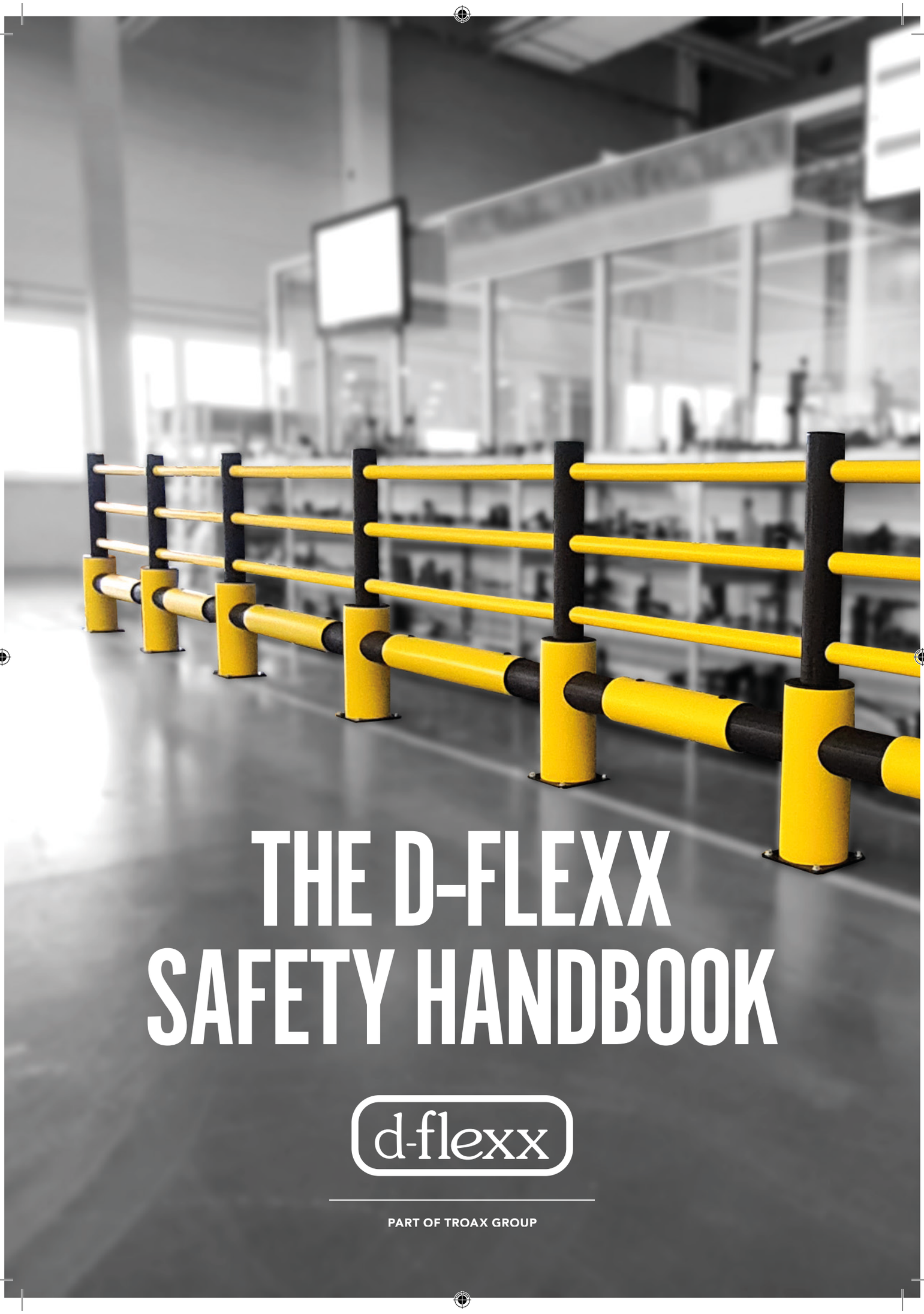


THE D-FLEXX SAFETY HANDBOOK

d-flexx

PART OF TROAX GROUP

CONTENT

Scope of this document

The d-flexx Safety Guide explains how to use polymer-based protection systems to improve workplace safety, focusing on traffic management in production plants and warehouses.

It supports compliance with PAS 13:2017, the BSI code for safe layout and impact protection.

This guide is intended for Safety Managers, Facility Planners, Industrial Professionals, and Intralogistics Specialists.

It outlines key safety principles, d-flexx product usage, and testing methods in line with PAS 13:2017.

This guide provides d-flexx's recommendations for implementing its safety systems and does not replace official standards or regulatory requirements.

KINETIC ENERGY & FORCE-TO-BOLT

What is kinetic energy?

Kinetic energy is the energy an object possesses due to its motion, determined by its mass and velocity.The greater the mass and the speed, the greater the kinetic energy.

In warehouses and production plants, circulating vehicles cumulate kinetic energy, which presents significant risks of injury and damage in the event of a collision. Enhancing safety in these workplaces involves two main approaches: (1) reducing collision occurrences and (2) minimizing the consequences when collisions occur.

This is where bollards, barriers, kerbs and other equipment come into play, segregating vehicle routes from pedestrian passages, and safeguarding people and assets.

Kinetic energy is calculated using a formula relating to an object's mass and velocity. It is defined as the product of half an object's mass and the square of its velocity.

$$KE = \frac{1}{2} mv^2$$

KE is kinetic energy in joules [J]
m is mass in kilograms [Kg]
v is velocity in meters per second [m/s]

Example with a 4-tons vehicle moving at 5 km/h (1,39 m/s)

$$KE = \frac{1}{2} 4000\ kg \times 1{,}39\ m/s^2$$

= 3.858 joules

Table of kinetic energy [J] for a vehicle considering weight and speed

Speed (km/h)	1-ton	2-tons	3-tons	4-tons	5-tons	6-tons	7-tons	8-tons
1	39	77	116	154	193	231	270	309
2	154	309	463	617	772	926	1.080	1.235
3	347	694	1.042	1.389	1.736	2.083	2.431	2.778
4	617	1.235	1.852	2.469	3.087	3.704	4.322	4.938
5	965	1.929	2.894	3.858	4.823	5.787	6.753	7.716
6	1.389	2.778	4.167	5.556	6.946	8.333	9.724	11.111
7	1.891	3.781	5.672	7.562	9.454	11.343	13.235	15.123
8	2.470	4.938	7.409	9.877	12.348	14.815	17.287	19.753
9	3.126	6.250	9.377	12.500	15.628	18.750	21.879	25.000
10	3.859	7.716	11.567	15.432	19.293	23.148	27.010	30.864
11	4.669	9.336	14.007	18.673	23.345	28.009	32.683	37.346
12	5.556	11.111	16.669	22.222	27.782	33.333	38.895	44.444
13	6.521	13.040	19.563	26.080	32.606	39.120	45.648	52.160
14	7.563	15.123	22.689	30.247	37.815	45.370	52.941	60.494

At a 3 km/h speed, a 4-ton vehicle would have a kinetic energy of about 1.389 joules.
At a 10 km/h speed, a 4-ton vehicle would have a kinetic energy of about 15.432 joules.
A barrier that can withstand 10.000 joules could sustain the impact of a 4-ton vehicle at 8 km/h.

