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Vehicle restraint systems —

Part 1: Fundamentals — Database

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Committees responsible for this Published Document

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Association of Safety Fencing Contractors
British Cement Association
British In-situ Concrete Paving Association
British Precast Concrete Federation Ltd.
County Surveyors' Society
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Institution of Civil Engineers
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Railtrack
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Contents

Foreword

This part of PD 6634 has been prepared by Subcommittee B/509/1. The other parts in the series are:

— *Part 2: Fundamentals of highway restraint systems;*

— *Part 3: Development of vehicle highway barriers in the United Kingdom;*

— *Part 4: Development of bridge parapets in the United Kingdom;*

— *Part 5: Development of barrier transitions and terminals;*

— *Part 6: Crashworthy roadside features — Impact attenuators.*

BSI Subcomittee B/509/1, whose constitution is shown in this Published Document, takes collective responsibility for its preparation under the authority of the Standards Committee. The Subcommittee wishes to acknowledge the personal contribution of Mr I. B. Laker.

Over the last 30 years the Department of the Environment, Transport and the Regions (DETR), the Transport Research Laboratory (TRL), the British Standards Institution (BSI) and other organizations have been involved in research, testing, design and the preparation of specifications and standards for vehicle restraint systems such as safety fences, barriers and bridge parapets. Much of this work has been published in the form of Transport Research Laboratory reports, drawings, specifications and standards.

In more recent years, particularly since the introduction of quality assurance schemes for both the manufacture of components and the erection of safety fences and parapets, the need for additional advice, guidance and background information has become apparant. In 1988 the then Department of Transport (DTp) and BSI agreed to the preparation of a comprehensive British Standard or Reference Manual on vehicle restraint systems.

A steering group of representatives from BSI, DTp and TRL was formed to supervise the project and the following terms of reference were formulated:

> "To prepare the draft of a comprehensive document on safety fences, barriers and bridge parapets covering research and development, design, specification, manufacture, installation, repair and maintenance."

It was decided to split the Reference Manual into several parts and the following groups were formed:

a) Working Group 1 — Part 1 dealing with the fundamentals of safety fences, barriers, parapets and transitions;

b) Working Group 2 — Part 2 dealing with the specification and layout of safety fences and barriers;

c) Working Group 3 — Part 3 dealing with the installation, inspection and repair of safety fences;

d) Working Group 4 — Part 4 dealing with the installation, inspection and repair of safety barriers;

e) Working Group 5 — Part 5 dealing with all aspects of bridge parapets.

Of these proposed parts PD 6634 forms part 1 and BS 7669-3 forms part 3. Work on the other parts has been suspended.

This publication does not purport to include all necessary provisions of a contract. Users are responsible for its correct application.

This Published Document is not to be regarded as a British Standard.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 23 and a back cover.

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Introduction

Since the early 1960s the Department of Transport (DTp), now the Department of Transport, Environment and the Regions (DETR), has been responsible for the approval and installation of vehicle safety road restraint systems on motorways and other specified major roads in the United Kingdom. These systems include vehicle restraint devices such as safety barriers, bridge parapets, arrester beds, crash cushions, safety kerbs and associated devices. The then Road Research Laboratory, now the Transport Research Laboratory (TRL), played a key role in the development and design of the various safety devices, under the aegis of the DTp. In addition, as the demand for such equipment developed and expanded, consultant engineers, manufacturers, installers and others played an increasing part in the production of novel designs of roadside safety systems.

Many reports and standards have been published on the subject, both in the UK and worldwide. However, there is no single reference document dealing with the fundamental design and performance of the vehicle restraint systems in use in the UK, which highlights the important developments from their beginning, in the late 1950s, to the present day. Accordingly, the Bridges Engineering Division of the Highways Agency (HA) has initiated the formulation of a Published Document, PD 6634, to fill this gap in the technical literature.

In this Published Document, for simplicity, the term "barrier" may be used as a generic term to refer to any vehicle restraint device whose purpose is to contain or redirect an impacting vehicle. Where the term "fence" is used it generally refers to a post and rail barrier, rather than a barrier with a continuous footing.

1 Scope

Part 1 of PD 6634 consists of 14 summary tables with brief descriptions that provide a background reference and a database, upon which the other parts of PD 6634 are founded.

2 Summary reference tables: Tables 1 to 14

The earliest roadside restraint systems were probably rails or parapets fitted to bridges for the protection of pedestrians or horse drawn vehicles. It is understood that in Rome examples of bridge parapets dating back to the period of the Roman Empire are still in use. However, it was not until after the 1939-45 World War, with the rapid increase in road traffic, that the pressing need for roadside safety restraint systems began to arise in the UK, and barriers had to be effective against impact by high speed traffic.

The first UK barriers were either constructed from a simple steel rail, w-shaped in cross-section bolted directly on to strong wooden posts, or mainly decorative bridge parapets constructed in masonry, concrete or steel. Little or no account had been taken of the possibility of impact by high speed vehicles; the subsequent impact performance of these barriers was found to be unacceptable.

Each of the summary tables is reviewed in the following paragraphs. Detailed analysis, development and performance of the barriers mentioned in the tables is the subject of other parts of PD 6634.

Table 1 — Untensioned corrugated beam barriers (UCB)

Table 1 summarizes untensioned beam barriers (UCB), sometimes known as blocked out beam (BOB) barriers. This type of barrier initially consisted of a steel horizontal beam, w-shaped in cross-section, mounted on strong wooden posts. The term "strong" generally indicated that the posts were not expected to fracture by vehicle impact, but to rotate in the soil. It was quickly realized that it was essential for the rail to be blocked out from the posts.

The presence of the block prevented direct contact between the leading wheel of the impacting car and the posts. In addition, the effect of blocking out the rail tended, on rotation of the posts in the soil from vehicle impact, to increase the effective height of the rail during the contact period between car and barrier. The vertical face of the beam was later sloped towards the base of the post in order to present a fuller contact area between the beam face and the impact vehicle as the post was pushed back and rotated.

Later, in the mid 1970s, in an attempt to remove the need for blocking out the rail, the strong posts were fitted with a frangible base joint. However, it was found difficult to control the operation of a frangible joint over the full range of vehicle impact energies, and so the method was not pursued.

The Christiani and Nielsen barrier listed in Table 1 is also a strong-post fence, but with the rail mounted on hinged posts restrained by hydraulic shock absorbers. Unfortunately, at high energy impacts, the hinged posts were forced to rotate to their full travel and the car was able to make contact with the strong posts, so causing an unacceptable vehicle to barrier response.

For low speed impacts the simple blocked out steel rail and strong-post barrier has been found to be acceptable for car park barriers and for the protection of buildings from circulating low speed traffic.

Table 2 — Concrete safety barriers (CSB)

The first vehicle impact tests at TRL, in the early 1960s, were on a concrete beam barrier mounted on wooden posts (DAV). The design suffered from the same restrictions as the UCB; in addition there was a tendency for the concrete beam to fracture under impact.

The USA and continental Europe have historically used concrete barriers constructed as a wall with a continuous footing. The face of the wall has been the subject of various shaped profile designs and many of these shapes, and novel ones, were tested by TRL in the mid 1970s. The shaped profiles were intended to permit the leading wheel of the impact vehicle to ride up and so absorb some of the impact energy. However, at high speed the vehicle tended to ride too high until, eventually, vehicle overturning was induced.

