TRACK TERMINATION (BUFFERSTOPS, HEADRAMPS)

RBDG-MAN-014E-0102_TS_Track Termination

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DOCUMENT HISTORY

This document has been issued and amended as follows:

Revision	Effective from	Author	Description of changes
1.0	27.06.2024	Jonathan Witte (O&M)	
2.0	03.12.2024	Jonathan Witte (O&M)	Classification of used Values and optimizations based on designer feedback

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
ETCS	European train control system
FS	Full Supervision
IM	Infrastructure Manager
OS	On Sight

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.
Emergency and Maintenance siding	Siding to allow parking of defective rolling stock, short-term parking of maintenance rolling stock and for rail/derail road-rail vehicles (see also RBDG-MAN-025-0108 Infrastructure Facilities).
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 vehicle 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.
Safety track	Safety tracks are the tracks behind flank protection turnouts to isolate vehicles from of overrunning on the open line or station through tracks. Safety tracks allow integration of Overlap and supervised location (SvL) of ETCS Movement authority (MA). (see also RBDG-MAN-025-0108 Infrastructure Facilities)

1. Introduction

1.1. The general requirements for track terminations and the interface with rolling stock are defined in chapter 3.4.4 in the RBDG-MAN-014-0107_RailwaySuperstructure-Track.

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

2. Effective forces on Buffer stops

2.1. 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.

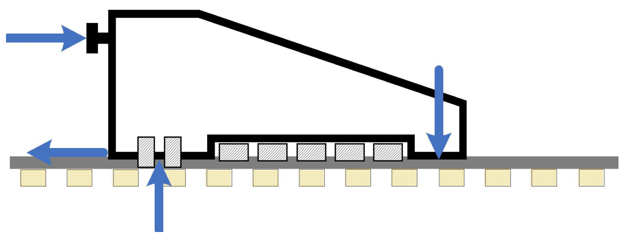

Figure 1: Effective forces on the Buffer stop

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

2.2. Due to the forces – explained above – a lift of the railway tracks is the result. To reduce the lift of the railway track

2.2.1. The length of the frame of the Buffer stop main frame can be extended.

2.2.2. The lift can be converted into horizontal braking forces (Friction buffer stop)

2.2.3. The track can reenforced to avoid lift (track reinforcements).

2.2.4. Additional impact reducing measures can be installed on the Buffer stop main frame.

2.3. Often a combination of friction, track reinforcement and additional impact reducing measures are applied.

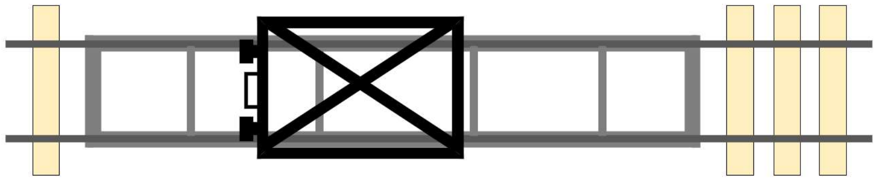

FIGURE 3: FRICTION BUFFER STOP WITH REINFORCED TRACK

2.4. 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

2.4.1. Up to 1.500 kN of impact energy

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

2.5. In case impacting forces are higher than allowed in the TSI, friction buffer stops – who can absorb higher forces and energy – must be foreseen and braking distance and installation space must be defined (see also chapter 3)

3. INSTALLATION SPACE FOR BUFFER STOPS

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

3.2. In exceptional cases – where the maximum possible installation space and/or safety distance cannot be foreseen – specific calculations should be used but proper justification must be provided and must be approved by RBR or the future IM.

3.2.1. Proper calculations and evaluation shall be done with the data and formulas provided in Annex 1 of this document (Reference document number 3 is provided for information only).

3.2.2. Also, the Excel file in Annex 2 of this document can be used to calculate the required installation space (RBDL-SOD-ZZ-ZZ-CAL-R-00001-Buffer stop calculation).

