ASSESSMENT OF ROAD EQUIPMENT RESISTANCE TO SNOW PLOUGH LOADS

Eng. M. Pezzucchi
Bridge section, Norwegian Public Roads Administration (Statens vegvesen),
Directorate of Roads, Norway
MATTEO.PEZZUCCHI@VEGVESEN.NO

ABSTRACT

An evaluation of safety barriers resistance to snow plough loads shall be added to road equipment assessment in accordance with EN 1317-5. The resistance to snow removal operations is now one of the mandate characteristics of safety barriers. Horizontal and vertical pressure of snow ploughed against the rail and minor impacts caused by the plough in the traffic face and the upper edge of the rail are evaluated through geometric and strength aspects. This paper presents this evaluation method explaining its historical background, its meaning and the use of it with its limitations. Finally, a possible evolution of this method is considered for future assessments.

Keywords: safety barriers, road safety, snow removal operations, EN 1317-5

1 INTRODUCTION

Road users await clear streets all year long even during heavy snowfalls time. Significant manpower and finance resources are spent on snow and ice control programs by national states and local governments. These programs focus generally on the clearing of traffic lanes during snowfalls and on the actions to be taken in preparation of the next snowfall [1].

Among other actions, clearing up generally includes removing accumulated snow from road shoulders and from bridge parapets and safety barriers to prevent vehicle ramping accidents. These operations are often time constrained and are required to be done as fast as possible; as a result, they often are really aggressive on vehicle restrain systems installed along the roads. This is why safety barriers should as well be chosen in function of their capability of resisting to snow plough loads.

During winter maintenance operations safety barriers may be hit in different ways and in different locations depending on what type of safety barriers they are and what type of vehicles are used for these operations. Damages can vary from general visual damage to dents or complete bending of the system. Snow and ice themselves can represent an issue with their weight since safety barriers can cause heavy snow deposits on the road and increase the height of the snow banks on the road side.

Therefore safety barriers generally need greater maintenance and have a shorter durability in areas subject to snowfalls than areas with a milder climate.

An evaluation method has been developed and shall be used to classify the safety barriers. The goal is to describe the system's behaviour when subjected to this kind of loads hoping that a correct choice of safety barrier could help improving the barriers durability without compromising their safety efficiency.

This paper gives a better understanding of how and why safety barriers should be assessed to “Resistance to snow removal” operations in accordance with harmonised product standard EN 1317-5 [2].

2 HISTORICAL BACKGROUND

Damages to safety barriers caused by snow plough clearing operations have historically been an important issue only in a few countries in the world. These countries are subject to snowfalls and heavy winter conditions for geographical reasons. This means that only very few researches and financed projects have been conducted on this subject until now.
In the following paragraphs the historical background of today’s standard classification of safety barriers for their resistance to snow plough loads is given in chronological order. Some of these data are from internal reports or research groups and they have never been published.

2.1 Collecting experience; the 90’s

The first published document considering the effect of snow plough loads can be dated 1993 under the title “Durability of guardrails in Northern Europe” [3]. This study was carried out by Helsinki University of Technology on a Finnish National Road Administration contract and involved maintenance personnel from Northern Norway, Northern Sweden and Finland. The purpose of the study was to collect good-practice and experience on the durability of safety barriers in use in those countries. The experts pointed out that the durability of the standard safety barrier (A-profile steel beam 300mm high and 3mm thick) subjected to snow plough loads can be easily improved by increasing the thickness of the steel rail.
This observation that might be obvious nowadays still leads to today’s classification logic as shown later in this paper.

Later that year Helsinki University of Technology published probably the first test method that has ever been developed to assess safety barriers performances to snow plough loads [4]. The test itself was quite simple, consisting of five different impacts caused by a blade on the barrier’s rail (single point). The notch caused by the blade was measured and classified.
This research confirmed the observation of the study conducted previously that year showing that 3mm rails could easily be damaged by the snow plough blade. Moreover, it made it possible to develop a first evaluation method setting the acceptable limit of the notch to a maximum of 18 mm.

2.2 Studying the subject and evaluating possible classification’s methods; the 00’s

It is in 2001 that a European research “ROADEX - Winter Maintenance Practice in the Northern Periphery” [5] completed a research program dedicated to winter maintenance. Although this research described many important features for the road design and road winter maintenance it did not focus on safety barrier classification, looking at them more as an obstacle to maintenance operation (“hindrance for cost-effective winter maintenance operations”) than as a part of the road infrastructure to be improved.
Few aspects of this research deserve to be mentioned in this paper; amongst others the research concluded that:

- In snowy areas, safety barriers can be exposed to high vertical and horizontal forces caused by snow plough vehicles during maintenance operations and by the weight of the snow that accumulates in snow-banks around the system.
- Safety barriers generally need greater maintenance in areas subject to snowfalls and have a shorter durability than barriers used in areas with a milder climate.
- Safety barriers are designed to contain and redirect vehicles in a safe way; too little consideration has been given to the forces caused by snow and winter maintenance vehicles during the design phase.
- The durability of the safety barrier can be increased by improving the barrier design (for instance by reducing the distance between the posts).

