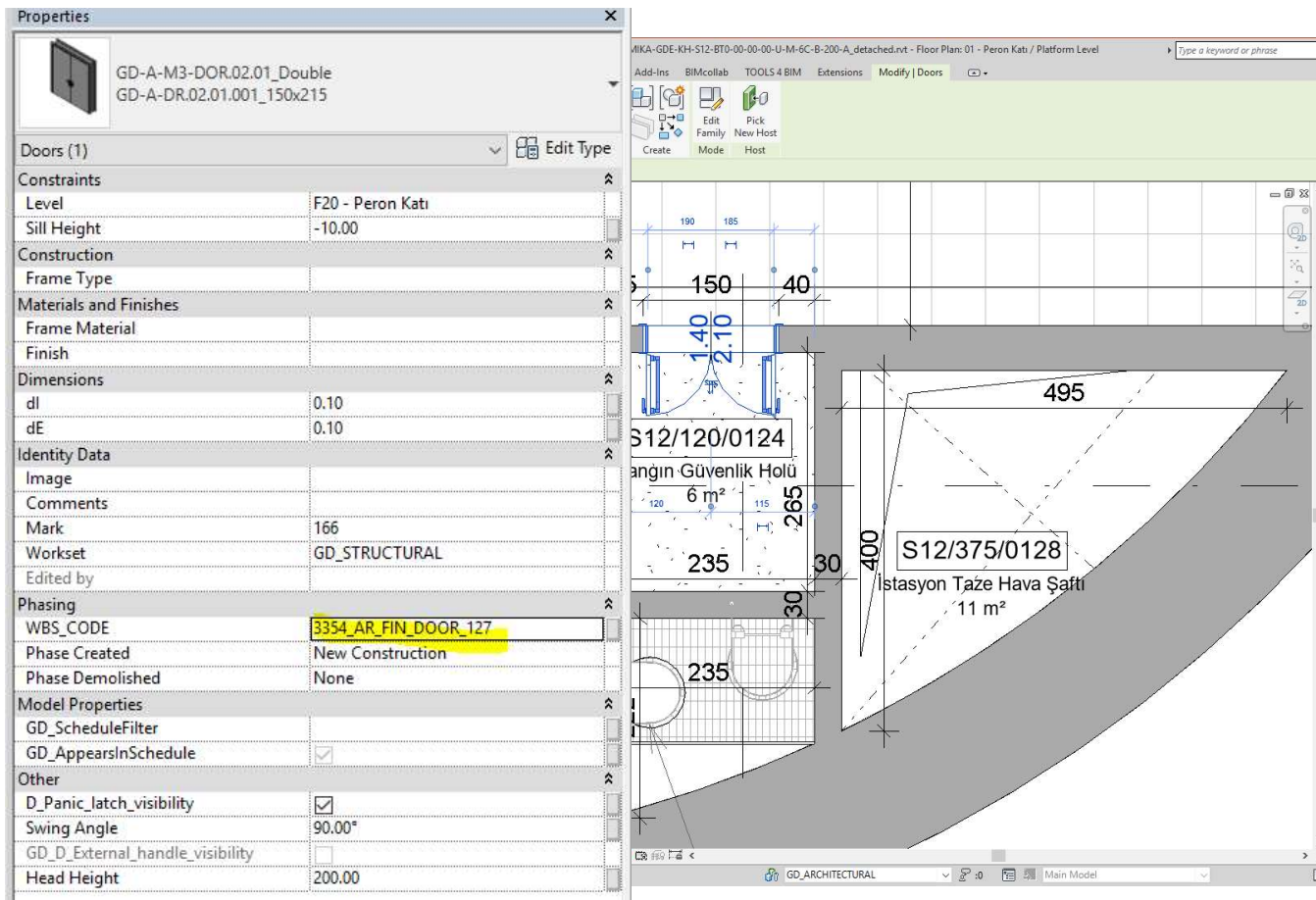
Type: GD-A-DR.02.01.001_150x215

Type Parameters

Parameter	Value
Assembly Code	
Type Image	
Keynote	
Model	
Manufacturer	
Type Comments	K04
URL	http://www.geodata.it/it/jobs/3354/unit-prices/door_011
Fire Rating	
Cost	
Assembly Description	
Type Mark	86
Workset	Family : Doors : GD-A-M3-DOR.02.01_Double
Edited by	
OmniClass Number	
OmniClass Title	
Code Name	
IFC Parameters	
Operation	
Analysis Results	
I-Fire	☒
I-Fire Hour	
Data	

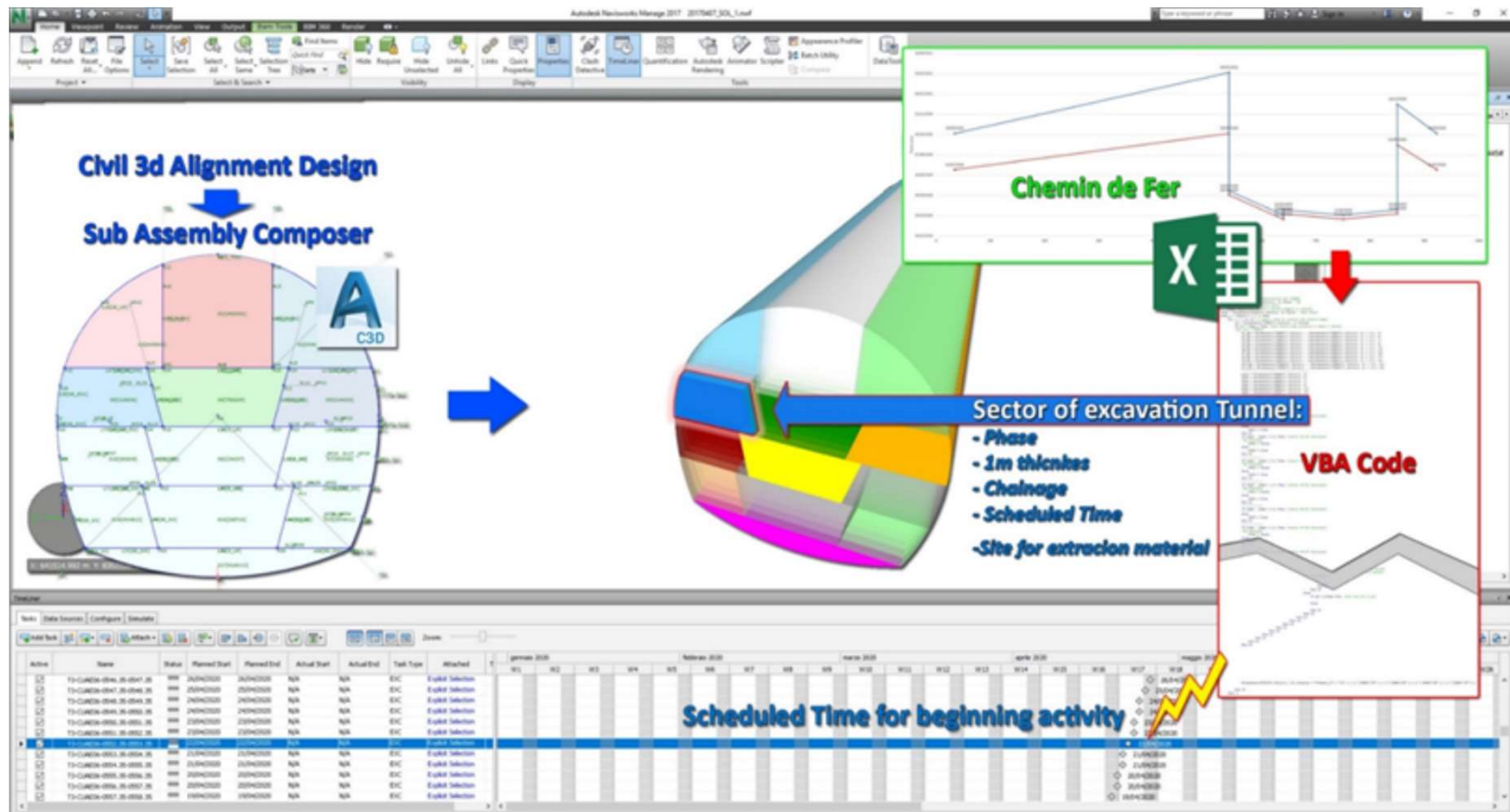
By specific parameters applied to families and materials, it was possible to **link Revit's internal materials to the technical specifications and unit prices**, in accordance with the local legislation, through an exchange of information with the company, which periodically updated the BoQ.