Later, in the mid 1980s, vehicle tests were made against a plain vertical wall. The impact severity was found not to be significantly increased and the trajectory of the vehicle during and after impact was satisfactory. This type of concrete barrier is now increasingly being used in the UK, both as a permanent and temporary barrier. Furthermore it has the capacity to act as a barrier suitable for the containment of heavy commercial vehicles.

Table 3 — Wire rope safety fence (WRSF)

The earliest type of WRSF tested at TRL in the early 1960s was an import from the USA and known as the Californian wire rope safety fence. It consisted of fairly tall posts, faced with wire mesh fencing material, held in place by four wire ropes attached each side at two heights. The wire rope attachment to the posts was modified by the inclusion of proprietary frangible clips. On impact the clips were intended to snap to release the ropes from the posts and then the posts were intended to be run down. Unfortunately, the clips did not fracture and release the posts as required and the mesh bunched in front of the test car so causing spin out.

However, the modified Californian fence was the first attempt, in the UK, to design a "weak post" barrier, in which the posts are intended to be contacted by the impact wheel of the test car and then be run down. This impact mechanism is quite distinct from the UCB where the blocking out is designed to keep the road wheel from making contact with the posts.

The WRSF was further developed by TRL to the extent whereby two ropes were laid in simple slots cut into the top of the weak posts. The bending moments of the posts were arranged to be high at right angles to the fence compared with the longitudinal direction. This arrangement allowed the posts to be easily run down in line longitudinal to the fence, but nevertheless contained vehicle penetration in the transverse direction.

The design suffered from the added costs required to make a hard, smooth, vehicle running surface in the close environs of the fence. Later, the fence was modified by Bridon plc to a four rope system (BRIFEN®[1)]). This design is currently in use on UK roads and does not require a hardened, surrounding running area.

Table 4 — Tensioned corrugated beam fence (TCB)

The TCB fence is essentially a development of the weak-post slotted wire rope fence. The wire rope was replaced by a fairly stiff horizontal w-sectioned steel beam attached to weak posts by shear bolts. Any slack between the bolted sections of the beams was removed such that, on impact, tension was quickly generated in the beam. The TCB fence acts much in the same way as the WRSF in that the posts are easily run down in the longitudinal direction, after fracturing the shear bolts, and contained in the transverse direction by the stronger bending moment of the posts in that direction.

The added stiffness of the w-section beam, compared to two wire ropes, tended to reduce the penetration of the car and associated deflection of the fence, thus permitting installation of the fence in highway locations where site space was somewhat limited.

The TCB fence continues to be the most prominent fence in use on UK roads.

Table 5 — Open box beam fence (OBB)

The OBB fence, in turn, was developed in the mid 1960s from the weak post concept to limit vehicle penetration even further, although the rail is untensioned. The section of the beam is approximately the shape of a top hat with the brim turned inwards and has a much stiffer section than a w-sectioned beam. The OBB fence was designed at TRL. The purpose of the "open" feature in the section permits the beam to be connected to the posts by simple clamps.

The OBB fence's mechanism performs in the same way as other weak-post fences, but in addition the component parts act as a set of standard components that permits easy assembly of double sided beam fences, double sided double height beam fences and even double sided triple height beam fences. Clearly the more material included in the fence, the more the fence impact deflection is reduced for the same energy of impact or, on the other hand, the more suitable the fence is against impact by heavy commercial vehicles.

[1)] BRIFEN is a trade mark owned by Bridon plc, Carr Hill, Doncaster, and is an example of a suitable product available commercially. This information is given for the convenience of users of this Published Document and does not constitute an endorsement by BSI of this product.

A version of the OBB fence has been successfully tested by impact with an articulated heavy commercial vehicle (38 t). For the stiffer designs, the barrier ceases to become a weak post fence for the lighter vehicles such as cars, and the need returns to protect the leading wheels from impacting the posts. Blocking out of the beams, or the inclusion of a light weight rubbing rail at about axle height is a solution that generates adequate car to barrier response.

The OBB fence is in general use on UK roads.

Table 6 — Transitions and connections (TRNCX)

In general, although not specifically, a transition is a barrier treatment that joins two barriers of differing vehicle containment characteristics. It can be of some considerable length (tens of metres) such as a flexible car safety barrier linked to a high containment bridge parapet. A connection, some times called a link, joins barriers of differing designs but equal containment levels; it can be quite short in length (one or two metres).

There is, of course, the need to make transitional links and connections between the various types of barriers, and also between barriers and parapets. Each of the various designs is selected for highway use bearing in mind the restrictions of site space and the economic cost of the installation. The barriers which permit higher impact deflections offer less impact severity to the colliding vehicle and so there is less risk of injury to the occupants. Accordingly, these flexible types of barrier are attractive if site space permits. However, there remains the need to use stiffer barriers, as the road site features or vehicle characteristics demand, and transitions or connections need to be constructed to suit.

The details of each transition or connection may be found in association with the relevant engineering drawings listed in Table 6.

Table 7 — Terminals (TERM)

A terminal is the engineered end-treatment of a safety barrier. It can be considered as the ultimate transition that exits between the point of full impact performance of the barrier and "fresh air" or anchorage where the barrier begins or ends.

Little work has been done in the UK, or indeed in Europe, on the development of terminals that are safe with regard to vehicle impact. Both steel and concrete designs usually consist of a ramped end that can cause a colliding vehicle to be launched and become air borne for tens of metres.

Other devices, such as "fish tailed" ends and bull nose treatments, can cause very poor vehicle impact response; in some cases penetration of the terminal components into the vehicle passenger compartment have caused serious and fatal injuries.

The subject of terminal performance is currently being discussed by Technical Committee CEN/TC 226/WG1 of the European Committee for Standardization (CEN).

Table 8 — Tensioned rectangular hollow section fence (RHS)

The RHS fence was designed and tested by the British Steel Corporation, Corby. Initial testing took place on the disused Harringworth airfield in Northamptonshire. The RHS fence is essentially an equivalent to the TCB fence in that it uses weak posts connected by frangible joints to the horizontal rail and includes tensioners to remove slack from the bolted beam joints. It is effective against high speed car impacts. The fence specifically uses products manufactured by the Tubes and Pipes Division of British Steel.

The RHS fence is in current use on UK roads.

Table 9 — Combined parapets (PCOMB)

A combined bridge parapet is constructed of both concrete and metal. Steel and aluminium alloy versions have also been designed and tested.

Tests in the late 1960s were made against the Maunsel concrete/steel parapet installed on the Westway approach into London, of which a section was built at TRL for test purposes. It was found to give fairly high deceleration values in high speed car tests and so attempts were made to cushion the impact by fixing energy absorbing material to the face of the parapet. The parapet is rated at the normal containment level.

Another concrete/steel parapet designed for the Midland Link road was tested with high speed cars of mass 1 500 kg and 850 kg. These tests proved successful and were also rated at the normal containment level. Eventually, these tests led to the development of the vertical faced concrete barriers now in general use on UK roads.

Concrete, as a material, lends itself to strong construction and combined parapets using both steel and aluminium alloys have been successfully tested by impact with rigid heavy commercial vehicles (30 t); the parapets were classified at the high containment level. It is essential that a balance is struck in that the construction is sufficiently strong to withstand the commercial vehicle impact, but the parapet fractures at its mounting if there is a danger of the bridge deck collapsing.

