Substructure: Design and construction. Profiles and minimum gauges

1 Purpose and scope

To ensure a high level of functionality and optimum reliability in the operational phase of new sections of line, space must be provided during the construction phase for the individual sub-systems so that functional, structural and maintenance requirements are fulfilled. This applies to the following systems: Power supply, signalling, telecommunications and track. This is all developed around the minimum infrastructure gauge.

2 Minimum infrastructure gauge

There must be a certain amount of space, free of obstacles on either side of the track, above the track and also between the rails, to ensure the necessary clearance for the conveyance of trains. The cross-section of this space is referred to as the 'minimum infrastructure gauge'.

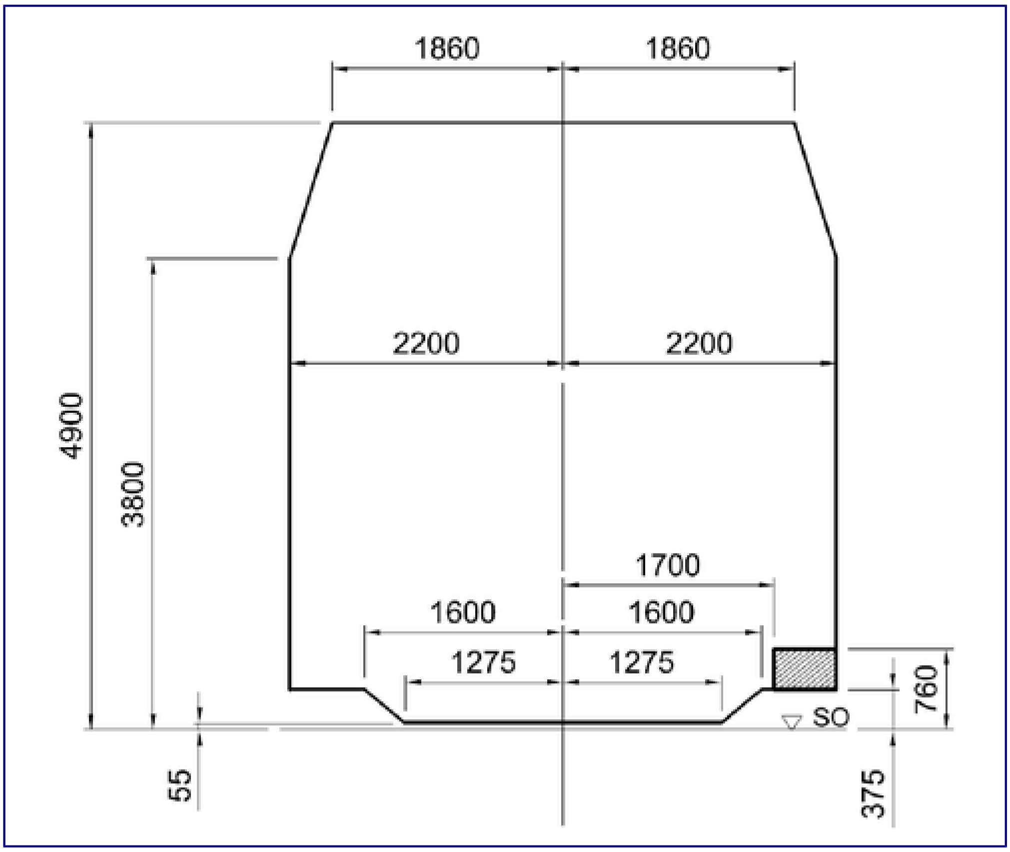
The measurement axis for the minimum infrastructure gauge is perpendicular to the track plane in the centre of the track.

A distinction must be made between the minimum infrastructure gauge for the conveyance of trains and the minimum infrastructure gauge for the conveyance of the overhead contact line system, including the current collector mounted on the train (Infrastructure gauge E). The minimum infrastructure gauge for the conveyance of trains is specified in items 2.1-2.5. Tverrsnitt E is specified in item 2.7. For a non-electrified section of line, the minimum total gauge will only be restricted by the minimum infrastructure gauge for the conveyance of trains. For an electrified section of line, the minimum total gauge will be the sum of the minimum infrastructure gauge for the conveyance of trains and minimum infrastructure gauge E.

A description and outline of the various profiles/load scenarios are described in https://trv.jbv.no/PDF/Underbygning/520/Vedlegg/T2005a00.pdf vedlegg a].

2.1 Minimum infrastructure gauge for trains, new lines

As a minimum, new lines must use the minimum infrastructure gauge as shown in Figur 1, referred to as 'Minimum infrastructure gauge for new lines'.



Figur 1: Minimum infrastructure gauge for new lines
Necessary width extensions and curve overthrow are specified in [Underbygning/Prosjektering_og_bygging/Profiler_og_minste_tverrsnitt#Breddeutvidelse_i_sirkelkurver_for_nye_baner|Breddeutvidelse_i_sirkelkurver_for_nye_baner]].

The hatched area is specified in Minste_tverrsnitt_på_stasjonsspor.

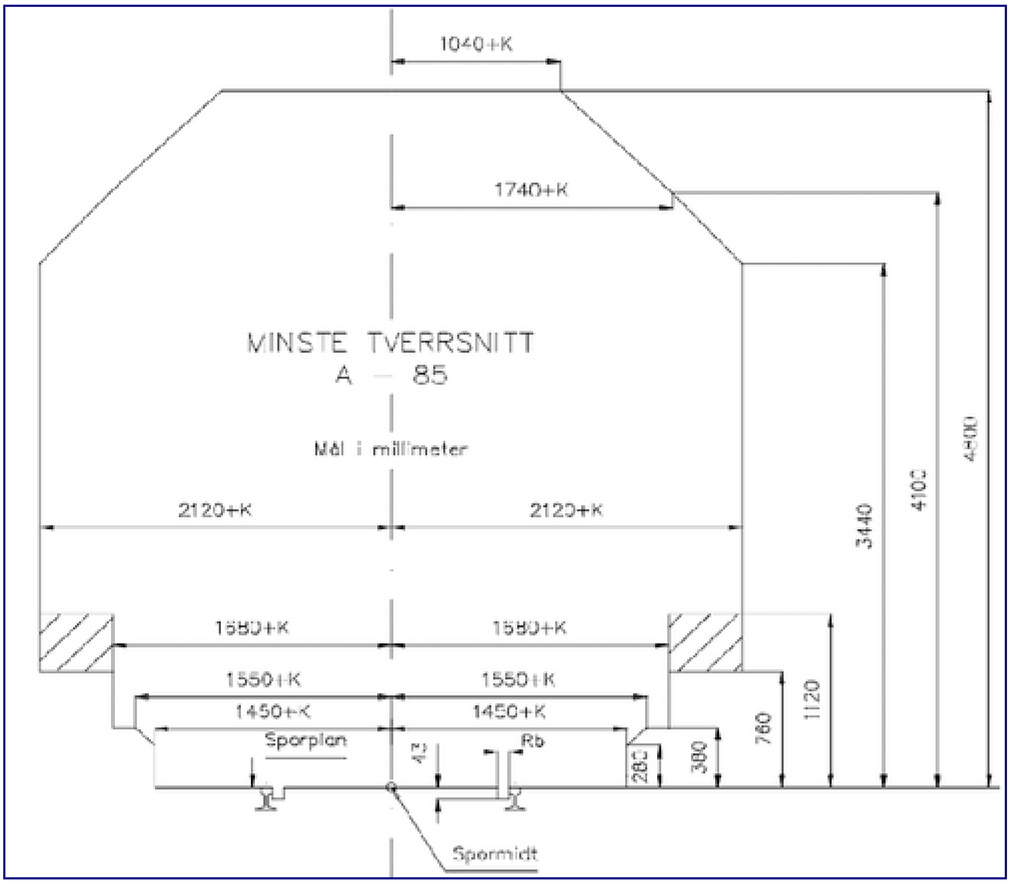
2.2 Minimum infrastructure gauge for trains, existing lines

For all sections of line, minimum infrastructure gauge A-85 applies. Three larger infrastructure gauges applicable to existing lines have also been defined. These infrastructure gauges are described as A-96, A-96T and A-C, respectively.

For electrified lines, the following profiles also apply

- open profile for current collector
- minimum infrastructure gauge E

2.2.1 Minimum infrastructure gauge A-85



Figur 2: Minimum infrastructure gauge A-85

K_i= curve overthrow towards the inner side of a curve

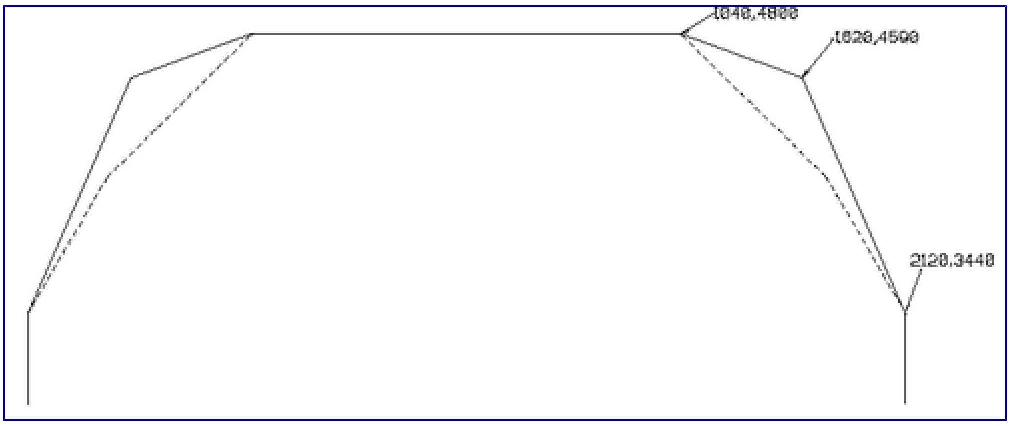
K_y = = curve overthrow towards the outer side of a curve

The hatched area is specified in [[[Underbygning/Prosjektering_og_bygging/Profiler_og_minste_tverrsnitt#Minste_tverrsnitt_på_stasjonsspor|avsnitt 2.4]].