Architectural and functional design



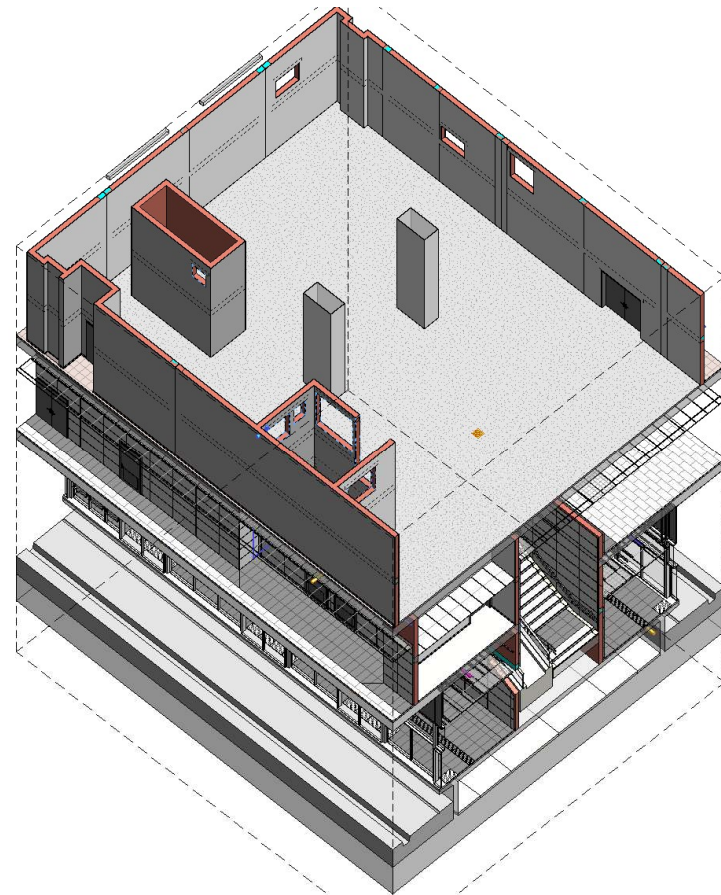
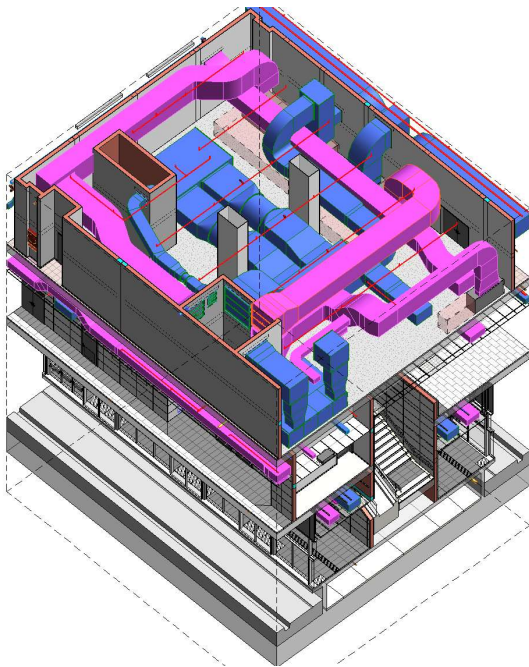
This procedure of parameterization and population of the families has been adopted also for writing the **WBS codes** useful for the **management of 4D and 5D**, developed in a post-modelling phase using **Navisworks**

4D and 5D simulations

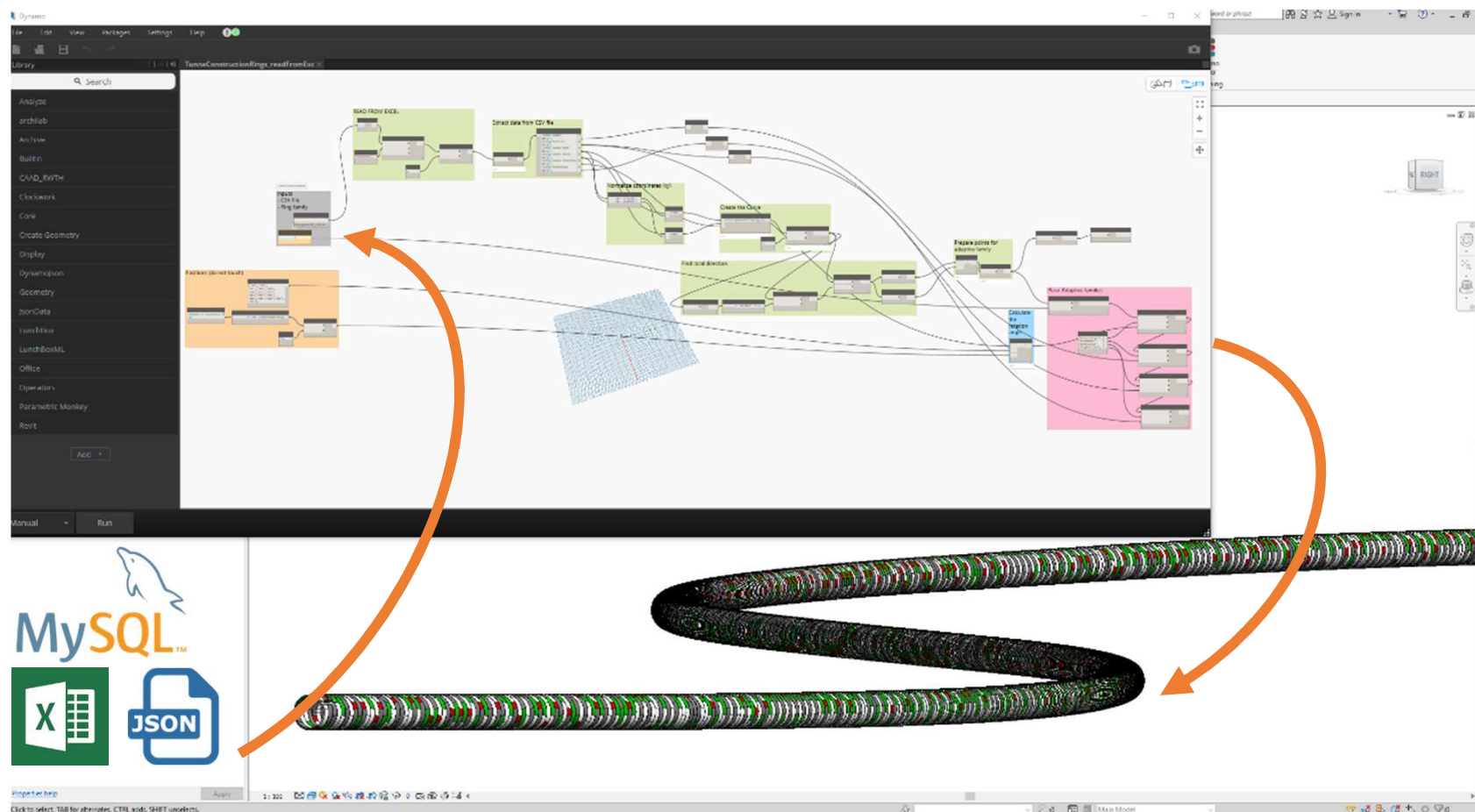


Revit MEP, clash detection and openings

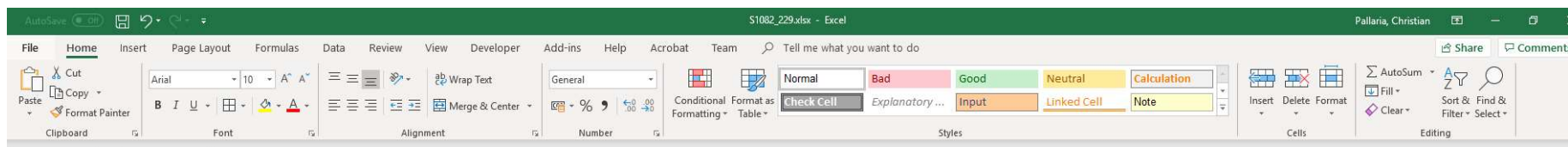
Use of specific Add In for realizing cut
Add In didn't work properly we also u
opening