Table 10 — Metal parapets (PMET)

The early aluminium alloy parapets (mid 1960s) were designed and supplied by the British Aluminium Company. They were tested against high speed car impacts by TRL at the disused airfield at Membury, Oxfordshire. Later tests at the Motor Industry Research Association (MIRA), under contract to TRL, found that aluminium alloy parapets were suitable for classification as low and normal containment parapets.

Also in the mid 1960s, the British Steel Corporation supplied parapet designs for testing at TRL; these early parapets were classified as low and normal containment. Later, consultants working under contract to TRL designed steel parapets suitable for the containment of heavy commercial vehicles. These were successfully tested at MIRA and rated at the high containment level. In addition, a transition was designed linking the parapet through stages of OBB fence to the single height version. The assembly was successfully tested with a 16 t heavy commercial vehicle.

Table 11 — Concrete parapets (PCONC)

Pre-cast and in-situ concrete parapets have been designed by consultants working for TRL for the impact containment of heavy commercial vehicles (30 t). Both versions were built on elevated bridge decks and after testing were rated at the high containment level.

Transitions connecting concrete parapets to single height OBB have been tested with a 16 t heavy commercial vehicle loaded to 13 t.

Table 12 — Masonry parapets (PMAS)

A British Rail design for a reinforced masonry parapet was successfully tested at MIRA to high containment levels. This parapet is essentially of composite construction whereby the masonry framework is reinforced and structurally bonded to a reinforced concrete core such that the facework cannot become detached.

Other tests on parapets constructed of masonry stones have been conducted by a group led by the County Surveyors' Society.

These tests will form a part of PD 6634-4 relating to bridge parapet design.

Table 13 — Arrester beds, bushes, earth walls, crash cushions, wood and sand barriers (REM)

Table 13 groups together the vehicle restraint systems that are not in wide public use, or have not been fully developed. Further details of these devices will be highlighted in PD 6634-6.

Of particular relevance are the activities both in the USA and Europe on the development of crash cushions. Some work has been done by TRL in the UK on crash cushions, primarily to establish impact severity criteria for the drafting of standards.

Table 14 — Computer models (MODL)

The computer simulation of vehicle impacts into safety barriers has been carried out mostly in the USA. It is estimated that at one period ten universities in the USA were engaged in the subject.

Of particular interest in Europe is the collaboration of the SWOV research laboratory in Holland and the University of Milan in Italy in producing a comprehensive crash model known as VEYDYAC. Other work in the computer modelling field is discussed in PD 6634-2, clause **8**.

3 Summary list of barrier and parapet tables

Table 1 — Summary of barrier details — Untensioned corrugated beam (UCB)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL Ltd.		TRL	**Tested by TRL** Sometimes known as blocked out beam (BOB)	JEHU, V.J. *DAV and blocked out beam (BOB)*. 1967 LR104	DEPARTMENT OF THE ENVIRONMENT, London: Technical Memorandum H9/73: *Safety fences*	
DTp		BS 6579-7:1989	**Early tests on BOB** TRRL 1962 Tests 6 to 10 Vertical face w-beam On wooden posts		DTp. Highways and Traffic Directorate, Bridges Engineering Department, Technical Document TD 19/85: *Safety fences and barriers*, + Amendment No. 1. London: DTp	
Christiani and Nielsen			**Later tests on UCB** TRL Test No.50, 63 and 64 May 1965 to March 1966		DTp. Highways and Traffic Directorate, Departmental Standard: TD 19/2003: *Vehicle restraint systems (safety fences and barriers). Highway construction details*. London: DTp	
			Sloping face w-beam Test No. 74 Sept 1966		DTp. *Manual of contract documents for highway works. Vol. 2. Notes for guidance on the specification of highway works. Series NG400: Safety fences, safety barriers and pededstrian guiderails*. London: DTp	
			Christiani and Nielsen hydraulic barrier	LAKER, I.B., and TAYLOR. *Impact tests on a modified Christiani and Nielson crash barrier*. 1969 LR246	BS 6579-7:1989, *Safety fences and barriers for highways —* *Part 7: Specification for components for untensioned corrugated beam safety fence*	
			Car park barrier March-1964 TRL Test G			
			MIRA tests on UCB J0007 110 × 50 Sept 1991 K0018 6 m radius Nov 1992 L0025 curved Restricted to 50 m/h	JEHU, V.J., and L.C. PEARSON. *A steel safety fence with frangible base intermediate posts*. 1981. LR988 Frangible base — Patent applied No. 7913368		
			Frangible posts LR988: 8 tests at MIRA			

Table 2 — Summary of barrier details — Concrete safety barriers (CSB)

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRRL, Crowthorne, Berkshire	Marshalls, Halifax, West Yorkshire	General Motors Barrier (GM) New Jersey Barrier (NJ)	**TESTS NOT TO BS 6579** DAV beam on posts TRL Tests 1 to 5: July 1982	JEHU, V.J. 1964. Safety fences and kerbs. *Trans. Eng and Contr.*	DEPARTMENT OF THE ENVIRONMENT, London: Technical Memorandum H9/73: *Safety fences*	TRRL, Crash-D, KRASH, Cranfield
BCA, Crowthorne, Berkshire	Buchan, Accrington, Lancashire	GM + 25 mm + NJ (Shape 1:LR801)	Shapes 1 to 3: MINI CAR Mass: 760 kg 116 km/h, 114 km/h and 101 km/h All overturned (O/T)	JEHU, V.J. *DAV and blocked out beam crash barriers*. Crowthorne, Bershire: TRL, 1967 LR 104	DTp. Highways and Traffic Directorate, Bridges Engineering Department, Technical Document TD 19/85: *Safety fences and barriers*, +Amendment No. 1. London: DTp	
	Bell & Webster, Grantham, Lincolnshire	NJ + 25 mm (Shape 2: LR801) NJ + Step (Shape 3: LR801) NJ Parapet (Shape 4: LR801) NJ Parapet 75 mm (Shape 5: LR801)	**TESTS TO BS 6579** LEYLAND 1800 Mass: 1 505 kg Shape 1: 116 km/h: (OK) Shape 2: 80 km/h: (OK) Shape 3: Not tested **TESTS TO BS 6579** LEYLAND 1800 Mass: 1 505 kg	JEHU, V.J. and L.C. PEARSON. *Impacts against shaped concrete barriers*. Crowthorne, Berkshire: TRL, 1977 LR801	DTp, 1985 *Code of practice for routine maintenance*. London: DTp DTp. *Manual of contract documents for highway works. Vol. 2. Notes for guidance on the specification of highway works. Series NG400: Safety fences, safety barriers and pedestrian guiderails*. London: DTp	
		NOTE Shapes 4 and 5 are discussed in detail in PD 6634-3:1999, clause **4**.	Shape 1: 116 km/h: (OK) Shape 2: 80 km/h: (OK) Shape 3: Not tested **TESTS TO BS 6579 and CEN/TC 226 EN 1317-1 and EN 1317-2**	LAKER, I.B. High containment safety barriers. *Transportation Research Circular*. Transportation Research Board (TRB), Washington DC 1988-12-01. No. 341. Crowthorne, Berkshire: TRL, RR75	DTp. *Manual of contract documents for highway works. Vol. 2. Notes for guidance on the specification of highway works. Series NG400: Safety fences, safety barriers and pedestrian guiderails*. London: DTp	
	Tarmac Pre-cast	Highway construction details (HCD): BCB — TRL 1040.45 — BS Spec VCB — TRL 1040.62 — Pre-casts 1989 TVCB-TRL 1040.66 – 1989 HVCB — draft for HCD THVCB-draft for HCD	**MIRA No. for BCB** (speed/angle/mass) A107-51.3/15/16: (OK) A108 64.4/15/0.78: (OK) B109 71.9/15/0.99: (OK) B110 52.5/15/38: (F) **MIRA No. for VCB** C137 72/20/0.78: (OK) C138 71/20/1.5: (OK) D143 70/20/1.5: (OK) D145 49.5/15/16: (F) D147 49.2/15/16: (F) H0003 **MIRA No. for TVCB** F188-50/201.5 looped, high penetration F203 50/20/1.5 bolted: (OK) B114, C118, G210, M0041, M0044, M0046 **MIRA No. for HVCB** G210 to 212, H0002, H213, J0014 **MIRA No. for PHVCB** L0020, L0026	LAKER, I.B. *A review of safety fence and barrier development at TRL 1961-1986.* PTRC Conference 1986. Crowthorne, Berkshire: TRL LAKER, I.B. *The development of a concrete barrier on high speed roads.* Road Safety in Europe, 1986. Gothenburg, Sweden LAKER, I.B. *Flexible and rigid highway safety fences and barriers for private cars*. University of Milan, Italy, 1989 MACDONALD. *The development of concrete barriers in the UK*. Concrete in Highway Structures. Coventry, 1992	DTp. Highways and Traffic Directorate, Departmental Standard: TD 19/2003: *Vehicle restraint systems (safety fences and barriers). Highway construction details*. London: DTp BRITISH STANDARDS BS 6579-7, *Safety fences and barriers for highways — Part 7: Specification for components for untensioned corrugated beam safety fence* BS 6579-8, *Safety fences and barriers for highways — Part 8: Specification. for concrete safety barriers*	