Table 1 summarises the behaviour of different safety barriers used in Nordic regions with reference to winter maintenance operations:

Table 1: List of main safety barrier's type used in the Northern Periphery and relevant experience (ROADEX)

Type	Width [mm]	Cost per meter [EUR/m]	Post distance [m]	Experiences
W-type	230-320	38	2/4	Collects drifting snow Damage by snowploughs, graders and blowers. Ploughs scratching the surface of the rail Some damage due to the weight of snow. Maintenance costs: 2-3 EUR/year/m
Kohlswa	160		2/4	Collects less snow than the W-type No damage recorded due to weight of snow The type with 4m-post interval is more easily damaged during ploughing. No damage reported due to ploughing on the type with 2m post interval Easier to clear the road edges
Pipe-type	2x70	48	2/4	Collects little snow 4m-post interval is more easily damaged during ploughing. No damage reported due to ploughing on the type with 2m post interval
Wire			3,2	Collects little snow Can be easily damaged during ploughing
Open Box Beam	***			Only in use in Scotland with minor snow drifts.

In 2002 the Norwegian Public Roads Administration enhanced the effort of reducing safety barriers maintenance costs, including reparation costs due to damages caused by snow plough equipments. That year an internal report was published “Vegrekkverk- vedlikehold og gjenbruk”[6], and a contract study “GuardRail Response Calculations” [8], was carried out.

The report analysed safety barriers already installed on the Norwegian road network and tested in accordance with EN 1317-1 and 2 (first release 1998 [9])[1]. The safety barriers consisted of W-type (so called A-profile) rail and three different post typologies: sigma steel post, plastic post and wooden post [7]. As a result the following typical damages were listed: flattening, yielding and rusting of the rail and bending or impairment of the posts. Two interesting remarks were also highlighted: firstly the posts final deformation is influenced by the soil resistance (any installation could perform differently in function of soil behaviour) and then the rail damages generally occur in a limited area that goes from the posts to 80 cm upstream (see figure 1).

[1] EN 1317-2:1998 has been replaced by EN 1317-2:2010

Figure 1: example of damages due to snow clearing operations

In order to increase the knowledge and understanding of snowplough-barriers interaction two tests were conducted on the three barriers:

- a quasi-static loading test (perpendicular to the safety barrier alignment);
- a simulation of snow clearing conducted with snowplough truck constantly pressing the rail and sliding along the safety barrier (this operation was repeated 8 times).

Results of the tests are shown in figure 2 and 3.

Figure 2: quasi-static loading test (from left to right: steel post, plastic post and wooden post)

Figure 3: result of snow clearing simulation test

Both tests have shown that a flexible barrier could deal better with these loads than a barrier with stiffer posts. It is then possible to conclude that the barrier should be seen as a whole and the evaluation of its component is not generally accurate enough to estimate the barrier resistance to snow plough loads.

As mentioned, those tests have shown that some types of safety barriers are better suited to withstand the loads from a passing snow plough truck than others. This information has been useful in the study commissioned that same year [8]. The aim was to establish a calculation model that could help explaining why certain combinations of beam-rails and posts behave better than others, and suggest acceptance criteria to be implemented within design regulations.
In order to reach these goals, a series of loading tests were conducted to evaluate the primary failure mode and the allowed force-deformation of well-known safety barriers[1] (the one analysed under ROADEX project). The rail was loaded perpendicularly to the safety barrier elongation and the deflection at the load points and the forces at failure in any loaded points were recorded. The results were plotted to form a No-Damage capacity curve (figure 4 and 5).
After comparing the the forces of the different systems at failure (figure 4), the 300 mm W-profile barrier with sigma posts (Standard Norwegian barrier) showed a better performance than smaller rail barriers (Swedish Kohlswa GuardRail and the Finnish 230/4 GuardRail) but this had already been proved wrong.