3.3. The installation space is defined by the values shown below, based on the decision to only use axle counters:

1) The necessary minimum length of the reinforced track in front of the Buffer Stop main frame
2) The length of the main frame of the Buffer stop
3) The braking distance of the Buffer stop main frame (applies for friction Buffer stops only)
4) Stabilization after track reinforcement and mounting of auxiliary brakes

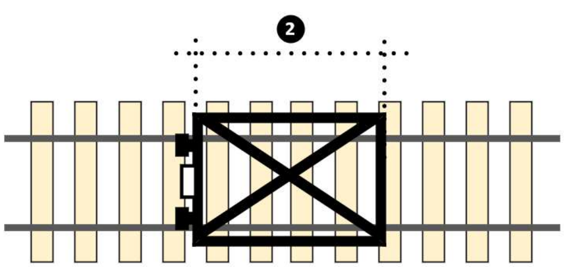

FIGURE 4: SIMPLE FIXED BUFFER STOP

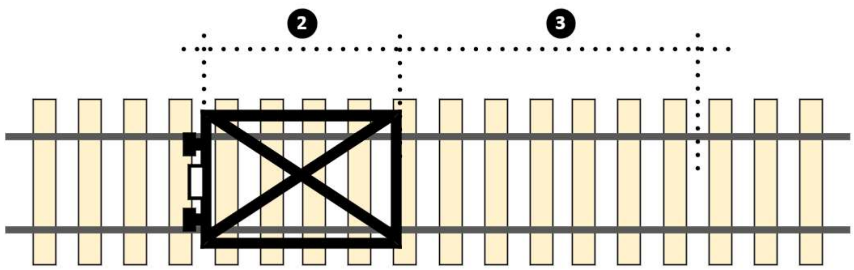

Figure 5: Space needed for friction Buffer stop

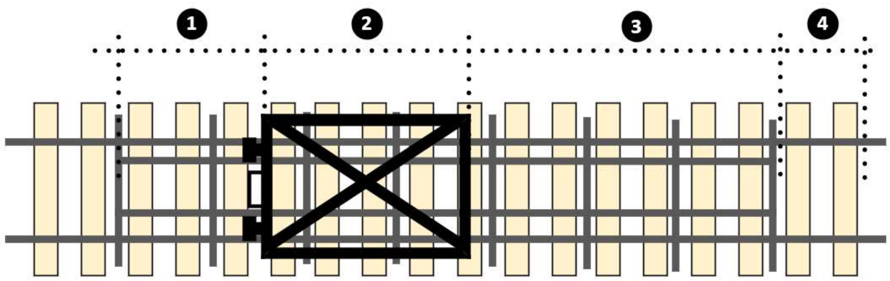

Figure 6: Space needed for friction Buffer stop with track reinforced track

Table 1: Required installation space for maximum braking distance of 20 m

Area	Description	Value
1	Distance from the start of the track reinforcement to the front edge of the Buffer stop in the initial state.	3 m
2	Length of the Buffer stop main frame at its longest point. Depending on Buffer stop main frame classification (CM) (see also Table 6)	4 m
3	Braking distance (depends on impact speed and train weight)	Between 4 m and 20 m
4	Stabilization after track reinforcement and mounting of auxiliary brakes	3 m
	Total maximum installation space for Fixed Buffer stop (②) (Figure 4)	4 m
	Total maximum installation space for Friction Buffer stop (②③)(Figure 5)	24 m
	Total maximum installation space for Friction Buffer Stop with reinforced track (①②③④)(Figure 6)	30 m

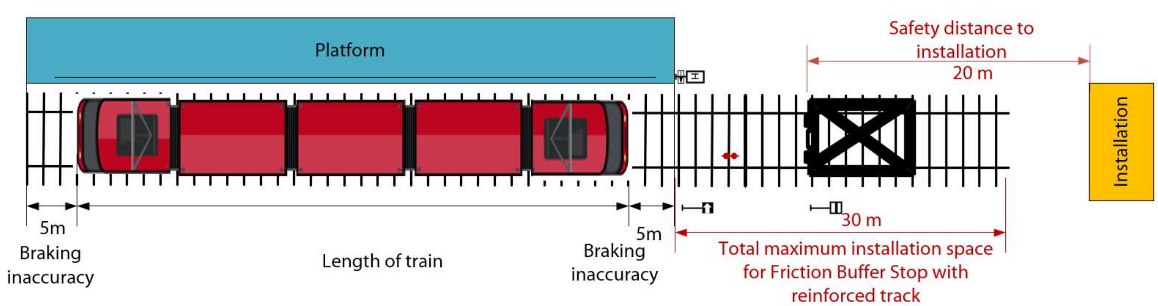

Figure 7: Installation length for friction Buffer stop with reinforced track

3.4. In general, a safety distance of at least

3.4.1. 20 m behind and

3.4.2. up to 5 m left and right of the track centre

behind the buffer stop for any installations or railway tracks is required.