For lower limits in minimum infrastructure gauges reference is made to 2.5.2.

2.2.2 Minimum infrastructure gauge A-96

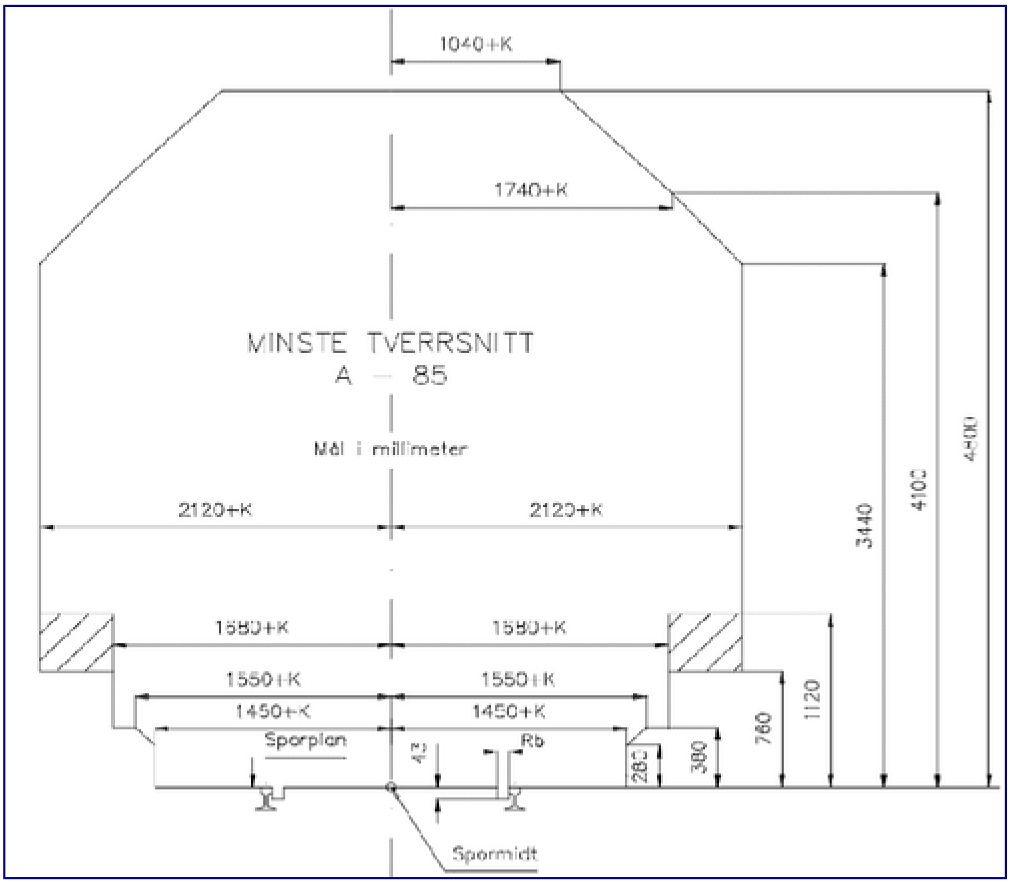
The minimum infrastructure gauge A-96 is identical to A-85 up to a height of 3440 mm above the top of the rail. Only the point (1740,4100) must be replaced. A-96 has point (1620,4590) instead. This infrastructure gauge satisfies the conveyance of 'multi-purpose' rolling stock and the respective load scenarios P and C.



Figur 3: Minimum infrastructure gauge A-96, upper part
In addition, there are curve overthrows, cf. Table 2 and Table 3.

2.2.3 Minimum infrastructure gauge A-96T

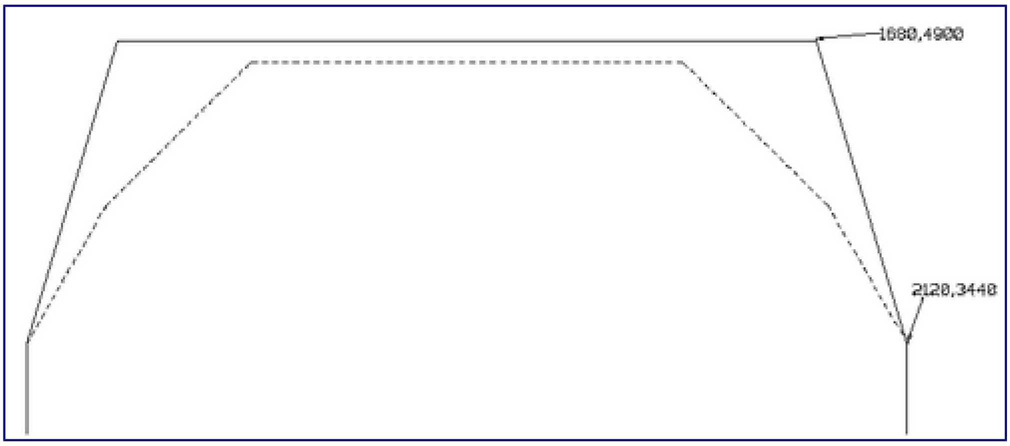
Minimum infrastructure gauge A-96T is identical to A96 with the exception of the top part, refer to Figure 4. A-96T has been designed to satisfy the conveyance of foreign goods wagons and double-decker passenger carriages.



Figur 4: Minimum infrastructure gauge A-96T
In addition, there are curve overthrows, cf. Table 2 and Table 3.

2.2.4 Minimum infrastructure gauge A-C

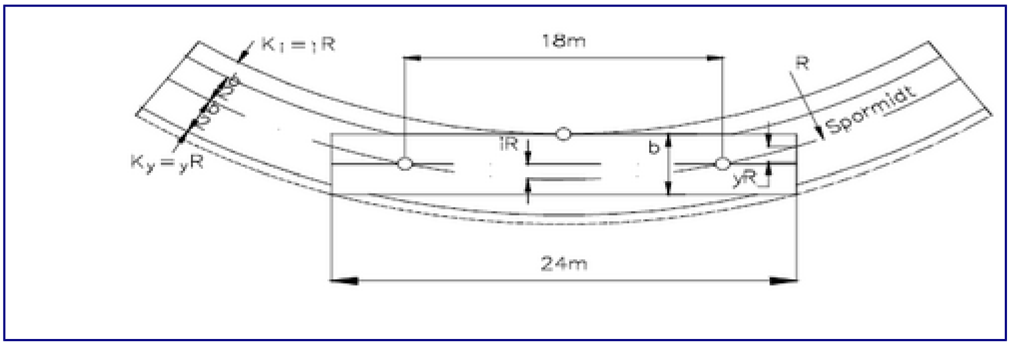
Minimum infrastructure gauge A-C is identical to A-85 lower than 3440 mm above the top of the rail. A-C has been designed to satisfy the conveyance of rolling stock with the designation UIC GC on existing lines.



Figur 5: Minimum infrastructure gauge A-C, upper part
In addition, there are curve overthrows, cf. Table 2.

2.3 Curve overthrow

The width of the minimum infrastructure gauge varies with the curvature of the track due to the extra space requirement when long wagons negotiate curves. All horizontal dimensions are increased in circular curves, transition curves and on straight lines in the vicinity of curves. The curve overthrows vary for the curve's inner and outer side. The size of curve overthrows are based on a theoretical wagon with a length of 24 m and an 18 m wheelbase.



Figur 6: Curve overthrow
The curve overthrow at platforms and loading ramps is calculated as shown in Overbygning/Prosjektering/Plattformer og spor på stasjoner

2.3.1 Width expansion on circular curves for new lines

For new lines outside of station areas, all horizontal dimensions are increased in circular curves, transition curves and on straight lines in the vicinity of curves in accordance with Tabell 1. Width expansion takes into account curve overthrow, and allows for dynamic movement.

Tabell 1: Width expansion outside station areas for new lines

R [m]	k [mm]
Straight line	0
20000	0
10000	0
5000	80
4000	100
3000	120

1000	120
600	130
500	140
300	150

Intermediate values are interpolated linearly and rounded up to the nearest whole cm.

For new lines within station areas, curve overthrows are calculated in accordance with **???,???,???** with a deduction of 80 mm. However, the distance from the centre of the track must never be less than 2.20 m (applies to 0.375/0.76–3.8 m above the track plane).

For existing lines, curve overthrows in circular curves are calculated in accordance with the following formulae:

$$K_i = \frac{81000}{2R}[mm], \quad K_y = \frac{63000}{2R}[mm] \qquad (1)$$

R = curve radius

Tabell 2: Curve overthrow values for A-85, A-96, A-96T and A-C

R [m]	**K_i [mm]**	**K_y [mm]**	**R [m]**	**K_i [mm]**	**K_y [mm]**
180	225	175	600	68	53
190	214	166	650	63	49
200	203	158	700	58	45
210	193	150	750	54	42
220	184	144	800	51	40
230	176	137	850	48	38
240	169	132	900	45	35
250	162	126	950	43	34
260	156	122	1000	41	32
270	150	117	1100	37	29
280	145	113	1200	34	27
290	140	109	1300	32	25
300	135	105	1400	29	23
325	125	97	1500	27	21
350	116	90	2000	21	16
375	108	84	3000	14	11
400	102	79	4000	10	8
425	96	75	5000	8	6
450	90	70	6000	7	5
475	86	67	7000	6	4
500	81	63	8000	5	4
550	74	58	> 8000	0	0

2.3.1.1 Reduced curve overthrow

To reduce the extent of measures with a cost implication, as a minimum requirement for short wagons specially designed for combination traffic, a 'reduced curve overthrow' has been established as an exemption criterion.