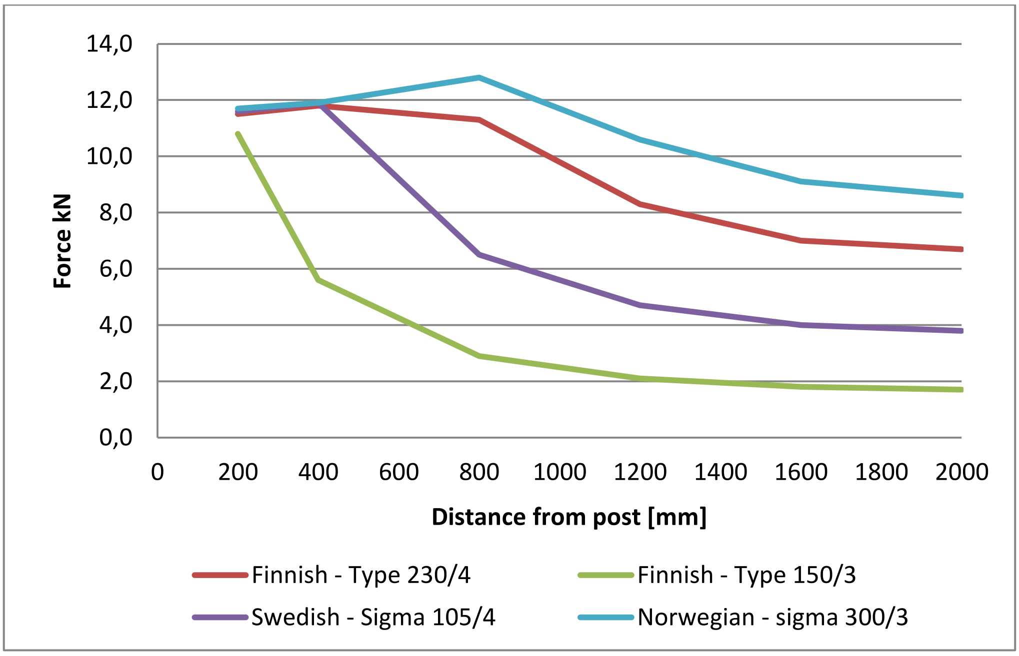

Figure 4: No-Damage Capacity Curve by force

It was therefore concluded that the allowable deflection under the plough load seemed of major importance and more reliable for the classification of the safety barriers than the force at failure. Safety barriers of similar type with narrower and/or thicker rail could withstand higher deflection before rupture (see figure 5).

[1]The following safety barriers have been considered: Finnish-1 (Rail: 230/4 (KO-1464) - Post: U -100/5), Finnish-2 (Rail: 150/3 - Post: U -100/5), |Swedish (Rail: Kohlswa - Post: Sigma 105/55/4), Norwegian-1 (Rail: 300/3 - Post: Sigma 105/55/4), Norwegian-2 (Rail: 300/3 - Post: Plastic (Ø 140x14)) and Norwegian-3 (Rail: 300/3 - Post: wooden (Ø 140)).