Vehicle speed is by far the primary risk factor in the context of indoor traffic. Regardless of the safety materials selected, controlling speed is crucial in preventing accidents.

Angles and energy deflection

When a vehicle collides with a barrier at a 90° angle, all of its energy is transferred directly to the barrier. At any other angle, part of this energy deflects away, reducing the impact on the barrier. The more the angle deviates from 90°, the greater the deflection and the lesser energy acts on the barrier.

To calculate this phenomenon, we incorprate the sine of the impact angle in addition to the previously established parameters.

$$KE = \frac{1}{2} m \left(V \cdot Sin(\Theta) \right)^2$$

KE is kinetic energy in joules [J]
m is mass in kilograms [Kg]
v is velocity in meters per second [m/s]
Sin(Θ) is the sine of the angle.

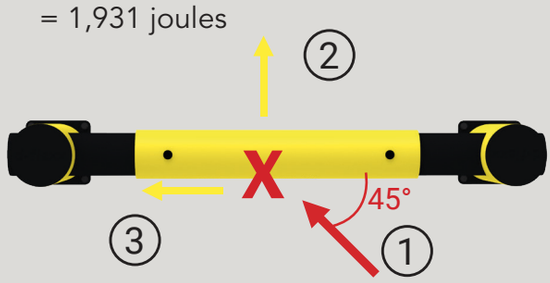
Here are the commonly used sines as defined in BSI's PAS.13:2017.

SIN90°= 1
Sin67.5°=0.924
Sin45°=0.707
Sin22.5°=0.383

Example with a 4-tons vehicle moving at 5km/h, colliding at a 45° angle.

$$KE = \frac{1}{2} 4000 \text{ kg} \times (1{,}39 \text{ m/s} \times 0{,}707)^2$$

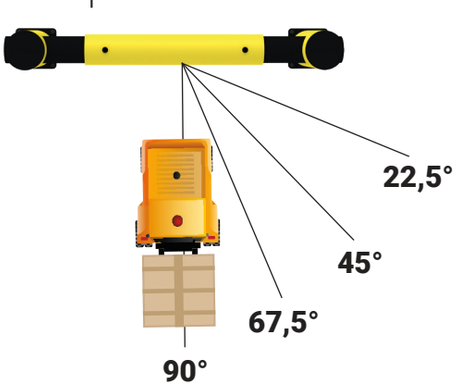
= 1,931 joules



In this case, the vehicle has a kinetic energy of 3.858 joules* (1). Colliding at a 45° angle would transfer 1.931 joules on a barrier (2). This means that 1.927 joules are deflected away from the barrier (3).

* Previously calculated kinetic energy for a 4-tons vehicle moving at 5 km/h.

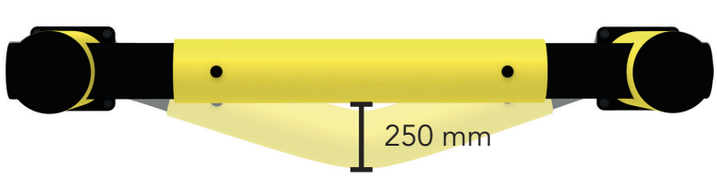
These calculations can produce a visual representation of the maximum kinetic energy a colliding vehicle can have without breaking a barrier, according to the angle of collision. Here is an example with an impact resistant d-flexx barrier.



Max sustainable kinetic energy [J]	90°	67.5°	45°	22.5°
	15,000	17,600	30,000	102,700

The barrier's maximum resistance is 15,000 joules, regardless of the impact angle. During a 90° impact, the full energy is transferred to the barrier, so the vehicle's kinetic energy must not exceed 15,000 joules. At other angles, only a fraction of the energy is transferred, allowing for higher kinetic energy. For example, a vehicle with 30,000 joules colliding at a 45° angle would not transfer more than 15,000 joules to the barrier.

Deflection zone



During an impact, the polymer barrier will absorb the force by bending, creating a deflection zone. This deflection zone needs to be taken into account when installing your barriers. It may differ from a barrier to another.

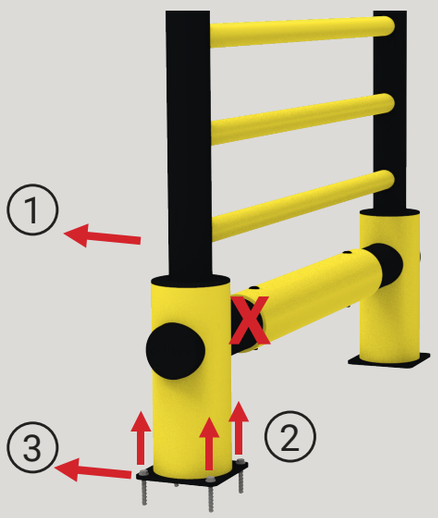
What is force-to-bolt?

During an impact, the kinetic energy from the colliding vehicle is spread across all components of the barrier, including the steel bolts and the concrete flooring to which it is anchored. Even the strongest barrier can't provide effective protection if its anchorage, specifically the bolts and the flooring, is not sufficiently robust. The force applied on the bolt, called force-to-bolt, is measured in newtons [N]. The maximal bolt resistance before failure is a vital parameter in your safety setup.

How energy is exerted on your barrier

1. The barrier's structure absorbs kinetic energy as previously calculated.
2. During an impact, the mounting plates are pushed upwards. This vertical force acting on the bolts is called tension force.
3. The impact will also push the mounting plates backwards. This horizontal force acting on the bolts is called shear force.