Reduced curve overthrows are suitable for various types of wagons with the following parameters:

1. wheelbase = 13.5 m and overhang = 2.0 m
2. wheelbase = 10.0 m and overhang = 3.0 m

This means that for an area higher than 3440 mm, a reduced curve overthrow for A-96 may be anticipated. This is shown in Tabell 3.

Tabell 3: Reduced curve overthrow for A-96

Radius [m]	**k_i [mm]**	**k_y [mm]**
200	114	98
250	91	78
300	76	65
400	57	49
500	46	39
600	38	33
700	33	28
800	28	24
900	25	22
1000	23	20
1200	19	16
1500	15	13
2000	11	10
5000	5	4
8000	3	2

2.3.2 Curve overthrow at locations with varying curvature

In transition curves and on straight lines in the vicinity of curves, the curve overthrow is calculated through interpolation in accordance with the following formulae:

$$K_i = \frac{L+10-x}{L+10} \cdot K_{ir} [mm], \quad K_y = \frac{L+15-x}{L+10} \cdot K_{yr} [mm] \quad (2)$$

L = length of transition curve [m]

x = distance from the OE (end of transition curve) to the calculation point [m]

K_{ir} = inner curve overthrow [mm]

K_{ir} = outer curve overthrow [mm]

In other curve combinations, the curve overthrow is calculated via plane geometric considerations adapted to each individual case.

2.3.3 Curve overthrow on vertical curves

For vertical curves with a radius R_v < 1500 m a curve overthrow (K_v) is calculated for all horizontal dimensions. K_v is calculated as follows:

$$K_v = \frac{81000}{2R} - 27 [mm] \quad (3)$$

2.4 'Minimum infrastructure gauge on station tracks

The hatched area of the minimum infrastructure gauge for new lines indicates reductions in the profile of platform edges and signalling installations within station areas.

The hatched area of minimum infrastructure gauge A-85 indicates the permissible track reduction within station areas.

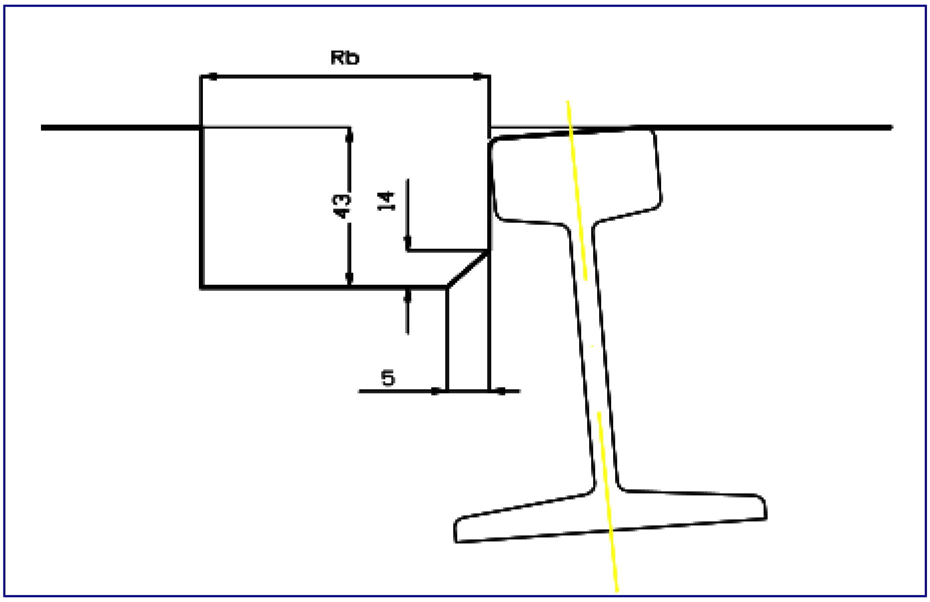
With regard to the conveyance of special loads, all stations should have at least one train path, preferably the mainline track, on which this hatched area is kept free of structures. This train path is described as the **transport track**.

There must be no loading ramps, dwarf signals or other permanent structures located closer to the transport track than 2120 mm + curve overthrow from the centre of the track, that are higher than 760 mm above the track plane.

Track connections to open loading areas and sidings to installations designed to receive special loads should satisfy the same requirements as the transport track.

2.5 The lowest limit of the minimum infrastructure gauge

2.5.1 Track groove



Figur 7: Track groove

The minimum width of the track groove must be:

R_b = 70 mm when the track width is ≤ 1445 mm

R_b = track width - 1375 mm for track width > 1445 mm

R_b = 100 mm on level crossings with wooden panels

Structural elements forming the track groove's inner limit (e.g. level crossing panels) must be protected from the rails so that the track groove's width cannot be reduced.

The requirements for track grooves on level crossings with wooden panels are specified in Overbygning/Prosjektering/Planoverganger#Planovergang_av_trelemmer.

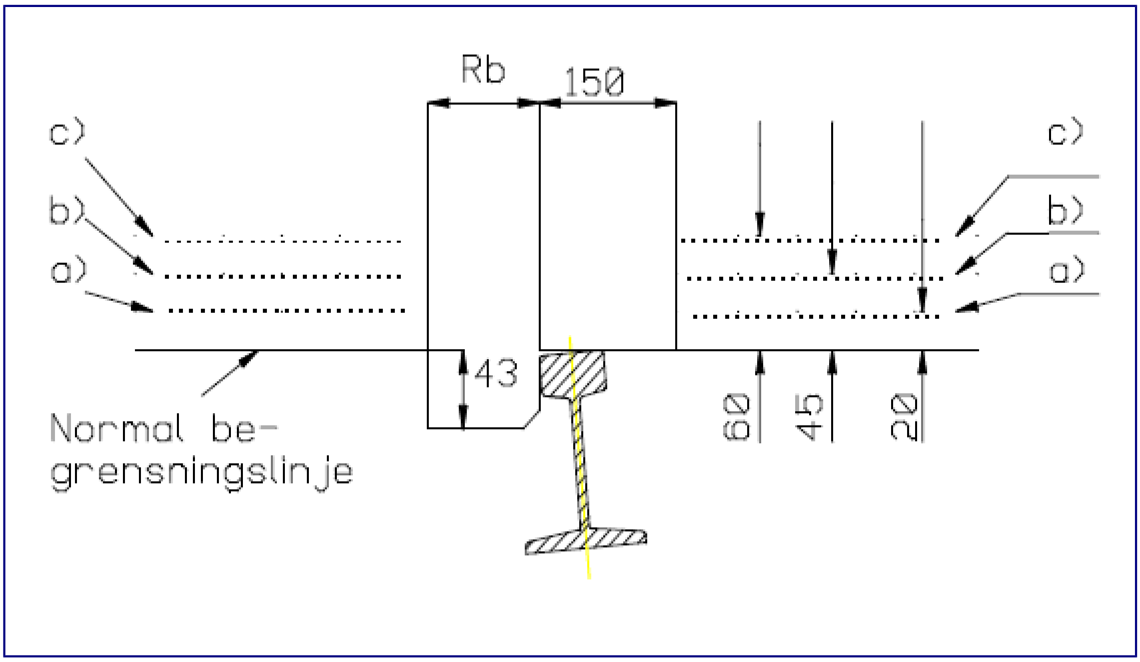
For certain structural elements the requirement is reduced to R_b. This applies to:

- check rails/wing rails in points
- crossings
- track brakes
- rubber strips on level crossings

2.5.2 Permanent structures within and outside of the rails

Apart from the track groove, the lowest limit line is in the track plane. The following exemptions apply:

- Level crossing panels on electrified sections of line or in insulated track circuits must be located at least 5 mm above the track plane, but not more than 20 mm.
- The height of the top of check rails in points may be up to 20 mm above the track plane (a).
- On tracks within station areas, the height of permanent structures may be up to 45 mm above the track plane (b).
- The height of the top of check rails in scissors crossings for points may be up to 60 mm above the track plane (c).

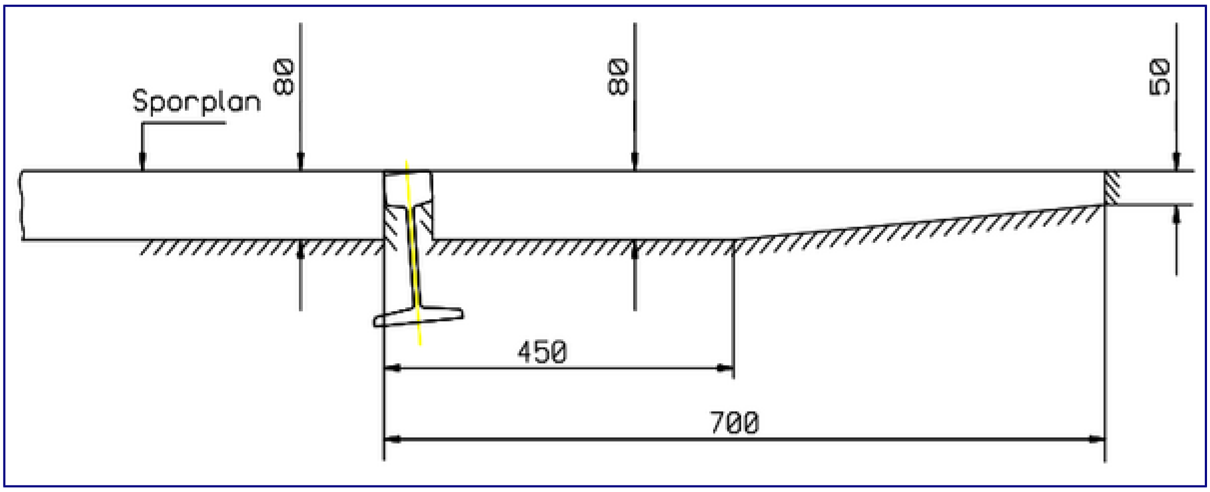


Figur 8: Limits within and outside of the rails

Between the rails, the exemptions apply to distances greater than R_b from the rail edge. Outside of the rails, the exemptions apply to distances greater than 150 mm from the rail edge. The exemptions do not apply at locations where vertical curves with $R_v \leq 1500$ m are present.