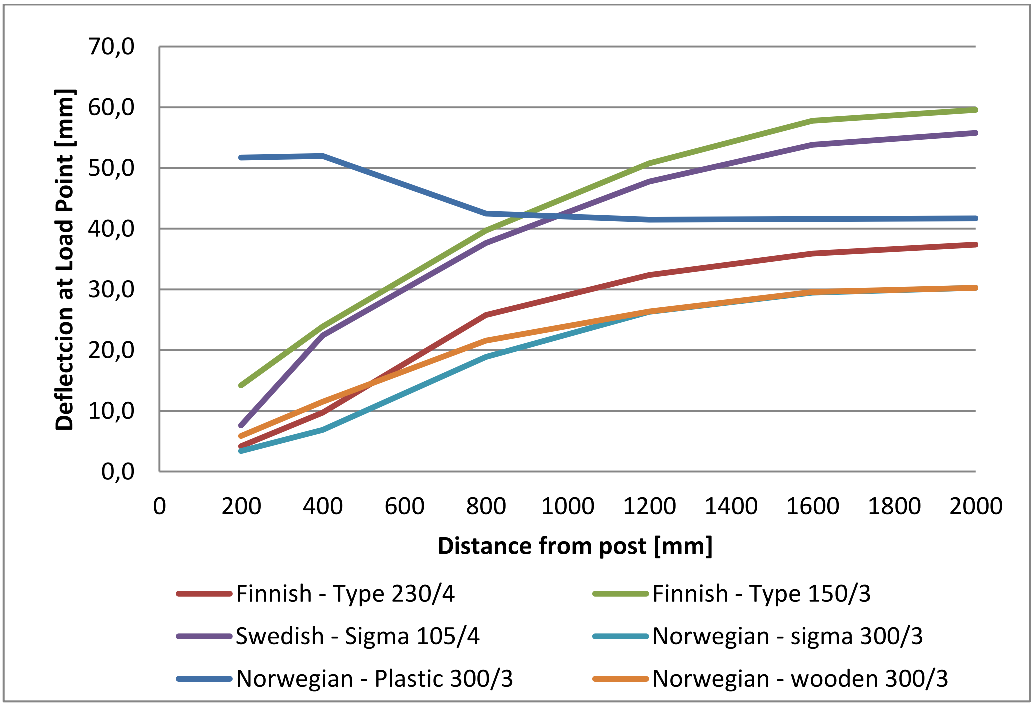

Figure 5: No-Damage Capacity Curve by deflection

Finally coupling the test results and the experience collected during that research and previous ones, it was possible to conclude that safety barriers with minor damages were in general more flexible than barriers that had more damages. This study concluded that a sort of minimum flexibility criteria should be developed for systems mounted in areas where snow clearing is needed.

Then a simplified calculation method was established based on the response to similar concentrated horizontal loads [7]. The safety barrier was simplified to a 6 degree of freedom equation system with the following assumptions: constant distance between the posts, small deformations at neighbouring support posts, small membrane (axial) force contribution and elastic response. The so built model was able to evaluate the deformation of the system subjected to a concentrated load (snow plough load measured in the test) in any point between two posts and was able to identify the possible failure of posts or rail.

This method allowed an evaluation of the system and helped identifying the safety barrier failure mode but unfortunately it was not of any help for safety barriers classification.

Thanks to inter-disciplinary knowledge, a consultant of the Norwegian Public Road Authority proposed an equation that could be used for controlling the design of safety barrier's rail in steel [10]. The equation (1) was taken from the offshore environment where it had been applied to pipes design exposed to possible boat collision.

$$P = 150 \cdot f_y \cdot \frac{t^2}{4} \cdot \sqrt{\frac{\delta_d}{d}} \qquad (1)$$

Where P is the load level, f_{yd} is the design yield strength of the rail material, t is the nominal steel thickness of the rail, d is the theoretical diameter of the rail and δ_d is the depth of the dent caused by the collision. The theoretical diameter could be evaluated using the real rail curvature facing the roadway based on the assumption that large curvatures provide greater resistance to impacts. An overview of the theoretical diameter evaluation is shown in figure 6.

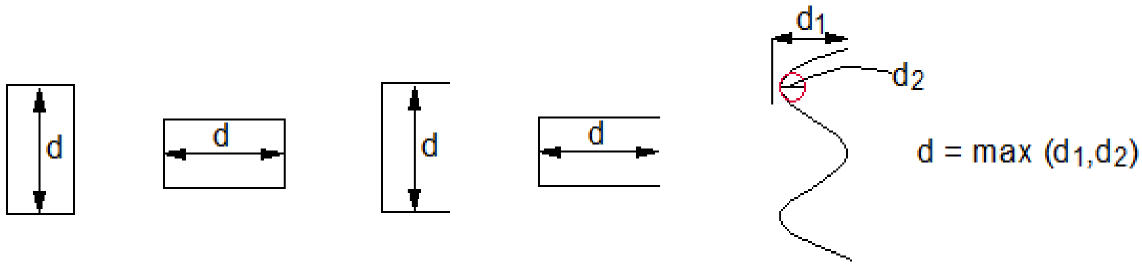

Figure 6: theoretical diameter evaluation

Based on experimental researches the dent δ_d was estimated to be 1.5mm and the minimum load resistance P 15 kN. Using equation 1, any combination of yield strength and theoretical diameter resulting in a load lower than 15 kN was considered to be too weak for holding loads caused by snow plough clearing operations.
Moreover less demanding requirements could be set when rails were mounted on more flexible posts (like plastic posts). For instance the load level could be reduced P_{red} as shown in equation 2. The reduced force was of 10 kN but this value could be higher depending on the post's properties.

$$P_{red} = \max\left(\frac{3EI}{h^3} \cdot \Delta, 10000N\right) \qquad (2)$$

At the same time, an experimental approach had been developed and tested by Finnish Road Authority. The full report of the test was presented in 2005 [11]. The experimental method consisted of selecting an existing road section[1] and testing the durability of the selected safety barrier on site. In this case four different barriers that had been installed in the 90's were investigated. Any deformation, flattening, dent or scrape were reported. Finally a classification of the evaluated systems was established.
This experimental approach was developed with the idea that other systems could be tested in a similar way and compared to those above to enlarge the classification.

Figure 7: the experimental method –field exposure test

Simultaneously the Finnish Road Authority improved the evaluation method first developed in 1993 by Helsinki University of Technology [12]. The method then allowed the evaluation

[1] the selected road type is a motorway with an ADT of about 30000 vehicles per day

of both rail and post and included a series of different test impacts on the safety barrier (the method was developed only for a rail-post safety barrier).
The test configurations are shown in figure 8. As in the previous version [4] the impact test was repeated five times.

