REVISION

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1 OBJECTIVE

The aim of this document is to define the line characteristics and maximum defects for which the tramway of Tallinn has been designed.

The design of the vehicle's suspension is subjected to the track characteristics and line defects. During the design of the suspension the track characteristics and line defects that affect the dynamic performance of the vehicle have been defined.

As for the line characteristics, the vehicle is going to be designed so as to run through specific track conditions: minimum curve radius and maximum track cant.

Concerning the line defects, in this document the construction, warning and intervention criterion are going to be established. These maximum values should not be exceeded in none of the lines through which the vehicles will run during their life.

Additionally, a formal advise will be given in relationship to the document "tram track norms_200314.docx", and attached [Annex E] to this document, as requested by TLT.

2 INFRASTRUCTURE AND VEHICLE CHARACTERISTICS

Certain track and vehicle characteristics need to be considered in order to define the limits of line defects. These characteristics are mentioned in this section.

2.1 Infrastructure characteristics

The following infrastructure characteristics have been considered in the line defect analysis:

- Nominal track gauge: 1067mm.
- New rail profiles: Ri60 and Ri62 [Annex A]
- Rail inclination: Vertical.

2.2 Vehicle characteristics

The following vehicle characteristics have been considered in the line defect analysis:

- Wheel back to back distance: 1017mm
- Wheel profile: X.06.00444 [Annex B]

The wheel back to back distance was defined by TLT to have the same distance than current KT4 trams, and the wheel profile for the new Tallinn trams was defined by CAF in the reference [3].

3 DEFINITIONS

In this section each of the line characteristics and defects mentioned in this document are going to be defined.

3.1 Line characteristics: Construction parameters.

These are the parameters that give the geometrical information of the tracks.

- **Minimum horizontal curve:** Geometrical minimum curve radius of the track. In this document the minimum curve radius refers to a curve with specific cant.

- **Maximum track cant:** Maximum difference in height between the inner and outer rails on curves. The tramway will be designed for a maximum track cant.

3.2 Line defects: Maintenance parameters.

The following line defects should be controlled and ensured that do not exceed the limits defined in this document:

- **Gauging**: Variation (increase/decrease) of the nominal gauge of the track. These variations are the consequence of the displacement and wear that the rail can experience.

- **Cant gradient/Track twist**: Amount by which cant is increased or decreased in a given length of track. The cant variation can be of short wave, when the length is equal or below the distance of the two wheels of the same bogie or of long wave, when the length is over this distance. In the figure below the cant gradient is represented.

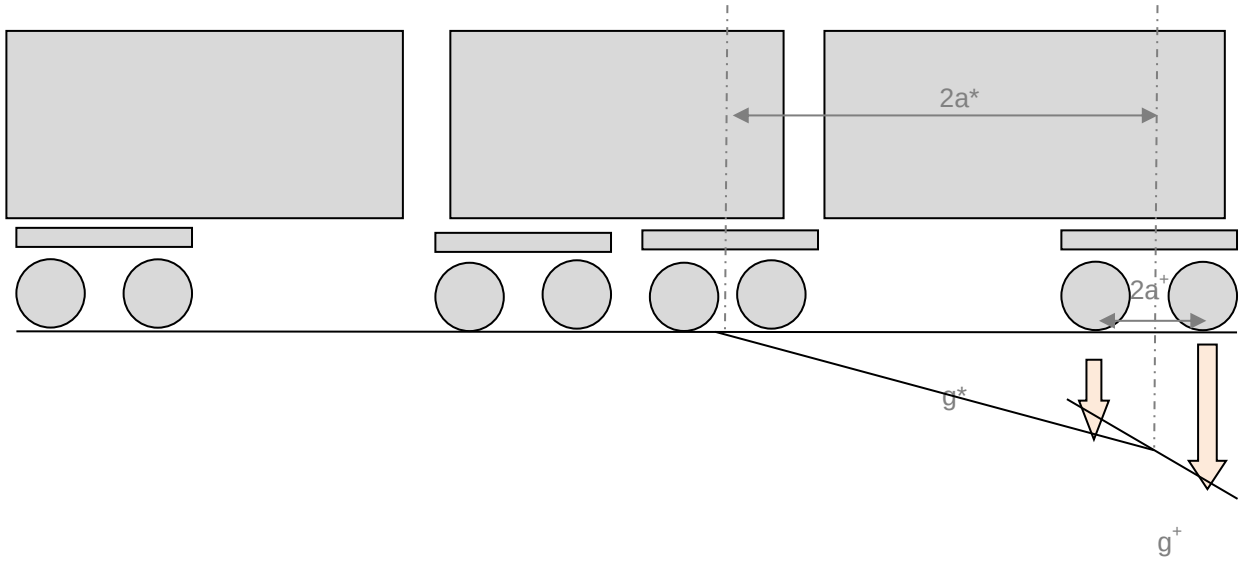


Figure 1. Long and short wave cant gradient.

