Rail Baltica
Coordinated by RB Rail

TECHNICAL SPECIFICATION

GEODETIC NETWORK ESTABLISHMENT FOR DESIGN STAGE OF RAIL BALTICA HIGH SPEED RAILWAY

RBDG-MAN-038-0101

Revision: 1.1

Author: VDC

Date: 01.10.2024

Co-funded by the European Union

The sole responsibility of this publication lies with the author.
The European Union is not responsible for any use that may be made of the information contained therein.

Document Development and Approval:

Ownership	
Document Owner	Virtual Design and Construction Department

Approved by	Decision No.	Date
CTO	-	06.06.2022
TRG	78/2024	06-17.09.2024

Document History

This document has been issued and amended as follows:

Revision	Issue Date	Author	Issue purpose	Description of changes
1.0	20.05.2022	Georgios Papastamos	First issue	Technical specification for implementation of Geodetic Network during design stage
1.1	01.10.2024	Andres Rüdja Georgios Papastamos Rait Leppik	Modifications	Corrections of terminology, definitions and abbreviations, improvement of technical information tables and drawings Revision is mandatory for agreements signed after 1st of July 2024

Contents

Acronyms and Abbreviations

The following acronyms and abbreviations are used throughout this document:

Abbreviation	Definition
BIM	Building Information Management; set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a Facility in virtual space. Including PIM (project information model) and AIM (asset information model)
BoQ	Bill of Quantities; an itemised list of classified materials, parts, and labour together with their unit cost and description what is basis for cost calculation, required to construct, install, maintain, and/or repair the infrastructure, specifically extracted from Rail Baltica BIM models
CDE	Common Data Environment – RB Rail AS/IB is the owner of this platform. It is a central repository where construction project information is housed
CP	Control Point – geodetic marks/benchmarks to be built in order to create new geodetic network for implementation of High-Speed Railway
DG	Design Guideline; set of predefined and standardized technically and economically justified engineering and design solutions for Rail Baltica infrastructure to be applied at design, construction and operation phases of Rail Baltica Railway, which forms an integral part of this Technical Specification; the Design guidelines may be changed by the Client, therefore, the Agreement always refers to the most current version of the Design guidelines
DRCHS	Digital Information Requirements for Construction and Handover Stages
DTD	Detailed Technical Design of Rail Baltica project
EH2000	Estonian Height System
EIR	Employer's Information Requirements; BIM Requirements which define the information that will be required from the Consultant for the development of the project and for the operation of the completed built asset
ETRF	European Terrestrial Reference Frame
ETRS	European Terrestrial Reference System
EUREF	IAG Reference Frame Sub-Commission for Europe
EUREF-EST97	Estonian Geodetic Reference System
EVRF	European Vertical Reference Frame
EVRS	European Vertical Reference System
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
IAG	International Association of Geodesy

Abbreviation	Definition
INS	Inertial navigation system
LAMBERT-EST	Estonian Map Projection
LAS-2000,5	Latvian Height System
LAS07	Lithuanian Height System
Latvia TM	Latvian Map Projection
Lithuania TM	Lithuanian Map Projection
L-EST97	Estonian Planar Coordinate System
LKS-92	Latvian Geodetic Reference System
LKS-92 TM	Latvian Planar Coordinate System
LKS94	Lithuanian Geodetic Reference System
LKS94 TM	Lithuanian Planar Coordinate System
MNCP	Micro-network Control Point
PUO	Public Utility Organisations/Owners
RBDatum	The Geodetic Reference System dedicated to the Rail Baltica Project
RB-GRES	RB Geodetic Reference System
RB-HRES	RB Height Reference System
RB-MAP	RB Map Projection
RB-PCS	RB Planar Coordinate System
RBR	RB Rail AS
RoW	Right on the way-clear visibility from point to point
SSP	Supervision Service Provider – service provider awarded with an Agreement to conduct supervision services for construction of railway and geodesy network specified in this document
TBM	Tunnel Boring Machine
TGMT	A Railway track geometry measuring trolley system
TS	Technical Specification
UELN	United European Levelling Network
EE	Republic of Estonia

Abbreviation	Definition
LV	Republic of Latvia
LT	Republic of Lithuania

Definitions

The following terms are used throughout this document:

Term	Definition
BIM Model	3D models containing information (PIM & AIM)
Consultant	Service provider awarded with an Agreement to design Rail Baltica high speed railway with geodetic survey delivery
Client	RB Rail AS and/or Implementing Bodies
Contractor	Service provider awarded with an Agreement to construct Rail Baltica high speed railway with geodetic survey delivery
Country	Republic of Estonia/Republic of Latvia/Republic of Lithuania
Digital Format	For drawings, 2D or 3D, is a vector format (dwg, dgn, .dxf, LandXML ifc, etc); for Tables or lists in xlsx, or ASCII format; Documents in Word, PDF or ascii format
Programme	Representation (including graphical) of the time schedule, tasks and milestones agreed between the Consultant and Client at the initial stage of the Agreement's implementation and forming a part of legal obligations of the Consultant
Rail Baltica highspeed railway	A new 249 km/h conventional double track electrified European standard gauge (1435 mm) railway line on the route from Tallinn through Pärnu - Riga - Panevėžys - Kaunas to Lithuanian - Polish border, with the connection of Kaunas - Vilnius
Order 0-3 Network	The hierarchy of the Project's Geodetic Network, 0 is the highest order, consisting of control points (CP) and corresponding geodetic measurements
Primary Geodetic Network	This network is indicated by two levels: Order 0 (CP0) and Order 1 (CP1)
Secondary Geodetic Network	These networks are indicated by levels: Order 2 (CP2), Order 3 (CP3) and MNCP
Service	Supervising Authority; can be RB Rail AS, and/or Implementing Bodies, and/or SSP

1 Introduction

1. The following technical specifications are made to make sure that Rail Baltica highspeed railway construction accuracy is in accordance with all applicable legislation and standards in all Baltic states and to ensure that all parties (e.g. designer, contractor, authorities, supervision, etc.) are working in the same geodetic reference system to consolidate the planning, designing and to coordinate construction and maintenance.
2. It is mandatory that the geodetic network for Rail Baltica project must be optimal in terms of geometry, precision and reliability. For this purpose, a dedicated to the Project geodetic network will be implemented to assure high accuracy during construction works, supervision and maintenance. The network will be connected to the States Reference Systems.

2 General Terms

The Consultant shall follow EU directives, all Country's construction and other national legislation, EU standards, Country-specific legislation/standards/rules and other legal acts applicable for the provision of construction of geodetic network and construction supervision services.

3 Baltic Reference Systems

3.1 Geodetic and Height Reference Systems

The European Geodetic Reference System ETRS89 and the European Vertical Reference System EVRS are the basis for geodetic systems in Europe according to the INSPIRE directive. However, the geodetic systems of the countries of the European Union may differ to some extent from each other. This is mainly due to the fact that geodetic systems and their components were created based on geodetic measurements and different kind of source data that were available at the time in these countries and in Europe in general.

This paragraph defines all data related to the existing National Geodetic and Height Reference Systems in the three Baltic states. Tables 1 - 4 provide summary information for the Consultant and/or Contractor to use this in the Geodetic Network implementation process.

Table 1. National Geodetic Coordinate Systems

Country	Estonia	Latvia	Lithuania
Geodetic Coordinate System	EUREF-EST97	LKS-92	LKS94
EPSG	6180	4949	4951
Valid area	Estonia	Latvia	Lithuania
Remarks	EUREF-EST97 geodetic coordinates in ETRF96 based on EUREF-ESTONIA97 GPS campaign	The LKS-92 geodetic coordinates are determined from the final solution of the EUREF-BAL92 GPS-campaign	LKS94 geodetic coordinates in ETRF2000 based on the NKG2003 GPS-campaign
Datum anchor point	13 points of the EUREF-ESTONIA97 GPS-campaign	4 points of the EUREF BAL92 GPS-campaign	4 points of the EUREF BAL92 GPS-campaign
Epoch	1997.56	1992.75	2003.75
System alias	-	Latvijas geodeziska koordinatu sistema 1992 (Latvian Geodetic Coordinate System 1992)	Lietuvos koordinačių sistema 1994 (Lithuanian Coordinate System 1994)
Datum remarks	EUREF-EST97 is consistent with ETRS89; legal act Regulation of the Estonian Minister of Environment No. 64, October 26, 2011 (RT I, 26.07.2017, 2).	LKS-92 is consistent with ETRS89; legal act Resolution No. 213 of the Government of Latvia, June 4, 1992	LKS94 is consistent with ETRS89; legal act Resolution No. 936 of the Government of Lithuania, September 30th, 1994
Prime meridian identifier	Greenwich	Greenwich	Greenwich
Ellipsoid identifier	GRS 80	GRS 80	GRS 80

Table 2. National Map Projections

Country	Estonia	Latvia	Lithuania
Map Projection name	LAMBERT-EST	LV TM	LT TM
Operation valid area	Estonia	Latvia	Lithuania
Coordinate system type	projected	projected	projected
Coordinate system dimension	2	2	2
Coordinate system axis name	*x* / northing	*x* / northing	*x* / northing
Coordinate system axis direction	North	North	North

Country	Estonia	Latvia	Lithuania
Coordinate systems axis unit identifier	metre	metre	metre
Coordinate system axis name	y / easting	y / easting	y / easting
Coordinate system axis direction	East	East	East
Operation method name	Lambert Conformal Conic Projection with 2 standard parallels	Transverse Mercator Projection	Transverse Mercator Projection
Operation parameter name	lower parallel	latitude of origin	latitude of origin
Operation parameter value	58°00′ N	0°	0°
Operation parameter remarks		0°, the Equator	0°, the Equator
Operation parameter name	upper parallel	longitude of origin	longitude of origin
Operation parameter value	59°20′ N	24° E	24° E
Operation parameter name	latitude grid origin / zero parallel	false northing	false northing
Operation parameter value	57°31′03.19415″ N	-6 000 000 m	0 m
Operation parameter name	longitude grid origin	false easting	false easting
Operation parameter value	24°00′ E	500 000 m	500 000 m
Operation parameter name	false northing	scale factor at central meridian	scale factor at central meridian
Operation parameter value	6 375 000 m	0.9996	0.9998
Operation parameter name	false easting	width of zone	width of zone
Operation parameter value	500 000 m	6°	6°
Operation parameter remarks		one 6° zone with central meridian 24° E	one 6° zone with central meridian 24° E

Table 3. National Planar Coordinate Systems

Country	Estonia	Latvia	Lithuania
Planar Coordinate System	L-EST97	LKS-92 TM	LKS94 TM
EPSG	3301	3059	3346
Underlying Geodetic Coordinate System	EUREF-EST97 (EPSG: EST97)	LKS-92	LKS94
Underlying Map Projection	LAMBERT-EST	Latvia TM	Lithuania TM

Table 4. National Height Systems

Country	Estonia	Latvia	Lithuania
Height System alias	EH2000	LAS-2000,5	LAS07
EPSG	9663	7700	9666
Height system valid area	Estonia	Latvia	Lithuania
Height system scope	valid from January 2018	valid from December 2014	valid from January 2016
Height system remarks	zero tidal system	mixed (zero/mean) tidal system	mixed (zero/mean) tidal system
Datum alias	Normaal Amsterdams Peil (NAP)	Normaal Amsterdams Peil (NAP)	Normaal Amsterdams Peil (NAP)
Datum type	vertical	vertical	vertical
Datum anchor point	UELN point 2211011was fixed with its height in EVRF2007 (2017 solution)	16 UELN points around Latvia were fixed with their heights in EVRF2007 (2012 solution)	10 UELN nodal points in Lithuania were fixed with their heights in EVRF2007 (2007 solution)
Datum realization epoch	2000; NAP sea level 1684 MHT	2000/2000,5; NAP sea level 1684 MHT	1998-2006; NAP sea level 1684 MHT
Remarks	Levelling network observed from 2003-2016; reduced to epoch 2000 using semi-empirical land uplift model NKG2005LU (Solution 201703 / NKG2005LU)	Levelling network observed from 2000-2010; reduced to epoch 2000,5 using empirical land uplift model of Latvia	Levelling network observed 1998-2006
Height system identifier	normal heights	normal heights	normal heights
Height system type	gravity related	gravity related	gravity related
Height system axis name	height	height	height

3.2 National Geodetic and Vertical Networks

3.2.1 Estonia

3. EUREF-EST97 coordinates based on the National Geodetic Network points and the Estonian permanent GNSS network ESTPOS. Estonian National Geodetic Network consists of three different classes:

   (a) I class consist of 13 points of them 12 ground points and 1 CORS. The distance between points is 70-110 km. The standard deviation of the coordinates is estimated to be better than ±1 cm;

   (b) II class consist of 199 points, the average distance between points is 15 km. The standard deviation of the position is estimated to be less than ±6 mm relative to the 1st order geodetic network;

   (c) Densification Network consist of 3922 geodetic, the density of points being one point, or point pair, per 16-25 km^2 (with an average spacing of 5 km), the distance between points in pairs is about *ca* 500 m. The standard deviation of the position is estimated to be ±1 … 3 cm relative to the higher order geodetic networks.

