

# Geodetic points on Ruško Pohorje



# GEODETTIC HIGHLIGHTS

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Authors: Mag Katja Oven, Dr Mihaela Triglav Čekada, Dr Klemen Medved, Rado Škafar, Sandi Berk, Dr Miran Kuhar, Dr Božo Koler, Dr Bojan Stopar

Authors of photos: Stane Tršan, Rado Škafar, Dr Božo Koler, Dr Oskar Sterle

Authors of sketches: Dr Miran Kuhar, Dr Klemen Medved, Sandi Berk, Dr Oskar Sterle, Niko Fabiani

Data sources: Surveying and Mapping Authority of the Republic of Slovenia, University of Ljubljana, Faculty of Civil Engineering and Geodesy, Archives of the Republic of Slovenia

Cartography: Geodetic Institute of Slovenia

Cartographic design: Špela Intihar

Produced by: Geodetic Institute of Slovenia

Designed by: Jani Demšar

Number of copies: 200

Ljubljana, 2026

## Introduction

The Geodetic Highlights series of booklets is dedicated to geodetic marks that hold special significance for geodesy and form part of our immovable geodetic heritage. Hikers and nature enthusiasts often come across geodetic marks while walking in the Slovenian hills; these are scattered across our mountains and show the rich history of land surveying in this area. Geodetic marks vary in shape, size and material – some were created recently, while others date back centuries – yet all bear witness to geodetic activities throughout history across our country.

Ruško Pohorje is an area where natural beauty and a rich geodetic history intertwine. Its peaks, plateaus and churches are home to numerous geodetic marks which, over decades and centuries, have been crucial to the development of the Slovenian spatial coordinate system. Žigartov vrh holds a very special place among these geodetic points. At 1,346 m, it is the highest peak in the eastern part of Pohorje and a popular hiking destination, but it is also an important hub in the history of geodesy in Slovenia. A first-order trigonometric point once stood there, forming part of the fundamental national geodetic network. This point was not only important for the local area but also played a crucial role in the wider region – it was already part of the Maribor triangulation base dating from 1860. It was here that generations of geodesists, through precise measurements, laid the foundations for understanding the landscape, map-making and the development of the land cadastre. Although the stone tower that served as the trigonometric point no longer stands, geodetic points – which in the past enabled positional determination and formed the basis for modern spatial data – remain of interest and importance.

In addition to the trigonometric point on Žigartov vrh, there are other important geodetic points on Ruško Pohorje: a geodetic point of the national combined geodetic network at Areh, an absolute gravimetric point in the Church of St Areh, lower-order trigonometric points, and benchmarks of levelling geodetic networks. Each of them has its own story and role in the development of geodesy, from classical triangulation and levelling surveys to measurements using modern GNSS technology.

Geodetic points are not merely technical objects; they are part of our shared heritage. They bear witness to the development of science, safeguard the accuracy and reliability of spatial data, and serve as a bridge between the past and future. Preserving and understanding them is important not only for geodesy but also for all those who appreciate the significance of space and the natural landscape.

Let this booklet take you on a journey through the geodetic highlights of Ruško Pohorje – a world where history, science and a love of the Slovenian mountains intertwine.

Dr Klemen Medved  
Director of the Geodesy Office at  
the Surveying and Mapping Authority of the Republic of Slovenia