2.5.3 Provision for use of track cleaners

On tracks where it is assumed that a track cleaner will be used, an area of up to 700 mm outside the rail edge must be kept free of obstruction during the winter.



Figur 9: Free space for the use of a track cleaner

Where the track cleaner has to be lifted because of permanent structures, this must be marked on open lines, using indicators for track cleaning operations.

2.6 Open profile for current collectors

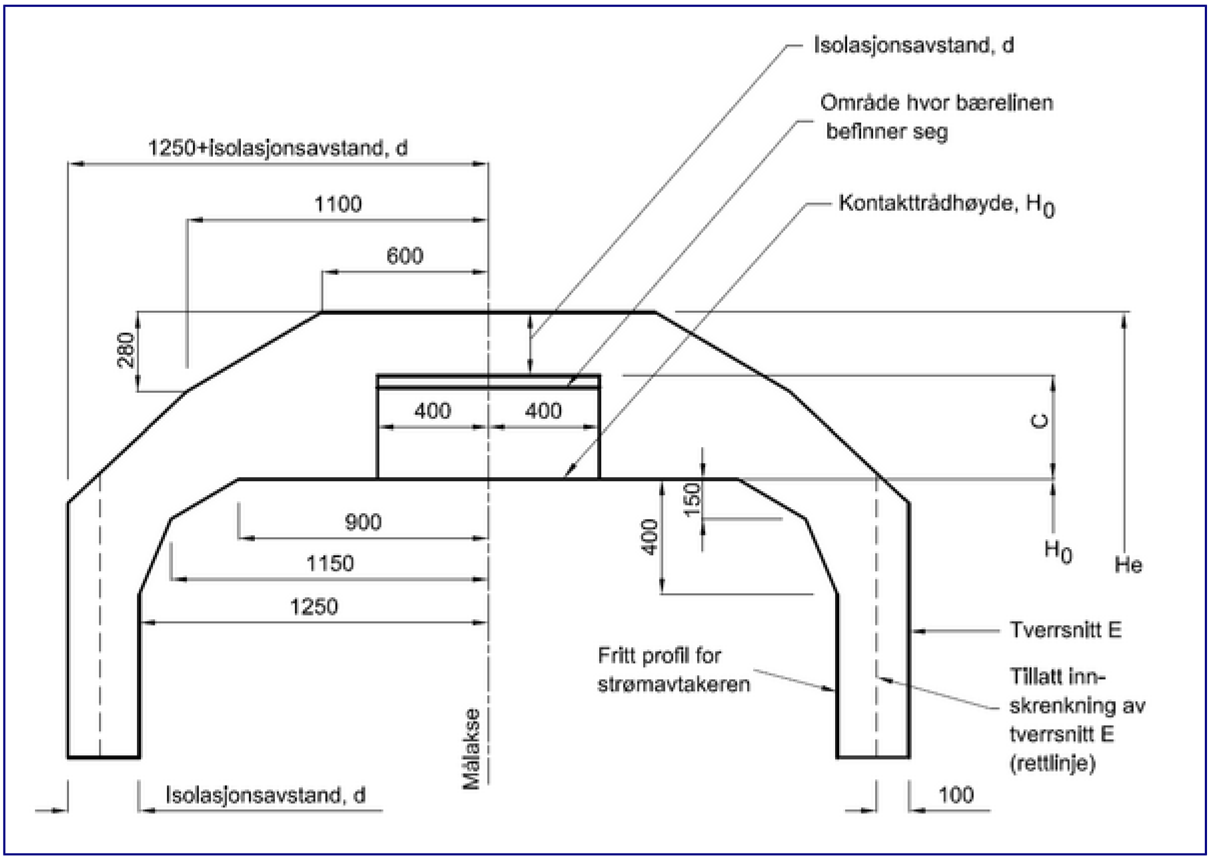
The open profile for the current collector is a dynamic profile that indicates the space requirement for the conveyance of the rolling stock's current collector. Only the current collector is permitted to be within this profile. The profile has no curve overthrow. The profile is shown in **Ingen henvisningsidentifikator er satt** and is described in more detail in Kontaktledning/Prosjektering/Kontaktledningssystemer.

2.7 Infrastructure gauge E

Infrastructure gauge E is the infrastructure gauge required for the open passage of the current collector and overhead contact line system (contact wires and messenger wires). The infrastructure gauge must be designed to ensure there is a sufficient insulation gap between the limit lines and live components. The measurement axis for infrastructure gauge E is perpendicular to the track plane in the centre of the track. Infrastructure gauge E has no curve overthrow. On straight-lined track and more than 30 m from the nearest OB (beginning of transition curve), KP (point of curve) or SS (points curve), it is permissible for infrastructure gauge E to be reduced laterally by 100 mm. The height of infrastructure gauge E (H_E) is dependent on the height of the contact wires at the point of suspension (H_0), the structural height of the overhead contact line (C) and the insulation gap (d).

$$H_E = H_0 + C + d \quad (4)$$

The basis for identifying infrastructure gauge E for existing and new lines is shown in Figure 10.



Figur 10: Open profile for current collectors and infrastructure gauge E for new and existing lines
The requirements for the height of contact wires, H_0, are specified in Kontaktledning/Prosjektering/Generelle_tekniske_krav. In addition, the most common contact wire heights for the various overhead contact line systems are shown in Table 6.

The requirements for structural height, C, (system height) are specified in Kontaktledning/Prosjektering/Kontaktledningssystemer.

The requirements for the insulation gap d are specified in Felles_elektro/Prosjektering_og_bygging/Isolasjonskoordinering_og_overspenningsbeskyttelse.

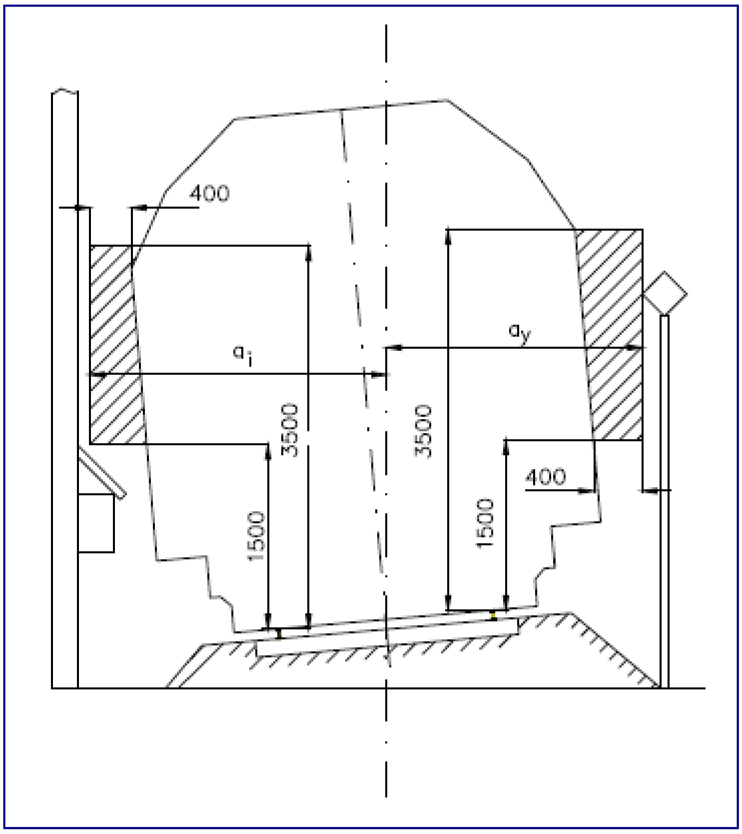
The minimum infrastructure gauge E may be identified by using the minimum values for height of contact wires, structural height and insulation gap.

Infrastructure gauge E does not provide the required space for the overhead contact line system's suspension structures (masts, brackets and cantilevers) and tensioning structures (anchoring wires, weights, fixed terminations and midpoint anchors). The structural height, C, will be greater for switch/section cantilevers than for normal single cantilevers. At locations with space restrictions (tunnels, bridges, culverts, etc.) recesses must be established for the overhead contact line system's suspension and tensioning structures. Space must also be established for any other structures associated with the overhead contact line system/power supply (including, for example, transformer and switchgear structures). The location and design of these structures must be adapted to the design of the overhead contact line system and other power supply equipment.

3 Special provisions for clearance gauges

3.1 Masts and other trackside objects

In areas where shunting operations occur, masts and other high objects (ramps for goods cranes, signage, signals, anchoring wires, water stands, etc.) must be located so that the distance to the minimum infrastructure gauge is at least 400 mm at a height between 1500 mm and 3500 mm above the nearest rail, cf. Figure 11.