4. The Estonian high precision levelling network was measured within the framework of the project of Estonian Land Board and the city of Tallinn in 2003 – 2016. The network belongs to one, the highest, order. The results of hydrodynamic levelling in 2011 were used to connect the mainland network with that of the Western Estonian islands. In Estonia, the heights of the EVRS system are denoted by the abbreviation EH2000. The standard deviation of the heights was estimated as ± 2 mm. EH2000 is available to the public mainly through the national levelling network and ESTPOS via quasigeoid model EST-GEOID2017.

3.2.2 Latvia

5. LKS-92 is realized by Class 0, Class 1 and Class 2 markers of the GNSS network and CORS stations of LatRef and/or LatPos:

   (a) Class 0 (G0) contain four points: "Rīga", "Kangari", "Indra" and "Arājs", with an agreed standard deviation of coordinates ±0 mm;

   (b) Class 1 (G1) contain 41 points, the standard deviation of coordinates is estimated to be ±20 mm relative to the G0 network;

   (c) Class 2 (G2) contain 752 points, the standard deviation of coordinates is estimated to be ±25 mm relative to the G0 network;

   (d) LatPos contain 48 CORS, the standard deviation of co-ordinates is estimated to be ±20 mm relative to the G0 network.

6. Measurement of the 1st order levelling network was carried out in 2000 – 2010. Data of the Latvian 1st order levelling network was integrated into UELN at end of 2011. Adjustment of the Latvian 1st order levelling network is based on heights of the sixteen 1st order levelling points from the aforementioned EVRF2007 solution. Prior to adjustment, height differences were reduced to epoch 2000.0 using EECVMM LV (Empirical Earth Crust Vertical Movement Model for the territory of Latvia). In Latvia, the official EVRS heights are defined in the Latvian Normal

Height System LAS-2000,5 at the epoch 2000,5. LAS-2000,5 is available to the public mainly through the national levelling network and LatPos via quasigeoid model LV´14. Levelling network of Latvia consists of 1st and 2nd order:

(a) 1st order levelling network (N1) with a standard deviation of ±1.0 mm/km includes 1911 points;

(b) 2nd order levelling network (N2) with standard deviation of ±2.0 mm/km includes 606 points, the network combines historical and newly measured levelling data.

3.2.3 Lithuania

7. LKS94 is available to the public mainly through the LitPos CORS stations and Lithuanian National Geodetic Network which consists of four different classes:

(a) 0th class contain four points: Akmeniškiai, Dainavėlė, Meškonys and Šašeliai, the standard deviation of the coordinates of these points relative to the initial geodetic points of the European geodetic networks shall not exceed ±9 mm; was updated in 2006 based on the NKG2003 GPS-campaign;

(b) Ist class contain 48 points, the average distance between points is 40 km, the standard deviation of the coordinates is estimated to be less than ±6 mm relative to the 0th class geodetic network;

(c) IInd class contain 1026 points, the distance between points is 7-10 km, the standard deviation of the coordinates is estimated to be less than ±5 mm relative to the 1st class geodetic network;

(d) IIIrd class contain 9700 points, point density being about 1 point / 5 km^2, the standard deviation of the position is estimated to be less than ±5 cm relative to the higher order geodetic networks.

8. The Lithuanian levelling network is composed of two orders:

(a) the measurement of the levelling network of the 1st order was carried out in 1998 - 2006, it is the basis of the Lithuanian Height System LAS07.

(b) the measurement of the levelling network of the 2nd order was carried out in 2010 - 2016, the standard deviation of the double run of one kilometre levelling do not exceed ±0.7 mm/km , that is, the 1st and 2nd order are practically identical in terms of precision, the network consist of 1384 geodetic points.

4 Rail Baltica Reference Systems

9. It is within the intention of RBR to establish a unified Geodetic and Height Reference Systems, Map Projection, and Planar Coordinate System along the whole railway corridor alignment.

10. The RB Geodetic Reference System, RB-GRES, will rely on the ETRS89 definitions, EUREF recommendations and RB Primary Geodetic Network. Within the RB-GRES geodetic coordinates (B and L) and ellipsoidal heights (h) are defined.

11. The RB Height Reference System, RB-HRES, will rely on the EVRS definitions, EVRF2019 heights of the National Levelling Networks, and RB Primary Levelling Network. Within the RB-HRES

absolute heights (*H*) are defined. Note that not all higher-order levelling benchmarks are part of the EVRF2019 solution.

12. Due to the Rail Baltica project alignment length, it is important to define a RB unified Map Projection, RB-MAP, which is defined by the following characteristics:
    (a) low distortion of engineering grids;
    (b) continuous, without zones of different projection parameters, which can be extended for kilometres;
    (c) unique scale factor along the alignment at ground level.
13. The RB Planar Coordinate System, also called the projected coordinate reference system, defined by RB-GRES and RB-MAP is abbreviated RB-PCS. Within the RB-GRESMAP rectangular coordinates (*x* and *y*) are defined.
14. When it is completed, Geodetic and Height Systems, Map Projection, and Planar Coordinate System will be the unified RB Project dedicated System, applicable along the whole alignment of Rail Baltica Project, and may hereafter be together referred as RBDatum.
15. In each country, all designing, and construction shall be carried out according to RBDatum if available. If not available, National Systems can be used.

5 Connection between Baltic and RB Reference Systems

16. RBDatum will be connected to each country's Coordinate and Height Reference Systems via connection measurements between RB and National Geodetic and Levelling Networks, and CORS.
17. The RB Geodetic Network shall be connected to at least two (2) ground points of the National Geodetic and Levelling Networks at least every 50 km.
18. The geometric levelling lines in each country shall be fully constrained at least on both ends to the levelling benchmarks of the existing National Levelling Networks of highest order and/or neighbouring DTD, RBR benchmarks if available. The connection between RB and National Levelling Networks shall be done with additional double-run levelling lines. For control purposes, it is recommended to measure additional interconnects wherever benchmark of National Levelling Networks are nearby.
19. For every connection point incl. Cross-border section, a 10 km long section that extends 5.0 km to both neighbouring countries, sets of RBDatum and national system coordinates and heights must be provided (Table 5).

Table 5. Collection of information related to coordinates and heights on the example of cross border sections

Estonia – Latvia border section	Latvia – Lithuania border section
RB-GRES	RB-GRES
EUREF-EST97	LKS-92
L-EST97	LKS-92 TM
LKS-92	LKS94
LKS-92 TM	LKS94 TM
EVRF2019	EVRF2019
EH2000	LAS-2000,5
LAS-2000,5	LAS07

20. The necessary transformations between the National Coordinate and Height Systems in the Estonian-Latvian border area can be done using a special transformation calculators:

    (a) Coordinate calculator - developed for the transformation of coordinates in the Estonian-Latvian border area between the Estonian coordinate system L-EST97 and the Latvian coordinate system LKS-92. The model area is L = 24.2° ... 27.5° and B = 57.4° ... 58.2°, the step of the model data is 0.02/0.01 arc degrees (ca 1.1 km). The model covers ca 2 km wide border corridor. Link: https://gpa.maaamet.ee/crdmudel.

    (b) Height calculator - developed for height transformation between the Estonian height system EH2000 and the Latvian height system LAS-2000.5 in the Estonian-Latvian border area. The model area is L = 24.2° ... 27.5° and B = 57.4° ... 58.2°, the step of the model data is 0.02/0.01 arc degrees (ca 1.1 km). The model covers a 2 km wide border corridor. Link: https://gpa.maaamet.ee/hmudel/.

21. Cross border coordinate and height transformation parameters shall be coordinated and approved with the Service.

6 Structure Of RB Networks

22. RB Geodetic and Vertical Network consists of five different levels with different types and density of Control Points (see Figure 1 and 2 and Appendix 1 for technical details):

    (a) CP0 – Order 0, control points every 5 km - 10 km,;

    (b) CP1 – highest precision primary level network Order 1, control points every 1.5 km - 2.0 km, primary level network;

    (c) CP2 – secondary level network Order 2, control points, as a rule, every 400 m (as exception up to 500 m), distances may be shorter in curves to ensure visibility between points;

    (d) CP3 – secondary level network Order 3, control points on Catenary posts;

    (e) MNCP – Micro-Networks, directly connected to higher order (0 - 3) networks and used for bridges, tunnels, and other structures.

