Using the Australian / New Zealand Standard to review barriers for Australian and New Zealand roads

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Abstract

The Australian / New Zealand Standard AS/NZS 3845.1:2015 was published last year although the procedures outlined in this standard revision have been implemented for some time. The Standard documents the procedure to demonstrate the suitability of new barrier systems for use on Australian and New Zealand roads. This includes the requirements for documentation, supply, erection and maintenance of those new systems. This paper will describe the development of the 2015 Standard and changes from the 1999 edition. The paper critically evaluates the value of the proposed procedure for evaluating barrier systems, as well as highlighting the importance of close control of installation and maintenance procedures to ensure barriers work effectively and as designed and tested.

Why assess safety barriers?

The community has been demanding a higher level of road safety driven by the Decade of Action and encompassed in the National Road Safety Strategy (ATC, 2015). The strong support for the Safe System approach that has been incorporated into the National Road Safety Strategy looks towards barriers to provide the safer roadsides (Jurewicz, Steinmetz, Phillips, Cairney, Veith & McLean, 2014). Within this environment, it is appropriate that the barriers that we use on our roads are fit for purpose and have been assessed competently.

In the US, the Federal Highway Administration (FHWA) reviews crash testing undertaken on a safety barrier and issues a letter of eligibility for reimbursement of federal funds when used on federally funded projects (FHWA, 2015). The FHWA indicates that the states should undertake their own assessment of safety barriers to determine if they are appropriate for their roads. Many states simply rely on the FHWA eligibility letter as evidence of the barrier's acceptability.

The Europeans used the CE Mark to indicate that the safety product has been tested to the CEN1317 requirements. This multipart standard does not assess durability of the product and this is left to the purchaser to quantify. Unfortunately within the European Union, it is sometimes difficult to exclude products because of their durability. (Everitt, 2103)

It was considered in Australia by the Standards Australia Committee CE33 that there should be a thorough assessment of barriers systems that covers a range of characteristics and uses. Part 1 of the Australian and New Zealand Standard AS/NZS 3845.1: 2015 provides guidance on this topic.

First edition of the Standard

The first edition of the Australian Standard AS/NZS 3845: 1999 provided the Australian Road Agencies with a common statement as to what constitutes an acceptable barrier. The principal method of assessment documented in AS/NZS 3845: 1999 was through full scale testing results to NCHRP 350 protocol (Ross, Sicking, Zimmer & Michie, 1993). The Standard lists the requirements for documentation to accompany a safety barrier. This list is useful to road agencies as the requirements assist installation design and maintenance procedures.

The Standard was produced at a time when a number of authorities were using a standard W-beam mounted on steel block-outs and steel posts. This Australian design had been developed from the

US standard design G4S, but used a block-out and post with a different cross section. At the time the standard was published, the Australian design had not been tested to the prevailing test protocol in AS/NZS 3845: 1999 which was the same as the test protocol in NCHRP 350. As a consequence, the Standards Australia Committee, CE33, chose to make the Australian W-beam system "deemed to comply" at NCHRP Test Level 3 without any full scale testing to establish its worth [1].

On the face of it this may seem to be irresponsible, however, the experience with the system was that the barrier was performing satisfactorily and there are advantages in having common components. There were few if any reports of vehicles breaching the system when it was considered that the barrier should have contained them. At the time of writing the first edition, the engineering profession generally accepted the "deemed to comply" status of these steel barriers.

Another issue in the development of the 1999 edition of the Standard was the use of test level 0. This was criticised internationally as being too weak to be a barrier and general international comment was that NCHRP 350 TL1 should be the minimum standard. In the 2015 edition, TL0 barriers were discontinued although these barriers could become "Longitudinal Channelising Devices" under the proposed AS/NZS 3845.2.