Where
2a*: Distance between canters of bogies.
2a+: Distance between canters of wheelsets.
g*: Long wave cant gradient. Length of defect: Over 1.85m.
g+: Short wave cant gradient. Length of defect: 1.85m or less.

4 LIMITS

In this section the limits of the parameters mentioned above are established.

4.1 Main track characteristics

- Minimum horizontal curve radius: 25m[1].
- Maximum track cant: 50mm.

These characteristics refer to the curve defined in 3.2.

The values given in the point 4 of the document “Tram track construction norms” are ACCEPTABLE for the normal operation of the tram.

4.2 Line defects

Three different tolerances have been considered for each of the line defects:

- Constructional design criterion.
- Warning criterion.
- Intervention criterion. (Immediate action)

In point 5 the limit definition criteria will be explained.

- **Gauging**:

The nominal track gauge must be 1067mm for all the straight zones and curves of the line.

In the following table the construction and maintenance tolerances are defined:

mm	*Construction criterion*	*Warning criterion*	*Intervention criterion*
+ gauging	0	+2	+3
- gauging	-2	-4	-5

Table 1. Track gauge tolerances

The track must fulfil with the intervention criteria. The construction and warning criteria are guidelines that may be modified.

[1] The mínimum horizontal curve radius in the depot is 20 meters, and the trams have been designed to run on curves up to 19 meters. The restriction is just for canted curves.

The values given in the point 2 of the document “Tram track construction norms” are NOT ACCEPTABLE for the normal operation of the tram.

- **Track twist**:

  As for the track twist the following tolerances have been considered for the transition of all the curves of the line:

mm/m	*Construction criterion*	*Alert criterion*	*Intervention criterion*
Short wave	2,5	4,0	5,0
Long wave	2,5	3,3	4,3

Table 2. Track twist tolerances.

The track must fulfil with the intervention criteria. The construction and warning criteria are guidelines that may be modified.

The values given in the point 5.1 of the Tram track construction norms are NOT ACCEPTABLE for the normal operation of the tram.

5 LIMIT DEFINITION CRITERIA

In the following section the limit definition criteria will be presented.

5.1 Track characteristics

The curve with maximum track cant and minimum radius is the riskiest curve from the point of view of the security against derailment by flange climbing. As the vehicle has been designed to run through lines 3 and 4, the worst curve of these lines have been selected:

- R=25m.
- H=50mm.

This curve is located in line 3 to 1.65Km of Hobujaama Station. [Annex C]

It must be checked that the lines through which the vehicle is going to run fulfil with the requirements defined in this section.

5.2 Line defects

5.2.1 Gauging

For the selection of the maximum and minimum gauge permitted, different criteria have been followed.

- Keeper rail contact with flangeback.
- Rail contact with flange.

Keeper rail contact with flangeback

In order to determine the maximum tolerable gauge, contact between the keeper rail and the flangeback of the wheel have been analysed.

It is considered that keeper wear will ultimately lead to the life expiry of the rail section as it will no longer be able to withstand the loads being imparted on it by the flangeback of the wheel and will therefore begin to present a derailment hazard. [1]

That is why, the maximum permitted gauge (1070 mm) has been defined with the aim of avoiding the permanent contact between the keeper rail and the flangeback. With the intervention track gauge it is ensured that the wheel contacts before with the flange than with the flangeback (Ri60 rail profile) or at least at the same time (Ri62 profile).

The following figure shows the contact between the wheel and the rail when the for the intervention gauge with Ri60 rail profile:

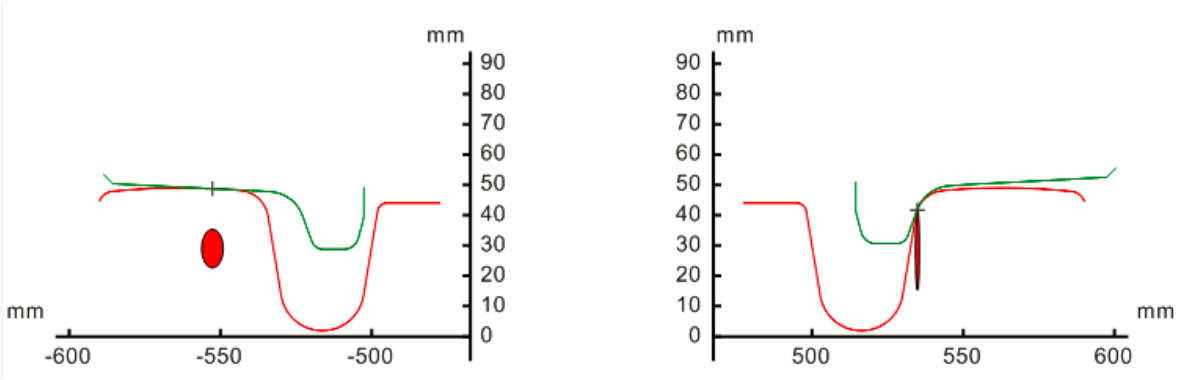


Figure 2. Ri60 rail and Wheel profile contact. Track gauge: 1070mm

As it can be observed from the figure above when the rail of one side is contacting the flange, there is still clearance left for the flangeback contact to occur.

Figures in Annex D represent the rolling radius variation for the nominal and the intervention track gauges for the different rail profiles. The contact of flange and flangeback can be analyzed on these figures.

Rail contact with flange

In order to determine the minimum tolerable gauge, contact between the flange and the rail of the wheel have been analysed.

With the minimum track gauge (1062 mm) it is ensured that the clearance between the rail and the wheel flange is big enough (around 4 mm). The aim of this criterion is to avoid excessive flange wear.

Figures in Annex D represent the rolling radius variation for the nominal and the intervention track gauges. The contact between flange and rail can be observed on these figures.

5.2.2 Track twist

The greatest derailment risk usually arises at the transition from curve to straight track. At this point the outer wheel of the leading axle losses load due to track twist and at the same time, it bears great lateral efforts due to curve negotiation. This combination enhances the risk of derailment by flange climbing.

So the transition from a curve with specific track cant to a straight track without cant, influences directly on the security against derailment. That is why it is necessary to define the maintenance track twist.

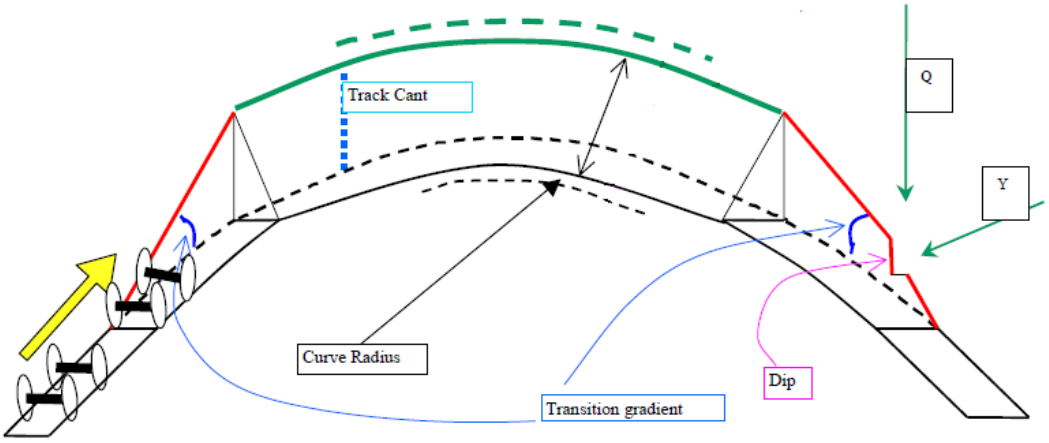


Figure 3. Security against derailment by flange climbing.

Considering the track twists defined in the European Standard EN14363:2005 [2], the intervention limits mentioned in section 4.2 have been defined for this tramway.

6 PENDING POINTS

Infraestructure designer, constructor and/or maintainer will have to carry out a compatibility analysis of the wheel [Annex B] with the track and special trackworks.

Moreover, it must be checked that the lines for which the vehicle will run and that are not being reconstructed comply with the parameters defined on this document.

7 CONCLUSIONS

The vehicle has been designed in order to have an adequate dynamic performance considering these track characteristics and defects limits.

These features have been limited since they have a big impact on vehicles dynamic performance, mainly on safety against derailment performance. In case the tolerances of the defects aforementioned are not fulfilled, apart from affecting the comfort, noise and wheel and rail wear, can compromise the dynamics of the vehicle, which can increase the tendency to derailment.

The compliance of the CAF suspension design with the dynamic performance requirements will be ensured provided these maintenance limits are not exceeded.

A new document edition will be performed in order to close the pending points.