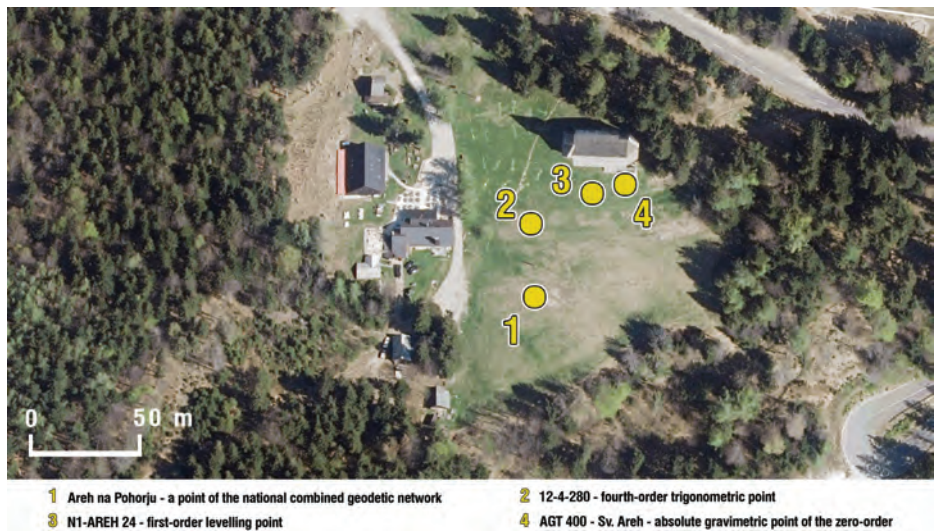
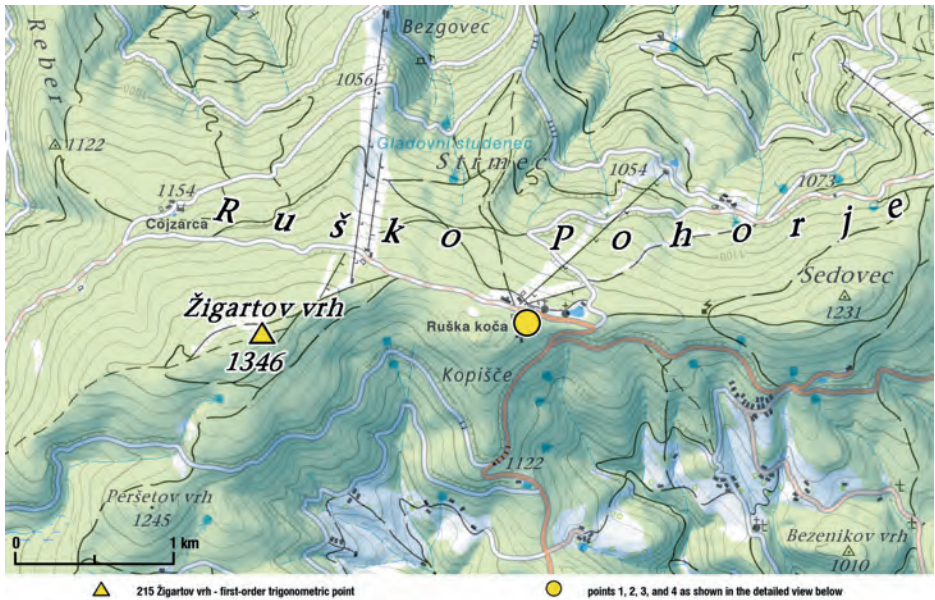
## Points of the national geodetic networks in Ruško Pohorje

Ruško Pohorje is an area containing many important geodetic points. Its highest peak, at an altitude of 1,346 m, is Žigartov vrh, which is also the highest peak in the eastern part of Pohorje. It is a popular hiking destination and is just 1.5 km, or an easy 30-minute walk along a marked trail, from the Ruška koča mountain hut on Areh. It is also the site where, in a clearing surrounded by woodland, the trigonometric point 215 ŽIGARTOV VRH once stood, which belonged to the first-order trigonometric network. Žigartov vrh is also known for its former wooden observation tower, 37 m high, which was built in 1903 on the same clearing and was a source of pride for Slovenian mountaineers.

Not far from Žigartov vrh on the Areh Plateau, south of the Ruška koča mountain hut and the Church of St Areha, lies one of the current most important national geodetic points: the AREH point of the national combined geodetic network. In the nearby Church of St Areh, there is also the absolute gravimetric point AGT400. There is also a height point on the side façade of this church, or benchmark 1-44-24, which is a point in Slovenia's new first-order national levelling network (N1).

In addition to the aforementioned geodetic points of the highest orders, there is a gravimetric point marked AGT401 on the rock directly beside the Church of St Areha, which serves as a backup point for AGT400. In the clearing in front of the church there is the fourth-order trigonometric point 12-4-280, while the cross at the top of the church bell tower (12-4-280-C) is also important for carrying out geodetic surveys.

Due to its exposed location and easy accessibility, the Ruško Pohorje area has long been a site where surveyors established highly significant geodetic points.



*Location of geodetic points on Ruško Pohorje*

# What is the significance of the highest order geodetic points?

## They present the points of the most important national geodetic networks

Geodetic points are, as a rule, linked to geodetic networks. The most important geodetic networks for surveying within the country are the national geodetic networks, of which there are several types. The most significant of these is the national combined geodetic network, which links and builds upon the following:

- trigonometric networks, in which we, as surveyors, have determined the positions of points in space, expressed using different types of coordinates – on the plane of a cartographic projection ( $e, n$ ) or on the Earth's ellipsoid ( $\lambda, \phi$ );
- levelling networks, in which we have determined the elevations of points ( $H$ ) and
- gravimetric networks, in which we have determined the values of gravitational acceleration ( $g$ ).

