



Ontwerp Rottemerentunnel, van aanbiedingsontwerp tot realisatie

Kenneth Wyns – Besix
Project A16 Rotterdam - Ontwerpmanager Deelgebied 2

Project introduction – A16 Rotterdam



Client: Rijkswaterstaat



Consortium De Groene Boog:

BESIX / Dura Vermeer / TBI Mobilis Croon Wolter & Dros / Van Oord / Rebel / John Laing



Construction period: 2019 – 2024 + 20 year maintenance



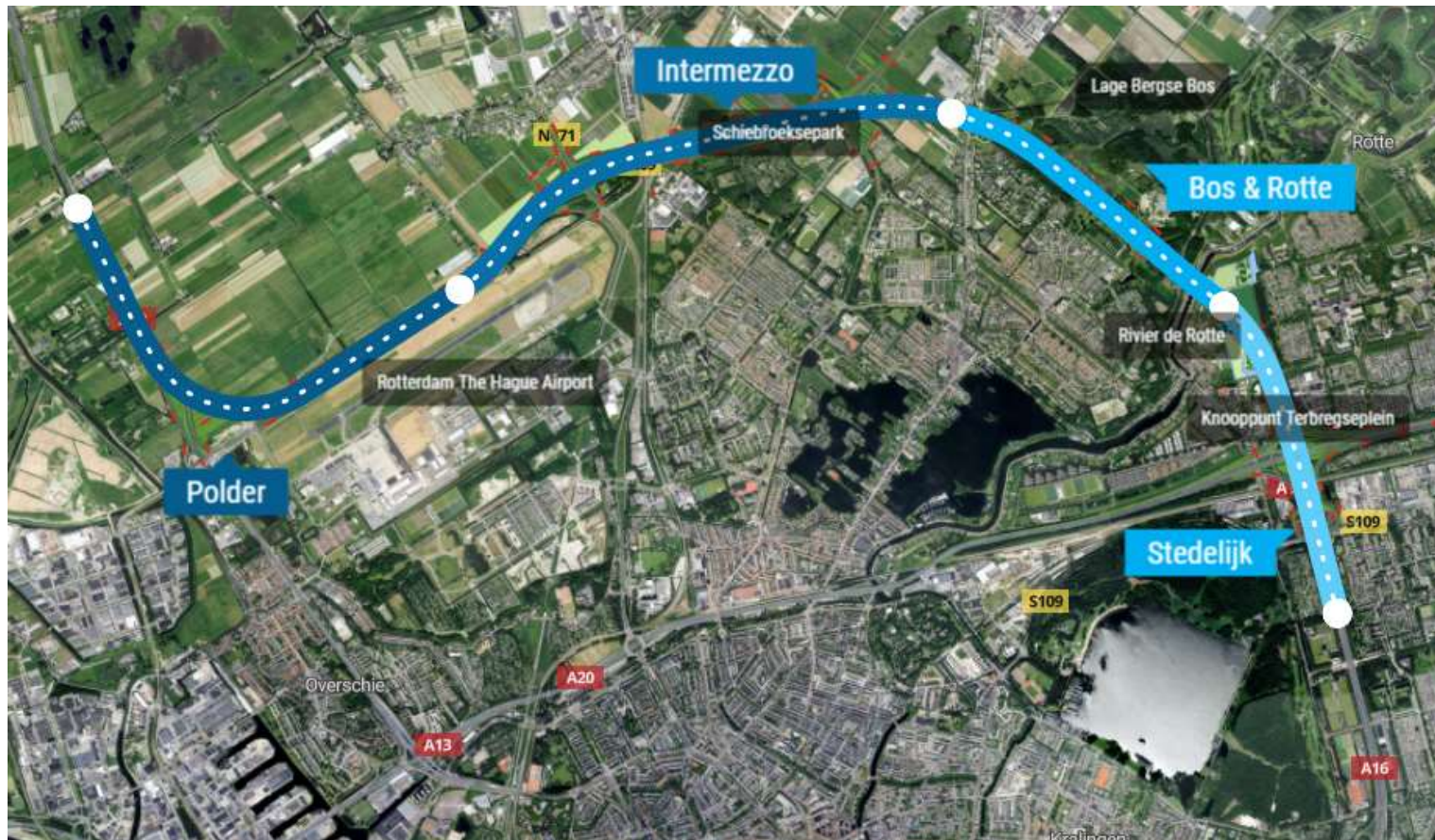
DBFM contract / +- €800 Mio



Project introduction – A16 Rotterdam



Project introduction – A16 Rotterdam



Project introduction – A16 Rotterdam

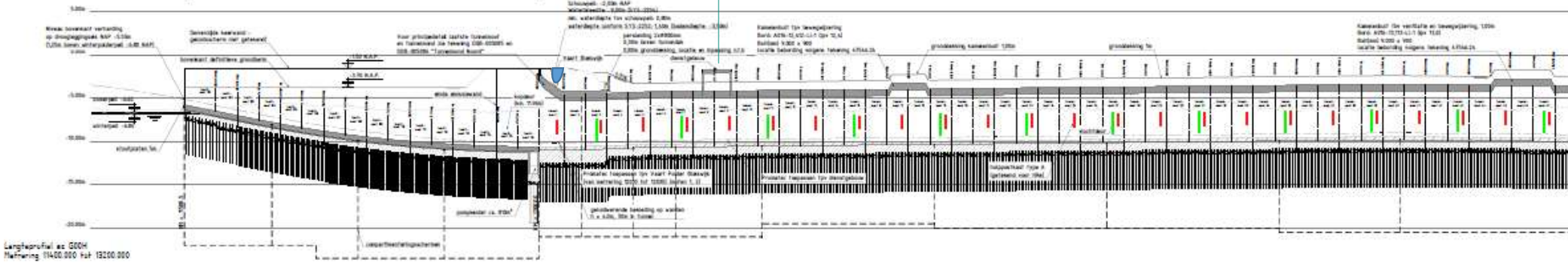


Rottmerentunnel

Dienstgebouw noord

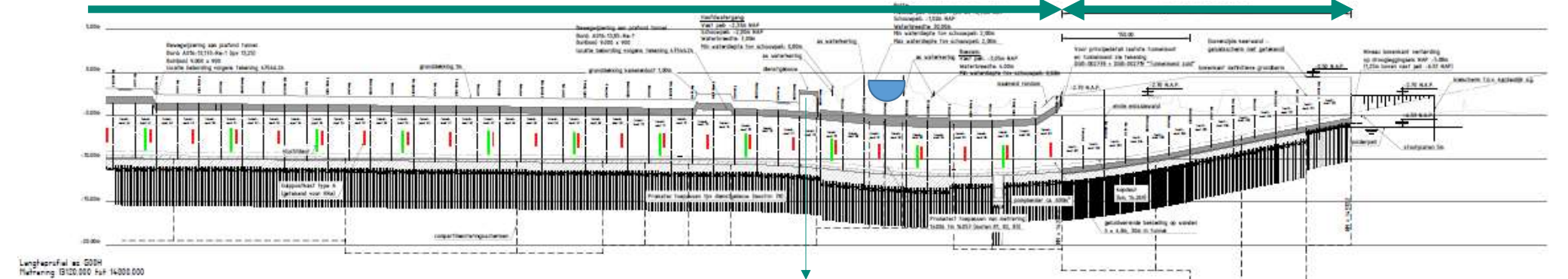
Toerit Noord: 411m