A barrier's force-to-bolt combines the tension force and shear force. It relies on the type of bolts used and the quality of the concrete flooring.



There are several categories of concrete. They are classified according to compressive strength, meaning the pressure they can sustain before they crack or fail. The four most common concrete types are the C20/25, C25/30, C30/37 and C40/50. The better the concrete quality, the higher force-to-bolt can be applied on the system.

During an impact, the force exerted on the bolts must remain lower than the concrete's strength. The opposite results in the breakage of the concrete in the form of a cone. This phenomenon is called a cone failure.

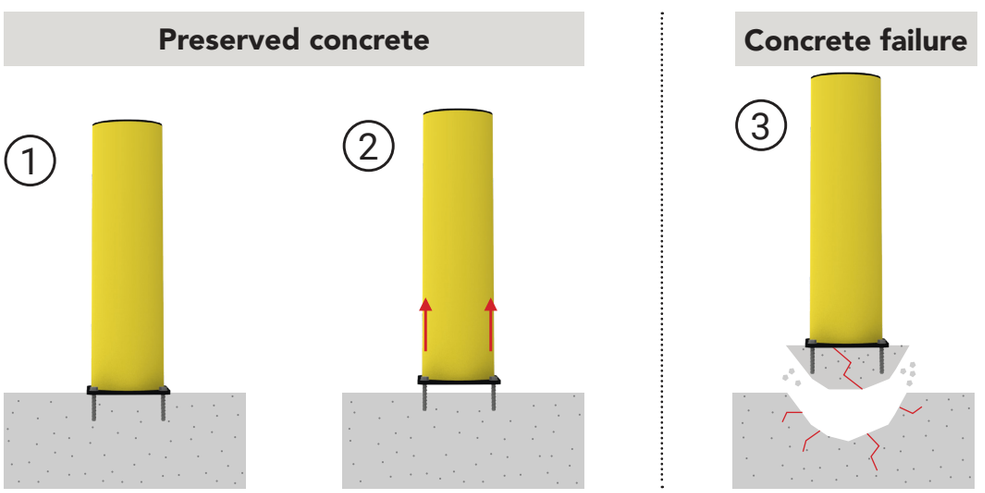


Figure 1 shows the ideal post-collision scenario: the impact force is below the whole system's resistance. Figure 2 illustrates a case where the force exceeds the anchorage strength but not the concrete's, causing the bolts to lift without major concrete damage. Figure 3 illustrates an impact where the barrier and anchor are intact, but forces surpasses the concrete strength. This results in ripping the flooring apart, leading to increased accident risk and costly repairs.

As a result, choosing the right protection goes beyond just looking at barrier resistance (joules) and force-to-bolt (newtons). The system's performance also depends on the concrete's resistance.

PREVENTING IMPACTS WITH BEHAVIOURAL DESIGN

What is behavioral design?

At d-flexx, we believe that safety lies first and foremost in behaviors and consistent habits. By understanding how people interact with their environment, we can design solutions that make long-lasting good habits effortless and automatic, while reducing accidents.

Behavioral design focuses on shaping environments to naturally guide people toward desired actions. In workplace safety, it moves beyond rule enforcement by creating spaces where safe behaviors become the most intuitive choice. This approach reduces the need for constant oversight and encourages lasting compliance.

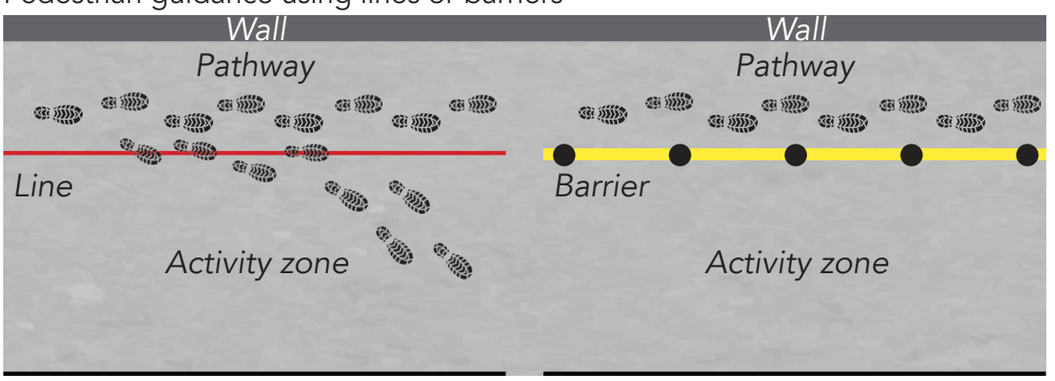
Since speed is the primary risk factor in traffic, controlling vehicle pace, though not sufficient on its own, is a top priority for enhancing workplace safety.

Implementing behavioral design

Designing pedestrian pathways

Pathway management involves directing pedestrians in the workplace using signage, landmarks, and spatial cues to promote safe and efficient navigation while reducing hazards. Among various guiding methods, safety barriers are the most effective, offering clear physical boundaries for pathways.

Pedestrian guidance using lines or barriers

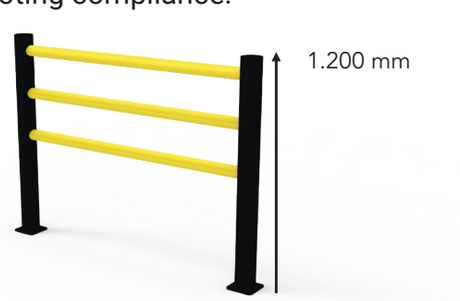


A line is easily crossed as it lacks presence, offering no boundary. A barrier, however, creates physical obstruction, instinctively discouraging crossing and promoting compliance.

Color psychology

Colors have a powerful and well-documented influence on behavior. Yellow, widely used in occupational safety, is valued for its high visibility and strong association with caution.