Modelling TBM tunnels



Modelling TBM tunnels



Ring Number	Date and time (Ring selection)	Ring	Ring center EAST value [m]	Ring center NORTH value [m]	Ring center HEIGHT value [m]	Ring center Stationing [m]
1	23.05.2018 18:27:10	U13	400217,058	4568159,562	51,136	27941,38
2	24.05.2018 07:00:38	U08	400218,015	4568158,407	51,147	27939,88
3	24.05.2018 15:09:40	U13	400219,004	4568157,270	51,144	27938,37
4	24.05.2018 22:14:33	U15	400220,011	4568156,157	51,185	27936,87
5	26.05.2018 15:53:50	U10	400221,019	4568155,044	51,181	27935,37
6	26.05.2018 23:44:07	U05	400222,031	4568153,936	51,197	27933,87
7	27.05.2018 06:28:25	U07	400223,026	4568152,809	51,206	27932,37
8	28.05.2018 16:17:58	U12	400224,026	4568151,695	51,200	27930,87
9	29.05.2018 03:52:33	U04	400225,026	4568150,579	51,204	27929,37
10	29.05.2018 11:37:20	U09	400226,022	4568149,456	51,188	27927,87
11	29.05.2018 18:07:55	U01	400227,012	4568148,326	51,178	27926,37
25	24 01.06.2018 22:27:04	U01	400239,920	4568133,675	51,182	27906,84
26	25 02.06.2018 02:53:39	U09	400240,913	4568132,553	51,186	27905,35
27	26 02.06.2018 06:28:20	U14	400241,858	4568131,384	51,201	27903,84
28	27 02.06.2018 11:01:49	U06	400242,887	4568130,287	51,180	27902,34
29	28 02.06.2018 14:57:09	U01	400243,863	4568129,142	51,187	27900,83
30	29 03.06.2018 23:04:20	U09	400244,832	4568128,035	51,191	27899,36
31	30 04.06.2018 02:01:08	U14	400245,855	4568126,897	51,186	27897,83
32	31 04.06.2018 05:31:47	U16	400246,835	4568125,812	51,199	27896,37
33	32 04.06.2018 09:45:40	U05	400247,870	4568124,667	51,210	27894,83
34	33 04.06.2018 13:34:03	U10	400248,870	4568123,547	51,212	27893,33
35	34 04.06.2018 16:14:56	U08	400249,866	4568122,454	51,210	27891,85

Modelling TBM tunnels

Properties

GD_3339TBM_Ring

Generic Models (1) Edit Type

Construction

InstallationDate	23/05/2018 18:27:10
RingNumber	178
SegmentPosition	U16
Stationing (m)	27941
Damage_SegmentA	RE+RE
Damage_SegmentB	
Damage_SegmentC	
Damage_SegmentD	RB
Damage_SegmentE	
NumberOfDamagesPerRing	3
HorizontalDeviation (mm)	14
VerticalDeviation (mm)	-43

Dimensions

PositionAngle	247.50°
Volume	

Identity Data

Image	
Comments	
Mark	

Phasing

Phase Created	New Construction
Phase Demolished	None

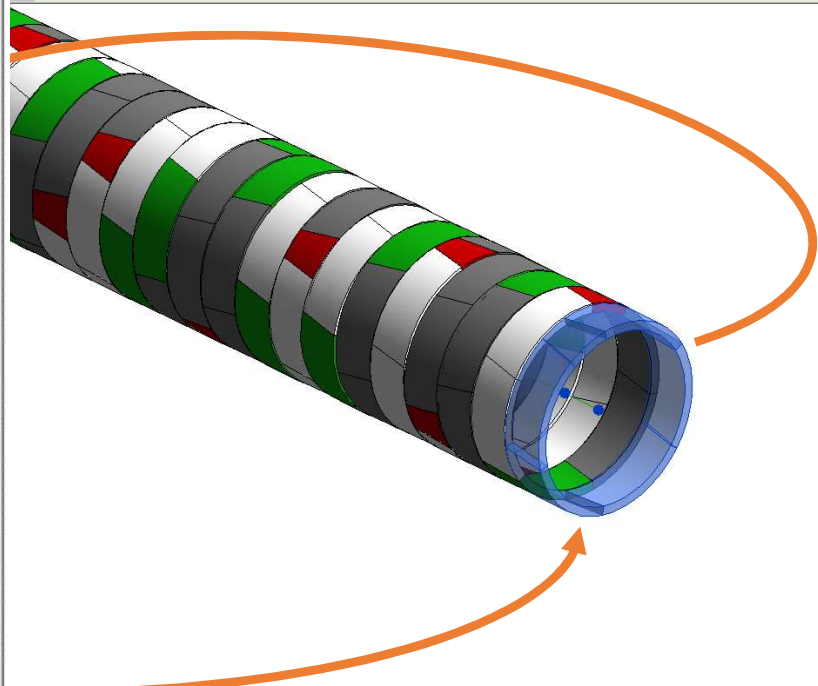
Adaptive Component

Flip	☐
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[Properties help](#) Apply

Autodesk Revit 2018 - Dynamo_TBM.rvt - 3D View: (3D)

Tools: View, Measure, Create, Mode, Host, Model

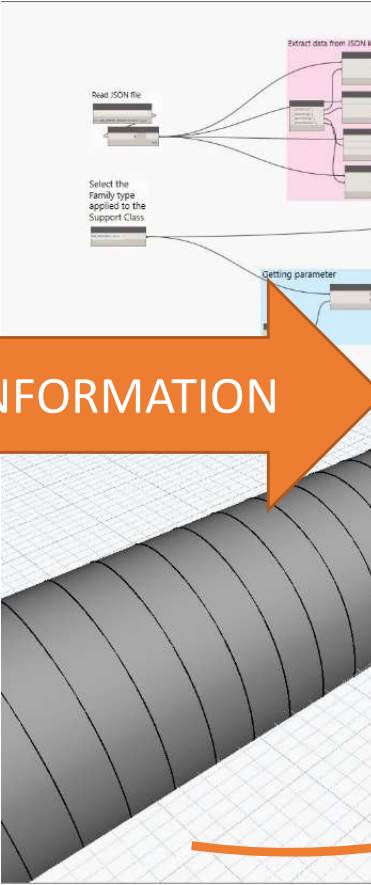


1:100

Main Model

Modelling NATM tunnels

INFORMATION



Read JSON file

Select the Family type applied to the Support Class

Extract data from JSON

Getting parameter

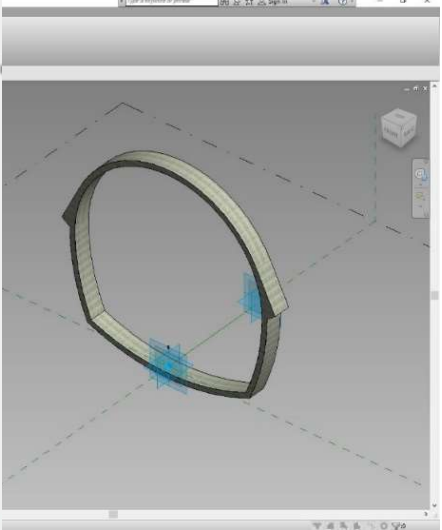
Tipi di famiglia

Nome del tipo: PW3_15cm

Parametri di ricerca

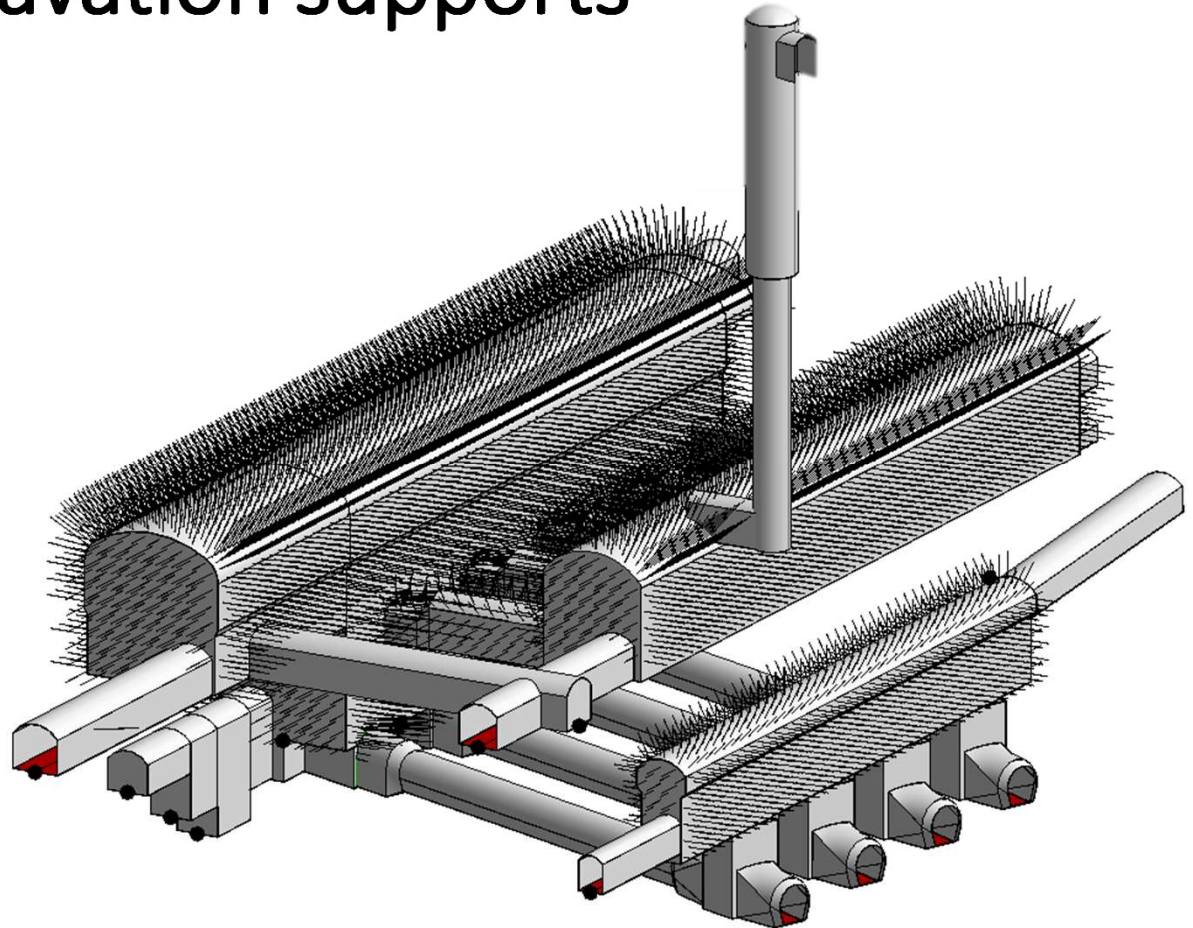
Parametro	Valore	Formula	Blocca
Costruzione			
GD_LongSpacing (default)	2.0000	=	☐
Materiali e finiture			
GD_Material	Concrete, Cast-in-Place, Gray	=	
Dati			
GD_STD_NumberOfElement	16	=	☐
GD_STR_NumberOfElement	0	=	☐
GD_TEI_ElementVolume	0.000000	=	
GD_WIM_ElementArea	0.000000	=	
Visibilità			
GD_ProfileSelector<Modelli gene	PRF_PW3	=	
Dati identità			
GD_CreatedBy	Alberto Bolzonello	= "Alberto Bolzonello"	
GD_ElementDescription	SHC: SFR40 - 15cm THICK	=	
Immagine tipo		=	
Nota chiave		=	
Modello	RCK	= "RCK"	
Produttore	Geodata Engineering	= "Geodata Engineering"	
Commenti sul tipo	SHC(T826.2) + STD(I62.1)	=	
URL		=	
Descrizione		=	
Codice assieme		=	
Costo		=	





