

IMPROVEMENT OF SAFETY BARRIERS ON GERMAN BRIDGES - RESULTS OF IMPACT TEST WITH HEAVY LORRIES

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Abstract

Bridges are fitted with safety barriers for ensuring the safety of traffic and pedestrians who live, work or stay under a bridge. The safety barriers usually installed on German bridges (Standard safety barrier “Einfache Distanzschutzplanke mit Geländer” for German bridges according to “Richtzeichnung Kap 1”) are able to protect lorries up to a mass of 13 t from breaking through the barrier and falling off the bridge. In cases of accidents involving heavier vehicles, conventional safety barriers reach the limit of their capability. These accidents may cause an undue hazard to a third party under the bridge. Therefore a research project was initiated in order to obtain safety barriers which are able to protect even heavy lorries from breaking through and falling down, without causing unacceptable bridge damages. Within the research project crash tests on safety barriers in accordance with EN 1317 were performed - for the first time inclusive measuring the forces acting on bridges. The measurements show the dimension of actions caused by a vehicle impact on the bridge.

Keywords: Traffic engineering, Highway equipment, Road safety, Safety barriers for bridges, Impact tests, Bridge forces, EN 1317

Résumé

Les ponts sont équipés de barrières de sécurité assurant la sécurité des véhicules et des personnes qui vivent, travaillent ou stationnent sous ces ponts. Les barrières de sécurité des ponts allemands peuvent retenir les camions de poids jusqu'à 13 tonnes, au-delà la barrière peut rompre et le véhicule tomber du pont. Mais en cas d'accidents avec des poids lourds les barrières de sécurité conventionnelles atteignent leurs limites de fonctionnement. Ces accidents peuvent causer un risque anormal à une personne sous le pont. Un projet de recherche a donc été lancé pour obtenir des barrières de sécurité en mesure de retenir les poids lourds, d'éviter leurs chutes et des dégâts trop important à la structure du pont. Dans ce projet de recherche, des essais de chocs ont été menés sur des barrières de sécurité, conformément à la norme EN 1317, avec, pour la première fois, des mesures d'efforts appliqués au pont. Ces mesures quantifient les actions causées par l'impact d'un véhicule sur le pont.

Mots-clés : Ingénierie routière, autoroute, sécurité routière, barrières de sécurité pour les ponts, essais de choc, force sur le pont, EN 1317

1. Introduction

A fall down of a lorry from a bridge may cause an undue hazard to people who stay under the bridge. Bridges often cross high-density areas (Figure 1).



Figure 1 - Typical situation with a bridge over a high-density area

Up to now the most used safety barrier on bridges in Germany is the “Einfache Distanzschutzplanke, EDSP” installed together with a parapet (Figure 2). This safety barrier showed in impact tests that it is able to protect lorries up to a weight of 13 t with an impact speed of 70 km/h and an impact angle of 20° from breaking through the barrier. The “EDSP on bridges” reaches the containment level H2. To avoid a fall down of heavier vehicles new safety barriers with higher containment levels are needed, because the standard safety barrier reached the edge of its capability in the H2- test.

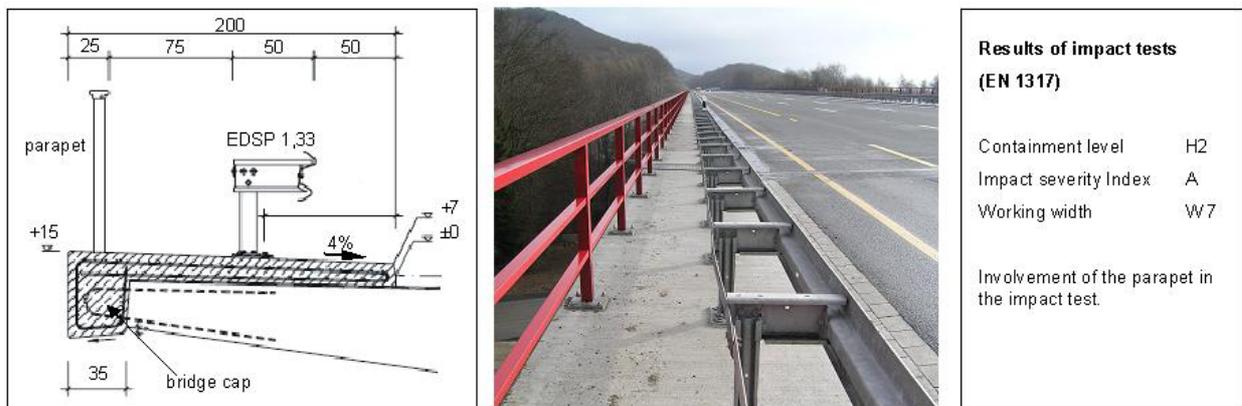


Figure 2 - Standard safety barrier “Einfache Distanzschutzplanke mit Geländer” for German bridges according to “Richtzeichnung Kap 1”