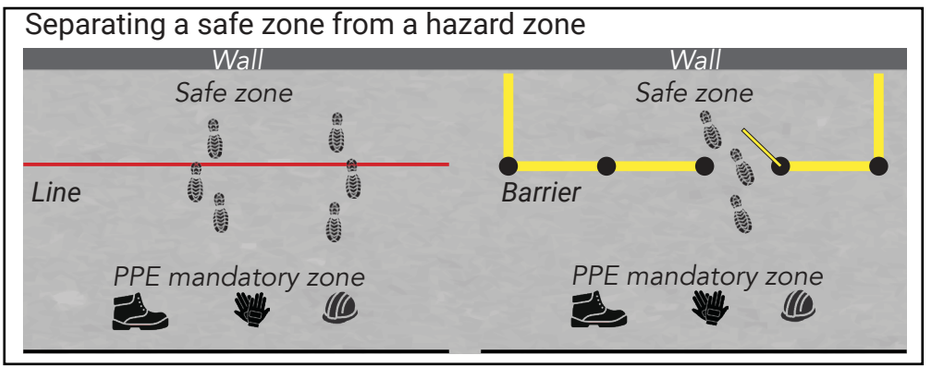
d-flexx selected a vivid yellow to create attention-grabbing contrast and evoke a natural sense of vigilance.



d-flexx recommends a minimum height of 1,200 mm for barriers intended for pathway management, ensuring clear visibility and encouraging use of designated walkways.

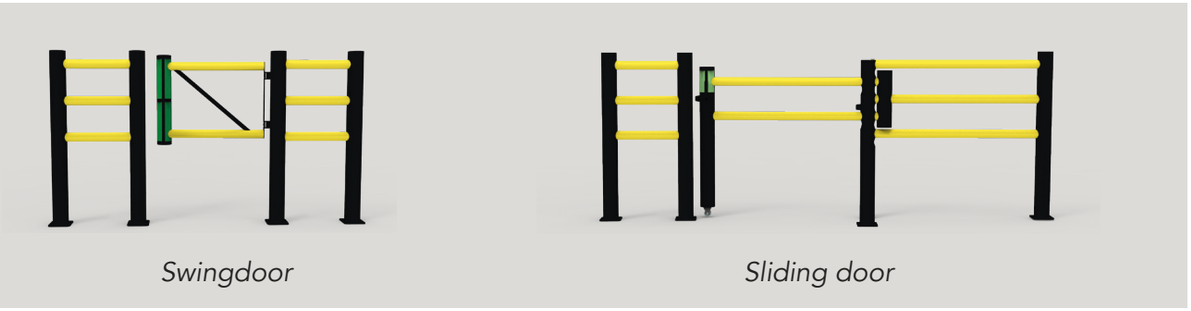
Desinging safe zones

Safety barriers provide more than pedestrian flow control. Crossing a physical obstacle prompts awareness and carefulness through a deliberate and engaging action.



The layout of an access point to a zone requiring personal protective equipment exemplifies the benefits of a physical barrier. The barrier not only controls access to hazardous areas but also greatly reduces the chances of entry without personal protective equipment (PPE). By requiring physical and cognitive effort to pass through, it effectively reinforces compliance.

Safety zone entries and exits

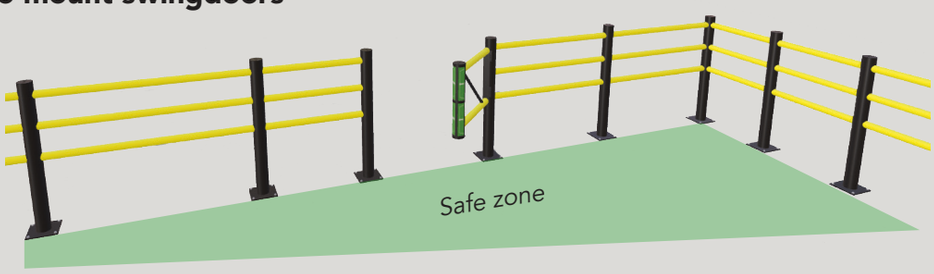


Swingdoor

Sliding door

Swingdoors offer controlled access and suit areas with intense traffic and higher risk. Sliding doors allow easier passage, ideal for areas with limited movement and minimal hazard, especially in indoor logistics where material handling is frequent. Once opened, they don't maintain access restriction.

How to mount swingdoors

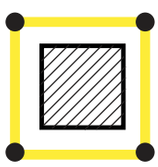


As a barrier separates safe zones from hazardous areas, d-flexx recommends installing swingdoors that open only toward the safe zone, using a gate stopper on the hazardous side. This setup increases awareness when entering the hazardous area, avoids interference beyond the barrier, and simplifies returning to safety.

Creating awareness on your strategic assets

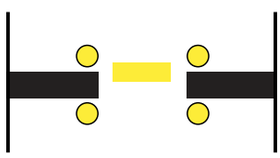
The latent awareness induced by colorful barriers influences both goods handling operations and pedestrian activity. Whether objects are moved with a pallet truck or a forklift, their movement presents a collision risk. Marking sensitive areas with highly visible obstacles encourages cautious movements and natural speed regulation, effectively reducing the risk of accidents.

Examples of sensitive area markings



Columns

Use safety barriers to mark critical structures



Gates and doors

Use bollards and height restrictors to minimize traffic-related risks

Working stations

Use safety barriers to mark pedestrian areas

The height of barriers and bollards is crucial for visibility from vehicles. Low barriers may fall out of sight, especially for forklift operators handling large loads. Properly elevated barriers and bollards ensure they remain visible, helping drivers navigate safely and avoid collisions.