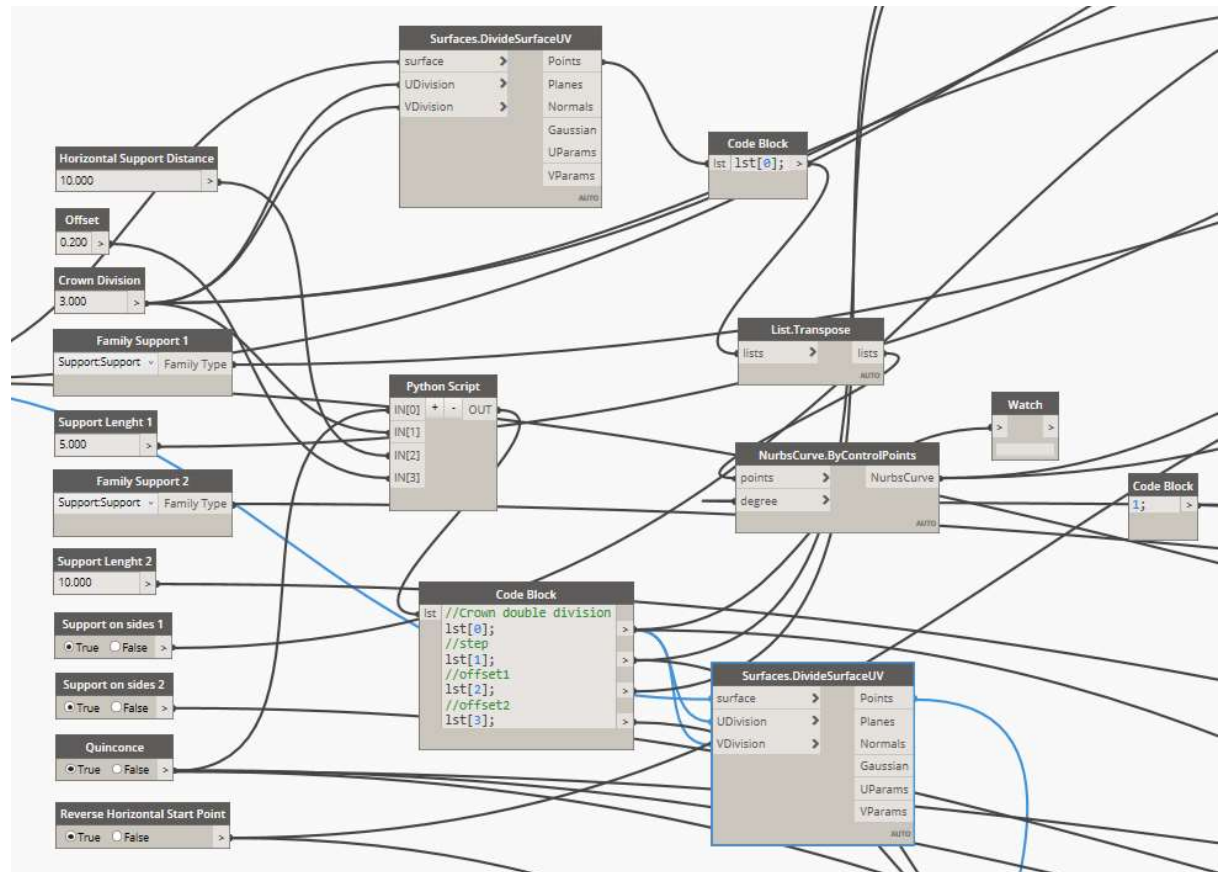
Modelling of excavation supports

- Dynamo has been used also for modelling of supports
- Clicking the surface, defining input data, supports were modelled automatically

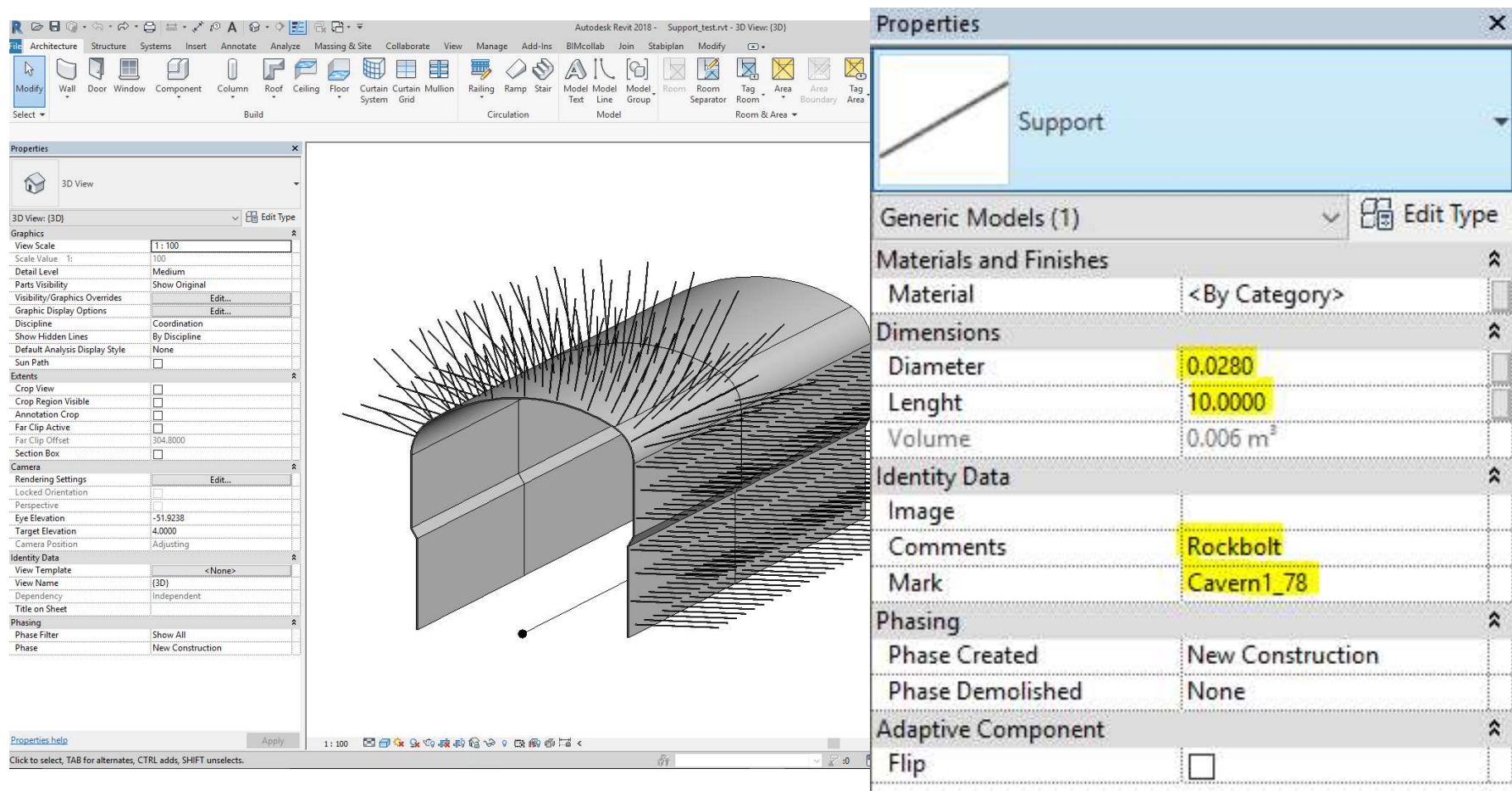


Modelling of excavation supports

- The code allows to control:
 - Initial offset of the starting point;
 - X support distance
 - Y support distance
 - Support length
 - Support radius
 - Support material and tipology
 - Set the type of support disposition (quinconce or normal)