Figur 11: Distance to masts and other objects for A-85, A-96 and A-C

$$a_i = 2520 + K_i + 2{,}3 \cdot h$$
$$a_y = 2520 + K_y - h \qquad (5)$$

In areas where shunting operations do not occur, permanent objects (ramps for goods cranes, signage, signals, anchoring wires, water stands, etc.) must be located/installed outside the minimum infrastructure gauge. The distance to the minimum infrastructure gauge must, as a minimum, satisfy the following track tolerances:

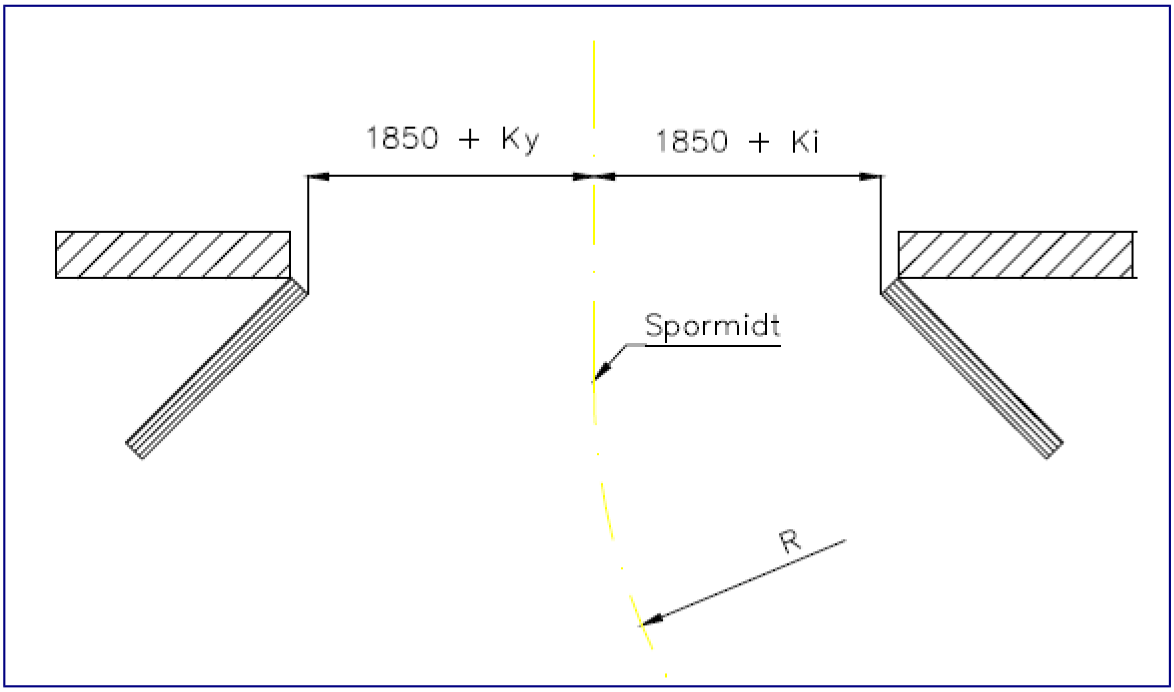
Tabell 4: Track tolerances

Lateral displacement	100 mm
Track raising	50 mm
Track lowering	20 mm
Changing camber	20 mm

When placing objects of a height lower than 1120 mm above the track plane, the lateral displacement tolerance may be reduced to 30 mm.

3.2 Gate openings

The minimum width (= normal width) of gate openings on straight-lined track is 3700 mm. If the track through the gate is located on or in the vicinity of a curve, the width increases with the curve overthrows.



Figur 12: Gate opening on a curve

In specific cases, the minimum infrastructure gauge is required at gate openings:

- When the track through the building constitutes the only connection to the track system on the other side of the building.
- In buildings designed to receive out of gauge loads.

The gates must have a minimum height of 5600 mm. The height may be reduced to 4800 mm in buildings where electrification is not an option.

3.3 Centre of the track

'Centre of the track' refers to the point where the distance between two tracks is sufficiently great for rolling stock to pass without any risk. The guideway pitch at the centre must be large enough to allow for a 100 mm clearance between the loading gauge designated to the one track and the minimum infrastructure gauge of the other track. The centre of the track is marked with a centre mark. The centre mark is a 50 cm light red (vermilion) painted area or a 20 cm long light-reflecting plate placed on the outside of both adjacent rails on tracks that meet or cross each other's path. The entire centre mark must remain in the middle. A curve overthrow must be calculated for both the loading gauge and the minimum infrastructure gauge, as well as allowances for any track camber.

If none of the tracks are running tracks, it is permissible for the above-mentioned gauges to extend up to 100 mm into each other.

The centre of the track must be calculated based on a loading gauge with a width of 3400 mm and, as a minimum infrastructure gauge, A-85, A-96 and A-C must be used, also for new lines.

For new lines, the guideway pitch at the centre, calculated in accordance with the above regulations, must not be less than 4000 mm.

3.4 Loading installations

It may be permissible for parts of permanent loading installations (e.g. flaps for chip ramps) to fall within the minimum infrastructure gauge under the following conditions:

- These parts must be securely placed outside the minimum infrastructure gauge once the loading operation has been completed.
- In addition, these parts must be secured when the loading layout is facing a train track.

On tracks that are only used for specific loading operations, it may be permissible for parts of loading installations to permanently fall within the minimum infrastructure gauge.

3.5 Location and laying of cable ducts

Cable ducts must be located outside of the cable-free profile, cf. Felles elektro/Prosjektering og bygging/Kabellegging og kabelkanaler.

The following requirements also apply:

- Cable ducts must be installed at formation level.
- Cable ducts should be located within mast foundations. This means that mast foundations should be placed at a sufficient distance from the centre of the track so that future space requirements for cable ducts are safeguarded.
- Cable ducts must be adequately supported on both sides so that they cannot shift, for example, during work on the ballast layer. Gravel backfill must not extend higher than 50 mm under cable duct covers.
- Cable ducts must be located in such a way as to ensure that subsoil settlement does not cause vertical displacement between elements.

For cable ducts in tunnels where the ducts are to be used as walkways, reference is made to Chapter 12, Tunnels.

4 Normal profiles

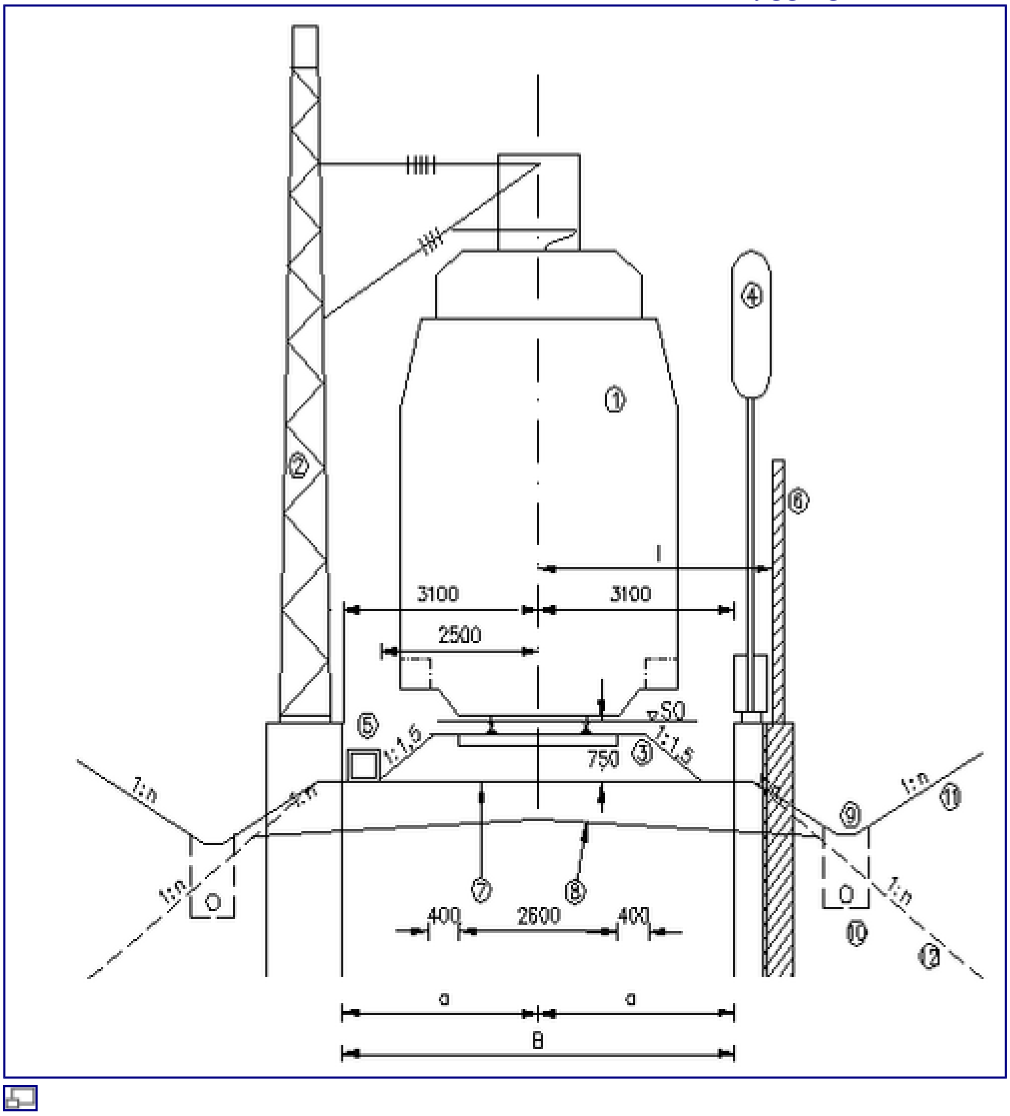
4.1 Normal profile for open sections of line

Structures along open sections of line comprise a number of elements. Table 5 shows a rough, numbered outline of the various structures and elements, as well as references to the parts of the regulations in which these are described in more detail. Numbers are used for figures 13 and 14.