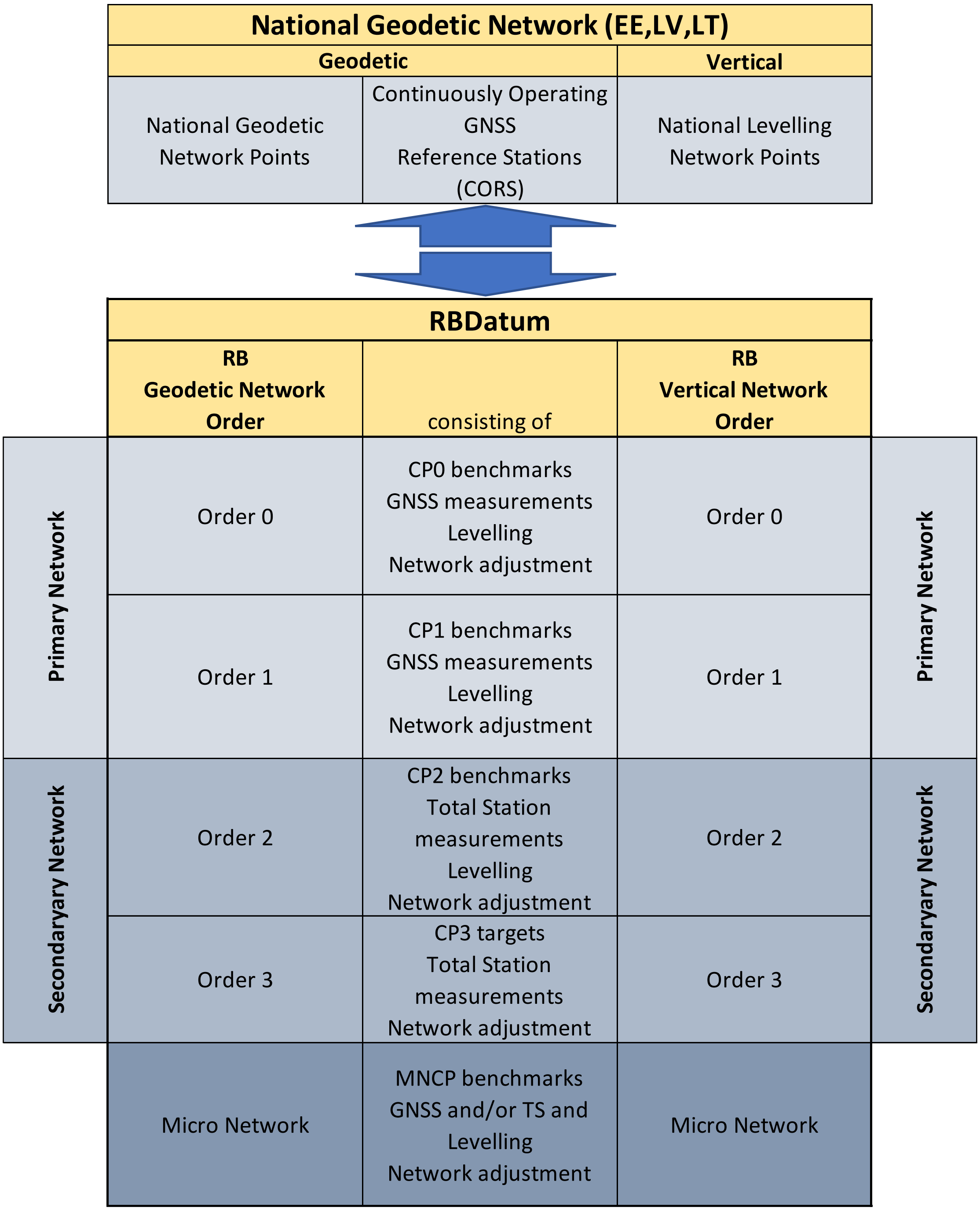


Figure 1. Classification of Rail Baltica Networks

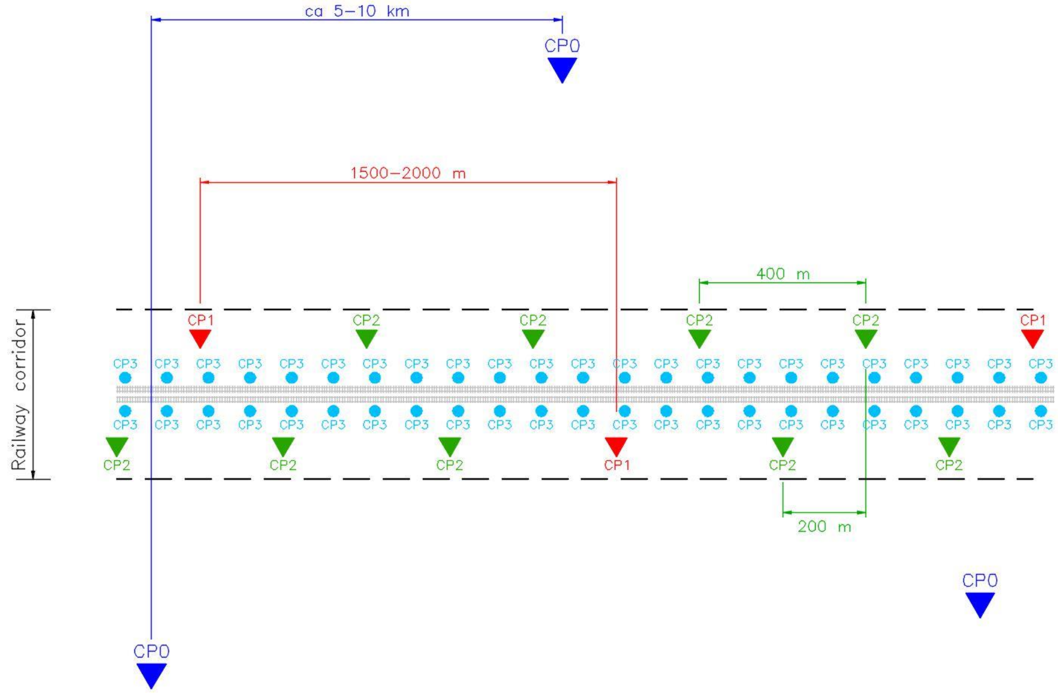


Figure 2. The basic structure of the Rail Baltica Networks

23. In addition, geodetic network CP1 benchmarks established by the Consultant in previous design stages, must be also evaluated by DTD Designer and according to the results and constructive type - included to the geodetic network.

24. All gathered data shall be integrated into RBR GIS platform and updated accordingly. Prepared material shall be linked with DTD designed BIM models.

7 Geodetic Network workflow

7.1 General instructions

25. The geodetic works needs to be carried out by a Consultant or Contractor, depending on project status, during the DTD stage of the Rail Baltica Project and this task shall include the following:

    (a) establishment of Order 0 Geodetic and Height Control Networks connected with the National Geodetic and Height Networks;

    (b) establishment throughout the entire alignment length, of a unified geodetic and a unified levelling networks (in every Order) within RBDatum and connection with the already existing one (Figure 3);

    (c) at the beginning of design activity and before installation of any order of the RB geodetic network benchmarks, Network Design need to be designed by the Consultant or Contractor and approved by Service.

	RBDatum			
obligation of	**RB Rail Geodetic Network Order**	consisting of	**RB Rail Vertical Network Order**	obligation of
Designer Consultant	Order 0	CP0 monuments GNSS measurements Leveling measurements Network adjustment	Order 0	**Designer Consultant**
Contractor	Order 1	CP1 monuments GNSS measurements Leveling measurements Network adjustment	Order 1	**Contractor**
	Order 2	CP2 monuments GNSS and/or TS and Leveling measurements Network adjustment	Order 2	
	Order 3	CP3 targets Total Station measurements Network adjustment	Order 3	
	Micro Network	MNCP monuments GNSS and/or TS and Leveling measurements Network adjustment	Micro Network	

Figure 3. Geodetic Network Obligation Status

26. Each RB geodetic control point is assigned a unique point number, which depends on its location and hierarchical level (Table 6), numbers increase from north to south.

27. New numbering will be provided by the Client together with approval of Network Design.

28. If abbreviated numbers are used in the measurement, the report must contain a table with both the measurement numbers and the numbers of the points compiled according to the principles given in Table 6.

29. For all geodetic works, the Consultant is obliged to inform the Client about changes.

30. All data (raw data, coordinate files, drawings) shall be stored in digital form and shall be transmitted to the Client CDE immediately in an agreed manner, provided it is requested by the Client and at a frequency has been mutually agreed upon.

31. For all geodetic measurements required for the Design of the Project, RBDatum shall be used if available.

32. All geodetic measurements, calculations and drawings must be delivered in digital form and must be signed by the Consultant before being given to the Client for approval.

33. During the design and establishment phase, the Consultant must take into account the existing design of the Project, including topographical information. Corresponding information is provided by the Service.

Table 6. Point numbering

<table>
<tr><th>Country</th><th>Estonia</th><th>Latvia</th><th>Lithuania</th></tr>
<tr><td rowspan="2">Every DPS contain all level of point classes with maximum possible amount of points</td><td colspan="3">CP0 – approx. 117 points</td></tr>
<tr><td colspan="3">CP1 – 999 points
CP2 – 999 points
CP3 – 999 points
MNCP – 999 points
TEMP – 999 points</td></tr>
<tr><td>Country code</td><td>EE</td><td>LV</td><td>LT</td></tr>
<tr><td>DS code</td><td>1 – 2 – 3</td><td>1 – 2 – 3 – 4</td><td>1 – 2 – 3 – 4 – 5 – 6</td></tr>
<tr><td>DPS code</td><td>1 – 2 – 3 – 4 – 5</td><td>1 – 2 – 3 – 4 – 5</td><td>1 – 2 – 3 – 4 – 5 – 6</td></tr>
<tr><td>Control point level
*TEMP - temporary point in CP and MNCP measurements</td><td colspan="3">CP0
CP1
CP2
CP3
MNCP
TEMP*</td></tr>
<tr><td>Point sequence number in every DPS (except CP0)</td><td colspan="3">001 – 999</td></tr>
<tr><td>All assigned numbers are written with a hyphen in the following form, for example:</td><td colspan="3">LV-CP0-39 (CP0 No 39, locating in Lavia)
LV22-CP1-039 (CP1 No 39, locating in Latvia in DS2, DPS2)
LV22-CP2-039 (CP2 No 39, locating in Latvia in DS2, DPS2)
LV22-CP3-039 (CP3 No 39, locating in Latvia in DS2, DPS2)
LV22-MNCP-039 (MNCP No 39, locating in Latvia in DS2, DPS2)
LV22-TEMP-039 (temporary point No 39, locating in Latvia in DS2, DPS2)</td></tr>
<tr><td>A special letter will be added for leveling markers in case of pillar monument</td><td colspan="3">U – upper leveling marker
L – lower leveling marker</td></tr>
<tr><td>For example:</td><td colspan="3">LV22-CP2-039U (CP2 nb 39 upper levelling marker, locating in Latvia in DS2, DPS2)</td></tr>
<tr><td>If an additional CP needs to be added between existing benchmarks, then an additional letter is added with an increasing number starting from the previous CP number on the northern side</td><td colspan="3">A – Additional
1 – first point
2 – second point</td></tr>
<tr><td>For example:</td><td colspan="3">LV22-CP1-039A1 (additional point 1 between CP1 points No 39 and No 40 locating in Latvia in DS2, DPS2)</td></tr>
<tr><td>If the CP needs to be replaced (either one or both markers in the case of pillar), an additional letter is added with the modification number</td><td colspan="3">R – Replaced
1 – number of first replacement
2 – number of second replacement</td></tr>
<tr><td>For example:</td><td colspan="3">LV22-CP1-039R1 (CP1 No 39 has replaced first time by new point, locating in Latvia in DS2, DPS2)</td></tr>
</table>

7.2 Method Statement – Network Design

34. For all the above and before the commencement of the Project's design works, the Consultant is obliged to submit to Client and/or SSP for approval the Methodology for the execution of all Geodetic Works. Method Statement shall include but not limited to the information presented in Table 7.

Table 7. Method of geodetic works content for Consultant

No.	Content topics
1.	General part - Introduction
1.1	Summary description of the project
1.2	Contractual obligations
1.3	Staffing of the survey department
1.4	General description of the methodology
2.	Reference Network
2.1	Establishment & increase of networks
2.2	Existing conditions
2.3	New network requirements
2.4	Preliminary activities
2.5	Contents of the submittals
2.6	Equipment
2.7	Solution methods, precision
2.8	Software
2.9	Maintenance
3.	Theoretical data
3.1	General description
3.2	Requirements
3.3	Software
3.4	Submittals
3.5	Forms
3.6	Approvals

No.	Content topics
3.7	Files
4.	Construction works
4.1	General description
4.2	Requirements
4.3	Methods
4.4	Equipment
4.5	Materials
4.6	Approvals
4.7	Submittals
5.	Measurements
5.1	General description
5.2	Requirements
5.3	Methods
5.4	Equipment
5.5	Software
5.6	Forms
5.7	Approvals
5.8	Submittals
6.	Health & safety
6.1	General description
6.2	Equipment
6.3	Conditions
6.4	Transportation
7.	Exchange of data with the Client/Service
7.1	General description
7.2	Templates of electronic files
7.3	Forms

No.	Content topics
7.4	Frequency
7.5	Storing
7.6	Archiving

35. Network Design shall be inspected and approved by the Service within regular time periods to be agreed upon, based on the progress of the construction works.

36. The completeness of the measurement methodology is an essential factor, to timely resolve any possible deficiencies and problems that may affect the operation of the monitoring system of the DTD survey works. Therefore, the submitted methodology must be approved by the Client/Service and any eventual comments must be considered by the Consultant. The recording of the results and the filing is performed based on the project's segmentation into Sections, as specified in advance. Data shall be provided according to RB Rail Design Guideline requirements. It is evident that the structure of the documents' filing system must be accompanied by the appropriate digital data format for the purpose of the correct and immediate data exchange with the Client.