Development of the second edition of the Standard

The 2015 edition of the Standard (AS/NZS 3845.1: 2015) is based on the 1999 version. Much of the content is very similar to the earlier edition but based on more current thinking. However, the major changes were the deletion of any reference to barriers being considered 'deemed to comply" to a test level, the removal of the specifications public domain barriers and components and an enlarged section on the assessment of the safety barriers.

Deemed to comply notation was removed because the committee considered that all barrier systems should be evaluated against the same standard and test protocol. A barrier should not be accepted as performing to a particular level without full-scale testing. In service performance may demonstrate weaknesses in a barrier system but it does not predict a performance test level that can be used for comparison. AS/NZS 3845.1 2015 recommends conducting in-service performance evaluations using the processes in Chapter 7 of MASH (AASHTO, 2009) or Ray, Plaxico and Anghileri, (2010). Unfortunately, in the author's opinion, in service performance evaluations are rarely done to an acceptable standard anywhere. So long as inferior products are included in the Standard, there was insufficient impetus for road agencies to either use better performing systems or for manufacturers to develop better systems (Wallace, 2015). Since this aspect was removed from the standard, additional MASH TL3 steel barriers have be designed and tested enabling more competition in the market place and potentially lower prices for W-beam systems.

Assessment process for safety barriers in AS/NZS 3845.1: 2015

AS/NZS 3845.1 2015 clearly states that: *"A successful full-scale testing program alone does not qualify a road safety system as suitable."*

In section 4.6, the standard states that the evaluation of a barrier system should consider:

"(a) Documentation supplied in accordance with this Standard.

(b) Any full-scale test results that are not in accordance with Clause 4.5 or verified using engineering calculations, computer simulation analysis, laboratory testing, bogie or

[1] Testing in the US demonstrated that the Australian barrier failed to meet NCHRP 350 TL3 testing protocol with a 2000 kg vehicle. Later testing of a public domain steel barrier with plastic block-outs and mid-post splices has passed NCHRP 350 TL3 testing protocol. This barrier has also been evaluated with non-compliance testing by a number of Australian Road Agencies and universities.

pendulum tests or component structural tests in the case of modification in accordance with Clause 4.4.2.

(c) Reasons to waive the required tests by this Standard.

(d) The expected ability to withstand a second impact before being repaired.

(e) Whether the road safety barrier system can reduce the severity of injuries to vulnerable road users.

(f) The durability of components.

(g) Workplace, health and safety requirements during installation and maintenance.

(h) The ease with which maintenance can be undertaken including the requirement to use specialized tools and the expected time to replace damaged components after an impact.

(i) Whether the road safety barrier system can be installed on a range of foundations or whether posts can be used in a range of foundation conditions."

Some of these issues could cause the barrier system to be unacceptable but in most cases the consideration of these points informs users. This list is also a prompt to manufacturers when designing a barrier system or promoting the use of a system. Interestingly, some manufacturers have looked at a barrier's ability to redirect a second impact (albeit at a lower energy level than the first). The commentary to the Standard (section D4.6) lists second order issues that a road agency could consider. However, these are more for interest rather than for evaluation.

The current standard indicates that MASH is the *"basis of testing procedures for road safety barrier systems"*. However, the Standard leaves the way open for the evaluation of barrier systems tested to EN1317. The test levels should be seen as a continuum. A barrier tested to EN1317 might give the assessor the view that the barrier system is performing better than a MASH TL3 but not as well as a TL4 system. It is noted that energy and vehicle differences need to be accounted for in quantifying the performance of the barrier to the Standard. To some engineers this is a difficult concept, as they would prefer to not make this comparison. However, the CE33 Committee did not want to preclude European products from entering the Australian market place, but felt that the barrier's performance needs to be described on a common basis with other accepted products. It may be that it is not necessary to provide a notional MASH performance level, but simply state the types of locations where installations would be acceptable. This position is also acceptable to the author.