Modelling of excavation supports



The screenshot displays the Autodesk Revit 2018 interface. The central 3D View shows a cross-section of an excavation with a sloped wall and a series of vertical supports (rockbolts) installed into the soil. The Properties panel on the right is open, showing the 'Support' element selected. The panel includes a 'Generic Models (1)' section with an 'Edit Type' button. Below this, the 'Materials and Finishes' section shows the material set to '<By Category>'. The 'Dimensions' section lists the following properties:

Property	Value
Diameter	0.0280
Length	10.0000
Volume	0.006 m ³

The 'Identity Data' section includes the following properties:

Property	Value
Image	
Comments	Rockbolt
Mark	Cavern1_78

The 'Phasing' section shows the following properties:

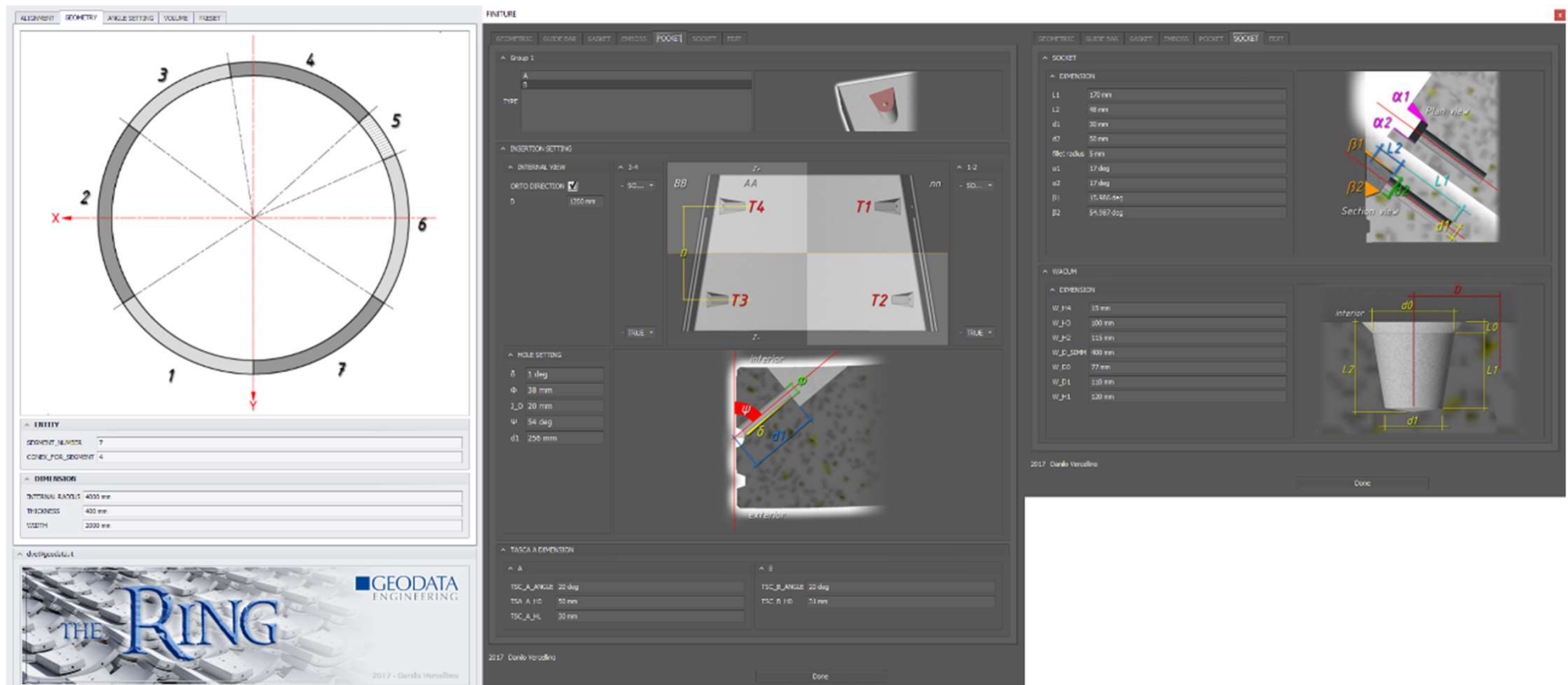
Property	Value
Phase Created	New Construction
Phase Demolished	None

The 'Adaptive Component' section shows the following property:

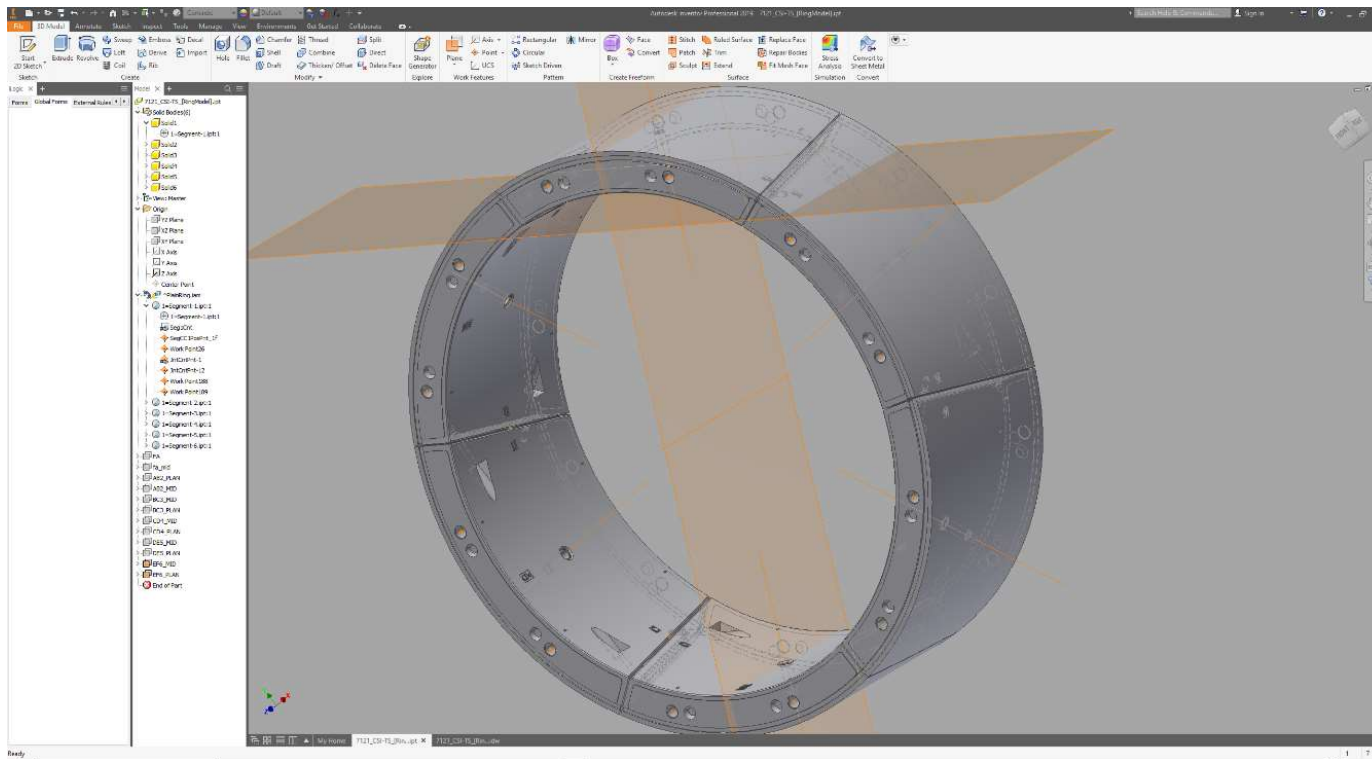
Property	Value
Flip	☐

The left Properties panel shows the '3D View' settings, including View Scale (1:100), Scale Value (100), Detail Level (Medium), and various visibility and rendering options.