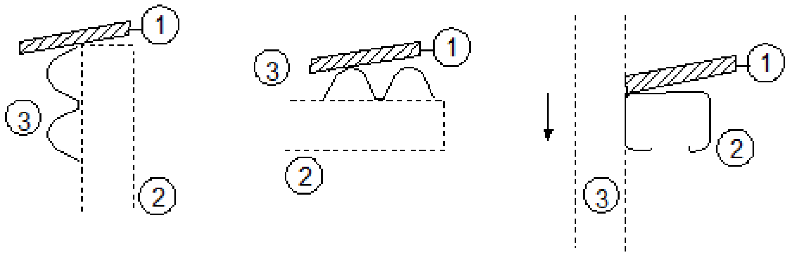

Figure 8: drop test configuration: 1-impacting blade; 2-barrier's post; 3-barrier's rail

The report that was written described how to measure and evaluate the deformed system. Classification was made according to table 2.

Table 2: drop test result and classification

Class	Front side of the rail		Upper edge of the rail		Post	
	Notch (mm)	Buckling (%)	Notch (mm)	Buckling (%)	Notch (mm)	Buckling (%)
4	< 12	< 10	< 36	< 10	< 12	< 10
3	< 24	< 20	< 72	< 20	< 24	< 20

Class 2 and 1 were used for other systems like wire rope safety barriers.
This last method and the classification were incorporated into the Finnish road regulation and notified to CEN[1].

All the above mentioned studies have proposed methods to evaluate the consequences of snow plough loads on safety barriers but none of them has taken into consideration the snow banks as a cause of possible damage. ROADEX research project highlighted how the weight of the snow could in some cases be enough to yield the system compromising its functionality and performances. That is why Professor Norem, on behalf of the Norwegian public Road Authority proposed a method to control that a safety barrier could resist against a given vertical load [13] of snow. This load was represented by the triangle pressing on the rail with an opening of 30 degrees (figure 9).

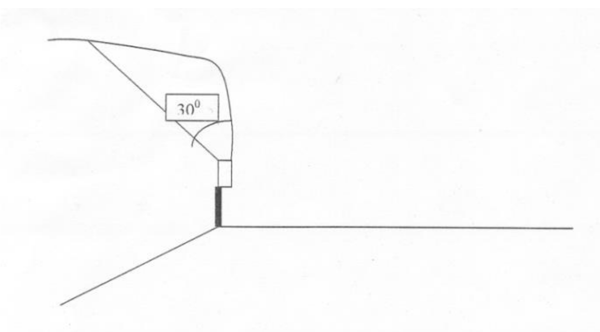

Figure 9: evaluation of snow bank weight

[1] CEN: Comité européen de normalisation

Then, two components of the force could be calculated (vertical and horizontal) considering that the snow bank slides down and laterally toward the road. The vertical load was therefore:

$$q_V = \frac{1}{2} \cdot \rho \cdot g \cdot h^2 \cdot \sin(30) \quad (3)$$

Where q_v is the load/meter, ρ is the snow density (400 kg/m^3) and h the height of snow bank over the safety barrier.

Thanks to the above experiences, testing methods and analyses a first proposal called “resistance to snow plough load” was elaborated and discussed in working group 1 within CEN Technical committee TC226 in 2006.

2.3 Including the resistance to snow plough load in the European standard; the 10’s

In the 10’s, CEN member states (and experts) tried to reach a consensus in order to include the resistance to snow plough load evaluation in the European product standard for safety barriers. The draft proposal was named “Resistance to snow removal” and it was first introduced in an official draft standard on May 2010.

The unanimity on the proposal has never been reached but the working group finally arrived to a general consensus thanks to the Finnish Road Authority who sent the notification of their own regulation about snow removal to CEN.

The proposal developed within the working group was finally approved and published in a Corrigendum of EN 1317 “Road restraint systems” - Part 5: Product requirements and evaluation of conformity for vehicle restraint systems[1]. The corrigendum became effective on 29 August 2012, meaning that from that date on it was possible to assess safety barriers according to their resistance to snow removal operations.

The published “Resistance to snow removal” clause is described and commented in the next chapter.

3 PUBLISHED STANDARD AND FUTURE IMPROVEMENTS

It is a well-known fact that snow removal operations may damage a safety barrier which does not have sufficient resistance.

An evaluation of safety barriers resistance to snowplough loads has been added to road equipment assessment in accordance with harmonised product standard EN1317-5. The resistance to snow removal operations is now one of the mandate characteristics of safety barriers.

