A40 Western Avenue Vehicle Restraint System Serviceability Inspection

Engineering Inspection Report on the serviceability of the vehicle restraint systems on the A40 between Target Roundabout and Greenford Roundabout

Version	Prepared By	Checked By	Date
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Overview

Transport for London (TfL) is the Highways Authority (HA) for all Greater London Authority (GLA) roads in London. This road network; referred to as Transport for London Road Network (TLRN); is circa 580km in length making up for only 5% of roads in London. Due to its strategic importance this network; albeit small; carries circa 30% of all vehicular journeys made in London.

The outer London part of the TLRN is mainly made up of dual carriageways with speeds of 40mph and more. Due to the nature of these roads a number of vehicle restraint systems (VRS) have been installed to protect errant vehicles from leaving the carriageway. The total length of VRS on the TLRN is of circa 430km.

This report focuses on the VRS on the A40 Western Avenue between Target Roundabout and Greenford Roundabout with special interest given to the serviceability of the VRS on the central reservation.

Background

All vehicle restraint systems should comply with BS EN 1317. BS EN 1317 consists of the following parts:

- EN 1317-1, Road restraint systems – Part 1: Terminology and general criteria for test methods;

- EN 1317-2, Road restraint systems – Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets;

- EN 1317-3, Road restraint systems – Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions;

- ENV 1317-4, Road restraint systems — Part 4: Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers;

- prEN 1317-4, Road restraint systems – Part 4: Performance classes, impact test acceptance criteria and test methods for transitions of safety barriers (under preparation: this document will supersede ENV 1317-4:2001 for the clauses concerning transitions);

- EN 1317-5, Road restraint systems –Part 5: Product requirements and evaluation of conformity for vehicle restraint systems;

- prEN 1317-6, Road restraint systems – Pedestrian restraint systems — Part 6: Pedestrian Parapet (under preparation);

- prEN 1317-7, Road restraint systems – Part 7: Performance classes, impact test acceptance criteria and test methods for terminals of safety barriers (under preparation: this document will supersede ENV 1317-4:2001 for the clauses concerning terminals);

- prEN 1317-8, Road restraint systems – Part 8: Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers (under preparation).

Definitions

It will be necessary for the reader to understand some definitions concerning VRS in order to better understand this report:

Set-back

The set-back is the lateral distance between the traffic face of a safety barrier and as appropriate:

1. Nearside: the back of the nearside hardstrip or hardshoulder;
2. Nearside: the kerb face for roads without a nearside hardstrip or hardshoulder;
3. Offside: the trafficked edge of the edge line or the kerb face where there is no edge line.

Containment Class

This is the level of containment for a vehicle restraint system for an errant vehicle. This will range from normal containment for light traffic, to high containment, designed for heavy traffic with a higher percentage of HGVs. The containment levels of safety barriers including vehicle parapets shall conform to the requirements of Table 2 of BS EN 1317-2 2010 when tested in accordance with the vehicle impact test criteria defined in Table 1 of the same British Standard.

Working Width

Figure 1 - Dynamic Deflection (D) and Working Width (W) sketch from DMRB, TD 19/06, Figure 1-1

Working Width (W) in this Standard is based on the BS EN 1317-2:2010 definition. The working width is the maximum lateral distance between any part of the barrier on the undeformed traffic side and the maximum dynamic position of any part of the barrier. If the vehicle body deforms around the road vehicle restraint system so that the latter cannot be used for the purpose of measuring the working width, the maximum lateral position of any part of the vehicle shall be taken as an alternative.

This definition assumes:

W = width of the restraint system + its maximum dynamic lateral deflection + vehicle intrusion beyond the restraint system (also known as overhang).

Available working width is sometimes restricted by street furniture which may not be possible to relocate.

Classes of working width and associated dimensions are found in the following table:

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Table 1 - Levels of Working Width from BS EN 1317-2:2010

Minimum “Full Height” Lengths of VRS

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Table 2 - Minimum "full height" lengths of safety barrier from DMRB, TD 19/06, Table 3-1

Generally, the installation and maintenance of barrier is expensive and therefore must only be installed where it is considered necessary.