Design TBM segments

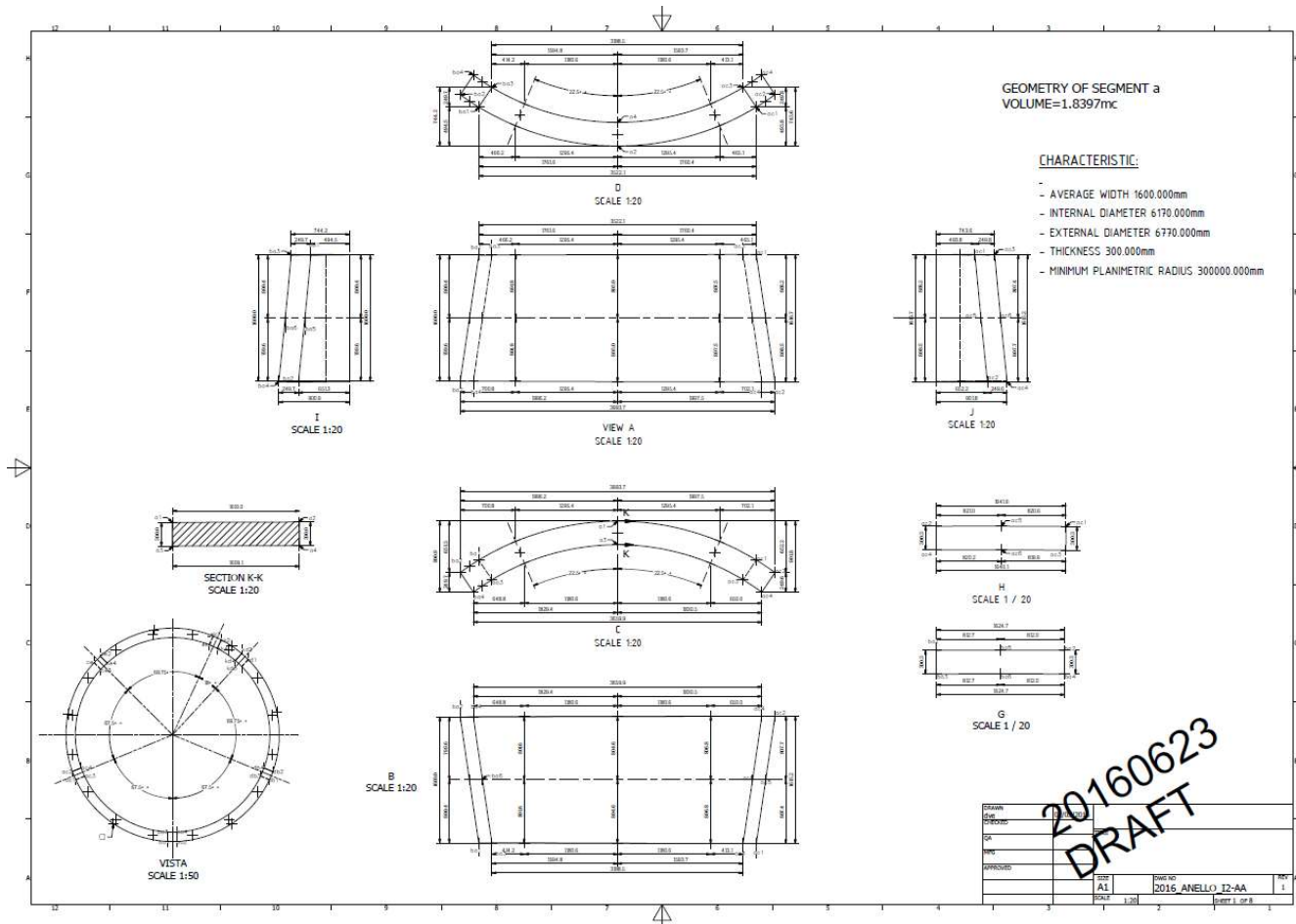


Design TBM segments



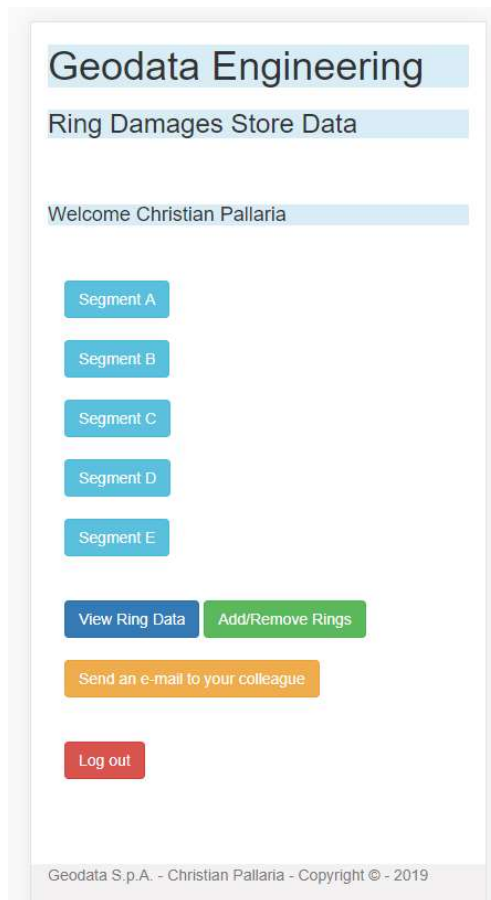
Parameter Name	Unit/Type	Equation	Nominal Value	Tol.	Model Value	Key	Comment
User Parameters							
A1_Beta_VIEW	deg	$(\beta_1 + 360) / 2$	324.00000		324.00000		
A1_PLAN_VIEW	deg	β_1	234.00000		234.00000		
Alfa_1	deg	0 deg	0.00000		0.00000		Angolo Alfa_taglio_conico_B2-C2
Alfa_2	deg	11 deg	11.00000		11.00000		Angolo Alfa_taglio_conico_C2-D1
Alfa_3	deg	11 deg	11.00000		11.00000		Angolo Alfa_taglio_conico_D1-C1
Alfa_4	deg	0 deg	0.00000		0.00000		Angolo Alfa_taglio_conico_C1-B1
Alfa_5	deg	0 deg	0.00000		0.00000		Angolo Alfa_taglio_conico_C1-A1
Alfa_6	deg	0 deg	0.00000		0.00000		Angolo Alfa_taglio_conico_A1-B2
B1_Beta_VIEW	deg	$(\beta_1 + \beta_2) / 2$	252.00000		252.00000		
B1_PLAN_VIEW	deg	β_1	162.00000		162.00000		
B2_Beta_VIEW	deg	$(\beta_1 + \beta_2) / 2$	36.00000		36.00000		Angolo piano vista conico B2
B2_PLAN_VIEW	deg	β_2	234.00000		234.00000		
Beta_1	deg	72 deg	72.00000		72.00000		Angolo Beta_taglio_conico_B2-C2
Beta_2	deg	133.45 deg	133.45000		133.45000		Angolo Beta_taglio_conico_C2-D1
Beta_3	deg	154.52000	154.52000		154.52000		
Beta_4	deg	216 deg	216.00000		216.00000		Angolo Beta_taglio_conico_C1-B1
Beta_5	deg	288 deg	288.00000		288.00000		Angolo Beta_taglio_conico_B1-A1
Beta_6	deg	0 deg	0.00000		0.00000		Angolo Beta_taglio_conico_A1-B2
C1_Beta_VIEW	deg	$(\beta_1 + \beta_2) / 2$	185.26000		185.26000		
C1_PLAN_VIEW	deg	β_1	95.26000		95.26000		
C2_Beta_VIEW	deg	$(\beta_1 + \beta_2) / 2$	102.74000		102.74000		
C2_PLAN_VIEW	deg	β_2	12.74000		12.74000		
CONC1_RET1	True	True					Angolo Beta_taglio_conico_D1-C1
CONEX_1	deg	18 deg	18.00000		18.00000		
CONEX_10	deg	360 deg	360.00000		360.00000		
CONEX_11	deg	342 deg	342.00000		342.00000		
CONEX_2	deg	54 deg	54.00000		54.00000		
CONEX_3	deg	90 deg	90.00000		90.00000		
CONEX_4	deg	126 deg	126.00000		126.00000		
CONEX_5	deg	144 deg	144.00000		144.00000		
CONEX_6	deg	162 deg	162.00000		162.00000		
CONEX_7	deg	180 deg	180.00000		180.00000		
CONEX_8	deg	234 deg	234.00000		234.00000		
CONEX_9	deg	270 deg	270.00000		270.00000		
D1_Beta_VIEW	deg	$(\beta_1 + \beta_2) / 2$	144.00000		144.00000		
D1_PLAN_VIEW	deg	β_1	54.00000		54.00000		
R64	mm	$2 \cdot d_f \cdot (\beta_1 + \beta_2) / 2$	5460.00000		5460.00000		
R65	deg	18 deg	18.00000		18.00000		
R66	deg	54 deg	54.00000		54.00000		
R67	deg	90 deg	90.00000		90.00000		
R68	deg	126 deg	126.00000		126.00000		
R69	deg	144 deg	144.00000		144.00000		
R70	deg	162 deg	162.00000		162.00000		
R71	deg	180 deg	180.00000		180.00000		
R72	deg	234 deg	234.00000		234.00000		
R73	deg	270 deg	270.00000		270.00000		
R74	deg	306 deg	306.00000		306.00000		
R75	deg	342 deg	342.00000		342.00000		
R76	mm	$2 \cdot d_f \cdot (\beta_1 + \beta_2) / 2$	2555.00000		2555.00000		Raggio interno conico
R77	mm	350 mm	350.00000		350.00000		
Diametro_asse_conex	mm	$2 \cdot d_f \cdot (\beta_1 + \beta_2) / 2$	5460.00000		5460.00000		
L_med	mm	1200 mm	1200.00000		1200.00000		Larghezza media conico
R_curvatura	m	$0.6 \cdot d_f \cdot \beta_1$	240.00000		240.00000		Raggio minimo
R_int	mm	2555 mm	2555.00000		2555.00000		Raggio interno conico
R_ext	mm	350 mm	350.00000		350.00000		Raggio esterno conico
sp_conico	mm	350 mm	350.00000		350.00000		