2. Actual Situation on German Bridges

In Germany the regulations for safety barriers are given in the “Richtlinien für passive Schutzeinrichtungen an Straßen” (FGSV 1989, 1996) and “Richtzeichnungen für Ingenieurbauten (RiZ-ING)”. Beside the mostly installed EDSP there is also the possibility to install a concrete barrier on the bridge. The EDSP was tested in accordance with EN 1317 and fulfilled, together with the parapet, the requirements of containment level H2 (Ellmers, 2003). The in-situ concrete barrier on a bridge was not tested in accordance with EN 1317 until now.

Most of the existing and also the new bridges in Germany have a so called bridge cap made of concrete on which the safety barrier and the parapet are installed. This cap has a width of 2 m and is shown in Figure 2. In the case of a lorry impact on the safety barrier high forces occur. These forces should not damage the bridge construction but may damage the bridge cap, because the cap is the wear part of the bridge. First studies (BASt 1989) had shown that new safety barriers for German bridges with higher containment level have the disadvantage of high impact forces. The expected forces in case of an impact may be higher than the design resistance of the bridge construction and may cause a failure of the cantilever arm.

This problem is not so relevant for new bridges, because the bridge construction can be designed for the high forces in case of a vehicle impact, but for existing bridges (37.000 on German highways) these reinforcements are very expensive and difficult to realise. Therefore new safety barriers should fit to the geometry and technical specifications of existing bridges. To solve these problems BASt developed a requirement specification for the construction of road restraint systems of the containment level H4b on bridges in Germany and gave it to the interested producers of safety barriers (Bergerhausen et al., 2005). The main content of the requirement specification is given in Figure 3.

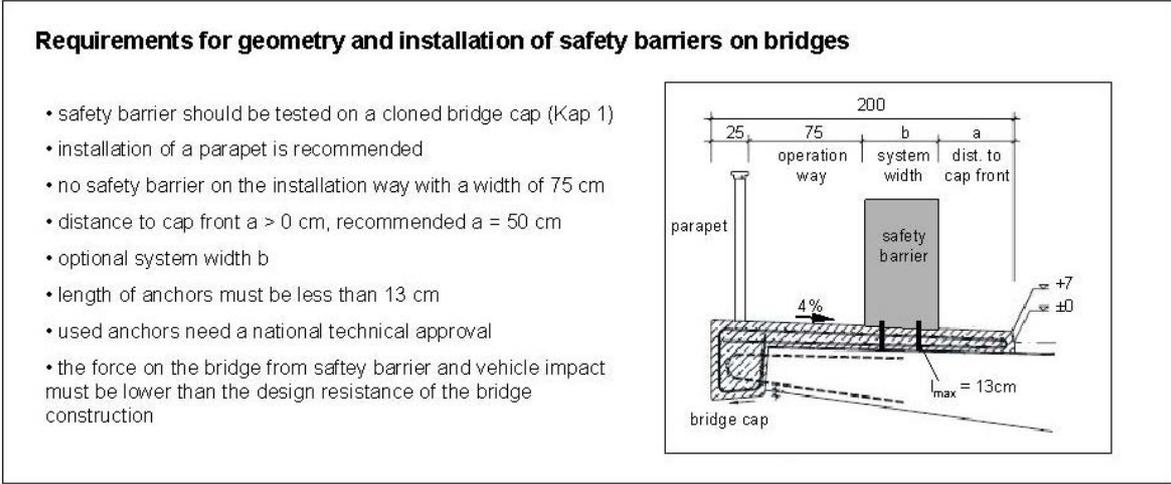


Figure 3 - Extract of the requirement specification for the construction of road restraint systems of the containment level H4b on bridges in Germany developed by BASt

In addition the safety barriers have to fulfill the requirements of the impact tests TB 11 (small car) and TB 81 (heavy lorry) according to EN 1317. The test parameters are given in Table 1. The test with the lorry shows the level of containment and working width of the safety barrier and the test with the small car is done to verify that the satisfactory attainment of the maximum level (lorry) is also compatible with safety for light vehicles.