3.5. In case of use of a friction Buffer stop, the safety distance begins behind the braking distance (see area 3 in the figures above). In case installations or other train movements are within the 20 m safety distance, a higher safety coefficient must be applied (use values in Table 3).

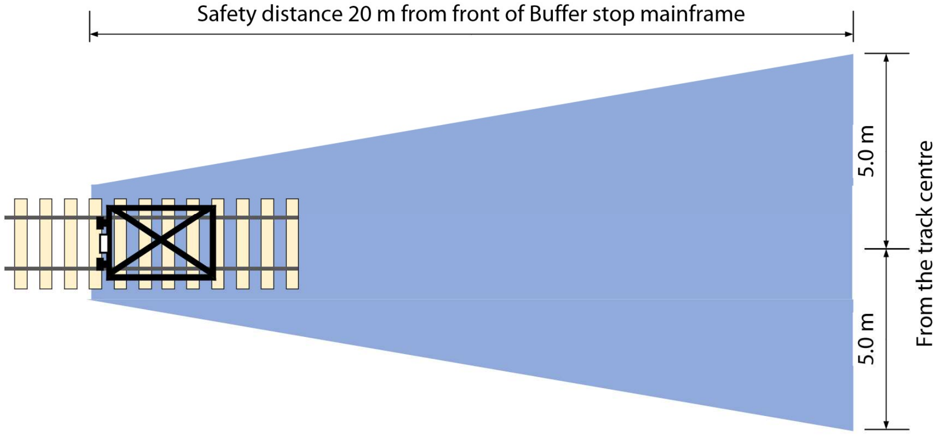

FIGURE 8: SAFETY DISTANCE UP TO 20 M BEHIND A (FRICTION) BUFFER STOP

4. TRACK ALIGNMENT REQUIREMENTS

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

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

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

4.4. 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).

4.5. 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.

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

4.7. Overlapping of structure gauge of the track section of the Buffer stop including the braking distance of the friction Buffer stop is not allowed with other structure gauges or installations.

5. DIMENSIONING OF HEAD RAMPS

5.1. In general, Head ramps shall consider the following dimensions shown in the figures and table below:

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 above top of the rail	1,20 m

5.2. **Explanation**: The Head ramp height of 1,235 m is the sum of the maximum height of the centre of the buffer above top of the rail of 1,065 m and the minimum height of the floor of freight wagons above the centre 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 slightly depending on the type of used freight wagon but shall always be above the buffer.

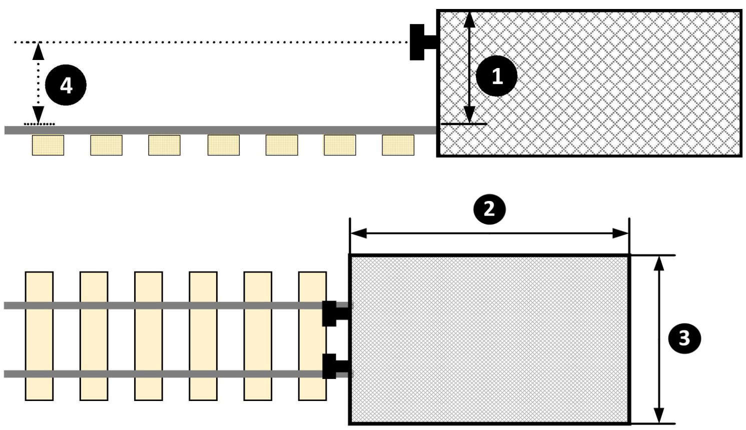

FIGURE 9: HEAD RAMP WITH MAIN DIMENSIONS

5.3. Furthermore, own calculations and dimensionsing differing from the shown values can be proposed. Proper justification or corrdination with connector and main user of the head hamps shall be documented and approved by the client.

5.4. 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.