Design TBM segments



WebApp for TBM Survey

A Web App able to store data about segment damages during excavation, setting the data, time and name of the inspector.



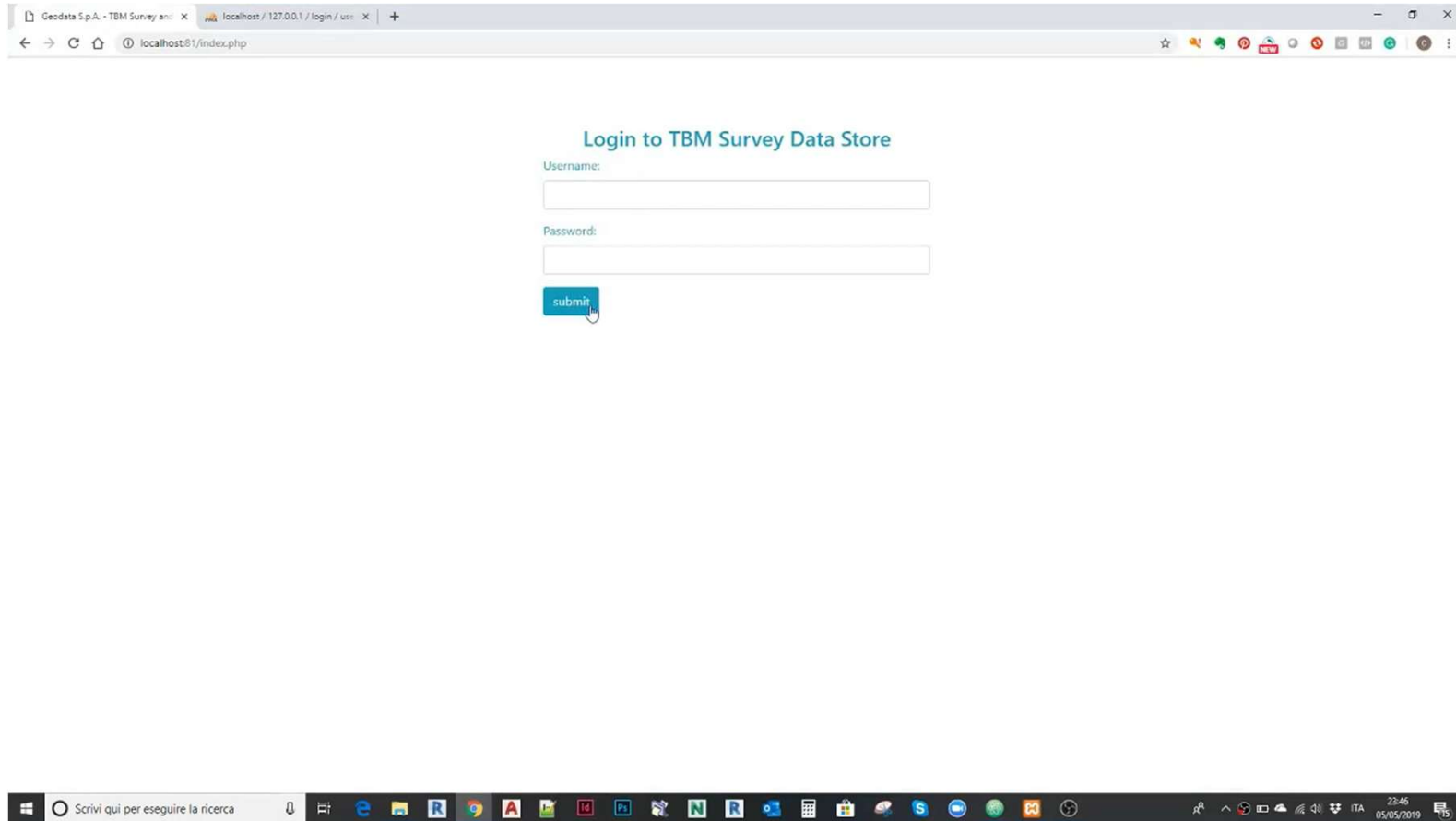
Ring VMT data

Ring Number	Ring Position	Stationing	Installation Date	X	Y	Z	Horizontal Deviation	Vertical Deviation
1	U13	27941,38	23.05.2018 18:27:10	400217,058	4568159,562	51,136	14	-43
2	U08	27939,88	24.05.2018 07:00:38	400218,015	4568158,407	51,147	61	-32
3	U13	27938,37	24.05.2018 15:09:40	400219,004	4568157,270	51,144	71	-35
4	U15	27936,87	24.05.2018 22:14:33	400220,011	4568156,157	51,185	53	6
5	U10	27935,37	26.05.2018 15:53:50	400221,019	4568155,044	51,181	34	2
6	U05	27933,87	26.05.2018 23:44:07	400222,031	4568153,936	51,197	8	18
7	U07	27932,37	27.05.2018 06:28:25	400223,026	4568152,809	51,206	8	27
8	U12	27930,87	28.05.2018 16:17:58	400224,026	4568151,695	51,200	-4	21
9	U04	27929,37	29.05.2018 03:52:33	400225,026	4568150,579	51,204	-15	25
10	U09	27927,87	29.05.2018 11:37:20	400226,022	4568149,456	51,188	-19	9
11	U01	27926,37	29.05.2018 18:07:55	400227,012	4568148,326	51,178	-13	-1
12	U15	27924,88	30.05.2018 00:29:36	400227,996	4568147,209	51,185	-12	6
13	U07	27923,37	30.05.2018 13:47:31	400228,990	4568146,068	51,184	-1	5
14	U15	27921,88	30.05.2018 23:01:06	400229,973	4568144,950	51,195	1	16
15	U07	27920,38	31.05.2018 03:48:31	400230,975	4568143,840	51,193	-16	14
16	U02	27918,88	31.05.2018 10:41:31	400231,977	4568142,714	51,194	-22	15
17	U07	27917,36	31.05.2018 16:49:18	400232,969	4568141,563	51,195	-4	15
18	U12	27915,85	31.05.2018 22:45:46	400233,967	4568140,438	51,186	-7	7
19	U14	27914,35	01.06.2018 02:14:21	400234,960	4568139,308	51,181	-4	2
20	U16	27912,85	01.06.2018 05:59:05	400235,966	4568138,199	51,165	-24	-14
21	U05	27911,36	01.06.2018 10:19:10	400236,961	4568137,095	51,186	-40	7
22	U07	27909,85	01.06.2018 14:18:47	400237,954	4568135,952	51,184	-27	4

WebApp for TBM Survey

 Dynamo

 python™ 



The screenshot shows a web browser window with the address bar displaying 'localhost/127.0.0.1/login/...' and the page URL 'localhost61/index.php'. The page content is a login form titled 'Login to TBM Survey Data Store'. It includes two input fields: 'Username:' and 'Password:'. Below these fields is a blue 'submit' button. The browser's taskbar at the bottom shows various application icons and the system clock indicating 23:46 on 05/05/2019.