7.3 Primary Network CP0

7.3.1 Selection of benchmark locations

37. The Primary Network CP0 is the highest precision, primary level Geodetic Network of the Project for the following tasks:

    (a) it is the connection between the RBDatum Geodetic Network and each country's National Geodetic and Vertical Networks;

    (b) it is the most accurate of all networks related to the Project (Order 1-3, MNCP);

    (c) all activities including densification of networks rely on the CP0 network;

    (d) it will be the asset that will remain for all stages of the project - construction & operation & maintenance.

38. CP0 geodetic network should be delivered by the Consultant.

39. In order to create a RBDatum unified Geodetic and Vertical Networks of Order 0 (if not existing) along Rail Baltica railway line, existing national network benchmarks shall be investigated in the DTD stage, and if densification is needed, new geodetic benchmarks shall be designed, constructed, measured and re-integrated into the network.

40. To ensure the highest precision required for high-speed railway construction, the DTD Designer and/or Contractor (depending on project status) must immediately inspect and replace damaged or destroyed CP0 geodetic benchmarks, including benchmark construction, measurements and calculation works.

41. Primary geodetic network benchmarks have to be available for at least 30 years. Therefore, at all stages of the design, information on the established primary geodetic network points must be provided to check possible inconsistencies between the location of the point and the design.

42. CP0 benchmarks will be established along the railway corridor at intervals of approximately 5 - 10 km, at a distance of 2 - 10 km away from the alignment, at easily accessible locations and outside the influence zone of the Rail Baltica Project or related roads (Figure 2).

43. The locations of all CP0 benchmarks must be suitable for high precision static GNSS measurements and high-precision geometric levelling.

44. When selecting the location of the benchmarks, it must be ensured that a GNSS network formed by triangles can be established between them.

45. For GNSS measurements, it must be ensured that the horizon of the benchmark is open above 10 - 15°, and there are no sources of electromagnetic radiation nearby.

46. To ensure levelling, it is important that the levelling line can be built in such a way that it does not decrease the measurement precision (e.g. due to large height differences, soft soil, etc) and that it is possible to place a 3 m long levelling rod vertically on the mark.

47. When using existing benchmarks, it must be ensured that they are equipped with anchors and that the anchors are located below the freezing layer of the soil.

48. When using existing benchmarks, it must be ensured that the marker is equipped with an definable centre mark so that the levelling rod can be placed unambiguously on the mark.

49. When choosing the location of the benchmark, access and the preservation of the mark as long as possible are taken into account.

50. When choosing the location of the benchmark to be built, preference is given to the distribution areas of sedimentary bedrock, moraine or a coarse-grained sand.

51. Higher places and low groundwater level are preferred when choosing the location of the benchmarks to be built.

52. The locations of these benchmarks shall be defined in cooperation with the Client.

7.3.2 CP0 Geodetic Network

53. The network shall be connected to at least three (3) points of the closest RB own (if available) Continuously Operating Reference Stations (CORS) or EstPos, LatPos, LatRef, LitPos (if they are available) or Private CORS included to the State Geodetic Points Database (Figure 4).

54. CP0 points shall be measured using Relative Static GNSS measurement method. The use of all other GNSS measurement methods is prohibited.

55. The standard deviations of the planar position of the CP0 points and the standard deviation of the ellipsoidal heights obtained from the least squares adjustment must not exceed ±10 mm.

56. CP0 Network GNSS measurements shall be carried out according to the following conditions:

(a) measurements are designed in such a way that only so-called independent GNSS vectors belong to the network - in each session where "n" number of GNSS receivers participate, there are "n - 1" number of independent GNSS vectors;
(b) wherever possible, a network consisting of triangles should be formed from independent vectors;
(c) GNSS antennas are oriented towards the north during measurements;
(d) the cut-off angle of GNSS signals is 10 degrees;
(e) the maximum recording interval of GNSS signals is 5 seconds;
(f) in the measurements a wooden tripods and rotatable centering devices equipped with cylindrical plummets which mean square error of centering does not exceed ±0.5 mm are used;
(g) in the event that several consecutive measurement sessions are performed on a same benchmark, the GNSS antennas are re-centered between sessions and different sets of GNSS measurement equipment are used where possible;
(h) in the course of GNSS measurements, field reports are filled in, where point number, point name, session date (format: yymmdd), session number (consecutive sessions of one day are denoted by A, B, C, etc), session start time, session end time, GNSS receiver serial number, GNSS antenna serial number, operator's name, operator's signature, measured antenna height with information whether the slant or vertical height was measured and to which antenna element it was measured are entered;
(i) baseline lengths between CP0 to CORS should remain 15 - 20 km in maximum. Baseline lengths between CP0 to National Geodetic Network points, if they are included, should remain under 15 km;
(j) the PDOP value should be less than 5;
(k) the minimum duration of GNSS measurement sessions is 2 hours. At least 2 measurement sessions are performed on the mark to be determined.

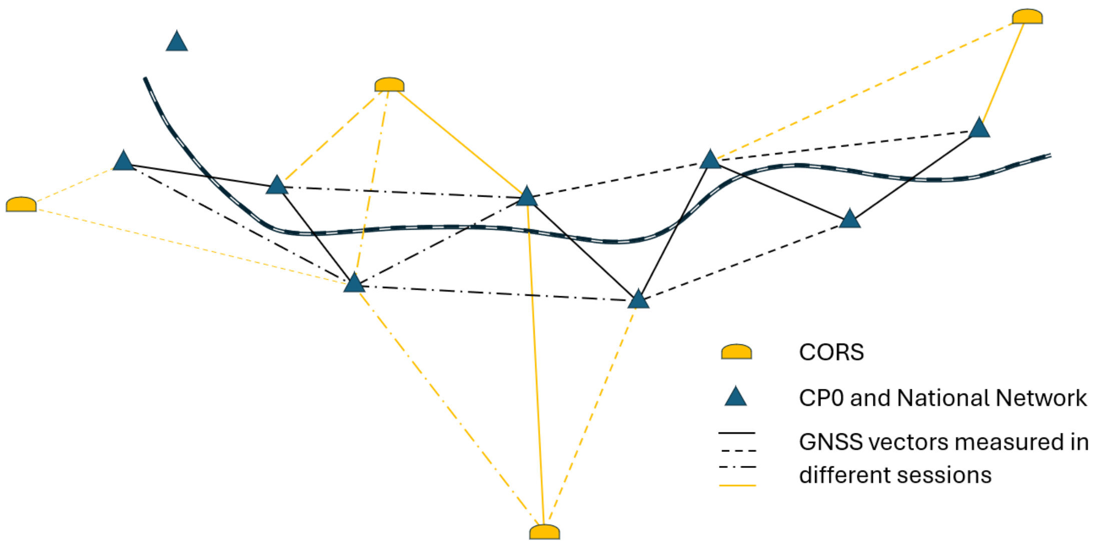


Figure 4. A basic example of a CP0 GNSS network fragment

57. In order to achieve the desired precision estimates, it is necessary to follow the following criteria:

   (a) the GNSS instruments must have the ability to receive at least signals from the GPS, Galileo and GLONASS satellite systems;

   (b) the receiver performance, precision, for static GNSS measurements shall be for the horizontal component of the coordinates ±3 mm + 0.1 ppm or better and for the vertical component ±5 mm + 0.5 ppm or better;

   (c) in the measurements GNSS antennas, whose multipath reduction properties, antenna sensitivity, mounting accuracy of antenna elements, etc. are in accordance with the requirements of high-precision GNSS measurements, are used; Choke ring antennas are preferred;

   (d) GNSS antenna phase centre precision must be ±2 mm or better;

   (e) the absolute calibration parameters of the antenna type must be known.

58. All the raw measurement data should be delivered to the Client for review and/or for Postprocessing and Adjustments', unless otherwise stipulated in the procurement documents.

59. The following should be considered when processing GNSS measurements:

   (a) The information about software and methodology to be used shall be submitted to the Service for prior approval.

   (a) GPS, GLONASS and Galileo satellite navigation system signals are used in GNSS vector calculation;

   (b) in the GNSS data processing, the final, precise satellite orbits and clock corrections are used;

   (c) in the Network Design and Report, the ionospheric and tropospheric models used and the way they are implemented are described;

   (d) the linear combinations used in vector calculations are chosen based on the lengths of the vectors;

   (e) when different type of GNSS antennas are used, constant and GNSS signal direction-dependent corrections of their phase centres are taken into account using the calibration parameters given in the ANTEX (Antenna Exchange Format) file of the International GNSS Service (IGS);

   (f) during vector calculations, the ambiguities are solved;

   (g) the network formed from GNSS vectors is adjusted using the least squares method;

   (h) adjustment calculations are carried out in the three-dimensional Cartesian coordinate system;

   (i) To separate the testing of observations and known, initial, stations, the adjustment of a network is subdivided into two separate steps or phases:

      - free network adjustment;
      - constrained adjustment.

   (j) statistical tests (e.g. F-test, W-test, T-test, etc) are used to identify gross and systematic measurement errors (incl. possible inaccuracies in the initial points) and to assess the reliability of the results;

   (k) final coordinates and ellipsoidal heights must be given showing to 4rd decimal.

60. The information about GNSS system and the software to be used shall be submitted to the Service for prior approval.

7.3.3 CP0 Levelling Network

61. CP0 Levelling Network should be delivered by the Consultant.

62. All the raw data of the measurements should be delivered to the Client for review and/or for Postprocessing and Adjustments' control, unless otherwise stipulated in the procurement documents.

63. The levelling lines are designed with the consideration that they run on solid ground and areas with a slight slope.

64. The identification of the points of the levelling network shall be permanent and, in a way, ensuring their preservation during the construction of the Project, as well as for their future use.

65. The levelling network will be measured by means of geometrical double-run foot levelling and will be connected to each country's National Levelling Network. Moreover, it shall consist of an adequate number of loops, to ensure the maximum possible redundancy in the adjustment phase.

66. The geometric levelling lines in each country shall be fully constrained at least on both ends to the levelling benchmarks of the existing National Levelling Networks of highest order and/or neighbouring DTD, RBR benchmarks if available. The connection to the National levelling networks shall be done with additional double-run levelling lines. For control purposes, it is recommended to measure additional interconnects wherever benchmarks of National Levelling Networks are nearby.

67. The levelling lines shall pass over Order 0 benchmarks, heading from the beginning to the end of the DTD project, and connecting each benchmark with its previous and next. If additional benchmarks need to be built, they must comply with the precision of levelling. Other existing benchmarks can be used additionally if the alignment of the levelling rod is guaranteed to be uniform on the marker.

68. The instruments to be used shall be high precision digital levels, with a precision not worse than ±0.3 mm per 1 km double run, along with their corresponding invar rods to achieve the precision required. Instrument specifications shall be submitted to the Service for approval. The levelling instrument should be checked at least once a day, according to the temperature variations during the day.

69. The length of a sight must not exceed approx. 30 meters.

70. A massive wooden tripod is used for levelling, the leg lengths of which are not adjustable.

71. Three meter long invar barcode rods are used for levelling. In case it is not possible to place a 3 meter rod vertically on the geodetic mark, 2 and 1 meter long invar barcode rods can be used as an exception.

72. When levelling, it is allowed to use an invar levelling rod with an extended base made at the factory by the manufacturer. The use of a removable base extension is not permitted.

73. A metal piles with a round end is used as a bases for the rod in the levelling connection points.

74. Levelling order at stations:
    (a) odd numbered station BFFB (back-fore-fore-back);
    (b) even numbered station FBBF (fore-back-back-fore).

75. There is an even number of measuring stations in the section. In the case of geodetic marks located in close proximity, there may be one measuring station. In such a case, the condition is to use the same bar on both marks.

76. When levelling the levelling instrument at the station, it is always directed towards the same levelling rod.

77. Levelling is carried out in forward and backward directions. The forward and backward levelling of the section takes place at different times of the day, also in case of partly cloudy weather.

78. The sections in the levelling line are levelled in a changing direction – the sections of the first measurement day are levelled in the direction of the line, the sections of the second measurement day are levelled in the direction opposite to the line (direction B), the sections of the third day again in the direction of the line (direction A), etc.