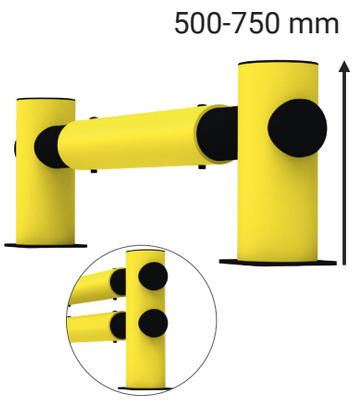
IMPACT PROTECTION

Impact resistance

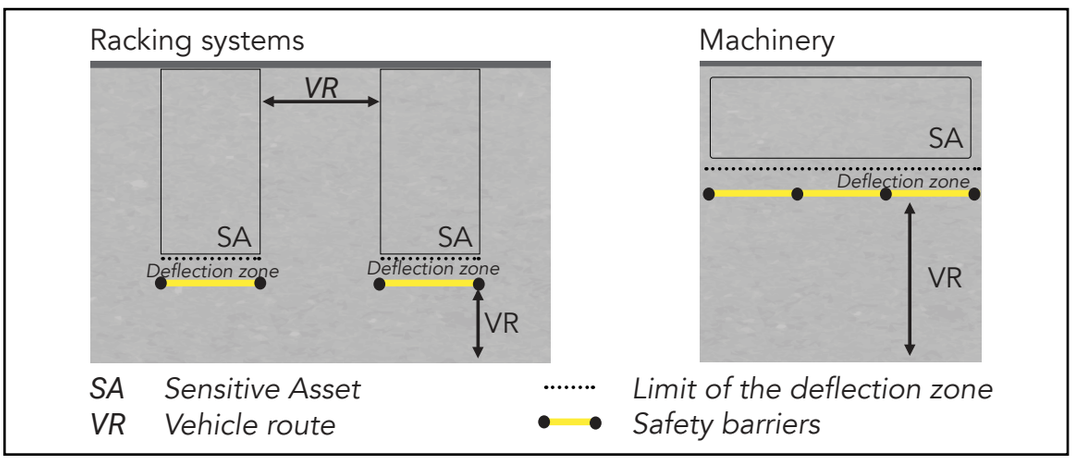
In spite of the best efforts to implement preventive measures, the movement of vehicles inherently carries a risk of collision. While shaping behaviors greatly reduces the frequency and severity of incidents, it cannot eliminate them entirely.

This is why critical areas require materials that do more than simply mark or signal hazards. They must be engineered to absorb impacts, withstand shocks, and minimize damage effectively.

Our barriers, engineered to sustain impacts, feature larger connecting rails that provide exceptional stopping power. Designed to protect key assets such as racks or machinery, they are typically lower than barriers intended for pedestrian guidance. For areas requiring enhanced protection, the rails can be doubled to further increase resistance and durability.



Protecting sensitive assets

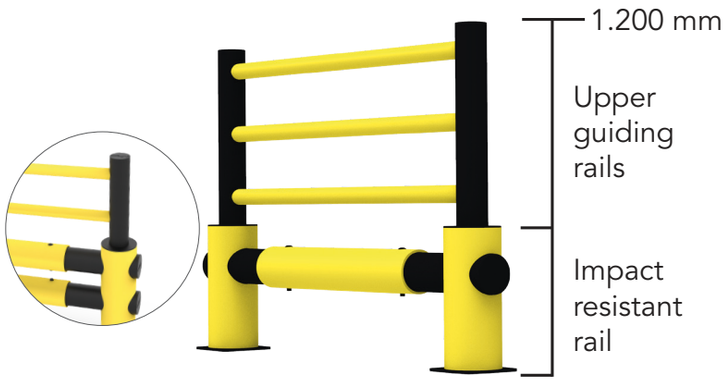


Stopping barriers provide reliable protection wherever vehicles circulate near strategic assets like racking systems, machinery, storage tanks, or electrical panels. Designed to withstand multiple impacts, they bend and bounce back to their original shape, minimizing damage to vehicles and flooring. This flexibility and durability helps reduce costly repairs and downtime.

It is crucial to consider the deflection zone when placing stopping barriers to ensure adequete space for deformation during collisions, without compromising the assets. The adequate barriers depend on circulating vehicle's weight and speed, as detailed on page 3.

Combining pedestrian guidance and impact protection

Some workplaces have heavy traffic near pedestrian pathways. This puts pedestrians, the most vulnerable group, at significant risk in case of accidents. Reinforced guiding barriers with stopping power are essential in such environments.

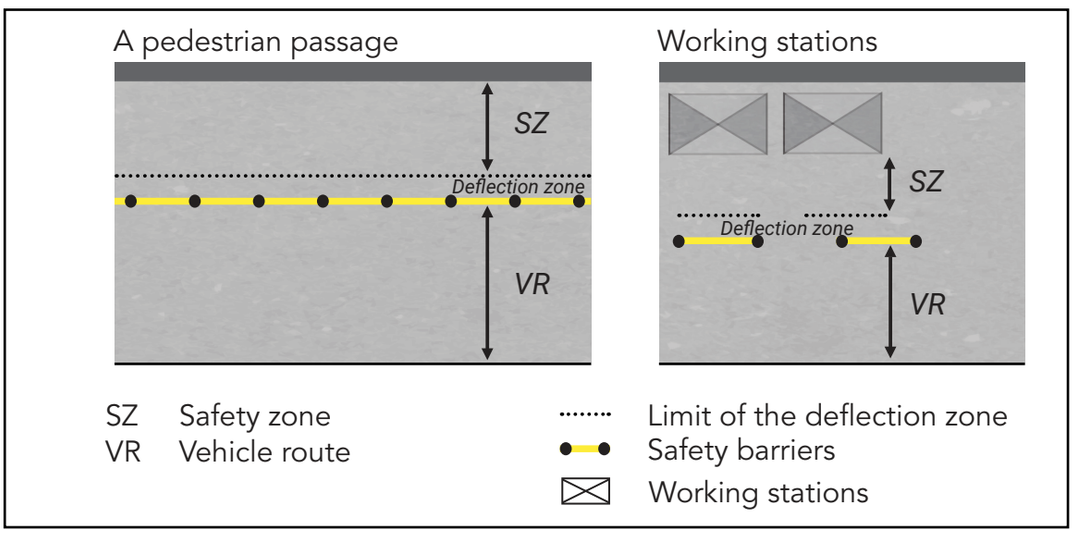


These safety barriers hybridize impact protection and pedestriance guidance in one element.

They reliably stop vehicles while defining clear pathways, preventing climbing attempts and nudging drivers toward carefulness.

These barriers are compatible with sliding and swingdoors.

Guiding and protecting pedestrians



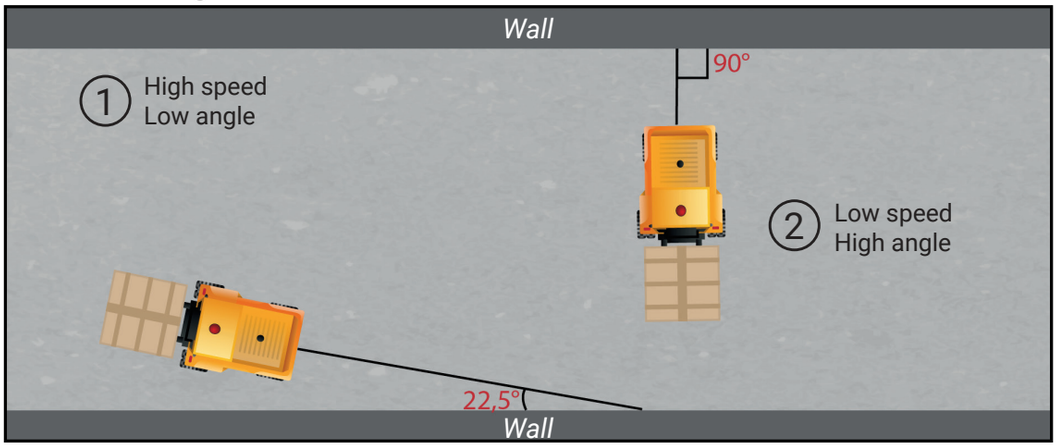
Space	Recommended width in mm
Safety Zone	1.000
Deflection zone	Depends on the barrier
VR	Max vehicle width