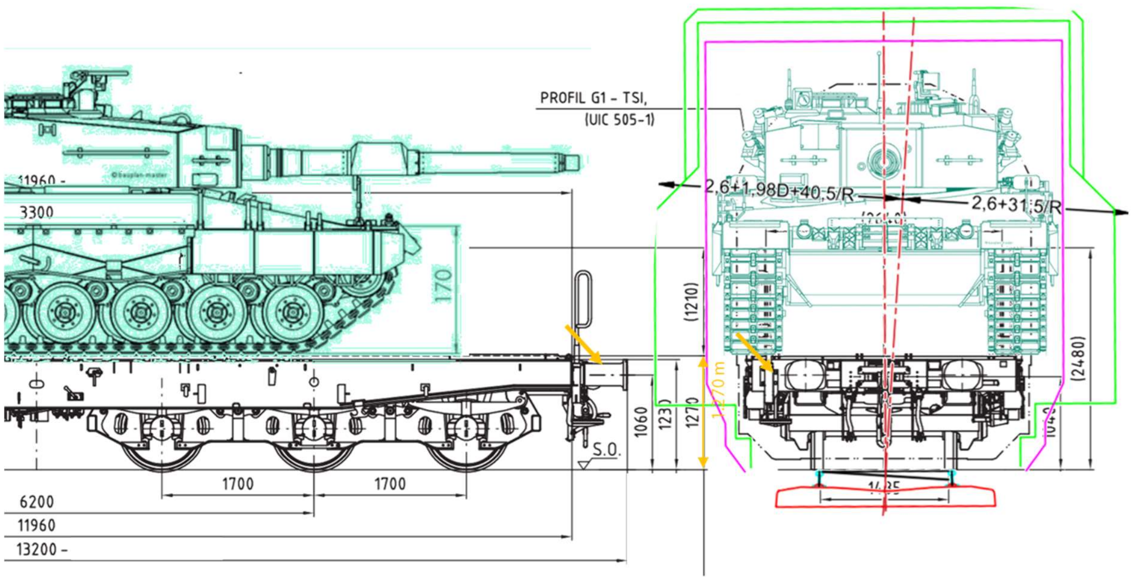

FIGURE 10: TYPICAL DIMENSION OF FREIGHT WAGONS OVER THE BUFFER FOR A SAMMNPS[1]

FIGURE 11: HEAD RAMP (UNDER CONSTRUCTION IN BONN-BEUEL FOR LOADING CIRCUS TRAINS)[2]

REFERENCES

Ref:	Document Number:	Document Title:
1.	Internal Referenced Documents	
1.1.	RBDG-MAN-014-0105	Railway Superstructure-Track
1.2.	RBDL-SOD-ZZ-ZZ-CAL-R-00001-	Excel for Buffer stop calculation
1.3.	RBDL-SOD-ZZ-ZZ-NTF-R-00005	Explanation note for Track termination
2.	External Referenced Documents	

[1] Source: pictures from https://tatravagonka.sk/wagons_tax/flat/?lang=en, own adjustments
[2] Source: https://www.lok-report.de/news/deutschland/mit-der-kamera-notiert/item/8963-neue-kopframpe-in-bonn-beuel.html

2.1.	N/A	Petr Guziur "Friction Buffer stop Design", https://www.researchgate.net/publication/319893402_FRICTION_BUFFER_STOP_DESIGN
2.2.	DB: DS 800 01	„Bahnanlagen entwerfen – Allgemeine Entwurfsrichtlinien" "Bremsprellböcke Typ 4 bis 10 Z 8 nach DS 800 01"
2.3.	DB: 800.0113A07	Gleisabschlüsse – bauliche Gestaltung der Gleise und der Peripherie
2.4.	DB: 800.0113A11	Gleisabschlüsse – Dimensionierung von Kopframpen
2.5.	NAG 5-2-0.0	(ADIF) Instalación De Dispositivos De Atenuación De Impacto En Zonas Límite De Parada Con Estacionamiento De Viajeros, 2022
2.6.	EN 12663	DIN EN 12663-1:2024-02
2.7.	TSI rolling stock	Guide for the application of the LOC&PAS TSI 2023, GUI/LOC&PAS TSI/2023
2.8.	N/A	Petr Guziur "Friction Buffer stop Design", https://www.researchgate.net/publication/319893402_FRICTION_BUFFER_STOP_DESIGN