Table 1 - Test parameter according to DIN EN 1317

Containment level	Test	Impact velocity [km/h]	Impact Angle [degrees]	Total vehicle mass [kg]
H4b	TB 11	100	20	900
	TB 81	65	20	38000

3. Test facilities and conditions

To give all producers of safety barriers the same test conditions, BAST developed and built a bridge cap (scale 1:1) with measuring devices on which the safety barriers could be installed for the impact tests according to EN 1317. The bridge construction was built on the test site of the TÜV SÜD Automotive GmbH in Munich-Allach (see Figure 4), because there force measuring equipment and a substructure for the bridge cap already existed, based on a previous Austrian research project (Hellmich et al., 2002). The force measurement area shown in figures 4 and 5 has a length of 12 m, divided into 3 sections of 4 m. The clone of the bridge cap (concrete part) has a total length of 80 m. On this bridge cap, the producers can install their safety barriers for the impact tests with the same geometric conditions like on German bridges. Before the real crash tests the producers of the barriers made simulations to find the best constructive solutions for the impact tests.

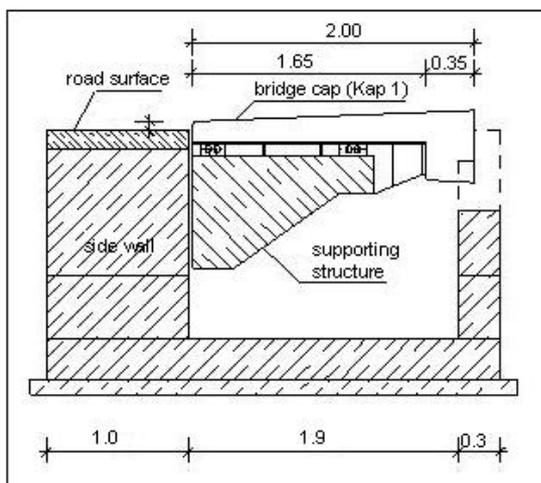


Figure 4 - Test facility with bridge cap (Kap 1)

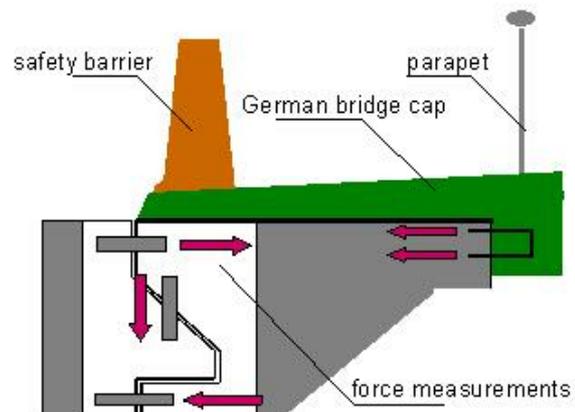


Figure 5 - Sketch of the test facility and position of force measurement

4. Impact tests on safety barriers

The tests were conducted by BAST in co-operation with TÜV SÜD Automotive GmbH (TÜV). The producers install their safety barriers on the bridge construction (see Figure 6) and BAST makes the documentation and geometric checks of the installation. After all test preparations the TB 11 starts.

To control the test vehicle on the planned approach and maintain the defined impact velocity, the ECV (Electronically Controlled Vehicle) system from TÜV is used. The test vehicle is accelerated with its own engine power to the prescribed impact velocity and is controlled during the acceleration phase by an electric cable laid in the ground, ensuring that the vehicle follows a defined course to approach the barrier. The connection between the test vehicle and the ECV system is broken shortly before the point of impact (steering, clutch); the vehicle then drives freely, i.e. without external force, and is therefore only affected by the system to be tested during the entire crash procedure. At the end of the test the vehicle is decelerated by means of a remote control. An example for an impact of a lorry is given in Figure 7.



Figure 6 - Overview of test site with a safety barrier before the impact test.



Figure 7 - Impact test TB 81 (example).

5. Results concerning EN 1317

Six different safety barriers shown in Figure 8 fulfilled the requirements of EN 1317. One safety barrier is a precast concrete barrier and the others are steel safety barriers. The steel barriers could be divided into barriers with posts and beams as the main parts (systems B, C, E) and barriers with a profiled steel socket (systems D and F).