The recommended width from d-flexx are safety guidelines aimed at minimizing collision risks for pedestrians. Following them helps establish clear boundaries between pedestrian and vehicle zones, reducing accidents. While not legally required, these guidelines contribute to the well-being of everyone on-site, ensuring traffic moves smoothly and safely in shared spaces.

Traffic conditions and risk assessment

Risk assessment considers two key factors: a vehicle's maximum possible speed and the maximum collision angle with surrounding elements. Together, these determine the vehicle's kinetic energy (see page 3). The layout of the workplace shapes vehicle paths and acceleration potential, directly affecting collision risks and potential damage.

Vehicles driving in a close environment



In this situation, a forklift can drive fast, but cannot hit the wall at a 90° angle (1). If a vehicle hits a wall at a 90° angle, it can only do so at a low speed (2). As a result, protections with intermediate resistance are suitable in both cases .

THE TROAX SAFETY SOLUTIONS

d-flexx safety solutions include both modular barrier systems and standalone protections. Modular systems provide high flexibility with customizable lengths and the ability to combine different barriers, ensuring continuous protection tailored to each area of the workplace.

Modular system for pedestrian guidance

Pedestrian Barrier System

Designed for guidance

By creating a physical obstacle, this barrier effectively separates pedestrian passages from other areas. It guides people through the workplace, and can be used to visually mark structures like columns.

Modular systems for impact protection

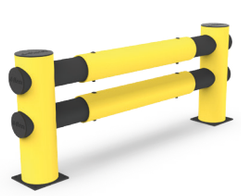
Impact Protection Barrier System

Impact zone - posts
4.000 joules

Impact zone - rail
9.000 joules*

This barrier preserves critical assets from forklift impacts. It is particularly adapted to protect strategic facilities like buildings, machinery or fluid tanks.

Impact Protection Barrier System - Double Rail



Impact zone - posts
4.000 joules

Impact zone - rail
15.000 joules*

This barrier serves the same purpose, but features an additional rail to sustain impacts from heavier vehicles.

Modular systems for impact protection for pedestrians

Pedestrian Protection Barrier System

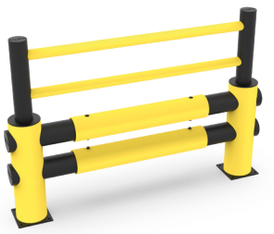
Impact zone - posts
4.000 joules

Impact zone - rail
9.000 joules*

This barrier combines impact protection with pedestrian guidance. It is the ideal solution for walkways directly neighboring vehicle routes.

**Calculated for a 90° impact angle*

Pedestrian Protection Barrier System - Double Rail



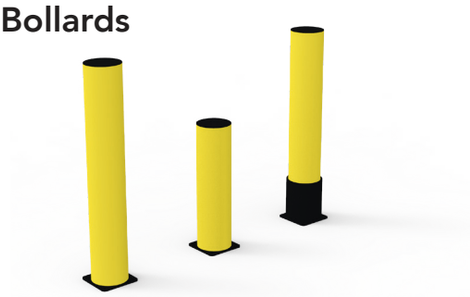
Impact zone - posts
4.000 joules

Impact zone - rail
15.000 joules*

This barrier serves the same purpose, but features an additional rail to sustain impacts from heavier vehicles.

Versatile standalones

Bollards



Impact zone - post
6.500 joules

The d-flexx bollard is an all-rounder able to mark sensitive areas to generate awareness, and offers impact resistance in case of collision. The bollard is available with a manchette for increased durability.

Working Station Barrier

Designed for guidance

This barrier is the ideal solution to visually mark an area in which people are standing, such as a workstation. It is designed to catch attention and promote instinctive safe behaviors.

Working Station protection barrier

Impact zone - posts
4.000 joules

Impact zone - rail
9.000 joules*

The ideal solution to visually mark an area in which people are standing, such as workstations. Its central rail provide high impact resistance.

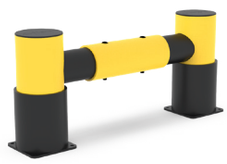
Kerb Rail

Designed for marking

MIKE Kerb is a ground-level barrier designed for versatile use across various applications. It effectively prevents forks or pallets from sliding underneath pedestrian or impact protection barriers. Additionally, it can serve as a standalone solution, offering impact protection in areas such as charging stations, workstations, walls, or other critical zones within the workplace.

**Calculated for a 90° impact angle*

Rack End Barrier - Simple railing



Impact zone - posts
4.000 joules

Impact zone - rail
7.000 joules*

This barrier is specifically designed for storage areas, where forklifts move wares daily. They protect the rack ends, safeguarding your stock and preventing the structure to collapse due to an impact. Available in multiple length, with manchettes for increased durability.

Rack End Barrier - Double railing

Impact zone - posts
4.000 joules

Impact zone - rail
13.000 joules*

This variant features an additional rail to sustain impacts from heavier vehicles.

Topple Barrier system

Impact zone - post
4.000 joules

The topple barrier is designed to separate spaces and prevent objects from falling from high stations. It is ideal where pedestrians circulate close to storage zones.

Topple Barrier system with impact protection

Impact zone - post
4.000 joules

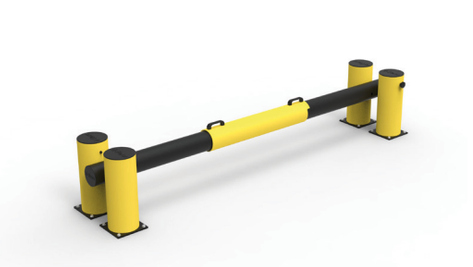
Impact zone - rail
9.000 joules*

The topple barrier can be supplemented with a rail to increase impact resistance where traffic neighbors storage zones.