REFERENCES

[1] Dr Paul Allen, Dr Adam Bevan. Determination of Tramway Wheel and rail profiles to minimize derailment. February 2008.

[2] EN 14363. “Railway applications–Testing for the acceptance of running characteristics of railway vehicles – Testing of running behaviour and stationary tests”, June 2005.

[3] Q.44.93.450 Wheel profile selection. Document issued by CAF for the Tallinn Tram Project .

ANNEX A. RAIL PROFILE

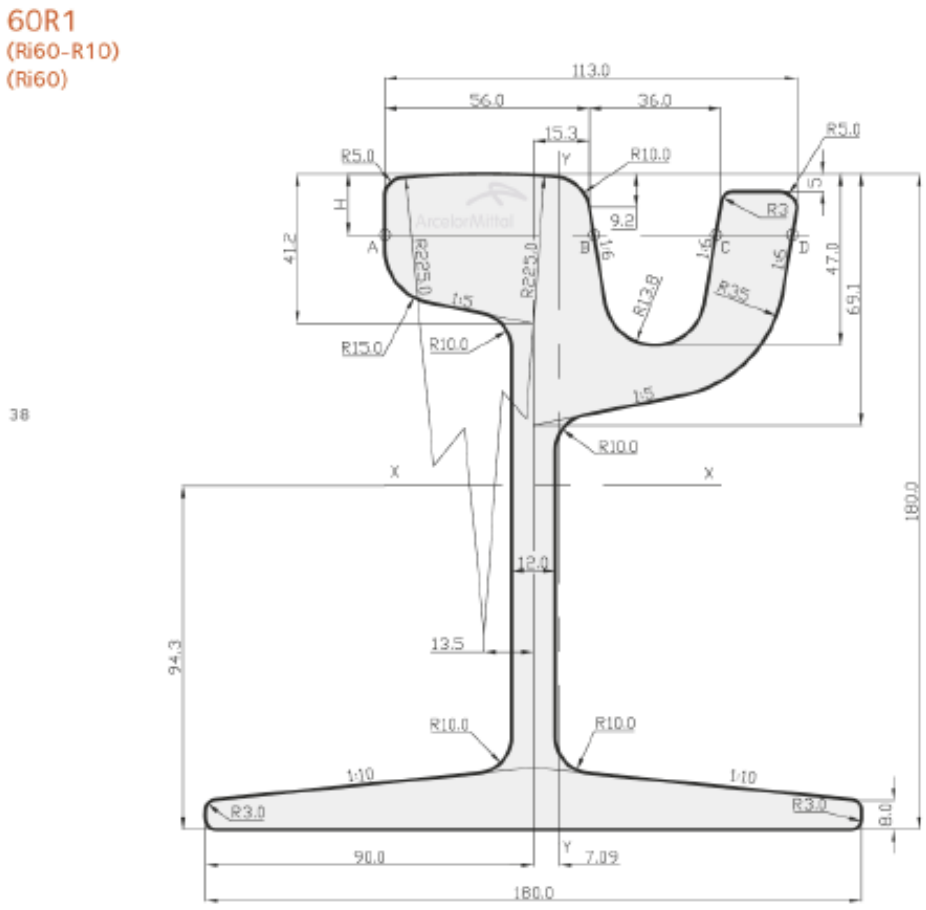


Figure 4. Ri60 rail profile

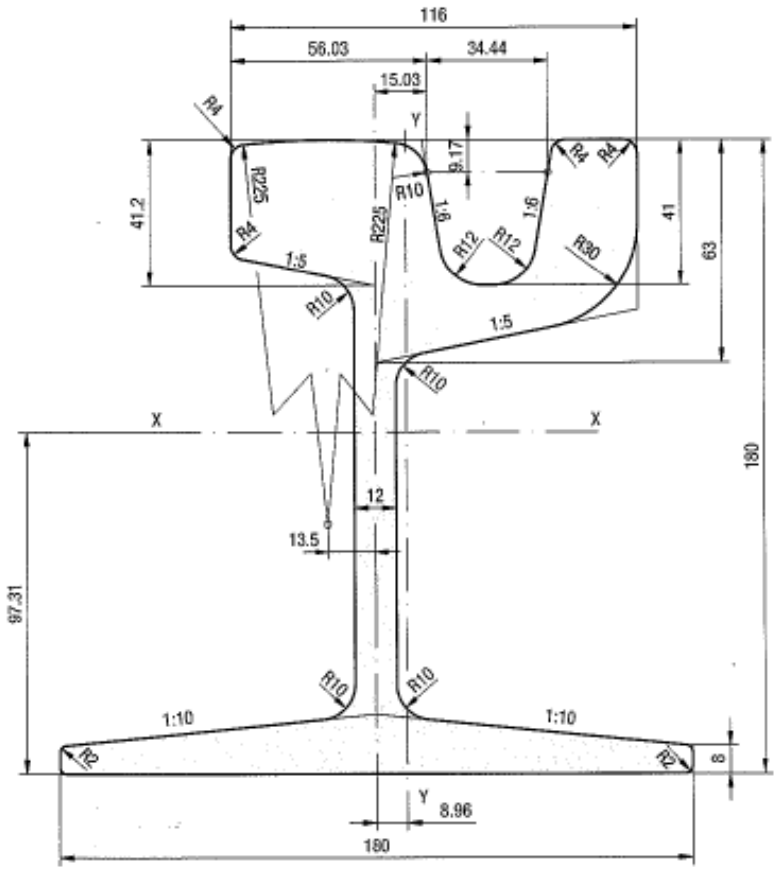
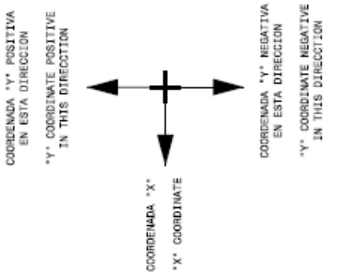


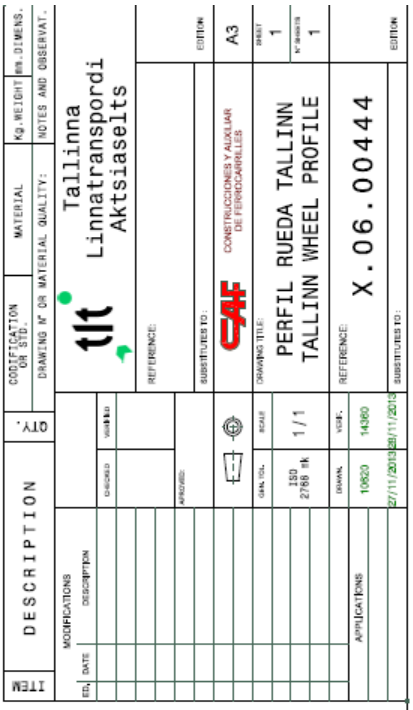