79. Levelling starts no earlier than one hour after sunrise and ends no later than one hour before sunset.

80. In sunny weather, levelling is not carried out at the time period from two hours before to two hours after noon.

81. To achieve quality measurements bad weather conditions such as heat haze, heavy wind and rain or fog, should be avoided when observations are made.

82. When levelling the section in the opposite direction, the positions of the levelling rods are changed, i.e. another rod is placed on the benchmark.

83. All measuring devices use only the standard time.

84. Earth curvature, refraction, etc corrections are not automatically applied during levelling - the corresponding functions are turned off in the levelling instrument.

85. The back-sight and fore-sight length at the station must not differ by more than 0.5 m, and the sum of the differences in the section cannot exceed 1.0 m.

86. Height differences at station must not vary by more than 0.1 mm.

87. The maximum allowable difference between forward and backward levelling runs in a sections is 1.0 mm√km. In case of higher differences, the measurements must be repeated. The assess-

ment of differences with the height values of the National Networks is carried out during the adjustment procedure of the entire levelling line or certain part of it.

88. The following should be considered when processing levelling measurements:

    (a) the information about software and methodology to be used shall be submitted to the Service for prior approval.
    (b) adjustment calculations must be performed using the least squares method.
    (c) the average values of the height differences measured in the forward and backward direction are included in the adjustment calculations.
    (d) before adjustment calculations, appropriate corrections are made to the levelled height differences.
    (e) to separate the testing of observations and known, initial, stations, the adjustment of a network is subdivided into two separate steps or phases:
        - free network adjustment;
        - constrained adjustment.
    (f) statistical tests (e.g. F-test, W-test, T-test, etc) are used to identify gross and systematic measurement errors (incl. possible inaccuracies in the initial points) and to assess the reliability of the results;
    (g) final height values must be given showing to 4th decimal.

7.4 Construction of new geodetic benchmarks

89. The construction of new CP geodetic benchmarks and the materials used depends on the type of geodetic network and the characteristics of the soil at the location of the geodetic mark, which is determined in the Network Design stage.

90. The anchor of the CP0 – CP2 benchmarks, except for the marks to be anchored to the bedrock, must be placed below the freezing layer of the soil.

91. In the distribution areas of sedimentary bedrock, benchmarks are established without an anchor. When installing a mark, a hole must be dug, loose layers must be removed and a hole, at least 200 mm in depth and at least 100 mm in diameter, must be drilled for anchoring the mark with concrete.

92. In the case of clayey or stony soil, sand is used for backfilling when installing a benchmark to be built into the soil.

93. The soil around the casing pipe or center rod is compacted.

94. In poor soil conditions (marshes, bogs and flooded areas), benchmark types with a crown or anchor drilled with threaded pipes to the bearing subgrade, must be used for the CP1 – CP3 networks. Poor soil conditions are not allowed for CP0 locations.

95. The CP0 benchmark to be built into the soil is installed with the assumption that it would have passed the autumn-winter-spring time period before the measurement. For frequently measured CP benchmarks, CP1 – CP2 and MNCP, the minimum stabilization period between installation and measurements is two weeks.

96. Any benchmark constructed must be able to keep results within the tolerances listed in Table 8.

Table 8. Acceptable positional deviations of the geodetic benchmark in the horizontal and vertical directions

Point class	Horizontal precision [mm]	Vertical precision [mm]
CP0	±2	±1
CP1	±2	±1
CP2	±2	±2
MNCP	±2	±1

97. The basic construction specifications of the CP0 – CP2 benchmarks are given in Annex 2. The preferred CP0 benchmark type is type 2. Benchmark type 3 is not allowed for new CP0 and CP1.

98. The identification of the geodetic benchmarks shall be permanent and, in a way, ensuring its preservation during the construction of the Rail Baltica project, as well as for their future use. CP0 control benchmark shall be marked according to following specifications:

   (a) an identification post(s) (steel, concrete or plastic) have to installed for external decoration, to which an identification label have to added;
   (b) protective fence (steel or plastic) have to installed to secure the benchmark and identification post.

99. The types of identification posts and protective fences need to approved with Service and other necessary institutions.

100. In addition, the legislation of the specific country where the work is performed, must be taken into account when building and marking new benchmarks.

101. For CP benchmarks, information needed for compilation of Point Cards must be collected. The collection of information must be based on the requirements of the Client/Service and local legislation.

102. The post-construction positions of installed CP0 geodetic benchmarks are determined with a standard deviation that does not exceed ±0.1 m.

103. The geotagged photos of the fabrication of the centers, the completed mark, and the various stages of benchmark installation must be taken.

104. The design life of CP0 – CP2 benchmarks must be at least 30 years.

7.5 Documentation of the CP0 geodetic works

105. The geodetic works described in these requirements must be documented in accordance with the requirements of the Service. In addition, the relevant legislation of the specific country where the work is performed, if any, must be taken into account.

106. In the course of the works a report shall be compiled in English and submitted to the Client/Service in a digital form.

107. Benchmark Construction Report contain:

(a) explanation letter with description of construction and installation details, the information must be provided in MS Word and in PDF format;

(b) overall map with installed CP0 point locations, the information must be provided in CAD and in PDF format;

(c) drawings of benchmark types;

(d) overview table with detail description of CP0 points, preliminary coordinate table, location schemes (approx. 40 m around the CP0 benchmark in scale M 1 : 500) and panoramas (sky plots). The information must be provided in MS XLSX, PDF, JPEG, DWG format;

(e) all relevant data on construction and installation stages (like used materials, machinery, etc);

(f) photos of benchmark construction and installation as following:

- photos of each stage of the benchmark fabrication process (at least 3 pcs), in stationary conditions or on site;
- geotagged photos of each stage of the benchmark installation process (at least 3 pcs.) on site;
- geotagged photos of each installed benchmark (3 pcs) - photo of benchmark marker, close-up photo of the benchmark, photo of benchmark from a distance;
- all photos must be logically catalogued according to point numbers and work stages.

108. Measurement Report contain:

(a) explanation letter with description of measurement details, precisions and achieved results. The information must be provided in MS Word and in PDF formats;

(b) overall measurement schemes (GNSS, traverse, geometric levelling), incl. CP0 point locations, the information must be provided in CAD and in PDF formats;

(c) list of measuring instruments (type, number and specifications);

(d) results of the inspection and calibration of the measurement instruments;

(e) description of measurement methodology, incl. corrections applied;

(f) list of initial points for the horizontal and vertical control;

(g) network adjustment reports, including results of statistical tests and estimates of precision (for points and relative precision);

(i) measurement data in native and ASCII formats (for GNSS in the RINEX format), and if necessary, corrected versions.

109. Data Processing Report contain:

(a) explanation letter with description of measurement and data processing details (incl. corrections), precisions and achieved results. The information must be provided in MS Word and in PDF formats;

(b) overall measurement scheme, incl. CP0 point locations, the information must be provided in CAD and in PDF format;

(c) description of Reference and Height Systems, Map Projection and sources (official documentation of the reference systems used);

(d) final, cleaned project files (GNSS vector calculation, GNSS adjustment, levelling adjustment) of adjustment software;

(e) table containing necessary information for point locations, coordinates and heights of the points; the information must be provided in MS XLSX, MS Word and PDF formats;

(f) all adjustments data in native and pdf format.

7.6 Construction supervision of the CP0 geodetic network

110. To ensure the quality of Geodetic Reference System, Height System and control network Client shall inspect the chosen Reference System, Height System and the control network.

111. In accordance to high speed railway construction accuracy requirements and scope of work defined in respective local law, Client shall perform all necessary tasks to ensure that the quality of Geodetic Networks is in accordance to all applicable laws and standards for constructing highspeed railway.

112. The main tasks (not limited to) that Client is obligated to perform before construction works:

(a) get design solutions defined by the requirements for establishing a geodetic network;

(b) to develop quality control system of geodetic works in accordance with the specifics and scope of the geodetic works to be performed;

(c) to get acquainted with Designer/Consultant developed work execution plan and quality assurance plan for geodetic works; in case of any discrepancies with respective national requirements and design solutions, object such Designer/Consultant 's proposals and give notification to the Client;

(d) review, approve and provide opinion for Designer/Consultant network design before beginning of works;

(e) verify imposed standards and regulations;

(f) check and coordinate the compliance of the Designer's /Consultant 's subcontractors with the Contract terms;

(g) check and verify calibration certificates of instruments used for geodetic measurements, inform the Consultant about the use of non-compliant equipment;

(h) to review and approve Designer/Consultant method of statement.

8 References

8.1 Standards

ISO 17123 Optics and optical instruments. Field procedures for testing geodetic and surveying instruments:

— Part 1: Theory

— Part 2: Levels

— Part 3: Theodolites

— Part 4: Electro-optical distance meters (EDM measurements to reflectors)

— Part 5: Total stations

— Part 6: Rotating lasers

— Part 7: Optical plumbing instruments

— Part 8: GNSS field measurement systems in real-time kinematic (RTK)

— Part 9: Terrestrial laser scanners

EN 13848 - Standard: Railway applications - Track - Track geometry quality:

— Part 1: Characterization of track geometry

— Part 2: Measuring systems - Track recording vehicles

— Part 3: Measuring systems - Track construction and maintenance machines

— Part 4: Measuring systems - Manual and lightweight devices

— Part 5: Geometric quality levels - Plain line

— Part 6: Characterisation of track geometry quality

EN 13231 Railway applications - Track - Acceptance of works:

— Part 1: Works on ballasted track - Plain line, switches and crossings

— Part 2: Acceptance of reprofiling rails in plain line, switches, crossings and expansion devices

— Part 3: Acceptance of reprofiling rails in track

— Part 4: Acceptance of reprofiling rails in switches and crossings

— Part 5: Procedures for rail reprofiling in plain line, switches, crossings and expansion devices

8.2 Local norms

All local norms and guidelines that regulate geodetic works in Estonia, Latvia and Lithuania.

8.3 Applicable Guidelines

RBDG-MAN-039-0101 - Geodetic Network establishment for Construction stage of Rail Baltica high speed railway

RBDG-MAN-030-0106 - Building Information Management (BIM) Employer's Information Requirements

RBDG-MAN-033-0102 - BIMManual

RBGL-DMT-PRC-Z-00001 - Document Numbering and File Naming Procedure

RBGL-DMT-LST-Z-00001 - Document Numbering and Master Coding

RBDG-MAN-034-0101 - CADStandards

9 Annexes

Annex1. Detailed Technical Requirements

Table 9. GNSS Method vs Geodetic Network Order level

Order (CP)	0	1	2	3	4 (MNCP)
Static	✓	✓	N/A	N/A	-
Guide to minimum station spacing km [1]	5	1.0	N/A		N/A
Typical station spacing in km [2]	7-10	1.5-2	N/A		N/A

Table 10. Traverse Measurement Requirements

Order (CP)	0	1	2	3	4 (MNCP)
Number of full sets of measurements	N/A (only GNSS measurements)		4	6	4
Move prisms between sets			Yes	Yes	Yes
Difference between half sets			≤ 6“	≤ 10“	≤ 6“
Difference between full sets			≤ 3“	≤ 5“	≤ 3“
Allow minimum warm up time			Yes	Yes	Yes
Graduation Interval			≤0.2 °C	≤0.2 °C	≤0.2 °C
Instrumental precision of air temperature			≤0.2 °C	≤0.2 °C	≤0.2 °C
Estimate air pressure to			≤0.3 hPa	≤0.3 hPa	≤0.3 hPa
Relative humidity readings			Optional	Optional	Optional
Meteorology before and after measurements			Yes	At time of observations	Yes
Reciprocal vertical angles			Yes	Optional	Yes
Traceable calibration (incl. the differences between the etalon and the measurement result) of EDM and Prisms with a interval of 1 year			Yes	Yes	Yes

[1] **Guide to minimum station spacing in km:** minimum distance between stations on the same level of points.