The significant parameters of the safety barriers are given in Table 2. The height of the barriers varies from 1.07 m above road surface to 1.76 m above road surface. The weight of the tested systems differs in a range between 76 kg/m and 783 kg/m. This shows that the containment level H4b could be reached with very different constructions, heights and weights. The position of the safety barriers concerning the front of the system is also very different. Some systems were installed near to the front of the cap, others were installed with a distance up to 50 cm which is normally the distance between the front of the cap and the

front of the safety barrier in Germany (Kap 1). Shear connectors or concrete-screws were used to fix the safety barriers on the bridge. The maximum length of the anchorage in the cap was 13 cm. Barrier A was fixed at the position of the element joints. Each element of Barriers D and F were fixed at two points. The steel safety barriers B, C and E were fixed to bridge cap by anchors at the base-plates of the posts.

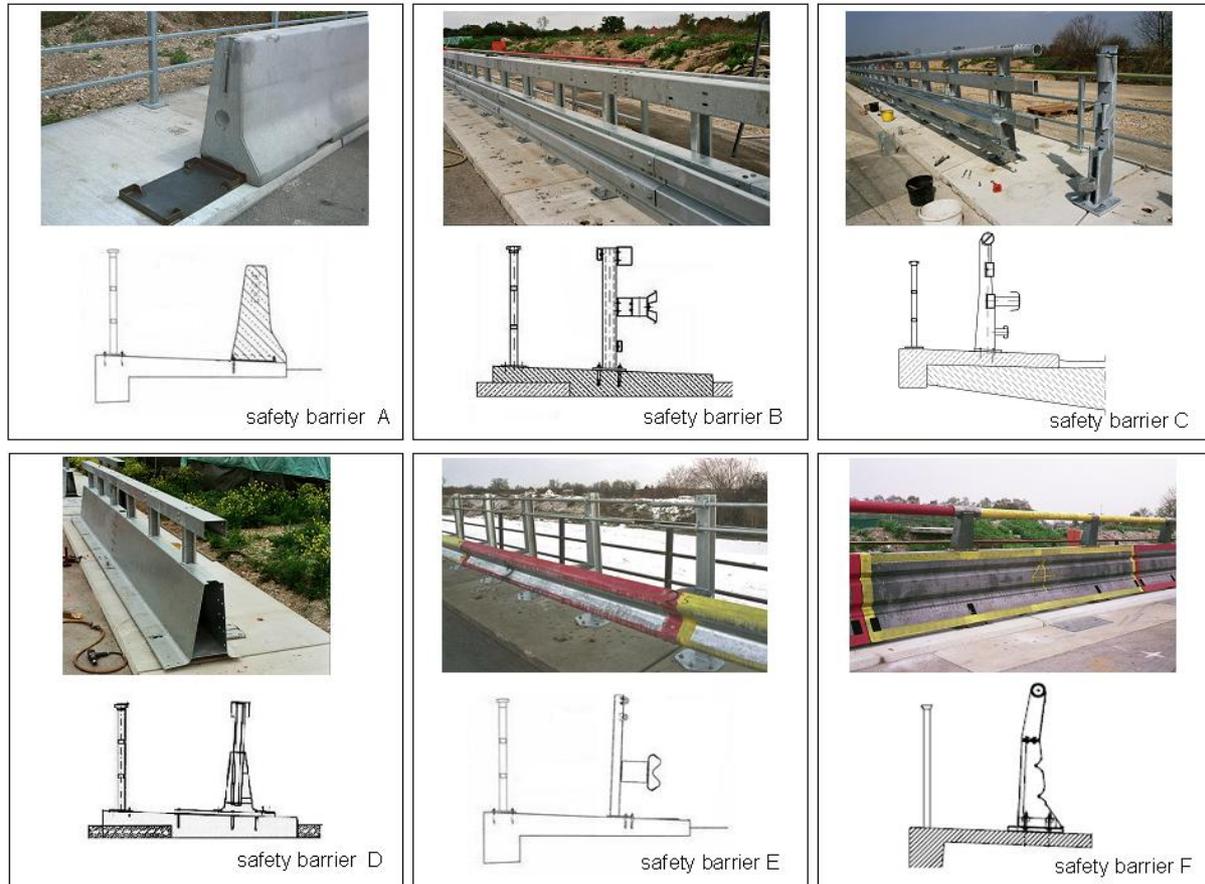


Figure 8 – Safety barriers for bridges tested by BASt

Table 2 - Parameter of the different safety barriers in the tests.