Table 3 — Summary of barrier details — Wire rope safety fences (WRSF)

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL, Crowthorne, Berkshire	BRIDON, Carr Hill, Doncaster	RRL Report LR 98: 1968 Provisional specification for a wire-rope crash barrier	**TESTS NOT TO BS 6579 WRSF with chain link fencing** TESPA clips and U bolt fixings Test Nos. 11 to 21	JEHU, V.J., and I.B. LAKER. *Cable and chain link barriers*. TRRL, 1967 LR105. Patent Bender 1012212. 1965	DEPARTMENT OF THE ENVIRONMENT, Engineering Intelligence Division. March 1974 Technical Memorandum H9/73: *2-Rope safety fence*	BRIFEN plc Simulation Model — BRISIM prepared by Sheffield University
BRIDON, Carr Hill, Doncaster	Darfen	TD 32/89, DTp, Departmental Standard	**Slotted weak post WRSF** Test Nos. 22 to 47 Mini Van, Vanguard, Bedford Truck	JEHU, V.J., and I.B. LAKER. *Wire rope slotted-post barriers*. TRRL, 1967 LR127 Patent Jehu, Pearson 1103873. 1968	DTp. 1990 Technical Document TD 32/89, *4-Rope safety fence*	
		WRSF Drawings WR/01 to WR/13:1990	Speeds: 21 to 64 mile/h Slot depths: 2 in to 6 in	PEARSON, L.C. *Provisional specification for WRSF*. TRRL, 1968 LR96	Committee draft BS 6579-11, *Safety fences and barriers for highways. BRIFEN 4-Rope safety fence Design manual for roads and bridges.* TD 32/83 WRSF	DYNA-3D
		TD 32/93 Update on anchor posts	One and two height cables Static tension: 2 000 to 5 000 lbs	LAKER, I.B. *Flexible and rigid highway safety fences and barriers*. University of Milan, Italy: 1989		
		Highway construction details (HCD) Drawings WR/00 to WR/13: July 1993	Cable length: 100 ft to 5 000 ft Rope heights: 25 in to 30 in 1-Section posts 2- and 3-rope fences	LAKER, I.B., and H. GUTTERIGE. *The development of the British wire rope safety fence*. TRB, Washington, BR2 C89 Jan. 1990	DTp, Highways and Traffic Directorate. Departmental Standard TD 19/2003: *Vehicle restraint systems (safety fences and barriers)*. May 1995 *Manual of contracts for highway works — Vol. 1. Specification for highway works (Series 400) — Safety fences, safety barriers and pedestrian guard rails*. August 1993	
		GENERAL 3- and 4-rope fences Lengths: 100 to 626 mm Z posts: 5 mm and 6 mm Rope height: 400 mm to 635 mm Static tension: 1 364 kg to 3 182 kg Vehicle masses: 726 kg to 1 512 kg Angles: 19° to 30° Impact speeds: 83 km/h to 115.8 km/h No. of tests: >20	**TESTS TO BS 6579 and CEN prEN 1317/1/2 BRIFEN Fences** Test houses: MIRA: E160 to 167 E190, J0903/4 N6015 6016, M6035 WRSF/OBB: H0001 WR/OBB x over: H215 WR/OBB ramp: H216 WR + Gulley: L0028, L0029 WR +Dm Ch.: L0030 WR + Dr. Ch. over: N0011 **TRL Tests** 02FB + 100 mm 04FB − 75 mm LIER (INRETS) France, No.731 VTI, Sweden. No. 7.11, 12.25 TTI, Texas USA Test 405561-2 2 500 kg p-up	LAKER, I.B., and A.W. NAYLOR. *The development and use of a 4-rope safety fence*. Bridon Ropes Ltd. Presented at VTI Sweden 1992. GUTTERIGE, H. and A.R. Stringer. *Development and proving tests of a 4-rope wire rope safety fence*. IRF Conference. Ottowa, Canada, 1994 Computer Simulation HOWARD and JOHNSON, 1990. *Design analysis of a rope barrier*. Sheffield University BATEMAN, 1995: *Investigation into the use of GFRP plastic posts in the BRIFEN System*. Sheffield University	BS 6579-11 *Safety fences for barriers and highways — Part 11: Components for WRSF*	

Table 4 — Summary of barrier details — Tension corrugated beam (TCB)