EN 1317 list of compliant VRS

Highways England has published an EN 1317 Compliant Road Restraint Systems list to provide a list of road restraint products that have been put through rigorous testing and are available for use on the Highways England Trunk Road Network. TfL uses this published literature for compliance assessment.

The road restraint products in the list are divided into the following categories:

- Safety Barriers
- Temporary Safety Barriers
- Parapets
- Terminals
- Vehicle Attenuators
- Transitions
- Crash Cushions
- Miscellaneous

Each category states what standards the products have been tested against, and specifies what Containment Performance Class and Working Width Class applies to each product.

This list can be found at:

http://www.standardsforhighways.co.uk/ha/standards/tech_info/en_1317_compliance.htm

Non-Proprietary Safety Barrier Systems

Since the introduction of BS EN 1317, non-proprietary safety Barrier systems (NPSBS) have been withdrawn from use and literature around said systems can only be used for reference purposes, maintenance, inspections and minor maintenance replacements works, and repair for accident damage.

Most of the VRS on the TLRN is NPSBS. Therefore this section is of the utmost importance when assessing existing assets on the TLRN.

The non-rigid (steel) systems covered under NPSBS are:

- Single Sided Open Box Beam Safety Barrier (SSOBB) with posts at 1.2m centres
- Single Sided Open Box Beam Safety Barrier (SSOBB) with posts at 2.4m centres
- Double Sided Open Box Beam Safety Barrier (DSOBB) with posts at 1.2m centres

- Double Sided Open Box Beam Safety Barrier (DSOBB) with posts at 2.4m centres
- Single Sided Tensioned Corrugated Beam Safety Barrier (SSTCB) with posts at 3.2m centres
- Double Sided Tensioned Corrugated Beam Safety Barrier (DSTCB) with posts at 3.2m centres
- Double Rail Open Box Beam Safety Barrier (DROBB)

The Containment Class of all the above systems is N2 with the exception of DROBB which is H1.

The working width of each system is set in Table 3 below:

System Name	Working Width
SSOBB @ 1.2m centres	W4
SSOBB @ 2.4m centres	W5
DSOBB @ 1.2m centres	W4
DSOBB @ 2.4m centres	W5
SSTCB @ 3.2m centres	W6
DSTCB @ 3.2m centres	W6
DROBB	W4

Table 3 – Working Width of non-rigid NPSBS

Inspection

An inspection of the VRS on the A40 Western Avenue between Target Roundabout and Greenford Roundabout was carried out on the 13th of December, 2017 at 11.00pm. The Traffic Management in place was a bi-directional lane 3 closure giving safe access to the central reservation where the inspection was carried out. The inspection was completed at 2.00am.

The tools used to carry out the inspection were:

1. Measuring tape – used to measure set-backs, mounting heights and working widths
2. Hammer – used to assess extent of corrosion by tapping and hammering at various locations along the asset

VRS situated on the near-sides (left hand side in the direction of travel) were not inspected.

General Observations

The VRS on the central reservation along this road is made up of the following types:

1. Between Target Roundabout and the Dunelm Mill Superstore the VRS is a DSOBB with predominant post spacing at 2.4m centres. The approximate length of DSOBB from the top of the Target Underpass to Dunelm Mill Superstore is 1000m.

2. Between Dunelm Mill Superstore and Greenford Roundabout the VRS is a SSOBB facing each direction with predominant post spacing at 2.4m centres. The approximate length of SSOBB from Dunelm Mill to Greenford Roundabout where it changes back to DSOBB is 800m.

Compliance with DMRB TD19/06

Both systems are considered to have a containment class of N2 and a working width of W5. Both systems exceed the allowable deflection currently available.

In the section of DSOBB the working width of the system is expected not to exceed 1.7m but to be larger than 1.3m. The central reservation width is approximately 1.8m when measured with the available working width (with the VRS being situated at the centre of the 1.8m central reservation) being approximately 0.75m. The system does not meet the requirements as set in TD19/06.

The SSOBB sections are expected to deflect by more than 1.3m and for the deflection to be less than 1.7m. The current spacing between the 2 systems is of approximately 1.2m and therefore the systems would hit the back of each other under deflection. This section also does not meet the design requirements as set in TD19/06 with regards to the available working width.

