Rail Baltica
Coordinated by RB Rail

DESIGN GUIDELINES

TRACK TERMINATIONS (BUFFERSTOPS, HEAD RAMPS)

13-05-2024

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1.0	13-05-2024	Systems and Operations department	First issue	
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Contents

Acronyms and Abbreviations

A full list of acronyms and abbreviations can be found in RBR Glossary of Abbreviations. The following acronyms and abbreviations are used throughout this document:

Abbreviation	Definition
CM	Class of main frame for the Buffer stop
IM	Infrastructure Manager

Definitions

The following terms are used throughout this document:

Term	Definition
Auxiliary brakes	Additional braking jaws or friction elements that are mounted on the rail behind the mainframe of the Buffer stop. In case of an impact, the sliding mainframe will hit the additional clamps one after another and will gradually build up a braking force.
Braking jaw	Braking jaw or friction elements that are mounted to the head of the rail and are not fixed to the main frame of the buffer stop. They glide along the rail and absorb kinetic energy by friction between the rail and the steel clamp.
Buffer stop	A buffer stop, (also known as bumper, bumping post, bumper block or stopblock), is a device to prevent railway vehicles from going past the end of a physical section of track.
Friction buffer stop	Buffer stop which is designed to dissipate impact energy in a controlled manner by sliding barking jaws installed between the frame and the rail profile.
Track reinforcements	Impact reducing installation for tracks reinforcement to avoid the deforming of the superstructure because of an impacting vehicles on a buffer stop mainframe.
Impact reducing installation	Measures that are used additionally for buffer stops, if the normal friction elements are not sufficient to stops an impacting train in the available braking distance and/or the expected weight of the train is too high.

1 Introduction

1. The general requirements for track terminations are defined in chapter 3.4.4 in the RBDG-MAN-014-0107_RailwaySuperstructure-Track.

2 Effective forces on Buffer stops

1. As a result of an impact of rolling stock on a Buffer stops the impact energy will be transmitted onto the Buffer stops. As a result, there is a compressive load on the rear part and a tensile load on the front part of the frame of the Buffer stops. At the same time there is a tensile load in the directions of the railway track.

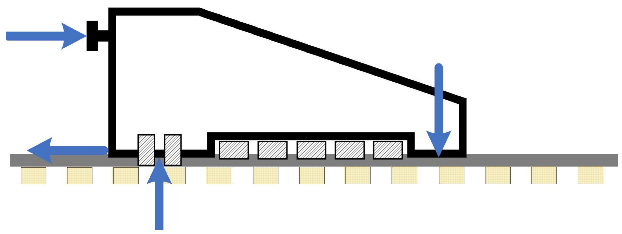

Figure 1: Effective forces on the Buffer stop

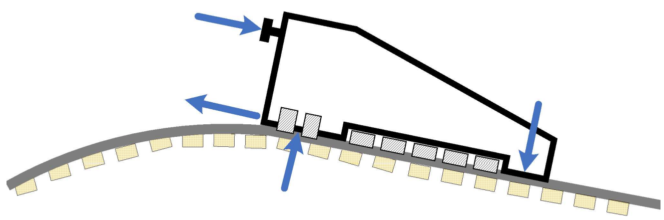

Figure 2: Track elevation as a result of an impact on the Buffer stop

2. Due to the forces – explained above – a lift of the railway tracks is the result. To reduce the lift of the railway track
    2.1. The length of the frame of the Buffer stop main frame can be extended.
    2.2. The lift can be converted into horizontal braking forces (**Friction buffer stop**)
    2.3. The track can reenforced to avoid lift (**track reinforcements**).
    2.4. **Additional impact reducing measures** can be installed on the Buffer stop main frame.
3. Often a combination of friction, track reinforcement and additional impact reducing measures are applied.

