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Presented by
Hungary

LAMINATED SAFETY GLASING
(SOME EXPERIENCES WITH WINDOWS AND WINDSCREENS IN BUS ROLLOVERS)

1. The possible use of laminated side windows on buses to prevent the partial and total ejection of passengers in rollover is discussed in GRSG and the expert group IG/R.66 also got the task to study this question. CC (UK) carried out a study based on computer simulation and presented its results on the 92nd GRSG session (informal doc. GRSG-92-20) To the validation of the different computer models the real behaviour of the glued laminated side windows would be necessary and useful.

2. This kind of experience does not exist because laminated side windows are not in use. But it could be useful to study the behaviour in real rollover situations
   - the laminated windscreens with different bounding
   - toughened safety glass side windows
   - the relation between the structural deformation and the behaviour of the wind screens and side windows

3. Some examples are shown below coming from real rollover accidents or full-scale rollover tests.

3.1. **Real rollover accident**




- Class III. 11 m. Strong, approved superstructure
- ½ rotation (stop on its roof), no significant structural deformation. Soft, grassy ground.
- two-part windscreen, laminated safety glass built in rubber profile. One side cracked, but did not drop out.
- Side windows (toughened safety glass) in rubber profile did not break or drop out.

3.2. **Rollover test (depth of the ditch was 1 m)**

- The same vehicle shown in 3.1. but not approved yet, the superstructure before the final reinforcement.
- Large scale structural deformation, the residual space was harmed
- The windscreen (laminated glass) built in rubber profile fell out and cracked at the corner of the impacted cantrail.
- The rear window (toughened safety glass) built in rubber profile dropped out and broke.
- The side windows (also in rubber profile) were broken.

3.3. **Real rollover accident**

- Class II. Vehicle, 11 m, strong, approved superstructure
- Rolling down on a slope, 2 ¼ rotations, 9-10 m level difference
- Same superstructure as in 3.1.
- No significant structural deformation
- Laminated windscreen in rubber profile, cracked and dropped out.
- Side windows (toughened safety glass) in rubber profile, on the impacted side all windows were broken, but on the right side only two windows.

3.4. **Real rollover accident**

- Class III, 12 m Strong, approved superstructure
- ¾ rotation on a slope, no significant structural deformation. The ground was soft, grassy, blunted dynamic impact forces.
- Glued laminated safety glass windscreen cracked and it was broken out for emergency exit. (At the upper edge of the windscreen the overlapping for the gluing is rather narrow)
- Glued side windows were broken, but not all of them
- The glued rear window did not break

3.5. **Rollover approval test**

- Same vehicle as shown in 3.4.
- Small structural deformation, the residual space remained intact.
- Glued windscreen (laminated glass) cracked but remained in its place
- Some of the glued side windows were broken but not all.
- The glued rear window did not break.

3.6. **Rollover test (depth of the ditch was 1,4 m)**

- Class I. vehicle, 11 m
- Large scale structural deformation, the residual space was harmed
- All the glasses were toughened safety glass built in rubber profile
- The windscreen dropped out and broke
- The side windows on the impact side were broken, but on the other side they did not break or fell out.

3.7. **Rollover test (depth of the ditch was 1 m)**

- Class I. and II. 11,4 m
- Large scale structural deformation, the residual space was harmed.
- All the glasses were glued.
- The windscreen (laminated glass) was cracked and broken but generally it remained in its place. It was glued to an auxiliary frame (profile) which was separated from the main frame.
- The rear windows was completely broken
- Some of the side windows were cracked or partially broken, but most of them survived.

3.8. **Real rollover accident**

- DD coach, tip over (Austria, 2006)
- Both windscreens (upper and lower) glued laminated safety glass, cracked but did not drop out. The upper one probably was “opened” for emergency exit.
- Slight deformation of the upper superstructure, all side windows were broken out.

3.9. **Real rollover accident (after frontal collision)**

- DD coach, rollover
- Upper superstructure collapsed, all upper side windows were broken out.
- Lower side windows remained in their place, one was broken out probably for emergency exit.

3.10. **Real rollover (tip over) accident**

- DD coach, turned on its side
- The glued lower windscreen was cracked and “opened” probably for emergency exit.
- No structural deformation, the glued side windows remained intact.

3.11. **Real “rollover” accident**

- Class III. vehicle
- The windscreen (laminated safety glass) built in rubber profile. It dropped out, fall dawn, cracked but remained in one piece.

3.12. **Rollover tests (very severe one made by VOLVO)**

- Class I. low floor vehicle, strong, approved superstructure
- Rollover on a slope, 3 ¼ rotations,18-20 m level difference. The ground was hard, stony, strong dynamic impact forces.
- Laminated windscreen built in rubber profile. After the first impact it started to fall out as one unit. After the second impact it left completely its bed.
- One of the glued side windows (toughened safety glass) was broken out (on the left side), the others remained intact after 3 ¼ rotations.
- The side window of the driver's cab – in a special frame – dropped out and broke in the first rotations.

4. **Some outcomes for considerations**.

The best way to get some information about the retention capability of laminated side windows is to make simple rollover tests with simplified body sections. The computer simulation of this problem would be also a useful tool if it could be validated by real tests and the required material properties of the laminated glasses and the glued joints would be available, based on laboratory measurements. Missing these data and information the experiences – coming from real rollover accidents and rollover tests – may be considered as first approach.

- The retention capability of the laminated side windows is important mainly in the range of small structural deformations, when the superstructure is strong enough. If the residual space is harmed (large scale structural deformation) the main problem is not the ejection of the occupants, but their "intrusion"
- In the studied examples three kinds of window installation systems could be observed:

- windows are installed with rubber profile into the steel frame of the bus
- windows are glued to the steel frame
- windows are mounted with an auxiliary frame into the steel frame of the bus (this windows generally are movable, openable)

- The general way of losing windows mounted with rubber profile: first the window falls out and after – coming the ground – breaks.
- The glued windows first crack, after break out, their glued edges – if the overlapping is wide enough and the gluing technology is correct – do not part from the steel :frame of the bus.
- There is no information enough about the windows with auxiliary frame. Different constructions and mountings may exist.
- The integrity, the soundness of the side windows depends on three major factors:
  - deformation of the structural frame in which the window is installed
  - the dynamic of the impact forces
  - the local contact of the window in its plane with the ground (local elevation, stone, etc.)

  In case of no structural deformation, no local contact an low dynamic impact forces the side windows could remain intact even in the case of one or more rotations. But these circumstances come together not too often.
- Some information about the general behaviour of the laminated glasses may be learned about the behaviour of the windscreens. The laminated, glued windscreen – even in the case of large distortion in its frame – does not fall out, does not “open” the window aperture. It cracks, but does not break.
- After the rollover more cracked windscreen were cut out (by firemen) to open emergency exit. Presumable the standard window breaker hammer is not enough to do that. This technology should be studied, perhaps it could be an easy solution for emergency windows.