## They present the foundation of our national spatial coordinate system

National geodetic networks constitute the national coordinate system, which serves as the basis for the uniform and organised definition of the position of objects and phenomena in space. This means that the position of any object or phenomenon in space can be uniquely represented or described using coordinates within the national coordinate system.

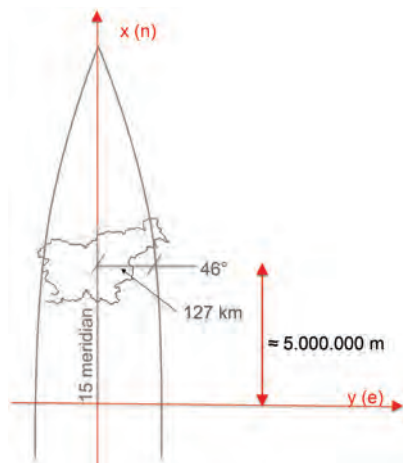
In geodesy, spatial position is treated separately in horizontal and vertical terms; consequently, our national spatial coordinate system also has two components: horizontal and vertical. They are separated because elevation is highly dependent on the physical properties of the Earth as a planet, whereas horizontal position is much less so. For example, to determine the elevation ( $H$ ) of a geodetic point on a hill, we must also know the geometric properties of the Earth's gravitational field. The geometry of the Earth's gravitational field is determined using geodetic, astronomical and gravimetric measurements.

## National Horizontal Coordinate System

This system is designated by the abbreviation D96, where 96 denotes the reference year 1996 for the geodetic measurements that were carried out to establish it. The letter D represents the geodetic datum, which specifies how the coordinate system is related to the Earth's body. The designation D96 thus indicates how and when the national coordinate system was established.

The national horizontal coordinate system – the coordinate system in the plane of the cartographic projection – is designated D96/TM, where TM stands for the transverse Mercator cartographic projection. The coordinate axes of the D96/TM coordinate system are e (easting) and n (northing),

where the n-axis represents the projection of the central meridian (in our case, the meridian with a longitude of 15° east of Greenwich), while the e-axis represents the projection of the equator onto the plane of the transverse Mercator projection. The origin of the coordinate system lies at the intersection of the two coordinate axes. For practical reasons, the coordinate origin has been virtually shifted closer to our country from the point of intersection of the projection of the 15<sup>th</sup> meridian and the equator. All n-coordinates are thus reduced by 5,000,000 m. However, to avoid negative coordinates west of the 15<sup>th</sup> meridian, all e-coordinates are increased by 500,000 m.



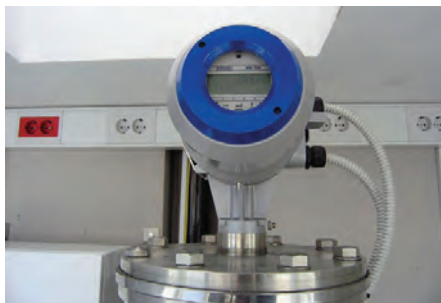
Origin of the horizontal coordinate system.

## National Height Coordinate System

The name of the national height system is the Slovenian Height System 2010, and it is designated SVS2010 (Koper datum). SVS stands for the Slovenian Height System (*Slovenski višinski sistem*); it was established in 2010, while the addition of (Koper datum) means that the origin of the height coordinate system is in Koper, specifically at the Koper tide gauge station. The elevation reference point was determined as the average sea level based on 18.6 years of continuous sea level measurements. The year 2010 also marks the mid-point of the period during which sea level measurements were carried out at the Koper tide gauge station.

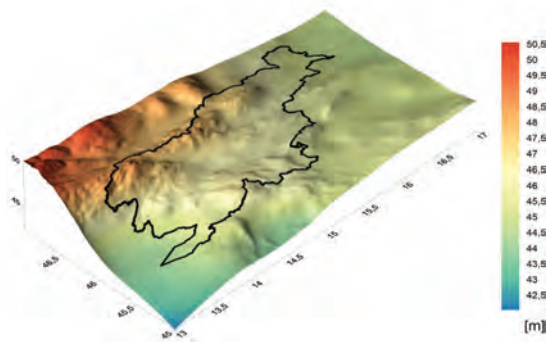
The height system has another distinctive feature. To determine height in space accurately, we must also know the Earth's gravitational field. Thus, at the height points of the first-order levelling network, which constitute our height system, the gravitational acceleration  $g$  is also measured. The value of gravitational acceleration is determined by gravimetric measurements.