Gesloten gedeelte: 2235m

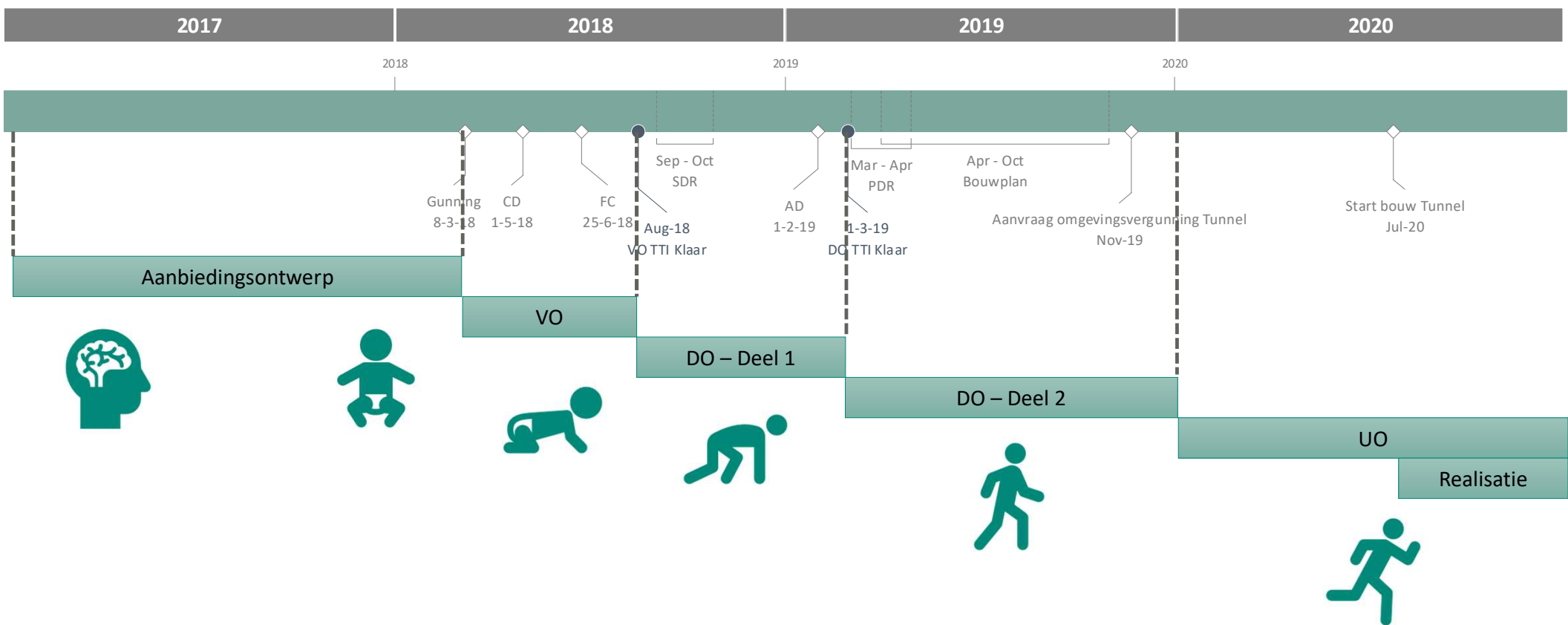


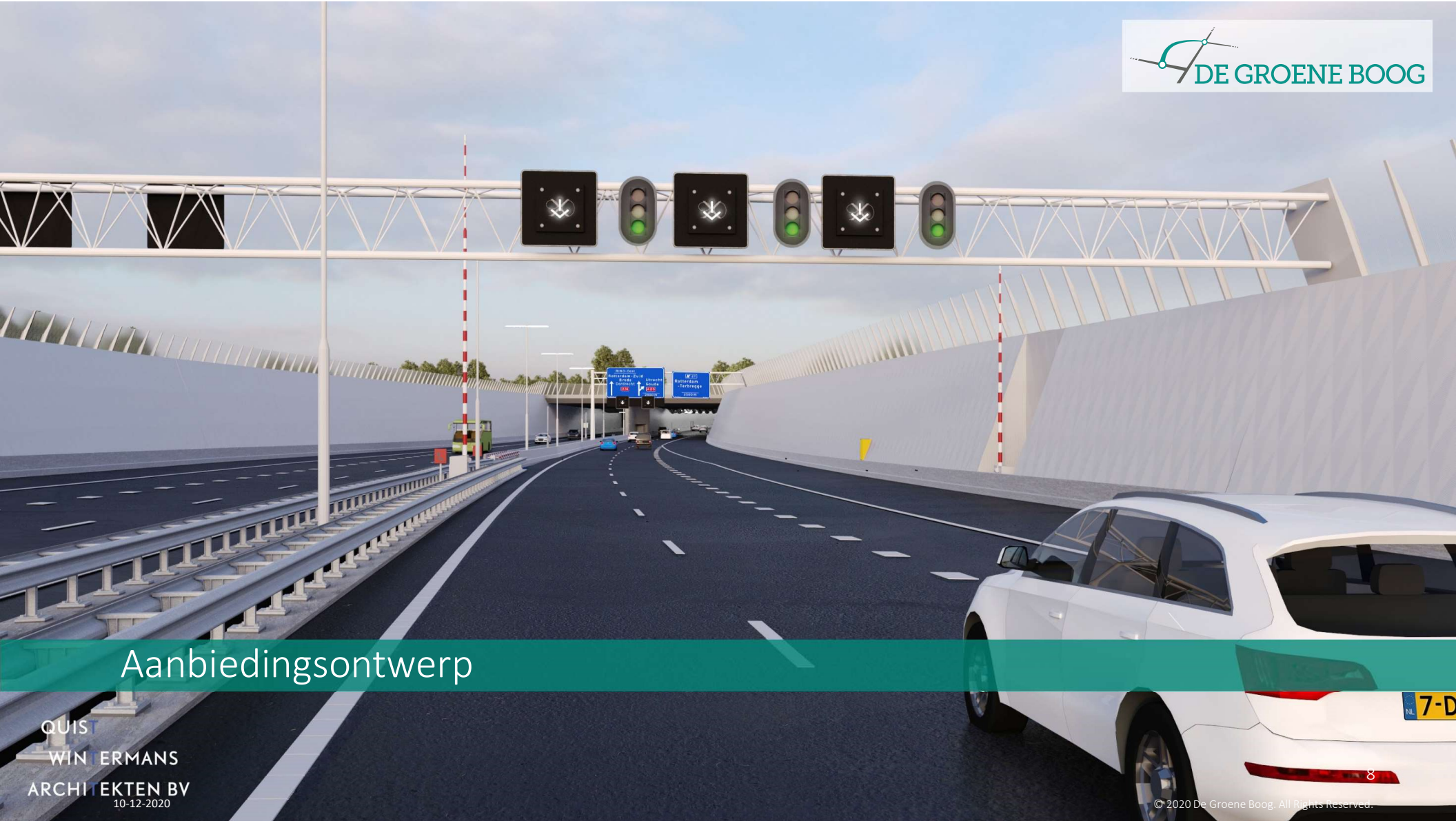
Toerit Zuid: 337m

Dienstgebouw zuid



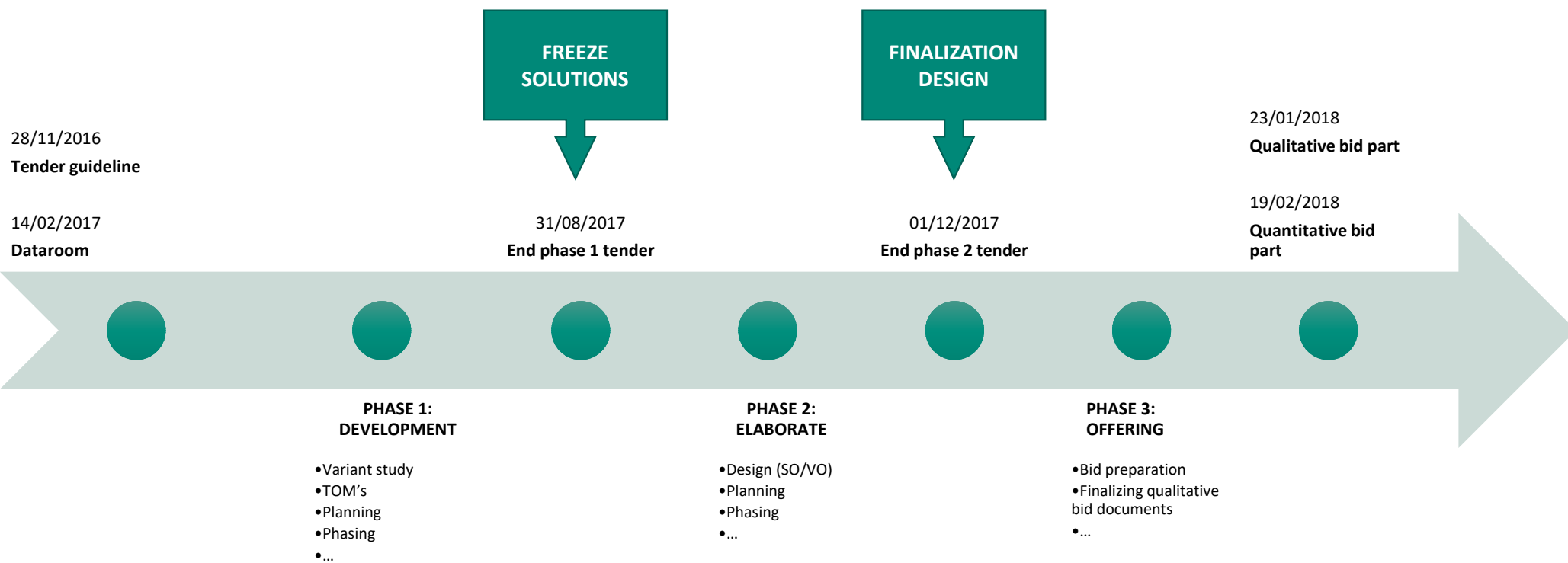
Rottemerentunnel, van aanbiddingsontwerp tot realisatie





Aanbiedingsontwerp

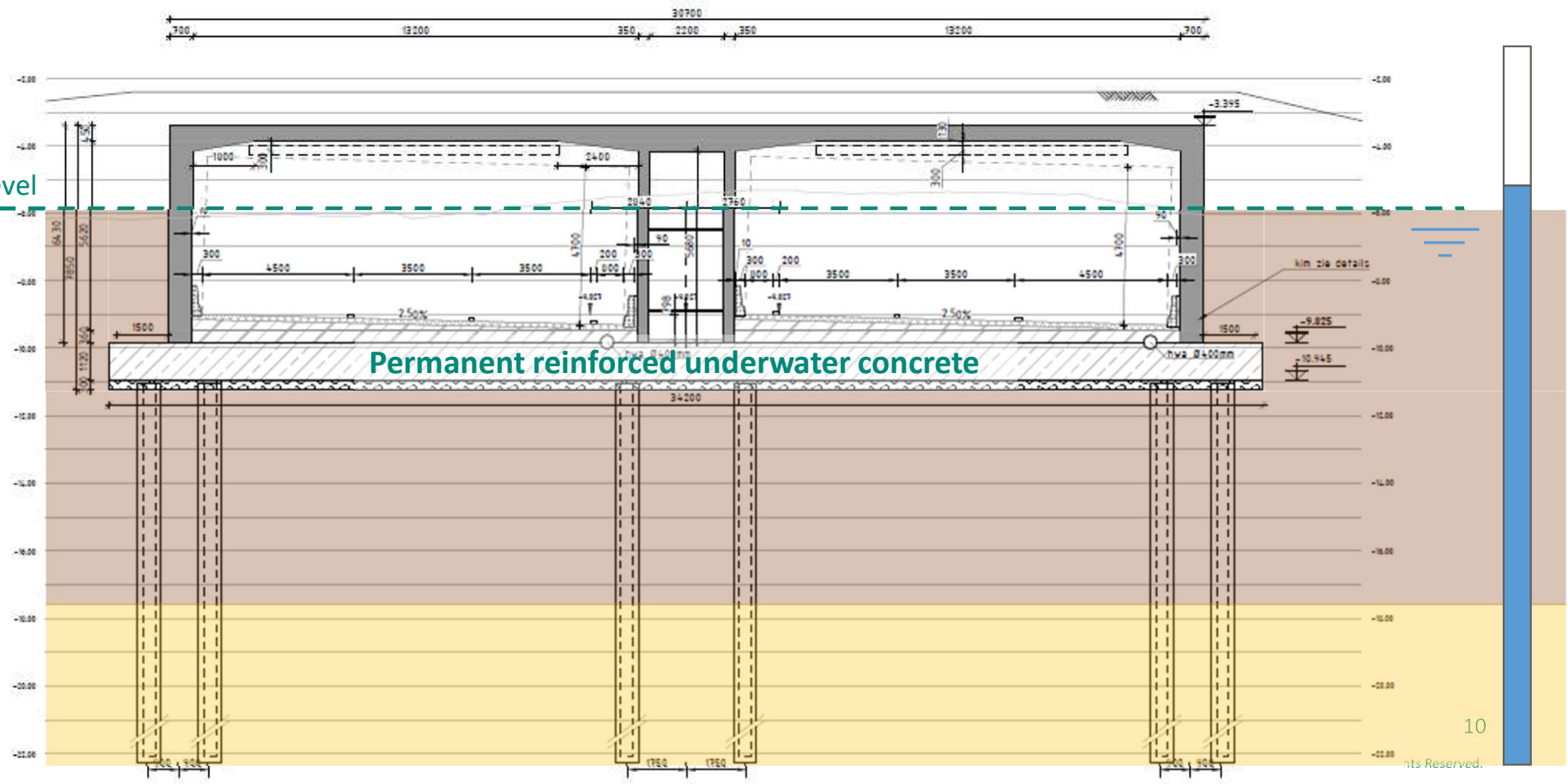
Tender: Planning & Strategy



Tender design

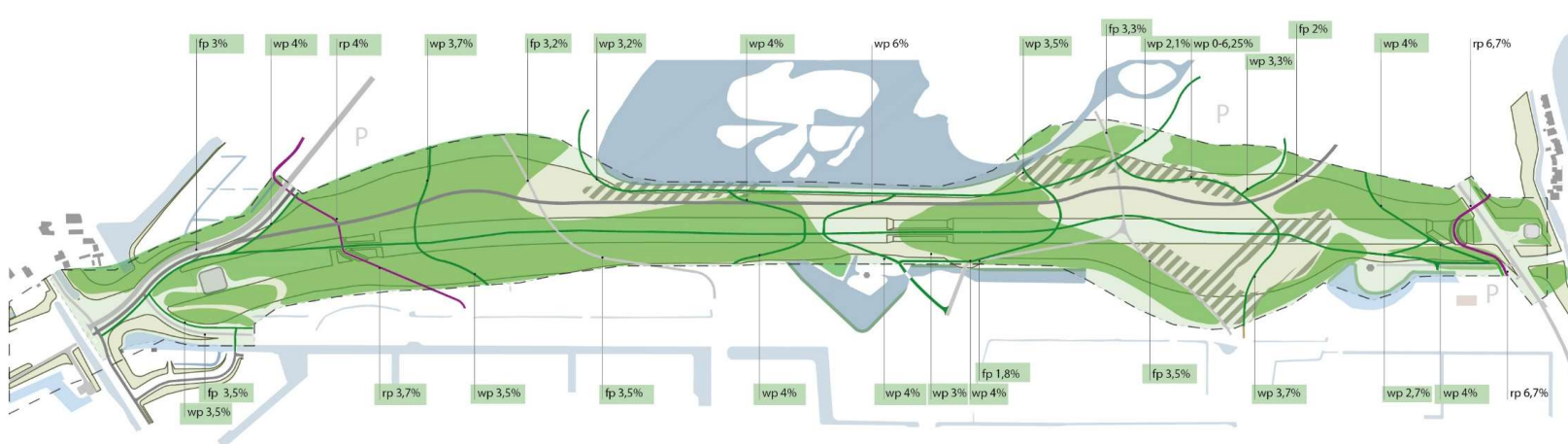
1. Construction method

Natural ground level



Tender design

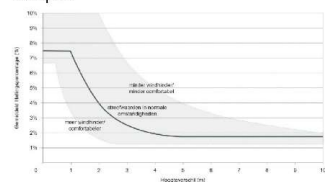
2. Geometry: longitudinal alignment & internal dimensions



CROW richtlijnen

-  ruitepad
 -  fietspad tussen 0%-7%
 -  wandelpad <4%
- Helling berekening
(Hoogte : Lengte) x100 = helling %
- Maximale hoogteverschil: 3,5m