Figure 5. Ri62 rail profile.

ANNEX B. WHEEL PROFILE

COORDENADAS DE PUNTOS POINT COORDINATES		
PUNTO POINT	COORDENADA "X" "X" COORDINATE	COORDENADA "Y" "Y" COORDINATE
A	0	8.711
B	0.348	11.326
C	1.844	16.849
D	6.67	20.541
E	13.477	20.541
F	17.236	17.909
G	20.322	9.404
H	30.703	1.542
I	39.408	0.992
J	83	-1.215
K	86	-4.215

COORDENADAS DE RADIOS RADIUS COORDINATES		
PUNTO POINT	COORDENADA "X" "X" COORDINATE	COORDENADA "Y" "Y" COORDINATE
L	10	8.711
M	6.67	15.541
N	13.477	16.541
O	31.608	13.508
P	57.109	350.544





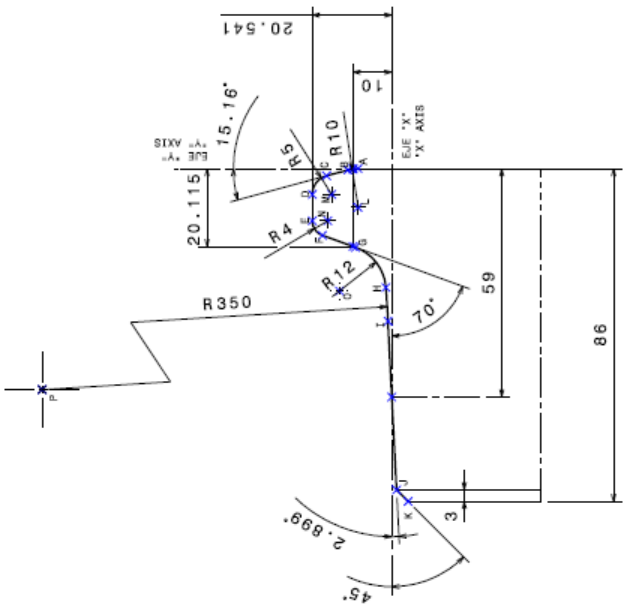


Figure 6. Wheel profile.