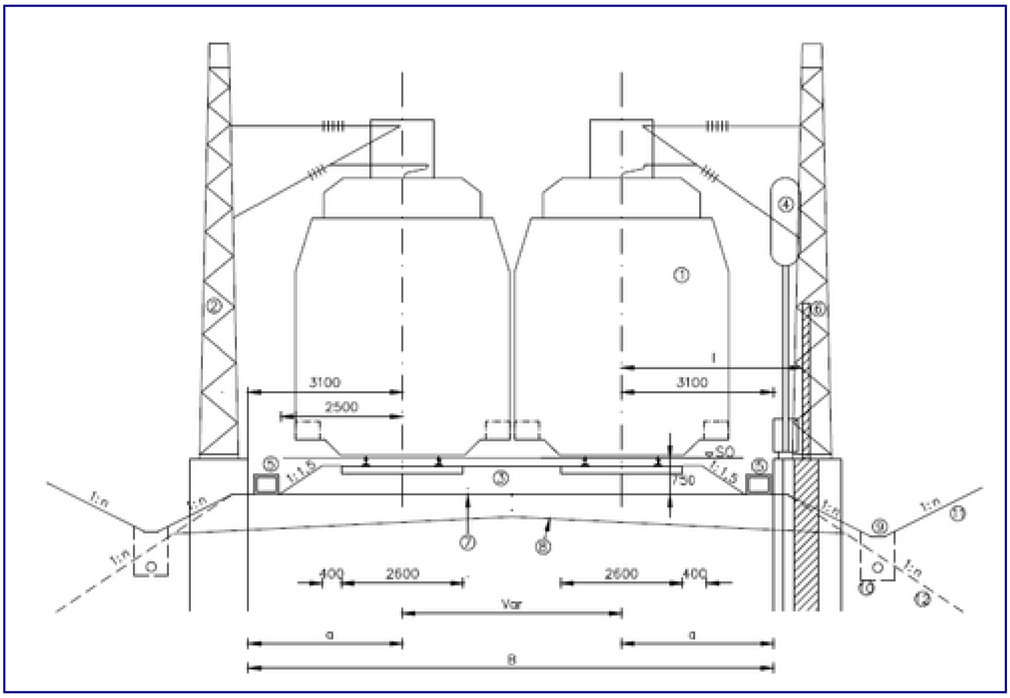
Tabell 5: Normal profile for open sections of line, single-track line

Part	Structure/element	Reference
1	Minimum infrastructure gauge for trains and infrastructure gauge E	Section 2
2	Overhead contact line mast	Kontaktledning/Prosjektering/Konstruksjoner
3	Ballast profile	Overbygning/Prosjektering/Ballast
4	Signal mast	Signal/Prosjektering/Lyssignal
5	Cable duct	Tele/Prosjektering og bygging/Kabelanlegg
6	Acoustic barrier	Underbygning/Prosjektering og bygging/Støyskjermer
7	Formation level	Underbygning/Prosjektering og bygging/Banelegeme
8	Formation	Underbygning/Prosjektering og bygging/Banelegeme

9	Open lineside ditch	Underbygning/Prosjektering og bygging/Drenering
10	Closed lineside ditch	Underbygning/Prosjektering og bygging/Drenering
11	Slope gradient	Underbygning/Prosjektering og bygging/Stabilitet



Figur 13: Normal profile for open sections of line, single-track line<



Figur 14: Normal profile for open sections of line, double-track line

4.2 Normal profile for tunnels

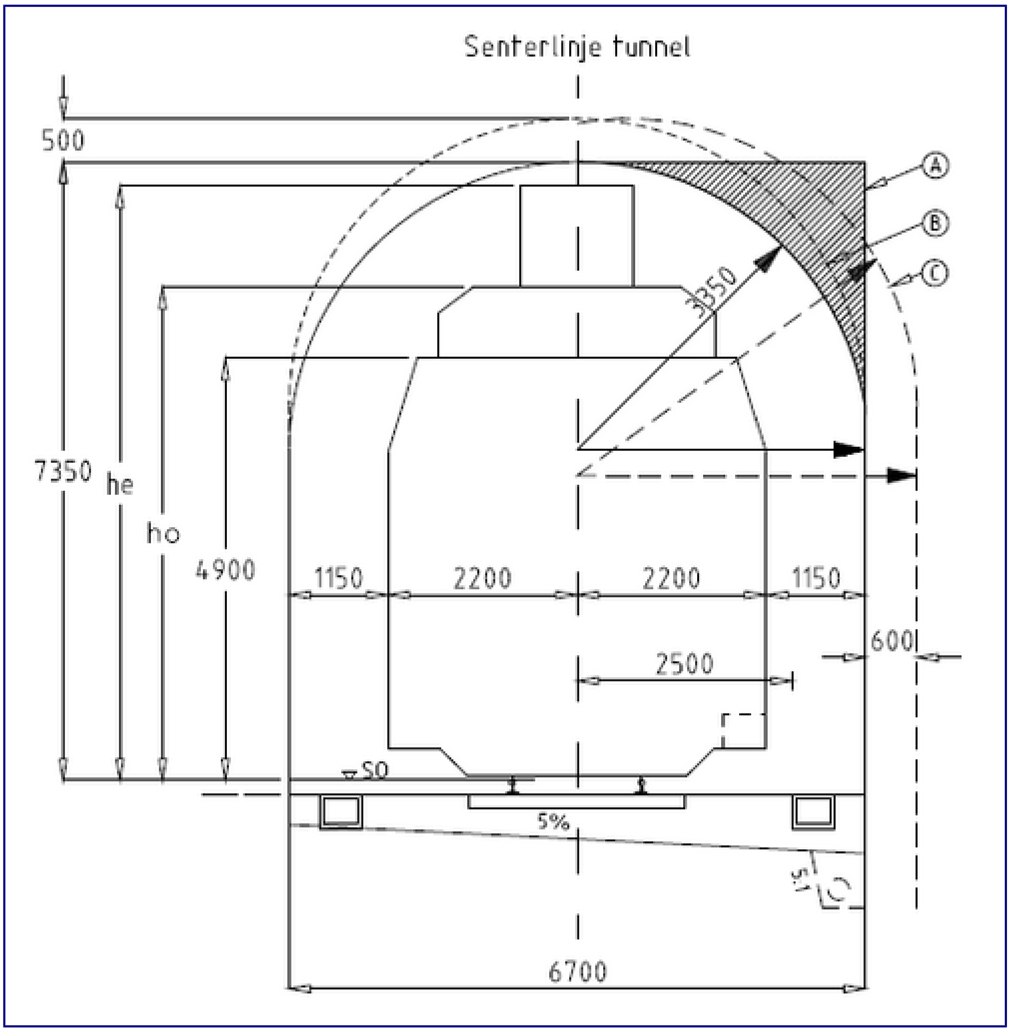
The normal profile for tunnels applies when the structure's length above the longitudinal direction of the track is greater than 20 m. Such structures may be tunnels, snow sheds and other superstructures (structures that support houses, car parks, etc.). In such structures, there must be sufficient space for the minimum infrastructure gauge, the overhead contact line system's cantilevers and tensioning gear, signalling systems, cable installations, etc. There must also be space for personnel in proximity to the side of the line whilst trains are passing. Air resistance and any safety requirements must also be taken into account, as well as necessary space considerations in respect of the construction and maintenance of structures.

The normal profiles for single and double-track lines in figures 15 and 16 apply to speeds of 200 km/h. Figures 17 and 18 show the correlation between a normal profile and a theoretical blast profile and apply to double-track tunnels with speeds of, respectively, 200 km/h and 250 km/h. The above space requirements are included.

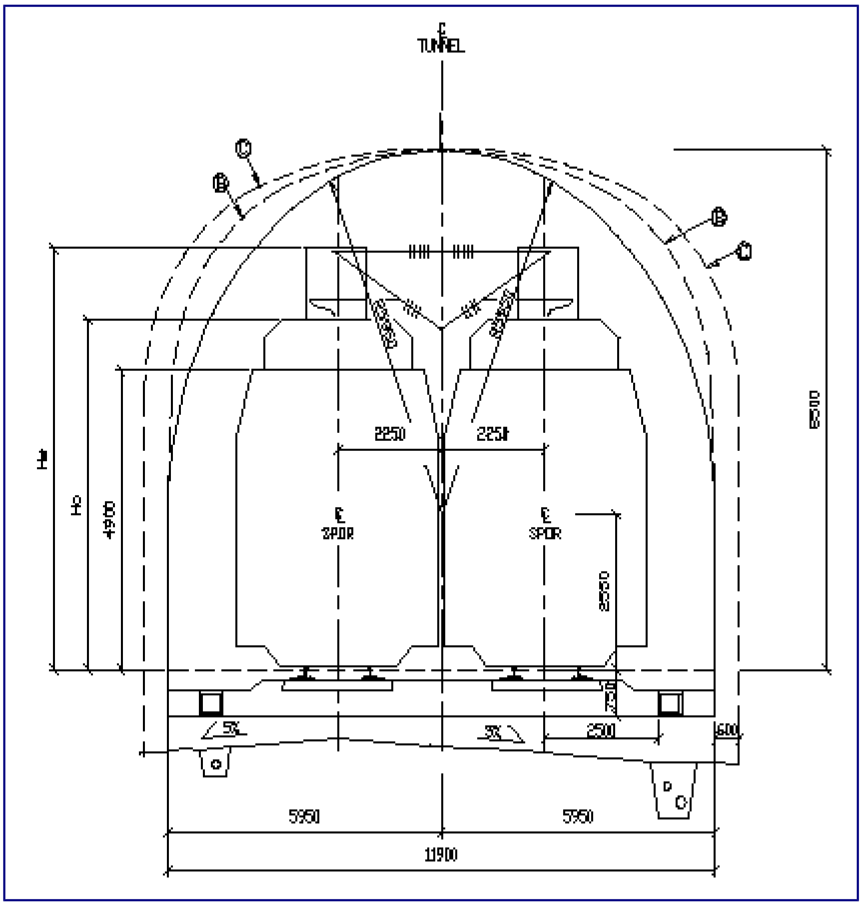
For speeds of between 200 and 250 km/h, a 4.7 m guideway pitch between the centres of the track must be used in double-track tunnels.

