

Vehicle restraint systems —

Part 1: Fundamentals — Database

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- Aluminium Federation
- Association of Consulting Engineers
- Association of County Councils
- Association of Safety Fencing Contractors
- British Cement Association
- British In-situ Concrete Paving Association
- British Precast Concrete Federation Ltd.
- County Surveyors' Society
- Department of the Environment, Transport and the Regions (Highways Agency)
- Institution of Civil Engineers
- Motor Industry Research Association
- National Fencing Training Authority
- Railtrack
- Royal Society for the Prevention of Accidents
- Transport Research Laboratory
- UK Steel Association

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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 Subcommittee 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 apparent. 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, sometimes 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 exists 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 Maunsell 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 SVOV 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

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