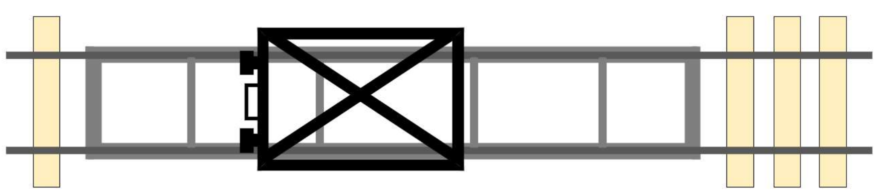

Figure 3: Friction Buffer stop with reinforced track

4. According to the rolling stock TSI the minimum longitudinal forces, structural elements of the trains must be able to withstand forces corresponding to category P II in accordance with standard EN 12663. This can be

   4.1. Up to 1.500 kN of impact energy

   4.2. Less than 2.5 m/s² of deceleration at impact.

3 General requirements for track termination

The general requirements for track terminations are defined in chapter 5.9 in the RBDG-MAN-014-0107_RailwaySuperstructure-Track.

4 Installation / space requirements for Buffer stops

4.1 Installation space for Buffer stops

1. The **installation space** is the minimum space that must be available to install the Buffer stops and are shown in the figures below.
2. The installation space is defined by:
   1) The necessary distance between the buffer Stop main frame or the reinforced track and the first installations
   2) The necessary minimum length of the reinforced track in front of the Buffer Stop main frame
   3) The length of the main frame of the Buffer stop
   4) The braking distance of the Buffer stop main frame (applies for friction Buffer stops only)
   5) Stabilization after track reinforcement and mounting of auxiliary brakes

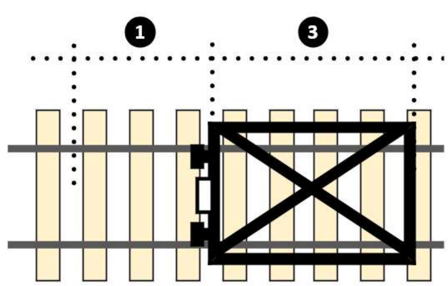

Figure 4: Simple fixed Buffer stop

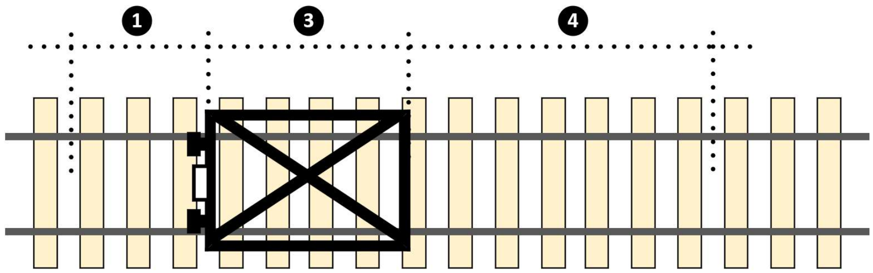

Figure 5: Space needed for friction Buffer stop

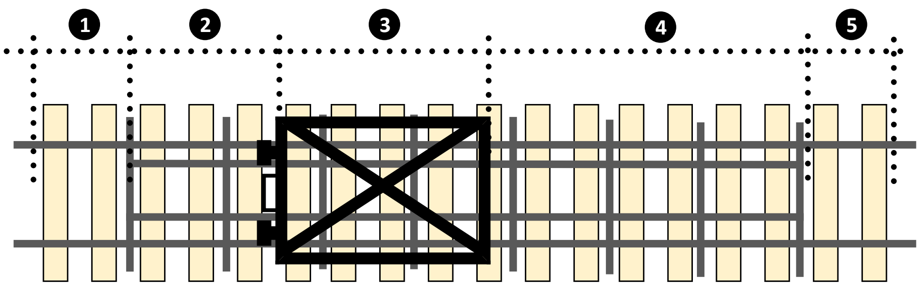

Figure 6: Space needed for friction Buffer stop with track reinforced track

Table 1: Required minimum distance for installation space

Area	Description	Value
1	Distance from last insulation or control joint to the beginning of track reinforcement or Buffer stop	3 m
2	Distance from the start of the track reinforcement to the front edge of the Buffer stop in the initial state	3 m
3	Length of the Buffer stop main frame at its longest point. Depending of Buffer stop main frame classification (CM) (see also Table 6Table 6)	4 m
4	Braking distance	Between 4 m and 20 m
5	Stabilization after track reinforcement and mounting of auxiliary brakes	3 m
	Total installation space for Fixed Buffer stop (○○)	**7 m**
	Total installation space for **Friction Buffer stop** (○○○)	**27 m**
	Total installation space for **Friction Buffer stop with reinforced track** (○○○○○)	**33 m**