Geodsta S.p.A. - TBM Survey and ... localhost / 127.0.0.1 / login / use ... +

localhost61/index.php

Login to TBM Survey Data Store

Username:

Password:

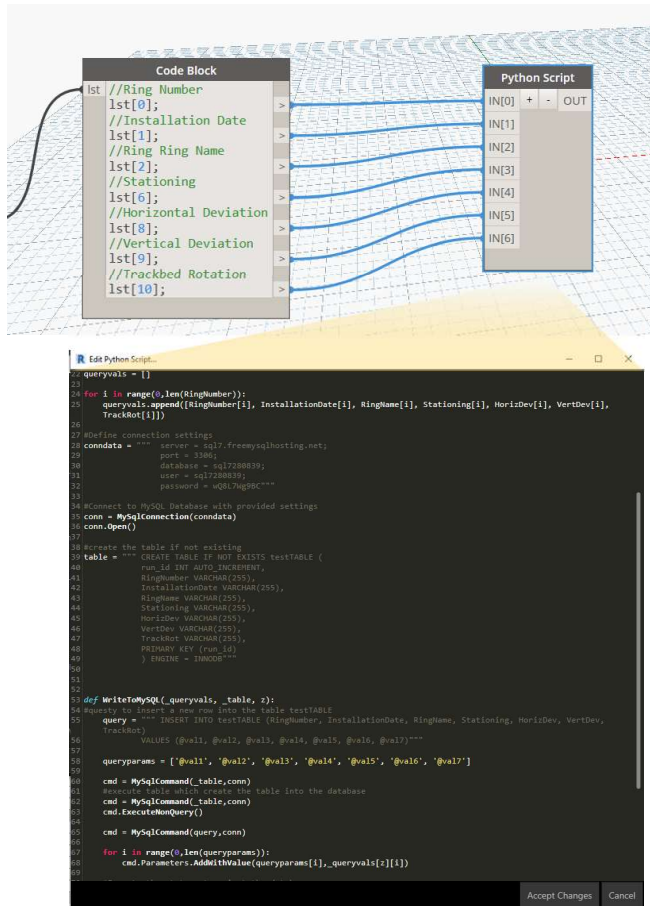
submit

Scrivi qui per eseguire la ricerca

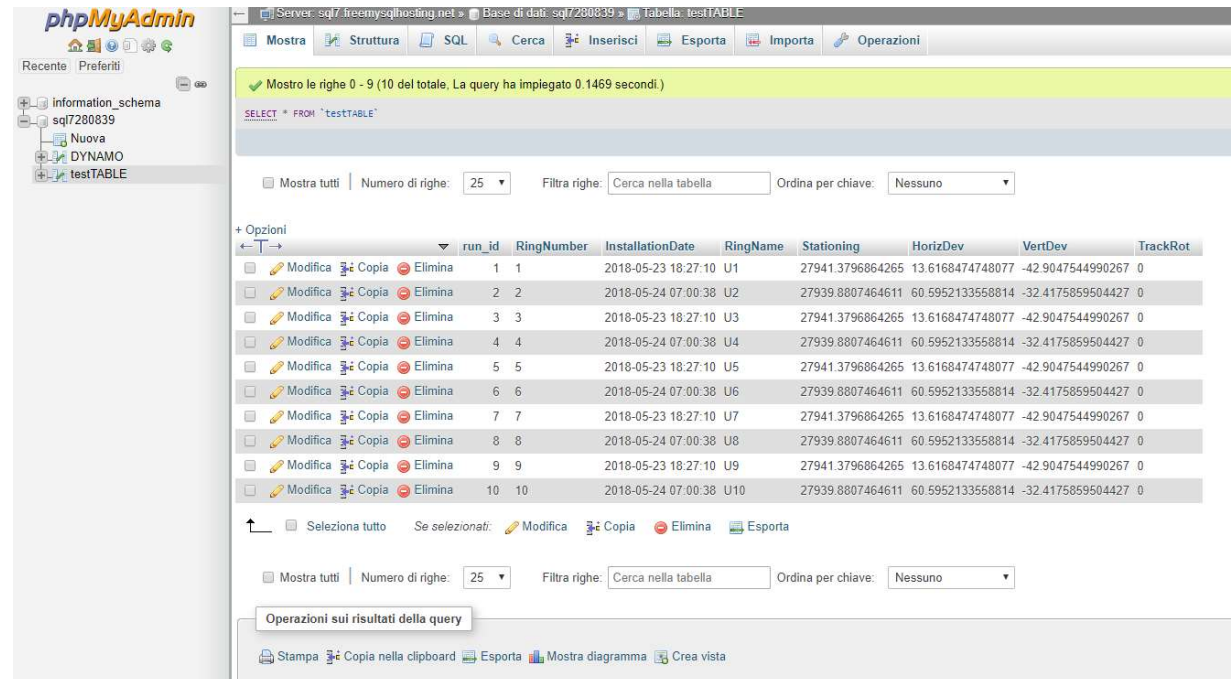
23:46 05/05/2019

Connecting to MySQL DB

Dynamo



While the inspector is storing data, a Dynamo code can connect the model to a MySQL database and read that data, updating the model automatically



TBM Survey workflow

Dynamo

python™ MySQL®

Properties

GD_3339TBM_Ring

Generic Models (1) Edit Type

Construction

InstallationDate	23/05/2018 18:27:10
RingNumber	178
SegmentPosition	U16
Stationing (m)	27941
Damage_SegmentA	RE+RE
Damage_SegmentB	
Damage_SegmentC	
Damage_SegmentD	RB
Damage_SegmentE	
NumberOfDamagesPerRing	3
HorizontalDeviation (mm)	14
VerticalDeviation (mm)	-43

Dimensions

PositionAngle	247.50°
Volume	

Identity Data

Image	
Comments	
Mark	

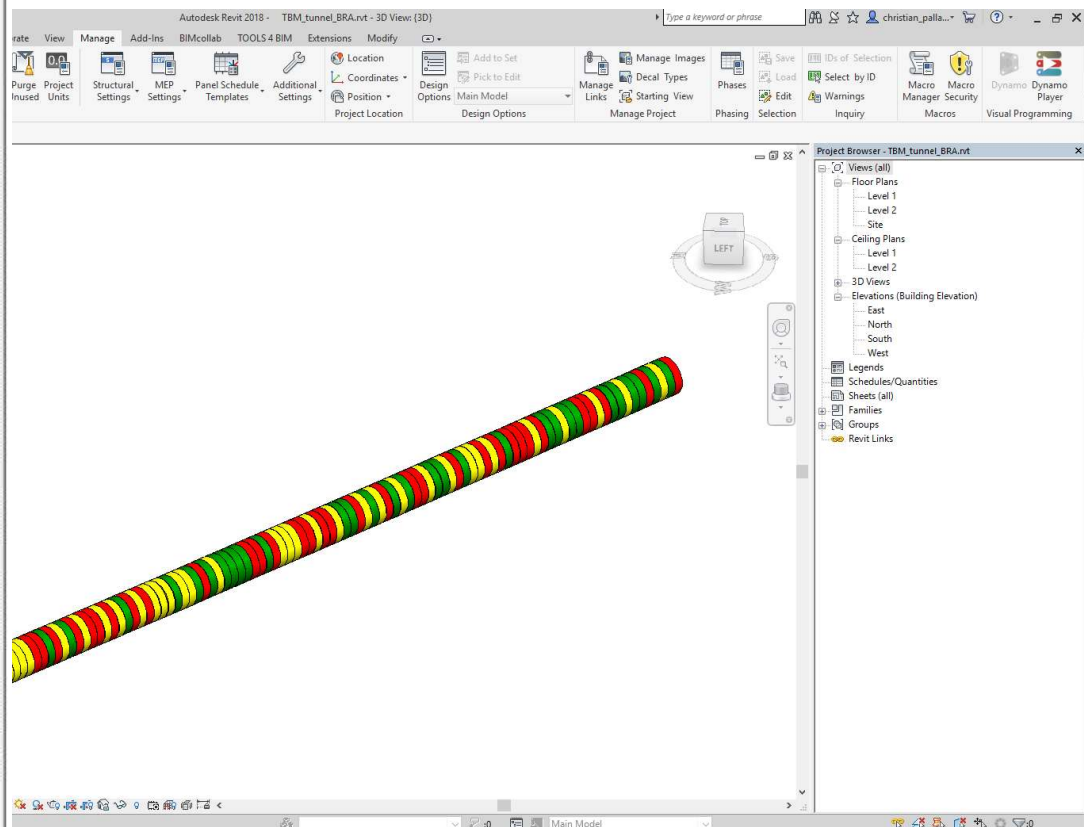
Phasing

Phase Created	New Construction
Phase Demolished	None

Adaptive Component

Flip	☐
------	--------------------------

[Properties help](#) Apply



Try the WebApp



Scan the code
or go to

www.wtc2019.altervista.org

User: wtc2019
Password: wtc2019

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Società Italiana Gallerie
Italian Tunnelling Society



Thank you!

Christian Pallaria



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