An important addition to the Standard is the recommended testing of motorcyclist protection devices. The standard utilises the CEN Technical Specification CEN/TS 1317-8 developed by the CEN Technical Committee CEN/TC 226. However, the Australian standard also included measurements of thorax compression (Grzebieta, Bambach & McIntosh, 2013 and Bambach, Grzebieta & McIntosh, 2012) as it was found that approximately half the riders tended to be upright on the bike during impact and not sliding along the ground as in tests specified by the TS1317.8.

Application of the evaluation process outlined in the Standard

Using test results from a similar product

It is argued that the best evaluation should include all available information. This then leads to a question as to whether tests from other devices that act in a similar way should be used in the evaluation. It might be reasonably expected that they will operate similarly, but small differences in the design can make a difference to the test outcome. It would seem to be wrong to fail or condition a product based on the test of another product. Therefore the results from another product should not be used to fail a system.

On the other hand if one product shows a major concern, it would be appropriate to check if the concern is likely to occur in similar products. In my view, if the concern is serious then it would be worthwhile investigating with the manufacturer the issue and establishing if the concern is warranted. In any case it is not appropriate to share confidential information from one manufacturer to another, and this discussion needs to be done carefully and respectful of confidentiality.

At times there is a need to assess a family of products belonging to the same family. Crash cushions are a typical example. Often a manufacturer will propose a number of different configurations to cover a range of impact conditions and hazard widths. Not all configurations will be tested and the assessment will need to look at the justification for extending crash tests across the family of products. A well-documented case with energy and momentum calculations will assist in the assessment.

In recent times, some manufacturers have provided non-compliance testing to assist the evaluation. These tests may or may not have acceleration plots, but will generally have good video footage. They do provide another view of the operation of the barrier system. It has been said that a manufacturer needs to have testing to establish compliance with a testing protocol as well as other testing which documents the performance of the system over a broader range of site and impact conditions (warranty testing). This latter testing gives the manufacture peace of mind and an ability to better describe unfavourable site conditions and what to do about it. In many respects this warranty testing is as important as compliance testing. The warranty testing could also be gained from an in-depth assessment of crashes into the barrier system. Either way it is important that manufacturers gathers information about a broader range of impacts than those in the compliance testing and use this information to inform designers and installers.

The question whether the non-compliance tests should be used in the assessment. R&D tests are not required to be reported, yet are important for the manufacturer in the development stage. These R&D tests are generally provided if they show a positive aspect of the product, the manufacturer may offer non-compliance tests to be considered in the assessment. Non-compliance tests can also be used to explain an issue for the assessors, although this should be used infrequently. Undoubtedly, there is always an issue that could be tested. However, this becomes onerous to the manufacturer and only compliance testing should be requested by the assessor. Occasionally, the Road Agencies will perform full scale testing on a barrier system in order to develop a broad understanding of the performance of the systems (Hammonds and Troutbeck, 2012). Again, it is the author’s opinion that this testing should not be under compliance testing standards, as the task is not to know whether a particular barrier is acceptable or not, but to rather gain an insight as to the performance of a type of barrier system.

Waived tests

Full scale testing is expensive and at times a manufacturer will not undergo a full testing program as specified in AS/NZS3845.1: 2015 and indeed MASH. If the product is for the US market, then in the past the FHWA entered into dialogue with the testing agency and may have agreed that some tests are not required, based on the testing of other safety barrier systems or previous tests on the same device. There would seem to be nothing wrong in allowing tests to be waived, but there is a risk that the estimated performance of the system would not be correct. Any request for waiving a test must be comprehensive and in many cases it may be easier to undertake the test rather than provide an acceptable reasoned argument.

Learnings from barrier system assessments

Installations on embankments and in weaker soils

In the design of roads we use the concepts of “normal design domain” and “extended design domain”. The normal design domain describes the required attributes of a road to produce a rational and safe design according to establish local and international practices. The extended design domain establishes the practices that are acceptable given qualifying road characteristics. For instance the normal design domain specifies the minimum paved width of a road for different design (or operating) speeds. If the sight distances are adequate, then in some cases it may be acceptable to have a narrower paved area; the conditions under which this would be acceptable are given in the extended design domain (DTMR, 2013).

