1. Equivalent Barrier Speed

The **Equivalent Barrier Speed** (**EBS**) is the speed that equalizes the vehicle's kinetic energy with the energy absorbed in plastic deformation. The EBS is determined according to the formula:

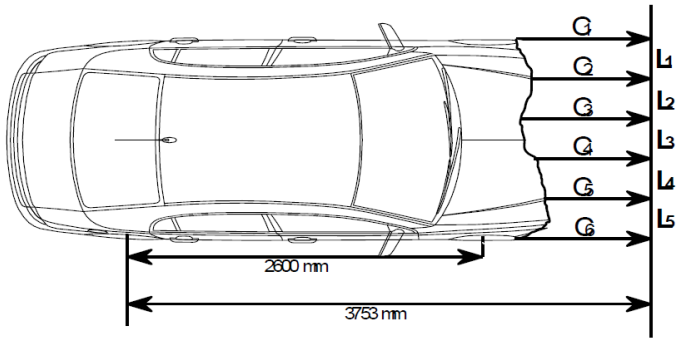
$$EBS = \sqrt{\frac{2E_a}{m}}$$

Where:

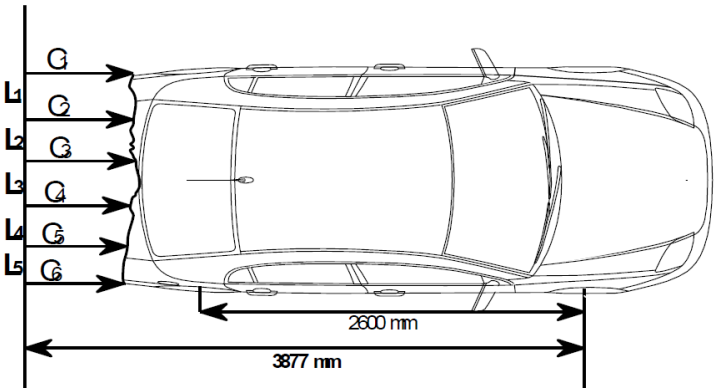
- **m**: Vehicle mass
- $\mathbf{E_a}$: Energy deformation

The most used methods to calculate strain energy are the **McHenry** and **Prasad** methods (both based on the Campbell method). These methods are based on measuring the deformation of the vehicle, dividing the length of the deformed face into segments (of equal or variable length), and measuring the depth of the deformation relative to a reference measurement.

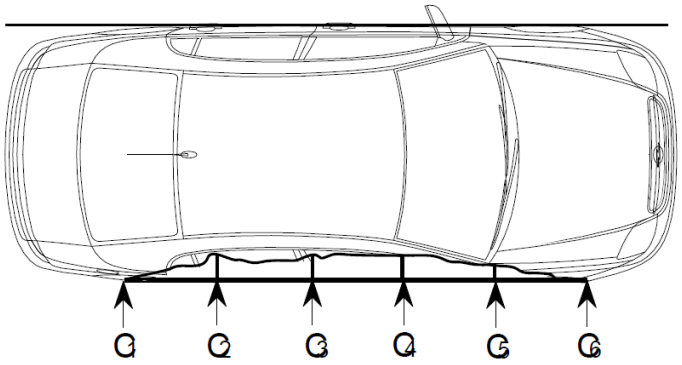
Measurement of the frontal area deformation:



Measurement of the posterior area deformation:



Measurement of the lateral zone deformation:



1.1. Vehicle deformation energy using McHenry's method

This method determines the energy absorbed in a crash against a fixed barrier by introducing a series of strain measurements into the following expression:

$$E_d = \sum_{i=1,n} L_i \left(A \left(\frac{C_{i-1} + C_i}{2} \right) + \frac{B}{2} \left(\frac{C_{i-1}^2 + C_i^2 + C_{i-1}.C_i}{3} \right) + \frac{A^2}{2B} \right)$$

Where:

- **L**: Width of deformation.
- **A**: McHenry stiffness coefficient A.
- **B**: McHenry stiffness coefficient B.
- **Ci**: Deformation depth.
- **Li**: Distances between measurements.