3.1 The published reference standard

Horizontal and vertical pressure of snow ploughed against the rail and minor impacts caused by the plough in the traffic face and the upper edge of the rail are evaluated

[1] EN 1317- 5:2007+A2:2012/AC:2012

through geometric and strength aspects. This means that the classification is essentially based on the experience collected during the last decades (chapter 2) and limited to the safety barriers already in use in the countries where winter maintenance is an important issue.
This simplified evaluation method is intended to be used for normal steel beam barriers, rope fences and monolithic pre-cast or cast-in-place concrete barriers.

Classes and minimum requirements for each class as stated in the standard are shown in table 3. Three classes are defined for steel barriers and one (Class 1) for other types. Wire rope fences have their own class (Class2) among steel barrier types. Pre-cast or cast-in-place monolithic concrete safety barriers shall be declared to belong to class 4 when the strength class is C 25/30 or higher.

Table 3: Resistance to snow removal of metal beam safety barriers, EN 1317-5

Class	Modified material thickness of a rail in steel		Modified section modulus against horizontal loads		Strength against vertical loads of the connection between a post and a rail
	Open profile (mm)	Tube (mm)	Rail (cm^3)	Post (cm^3)	
4	$\geq$ 4	$\geq$ 2.9	$\geq$10	$\geq$12	$\geq$ Shear strength of M10 4.6 bolt
3	$\geq$ 3	$\geq$ 2.2	$\geq$5	$\geq$9	$\geq$ Shear strength of M10 4.6 bolt
2	Rope fence				
1	Other				

Table 3 classification is based on a "Modified material thickness" of a steel rail and a "Modified section modulus" of the barrier's main components. "Modified" means that the real thickness and section modulus of these components shall be re-evaluated before classifying in order to include variations due to material quality. The calculation uses a standard barrier made of JR235 steel as a reference.
The modified material thickness shall be calculated by using the following equation [1] (4):

$$t_{mod} = t \cdot \left(\frac{f_{yd}}{235\ N/mm^2} \cdot 1.1\right)^{1/2} \qquad (4)$$

Where t_{mod} is the modified material thickness of the rail, t is the nominal steel thickness of the rail and f_{yd} is the design yield strength of the rail material
The modified section modulus of the post and rail against horizontal loads shall be calculated on the basis of the post and rail profile by using the following equations (5, 6):

$$W_{mod} = W_{rail} \cdot \frac{f_{yd}}{235\ N/mm^2} \cdot 1.1 \qquad (5)$$

$$W_{mod,post} = W_{post} \cdot \frac{f_{yd}}{235\ N/mm^2} \cdot 1.1 \qquad (6)$$

[1] The parameters used in the equation (4), (5) and (6) shall be applicable for short duration loads in temperature of -5o (EN 1317-5, Annex C)

Where $W_{mod, rail}$ is the modified section modulus of the rail and W_{rail} is the original (elastic) section modulus of the rail against horizontal loads and $W_{mod, post}$ is the modified section modulus of the post and W_{post} is the original (elastic) section modulus of the post against horizontal loads normal to the road.

Once again knowledge and experience make it possible to establish a minimum strength criterion for safety barriers to resist against vertical loads. A single bolt (M10 4.6) connection or any other connection type able to resist to an equivalent vertical point load as a M10 4.6 bolt in simple shear is considered resistant enough to belong to both class 3 and 4.

Moreover some design prescriptions are given for safety barriers belonging to class 3 and 4. These are made to avoid well-known problems due to contact with snowplough blades such as impacts with the barrier post and rail damages. Therefore a minimum protruding distance from the post to the front edge of the rail is requested as well as a gliding condition list including no bolt or roughness on the rail to prevent the blade from gliding along the safety barrier.

The classification method showed in table 3 is considered reliable when applied to well-known design barriers that have been used for a long time on mountain roads or in snowy areas. Unfortunately it is of a more difficult comprehension when a new barrier or a barrier that has never been installed in such climate shall be evaluated. The difficulty stands in the lack of evaluation of the flexibility (elasticity) of the whole system.

A field exposure test has been added to the above classification in order to consider other safety barrier configurations a so called innovative safety barrier types. This test recalls the experimental approach developed and tested by Finnish Road Authority at the beginning of 00's [11]. During field exposure test the safety barrier is compared with a reference safety barrier (preferable two other safety barrier types) which is already classified in accordance with Table 3. In the standard few provisions are given in order to have a guideline for the test: the barriers must be installed on the same road section, the plough blade should be in contact with the rail during snow removal operations, and snow shall be removed at least 100 times before the evaluation. The evaluation is then based on the damage photographs and damage description of the system.
This type of test is unfortunately strongly depending on the type of equipment used for the test and on the skills of the personnel. Moreover it is known that the clearing of the snow at the asphalt level under the rail is almost impossible making the evaluation of the test more complicated. All these aspects tend to lower the reliability of the test.