	material	width	height (over road surface)	distance to front of cap	anchors	weight
Barrier A	concrete	0.58 m	1.07 m	0.0 m	1 shear connector (M16) each 6 m	783 kg/m
Barrier B	steel	0.60 m	1.24 m	0.4 m	4 shear connectors (M16) each 1.33 m	88 kg/m
Barrier C	steel	0.56 m	1.59 m	0.50 m	3 shear connectors (2 M16, M10) each 1.5 m	202 kg/m
Barrier D	steel	0.95 m	1.36 m	0.22 m	6 concrete-screws (B16) each 2.66 m	168 kg/m
Barrier E	steel	0.67 m	1.56 m	0.40 m	3 concrete-screws (B16) each 1.33 m	76 kg/m
Barrier F	steel	0.61 m	1.76 m	0.31 m	8 shear connectors (M16) each 3 m	104 kg/m

Figure 9 shows the damage and deflection of the six safety barriers after the impact test TB 11. All safety barriers were pushed back by the car. The safety barriers with spacers react with deformation of the spacer and front beam. The concrete barrier and the barriers D and F are displaced in the area of impact. The dynamic deflection at the front of the safety barriers varies between 0.06 m and 0.28 m. The distance of vehicle contact varies between 4.2 m and 5.4 m. The measured impact severity index is given in Table 3. One barrier reaches an impact severity index of A ($ASI \leq 1,0$, $THIV \leq 33$ km/h and $PHD \leq 20$ g), the others B ($1,0 < ASI \leq 1,4$, $THIV \leq 33$ km/h and $PHD \leq 20$ g). These results show that it is possible to construct safety barriers that are able to avoid a fall down of heavy lorry from a bridge and are compatible with safety for light vehicles.

Table 3 - Results of the TB11-impact tests.

	ASI	THIV	PHD	impact severity level	distance of vehicle contact
Barrier A	1.4	25.8 km/h	12.0 g	B	4.5 m
Barrier B	1.4	28.4 km/h	10.0 g	B	4.2 m
Barrier C	1.4	28.8 km/h	11.2 g	B	4.4 m
Barrier D	1.2	18.8 km/h	13.3 g	B	5.0 m
Barrier E	0.9	22.7 km/h	5.2 g	A	4.8 m
Barrier F	1.4	30.4 km/h	10.9 g	B	5.4 m

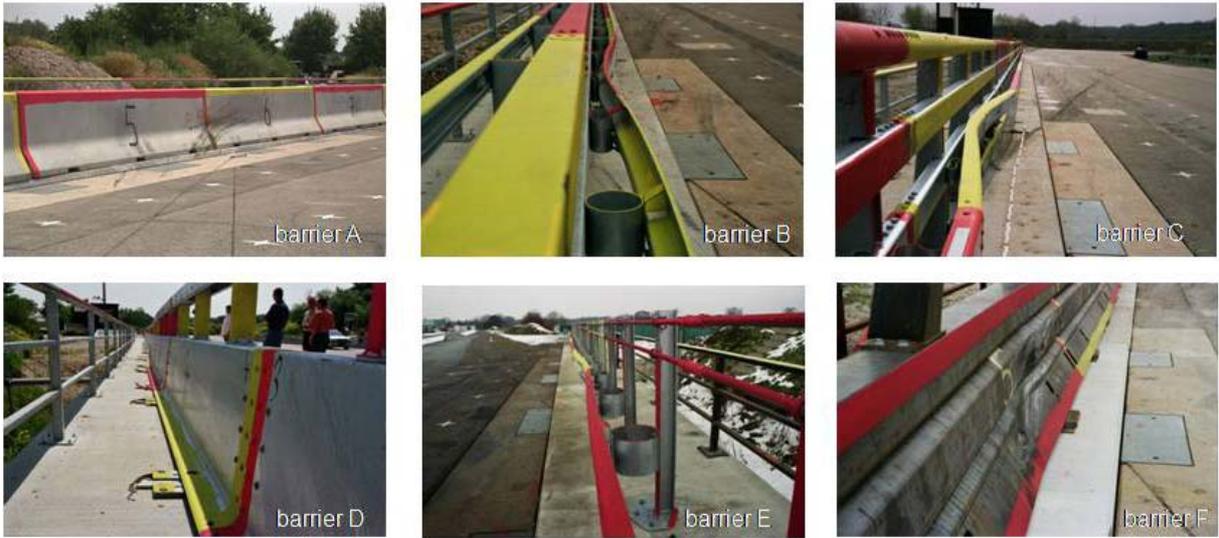


Figure 9 - Damage and deflection of the safety barriers after TB11-test.