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL, Crowthorne Berkshire	BRITISH STEEL	TCB IMP, 1-Section SG 1040.02/A TRL: Dec 1966	**TESTS NOT TO BS 6579**	COBURN, T.M. Oct 1949. RN/1242 *A survey of published work on Traffic Guards*. TRL JEHU, V.J. Jan 1964. Safety fences and kerbs. *Traff. Eng & Control*, 1964, **5**(9) 534-540	DEPARTMENT OF THE ENVIRONMENT, Engineering Intelligence Division. March 1974 Technical Memorandum H9/73 DTp. Highways and Traffic Directorate, Bridges Engineering Department, Technical Document TD 19/85: *Safety fences and barriers*, + Amendment No. 1. London: DTp.	CRASH-D Cranfield KRASH NTIS, Springfield USA CVS, NTIS Springfield USA Barrier 7, NTIS Springfield USA
	Hill & Smith	TCB IMP, Z-Section SG 1040.02/B TRL: 1966/67 TCB Metric: 1970/76 SG 1040.02/C TRL	**Tested at TRL** No. 50/76 and 81, 82, 96 Speeds: 42 mile/h to 69 mile/h Angles: 18.5° to 35° Tube release mechanism Shear bolts: 1/4 in to 3/8 in Lengths: 180 ft to 2447 ft Double and single sided posts: 1-Section posts: 2.5 in × 1 in; 3 in × 1.5 in Z-Section posts: 30 mm × 100 mm	MOORE, R.L., and V.J. JEHU. July 1964. Safety fences. *Traff. Eng. & Control* 160-183 MOORE, R.L., and V.J. JEHU. Sept 1964. *Road Safety and the Central Reservation* 7th International study week in Trf. Eng. London JEHU, V.J. Nov 1967. A tensioned-beam crash barrier. *Survey & Municipal Eng.* Vol. Cxxx No. 3935 JEHU, V.J., and C.W. PRISK. Dec 1967. *Research on crash barriers*. OECD Paris	DoE/DTp. June 1985. *Code of practice for routine maintenance*. London: DTp DTp. Highways and Traffic Directorate. Departmental Advice Note TA 45/85 June 1985 *Treatment of gaps in central reserve fence*. London: DTp *Manual of contracts for highway works — Vol. 1. Specification for highway works (Series 400) — Safety fences, safety barriers and pedestrian guard rails*. August 1993	
	Lionweld Kennedy	RM/F DTp Drawings: 1977 Includes tensioning procedure Howard Humphries Drawings: Feb. 90	Wooden posts Spacing 5.25 ft to 10.5 ft Vehicles 2 800 lb to 8 428 lb	PEARSON, L.C. 1968. *Instructions for using RRL post setting rig when erecting TCB barriers*. RRL Report LR 178 MOORE, R.L., and V.J. JEHU. Sept 1968. *Recent developments in barrier design*. 9th International Study Week, Theme 11 MOORE, R.L., and V.J. JEHU. Dec 1968. Recent developments in barrier design. *Traff. Eng. & Control*. OTA Study Week MOORE, R.L., and R.F. NEWBY. April 1969. *A re-assessment of the economic benefits of safety fences*. TRL TN 391	DTp. Highways and Traffic Directorate. Departmental Standard TD 19/2003, May 1995. *Vehicle restraint systems (safety fences and barriers)* BS 6579, *Safety fences and barriers for highways — Part 1: Specification for components for tensioned corrugated beam safety fence on Z posts*. (Includes guidance on vehicle impact performance) BSI Draft 91/12311. Mar. 1991 *Specification for performance*. (This document formed the basis for EN 1317-1 and EN 1317-2)	
		Highway construction details (HCD) 1986/91	**TESTS TO BS 6579 Tested at MIRA under contract to TRL** Standard height fence, plus 100 mm, minus 75 mm. Beam slack −25 mm Double and single sided D149 to 152, D157, E174 to 176 THTCB-L0020	PEARSON, L.C. 1969. *Specification and installation procedure for the RRL TCB barrier*. RRL Report LR 278 LAKER, I.B. 1970. *A post driving technique for the erection of TCB crash barriers*. RRL Report LR 338 MORSE, G., and E.J. MORGAN. 1971. *Highway crash barriers*. IPC Building and Contract Journals LTD. London		

Table 4 — Summary of barrier details — Tension corrugated beam (TCB) *(continued)*

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
		Post extensions, TCB and OBB SG 1040.44.S TRL: Dec 1987 Road surface overlay SG 1040.44.G TRL: 1979/82 No weld terminal: S TRRL SG 1040.00 Knock-off release terminal TRRL SG 1040.000.249 /345: 1966 Post Pulling Rig SG 1040.60 TRL: Jan 1988 EPP/PTE DTp: Feb 1988 Anchor bolt pullout rig SG 1040.53 TRL: Mar 87	Drainage gullies L0031-32, N00010, N00012 DSTCB full height + 1/2 post spacing J0005 and J0006 TCB on OBB posts F205 Emergency cross over ECP D141, D146 TCB/Crash cushion No. F189, F200, F204	JEHU, V.J., and L.C. PEARSON. 1972. *Vehicle impact tests on the TCB and OBB crash barriers*. TRRL Report LR502 JOHNSON, H.D. 1980. *Cross-over accidents on all-purpose dual carriageways*. TRRL SR617 JEHU, V.J., and L.C. PEARSON. 1981. *A steel safety fence with frangible base intermediate posts*. TRRL LR988 LAKER, I.B. 1986. Safety fences and bridge parapets. TRRL papers for the 1986 TRB Annual Meeting, Washington, USA: LAKER, I.B. *Paper 1. High containment safety barriers* MACDONALD, M.D. *Paper 2. Severe impacts with motorway fences* MACDONALD, M.D. *Paper 3. Safety fence post footings* WATTS, G.R. *Paper 4. Safety fence criteria for dual carriageway roads* SADEGHI, M. *Paper 5. Vehicle to safety fence impact studies* MACDONALD, M.D., and I.B. LAKER, 1987. *Revises criteria for TCB post installation testing*. TRRL WP No. 85 SOWERBY, K. 1987. *Safety fence criteria for all-purpose dual carriageway roads*. JMP Consultants Ltd. Contract Report No. 57: TRRL HEATH, P.J. Mar 1988. *Noise barrier, safety barrier and post foundation investigation*. TRRL 1040/R07 LAKER, I.B. 1989. *Flexible and rigid highway safety fences and barriers for private cars*. University of Milan, Italy LAKER, I.B. Feb 1992. *An introduction to safety features safety barriers*. Bridge Parapets and Energy Absorbers. Seminar: Crash protection and roadside design, PTRC. B91		