For tunnels with significantly lower speeds than 200 km/h, the infrastructure gauge may be specially designed. This is because the required infrastructure gauge is at least as dependent on the system chosen for technical installations as it is on actual compression and suction forces.

Figure 19 shows an example of a TBM profile for speeds up to 200 km/h.

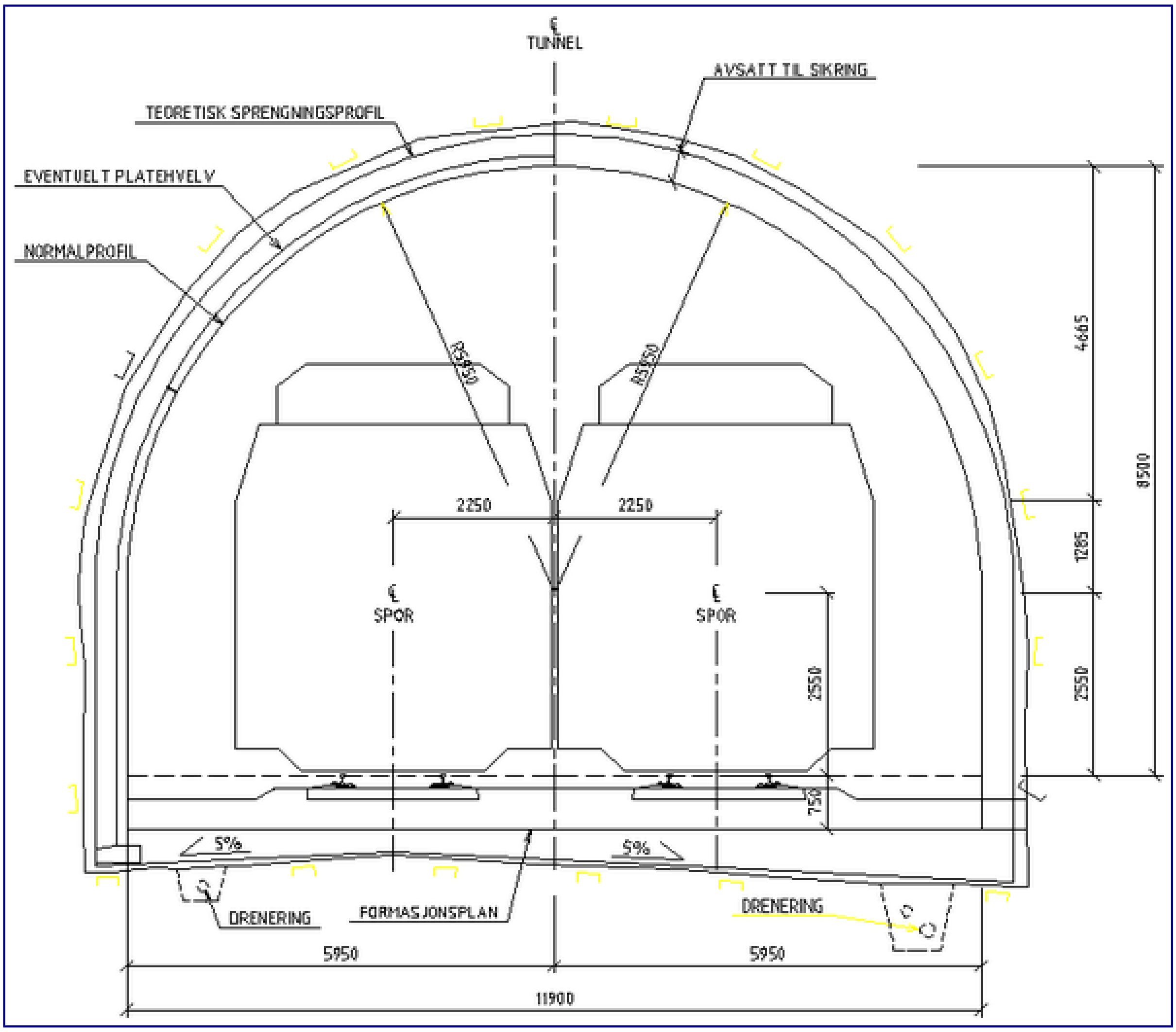


Figur 15: Normal profile tunnel, single-track line, V = 200 km/h

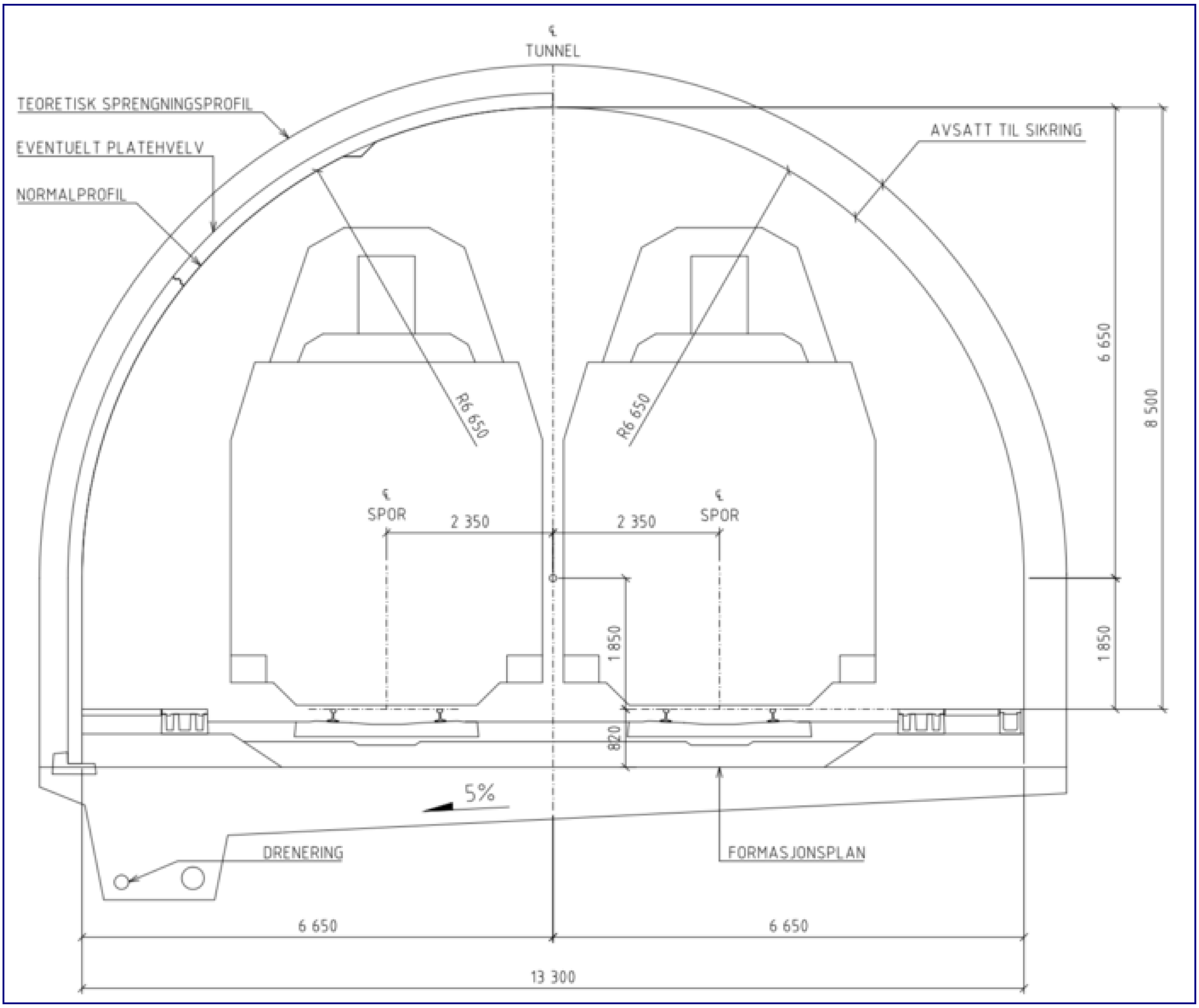


Figur 16: Normal profile tunnel, double-track line, V = 200 km/h

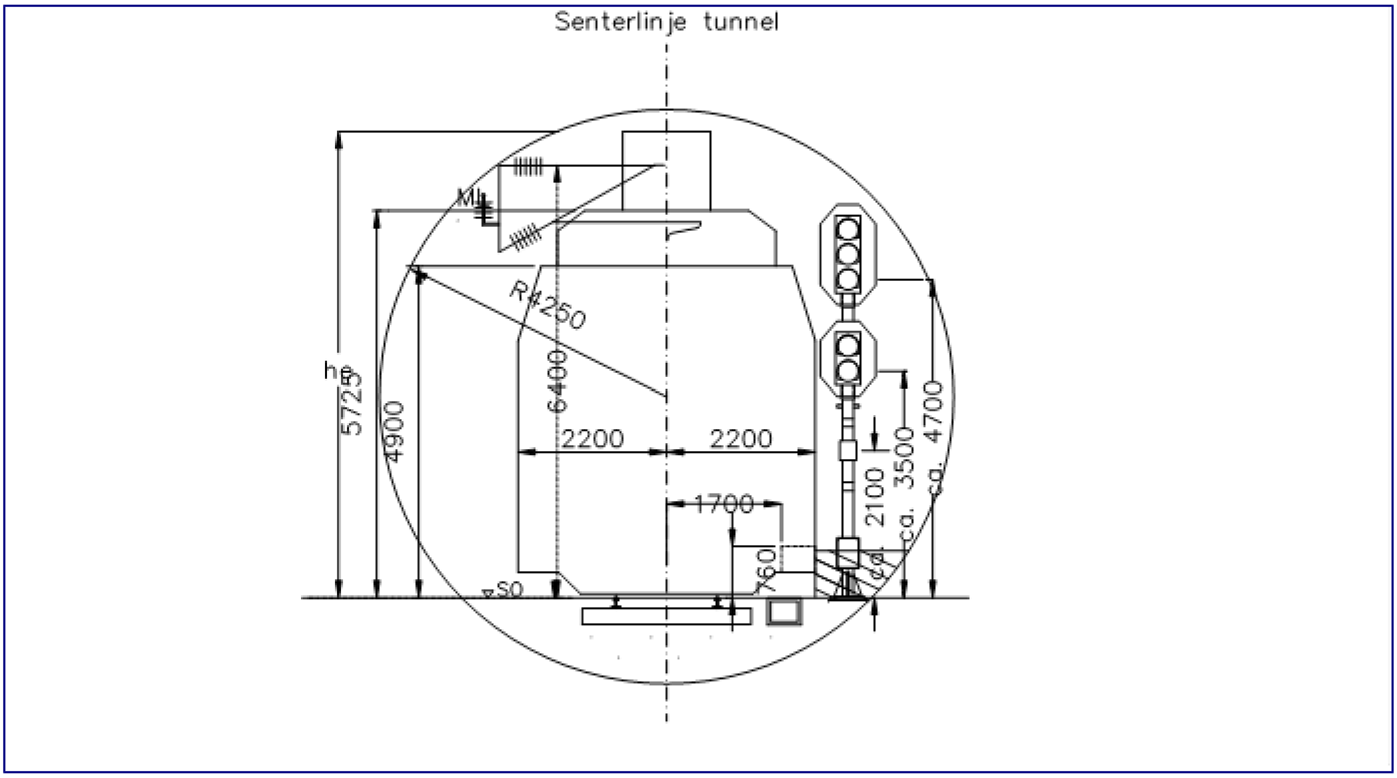
The overhead contact line system requires three different recesses - recess A, B and C: Recess A is for cantilever and cantilever fittings. Recess B is for overlap span and overlap section. Recess C is for tensioning the overhead contact line system via counterweights.



Figur 17: Correlation between a normal profile and a theoretical blast profile. Example from a double-track line, V = 200 km/h.



Figur 18: Correlation between a normal profile and a theoretical blast profile. Example from a double-track line, V = 250 km/h



Figur 19: Example of TBM profile for speeds up to 200 km/h

The height of the contact wires, h_0, is dependent on the type of overhead contact line system. The most common values for the height of contact wires appear in Table 6.

Refer also to Kontaktledning/Prosjektering/Generelle_tekniske_krav.

Figur 19: Example of TBM profile for speeds up to 200 km/h

Overhead contact line system	**h_0 [m]**
System 35	5.05-5.60