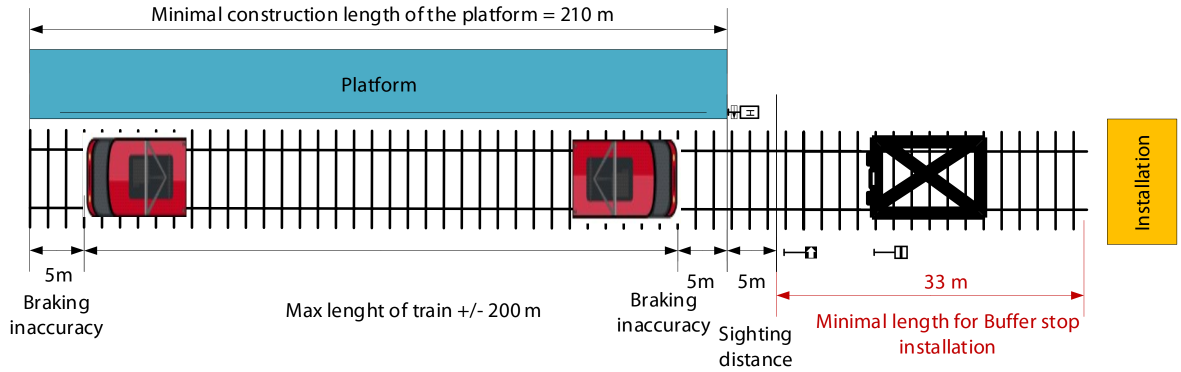

Figure 7: Installation length for friction buffer stop

3. In general, behind the Buffer stop a safety area of at least 20 m is required. Within this area, no other installations are allowed. In case it is not possible to make the required space of 20 m behind the Buffer stop must be designed to handle the higher necessary braking work to create the 20 m space. Also, the higher safety coefficients must be considered.

4. In general, the **maximum possible installation space shall be foreseen for track termination during spatial planning and infrastructure design** (see maximum value in the table above).

5. In **exceptional cases** – where the maximum possible installation space cannot be foreseen – the lower values may be used but **proper justification must be provided** and **must be approved by the client**.

6. Proper calculations and evaluation shall be done with the data and formulas provided in chapter 6 of this document or the extended reference document (RBDL-SOD-ZZ-ZZ-NTF-R-00005 Track termination).

7. Also, the Excel file in the annex of this document can be used to calculate the required installation space.

4.2 Track alignment requirements

1. The installation of Buffer stops is only permitted on straight track sections.

2. The installation space is not allowed to be in conflict with border points in turnout areas

3. This area extends from 20 m in front of the starting point of the Buffer stop until the end of the planned braking distance.

4. As an exemption, the installation of brake buffers is permitted in track curves ≥ 1000 m. The track radius must remain unchanged 20 m in front of the brake buffer until the end of the planned braking distance. (no radius change).

5. Design of the track: pitch maximum of – 10 ‰ and slope maximum of + 25 ‰. The structure gauge of other tracks is not allowed to touch at any time. The minimal radii should be at least 1.000 m.

6. The distance between the sleepers in the area of the track termination is max. 65 cm.

7. Installation is permitted only on concrete sleeper designs used by the IM with the associated superstructure types.

5 Dimensioning of Head ramps

1. The following dimensions should be adhered to:

Table 2: Dimension of Head ramps

Area	Designation	Dimension
1	Minimum height of the Head ramp above top of the rail	1,235 m*
2	Installation length for road-bound vehicles in front of the Head ramp	Min. 20 m
3	Head ramp width	6,35 m
4	Height of the side edges for combined ramps	1,20 m

2. **Explanation**: The Head ramp height of 1,235 m is the sum of the maximum height of the center of the buffer above top of the rail of 1,065 m and the minimum height of the floor of freight wagons above the center of the buffer of 0,17 m. This means that the Head ramp has usually the same height as the loading area of the freight wagons. The exact height of the headramps can differ slighty depending type of used freight wagon but shall always be above the buffer.

3. Dimensioning different from the shown values, based on own calculations, may be used, in justified cases. The justification and calculations must be documented and approved by the client.

