SAFETY BELTS IN TOURING COACHES

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ABSTRACT

The touring coach is the safest means of transportation, safer than aircraft, railway, truck and passenger car. Nevertheless, spectacular accidents happen and attract the attention of the general public. Especially when coaches overturn, there are severe injuries and in individual cases even fatalities to be regretted. The paper deals with accident situations of coaches. Collision types with relevant deceleration phases and collision velocities will be deduced from that. The kinematics of dummies, the dummy-loadings, the belt forces to be transferred to the structure as well as the safety potential will be determined by computer simulation (MADYMO 3D). Relevant collision types are the 90° rollover, and, to a far lesser extent, the frontal crash. The two-point belt proves to be superior to the conventional three-point belt.

AS A RESULT of a number of serious bus accidents in the recent past, there has been increased public discussion about the safety of busses and questions concerning how to increase their safety have been raised. Studies dealing with accident types and accident frequencies and with safety measures and their implementation have been initiated or undertaken by bus manufacturers, bus operators, insurance companies, research institutes and legislative organs [1-6].

One particularly promising measure is the installation and use of safety belts [7]. In contrast to the situation with passenger cars, the installation and use of belts on passenger seats of motor coaches is not yet required by law. Today belts are installed on passenger seats only upon request by the customer. However, at present there exist no standardized testing specifications for determining the effectiveness of belts installed on passenger seats in motor coaches.

Before concrete steps can be taken to introduce belts in touring coaches, the accident situation must be analysed, requirements for the belts have to be formulated, and the consequences of using belts have to be predicted. The protection potential as well as the hazard potential have to be analysed. These questions were investigated in a research project carried out at the Institut für Straßen- und Schienenverkehr (Institute for Road and Railway Traffic) of the University of Berlin commissioned by the FAT (Forschungsverband Automobil Technik, Research Association of Automotive Technology). Computerized occupant simulation in the collision types, which are relevant for the safety of bus occupants, and the effect of belts as a restraint system constituted a substantial component of the studies.

LEGISLATION

Based on a resolution of the European Conference of Transport Ministers the coordination of technical specifications for coaches was taken up by the ECE working group WP 29 in 1967 as their working goal. In the process, a high level of safety was supposed to be maintained [4,5].

Four ECE regulations resulted from these tedious negotiations, which were shaped by compromises:

No. 36	Construction and function specifications for single-deck coaches
No. 52	Construction and function specifications for busses with small capacity
No. 66	Stability of the bus structure
No. 80	Stability of seats and their anchoring.

These ECE regulations came into force between 1976 and 1989. The application of ECE Regulation No. 66 for touring coaches is required by the national law in Great Britain and Spain. Although the Federal Republic of Germany has accepted the ECE regulations, it has not yet been considered making their introduction obligatory, because Germany is waiting until the final decisions about the future EU Guideline "Coaches" have been made.

Among other things, this future EU Guideline "Coaches" will contain the ECE regulations for "structure stability" and "seat stability" and will cover altogether the following areas:

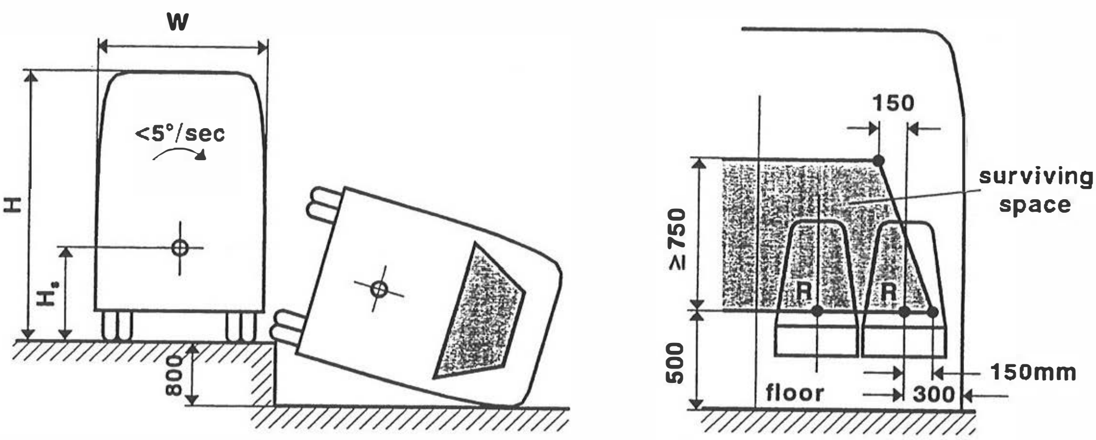
For normal operation:	safe entering and exiting, safe transport, safe handling of the vehicle.
In the case of a catastrophe:	avoidance of injuries, reduction of severity of injuries, emergency exits, evacuation, reduction of fire risk.