When installing barrier systems, it is assumed that the soil conditions will match the AASHTO standard soils used in the testing. Essentially the testing is only pertinent to installations with similar to the soil conditions used in the tests. It is generally accepted that the soil, foundations or footings characteristics significantly affect the performance of a barrier. A test can be easily made to fail if posts are not embedded in material that can resist the forces. When the material used in the foundations or footings differs from that used in the testing then this is an "extended design domain" issue, and additional information provide by the barrier system supplier or the road agency should specify the characteristics of the appropriate foundation material. The footings should be designed using this information

Where this becomes particularly important is the installation of barriers at the hinge point or on an embankment. Some barrier system suppliers have tested their product in this way and it has been found to meet the testing protocol. However, the expected performance of the barrier will be a function of the soil characteristics on the embankment, which is often not compacted to the same extent as the shoulder. Accordingly there is a greater variation of the ability of the embankment to resist post loads and for the barrier system to operate as expected, and it is the right of a road agency to specify the conditions where barriers can be installed on embankments or not at all. Conversely, it is appropriate for the barrier system manufacturers to develop systems that allow the barriers to be located further from the travelled lanes as this can reduce the cost of road construction or reduce the cost of road upgrades.

Installations in weaker soils, still needs attention. Some systems are more tolerant when installed in softer soils depending on the post footings. There needs to a greater effort to provide more information on this issue. Clause 2.5.4 of the Australian Standard states:

"(d) For systems that contain posts, the documentation shall include the load to which the post can be tested that ensures that it provides the necessary support to the system.

(e) For tests on wire rope barriers, the documentation shall include a test load to be exerted on the anchors to confirm their adequacy."

The Standard continues in Clause 4.3.2 and requires Section 3.3.2 of MASH to apply with the additional requirement:

"*For all road safety barrier systems that utilize posts, a load/deformation plot shall be provided based on the same soil conditions used for the crash testing. The post shall be loaded until it yields."*

Greater understanding of the post soil interaction will assist in providing more effective barrier system designs.

Design of post fittings

Following the comments above, there is a growing concern that adequate designs of post footings are not undertaken. The New Zealand Transport Agency has issued a Technical Advice Note 16-01 in February 2016 on the "Wire Rope Safety Barrier systems – post footing issues". The advice points out that the footings have failed because the "*installation locations are inappropriate for the* *soil conditions. This may result from a combination of inadequate site investigation during design, poor soil compaction during earthworks operations and/or poor installation practices. Additionally, limited in situ testing of WRSB installations may have masked any installation issues*."

The Technical Advice Note states that inadequate footings are likely to results in a poorer barrier performance, increased chance of injury and increased maintenance costs. The Technical Advice note provides two photographs to illustrate the issue. These comments are not specific to a particular barrier type but rather to wire rope safety barriers as a whole. These are reproduced below.

Figure 1. Post failures shown in NZTA TAN 16-01

The New Zealand Transport Agency, through the TAN, recommends:

1. That only approved barriers be used and that these are installed *"compliant with the crash tested design or the road safety hardware system configuration granted acceptance by the Transport Agency, as listed on the Transport Agency M23 webpage".*

2. That installation designers have *"attended and passed the Transport Agency Road Safety Barrier Design Course within the last five years."*

3. That "*the Installation Designer must confirm the ground conditions at the installation site as part of the design process".*

4. That the *"System Supplier must have available the design horizontal force(s) and/or bending moment(s) at a nominated height and at an angle of 90° to the barrier as measured from data recorded during crash testing of the WRSB system."*

The requirements in these recommendations are aimed at reducing the probability of post footing failures and ensuring the barrier is more able to withstand the impact loads. The reader will note that the responsibility is shared between the Installation Designer, the Supplier and the Installer.