Fietspad



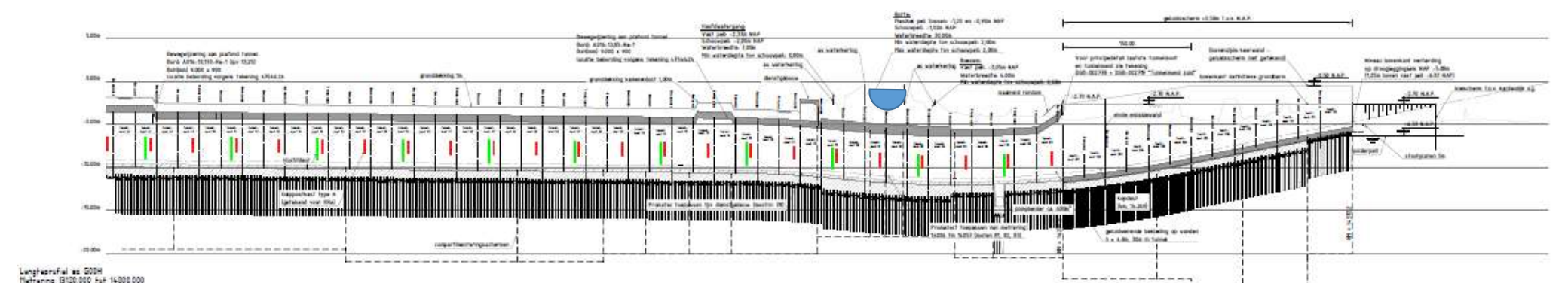
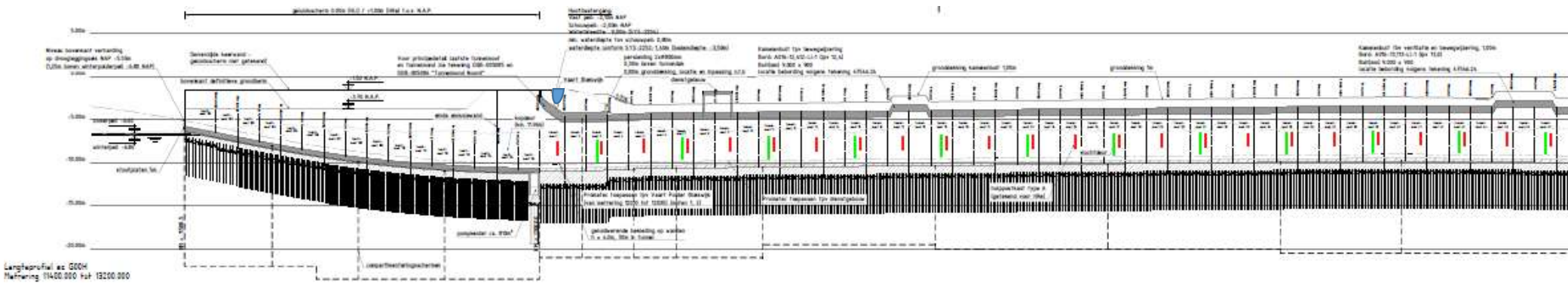
<1m hoogteverschil: advies 7,5%, max 10%
3m hoogteverschil: advies 2,5%, max 7%

Wandelpad

- Hoogteverschil >1m: helling 1:25max (4%) (helling flauwer dan 1:25 worden benoemd als "vals plat", vlakke voetgangersroute.

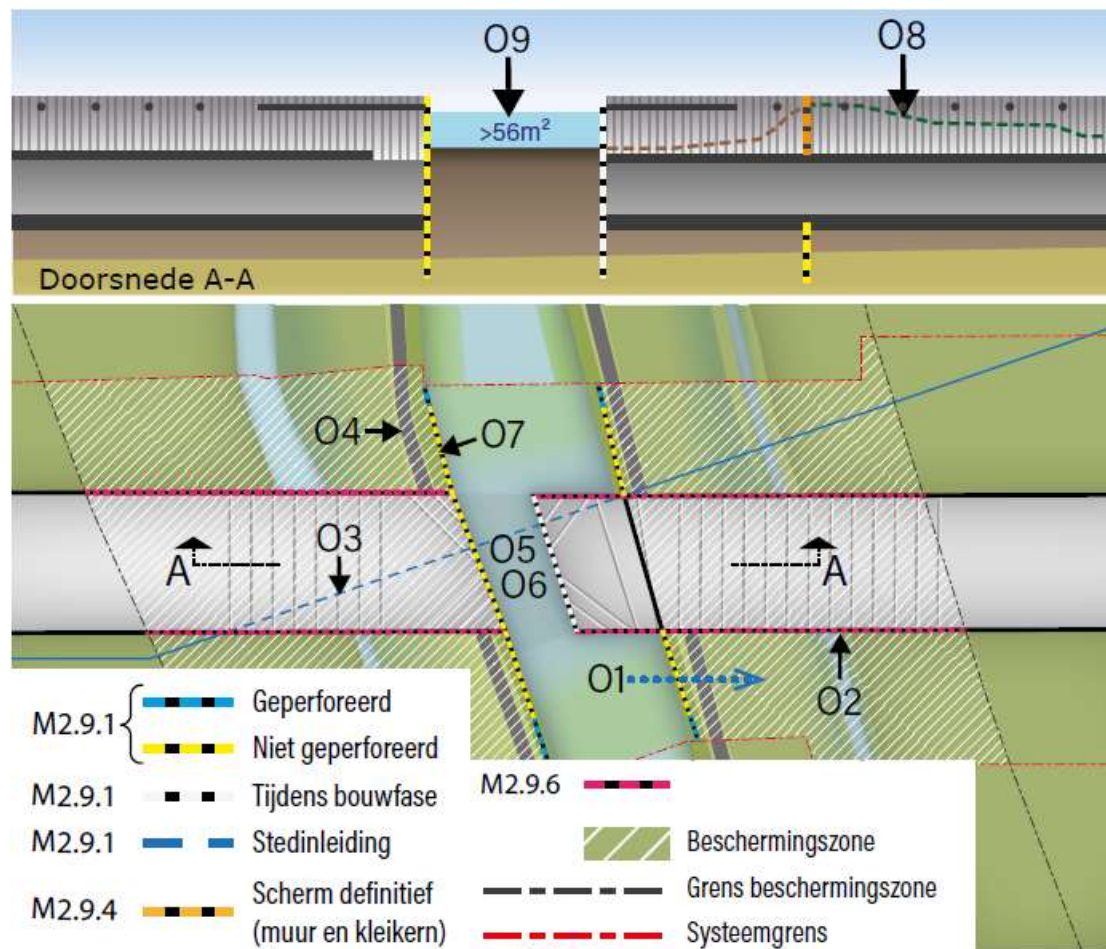
Tender design

2. Geometry: longitudinal alignment & internal dimensions



Tender design

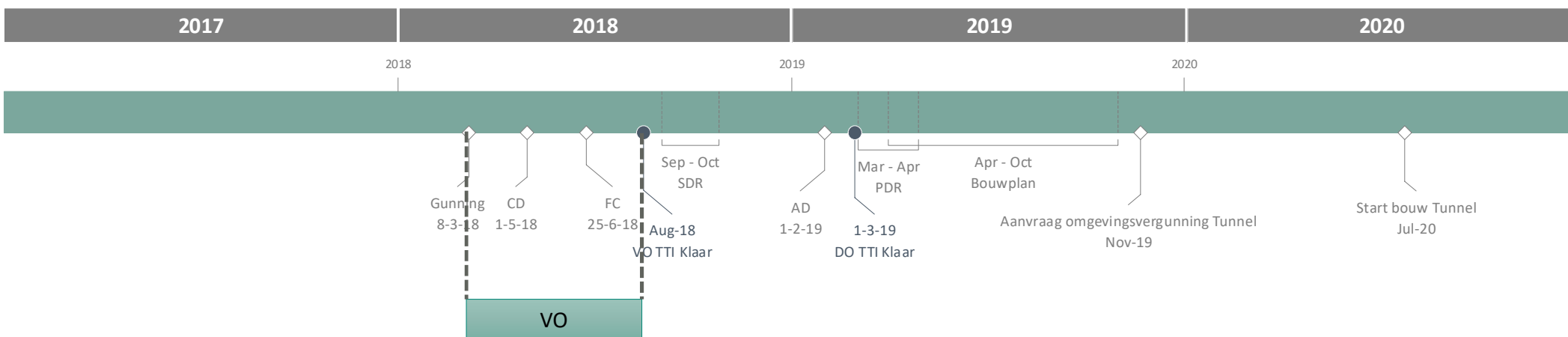
3. Crossing Rotte





VO / DO / UO

Voorontwerp



1. Scrum sessions and thematic sessions:

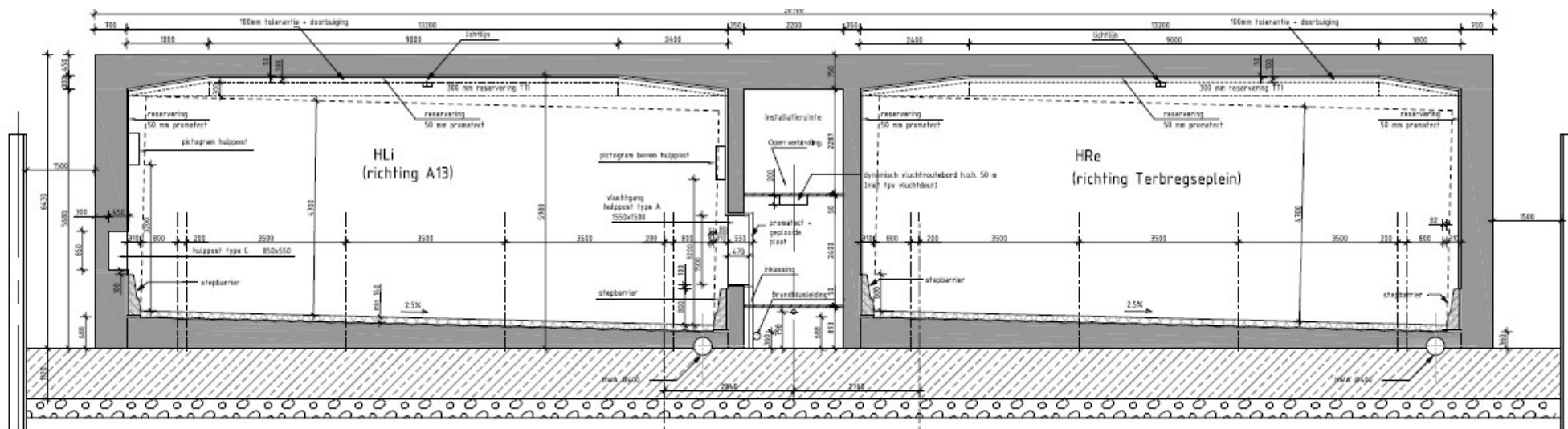
- a. Scrum sessions: Validate client's requirements and agree on verification method
- b. Thematic sessions: Meet stakeholders, validate tender design, create goodwill, collect stakeholders' knowledge and boundary conditions,...

2. Integrated design incorporating procurement, construction, maintenance, safety,...

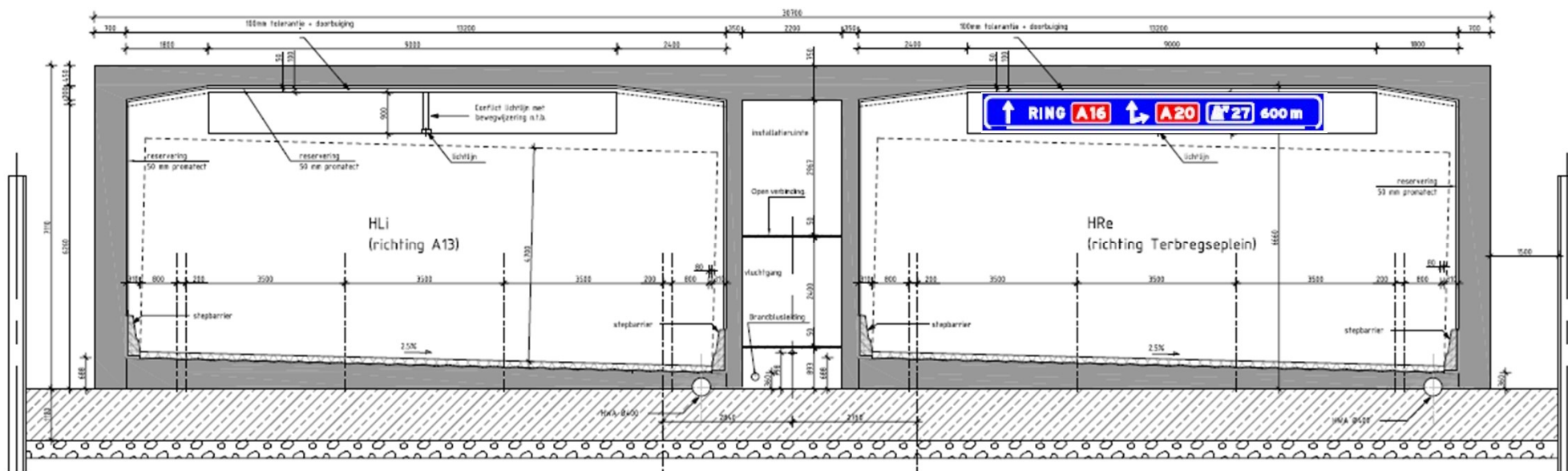
Boundary conditions from procurement, construction, planning, maintenance, safety, ... shall be fixed with each other to serve as starting point for the DO stage.

Road alignment has been frozen.