Table 5 — Summary of barrier details — Open box beam, DHOBB and SHOBB

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL, Crowthorne, Berkshire	British Steel	RM/F DTp Drawings: 1977	**TESTS NOT TO BS 6579** **Tested at TRRL** No. 103 107, 109, 115, 116, 133	JEHU, V.J., and L.C. PEARSON. 1972. *Vehicle impact tests on the TCB and OBB crash barriers*. TRRL Report LR502	DEPARTMENT OF THE ENVIRONMENT, Engineering Intelligence Division. March 1974 Technical Memorandum H9/73	CRASH-D Cranfield
	Hill & Smith	SG 1040.16/B SHOBB: Dec 1985 SG 1040.18/B DHOBB: Nov 1987	Speeds — 56 mile/h to 63 mile/h Vehicles — 1.46 t to 5.1 t Lengths — 37 m to 105 m Double height (DHOBB) Single height (SHOBB)	LAKER, I.B. 1986. *Safety fences and bridge parapets*. TRRL papers for the 1986 TRB Annual Meeting HEATH, P.J. July 1966. *OBB safety fence joint tension tests*. TRRL SG 1040/R04	DTp. Highways and Traffic Directorate, Bridges Engineering Department, Technical Document TD 19/85: *Safety fences and barriers*, + Amendment No. 1. London: DTp	KRASH NTIS Springfield USA
	Lionweld Kennedy	SG 1040.44 Post extension: Dec 1987 EPP Drawings: Feb 1988	Z-section posts **TESTS TO BS 6579** **Tested at MIRA under contract to TRL** DHDSOBB	STRANGER, H. Nov 1985. (Test house) *Testing of (OBB) hexagonal mounting brackets*. Report 1848/85/1	DoE/DTp. June 1985. *Code of practice for routine maintenance*. London: DTp	
		Howard Humphries Drawings: Feb 1990	A021, A022, A100-A103, A105, A106 B112, B113, B116, B117, C122	HEATH, P. July 1966. *OBB safety fence load extension tests*. TRRL 1040/R06	DTp. Highways and Traffic Directorate. Departmental Advice Note TA 45/85 June 1985 *Treatment of gaps in central reserve fence*. London: DTp	CVS, NTIS Springfield USA
		Highway construction details (HCD) 1986/91	THDSOBB C123, C125 B116 Abnormal load DHDSOBB transition F201 Noise barrier + OBB C127 to 129 E177-SSOBB ½ spacing E178 SSOBB Standard (wrong bolts) E179-SSOBB Standard E180 SSOBB + 100 mm E181-DSOBB spaced for lighting columns E182-DSOBB −75 mm F901 DHDSOBB F205 TCB + OBB M0053 curved OBB P0002-OBB/TCB connection P0003-OBB/DHOBB connection	HEATH, P. Nov. 1986. *Load deflection characteristics of DHDSOBB safety barrier brackets and Z-post stand offs*. TRRL 1040/R06 SOWERBY, K. 1987. *Safety fence for all-purpose roads*. TRL Consultant Report No. 57. JMP Consultants (NOTE Also applies to TCB and other barriers.) MACDONALD, M.D. 1989. *Three car impact tests on the combined OBB safety fence and timber noise barrier*. TRRL, RR119 LAKER, I.B. 1989. *Flexible and rigid safety fences and barriers for private cars*. University of Milan, Italy	*Manual of contracts for highway works — Vol. 1. Specification for highway works (Series 400) — Safety fences, safety barriers and pedestrian guard rails*. August 1993 DTp. Highways and Traffic Directorate. Departmental Standard TD 19/2003, May 1995. *Vehicle restraint systems (safety fences and barriers)* BS 6579-5, *Safety fences and barriers for highways — Part 5: Specification for open box beam safety fence (single height)* BS 6579-6, *Safety fences and barriers for highways — Part 6: Specification for components for open box beam safety fence (double height)*	

Table 6 — Summary of barrier details — Transitions and connections (TRNCX)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL, Crowthorne, Berkshire		TCB/0BB	MIRA	LAKER, I.B. 1989. *A high containment bridge parapet with transition to a safety fence.* TRB Washington	DTp BE5 4th Revision. London: DTp	
		OBB/parapets WRSF/OBB WRSF/TCB Some in Highway construction details (HCD)	**WRSF Transitions** H0001: WRSF/OBB H215: WRSF/OBB H216: WRSF/OBB ramp **HC Parapet transitions** D155 P6 steel P6/OBB E159-P6 concrete transitition F202-P6 concrete P6/OBB L0021-steel: P1/P6 L0022 steel: P6/OBB L0023-P1st/P6 concrete L0024-OBB/ P6 concrete M0048-OBB/P6 **Connections** N0019-OBB: SH/DH N0020-OBB/VCB P0002-OBB/VCB P0003-OBB/DHOBB **TRL tests** 01FB-BS C OBB/P1 03FB-Aluminium OBB/P1	**TRL Consultant's report** BABTIE GROUP *Design, supervision build, and assessment of transitions between high containment parapets and normal containment parapets.* BST010842/MJM: Feb 1996 NOTE Michel Consultants are to report soon on the following transitions: OBB/P1 steel OBB/P1 aluminium	DTp. Highways and Traffice Directorate. Departmental Standard TD 19/2003, May 1995. *Vehicle restraint systems (safety fences and barriers)*	
			British Steel tests 100 mm × 100 mm: Feb 1976 Bridge parapet/RHS fence 100 mm × 200 mm: Aug 1975 Bridge parapet/RHS fence	Feb 1976. *Tests on an RHS bridge parapet/4 × 4 safety fence joint for the DoE*. Res. Report CE 75/136 Aug 1975. *Tests on an RHS bridge parapet/8 × 4 safety fence joint for the Midland RCU of the DoE*. Res. Report CE 75/43		

Table 7 — Summary of barrier details — Barrier terminals (TERM)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
TRL, Crowthorne, Berkshire		TRL Development Drawings	**TESTS AT MIRA** 1986: C130 — TCB ramp C131 — TCB ramp C132 — TCB latch C133 — TCB latch C134 — TCB latch H216 — WR/OBB ramp 1991	LAKER, I.B. Feb 1992. PTRC Seminar — *Crash protection and roadside design: An introduction to roadside safety features — Safety barriers, bridge parapets and energy absorbers* LAKER, I.B. June 1992. Technical Report: *A review of end-treatment to safety fences*. Ref: BR4.629. Presented to CEN/TC 226/WG1	prEN 1317, *Road restraint systems — Part 4: Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers*	
			WRSF Intermediate anchor TRRL Test No. 39	JEHU, V.J., and I.B. LAKER, 1967. LR 27 *The wire rope slotted post crash barrier*	JEHU and PEARSON Patent No. 1103873, Feb 1968	
		Highway construction details (HCD)	Concrete ramped end Untested in UK Fish plate and bull nose ends Untested in UK			

Table 8 — Summary of barrier details — Rectangular hollow section (RHS)

Designers	Manufacturers	Drawings	Barrier factors	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
British Steel	British Steel	Highway construction details (HCD), Bridges Engineering, DTp	**TESTED BY BRITISH STEEL** (at Harringworth, Northamptonshire)	Some references in TRL files 304/365/17 and 474/473/04 to British Steel test — CE 73/121 (3 tests in total) 1974 Harringworth (design, drawings, expansion joints; tensioning)	DTp. Highways and Traffic Directorate, Bridges Engineering Department, Technical Document TD 19/85: *Safety fences and barriers*, + Amendment No. 1. London: DTp	None
	Varley & Gulliver	HPP Series — British Steel Presently being updated by Varley & Gulliver	Two versions with the following rail sizes:			
			100 mm × 100 mm: Oct 1977 Report No. CE 73/47/1/A Test Nos. 1-4, 6, — 197/72 Approved for hardened reserves	(NOTE For some installations RHS can be fitted to sides of posts.)	*Manual of contracts for highway works — Vol. 1. Specification for highway works (Series 400) — Safety fences, safety barriers and pedestrian guard rails*. August 1993	
			100 × 200 mm: April 1974 Report No. CE/73/121 Test No. 4a, 5: 1971 Test No.1: 1974 Approved for unhardened reserves		DTp. Highways and Traffice Directorate. Departmental Standard TD 19/2003, May 1995. *Vehicle restraint systems (safety fences and barriers)*	
			Tests at MIRA M0054: curved (1994) P0001: 6 m curve (1996)		BS 6579-3, *Safety fences and barriers for highways — Part 3: Specification for components for tensioned rectangular hollow section beam (100 mm × 100 mm) safety fence*	
			Tests in 1995			
			Revalidation tests N0015: 200 × 100-Fiesta N0016 200 × 100-Rover N0017 100 × 100-Fiesta N0018 100 × 100-Rover			