Our national height system therefore also has a gravimetric component, designated GD06, where the letter G stands for gravimetric, the letter D for datum, while the number 06 refers to the reference year 2006 for the gravimetric measurements in Slovenia's basic gravimetric network. GD06 thus denotes the method of positioning the country's gravimetric system relative to the Earth's body, as carried out in 2006.



*The reference point of the height coordinate system at the Koper tide gauge station (left) and instruments for measuring sea level – tide gauges (right).*

However, if we wish to determine the elevation  $H$  of a point using GNSS measurements, we must also take into account the shape of the geoid surface. The shape of the geoid surface is determined on the basis of various types of geodetic measurements (terrestrial, satellite, gravimetric and astronomical). When the geoid is linked to the national height system, the surface thus determined represents the height reference surface and forms the basis for calculating elevations across the country. The height reference surface of the Slovenian height system SVS2010 (Koper datum) is designated SLO\_VRP2016/Koper. This is an abbreviation for the Slovenian Height Reference Surface (*Slovenska višinska referenčna ploskev*), which was linked to the national height system of Slovenia and the Earth's body in the manner implemented in 2016.



*New height reference surface SLO\_VRP2016/Koper.*

## Trigonometric networks

First-order trigonometric network in 1948.

In 1995, the first-order trigonometric point 215 Žigartov vrh was incorporated into the international EUREF GPS survey (European Reference Frame), which, together with several other international surveys using GNSS technology, formed the basis for the establishment and subsequent legal adoption of the national geodetic reference system in Slovenia.



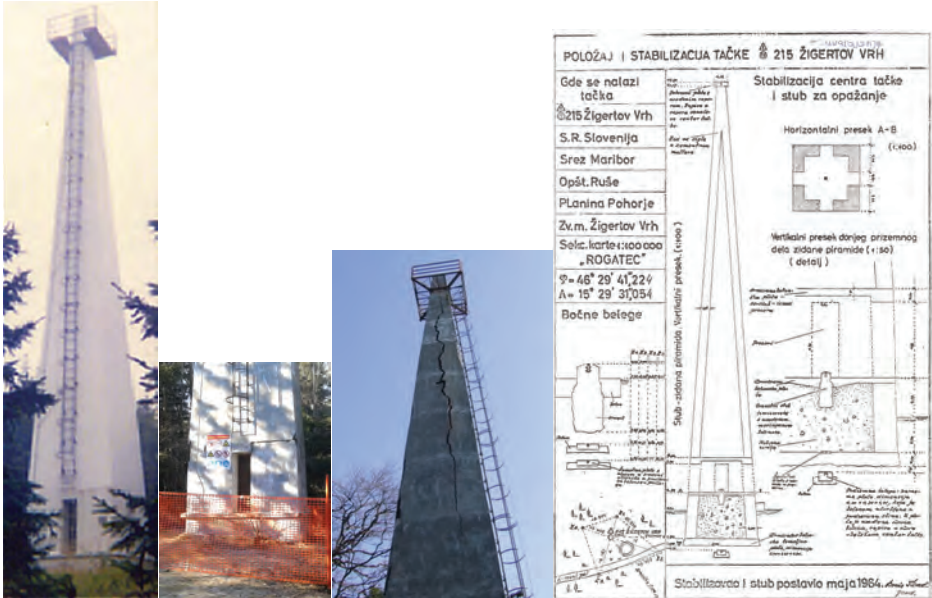
*Geodetic points in Slovenia included in the combined calculation of three EUREF GPS surveys, including 215 ŽIGARTOV VRH.*

## What does point 215 ŽIGARTOV VRH look like today?

Over time, the physical form of this trigonometric point has changed. It has been constructed and updated by various institutions: the Military Geographical Institute in Vienna and Belgrade, and the Surveying and Mapping Authority of the Republic of Slovenia. The last physical marker representing the point in the field was a 23.5 m brick tower, which was removed in 2019 due to the risk of collapse. At the top of the tower was a metal platform with a wooden railing, on which a surveyor could stand while taking measurements. At the very base of the tower there was an opening in the pillar through which another smaller pillar had been embedded into the foundation, and this represented the so-called main point of trigonometric point 215 ŽIGARTOV VRH. The main point of this trigonometric point was therefore not located at the top of the tall pillar but at its base.