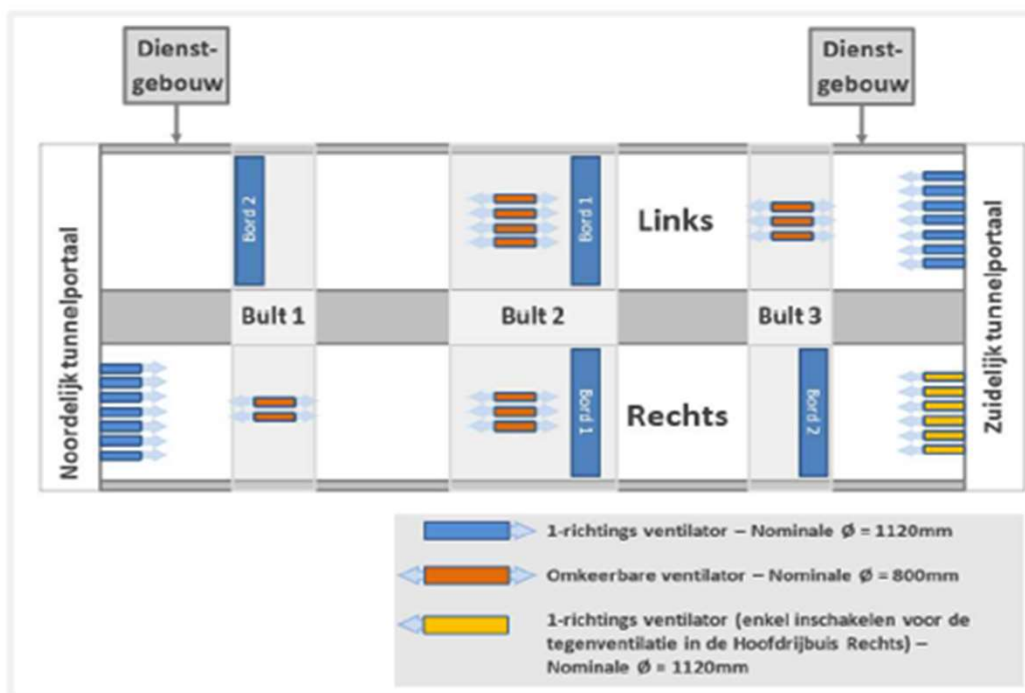
VO – Example of requirement validation



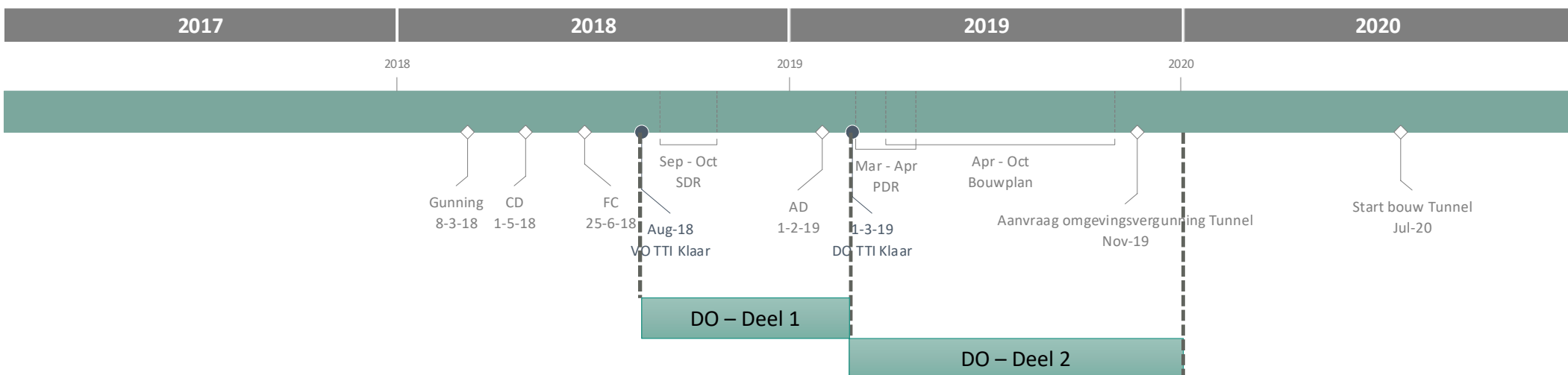
VO – Example of requirement validation



VO – Example of integrated design



Definitief ontwerp



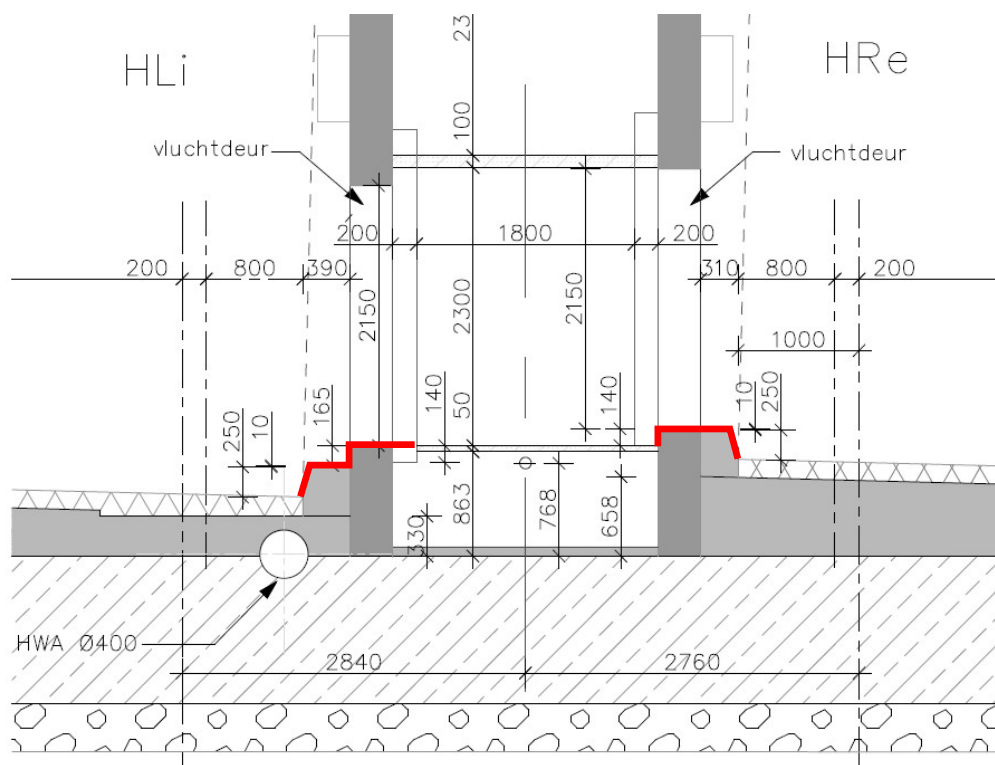
1. DO – Part 1: Multidisciplinary geometrical coordination + requirement verification

At the end of the DO part 1, the whole functional geometry is frozen, tolerances are agreed, the calculation basis of design is ready, and requirements are verified as much as possible. These design deliverables serve to proceed with PDR, review by Veiligheidsbeambte, and construction permit.

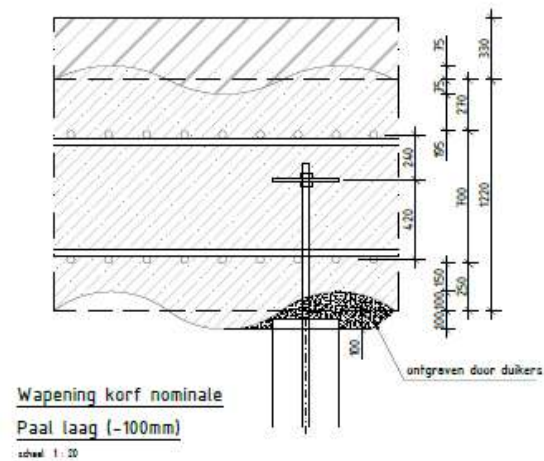
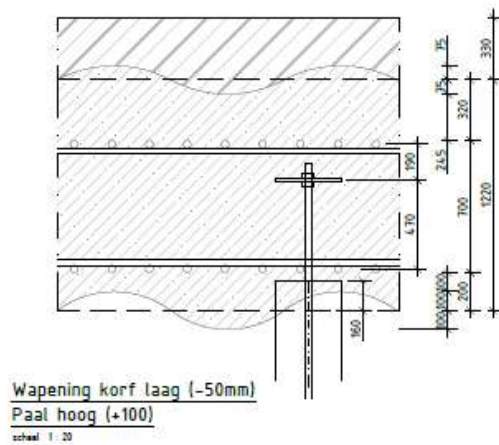
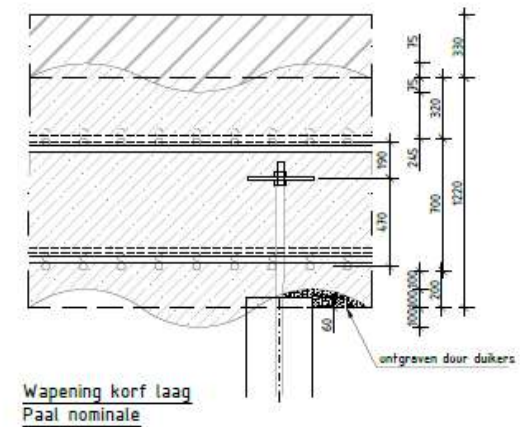
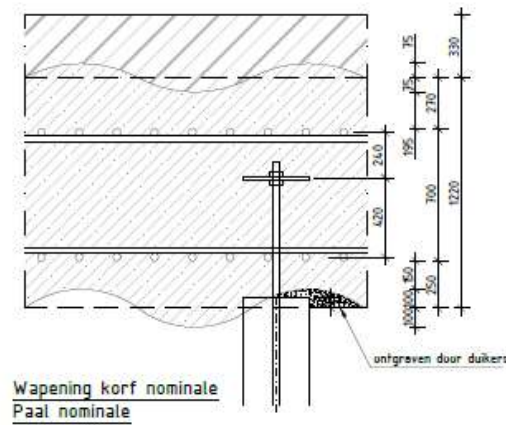
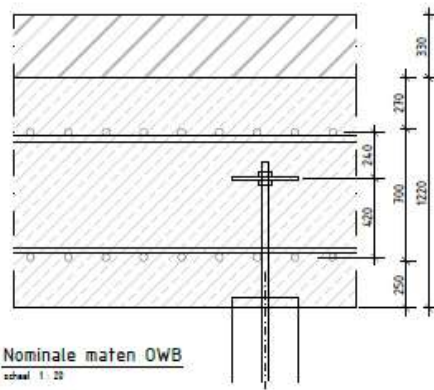
2. DO – Part 2: Calculations + finalisation dimensions

At the end of the DO part 2, all calculations are done and structural dimensions are fixed. Furthermore specifications are generated intended for procurement.

DO – Part 1: Example of geometrical coordination



DO – Part 1: Example of tolerance analysis



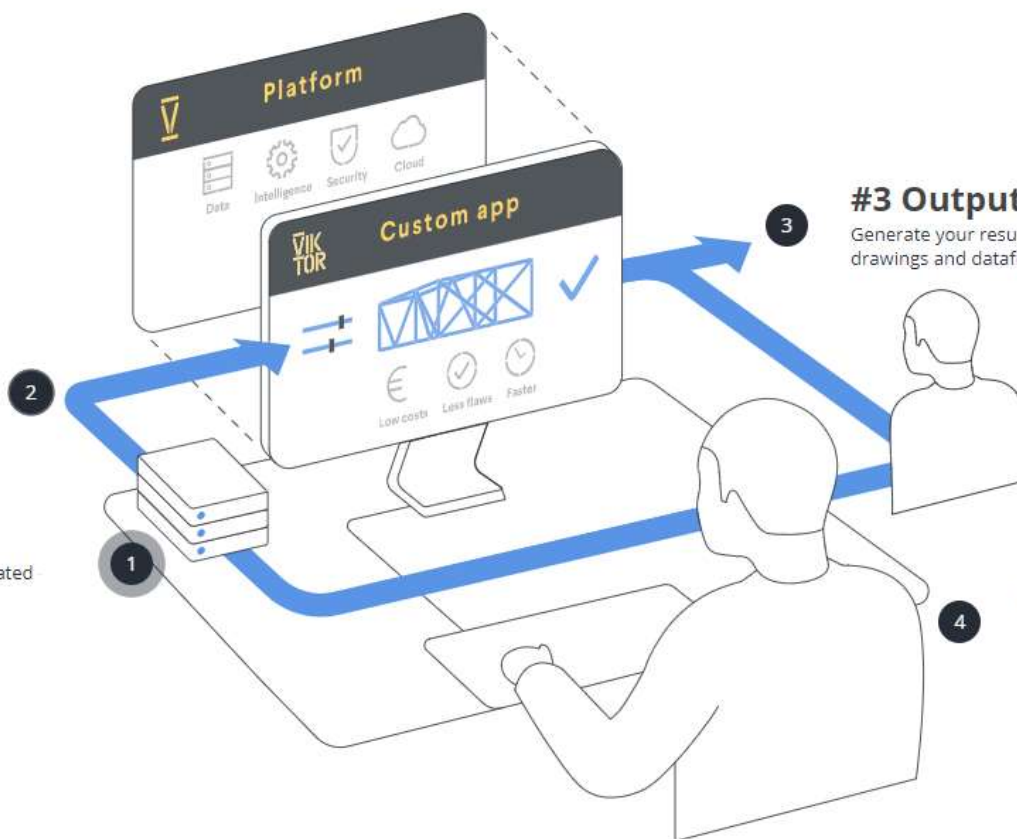
VIKTOR – The first date ...