[2] **Typical station spacing in km:** typical distance between stations on the same level of points.

Table 11. Electro-Optical EDM Reduction Procedures

Order (CP)	0	1	2	3	4 (MNCP)
Additive constant correction	N/A		Yes	Yes	Yes
Reflector additive constant correction			Yes	Yes	Yes
Cyclic error correction			On demand	On demand	On demand
Frequency correction			Yes	Yes	Yes
Air pressure correction			Yes	Yes	Yes
Air temperature correction			Yes	Yes	Yes
1st velocity correction (atmospheric correction)			Yes	Yes	Yes
Arc to chord correction (beam curvature correction)			Yes	Yes	Yes
Chord to chord correction (combined slope & geoid level)			Yes	Yes	Yes
Geoid to ellipsoid correction			Yes	Yes	Yes

Table 12. Levelling Measurement Methodology

<table>
<tr><th>Order (CP)</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4 (MNCP)</th></tr>
<tr><td>Instrument leveled by "unsystematic" method [3]</td><td>Yes</td><td colspan="2">Yes</td><td rowspan="10">trigonometric levelling, precision of heights ±1 mm</td><td>Yes</td></tr>
<tr><td>"Leap-frog" system of measurement used [4]</td><td>Yes</td><td colspan="2">Yes</td><td>Yes</td></tr>
<tr><td>Staff readings recorded to nearest</td><td>0.01 mm</td><td colspan="2">0.01 mm</td><td>0.1 mm</td></tr>
<tr><td>Temperature recorded</td><td>Continuous</td><td colspan="2">At start and finish of each leveling run and at pronounced changes of temperature</td><td>At start and finish of each leveling run and at pronounced changes of temperature</td></tr>
<tr><td>Maximum allowable length of sight</td><td>30 m</td><td colspan="2">40 m</td><td>50 m</td></tr>
<tr><td>Minimum height of line of sight</td><td>0.7 m</td><td colspan="2">0.5 m</td><td>0.5 m</td></tr>
<tr><td>Back-sight and fore-sight length to be equal within single setup/total in section</td><td>0.5 m/1 m</td><td colspan="2">0.5 m/1 m</td><td>1 m/2 m</td></tr>
<tr><td>Observing times</td><td>Starts no earlier than one hour after sunrise and ends no later than one hour before sunset; in sunny weather it is not carried out between two hours before and two hours after noon</td><td colspan="2">Starts no earlier than one hour after sunrise and ends no later than one hour before sunset; in sunny weather it is not carried out between one hour before and one hour after noon</td><td>Not restricted</td></tr>
<tr><td>Double-run leveling</td><td>Yes</td><td colspan="2">Yes</td><td>Yes</td></tr>
<tr><td>Even number of instrument set-ups between benchmarks</td><td>Yes</td><td colspan="2">Yes</td><td>Yes</td></tr>
</table>

[3] **Unsystematic** method of levelling: when levelling, the automatic levelling instrument should always pointed towards the same staff-man who will be „leap-frogging" each instrument set-up.

[4] **Leap-frog System:** "Leap-frog" levelling involves the one staff remaining at a particular change point for both sightings, the same staff is used for the first back-sight and the last fore-sight of each levelling run to avoid staff index error. This method assumes an even number of stations.

Order (CP)	0	1	2	3	4 (MNCP)
Minimum number of holding marks used for temporary suspension of levelling	3, overlapping marks re-leveled within 1 mm	Not be suspended	Not be suspended		Not be suspended
Maximum allowable difference (mm) between forward and backward levelling runs in section[5]	1.0√d	1.5√d	1.5√d		3√d
Minimum number of initial/connection benchmarks	3	3	2		2

[5] **d** is the distance in kilometres between benchmarks

Table 13. Levelling Equipment Testing

ORDER (CP)	0	1	2	3	4 (MNCP)
Traceable calibration of levelling system prior to commencement (eg ISO, or DIN)	Yes	Yes	Yes	N/A (only trigonometrical leveling)	Yes
Maximum standard error in the slope of the line of sight as determined by the system test	Spirit level: 1"/2mm run digital: 0.4" setting accuracy	Spirit level: 1.5"/2mm run Automatic or digital: 0.4" setting accuracy	Spirit level: 4"/2mm run Automatic or digital: 0.8" setting accuracy		Spirit level: 1.5"/2mm run Automatic or digital: 0.4" setting accuracy
Vertical collimation check (eg. Two-Peg test), Maximum collimation error	Daily, 2" or 0.3 mm over 30m (digital levels can Store the results)	Daily, 2" or 0.8 mm over 80 m	Daily, 4" or 1.5 mm over 80 m		Daily, 2" or 0.8 mm over 80 m
Level cross-hair verticality check	Yes	Yes	Yes		Yes
Levelling system calibration frequency	Immediately prior to commencement of levelling, and at 1 year intervals while in continued use				See Order 1
Staff bubble verticality to be within	5'	10'	10'		10'
Thermometers accurate to	0.5°C	1°C	1°C		1°C

Annex2. Benchmark constructions

Type 1

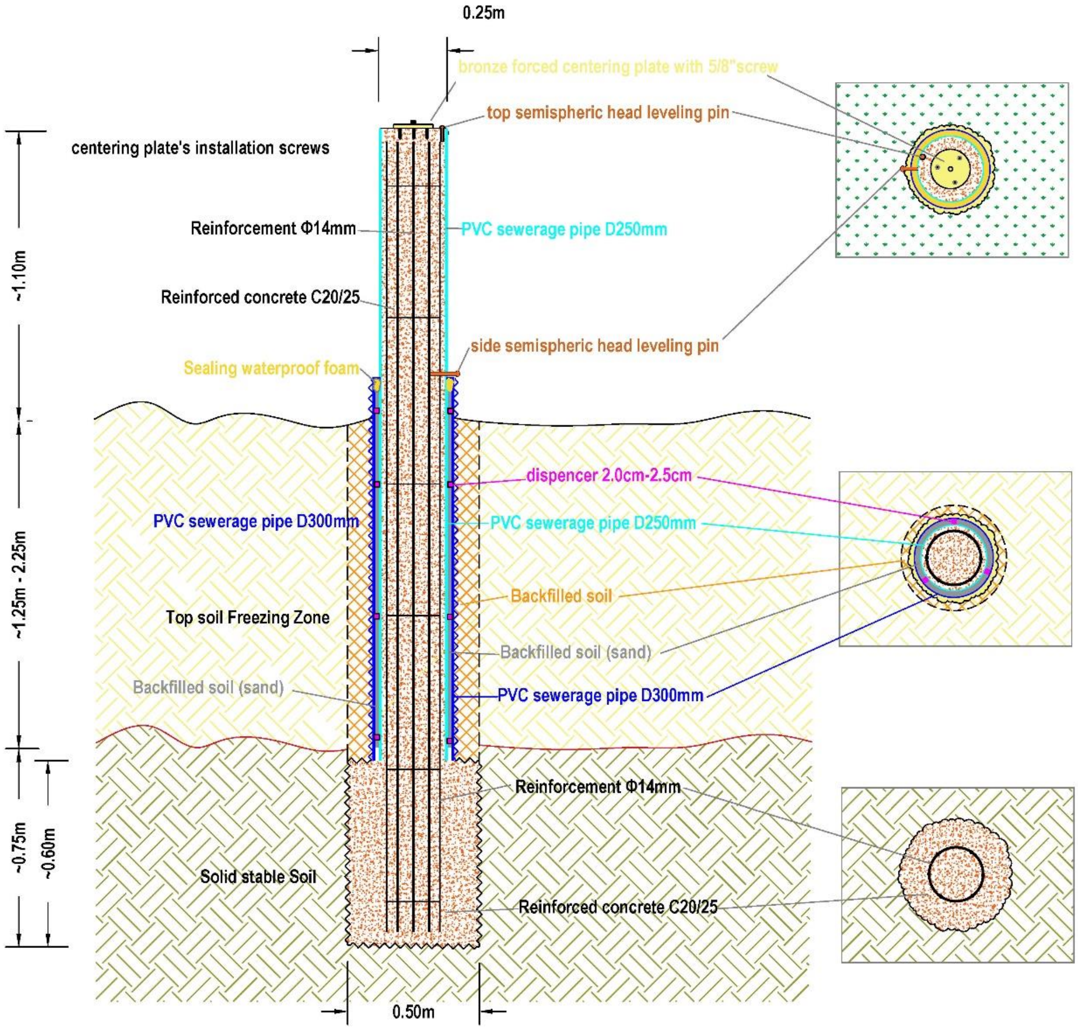


Figure 5. Benchmark type 1

TECHNICAL SPECIFICATIONS & INSTALLATION METHOD STATEMENT

Purpose of this type of monument is to create a stable, easy to use and long-lasting RB Geodetic Reference Network benchmark for high precision GNSS and levelling measurements.

Monument shall be constructed in such way to be well anchored in soil below the freezing layer of soil practically not affected by this phenomenon.

A forced centering plate is attached to the top of monument, to setup a tribrach of total station or GNSS receiver eliminating centering errors or malfunctions of tribrach, as well as to assist surveyors for fast and stable setup of the equipment.

TECHNICAL SPECIFICATIONS

113. Reinforced Concrete C20/25 pillar of 25 cm diameter

114. Height above ground L1=~ 1.10 m

115. Anchoring depth below lowest freezing layer L3= ~0.75 m

116. Protected part between ground and lowest freezing layer L2=~1.25 m depending on thickness of the freezing zone at the spot.

117. Steel reinforcement at pile shape caging, with 8 rebars of 14 mm diameter and length of L1+L2+L3.

118. PVC cylindrical sewerage pipe of 25 cm diameter and length of L1+L2

119. PVC cylindrical sewerage pipe of 30 cm diameter and length of L2

120. PVC dispensers of 2.0 cm~2.5 cm, placed in the gap between the 2 PVC pipes.

121. Bronze centering plate, with bolt of 5/8" with universal thread, suitable for tribraches.

122. Centering plate bolt thread length shall be between 1.0 cm and 2.0 cm

123. Centering plate diameter shall be 16 cm

124. Levelling pin with semispherical head shall be placed between the centering plate and the edge of pillar, ideally at 10 - 12 cm from the centering bolt.

125. Protective metal or plastic cap for the thread of the centering bolt.

INSTALLATION METHODOLOGY

126. Drilling with proper machinery a > 50 cm diameter vertical hole to a depth of L2+L3 meters.

127. Placement of the rebar cage till the bottom of the excavation. The remaining overground part shall be not more than 1.10 m.

128. Pour the C20/25 concrete in the pile hole, ideally with using a pipe to avoid separation of concrete materials for a length of L3 above the bottom, to reach the freezing zone lowest level. Concrete shall be vibrated, to tight up with the soil and the whole structure to be anchored to the stable soil.

129. Attaching the dispensers at the outer and lower part of the small diameter PVC pipe for the length of L2.

130. Sinking the 25 cm diameter PVC pipe, so to include the rebar cage, to the top of the poor concrete. The top of the 25 cm pipe shall be ~1.10 m higher than the ground level.

131. Sinking the 30 cm diameter PVC pipe, as an external sleeve to include the 25 cm PVC, to the top of the poor concrete. The top of the 30 cm pipe shall be at the ground level.

132. If there is gap between the soil and external PVC pipe, it shall be filled with sand or very thin aggregate.

133. Filling the 25 cm PVC pipe with C20/25 concrete to the top.

134. Level and smoothen the surface of the concrete to prepare for the installation of the centering plate and leveling pin.

135. Depending on the type of centering plate, it can be installed when the concrete is still fresh (if the plate has anchors, see Picture 2), or when dry (if the plate has installation screws, see Picture 1).

136. When the concrete is fresh, the leveling semispherical head bolt shall sink in concrete leaving only the head on the surface.