**Calculated for a 90° impact angle*

Dock and gates protection

Dock Gate

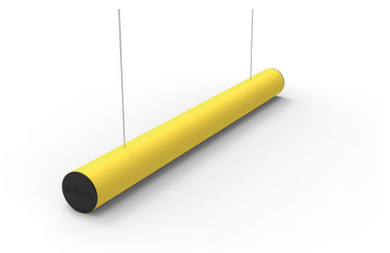


Impact zone - posts
4.000 joules

Impact zone - rail
4.500 joules*

The dock gate prevents forklifts or carriages from falling from an open dock gate. It also protects dock gates from impacts during daily loading and unloading operations.

Height Restrictor



Designed for marking

The Height Restrictor is ideally placed at gateways to visually mark the door head and prevent carriages from damaging the infrastructure.

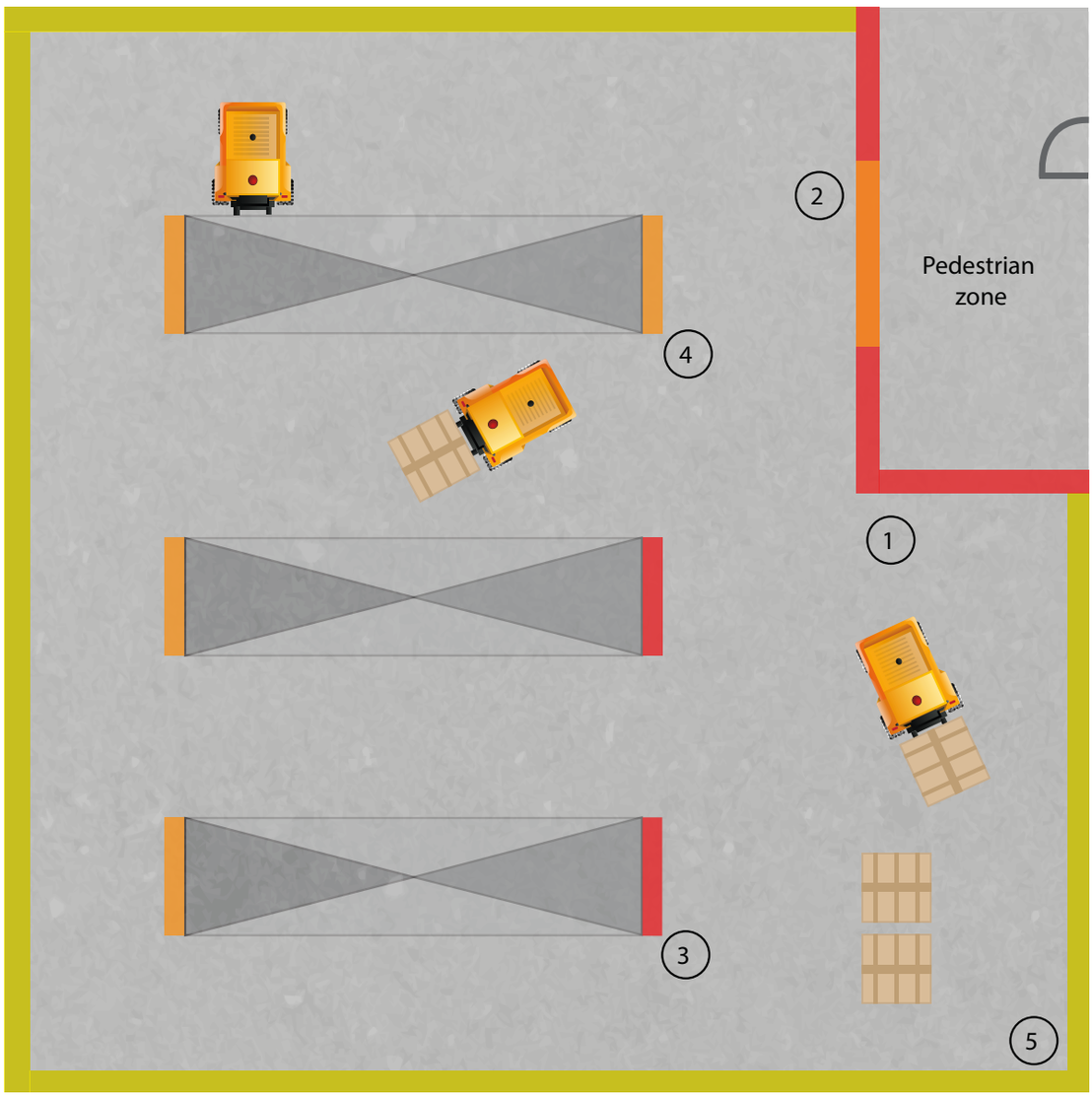
Gate protector

Impact zone - post
4.000 joules

A modular gate protector designed to visually signal and safeguard high gates during handling operations.

**Calculated for a 90° impact angle*

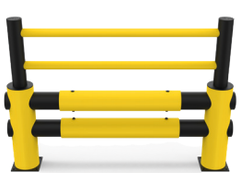
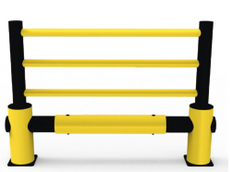
Case study - A warehouse



Potential impacts on the walls at various speed and angles.
Marking solutions are recommended

Low potential maximal speed and/or low maximal angle of impact
Impact protection up to 9.000 joules* are recommended

High potential maximal speed and angle of impact
Impact protection of 15.000 joules* and more are recommended

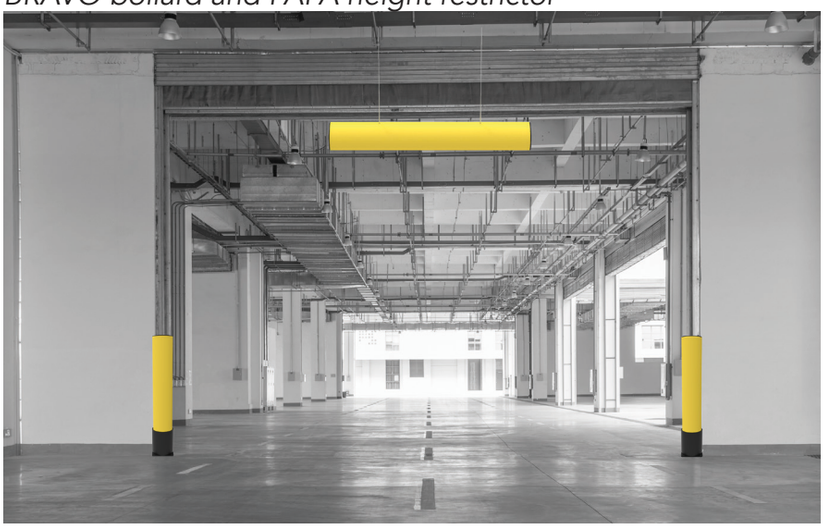
①	②	③	④	⑤
High risk factors on a pedestrian area.	Moderate risk factor on a pedestrian area.	High risk factor on a storage system.	Moderate risk factor on a storage system.	Need to mark and protect the walls.
				