#2 Input

Easy input of data, rules and requirements by the user or datafiles.

#1 Integrate

All engineering software is integrated within one VIKTOR application.



#3 Output

Generate your results in reports, drawings and datafiles.

#4 Multiple users

Create user groups with tailored access rights

Automation, integration and parametrisation – Why?

- Repetitive sections aren't identical
 - Different depth due to longitudinal alignment of the road
 - Varying geotechnical profile (i.e. subsoil sand dunes)
 - Different swelling pressure after excavation
 - Variable loads on tunnel (i.e. roads vs. sidewalks)
 - Different ground water levels
 - Different preloading time of backfill along tunnel

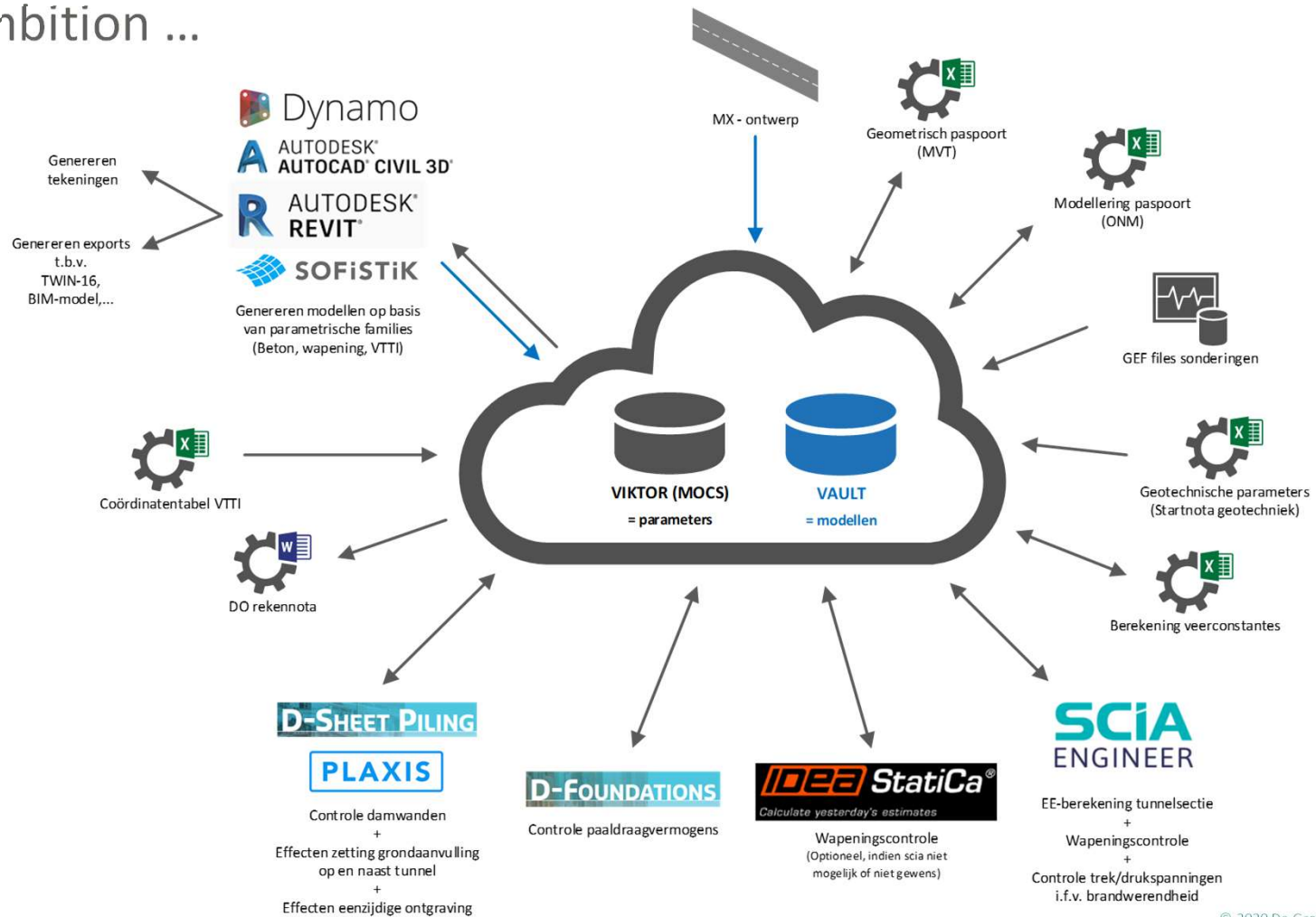
Optimisation:

1. 'Choose' no determining loads to create 'manual' envelope, but run automated calculation of all sections based on correct parametric input
2. Strive for uniform design to serve repetitive execution
BUT: Maybe the overview of U.C.'s shows the advantage of 5 'special' sections to optimise all others


Automation, integration and parametrisation – Why?

- How to find the drivers and sensitivity of the design?
 - Parametric design gives opportunity to easily determine key influencers
- Soil investigation will be available late in time
 - Automated re-run after importing new GEF-files and allocating soil layers
- Manual transfer of output software X as input for software Y
= time consuming and error prone
 - Ideally, calculation and modelling software use the same, centralised information about geometry, soil conditions, concrete cover, reinforcement configuration ...

The ambition ...



Approach

- Partner: 
- Scrum methodology with 2-weekly return period
- Team:
 - BED: Senior designer
 - Prepares all FE modelling and calculations in a 'classic' way
 - Defines the parametric data and decides about 'hard coded' items
 - Makes a functional analysis about the functionalities he wants to have developed
 - VIKTOR: 2 python software developers
 - Build project specific platform with GUI for parametric input
 - Build parametric FE model
 - Create central database with output and input
 - Integrate different software tools by managing data output towards data input
 - Build GUI for visualization of results

Platform structure

- **Level 1: Overall tunnel**
 - General geometric parameters, materials and load cases
 - Import MX-file with road alignment
 - Import load combinations and result classes
 - Create different reinforcement configurations
 - Visualise global results
- **Level 2: Individual sections**
 - Local soil conditions
 - Define deviations from overall parameters
 - Define applicable reinforcement configuration
 - Visualise local results

Level 1: Overall tunnel - Geometry

VIKTOR > Tunnel > Editor
bdirkx@besix.com

ALGEMEEN **GEOMETRIE** MATERIALEN BELASTINGGEVALLE >

Tunnelmoot ^

Breedte HLi (mm)	Breedte MTK (mm)	Breedte HRe (mm)
13430	2200	13280
Dikte dakplaat (mm)	Dikte buitenwand (mm)	Dikte binnenwand (mm)
450	700	350
Structurele hoogte (mm)	Offset bovenkant OWB t.o.v. G00H (mm)	
5950	768	

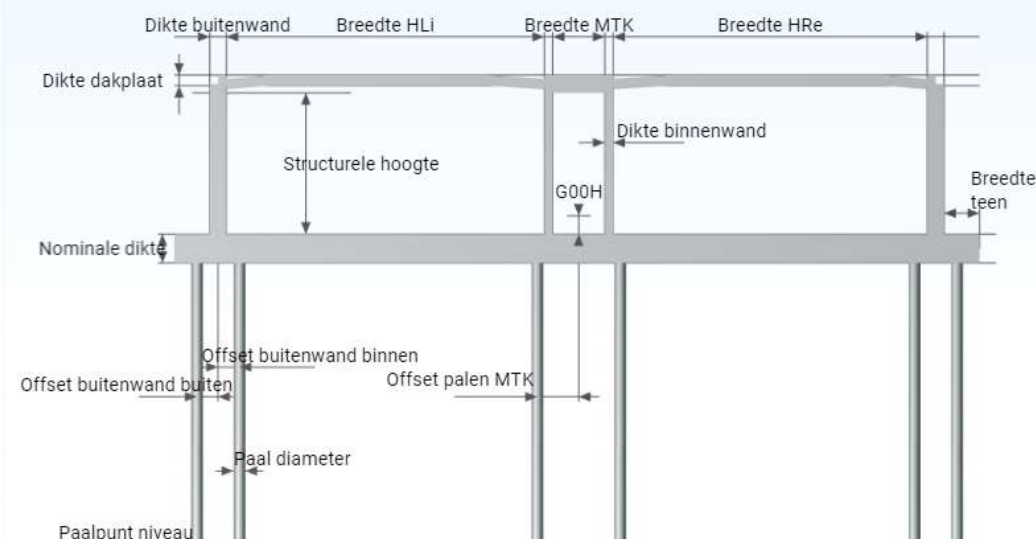
Vouten v

Vloer v

Palen v

Wapening v

TUNNEL LANGSDOORSNEDE **DWARSDOORSNEDE** VOUTEN INTERNE KRAI >



viktor.ai v2.3.2
28

Level 1: Overall tunnel – Load cases

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< ALGEMEEN GEOMETRIE MATERIALEN **BELASTINGGEVALLEN** >

Variabele maaiveldbelasting

Vulbeton

Asfalt

Technische installaties

Verkeer

Aslast rijstrook 1 (kN)	Aslast rijstrook 2 (kN)	Aslast rijstrook 3 (kN)
300	200	100

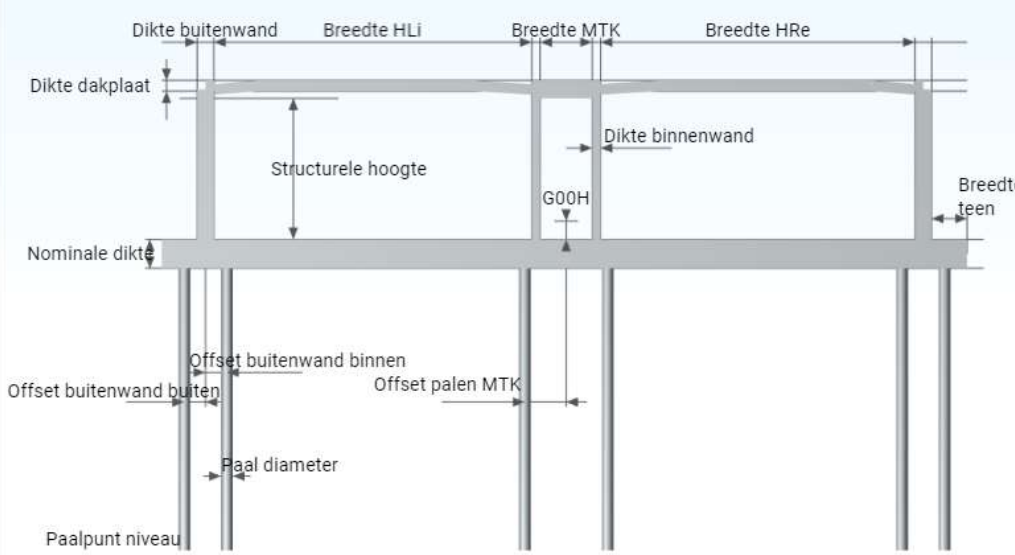
Spreid.len. dwars (m)	Spreid.len. langs, mootv...	Spreid.len. langs, centra...
3	4.17	7.67

GVB rijstrook 1 (kN/m ²)	GVB overige rijstroken (...)
10.35	3.5

Temperatuur

viktor.ai v2.3.2

TUNNEL LANGSDOORSNEDE DWARSDOORSNEDE VOUTEN INTERNE KRAI >



The diagram shows a cross-section of a tunnel structure with the following labels and dimensions:

- Dikte buitenwand**: Outer wall thickness
- Breedte HLi**: Width of the top slab
- Breedte MTK**: Width of the middle section
- Breedte HRe**: Width of the bottom slab
- Dikte dakplaat**: Roof slab thickness
- Structurele hoogte**: Structural height
- Dikte binnenwand**: Inner wall thickness
- Nominale dikte**: Nominal thickness of the base
- G00H**: Ground level
- Breedte teen**: Width of the toe
- Offset buitenwand buiten**: Offset of the outer wall to the outside
- Offset buitenwand binnen**: Offset of the outer wall to the inside
- Offset palen MTK**: Offset of the piles in the middle section
- Paal diameter**: Pile diameter
- Paalpunt niveau**: Pile tip level