ANNEX C. LINE 3 TRACK INFORMATION (Hobujaama round)

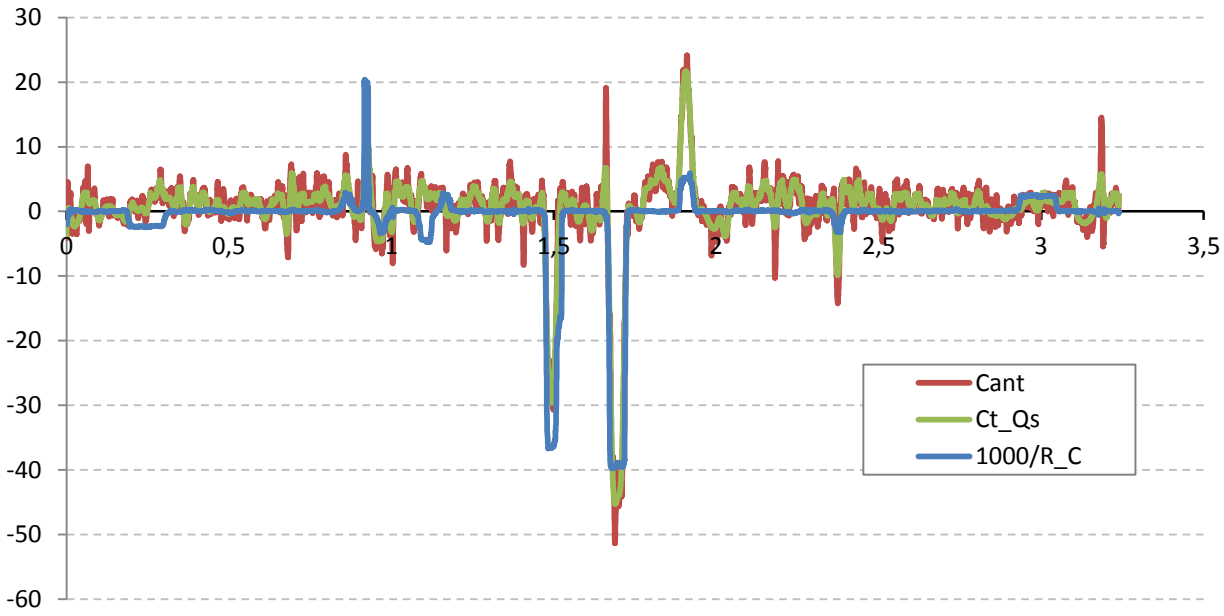
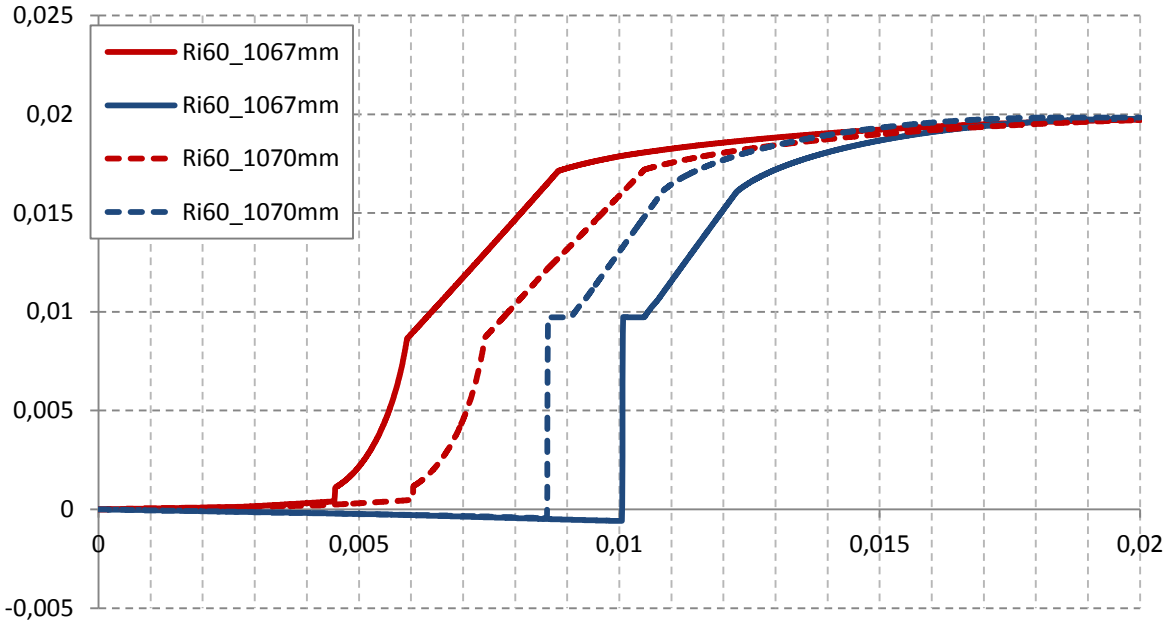