System 20 C_1	5.05-5.60
System 25	5.30

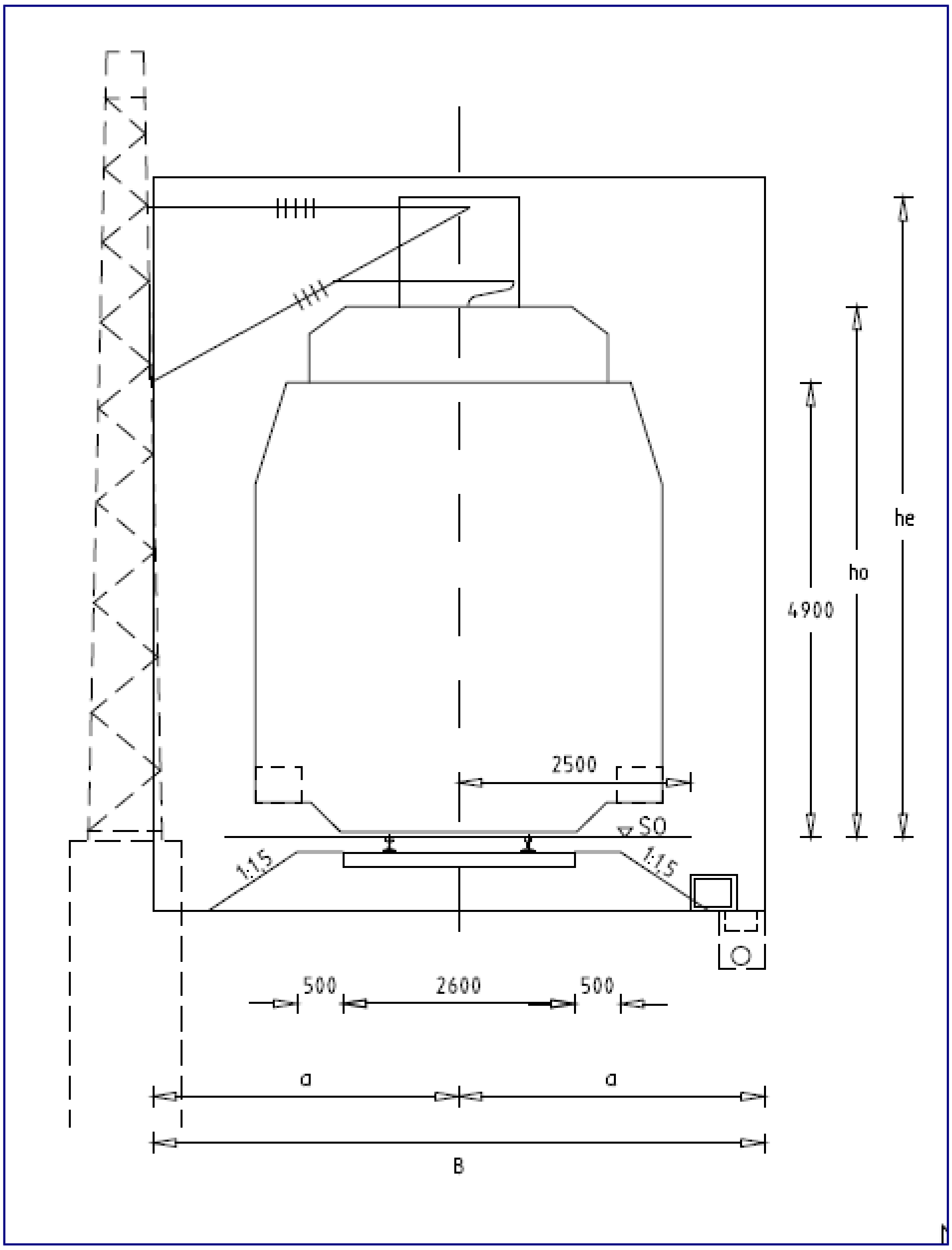
1 Normal profile above the track where the curvature of the track changes

On sections of line where the curvature of the track changes, the tunnel's width and horizontal dimension also changes. The transition between different values should be dealt with by carrying over the highest value up to 20 m past the nearest OB (beginning of transition curve), FOB (beginning of shared transition curve or KP (point of curve). The transition is levelled out linearly.

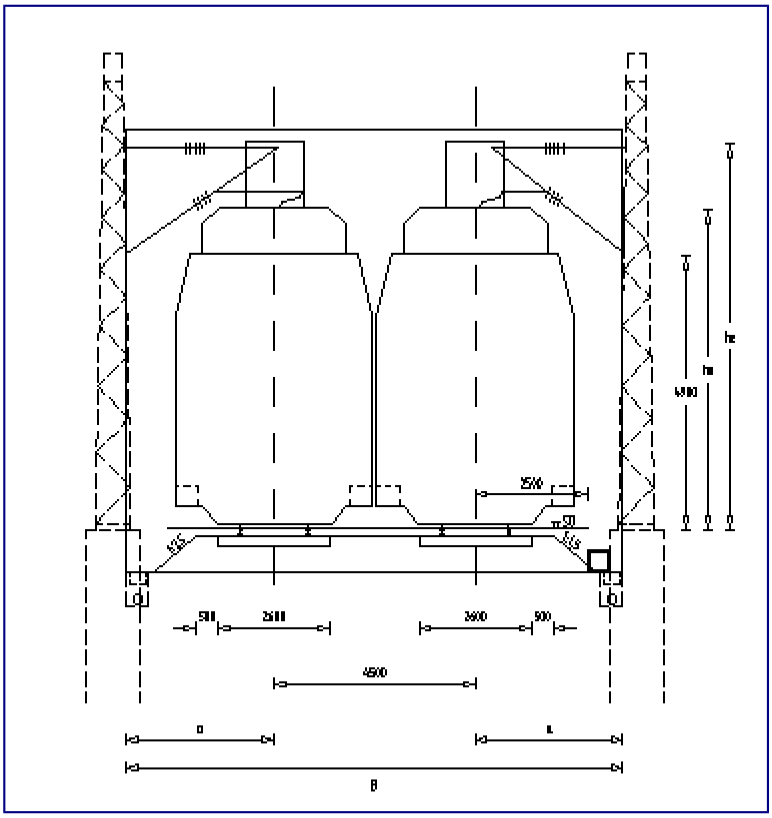
2 Normal profile for structures above the track

The normal profile for structures above the track applies when the structure's length above the longitudinal direction of the track is less than 20 m. Such structures may be tunnels, snow sheds and other superstructures (structures that support houses, car parks, etc.).

The bridge regulations apply to flyovers, refer to Bruer/Prosjektering_og_bygging/Overgangsbruer.



Figur 19: Example of TBM profile for speeds up to 200 km/h



Figur 21: Normal profile for structures above the track, double-track line

Tabell 7: Required width under structures with a length of ≤ 20 m

Radius R [m]	a [m]
1000	3.240
1000–1500	3.190
1500–2000	3.150
2000–2500	3.140
2500–5000	3.090
5000	3.000

For structures above the track with a length less than or equal to 20 metres, the calculation of infrastructure gauge E may use the value for structural height, C, equal to the highest structural height under the structure.

5 Appendix

Vedlegg a: Profiler ved Jernbaneverket