Level 1: Overall tunnel – Reinforcement configuration

VIK TOR > Wapeningconfiguraties > Editor

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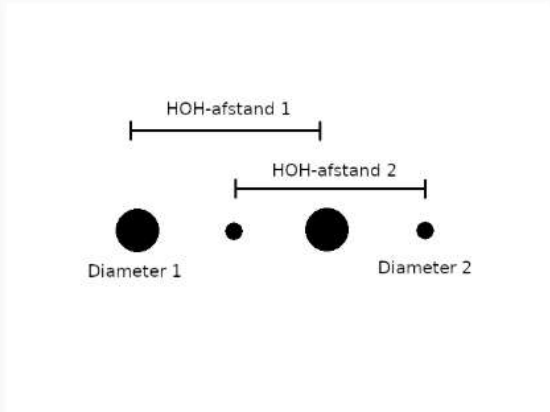
WAPENING

Configuraties ^

Wapening

Naam	Diameter 1 (mm)	HOH-afstand 1 (mm)	Diameter 2 (mm)
bovenstructuur min	10	400	10
bovenstructuur max	16	400	16
bodemplaat min	20	400	20

FIGUUR



HOH-afstand 1

HOH-afstand 2

Diameter 1 Diameter 2

viktor.ai v2.3.2

Level 1: Overall tunnel – Reinforcement configuration

VIKTOR > Wapeningconfiguraties > minimale wapening > Editor

LI DAKPLAAT RE DAKPLAAT MTK BODEMPLAAT STEKW >

FIGUUR

Grondzijde

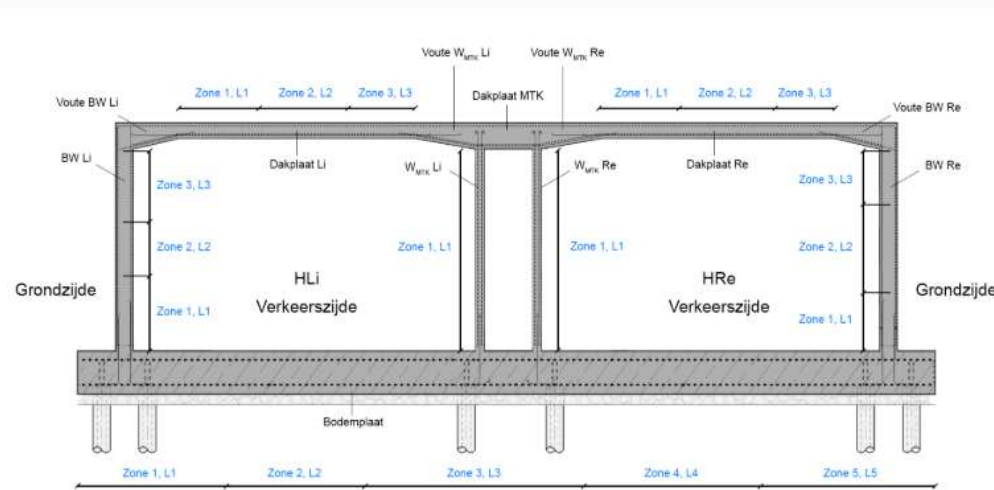
Dekking (mm)
40

L, zone 1 (mm) 3000 L, zone 2 (mm) 3000

Wapening, zon...
bovenst... **bovenstructuur min**

Verkeerszijde

bodenplaat min
bodemplaat max



viktor.ai v2.3.2

Level 2: Individual section – Local soil conditions

VIKTOR > Tunnel > Moot 20 > Editor

← 📁 🏠 ⓘ ↻ bdirko@besix.com

INVOER AFWIJINGEN DOWNLOADS ANALYSE >

MODEL EINDFASE MODEL BOUWFASE WATERDRUK / KORRELDRIJK INTERNE KRACHTEN

Algemeen

Hoogte as G00H (m-NA...
-9.481

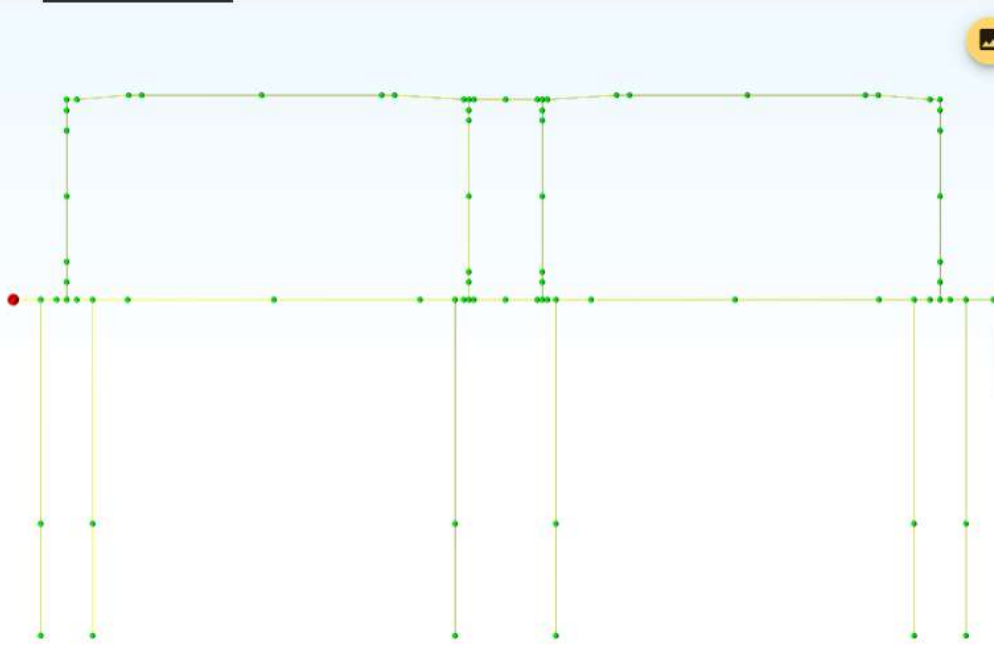
Visualiseer draadmodel Visualiseer grondlagen

Geotechniek

Kv paalpunt (MN/m) 100 Kv damwand (MN/m) 200 Stijfheid Hoog (√2) ▾

Beddings

Bovenkant laag (m-NAP)	Laag soort	qc	Grondwater
5.50	Zand	6.00	<input type="checkbox"/>
0.00	Klei	0.50	<input type="checkbox"/>
-3.00	Silt	6.00	<input type="checkbox"/>
-7.50	Zand	10.00	<input type="checkbox"/>
-11.50	Silt	4.00	<input type="checkbox"/>
-17.00	Zand	14.00	<input checked="" type="checkbox"/>
-19.00	Klei	2.00	<input type="checkbox"/>
-19.50	Zand	20.00	<input type="checkbox"/>



viktor.ai v2.3.2

Level 2: Individual section – Local soil conditions

VIKTOR > Tunnel > Moot 20 > Editor

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MODEL EINDFASE MODEL BOUWFASE WATERDRUK / KORRELDRIJK INTERNE KRACHTEN

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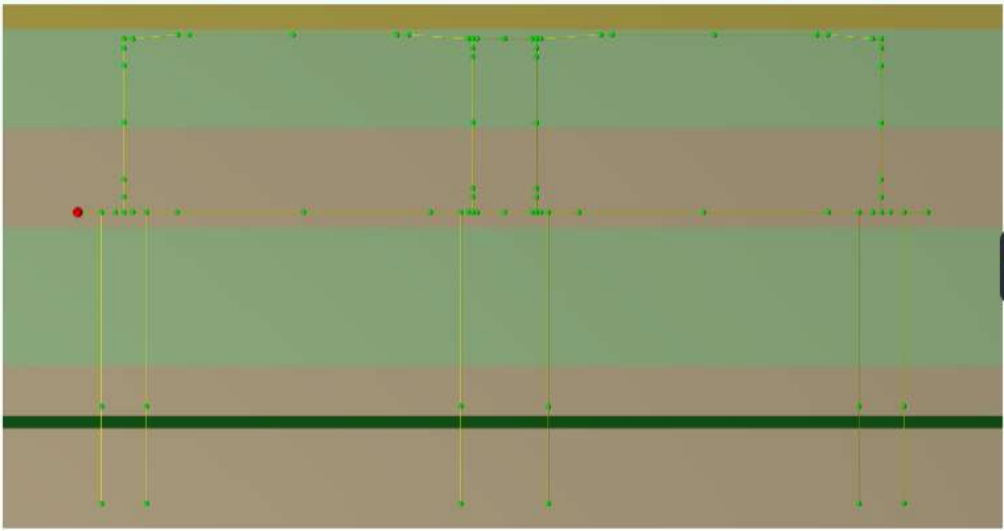
Visualiseer draadmodel Visualiseer grondlagen

Geotechniek

Kv paalpunt (MN/m) 100 Kv damwand (MN/m) 200 Stijfheid Hoog (√2)

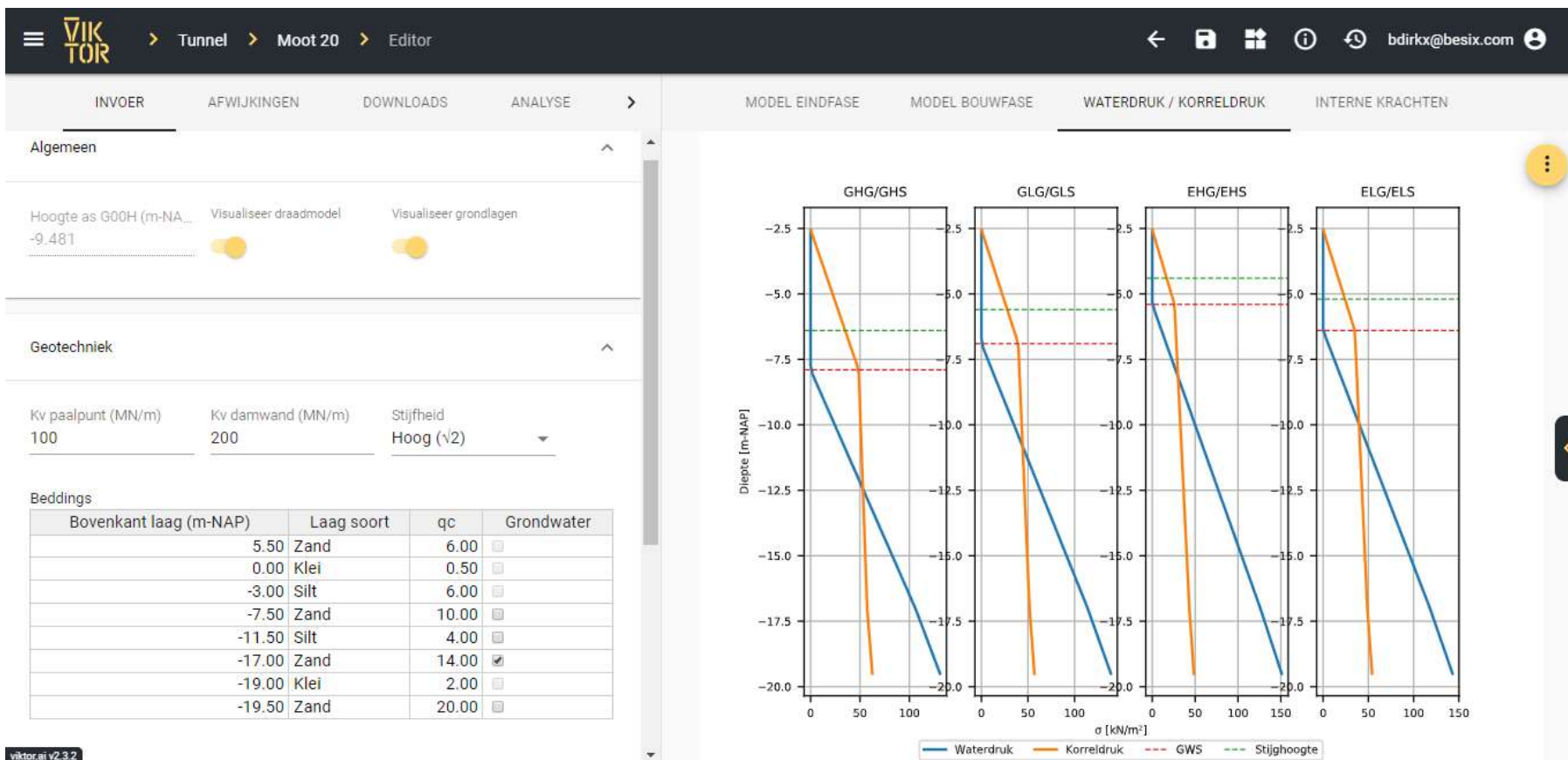
Beddings

Bovenkant laag (m-NAP)	Laag soort	qc	Grondwater
5.50	Zand	6.00	<input type="checkbox"/>
0.00	Klei	0.50	<input type="checkbox"/>
-3.00	Silt	6.00	<input type="checkbox"/>
-7.50	Zand	10.00	<input type="checkbox"/>
-11.50	Silt	4.00	<input type="checkbox"/>
-17.00	Zand	14.00	<input checked="" type="checkbox"/>
-19.00	Klei	2.00	<input type="checkbox"/>
-19.50	Zand	20.00	<input type="checkbox"/>