For the passive safety of touring coaches there are only two ECE regulations today, which are of importance, Regulation No. 66 (structure stability) and Regulation No. 80 (seat stability). Although, these regulations are not compulsory in Germany, they are taken into account by the bus manufacturers in the development and for the approval of new types by the authorities [8,9].

ECE Regulation No. 66: Testing of the stability of the seat backs and the seat anchoring in the case of a head-on collision when the passenger who is not wearing a safety belt hits the seat or seat back ahead of him. The testing conditions and specifications are described in Figure 1.

ECE Regulation No. 80: Testing of the roof structure of the bus, because after the bus has overturned onto the edge of its roof, a defined survival space must be preserved. Figure 2 shows the testing conditions and specifications. Proof can be supplied by testing or by computation [6], see Figure 3.

Fig. 1 - ECE Regulation No. 66. Stability of the bus structure



Energy to be absorbed by the roof structure

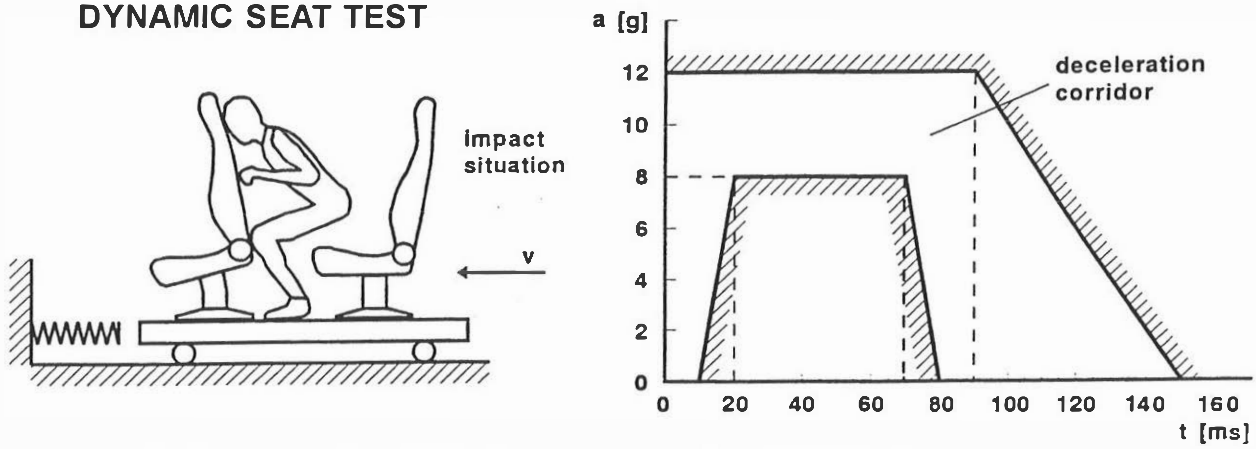
$$E^* = 0{,}75 \times M \times g \times \left(\sqrt{\left(\frac{W}{2}\right)^2 + H_s^2} - \frac{W}{2H} \times \sqrt{H^2 - 0{,}8^2} + 0{,}8 \times \frac{H_s}{H}\right)$$

M curb mass [kg]
g 9,8 m/s²
W width of the bus [m]
H_s hight of the center of gravity [m]
H hight of the bus [m]

Specification: No intrusion of the roof structure into the surviving space

Fig. 2 - **ECE** Regulation No. 80. Stability of seats and their anchoring in busses