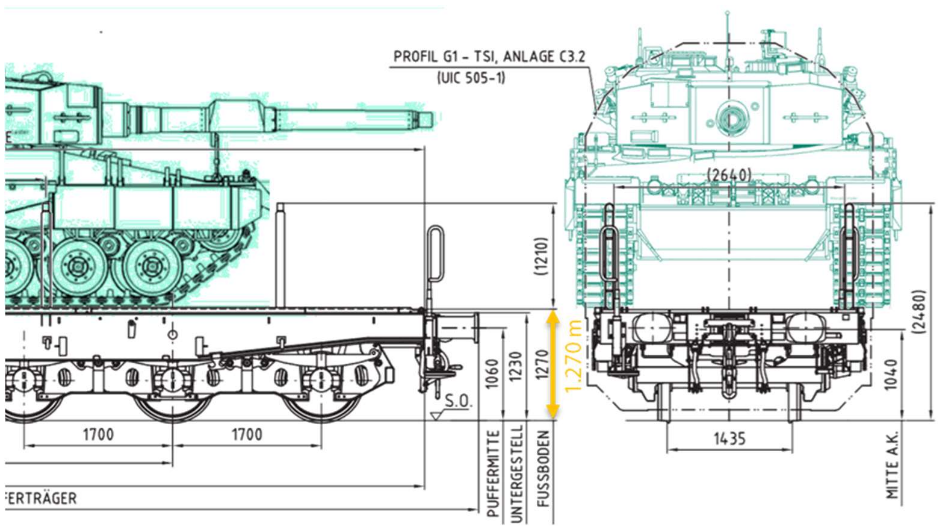

Figure 8: Typical dimension of freight wagons over the buffer for a Sammnps[1]

4. The total width of a Head ramp with several ramp heads should be 6,35 m, increased by the sum of the distance between Head ramp tracks.

[1] Source: own adjustments

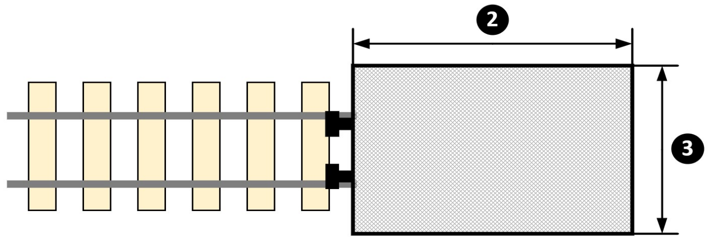

Figure 9: Head ramp with main dimensions

Figure 10: Head ramp (under construction in Bonn-Beuel for loading circus trains)[2]

[2] Source: https://www.lok-report.de/news/deutschland/mit-der-kamera-notiert/item/8963-neue-kopframpe-in-bonn-beuel.html

6 Annex values dan formulas

1. In this chapter the overall values that shall be used for dimensioning Buffer Stops are shown.
2. For including an inaccuracy entering the calculation of kinetic energy and to ensure the reliability of the design, **safety coefficient S** has to be counted in calculation ($E_{Impact} = E_{kin} = \left((1/2 \times m \times v^2) \pm E_{pot}\right) \times S$). The value of the coefficient varies and depends on type of train, location of dead-end track etc. Various infrastructure managers approach towards the assessment of the safety coefficient differently. Values of safety coefficient usually varies between 1,0 – 2,0[3].

Table 3: Possible safety coefficient

Type of train or installation to be protected	*S*
Freight trains and shunting	1.2
Passenger trains, freight trains and shunting, when it is necessary to protect various systems which are located behind or nearby Buffer stop	1.5
All trains, where there are traffic zones, structures or residential buildings located behind or nearby Buffer stop	1.8
Preventing the fall of any train or rolling stock into an abyss	2.0

3. The following initial values can be used:

Table 4 : Values used for calculating the impact energy

Values	Name	Description	
m [t]	Weight of trains	Typical freight train	1.500 t
		Typical passenger train	850 t
v [m/s]	Impact speed	The following design speeds are to be considered:	
		Open line train movements	4,2 m/s = 25 km/h
		Shunting movements	2,8 m/s = 15 km/h

4. **Braking force of each braking jaw** decreases along the braking distance. The value of the resisting force of the jaw mechanism depends on breaking distance and is assumed:

Table 5: Braking force of a braking jaw along the braking distance

[3] Petr Guziur “Friction Buffer stop Design”, https://www.researchgate.net/publication/319893402_FRICTION_BUFFER_STOP_DESIGN

Length of braking distance $l_{i,j}$ [m]	>0-5	>5-8	>8-12	>12-15
Braking force $F_{b,l,j}$ [kN]	40	36	32	28

5. The **main frame** of Buffer stops must be at least 2,20 m in length. The allowed maximum is 4,00 m in length. In the table below the following classes of main frames (CM) are defined as follows.

