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STUDY ABOUT THE INCIDENCE OF THE USE OF SAFETY BELTS WITH REGARD TO REGULATION 66 OF GENEVA

presented by Spain

(Based on the paper presented in the Meeting about Buses and Coaches.
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1. INTRODUCTION

In spite of the fact that transport by bus and coach is the safest system of collective transport except for the airplane, the social impact that accidents of this type of vehicles use to produce and the general desire of safety improvement of all means of transport, provokes that in last years it exists a great concern to introduce new requirements that make increase both active and passive safety in buses and coaches.

The international organisms of regulation are developing an intense and continuous labour to establish new safety requirements. Recently regulations 36 and 52 have been revised and regulation 80 with regard to the strength of seats and their anchorages as well as regulation 66 with regard to the strength of the superstructure in case of rollover have begun to been applied.

On the other hand, European Union adopted the decision of making obligatory the use of safety belts for all bus seats and a directive has been established to specify the technical requirements they must comply with.

However, this intense labour in the establishment of new safety requirements make it necessary that regulations are in perpetual evolution. In the present work carried out in collaboration among the company IRIZAR S. Coop. and INSIA is approached the possible incidence of the use of safety belts with regard to Regulation 66 of Geneva. It has been carried out hoping that works of this type let us know what happen in case of accident and constitute a support in decision making.

2. PREVIOUS CONSIDERATIONS ABOUT THE INFLUENCE OF INSTALLATION OF SAFETY BELTS IN REGULATION 66

Regulation 66 establishes that the superstructure of the vehicle will have strength enough to ensure that during and after the rollover test defined, no displaced part of the vehicle intrudes into the residual space defined and no part of the residual space projects outside the deformed structure.

This way, it is a vehicle without longitudinal speed that impacts laterally over a rigid surface so that the energy to be absorbed is the potential energy generated between the position of instability and the end of the compression phase.

$$E = 0.75 \cdot M \cdot g \cdot h$$

where:

M = the unladen kerb mass of the vehicle (kg)
g = 9.8 m/s^2
h = the fall of centre of gravity (m)
E = absorbed energy (J)

Alternatively, the energy can be calculated by means of the formula:

$$E = 0.75 \cdot M \cdot g \cdot \left(\sqrt{\left(\frac{W}{2}\right)^2 + H_S^2} - \frac{W}{2H} \cdot \sqrt{H^2 - 0.8^2} + 0.8 \cdot \frac{H_S}{H} \right) (Nm)$$

where:

W = the overall width of the vehicle
H_S = the height of the centre of gravity of the unladen vehicle (m)
H = the height of the vehicle (m)

As it can be observed, it is only considered the unladen kerb weight of the vehicle since the passengers do not have bond with the vehicle.

With the installation of safety belts it will exists a union between the passengers and the vehicle that should be considered. But it is not a rigid union, and therefore not their entire mass should be considered. At the present time no experimental data is available to evaluate the percentage of mass that should be included.

We will use two examples to estimate the maximum energy increment that may be produced, supposing the entire mass of passengers fixed to the vehicle.

Example nº 1:

Let us consider a standard coach 12 m length, 3.5 m height, 2.5 m width, a kerb mass weight of 13000 kg and height of the centre of gravity =1,33 m. According to the formula of determination of energy to be absorbed, E = 87.000 J is obtained.

When installing safety belts, and supposing 55 passengers, the increment of weight, considering 68 kg/passenger, is of 55 x 68 = 3740 kg, which supposes a 30 percent increase of the mass. From the formula of the energy, it can be observed that energy is proportional to mass and therefore the energy increment would also be of 30%. However, the variation in the position of the centre of gravity of the vehicle must be considered too. If it is considered that vehicle floor is situated 1.573 m above the road, seat height is 450 mm, and the position of the passenger's centre of gravity is 322 mm above the seat, then the position of the centre of gravity of the passengers is 2.345 m above the road. (fig. 1)