Figure 10 shows the safety barriers after the impact tests TB81. The safety barriers react in very different ways on the impact of the lorry. Some of them are displaced as a wall, others react with significant deformation of the posts and beams and are pressed down by the vehicle. In two cases (systems B and C) the safety barriers lateral displacement reaches the parapet (Table 4) and the impact causes damages also on the parapet. In these cases the parapet is part of the safety barrier because it was involved in the process of holding back the lorry from a fall down.

In two cases (safety barriers with lowest height) the maximum lateral position of the vehicle was about 1 m larger than the maximum lateral position of the safety-barrier. In the other tests

there were only small differences between the maximum lateral position of the system and the vehicle. The distance of vehicle contact was between 17 m and 49 m. The bridge cap was only damaged in the area of the anchorage. Damages of the bridge cap occurred in three cases.



Figure 10 - Damages, deflection and distance of vehicle contact of the safety barriers after TB81-test.

Table 4 - Results of the TB81-impact tests.

	maximum lateral position of system	maximum lateral position of vehicle	distance of vehicle contact	class of working width	involvement of the parapet	damages on the bridge cap
Barrier A	1.6 m	2.6 m	19 m	W 5	no	none
Barrier B	2.2 m	3.2 m	40 m	W 7	yes	none
Barrier C	2.0 m	2.3 m	49 m	W 6	yes	yes, flaking of concrete
Barrier D	1.4 m	1.4 m	17 m	W 5	no	none
Barrier E	1.3 m	1.4 m	28 m	W 4	no	yes, flaking of concrete
Barrier F	1.3 m	1.1 m	19 m	W 4	no	yes, flaking of concrete

6. Results concerning bridge forces

During the impact tests TB 81 the forces are measured (1000 values/second) in a 12m-area around the point of impact. The forces are measured by 18 strain gauges at the position of the cantilever fixing and 40 load cells at the position of the starter bars. The measured data were analysed for each position and the maximum values were identified (Bergerhausen, 2006). The measurements show the dimension of actions caused by a vehicle impact. The measured high forces not only appear in H4b tests, they were also observed in H2-tests. This shows that the values of the forces are no exception but will be relevant in the case of impacts with heavy vehicles. One main achievement of the analysis is the dimension of the load level compared to the design resistance of the construction. Within the tests the measured force obtain a load

level which is about 3 to 4 times higher than assessed in the “DIN-Fachbericht 101 Einwirkungen” (2003) which is Eurocode 1 transferred into a national standard.

7. Summary and conclusions

As a main result it can be shown for the first time that safety barriers on bridges are able to prevent the fall of a heavy lorry from a bridge compatible with safety for light vehicles and without causing unacceptable damage to the bridge structure. The results are based on impact tests according to EN 1317 with additional force measurements. At the moment six safety barriers exist that fulfil the requirements of the containment level H4b of EN 1317 and fulfil also the requirements for German bridges (e.g. length of anchorage). The forces in case of the impact were measured and loads will be calculated from the measurements. The measured dynamic force within this project obtain a load level which is about 3 to 4 times higher than assessed in the “DIN-Fachbericht 101 Einwirkungen” (2003). Additionally some safety barriers with containment level H 2 (13 t bus instead of 38 t heavy lorry) have been tested according to EN 1317 with force measurement. These tests also show that the bridge cap will not be damaged in the case of an impact but the forces are also high.

At the moment there exist several safety barriers with containment levels H2 and H4b for the German bridges. The updated German regulation for the use of safety barriers “Richtlinien für passiven Schutz an Straßen durch Fahrzeug-Rückhaltesysteme, Entwurf 2007” (FGSV, 2007) postulate that safety barriers of containment level H4b should be installed on bridges on highways if the fall down of a lorry may cause an undue hazard to a third party (e.g. high-density area or industries with danger of explosion under the bridge). In most other cases H2-barriers should be installed on bridges. These requirements aim for new bridges or maintenance of bridges. The now starting stepwise installation of the new barriers should improve the safety on German bridges. To avoid also a fall down of heavier trucks (60 t) in the future new systems with even higher containment levels have to be developed and tested.

8. Acknowledgements

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