Table 9 — Summary of barrier details — Combined parapets (PCOMB)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
Maunsell		BS 6779-3: 1994	**Tests at TRRL**	JEHU, V.J., and I.B. LAKER, 1972. LR485 *Vehicle impact tests on reinforced concrete bridge parapets*	DTp. Technical Memorandum (Bridges) No. BE5, 1982 *Technical Memorandum on the design of highway bridge parapets*. 4th Revision	
Midlands Link	British Aluminium		**Maunsell P1 Parapet** (normal containment)	Scott Wilson & Kirkpatrick Contract Report, TRL	BS 5400-1, *Steel, concrete and composite bridges — Part 1: General statement*	
Scott Wilson & Kirkpatrick under TRL contract	British Steel		Test 91 — Ensign 70 mile/h Test 92 — Coach 50 mile/h Test 94 — Vanguard 50 mile/h Test 97 — Z brackets 55 mile/h Test 98 — Onazote Test 99 — Polystyrene Test 100 — Polystyrene with plate Test 101 — Hex brackets Test 110 — Hex bracket — coach Test 111 — Zephyr 70 mile/h Test 112 — Stiff beam — coach Test 113 — High rail — coach Test 114 — Plastic padding **TESTS AT MIRA** **Midlands Link Parapet** (normal containment) B111: 1.5:20:70 B114: 0.78:20:70.6 B115: 16:20:51.3 **High containment** Steel: G207, G208 Aluminium: G209		DTp Scottish Office: BD 52/93, 1993 *The design of highway bridge parapets* BS 6779-3, *Highway parapets for bridges and other structures — Part 3: Specification for vehicle containment parapets of combined metal and concrete construction*	

Table 10 — Summary of barrier details — Metal parapets (PMET): steel and aluminium

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
LOW AND NORMAL CONTAINMENT Alcan Extrusions	Alcan Extrusions, Lillyhall, Workington	**Aluminium** See BS 6779-1, Annex F (Low and normal containment)	**LOW CONTAINMENT** **Aluminium vertical infill** (See LR281: 1969) TRL Test 83: 74 k/h/20/1.36: failed TRL Test 86: 3-rail 81.4 k/h/20/1.36: high pen	JEHU, LAKER and BLAMEY, 1967. *Bridge parapet tests carried out in collaboration with British Aluminium Company.* RRL LR 281 BLAMEY, C. 1972. *Bridge parapet tests carried out in collaboration with British Steel Corporation.* TRRL LR492 JEHU, V.J. *Vehicle impact tests on frangible and yielding post designs of bridge parapets.* LR 495 JEHU, V.J., and PEARSON. 1979. *Containment of heavy vehicles by bridge parapets of post and rail type.* TRRL, LR 884 COURTNADGE, J. 1980. *Feasibility study for the dynamic testing of high containment parapets.* TRRL 1040/R03 COURTNADGE, J. 1980. *Stress calculations for P % /HC high containment parapets.* TRRL 1040/R02 W S ATKINS and Partners for TRRL (Project Officer I B Laker), 1989. *P6 High containment steel parapet.* Contr. Report 121; +K23 LAKER, I.B. 1989. *A high containment bridge parapet with transition to a safety fence.* TRB 68th Annual Meeting, Washington DC 1989 BRITISH STEEL CORPORATION, Research Report, Nov 1974 CE 74/49 *Vehicle impact test on a P5 Bridge parapet/noise barrier for the Department of the Environment* BRITISH STEEL CORPORATION, Research Report, July 1975 CE 75/59 *Vehicle impact test on test No. 2 on a P5 bridge parapet/noise barrier for the Department of the Environment* RAE. Materials and Structures Department, RAE: Farnborough. Report No. RAE (F) MS/14/1/E 1704 *Consultation on aluminium parapets for BE Division, DTp*	DTp. Technical Memorandum (Bridges) No. BE5, 1982 *Technical Memorandum on the design of highway bridge parapets.* 4th Revision DTp Scottish Office: BD 52/93, 1993 *The design of highway bridge parapets* DTp. Highways and Traffice Directorate. Departmental Standard TD 19/2003, May 1995. *Vehicle restraint systems (safety fences and barriers)* BS 5400, *Steel, concrete and composite bridges* BS 6779-1, *Highway parapets for bridges and other structures — Part 1: Specification for vehicle containment parapets of metal construction*	Cranfield Crash-D Krash
British Steel Grundy/Phoenix	British Steel, Tubes & Pipes, P.O. Box 101, Corby, Northamptonshire	**Steel** See BS 6779-1, Appendix G (Low, normal and high containment) **Steel and aluminium** LR495 — Yielding and frangible posts Yielding: SG 1040.19/A SG 1040 20/A Frangible: SG 1040 21/A	**Steel vertical infill** (See LR492: 1972) TRL Test 93: 60 k/h/20/1.55: overturned TRL Test 95: 70 k/h/21.5/1.38: overturned TRL Test 105: 3-rail/mesh 82.6 k/h/19/1.47: OK MIRA test-N0029			
Lindley HDA **High containment** DTp; Bridges Engineering Division TRRL, Crowthorne, Berkshire	Varley & Gulliver	**Further tests on normal parapets in aluminium** **MIRA test numbers** J0010, J0012, K0015 to K0017, K0908, K0909, K0916, L0037 to L0039, L6002, to L6014, M0049, M0056, M0057 N0014, N0023, N0028 **Revalidation tests** K0019-4.12.92 M6032-21.7.96 **TRL tests on steel parapets** 03FB **Further tests on steel parapets** Stewart & Lloyds Tests 3 to 7 1962 Tests 1 to 3 1964 Tests 1 to 2 1974/75	**NORMAL CONTAINMENT** **Aluminium** (See LR281: 1967) TRL Test 84: 114 k/h/20/1.36: OK TRL Test 85: 93 k/h/20/1.36: high exit TRL Test 88: 113 k/h/23/1.36: high pen TRL Test 90: 111 k/h/23/1.36: OK (See LR492: 1972) TRL Test 108, 130-132 Test 104-111/18.5/1.47: OK **Steel** **MIRA tests** S44 1978; K0910 1992 L0027 1993; M043 1994 M0052 1994; N0013 1995 N0029 1995 **HIGH CONTAINMENT** **Steel 1987** Test at MIRA for TRRL D139, D140, D142, D144, D148, E173 With transition: D155, E159			

Table 11 — Summary of barrier details — Concrete parapets (PCONC)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
Atkins & Partners Manders Rakes & Marshall		BS 6779-2, *Highway parapets for bridges and other structures — Part 2: Specification for vehicle containment parapets of metal construction*	**TESTS AT MIRA** **Early parapet tests** P74, 75 R51, 66, 67, 74, 79, 99 R51, 66, 67, 74, 79, 97, 99, 111, W46-48 **In-situ P6 parapet** (high containment) C118-122, C124 **Pre-cast P6 parapet** (high containment) E183, E185-187, J0011	JEHU, V.J., and L.C. PEARSON. 1977. LR 801 *Impacts of European cars and a passenger coach against shaped concrete barriers* MANDER, RAKES and MARSHALL. 1978. SWRCU *Design studies for high containment bridge parapets in concrete* ATKINS, W.S. 1985. *P6 High containment in-situ reinforced concrete parapet*. Contractors Report — Final, TRL MRM PARTNERSHIP. 1967. *P6 High containment parapet — precast*. Contractors Report — Final. TRL LAKER, I.B. 1988. *The development of a concrete barrier for use on high speed roads*. International Conference on Road Safety, Gothenburg, Sweden 1988	DTp. Technical Memorandum (Bridges) No. BE5, 1982 *Technical Memorandum on the design of highway bridge parapets*. 4th Revision BS 5400-1, *Steel, concrete and composite bridges — Part 1: General statement* DTp Scottish Office: BD 52/93, 1993 *The design of highway bridge parapets* BS 6779-2, *Highway parapets for bridges and other structures — Specification for vehicle containment parapets of concrete construction*	