viktora! v2.3.2

Level 2: Individual section – Local soil conditions



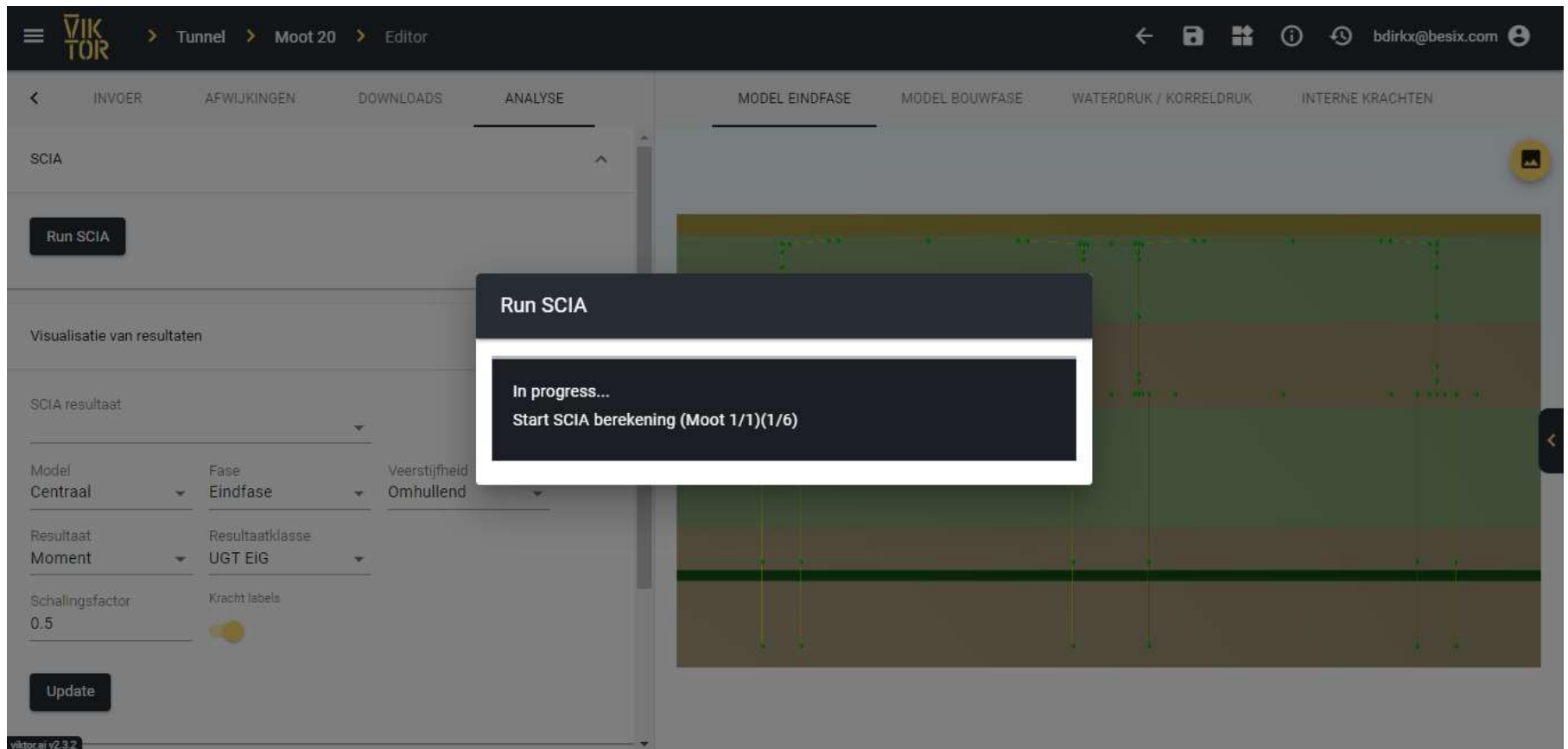
viktora v2.3.2

10-12-2020

34

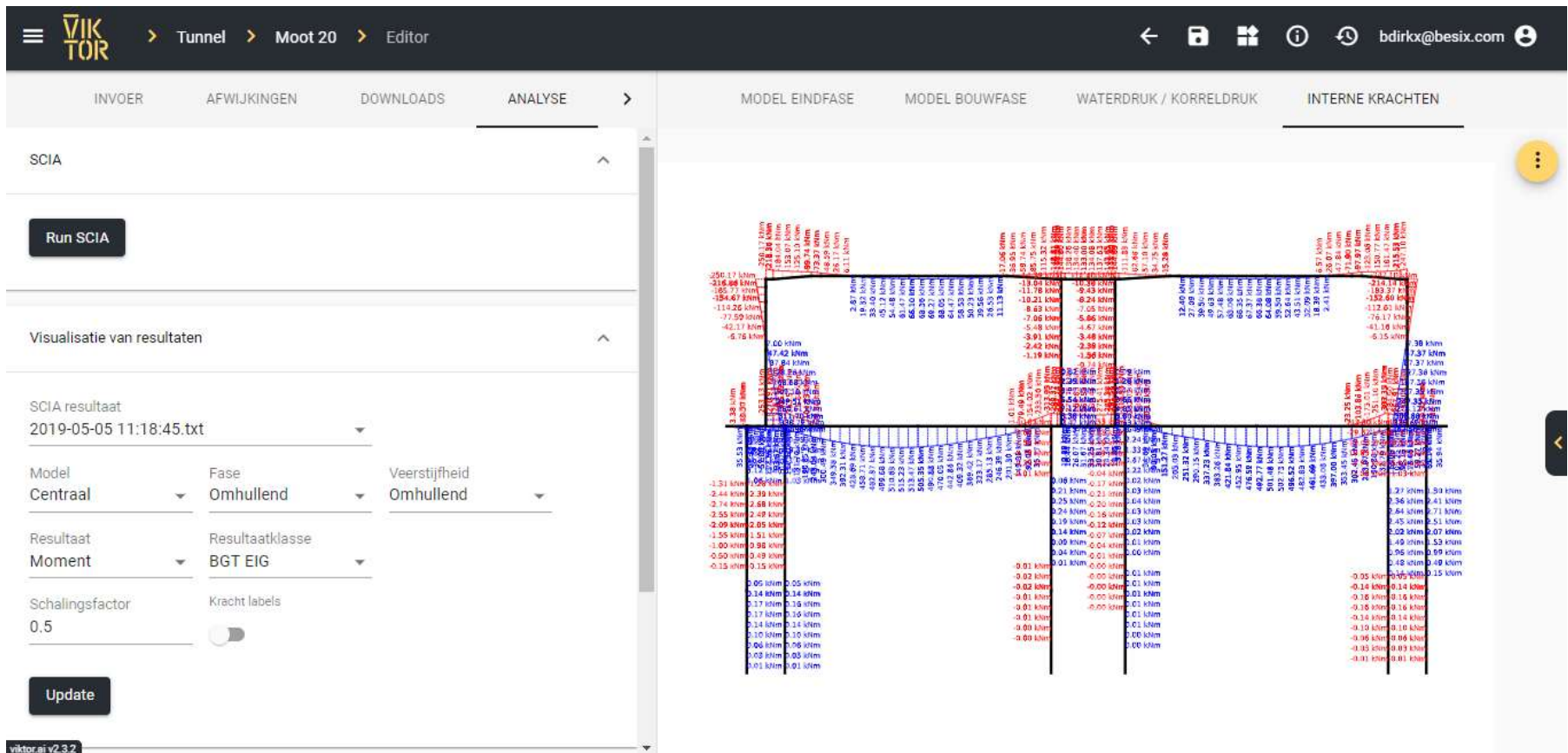
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Level 2: Individual section – Visualise local results



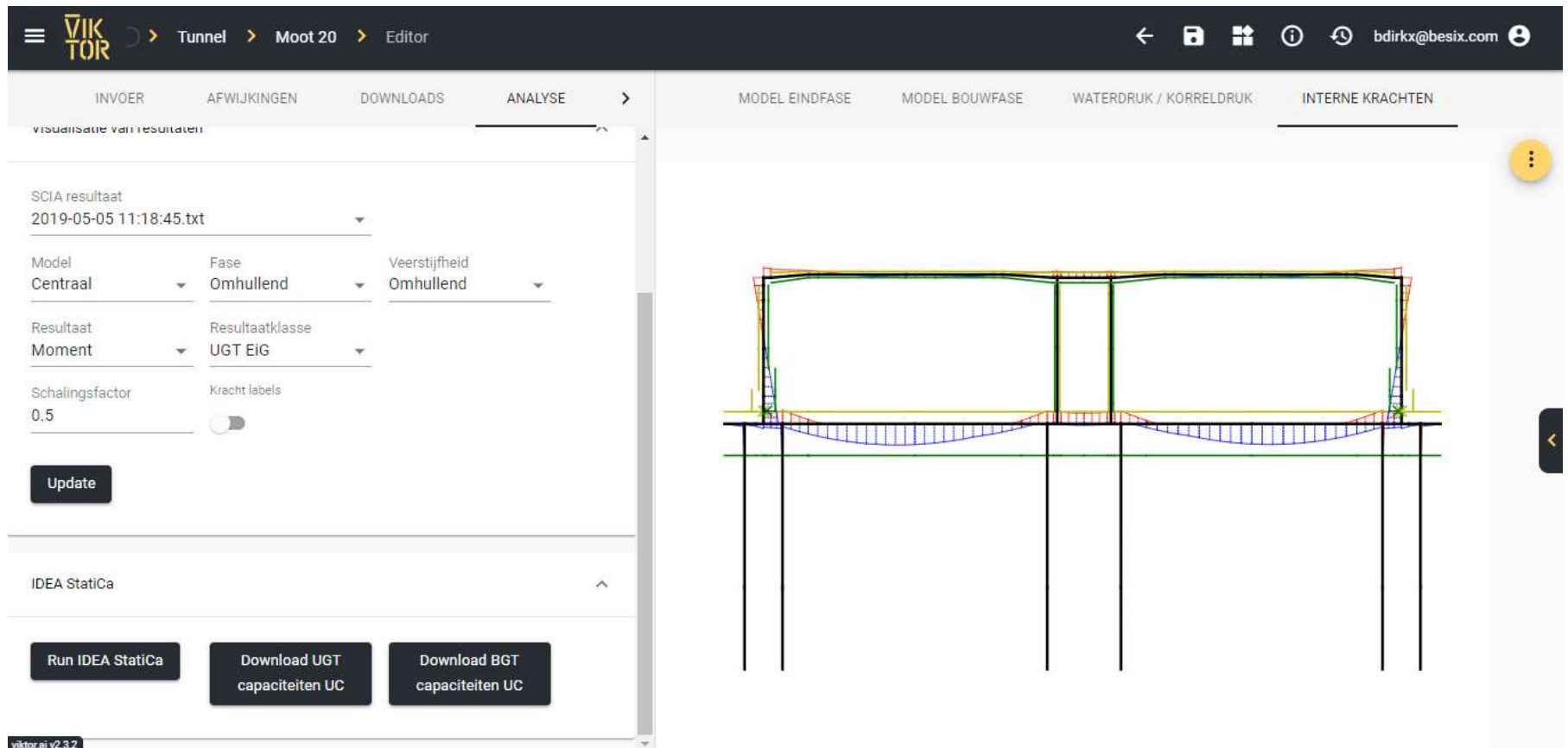
The screenshot shows the VIKTOR software interface. The top navigation bar includes the VIKTOR logo and the path: Tunnel > Moot 20 > Editor. The main interface is divided into several sections. On the left, there is a sidebar with tabs: INVOER, AFWIJINGEN, DOWNLOADS, ANALYSE, MODEL EINDFASE, MODEL BOUWFASE, WATERDRUK / KORRELDRIJK, and INTERNE KRACHTEN. The ANALYSE tab is active, and the SCIA section is expanded. A 'Run SCIA' button is visible. Below it, there is a 'Visualisatie van resultaten' section with a 'SCIA resultaat' dropdown menu. The main content area shows a cross-section of a tunnel with various layers and a central tunnel structure. A modal dialog box is overlaid on the main content, with the text: 'Run SCIA', 'In progress...', and 'Start SCIA berekening (Moot 1/1)(1/6)'. The bottom left corner of the interface shows the version 'viktor.ai v2.3.2'.