As an alternative, a third assessment is possible. This last test is based on the simulation of snow clearing previously proposed by the Norwegian Road Authority [6].
In this case as well the safety barrier shall be compared with two other types of safety barrier, which are already classified in accordance with Table 2. The advantage compare to the previous test is that the simulation can be carried out in a controlled environment (a single man, a specific equipment, in a test field) increasing the reliability of the results. A second advantage is that this test can be performed in short time (probably one working day) reducing the overall evaluation time of new systems. Despite not being a real life test, it should be a representative simulation of working practise.

3.2 Future improvements of the reference standard

An update of the published classification is under construction at the time of writing. The main goal is to bring about improvements of a technical nature in accordance with rules of new harmonised standard given by CEN. The new proposal should become effective after CEN inquiry and formal vote with positive result at the end of 2015/ beginning of 2016[1].

Since the ranking imprinting has already been given in the published standard there is no will of making significant changes in the classification structure. Five categories should be defined for all metal barriers[2] (from 0 to 4): category 0 means not evaluated or that the evaluated barrier does not belong to other classes; category 1 is for barriers with very poor resistance to snowplough loads; category 2 is for barrier with poor resistance, category 3 is for barrier with moderate resistance and category 4 is for barrier with good resistance to snowplough loads. The minimum requirements for each category are similar to the ones presented in table 3. The new draft proposal is presented in table 4.

Table 4: resistance to snow removal new proposal for barrier's ranking

Category	Modified material thickness of a metal rail		Modified section modulus against horizontal loads		Strength against vertical loads of the connection between a post and a rail
	Open profile (mm)	Tube (mm)	Rail (cm^3)	Post (cm^3)	
4	≥ 4	≥ 2.9	≥10	≥12	≥ Shear strength of M10 4.6 bolt
3	≥ 3	≥ 2.2	≥5	≥9	≥ Shear strength of M10 4.6 bolt
2	≥ 2	≥ 1.9	≥ 3	≥ 6	No requirement
1	Wire rope fence				
0	not evaluated or not fulfilling other classes				

In order to include any possible metal material (ex. Steel, aluminium, special alloy, etc.) the modified material thickness equation (4) and modified section modulus equation (5) are reformulated adding the square root of the ratio between the rail material modulus of elasticity and the steel modulus of elasticity (E).
The modified material thickness should be then calculated by using the following equation (7):

$$t_{mod} = t \cdot \left(\frac{f_y}{235\ N/mm^2} \cdot 1.1\right)^{1/2} \cdot \left(\frac{E}{210\ Gpa}\right)^{1/2} \quad (7)$$

And the modified section modulus shall be calculated by using the following equations:

$$W_{mod} = W_{rail} \cdot \frac{f_y}{235\ N/mm^2} \cdot 1.1 \cdot \left(\frac{E}{210\ Gpa}\right)^{1/2} \quad (8)$$

[1] This is an estimation based on the current status of the product standard and the work of working group 1 of TC226.
[2] Harmonized standards shall define product's classification based on product's performances; references to construction type shall be avoided (ex. Materials).

$$W_{mod,post} = W_{post} \cdot \frac{f_y}{235\ N/mm^2} \cdot 1.1 \quad (9)$$

These equations are applicable for metal rails and metal, concrete, plastic and wood posts, when f_y is replaced by a relevant strength parameter of the material.

Moreover, an effort has been made to include all possible types of barrier (not only rail-post barriers) within the classification. Therefore a new table should be introduced to give a “lateral resistance condition” for barriers lying freely on the ground without embedded posts. This condition is based on the results of TB11 test[1] [14]. The permanent lateral displacement in TB11 impact test is classified as shown in table 5; this condition should be applied only to category 3 and 4.

Table 5: resistance to snow removal operation - lateral resistance condition

Category	Permanent lateral displacement in TB11 impact test
4	< 0,05 m
3	0,05 m to 0,2 m
2 And lower	≥ 0,2 m

Both tables 4 and 5 should be used for barriers made of metal plate without embedded posts. For concrete barriers lying freely on the ground extra conditions might be added like a check of the damages reported during TB11 impact and an update of the minimum compressive strength class of the concrete (already included in the published standard).

Alternative test procedures (exposed field test and clearing simulation test) as described in chapter 3.1 have not been heavily modified for the moment.
During the exposed field test the safety barrier should be compared with two different barriers that belong to two different categories of table 4 and the inspection should be made annually during five consecutive years. The relevant change for this test might be the introduction of “density parameters” for the evaluation of the safety barrier damages due to impact with the snowplough blade. The density parameters measured as number of permanent deflections, dents and/or scrapes divided by length of the system are recorded for each type of barrier and compared to each other. The use of density parameters should simplify the evaluation and help the classification of new items.