*Arrangement of the lateral control points around the main point, a visible lateral control point in situ and a sketch of its above-ground and underground stabilisation.*



The appearance of the tower following its restoration in 1986 (left) and prior to its demolition (centre), along with a plan of the tower from 1964.

The position of the main point is secured by four geodetic control points, known as lateral points (points B1-B4), marked by granite stones embedded in the ground in the immediate vicinity of the pillar's location.

In 2023, during excavations carried out at the site of the former tower, a preserved underground foundation dating from 1897 was also discovered, which means that the first-order trigonometric point on Žigertov vrh has not been completely destroyed. Furthermore, we also maintain its coordinates in the national spatial coordinate system.



Excavation at the site of point 215 on Žigertov vrh (left) showing the foundation from 1897 (right).

## Point of the AREH National Combined Geodetic Network

A point of the AREH national combined geodetic network is one of the points of the national combined geodetic network, which is the most important geodetic network among those in Slovenia. The points of the National Combined Geodetic Network, including the AREH point, are set up in accordance with modern standards for the establishment of fundamental geodetic points and equipped with state-of-the-art surveying technology.

### The National Combined Geodetic Network

The network currently consists of seven survey points, which are distributed more or less evenly across the whole territory of Slovenia. The national combined geodetic network integrates and enhances the highest-order national geodetic networks to date: terrestrial networks, levelling networks and gravimetric networks. The points in this network form an important part of the national spatial coordinate system, as they link its horizontal and vertical components.

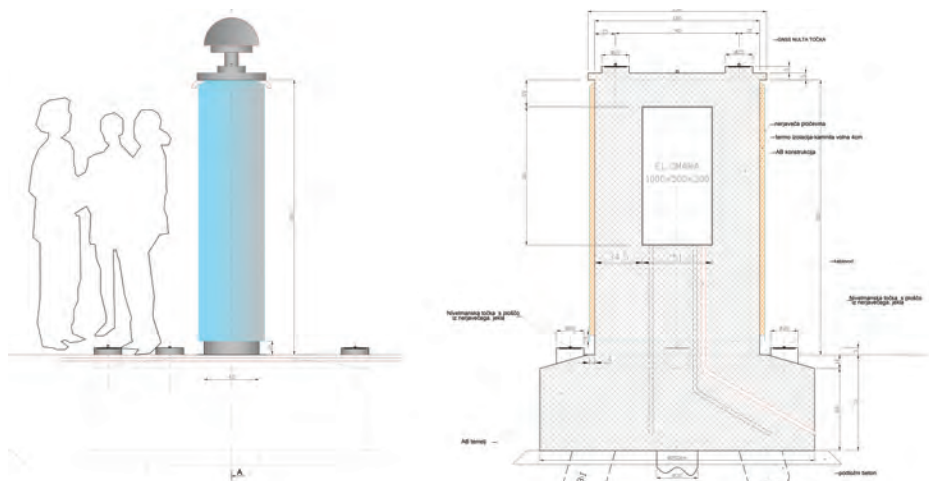
GNSS stations are installed at the points of this network, which continuously (24/7) receive signals from GNSS satellite systems for global positioning (GPS, GLONASS, Galileo, BeiDou) and transmit the observations to the control centre in Ljubljana. There, the data are used to continuously calculate positions with an accuracy of a few millimetres. The high accuracy of measurements at the points of this network also enables the monitoring of positional changes resulting from the movements of lithospheric plates.



*Locations of control points in the combined geodetic network and GNSS station designs.*

## What does point AREH of the national combined geodetic network look like today?

Point AREH of the national combined geodetic network is marked by an oval reinforced concrete pillar, approximately 2 m high above ground level. It stands on a foundation slab that is anchored to solid bedrock. The base slab, together with the pillar, forms a single reinforced concrete structure that ensures the necessary stability of the point. Two GNSS antennas are mounted on top of the pillar, and measuring instruments are housed inside it. The point's location is equipped with electrical and communications infrastructure and protected by a wooden fence.



View of the point AREH where continuous GNSS measurements are carried out (below) and details from the project documentation (above).