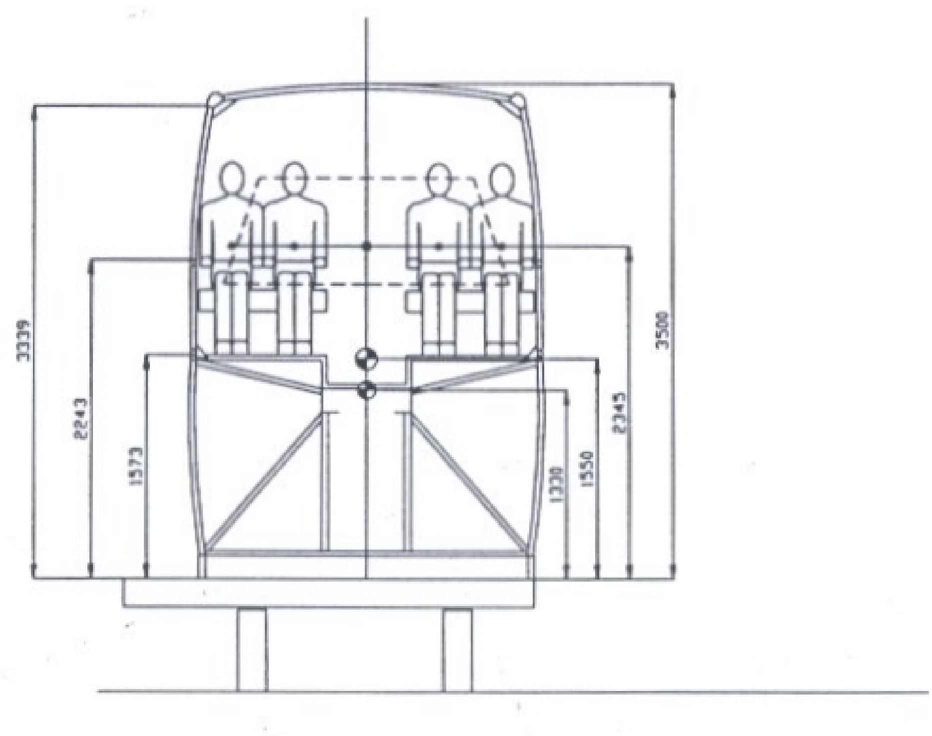

Figure 1

In this way, composing this mass and height of centre of gravity (3740 kg and 2.345 m) with mass and height of centre of gravity of the unladen vehicle, a vehicle with a mass of 16740 kg and a height of centre of gravity of 1.55 m is obtained. It means an energy to be absorbed E = 140000 J. Comparing this value with that of the unladen vehicle, the energy increment is of the 55%.

Example nº 2

Let us consider a standard small capacity coach with 19 seats, 2.7 m height, 2 m width, a kerb mass weight of 3770 kg and its centre of gravity located 1 m above the road. According to the formula of determination of energy to be absorbed, E = 21.000 J it is obtained.

If installation of safety belts is considered, the weight of the passengers will be 19 x 68 = 1292 kg (which implies a mass increment of 34%), located at 1.95 m above the road, the group will have a total weight of 5062 kg and centre of gravity will be 1.25 m above the road. Then energy to be absorbed is 38000J, that supposes an increment of 80% compared with the energy of the unladen vehicle.

As it is observed of the two outlined examples the energy increment to be absorbed may be high, increasing the tendency in vehicles of smaller dimensions.

3. THEORETICAL-EXPERIMENTAL STUDY CARRIED OUT

To determine the effective energy increment IRIZAR and INSIA have carried out a combined study on a vehicle type (CENTURY 12.35) whose dimensions with regard to Regulation 66 are shown in the following table:

Weight	13365	Kg
H_T	3.592	m
W	2.5	m
H_S	1.33	m
E_{R66}	88777	J

The approach carried out has been based on the results obtained from the analysis of two rollover tests of representative body sections of the superstructure of the vehicle mentioned above . The first one was a rollover test of a representative body section of the superstructure endowed with certain additional elements (seats and anchorages, lateral and floor plates, laminated glasses, baggage compartment panels, floor panels, etc). For the second rollover test an identical body section was prepared, in whose seats 12 dummies of 69 kg were located with the safety belts fastened. The data and results obtained from the analysis of both rollover tests and its later comparative analysis are summarized next:

	Body section 1	Body section 2
Mass	1140	$1140 + k\cdot 828$
H	3.592	3.592
W	2.5	2.5
H_S	1.824	$\frac{1.824\cdot 1140 + 2.345\cdot 828\cdot k}{1140 + 828\cdot k}$
E_{R66}	11733	17425

Where:

Mass ≡ Total mass of the body section and ballast.
H ≡ Total height.
W ≡ The overall width of the vehicle.
H_S ≡ Height of the centre of gravity.
E_{R66} ≡ Energy according to Regulation 66.
k ≡ Percentage of mass that intervenes in the energy increment.

The energy absorbed by body section 1 is obtained according to the expression of Regulation 66. A finite element model was made and validated, obtaining for body section 1 an absorbed energy very similar to the experimental one. The energy absorbed by body section 2 is then obtained from the finite element model, taking into account the deformations suffered by this body section 2 in the rollover test.

Therefore, the energy increment being present on the test of body section 2 in relation to body section 1 is:

$$\Delta E = 48.5\ \%$$

And the percentage of the total weight of the dummies that intervenes in the deformation is:

$$k \approx 0.5 \equiv 50\%$$

These results imply the following increments of both the vehicle mass and absorbed energy:

Considering a distribution in the vehicle of 55 passengers + bus driver, the total mass increment of the vehicle will be:

$$\Delta M = 3740\ \text{kg}$$

It implies the following estimated height of the centre of gravity of the vehicle:

$$H_S = \frac{13365 \cdot 1.33 + 3740 \cdot 0.5 \cdot 2.345}{13365 + 3740 \cdot 0.5} = 1.454\ m$$

And the energy to be absorbed according to Regulation 66 will be:

$$E_{R66} = 114633\ \text{J}$$

which represents an energy increment for the whole vehicle of:

$$\Delta E_{R66} = \frac{114633 - 88777}{88777} = 29\ \%$$

It stands out the high value corresponding to the energy increment , what induces to think that installation of safety belts in coach seats and its compulsory use increases the damages suffered by the superstructure.

It is also observed that not all the added mass becomes energy of deformation, but it is only a part of the mass that translates into additional deformations of the superstructure. This study reveals that the percentage of mass that is translated into energy of deformation is approximately 50% of the total mass of passengers.

Based on these results, it should be thought the possible necessity to carry out modifications of Regulation 66 in order that the security level reached in buses and coaches thanks to its application does not decrease. These modifications would be guided to take into account the percentage of the mass of passengers that translates into energy of deformation, outlining differences among vehicles depending on parameters such as the number of seats and their distribution.

4. CONCLUSIONS

- ✓ It is logical to think of a variation of technical prescriptions specified in Regulation 66 due to the installation of safety belts. It is necessary for this aim to extend the experimental studies outlined in the present work, in order to verify the percentage increment of the energy to be absorbed during a rollover, due to the presence of retained passengers.

- ✓ Not all the added mass becomes energy of deformation, but just a part of the passengers mass translates into additional deformations of the superstructure. From the experimental study carried out, the percentage of belted passengers mass to be considered added to the vehicle for the estimation of the amount of energy to be absorbed, should be about 50%.

- ✓ The problem can be bigger in the small capacity vehicles. Assuming 50% of belted passengers mass added to the vehicle, an energy increment of 40% takes place in a 19 seats vehicle, while in a 55 seats vehicle the energy increment is around 30% related to the unoccupied situation.

- ✓ The influence of passengers takes place through safety belts, seats and their anchorages. As technical requirements of these transmission elements are mainly defined with regard to longitudinal efforts, it is difficult to generalize their behaviour in rollovers. Side strength tests and requirements should be defined.

- ✓ Technical requirements with regard to their structural behaviour in small capacity vehicles and double-deck vehicles should be defined before thinking of the influence of installing safety belts on them.

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