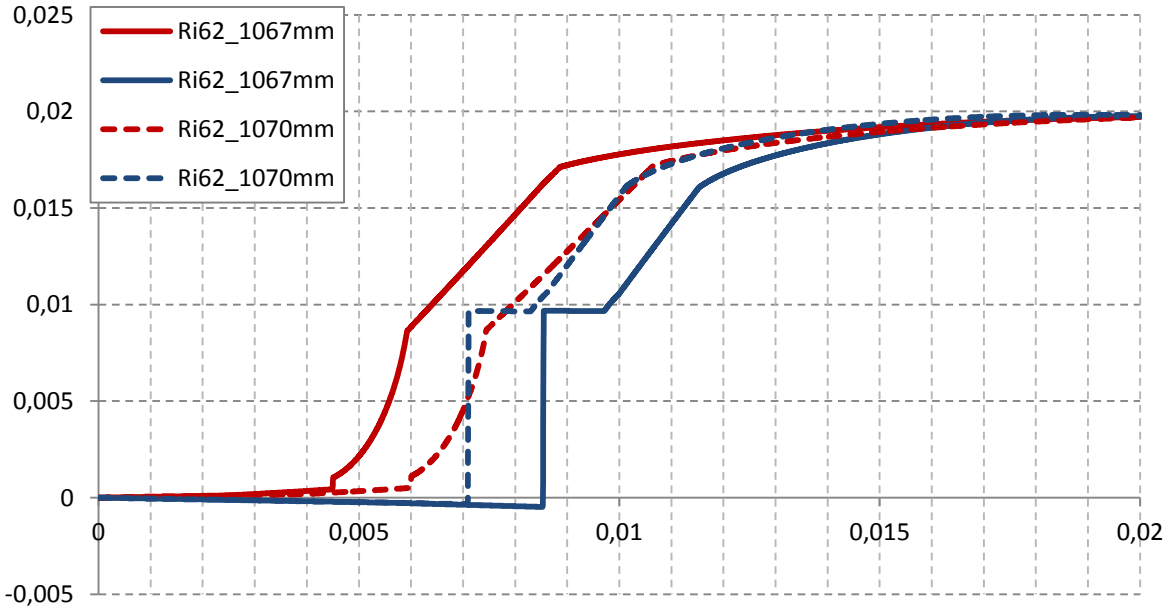
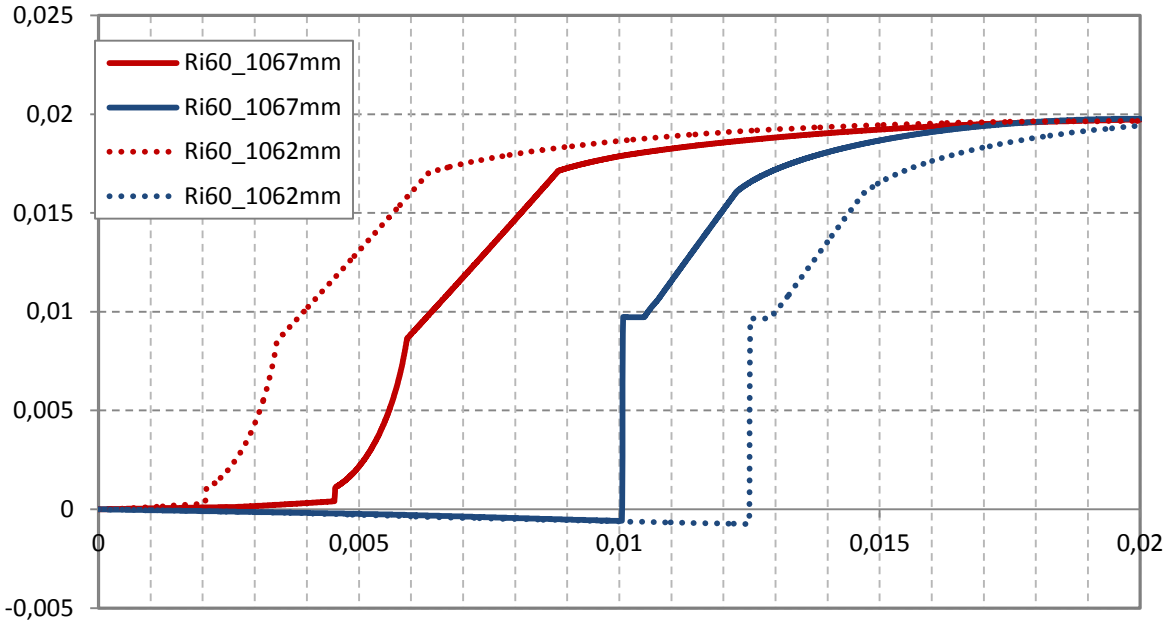


Figure 7. Line 3 track information.