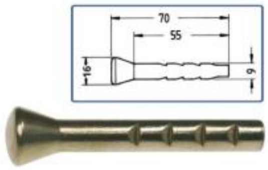
137. At a low level of the pillar, when concrete is dry, a second levelling pin (similar to the top one, Picture 3) shall be installed perpendicular to the pillar. Installation shall be by drilling and using epoxy glue to stabilize the pin.

138. Special care shall be taken to seal from water entrance the gap between the 2 PVC pipes, at the top of the 30 cm PVC pipe.

139. The number of each pillar shall be marked with color using 10 cm height font and text stencils (see Picture 4).

Picture 1

Picture 2



Picture 3

Picture 4

Type 2

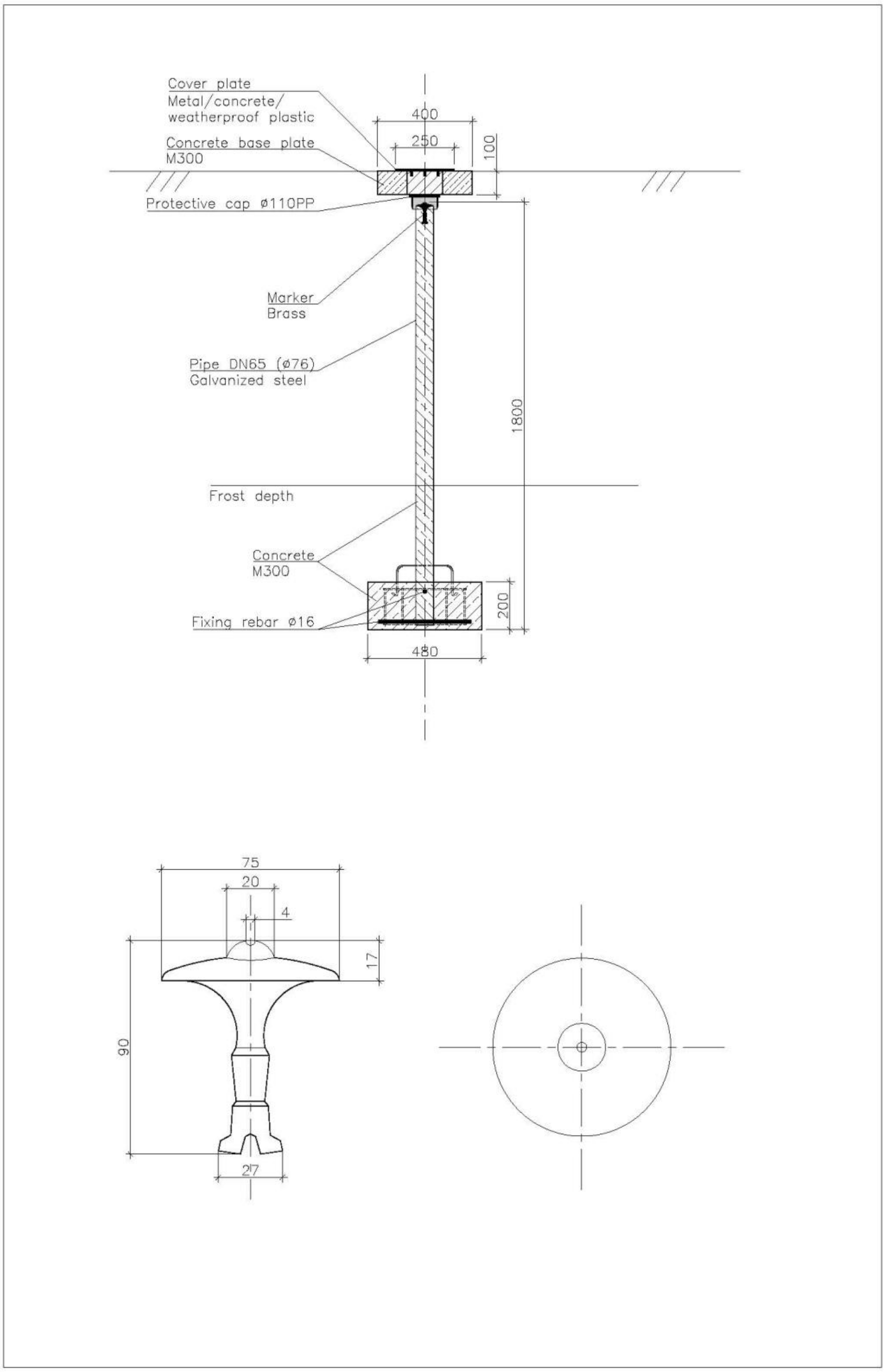


Figure 6. Benchmark type 2

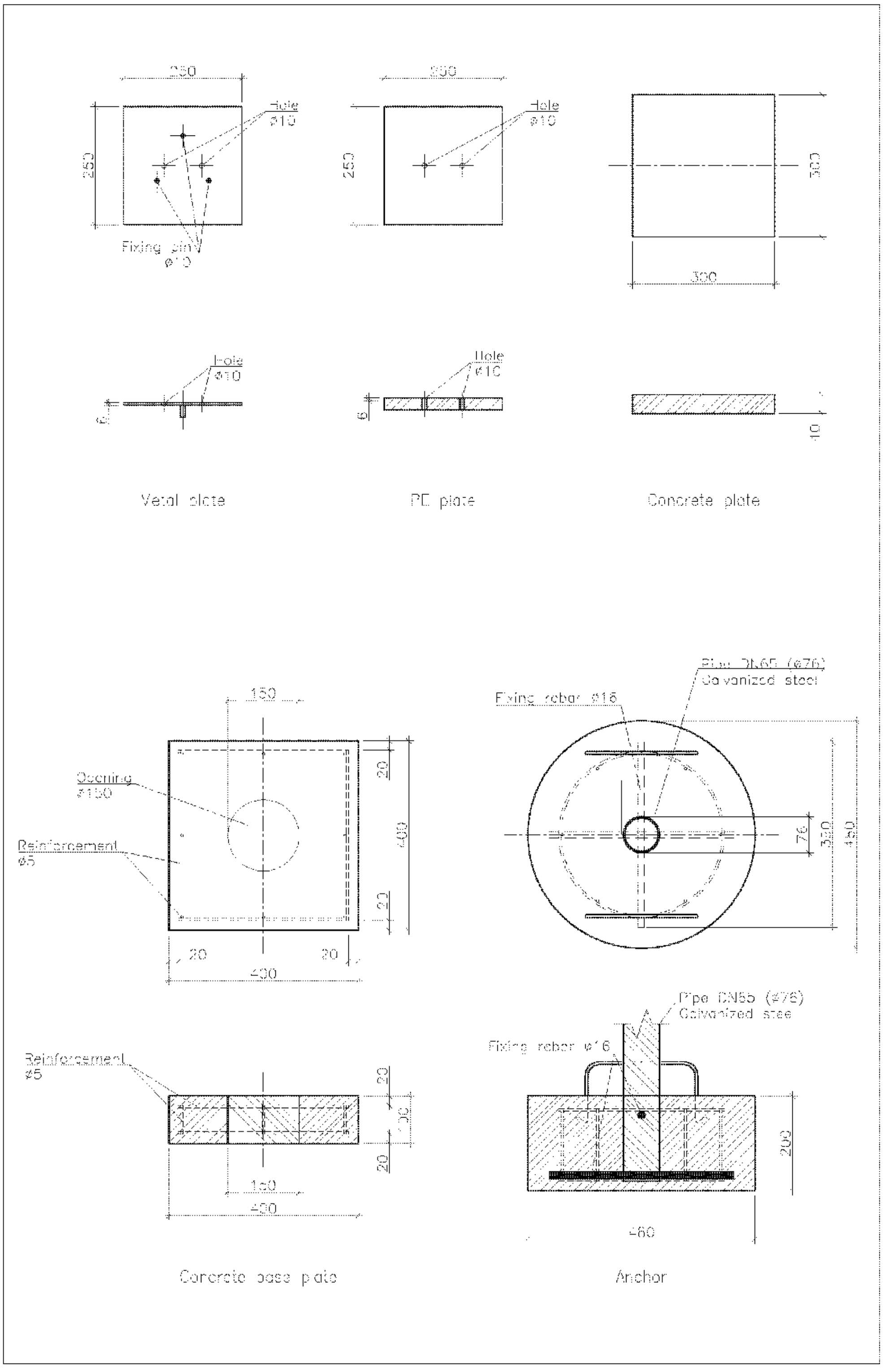


Figure 7. Benchmark type 2, construction details

TECHNICAL SPECIFICATIONS & INSTALLATION METHOD STATEMENT

This mark type is the basic type for CP0 network. It can be installed by both digging (preferred) and drilling methods, depending of the soil.

TECHNICAL SPECIFICATIONS

140. To ensure homogeneous quality, the benchmark must be produced under stationary conditions (workshop).

141. The mark consists of a casing pipe, and an anchor.

142. The casing pipe is made of a calvinized steel pipe with an outer diameter of 76 mm. The length of the casing pipe is 1.5 m - 2 m depending on the depth of the freezing layer.

143. The casing pipe is attached to the anchor with two fixing irons (reinforcing iron Ø 16 mm, *L* = 420 mm). The diameter of the circular anchor is 480 - 500 mm, height 200 mm. The reinforcement of the anchor is passivated with a primer and a concrete layer at least 20 mm thick. Rebar loops with a diameter of 5 mm are installed in the anchor.

144. The casing pipe is filled with non-shrinking concrete mix M 300. The anchor is made from the same concrete mix. During concreting, a corrosion resistant (brass, stainless steel) dial GOECKE GmbH & Co MESSUNGS-PUNKT or similar, is placed at the top of the casing pipe so that the top surface of the dial is flush with the edge of the casing pipe. The casing pipe and the anchor are concreted together, the concrete mixture is compacted by vibration.

145. After the concrete mixture hardens, the gaps between the main mark (from bronze) and the jacket tube and dial are sealed with Casco Marin&Teknik 4062 sealant or an equivalent sealant.

INSTALLATION METHODOLOGY

146. The anchor have to installed on undisturbed soil; the upper end of the mark must remain *ca* 0.15 m below the ground.

147. The anchor of the mark have to set below the regional freeze depth on the soil.

148. The base of the concrete anchor must be levelled and compacted.

149. The excavated soil must be backfilled and compacted, in case of clays and stony soil, sand is used for backfilling.

150. A square concrete collar made in stationary conditions (concrete brand 400) with dimensions of 400 x 400 x 100 mm or 500 x 500 x 120 mm must be placed on top of the mark.

151. Depending on the location of the benchmark, the following need to place on the concrete collar:

    (a) plate as shown in the Figure 7, in case of metal plate, it is coated with "Epitar" (or similar) epoxy paint;

    (b) a cast-iron cover hatch, the upper surface of which is flush with the ground.