Level 2: Individual section – Visualise local results



The screenshot displays the VIKTOR software interface for a tunnel analysis. The top navigation bar includes 'Tunnel', 'Moot 20', and 'Editor'. The main menu has 'INVOER', 'AFWIJINGEN', 'DOWNLOADS', and 'ANALYSE'. The 'ANALYSE' section is active, showing 'SCIA' results. A 'Run SCIA' button is visible. Below, the 'Visualisatie van resultaten' section shows the SCIA result file '2019-05-05 11:18:45.txt'. The analysis parameters are: Model: Centraal, Fase: Omhullend, Veerstijfheid: Omhullend, Resultaat: Moment, Resultaatklasse: BGT EIG, and Schallingsfactor: 0.5. The 'Update' button is at the bottom left. The main visualization area shows a cross-section of a tunnel with a grid of numerical values representing local results, such as moments and forces, in kNm and kN. The values are color-coded, with red indicating positive values and blue indicating negative values. The interface also shows a 'viktora v2.3.2' version indicator at the bottom left.

Level 2: Individual section – Visualise local results



The screenshot displays the VIKTOR software interface for visualizing local results. The top navigation bar includes a menu icon, the VIKTOR logo, and the path: Tunnel > Moot 20 > Editor. On the right side of the top bar, there are icons for back, save, window, information, and refresh, along with the email address bdirkx@besix.com.


The main interface is divided into two panels. The left panel, titled 'visualisatie van resultaten', contains the following settings:






- SCIA resultaat: 2019-05-05 11:18:45.txt
- Model: Centraal
- Fase: Omhullend
- Veerstijfheid: Omhullend
- Resultaat: Moment
- Resultaatklasse: UGT EIG
- Schalingsfactor: 0.5
- Kracht labels:

An 'Update' button is located below these settings. The right panel, titled 'INTERNE KRACHTEN', shows a cross-section of a tunnel structure with internal forces. The structure is supported by four vertical columns. The internal forces are visualized as a blue shaded area at the bottom of the structure, indicating the distribution of moments. The top of the structure is outlined in green and yellow.

At the bottom left of the interface, the version number 'viktor.ai v2.3.2' is displayed.

Level 1: Overall tunnel – Visualise global results


VIKTOR > Tunnel > Editor





bdirkx@besix.com


MATERIALEN
BELASTINGGEVALLEN
ANALYSE
DOWNLOAD

SCIA ^

Mesh-breedte (mm)
500 Run alle moten

Moten
Moot 20, Moot ... Run geselecteerde moten

Visualisatie van resultaten ^

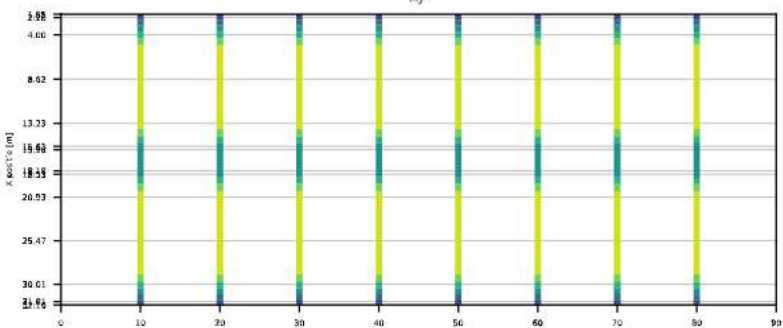
Model	Fase	Component
Centraal v	Eindfase v	Dakplaat v
Veerstijfheid	Resultaat	Resultaatklasse
Omhullend v	Moment v	UGT EIG v

Visualiseer laatst gemaakte resultaten

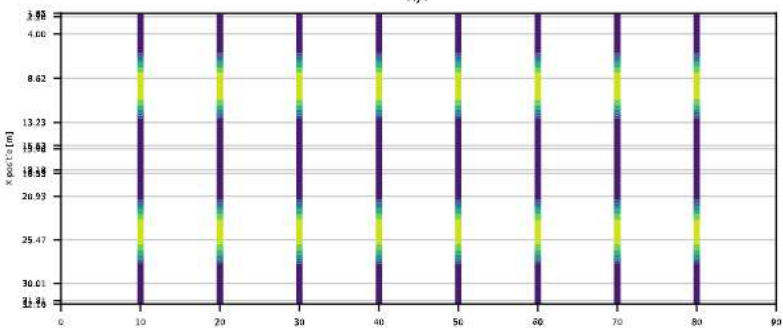
viktor.ai v2.3.2

UNNEL
LANGSDOORSNEDE
DWARSDOORSNEDE
VOUTEN
INTERNE KRACHTEN

My-



Moot My+



-0.0

-25.1

-50.1

-75.2

-100.2

-125.3

-150.4

-175.4

-200.5

-225.6

-250.6

kNm

69.30

62.37

55.44

48.51

41.58

34.65

27.72

20.79

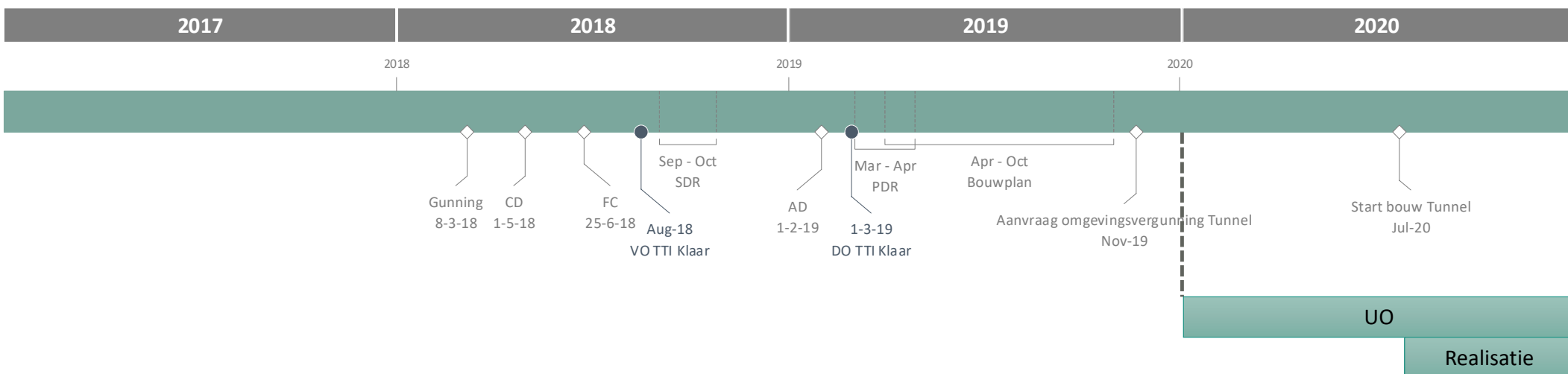
13.86

6.93

0.00

kNm

Uitvoeringsontwerp & realisatie



1. UO: Monodisciplinary detailed design – First Time Right

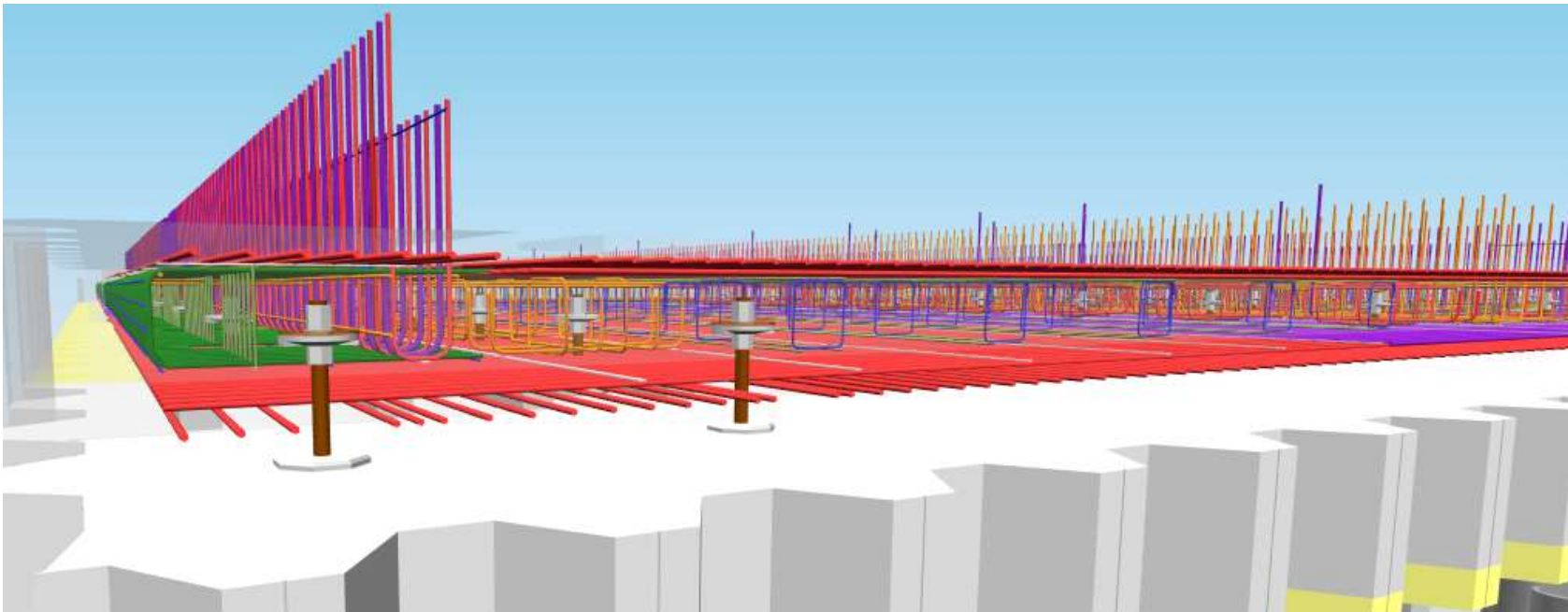
Only detailed development of DO calculation notes and models towards execution drawings. Changes with impact on integrated design result in major failure costs

2. Execution – Site engineering

Support on site related questions and nonconformities

UO – Reinforcement detailing

- Allplan model by Buigcentrale Steenberg



UO – Reinforcement detailing

- Mock-up in dry conditions



Proefbouwkuipen

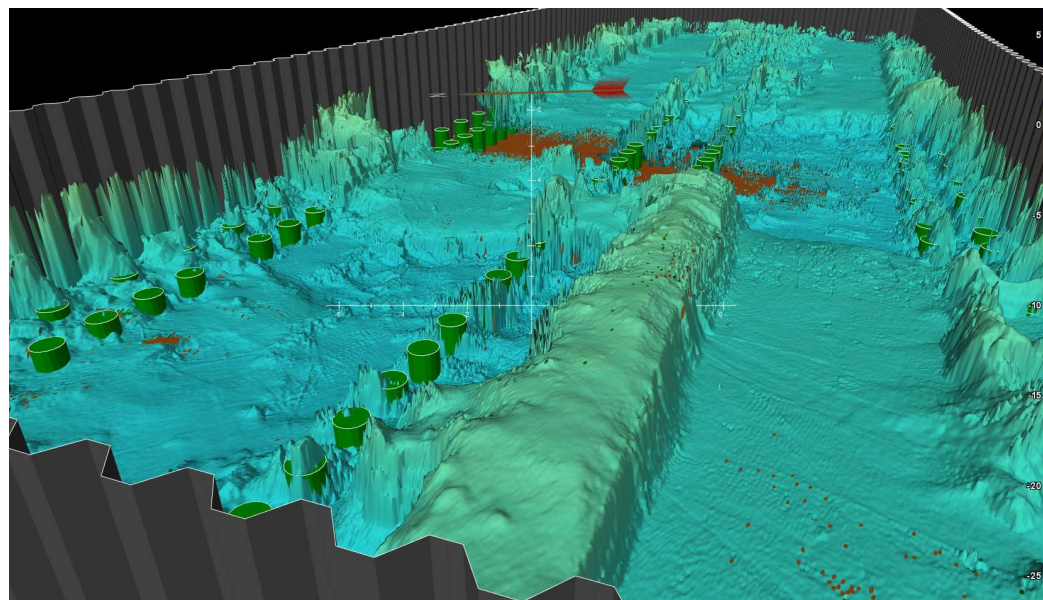
Omgevingsvergunning verleend 20-04-2020

→ Planningsbuffer tot start bouw (30-07-2020) niet nodig

→ 2 proefbouwkuipen geven kans tot leercurve



10-12-2020



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Execution





Thank you!

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