4 REMARKS AND FINAL CONCLUSIONS

The new assessment for safety barriers resistance to snow plough loads adopted within the last published revision of EN 1317-5 is a step forward for improving the correct use of these systems when installed on mountain roads or in Nordic countries.

[1] TB11 test is an impact test carried out with alight car (900kg) impacting the VRS at 100 km/h and with an angle of 20 degrees.

Unfortunately this does not mean that the safety barriers currently on the market will be certainly assessed to snow resistance for two reasons: firstly the producers can declare a “NPD” (no performance declared) avoiding affixing any information related to this assessment and secondly this applies only to systems that have been assessed after the publication of the corrigendum of the product standard in August 2012. Old products can obviously be reassessed on demand but this is an expensive procedure. Local and national authorities should press the producers of barriers requiring systems that are assessed for resistance to snow removal operations when preparing their own tenders but only few countries in Europe are interested in this issue.

Unfortunately prediction of permanent damages caused by winter maintenance operations is really difficult if not impossible because it depends on many variable factors that are sometimes controllable, but environmentally dependent (they change from place to place), and sometimes totally random. This is why the standard has so far been constructed on collected experience and good-practice; calculations or virtual methods have not been able to demonstrate their reliability.

The evaluation method described in the standard is based on the experience of only few countries and has not been applied to all possible types of systems; it is therefore limited. An example of these limits is the use of this method for bridge parapet that is of a possible uncertainty particularly because these safety barriers have generally really stiff posts and anchorages which leads to a possible higher concentrate load on the barrier rail just before the posts.

At the moment being some barrier layout/construction types are not included in this classification: the expected changes developed for the next revision of the standard could improve the current situation including all known systems.
Some other already classified systems can lead to unresolved dilemmas such as wire rope fences for example: when evaluating the resistance to snow removal operations a barrier shall be classified as a wire rope fence as long as a metal beam does not prevent the plough truck from having a direct contact with the posts, and as long as the main longitudinal elements are made of metal wire rope. Taking in consideration the new ranking (from category 0 to category 4) the wire rope systems are defined as category 1, very poor resistance, but in some cases they have shown better performance than other systems that were ranked in a higher category. Figures 10 and 11 show a real installation on a mountain road in Norway where a wire rope and standard Norwegian safety barrier are installed on the same road section.

Figure 10: wire rope safety barrier on a mountain road in Norway

Figure 11: standard Norwegian safety barrier (wooden posts) on a mountain road in Norway

The Norwegian standard safety barrier would be ranked in new category 2 and the wire rope barrier in category 1. Despite the fact that the Norwegian standard safety barrier has been installed for many more years, this shows that wire rope can be used on mountain roads if the snow clearing operation is made without constant contact with the rail and if the personnel are skilled. This is why the ranking must be properly explained to the final users (national and local authorities as well as road owners) in order to avoid any misunderstanding or misinterpretation.

The likely future improvement on the standard will help the harmonization and the correct ranking of safety barriers. An evaluation that could include all different materials and typologies of safety barriers is indeed necessary but there are still some doubts concerning the equity of different material rankings that maybe need to be investigated before the revised standard is published. This is independent from the fact that damages to safety barrier are generally more common on steel barrier.
A flexibility criterion should be analysed more deeply in order to combine the ranking evaluation with the real behaviour of the system as a whole.

The field exposure test is probably the best way of studying the response of a safety barrier when performed in a controlled and reliable environment. Resistance to snow plough operations being one of the mandate characteristics of a safety barrier, it shall be assessed at the same time of the “Performance under vehicle impact”, meaning that a long term assessment method is probably not of any practical use. The exposed field test that requires a minimum of 100 passages (snow clearing) or a five-year inspection period is or will be impossible to use for new products. New products cannot be installed on traffic roads before the assessment is completed; moreover, if the manufacturer decides to declare a NPD, a reassessment some years later will be unlikely to happen since it is an expensive process.

The new draft of the standard should include an evaluation of snow banks weight (vertical loads) that could go beyond the good-practice method used at the moment. It seems that a simple calculation should be enough to avoid problems or any damage of the safety barrier. It is necessary that the proposal of Professor Norem or a similar one is included in the next revision.

In general safety barriers should not be seen as a problem for winter maintenance operations but as a part of the road system that should be maintained operative during winter period.

Finally, ploughing speed is considered a main factor in order to achieve a cost-effective result; unfortunately maintenance operations driven at higher speed increase the risks of a safety barrier suffering major damages. An interesting step would be to make different rankings based on equipment's speed class.

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