Table 12 — Summary of barrier details — Masonry vehicle parapets (PMAS)

Designers	Manufacturers	Drawings	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
Assessment by County Surveyors' Society			**MIRA tests** K0912 British Rail — P6, 1992	COUNTY SURVEYORS' SOCIETY. *The assessment and design of unreinforced masonry vehicle parapets*. County Surveyors' Society Guidance Note, 1995 CSS Bridges Group Report No. Eng/1-95 ISBN 0 9022289 19 Those involved: County Surveyors' Society, Lancashire CC, Parkman, Liverpool University Video of vehicle impact tests and work of Liverpool University is available from Lancashire CC Tel: 01772 264584; Fax: 01772 582537 PC based software is available from Parkman Tel: 0161 7360442; Fax: 0161 7360449	BS 6779-4, *Highway parapets for bridges and other structures — Part 4: Specification for parapets of reinforced and unreinforced masonry construction*	Liverpool University

Table 13 — Summary of barrier details — Arrester beds, bushes, kerbs, earth walls, crash cushions, wood and sand barriers (REM)

Restraint system	Manufacturers	Barrier factors tests/performance/etc.	Technical papers (United Kingdom only)	British Standards and DTp (Highway Agency) notes	Computer models
Rose bushes		**TESTS AT** TRL Langley	LAKER, I.B. *Vehicle impact tests on a hedge of Rosa multiflora japonica*. 1966 LR No. 3		
Arrester beds		**TESTS AT** Crowthorne and RAE, Farnborough	LAKER, I.B. *Vehicle deceleration in beds of loose gravel*. 1966 LR 19	DTp, Advice Note TA 57/87	
		TESTS AT Crowthorne and Farnborough Included LYTAG, at TRL	JEHU, V.J., and I.B. LAKER. *Vehicle decelerations in beds of natural and artificial gravels*. 1969 LR 254		
	High Wycombe Borough Council Christiani and Nielson Ltd.	**TESTS AT** Booker Airfield, High Wycombe	LAKER, I.B. *Tests to determine the design of roadside soft arrister beds*. 1971 LR 376		
Safety kerbs	TRIF kerb, Belgium	**TEST AT** TRL	JEHU, V.J. 1964. Safety fences and kerbs. *Traffic Engineering and Control*, 1964 **5**(9), 534-540		
Earth walls		**TESTS AT MIRA** Tests W30 and W31	PEARSON, L.C. *Earth noise barriers — Vehicle impact tests*. TRL Working Paper, Jan 1981		
IBC barrier	International Barrier Co.	**TESTS AT MIRA** Tests X71, X80082, A104	EMERSON, *Results of a dynamic test of an IBC roadside safety barrier*. MIRA report, 1982 K/43601/1.		
			MACDONALD, M.D., and EMERSON. *Vehicle impact tests on the IBC Mk V11 sand filled barrier* 1989 RR211		
Crash cushions		**TESTS AT MIRA** D153, D154, D156, E158, E170 to E172, E184, F189 F200, F204, J0008, J0009 M0059, M0062	MACDONALD, M.D. *A progress report on the development of the TRRL crash cushion* 1989 VS/89/8	prEN 1317-3, *Road restraint systems — Part 3: Crash cushions — Performance classes, impact test acceptance criteria and test methods*	
Truck mounted attenuators (TMA)		**TESTS AT MIRA** M0051, N0025 to N0027			
Wooden safety barriers	Devon CC Oakford Bridge				
Bull-nose barrier	TRL Drawing OBB 00/1 July 94	**TESTS AT MIRA** M0053	MIRA report No. 430053		

Table 14 — Summary of Barrier details — Computer models (MODL)

Designer or user	Computer model identification	Technical papers (United Kingdom only)
Cranfield under contract to TRL	CRASH-D — Finite element model KRASH Model car with elastic springs representing crush (These models are an interactive pair)	SADEGHI. *Vehicle to barrier impact studies*. Contract Report CIC No. 123 to TRL, Aug 1985 SADEGHI. *Vehicle to safety Barrier Impact Studies — Phase 2*. Contract Report CIC to TRL, Aug 1987 SADEGHI. *The effect of halving the post-spacing of a normal containment parapet*. Contract Report CIC to TRL, Oct 1988
	CVS — Simulates movement of occupant in crash car	SADEGHI. Vehicle to safety fence impact studies — Paper 5. *In*: LAKER, ed. *Safety fences and bridge parapets. TRRL Papers for 1966 TRB Annual Meeting RR75*: TRL
BRIDON plc, Doncaster	Bridon impact simulation model (BRISIM) (Vehicle impact into WRSF no car crushing)	HOWARD and JOHNSON. *Design analysis of a rope barrier*. Sheffield University Nov 1990
I.B. Laker (under contract to TRL)	Program THIVPHD Calculates the impact velocity and deceleration of a free moving head in a crashing car Includes ASI, OIV, RDA	BATEMAN. *Investigation of the use of GFRP plastic posts in the BRIFEN system*. Sheffield University June 1995 LAKER, I.B. Contract Reports:
Calspan (USA) (1976)	Programs known to have been used in the UK:	Interim No. 1 — *"THIVPHD" — A computer program for the calculation of THIV and PHD* TRL 1.A94, Oct 1994
University of California (USA 1973)	HVOSM — 3D lump mass rigid vehicle	Interim No. 2 — *A sensitive analysis on THIV and PHD: Errors in yaw* motion. TRL 1.B94, Nov 1994
	Barrier V11 — 2D finite element with flexible barrier	Interim No. 3 — *The effect on THIV and PHD of an added error on the yaw angle*. TRL 1.196, Dec 1994
NTRI (USA 1976)		Interim No. 4 — *A note on the generation of analytic data to validate THIVPHD*. TRL1.B94, Jan 1996
Calspan (USA) (1976)	GUARD — 3D FE Vehicle/barrier with bumper modelling	Interim No. 5 — *The effect of displacing accelerometers a distance from the CG*. TRL1.296, Feb 1996
		Interim No. 6 — *The validation of computer program THIVPHD*. TRL1.396, Mar 1996
	CVS — Occupant response	Interim No. 7 — *THIV and PHD analysis of four impact tests*. TRL3.396, Mar 1996
	CRASH — 2D vehicle impact model	Interim No. 8 — *Extension of complete program THIVPHD to include the severity indices THIV (ongular velocity), ASI, OIV, RDA — Comparison of indices and some effects of data filtering*. TRL1.596, May 1996
	DYNA3D — Details FE model	
		Interim No. 10 — *Instrumentation chain for THIV/PHD data collection*. TRL1.98B, Jan. 1996

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