ANNEX D. ROLLING RADIUS VARIATION WITH DIFFERENT TRACK GAUGES






0,025
0,02
0,015
0,01
0,005
0
-0,005
0
0,005
0,01
0,015
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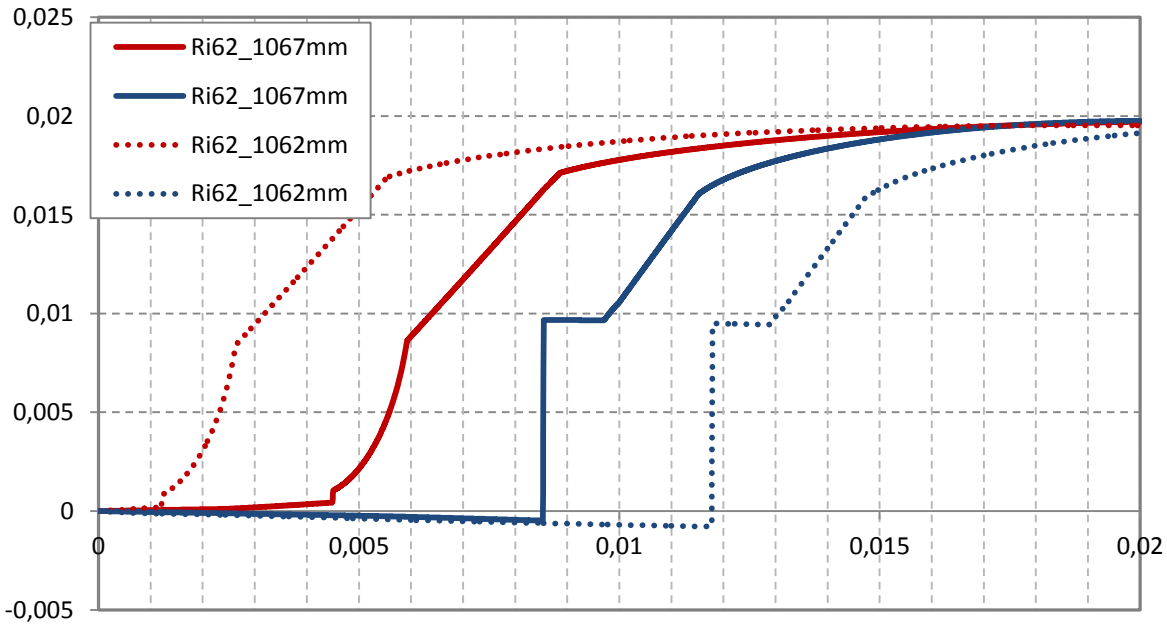
Ri60_1067mm
Ri60_1067mm
Ri60_1062mm
Ri60_1062mm


0,025
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-0,005
0
0,005
0,01
0,015
0,02
Ri62_1067mm
Ri62_1067mm
Ri62_1062mm
Ri62_1062mm

ANNEX E. Tram track norms_200314.doc

Tram track construction norms

2. Track gauge

	Norms	Allowed deviations, mm
Gauge	1067 mm	+1; -2
Curves R< 20m	1067 – 1069mm	+1; -2
Curves 20≤R≤25	1071 mm	+1; -2
Curves 26≤R≤75	1072 mm	+1; -2
Curves R >200m	1067 mm	+1; -2
Switches and crosses	1067 mm	+1; -2

3. Cant and twist

Cant and twist – 0 mm

4. Cant from outer rail in relation to inner rail

Curve radius	Cant (separated track)	Cant on track under road traffic
R ≤ 50 m	50 mm	35 mm
51<R≤200	35 mm	35 mm
201<R≤500	30 mm	30 mm
501<R≤1000	20 mm	20 mm

5. Transitions

5.1 Cant in transitional curves may not be higher than 5 ‰, in difficult conditions 7‰.

5.2 Gauge in curves is widened within the transitional curve, without transition on the straight section before the curve not more than 1 mm per meter (except S-curves where gauge is calculated separately).

6. Tie bars

Tie bars must be placed after every 1,5 meters in both, straight and curve sections.