We can see several different geodetic points on the pillar and at its base:

- three levelling benchmarks at the base of the pillar;
- two GNSS points at the top of the pole and a point on the pole's axis for conventional geodetic surveying;
- the main point at the base of the pillar, where we also carry out conventional terrestrial geodetic and gravimetric measurements.



*View of the pillar with three benchmarks for levelling, a point for conventional and gravimetric measurements at the base of the pillar (left) and two GNSS points on the pillar and a point on the pillar's axis (right).*

Outside the fenced-off area, at distances of between 30 m and 40 m from the pillar, four additional points (lateral points) have been stabilised, forming a so-called backup micro-geodetic network, which is approximately square in shape. These points are anchored to the bedrock, surrounded by concrete pits and protected by metal covers. The points of the backup micro-geodetic network are intended to determine the local stability of the pylon.



*Position of a lateral point relative to the AREH points (left) and its appearance.*

At the AREH point, as well as at all other points of the national combined geodetic network, control geodetic measurements are carried out periodically to determine their local stability.



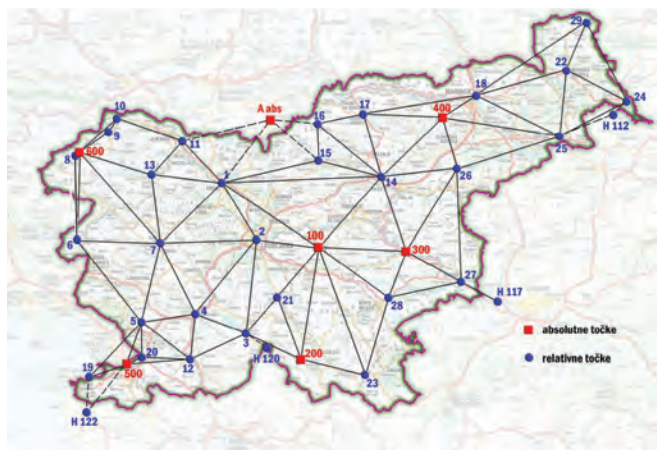
Carrying out geodetic control surveys at the AREH point.

## Absolute gravimetric point of the zero-order AGT400

The absolute gravimetric point AGT400 is one of six absolute gravimetric points in Slovenia that form the zero-order gravimetric network. Absolute measurements of gravitational acceleration ( $g$ ) are carried out at these points using specialised instruments known as absolute gravimeters, which enable its determination with high precision. The first absolute gravimetric measurements in Slovenia were carried out in 1996, when the AGT400 point was also measured for the first time.

## Gravimetric networks

The zero-order gravimetric network is based on the International Gravity Standardisation Network 1971 (IGSN71). It forms the basis for the first-order gravimetric network, and together they constitute the basic gravimetric network of Slovenia, or the gravimetric datum (GD06). The first-order gravimetric network comprises 29 points at which the value of gravitational acceleration is measured using relative gravimeters.

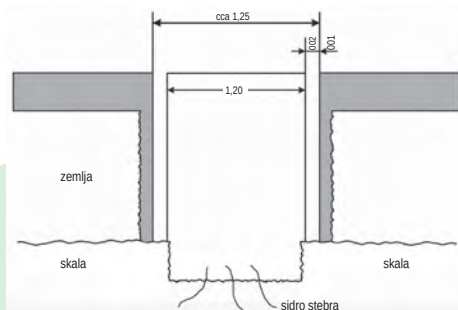


Basic gravimetric network (red – absolute gravimetric points, blue o – relative gravimetric points).

The basic gravimetric network of Slovenia consists of 35 gravimetric points<sup>1</sup>. All measurements of gravitational acceleration carried out on the highest-order (**first-order**) levelling network – which constitutes the national height system – are referenced to this network, as are all measurements required for the calculation of the geoid and the height reference surface.

## What does point AGT400 look like today?

Absolute gravimetric points are stabilised by being directly anchored to the bedrock, and the physical markers of these points are connected to the bedrock by an anchor drilled 6 m deep. The pillars are constructed so that their upper surface is level with the surrounding ground or slightly below it. The point at the centre of the pillar is marked with a brass pin to which the measured values of gravitational acceleration are referenced. The AGT400 point was established in 1995 in the sacristy of the Church of St Areh on Pohorje. Absolute gravimetric measurements were carried out at this point on two occasions, in 1996 and 2014.