ANNEX 1. VALUES AND FORMULAS

5.1. In this chapter the overall values that shall be used for dimensioning Buffer Stops are shown.

5.2. 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 the calculation ($E_{Impact} = E_{kin} = \left((1/2 \times m \times v^2) \pm E_{pot}\right) \times S$). The value of the safety coefficient (see Table 3 below) varies on the type of train operations and installations within 20 m safety distance behind the Buffer stop installation (see Figure 8)

TABLE 3: POSSIBLE SAFETY COEFFICIENT

Type of train or installation within the safety distance	S
No other train movements or technical installations within the 20 m safety distance behind the Buffer Stop.	1.0
Other freight trains and shunting movements behind or nearby the Buffer stop (within 20 m).	1.2
Other passenger trains, freight trains and shunting movements, when it is necessary to protect various technical systems which are located behind or nearby the Buffer stop (within 20 m).	1.5
All trains, where there are traffic zones, structures or residential buildings located behind or nearby the Buffer stop (within 20 m).	1.8
Preventing the fall of any train or rolling stock into an abyss behind the Buffer stop (within 20 m).	2.0

5.3. The breaking distance l_w of the buffering stop depends on the kinetic Energy E and the and the braking resistance force of the Buffer stop F_b and is equal to:

$$l_w = \frac{E_{impact}}{F_B} = \frac{\left((1/2 \times m \times v^2) \pm E_{pot} \times S\right)}{n_B * F}$$

5.4. Please also use the Excel file for the braking distance in the excel file see also RBDL-SOD-ZZ-ZZ-CAL-R-00001-Buffer stop calculation).

5.5. The following initial values can be used (still coordination with RBR on assumed values for trains weight and speed is required):

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
		Regional express passenger train (RE): empty 170 t/full 220 t for 100 m long EMU single-traction[3] (double-traction = 340 t / 440 t) High speed train (HST): 450 t for 185 m long PKP Pendolino EMU in single-traction (double-traction = 900 t)	
v [m/s]	Impact speed	The following design speeds are to be considered:	
		Open line train movements without ETCS	4,2 m/s = 15 km/h
		Shunting movements (applies also on emergency & maintenance sidings)	2,8 m/s = 10 km/h

[3] Source: Stadler FLIRT 3 6-car unit

Values	Name	Description	
		Operation under ETCS FS/OS with release speed (applies also on safety tracks)	0,8 m/s = 5 km/h[4]
		Separated areas of depots and workshops and in the area of Head ramps where general maximum speed is reduced (typical values on the right).	0,8 m/s = 5 km/h
			0,5 m/s = 3 km/h

5.6. **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

Length of braking distance $l_{i,j}$ [m]	>0-5	>5-8	>8-12	>12-15	>15-20
Braking force $F_{b,I,j}$ [kN]	40	36	32	28	24

5.7. 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

5.8. 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 (Ax) 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[5]	10	12	Yes	No
12 Ax	12	11	Yes	Yes
14 Ax	14	10	Yes	Yes
16 Ax	16	9	Yes	Yes

[4] Final value subject to definition with CCS/ETCS design for operation under ETCS FS/OS
[5] x defines the number of chosen numbers of additional braking jaws behind the mainframe. The maximum number of additional braking jaws is 34.

5.9. 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.

5.10. 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.

ANNEX 2. EXCEL FILE FOR BUFFER STOP CALCULATION

5.11. 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 safety coefficient must be set (see also in Figure 12 below).

Type of train	S
No train movements or installation within 20 m behind Buffer Stop installation.	1.0
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

Design speed to be considered	km/h	m/s
Open line train movements w/o ETCS	15	4.2
Operation under ETCS FS/OS with release speed	10	2.8
Shunting Movements	10	2.8
Seperated Depot or Workshop tracks	5	1.4
	3	0.8

Type of train	Weight [t]
RE single-traction 100 m long (empy)	170
RE single-traction 100 m long (in operation)	220
RE double-traction 200 m long (empty)	340
RE double-traction 200 m long (in operation)	440
HST train single-traction 200 m long	450
HST double-traction 400 m long	900
Freight train (typical weigth)	1,500
Freight train (heavy haul)	3,000
Freight train maximum weight	4,000

FIGURE 12: INPUT VALUES FOR CALCULATION OF THE BRAKING DISTANCE

5.12. 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

5.13. 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** .