Both systems had sufficient set-backs (with some relaxations) and an optimum mounting height of approximately 610mm

Condition

The condition of the VRS on the A40 was assessed visually for:

1. Accident damage – errant vehicle collisions that have resulted in damage to the asset and that has not been repaired.

2. Missing and non-compliant components – missing bolts, posts, beams and other VRS components

3. Corrosion damage – damage to the inner parts of the beams, the fixing plates, and the posts

Accident Damage

It was noted that through the walk there were 10 instances of accident damage that had not been repaired. The accidents damage varied in severity but it has been noted that:

1. Long sections; typically 20-30m; of beam is no longer supported by the post (as the post to beam bolts have sheared) at various accident locations

2. The beam is no longer aligned and is located towards the edge of carriageway in the area of DSOBB or closer to the back of the opposite VRS in the areas of SSOBB.

3. The make safe action in LoHAC for damaged VRS seems to require the placement of cones in front of the damaged section. This does not make the asset safe. It just highlights that the asset is no longer functional.

The extent of damage by errant vehicle collisions on this section of VRS is quite significant and proportionally makes up approximately 10% of the total length surveyed. Most of the posts in the area are driven posts (hammered into ground) and it is not feasible to re-drive in the same locations. Therefore amendments to post locations or the introduction of socket foundations would be required in order to repair these sections.

Missing and non-compliant components

The systems currently in place along the site were riddled with component non-compliances. Wherever there was accident damage there were a number of beams not attached to the posts in areas on either side of the accident damage. Missing bolts and missing connector plates were the two most prevalent defects.

A number of beams had adjustable height posts (height adjuster sleeved onto Z-posts) to ensure that the mounting height of the VRS is to specification. The issue is that some of the posts were really short and the height adjusters were not fastened to the posts as per the system's original specification. This would result in the system behaviour being different to the "as tested" position.

Corrosion Damage

Corrosion damage is extensive and is visible all along the site. The stages of corrosion vary between the DSOBB and the SSOBB section.

The corrosion along the DSOBB is severe. The corrosion can be seen in the form of major pitting of the beam, fixing plates and posts resulting in exfoliation of the metal grain boundaries.

Hammer tapping was used to assess delamination corrosion. Albeit not complying with industry practice with regards to the size of hammer and the tapping distance, the test is very indicative and exposes major corrosion. With light tapping, the fixing plates and beams exfoliated severely leaving at times less than 2mm of the original 5mm thickness on the steel.

Photo 1 – Original fixing plate thickness – 5mm

Photo 2 – Reduction in fixing plate thickness – 2mm

The corrosion on the posts is so extensive that mild hammer tapping on some of the posts resulted in perforation.

Photo 3 – Corrosion on posts

Photo 4 – Perforation of post with mild hammer tapping

The DSOBB is in such an advanced stage of corrosion that there were already sections where:

1. the post had split in two along the horizontal plane

2. the beam had exfoliated relatively thick pieces of steel; in the region of 3-4mm thick; leaving approximately 1-2mm of material. Some of these exfoliates were more than 30cm in length

3. bolts that had broken off due to the extensive corrosion around the fixing plates

The SSOBB section show signs of corrosion but not to the extent of the DSOBB. The SSOBB is in soft ground and that has helped with the removal of salts and water from the areas around the posts. Where the fixing plates have retained water there is the corrosion seen in the DSOBB sections but this is less prominent and less wide spread than in the DSOBB sections.

In conclusion the section of DSOBB is at such an advanced stage of corrosion that it is reasonable to assume that its strength and its ability to withstand impact have been severely reduced. It is therefore deemed not fit for purpose.

Photo 5 – Beam Inner Face Exfoliation

Conclusion

The site inspection has identified a number of defects with the VRS on the A40 Western Avenue between Target and Greenford Roundabouts.

The defects vary in severity with corrosion, accident damage and non-compliant or missing components being the three most prevalent defects.

The cumulative effects of all defects found on site lead to the assumption that the VRS currently in place on the A40 will not perform as intended when protecting an errant vehicle from entering the opposing carriageway.