Table 6: Classes of main frame (CM)

Class of Main frame	Length of main frame on the track (a)
CM1	2,20 until < 2,50 m
CM2	2,50 until < 3,00 m
CM3	3,00 until < 3,5 m
CM4	3,5 until 4,00 m

6. The foreseen **indicative types of Buffers stops** are listed in the table below. The indicative types of Buffer stops must still be certified by the safety authorities of the Baltic countries and shall be compliant with the TSI.

Table 7: Foreseen Types of Buffer stops

Type	Number of braking jaws under mainframe	Maximum possible number of additional braking jaws behind the main frame	Track reinforcement required	Additional impact reducing elements required
4	4	0	No	No
6	6	0	No	No
8	8	0	No	No
10	10	0	Yes	No
10 Ax[4]	10	12	Yes	No
12 Ax	12	11	Yes	Yes
14 Ax	14	10	Yes	Yes
16 Ax	16	9	Yes	Yes

x defines the possible number of additional braking jaws behind the Buffer stop mainframe.

[4] x defines the number of chosen number of additional braking jaws behind the mainframe. The maximum number of additional braking jaws is 34.

7. If at least 10 braking jaws are hit in case of impact, the track of Buffer Stop shall be reinforced to avoid damage of the superstructure and ensure sufficient and safe energy absorption.

8. If more than 10 braking jaws are hit in case of impact, the Buffer stop shall be equipped with additional impact reducing elements, to reduce the deceleration of the rolling stock. Typical additional impact reducing elements are for example hydraulic dampers.

7 Excel file for Buffer Stop calculation

1. In the annex a Excel file in included to calculate the required braking distance of Buffer stop mainframes. For calculation the foreseen Mass of the train, collision speed and saety coefficient must be set (see also in Figure 11 below).

Friction buffer stop design calculation

Mass of the train: 1,000 tons

Collision speed v= 10 km/h = 2.7 m/s

Safety coefficient 1.2

Type of train	*S*
Freight trains and shunting	1.2
Passenger trains, freight trains and shunting, when it is necessary to protect various systems which are located behind or nearby buffer stop	1.5
All trains, where there are traffic zones, structures or residential buildings located behind or	1.8
Preventing the fall of any train or rolling stock into an abyss	2

Kinetic energy E (KJ) of the impacting railway vehicles

E =	**4374**	[kJ] with safety coefficient: 1.2
d =	**0.5**	distance between braking jaws

Figure 11: Input values for calculation of the braking distance

2. Values marked in green is the kinetic energy that needs to be absorbed if a **1.000 t heavy train** hits the Buffer stop with a **speed of 15 km/h** and need to be broad to a standstill after a **certain braking distance** with a **safety coefficient of 1,0** .

Table 8: Braking work for the types of friction Buffer stops from Types 4 till 10 and 10A12 in kJ