The comments in this Technical Advice Note are applicable to Australia as well as New Zealand.

System Deflection

When performing full-scale tests, a testing house often measures and records the deflection to the millimetre. In fact the deflection is a measurement applicable the conditions that exist at testing. It is noted that while the broad outcomes of a test are repeatable, the precise deflection is not. The foundation conditions alone could affect the deflections.

Wire rope barrier systems are even more susceptible to variation in deflection from one impact to another. The posts have to keep the ropes at a height so that they will engage with the vehicle. Mazougui, Mahadevaiah, Tahan, Kan, McGinnis and Powers (2012) have demonstrated that ropes lower than the lower edge of a bumper bar will be forced under the vehicle and ropes that are higher than the lower edge of the sloping part of the bonnet will ride over the vehicle. It is not uncommon for two out of four ropes to not engage with a vehicle and at times only one rope does so. The deflection of a wire rope barrier is dependent on the number of ropes that engage and the tension in the ropes.

The tension in wire rope systems has been increasing over time from a nominal 15 kN to 25 kN (O'Callighan, 2015). Increased tension affects test deflection and the deflection in the field will be a function of the deflection in the system which is based on the temperature of the day. This aspect also influences the design of the cable anchors. Again consultation between the barrier suppliers and the installation designers is required to ensure that the anchorages are appropriately designed.

It is important that installation designers consider system deflections as notional and not a precise absolute value. The deflection of a system in real installations will depend on the impact angle and speed and the mass of the vehicle, While MASH and hence the Australian and New Zealand Standard expects test conditions to be reasonably extreme, deflections in the real installations can be greater than those recorded in the full scale tests. Installation designers should not accept hazards just a little further away from the barrier than the design deflection.

Eliminating unsatisfactory installations

Unsatisfactory installations occur if the type of barrier used is not appropriate for the situation, if the barrier is not located appropriately or the barrier is not installed correctly. Austroads Road Design Guide Part 6 (Austroads, 2010) describes the appropriate barrier type for different situations and also their appropriate length and location. Grzebieta, Zou, Jiang and Carey (2005) have illustrated examples of poor barrier installations. To eliminate unsatisfactory installations, the installation designers and installers need to be conversant with both the Austroads guidelines, and the installation requirements of different barriers.

The Australian and New Zealand Standard AS/NZS 3845.1:2015 outlines the requirements for installation manuals for each barrier system. However, these manuals are of no use unless they are read and understood.

Davis (2015) undertook a survey of barrier installations on three sections of State Highway 2 in New Zealand, namely from Woodville to Hastings, SH33 to Matata and Athenree to Katikati. He classified the deficiencies in the barrier installation on the design of the installation (the length relative to the hazard, the location of the terminals; the clear area behind terminals and the appropriateness of the terminal); the installation compliance with the supplier's requirements and the general condition of the maintenance.

Davis commented:

"The likelihood of barrier hardware performing as designed, tested and accepted becomes increasingly questionable as the installation conditions vary further from those that were tested. As technical advances in barrier hardware and design have not been well understood by practitioners significant faults that will affect performance continue to be common place."

Davis found that:

"About 86% of the surveyed installations had significant or serious installation deficiencies. However, most installation deficiencies are readily repairable. Typically these include end treatment issues associated with height, grading, or missing or incorrect terminal bolting patterns.

About 75% of installations had issues relating to outstanding end treatment maintenance, and about 20% of installations had barrier maintenance issues. Most of the significant and serious maintenance issues could be easily identified and remedied. Typical examples include anchor cable tightening. It could be that network managers or contractors were not trained to identify appropriate maintenance issues, or are avoiding contractual obligations."