It is recommended that the VRS at said location is replaced as it is deemed to be in disrepair

It is recommended that the “make safe” activity for VRS in TfL’s contracts is amended to include fixing the damaged VRS rather than to just place cones around the affected area as this is not deemed to make any safety improvements to the affected asset.

Annex A: Potential Mitigation Measures

Note: This section does not form part of the factual report and is here to initiate some “thinking” into what other mitigation measures can be put in place if there isn’t the budget to replace the asset as recommended in this report.

Temporary barriers

The installation of temporary vehicle restraint systems such as Temporary Vertical Concrete Barriers (TVCB) along the route would result in a risk reduction. Temporary systems can provide a range of containments and working widths to suit. If this option is taken forward a value engineering exercise could be undertaken to assess cost versus risk reduction for a number of systems available in the market.

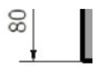

Figure 2 – Typical Temporary Vertical Concrete Barrier

Speed Reduction

High speed is the primary driver for the installation of vehicle restraint systems. With increasing speed the risk of an accident happening and the associated consequences (especially in terms of Killed and Seriously Injured - KSI) tend to increase.

A reduction in speed limit would significantly reduce these risks. Below is an attempt to mathematically quantify benefits of reducing speed when having an asset that does not perform to the required standard.

The tests shown in Table 1 of EN 1317-2 (shown below) dictate the impact speed, angle of impact, total mass and type of vehicle to be used in the test.

Table 1 — Vehicle impact test descriptions

Test	Impact speed km/h	Impact angle °	Total mass kg	Type of vehicle
TB 11	100	20	900	Car
TB 21	80	8	1 300	Car
TB 22	80	15	1 300	Car
TB 31	80	20	1 500	Car
TB 32	110	20	1 500	Car
TB 41	70	8	10 000	Rigid HGV
TB 42	70	15	10 000	Rigid HGV
TB 51	70	20	13 000	Bus
TB 61	80	20	16 000	Rigid HGV
TB 71	65	20	30 000	Rigid HGV
TB 81	65	20	38 000	Articulated HGV

Table 4 – Vehicle Impact Tests Descriptions

Table 2 of EN1317-2 (shown below) indicates which of the above tests must be used to quantify whether the system is suitable for a certain containment class.

One way to reduce risk is to drop the classification of the containment available on site from N2 to N1. By doing so the system currently in place on the A40 no longer requires passing TB32 test – 1500kg Car, 20^{o} impact angle and 110km/h (68.35mph) and would only need to meet TB31 criteria – 1500kg Car, 20^{o} impact angle and 80km/h (50mph).

In essence the same system would have different working widths at different containment levels. A system that would have a working width of W3 at N2 test could easily have a W1 when tested for N1 containment.

The standard test for Containment level N1 barriers (test TB31) consists of an impact test with a vehicle of 1500 kg mass at speed of 80 km/h and impact angle of 20 degree. The impact test standard requirements are guided by three criteria: 1) the vehicle (and its occupants), must not be decelerated too heavily, 2) barrier and car cannot move beyond the barrier working width, 3) the barrier must redirect the car in the road direction.

The first target can be obtained by having a deformable barrier, as in the case of steel safety systems, or, as in a mass based mechanism, by transferring some of the vehicle kinetic energy ($0.5mv^2$) to the barrier. The system's functioning mechanism is *mass based;* conservation of momentum law (mv) can be used to calculate the barrier effective mass necessary to slow the vehicle.

By further reducing the speed to 30mph the deflections expected to be achieved by the VRS are significantly reduced since velocity and reduction in velocity is key to conservation of momentum law.

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Table 5 – Containment Levels

Change Highway Alignment

The A40 has some of the best vertical and horizontal highway alignments available on the TLRN. In simple terms it is very flat and straight and you can see for hundreds of metres. Lane widths on this section of road are in the region of 3.5m and these widths tend to invite speeding.

A 50mph average speed has recently been introduced by TfL on the A40 corridor which helps with speed control. In order to reduce speeds further and control driver behaviour it is recommended that further work on lane widths and carriageway space utilisation are carried out. It may be necessary to narrow some lanes and leave some unutilised highway.

Further design work and studies would need to be carried out to assess whether said option is feasible at this location.