Length of braking distance $l_{i,j}$ [m]	Braking force $F_{b,i,j}$ [KN]	Buffer stop type: 4	6	8	10	10A1	10A2	10A3	10A4	10A5	10A6	10A7	10A8	10A9	10A10	10A11	10A12
		Without additional braking jaws				*With additional braking jaws*											
		Total number of braking jaws (n_b): 4	6	8	10	11	12	13	14	15	16	17	18	19	20	21	22
1	40	160	240	320	400	440	480	520	560	600	640	680	720	760	800	840	880
2	40	320	480	640	800	880	960	1,040	1,120	1,200	1,280	1,360	1,440	1,520	1,600	1,680	1,760
3	40	480	720	960	1,200	1,320	1,440	1,560	1,680	1,800	1,920	2,040	2,160	2,280	2,400	2,520	2,640
4	40	640	960	1,280	1,600	1,760	1,920	2,080	2,240	2,400	2,560	2,720	2,880	3,040	3,200	3,360	3,520
5	40	800	1,200	1,600	2,000	2,200	2,400	2,600	2,800	3,000	3,200	3,400	3,600	3,800	4,000	4,200	4,400
6	36	944	1,416	1,888	2,360	2,596	2,832	3,068	3,304	3,540	3,776	4,012	4,248	4,484	4,720	4,956	5,192
7	36	1,088	1,632	2,176	2,720	2,992	3,264	3,536	3,808	4,080	4,352	4,624	4,896	5,168	5,440	5,712	5,984
8	36	1,232	1,848	2,464	3,080	3,388	3,696	4,004	4,312	4,620	4,928	5,236	5,544	5,852	6,160	6,468	6,776
9	32	1,360	2,040	2,720	3,400	3,740	4,080	4,420	4,760	5,100	5,440	5,780	6,120	6,460	6,800	7,140	7,480
10	32	1,488	2,232	2,976	3,720	4,092	4,464	4,836	5,208	5,580	5,952	6,324	6,696	7,068	7,440	7,812	8,184
11	32	1,616	2,424	3,232	4,040	4,444	4,848	5,252	5,656	6,060	6,464	6,868	7,272	7,676	8,080	8,484	8,888
12	32	1,744	2,616	3,488	4,360	4,796	5,232	5,668	6,104	6,540	6,976	7,412	7,848	8,284	8,720	9,156	9,592
13	28	1,856	2,784	3,712	4,640	5,104	5,568	6,032	6,496	6,960	7,424	7,888	8,352	8,816	9,280	9,744	10,208
14	28	1,968	2,952	3,936	4,920	5,412	5,904	6,396	6,888	7,380	7,872	8,364	8,856	9,348	9,840	10,332	10,824
15	28	2,080	3,120	4,160	5,200	5,720	6,240	6,760	7,280	7,800	8,320	8,840	9,360	9,880	10,400	10,920	11,440
16	28	2,192	3,288	4,384	5,480	6,028	6,576	7,124	7,672	8,220	8,768	9,316	9,864	10,412	10,960	11,508	12,056
17	28	2,304	3,456	4,608	5,760	6,336	6,912	7,488	8,064	8,640	9,216	9,792	10,368	10,944	11,520	12,096	12,672
18	28	2,416	3,624	4,832	6,040	6,644	7,248	7,852	8,456	9,060	9,664	10,268	10,872	11,476	12,080	12,684	13,288
19	28	2,528	3,792	5,056	6,320	6,952	7,584	8,216	8,848	9,480	10,112	10,744	11,376	12,008	12,640	13,272	13,904
20	28	2,640	3,960	5,280	6,600	7,260	7,920	8,580	9,240	9,900	10,560	11,220	11,880	12,540	13,200	13,860	14,520

Values marked in green is the kinetic energy that needs to be absorbed if a **1.000 t heavy train** hits the Buffer stop with a **speed of 15 km/h** and need to be broad to a standstill after a **certain braking distance** with a **safety coefficient of 1,0** .

8 References

Ref:	Document Number:	Document Title:
Internal Governance Documents		
1.	RBDG-MAN-014-0105	Railway Superstructure-Track
External references		
2.	N/A	Petr Guziur "Friction Buffer stop Design", https://www.researchgate.net/publication/319893402_FRICTION_BUFFER_STOP_DESIGN
3.	DB: DS 800 01	• „Bahnanlagen entwerfen – Allgemeine Entwurfsrichtlinien" • "Bremsprellböcke Typ 4 bis 10 Z 8 nach DS 800 01"
4.	DB: 800.0113A07	Gleisabschlüsse – bauliche Gestaltung der Gleise und der Peripherie
5.	DB: 800.0113A11	Gleisabschlüsse – Dimensionierung von Kopframpen
6.	NAG 5-2-0.0	(ADIF) Instalación De Dispositivos De Atenuación De Impacto En Zonas Límite De Parada Con Estacionamiento De Viajeros, 2022
7	EN 12663	DIN EN 12663-1:2024-02
8	TSI rolling stock	Guide for the application of the LOC&PAS TSI 2023, GUI/LOC&PAS TSI/2023