LIMA barrier system	ECHO barrier system	GOLF - double railing	GOLF - single railing	Mike kerb

**Calculated for a 90° impact angle*

Case study - A gate

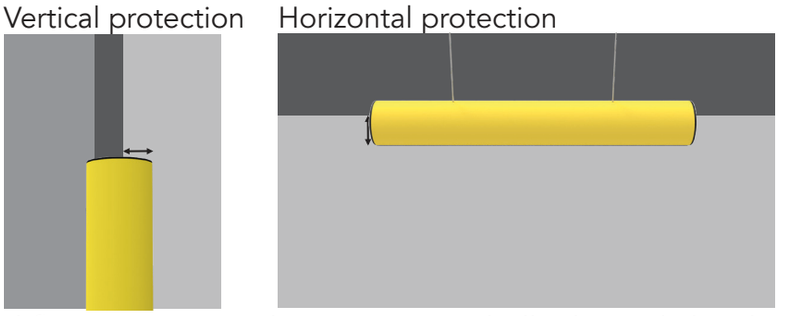
Gates are vulnerable points in indoor traffic zones, with both the lintel and side jambs exposed to frequent impact risks. Protective measures are essential to prevent damage from regular vehicle movement.

BRAVO bollard and PAPA height restrictor



The standard d-flexx setup implies BRAVO bollards to safeguard the gate's jambs, and the PAPA height restrictor to visually mark the lintel.

Vertical protection Horizontal protection



d-flexx recommends positioning bollards and height restrictors to extend at least 50 mm beyond the opening, both vertically and horizontally.

SIERRA gate protector

The SIERRA gate not only outlines your gates and doors, but also provides impact protection both vertically and horizontally.

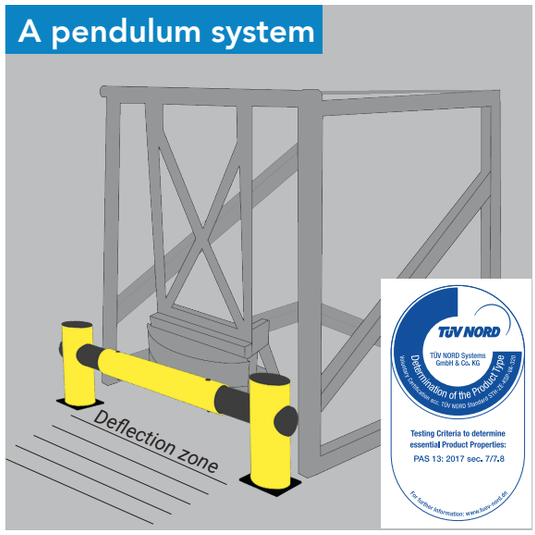
HOW OUR BARRIERS ARE TESTED

Test principle, procedure and equipment

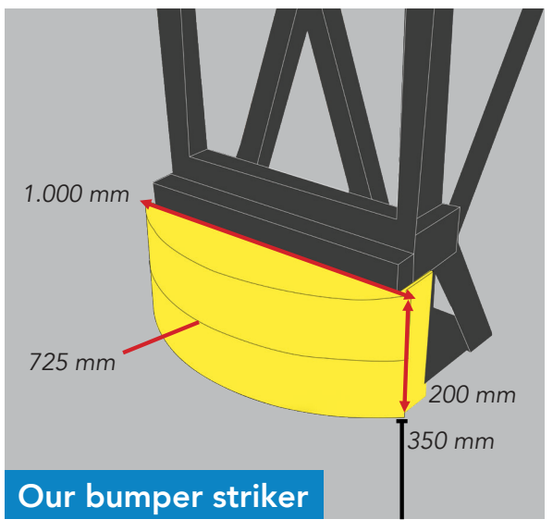
Safety barriers and bollards are tested using a pendulum striker, with impacts delivered 350 mm above ground level, in accordance with PAS 13:2017. A rigid bumper on a swinging arm delivers controlled impacts. Multiple tests ensure consistent, reliable results, with measuring instruments assessing performance.

Products are mounted on a test fixture with deflection zones marked on the floor. A load cell records absorbed force and force-to-bolt. Kinetic energy is adjusted by adding weights or increasing the release angle. All tests are recorded and linked to documentation for traceability. Data is processed and used as a reference for future tests.

A pendulum system



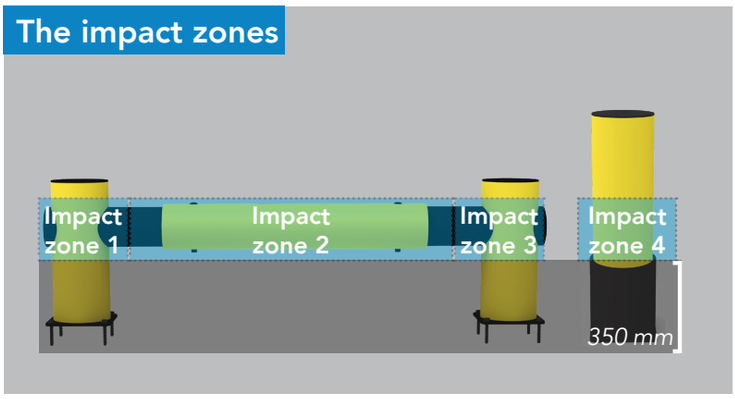
For TÜV certifications, products are kept in a controlled environment with tracked temperature and humidity for at least 4 hours before testing.



Our bumper striker

Every product component is tested. A product may have one or several impact zones, each with specific success criteria.

The impact zones



NOTES

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MAKING YOUR WORLD SAFE

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