*Appearance of the point AGT400 in the Church of St Areh, where absolute gravimetric measurements are carried out, and its dimensions.*

Each absolute gravimetric point also has one control point, which we surveyors also refer to as an eccentric point. For point AGT400, this is located on the rock face immediately adjacent to the Church of St Areh, on the eastern side, and is designated AGT401.



*Carrying out relative gravimetric measurements at control point AGT401 on the rock beside the Church of St Areh.*

<sup>1</sup> see examples in booklet *Geodetic Highlights Kozinski pil - Column of Kozina*

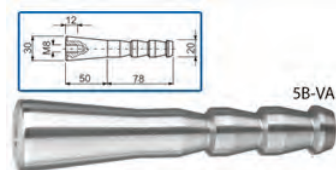
## Levelling networks

The first-order levelling network is the most important height network. Surveyors densify this network with levelling networks of lower orders (second, third and fourth orders) right down to urban levelling networks. In doing so, we create progressively smaller levelling loops and shorter levelling polygons. They enable us to measure the elevation of any selected point anywhere in Slovenia. The reference point is located at the tide gauge station in Koper.

## What does point 1-44-24 look like today?

Elevation points are stabilised with metal pins, which we call benchmarks, and these are embedded in structures or rock. Benchmarks come in various shapes and sizes and are made of different materials (aluminium, cast iron, steel, brass), all of which are sturdy and corrosion-resistant. They consist of a head, which is usually round and a few centimetres in diameter, and a head support, which is a few centimetres long, or possibly longer. The supports enable the benchmarks to be firmly embedded or anchored into a solid foundation.

To stabilise a height point in a first-order levelling network, such as point 1-44-24, we use benchmarks of the type shown in the figure below.

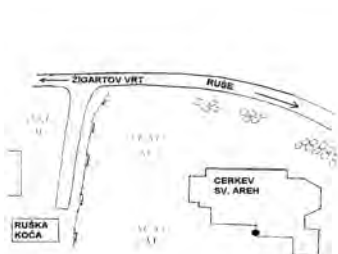


*Examples of the appearance and dimensions (mm) of first-order levelling benchmarks.*

On the façade of the Church of St Areh, the benchmark is set into the wall to the right of the side entrance, as shown in the sketches and photographs below. The benchmark was installed in 1998.



*Location of benchmark 1-44-24 on the façade of the Church of St Areh.*

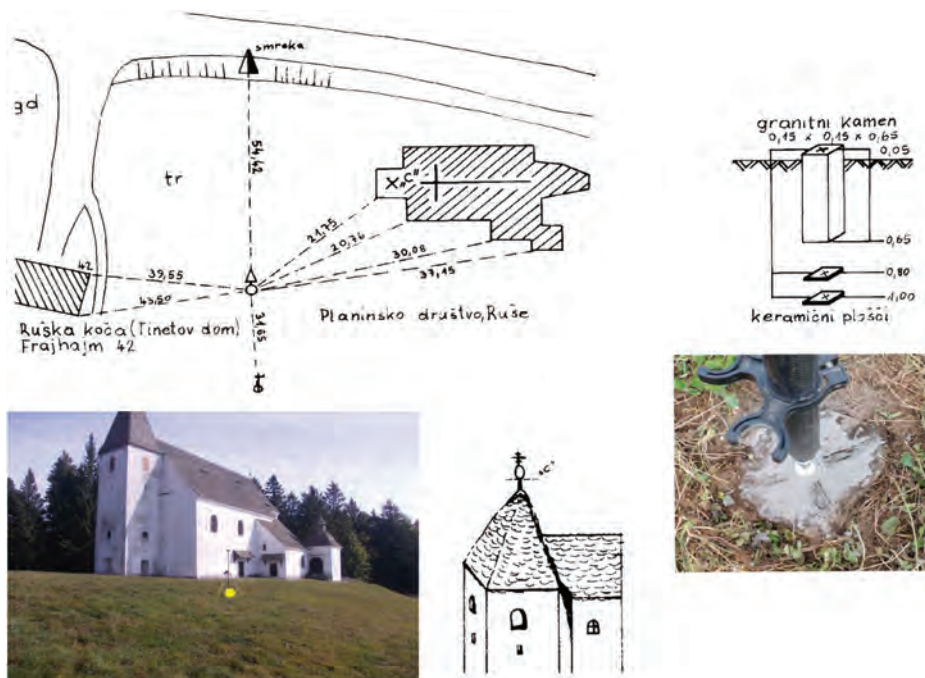


*Sketch of the location of the Church of St Areh and the position of benchmark 1-44-24 on it.*

## Fourth-order trigonometric point 12-4-280

In addition to the survey points already described, there is also a fourth-order trigonometric point 12-4-280, situated on the rock directly next to the Church of St Areh. This point is used for carrying out surveying measurements, as is the signal – the cross at the top of the church bell tower (12-4-280-C).