Davis made a number of recommendations that affect the installation and maintenance. Some of these have been paraphrased as:

- Establish performance measures in design, installation, and maintenance contracts to achieve road safety barrier quality assurance system and to monitor and report progress.
- Develop an industry training regime that addresses design, installation, and maintenance issues
- Improve quality assurance regime through appropriately trained designers and installers of barrier systems and an audit program of design, installation and maintenance.
- Develop a road safety barrier installation and maintenance manual to cover the identification, installation and maintenance checklists for common barrier hardware.
- Installation deficiencies of incorrect bolting patterns, missing bolts, delineation and grading and so on should be rectified in routine maintenance programs
- Maintenance contract documents to reinforce the need for routine rather than random maintenance.

Cassar (2015) has documented a number of examples in which it would appear that the installer was not aware of the correct procedures or to purposely "cut corners' in order to finish the installation quickly. Two examples in Cassar (2015) are shown in Figure 2 in which the details of the design of extruding terminals were not understood and the installation made the terminal ineffective if impacted head on. Cassar has provided examples where posts are not driven to the required depth and the intention is to cut off the posts (Figure 3). These posts will obviously not function as expected.

At times an installer will be a little too innovative. Figure 4 shows two examples where an installer has formed a non-standard anchorage and where the barrier system has been repaired using posts from another system (affecting the rope heights and orientation).

Both Davis and Cassar have indicated that some installations are so poor that the performance of the barrier would be severely affected. There is no purpose installing barriers if they are ineffective or become worse than impacting the hazard. It is incumbent on the road agencies, the suppliers and the installers to have the highest standard of safety barrier installations.

Daniel Cassar has been working diligently with industry to establish an installer accreditation and training scheme. He indicated the importance of installation being compliant with the tested configuration and with supplier's requirements. A sentiment also reflected by Davis. This must be an imperative if non-compliant installations are to be a thing of the past.

Figure 2. Incorrect installations from Cassar (2015)

Figure 3. Posts not embedded to the correct depth from Cassar (2015)

Figure 4. Inappropriate wire rope barrier installations from Cassar (2015)

Concluding remarks

The community deserves safer roads and roadsides. They assume road agencies are providing the best available. The Australian and New Zealand Standard AS/NZS 3845.1; 2015 has described a process for evaluating safety barriers in which the results of full scale testing is one element. The standard lists a number of other attributes, which the assessor should consider. These have been listed above. The standard also provides details for testing motorcyclist protection systems including thorax measures for riders who are upright when colliding with a barrier.

This evaluation testing and assessment protocol in the current Standard has set the standard for industry and as a consequence, the promulgation of the public domain steel W beam barrier on steel posts and block-outs can no longer be justified as being deemed to comply with NCHRP 350 Test level 3 without testing to the Standard's protocol.

This paper describes the information that should be included in the assessment. It is argued that the prime information is the results from full-scale tests, but other testing should be used to inform but not fail a barrier. A poor performance for a non-compliance test, or from another similar product would give reason for discussion with a manufacturer. Tests should only be waived if there is solid evidence that the outcome is likely to be successful and it is always better to run the test

Installations on embankments and in weaker soils need to be more closely examined and designed. In general these should not be part of "normal" design and should be considered to be in the extended design domain or as a design exception. This would then require more justification and explanation.

The design of safety barrier installations needs to be more comprehensive and include designing for the soil characteristics at the site. The New Zealand Transport Agency has produced a Technical Advice Note to address this issue. It is applicable to safety barrier designers and installers in Australia as well.

The paper warns that system deflection should be taken as notional as soil characteristics and rope tension have a significant influence.

Finally many installations are sub-standard and not compliant with the tested configuration or the supplier's requirements. The installations should be audited and the installers trained and accredited.

Personal view

Professor Troutbeck is employed as an independent member on the Austroads Safety Barrier Assessment Panel (ASBAP). However, this paper provides a personal view of appropriate assessment practices and does not necessarily represent the views of Austroads, ASBAP or any road agency.

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