Type 3

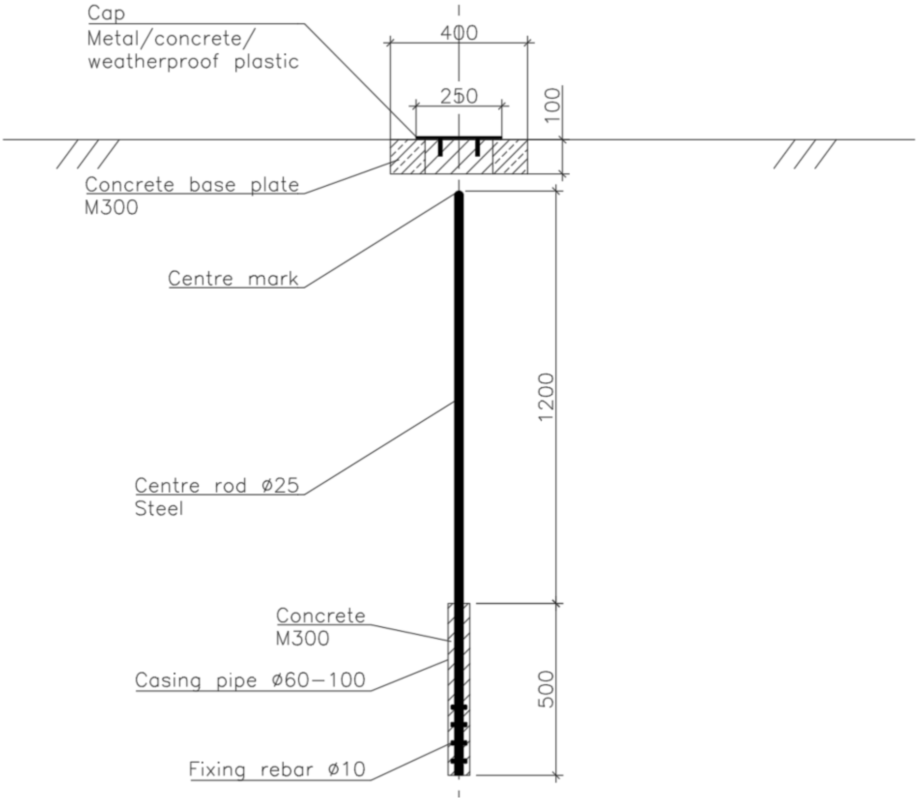


Figure 7. Benchmark type 3 with cover plate

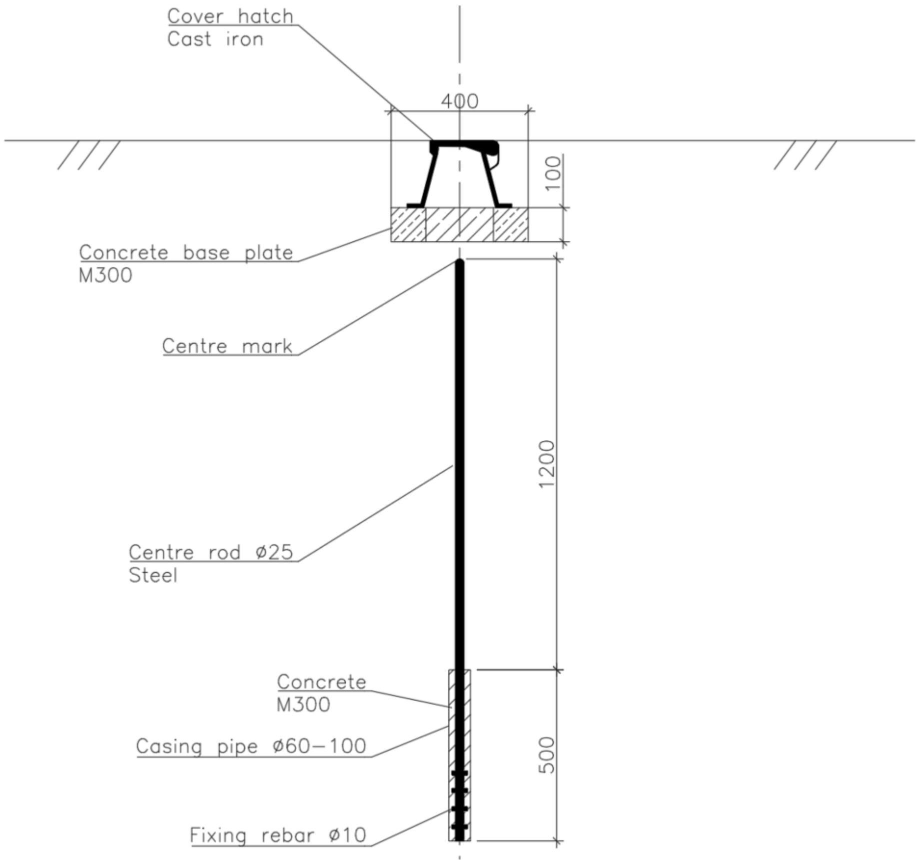


Figure 8. Benchmark type 3 with cover hatch

TECHNICAL SPECIFICATIONS & INSTALLATION METHOD STATEMENT

This benchmark type can be placed when type 1 or type 2 will not possible to install.

TECHNICAL SPECIFICATIONS

152. The benchmark needs to be produced under stationary conditions to guarantee homogeneous quality.

153. The center rod is a round iron with a diameter of 25 mm and a length of 1700 mm.

154. The center rod have to be completely coated with epoxy resin coating "Epitar" or similar.

155. A hole with a diameter of Ø2 mm have to drilled in the upper, curved center of the center rod.

156. The anchor is a 0.5 m long and Ø60-100 mm pipe filled with concrete (concrete brand 400).

157. The concrete mixture is compacted in a plastic tube by vibration.

158. A square concrete collar with dimensions 400x400x100mm (see Figure 7), made in stationary conditions (concrete brand 400), have to placed on top of the center rod.

159. Depending on the location of the benchmark, the following is placed on the concrete collar:
   (a) plate according to Figure 7, in case of metal plate, it is coated with epoxy resin coating "Epitar" or similar;
   (b) a cast-iron cover hatch, the upper surface of which is at the same level as the ground.

INSTALLATION METHODOLOGY

160. The center have to placed in a hole pre-drilled with a drilling machine in the location chosen for the mark in nature.

161. Drilling with proper machinery a 12 cm diameter vertical hole to a depth of *ca* 2 meters.

162. The anchor of the benchmark have to set below the regional freeze depth of the soil on the ground of undisturbed structure.

163. The base of the concrete anchor must be compacted.

164. The hole around the rod have to filled with sand and compacted by tamping.

Type 4

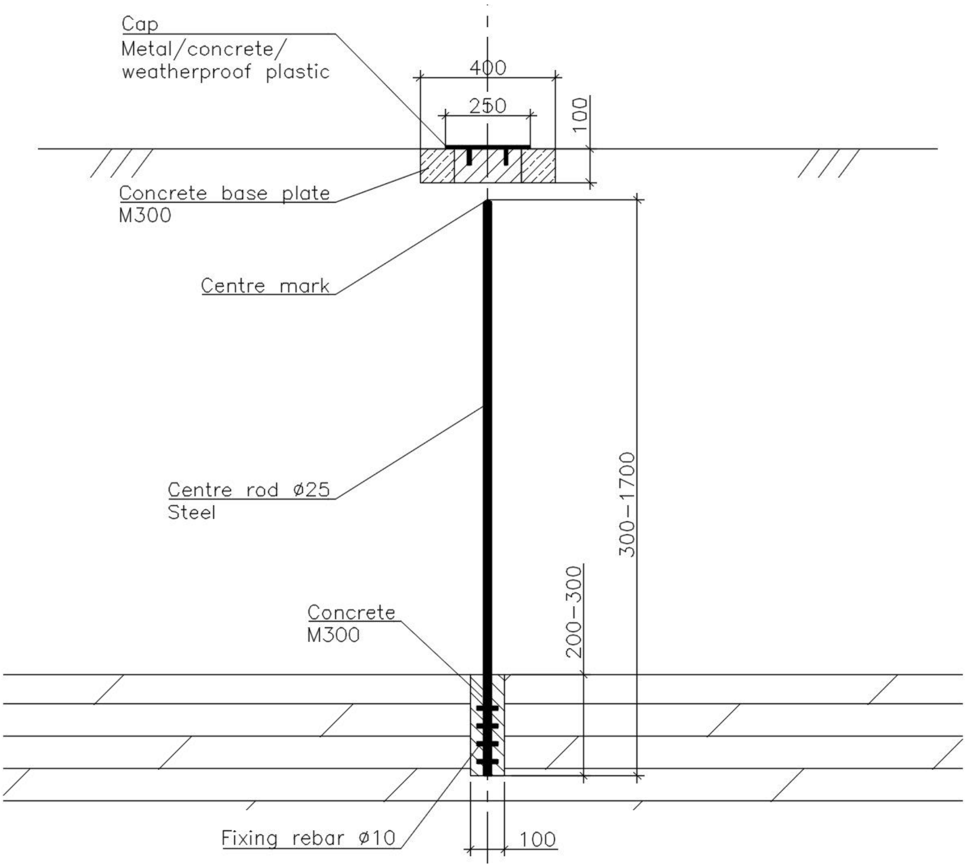


Figure 9. Benchmark type 4 with cover plate

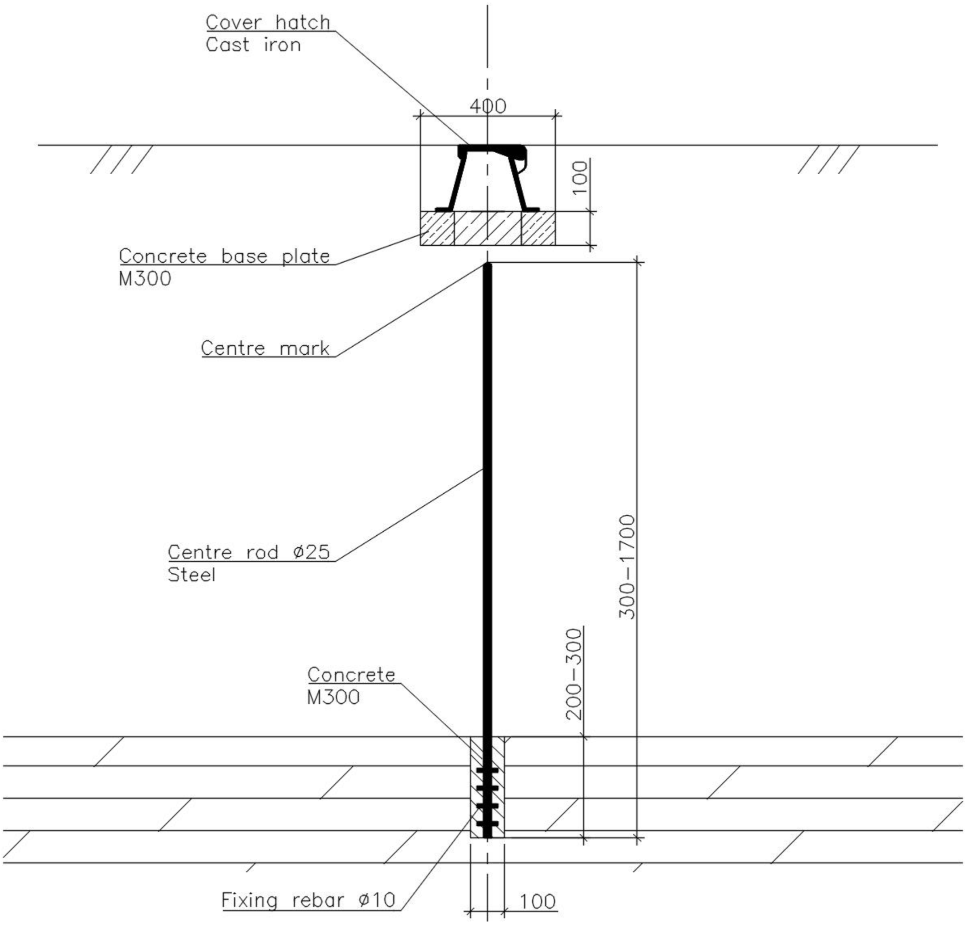


Figure 10. Benchmark type 4 with cover hatch

TECHNICAL SPECIFICATIONS & INSTALLATION METHOD STATEMENT

The marker type is used at the depth of the sedimentary bedrock in the range of 0.3 - 1.8 m.

TECHNICAL SPECIFICATIONS

165. The benchmark needs to be produced under stationary conditions to guarantee homogeneous quality.

166. The length of the center rod is chosen based on the depth of the bedrock.

167. The benchmark anchor is not made. In other aspects, the mark is the same as that shown in Figure 7.

INSTALLATION METHODOLOGY

168. The sign is placed in a hole drilled in the bedrock with a diameter of at least 100 mm and a depth of at least 200 mm and concreted.

169. The hole around the rod have to filled with sand and compacted by tamping.