The trigonometric point is stabilised by a granite block measuring  $0.15\text{ m} \times 0.15\text{ m}$  in cross-section, which extends  $0.7\text{ m}$  into the ground. It is protected from damage by two underground chambers made of ceramic slabs, situated at depths of  $0.8\text{ m}$  and  $1\text{ m}$ .



View of the location and stabilisation of point 12-4-280 and its position in space.

## An additional point of interest – the wooden tower on Žigartov vrh

On Žigartov vrh, the concrete hexagonal foundation of the former wooden observation tower from 1903 is still visible; it once stood 37 m tall and was a source of pride for Slovenian mountaineers. In the 1967 issue of *Planinski vestnik*, we find a sketch of this tower, alongside a sketch of the clearing on Žigartov vrh from 1961 – that is, before the re-establishment of point 215 ŽIGARTOV VRH in 1964. It shows the pillar of point 215, most likely from 1953, with an observation pyramid. Next to it, a fallen observation pyramid and the hexagonal foundation of the former wooden tower are also visible.

A depiction of the hexagonal foundation of the former wooden tower can also be found in the topographical sketches of trigonometric point 215 ŽIGARTOV VRH.



*Remains of the concrete hexagonal foundation of the former wooden tower from 1903 (left), a sketch of the wooden Žigartov tower (centre) and a sketch of the view of the clearing on Žigartov vrh.*

## The importance of protecting and preserving geodetic points

As we have learned in this booklet, the Ruško Pohorje is not only an interesting hiking destination but also an area with a rich history of geodesy stretching back over two centuries. The geodetic points presented here are used by surveyors in their work. Due to its dilapidated condition and the danger it posed to hikers, the brick tower marking first-order trigonometric point 215 on Žigartov vrh was removed in 2019. However, we are endeavouring to create a suitable marker in the clearing at the top of the hill where this trigonometric point once stood.

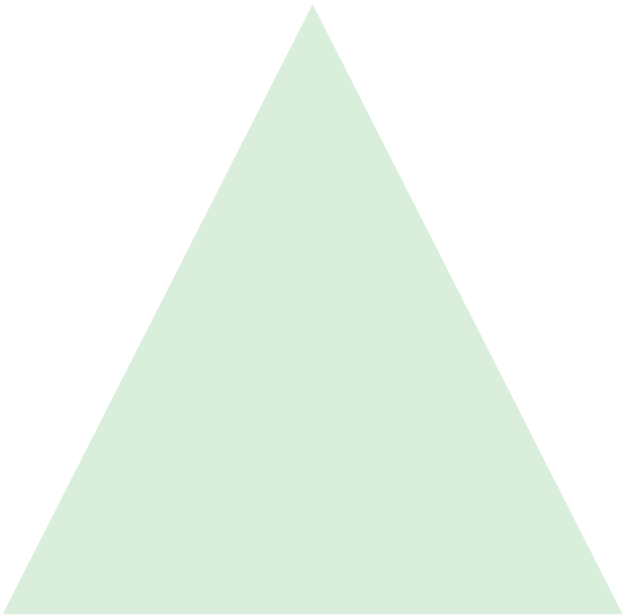
The protection and preservation of physical markers of geodetic points in the natural environment are important not only for the smooth execution of geodetic work, but also because of our desire to inform the public about their significance. Continuing to identify and evaluate geodetic markers as part of our geodetic heritage, and promoting them, is important both for the geodetic profession and for all users of space and the natural landscape. Geodetic heritage represents our knowledge, work and tradition. It is part of our geodetic identity, which we wish to preserve for the future.

More details about the geodetic points mentioned in this booklet are available in:

GOV.SI: **National Coordinate System**. Surveying and Mapping Authority of the Republic of Slovenia. <https://www.gov.si teme/drzavni-koordinatni-sistem/>

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This booklet was produced in the Applied research project L2-50090,  
co-financed by:



Slovenian Research and Innovation Agency



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