McHenry coefficients are determined for each type of vehicle and type of crash according to the following table:

Category	**Front**		**Side**		**Rear**	
	A (N/m)	B (N/m^2)	A (N/m)	B (N/m^2)	A (N/m)	B (N/m^2)
Category 1	52.850	323.830	13.475	254.930	64.050	261,820
Category 2	45.325	296.270	24.500	461.630	68.425	282,490
Category 3	55.475	385.840	30.275	392.730	71.750	303,160
Category 4	62.300	234.260	25.025	344.500	62.475	389,570
Category 5	56.875	254.930	30.975	323.830	51.975	482,300
Van	67.025	868.140	0	0	52.500	378,950

1.2. Vehicle deformation energy using Prasad's method

This method determines the energy absorbed in a crash against a fixed barrier by introducing a series of strain measurements into the following expression:

$$E_d = L.\frac{d_0^2}{2} + \sum_{i=1,n} L_c\left(d_0.d_1.\left(\frac{c_i - c_{i-1}}{2} + c_{i-1}\right) + \frac{d_1^2}{2}\left(\frac{(c_i - c_{i-1})^2}{3} + c_{i-1}^2 + (c_i - c_{i-1}).c_{i-1}\right)\right)$$

Where:

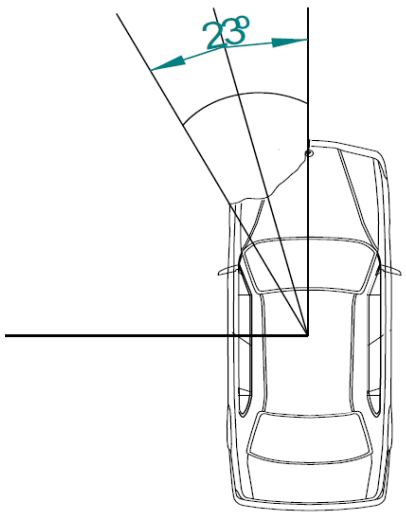
- **L**: Width of deformation zone.
- **d0**: Prasad Stiffness coefficient d0.
- **d1**: Prasad Stiffness coefficient d1.
- **Ci**: Deformation depth.
- **Lc**: Distances between measurements.

Prasad coefficients are determined for each type of vehicle and type of crash according to the following table:

Category	**Front**		**Rear**		**Side**	
	d0	d1	d0	d1	d0	d1
Category 1	92,87	569,06	125,18	511,68	26,69	504,9
Category 2	83,27	544,31	128,74	531,74	36,06	679,43
Category 3	89,31	621,16	130,31	550,6	48,31	626,68
Category 4	128,68	484,16	100,09	624,16	42,64	586,94
Category 5	112,64	504,91	74,84	694,48	54,43	569,06
Van	71,94	931,74	85,28	615,5	0	0

1.3. Energy correction factor in oblique collisions

In angular collisions against a fixed barrier, the force does not act like a perpendicular line to the affected surface of the vehicle. However, the deformation depth is measured perpendicular to the vehicle surface, so an adjustment is needed to consider the extra distance the vehicle surface moves while being deformed.



For the angular correction of the energy lost in the deformation, the following formula is used:

$$edef_c = edef * (1 + tan^2\alpha)$$

Where:

- **α**: Angle of crushing relative to a perpendicular to the involved end or side of the vehicle.
- **edef**: Deformation energy.
- **edef$_c$**: Corrected deformation energy.

2. Calculate speed from skid marks

The skid marks during an accident reconstruction process allow us to estimate, with a great degree of approximation, the driving speed, the speed at the beginning of the skid marks, and the post-collision speed.

2.1. Coefficient of friction between the tires and the roadway

It is necessary to consider the type of surface, its condition, the humidity conditions, and the estimated speed at the braking time to calculate the speed from the skid marks. For this, the following table of friction coefficients is used:

Surface Status	**Dry**		**Wet**	
	< 50km/h	**> 50km/h**	**< 50km/h**	**> 50km/h**
Concrete				
New	0.80 - 1.20	0.70 - 1.00	0.50 - 0.80	0.40 - 0.75
Used	0.60 - 0.80	0.60 - 0.75	0.45 - 0.70	0.45 - 0.65
Polished by traffic	0.55 - 0.75	0.50 - 0.65	0.45 - 0.65	0.45 - 0.60
Asphalt				
New	0.80 - 1.20	0.65 - 1.00	0.50 - 0.80	0.45 – 0.75
Used	0.6 - 0.8	0.55 - 0.7	0.45 - 0.7	0.4 – 0.65
Polished by traffic	0.55 - 0.75	0.45 - 0.65	0.45 - 0.65	0.4 – 0.6
With excessive tar	0.5 - 0.6	0.35 - 0.6	0.3 - 0.6	0.25 – 0.55
Paving stone				
New	0.75 - 0.95	0.6 - 0.85	0.5 - 0.75	0.45 - 0.7
Polished by traffic	0.6 - 0.8	0.55 - 0.75	0.4 - 0.7	0.4 - 0.6
Compact stone				
New	0.75 - 1.0	0.7 - 0.9	0.65 - 0.9	0.6 – 0.85
Polished by traffic	0.5 - 0.7	0.45 - 0.65	0.3 - 0.5	0.25 - 0.5
Gravel				
Compacted	0.55 - 0.85	0.5 - 0.8	0.4 - 0.8	0.4 – 0.6
Loose	0.4 - 0.7	0.4 - 0.7	0.45 - 0.75	0.45 – 0.75
Slag				
Compacted	0.5 - 0.7	0.5 - 0.7	0.65 - 0.75	0.65 – 0.75
Stone				
Crushed	0.55 - 0.75	0.55 - 0.75	0.55 - 0.75	0.55 – 0.75
Ice				
Smooth	0.1 - 0.25	0.07 - 0.2	0.05 - 0.1	0.05 – 0.1
Snow				
Compacted	0.3 - 0.55	0.35 - 0.55	0.3 - 0.6	0.3 - 0.6
Loose	0.1 - 0.25	0.1 - 0.2	0.3 - 0.6	0.3 - 0.6
Metal grille				
With slots	0.7 - 0.9	0.35 - 0.75	0.25 - 0.45	0.2 - 0.35

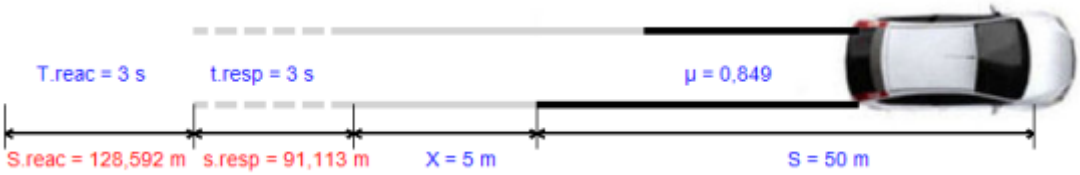
2.2. Description of the calculation method

The estimated speed from the skid marks is determined according to the following formula:

$$v_i = \frac{1}{2}(\mu.cos\alpha + sen\alpha).g.t_r + \sqrt{v_f^2 + 2.(\mu.cos\alpha + sen\alpha).g.(X+S)}$$

Where:

- **v_f**: Final speed in m/s. It is 0 if there is no collision, otherwise it is the speed at which the collision occurred (it may be the EBS).
- **S**: Length of skid.
- **X**: Crawl space without skid mark. This gap corresponds to the moment when the wheels lock but there are no skid marks due to the time it takes to warm up. Usually this space is between 1 and 3 meters.
- **μ**: Roadway friction coefficient.
- **t_r**: The time elapsed from when the brake is applied until the wheel are locked. The response time of the brake system is between 0.2 and 0.6 seconds, with 0.25 seconds as the most usual value.
- **α**: Roadway slope.
- **g**: Acceleration due to gravity.



3. Braking distance

The stopping distance of a vehicle is determined according to the following formula:

$$D = v.(t_{reac} + t_{resp}) - \frac{\mu.g.t_{resp}^2}{4} + \frac{(v - \frac{\mu.g*t_{resp}}{2})^2}{2.\mu.g}$$

Where:

- $\mathbf{v_f}$: Driving speed in m/s
- $\mathbf{t_{resp}}$: Brake system response time.
- $\mathbf{t_{react}}$: Driver reaction time.
- **μ**: Roadway friction coefficient.
- **g**: Acceleration due to gravity.