DYNAMIC SEAT TEST



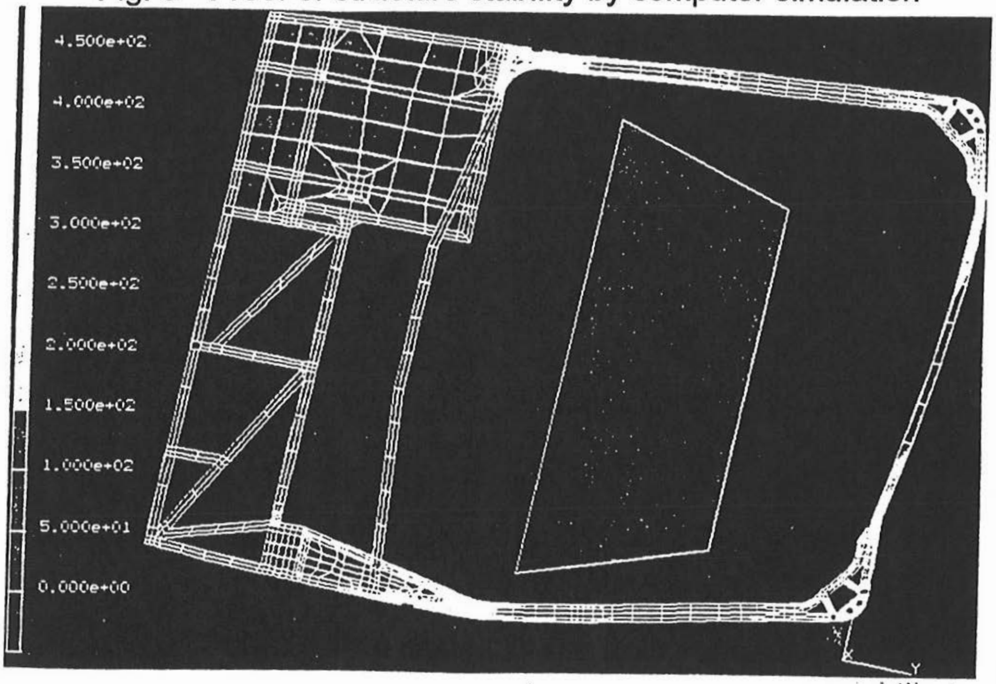
Specifications: **head HAC ≤ 500**
thorax ThAC ≤ 30g
femur FAC ≤ 10kN

v = 30 - 32km/h
$\bar{a}$ **= 6,5 - 8,5g**

STATIC SEAT TEST

Specifications: Under defined loadings to the seat back criteria of energy absorption and deformation have to be fulfilled

Fig. 3 - Proof of structure stability by computer simulation

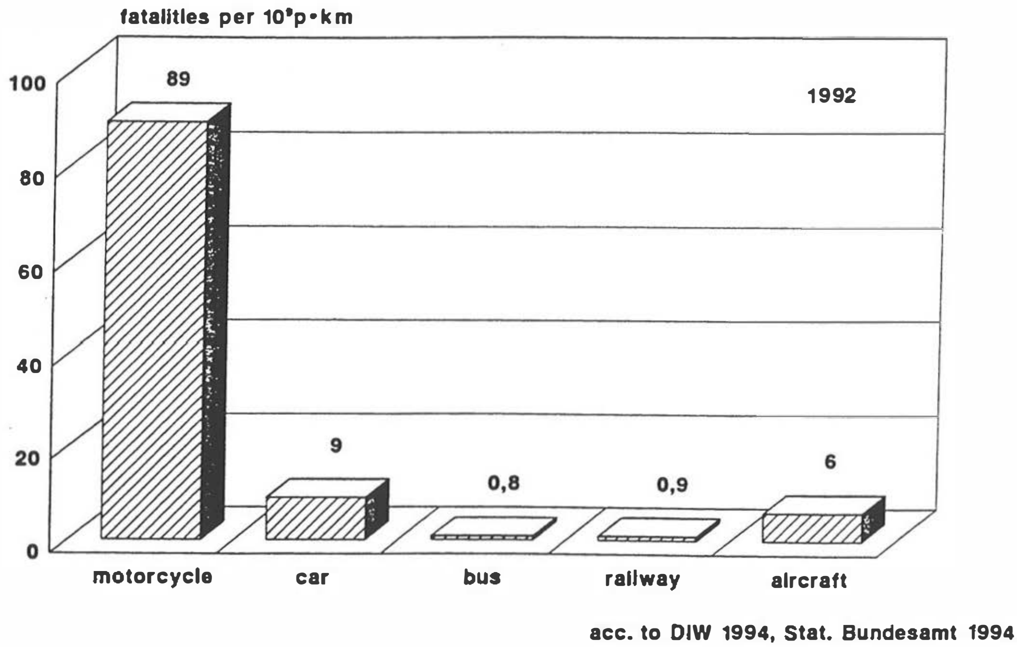


According to the latest version of the **EU** Guideline, safety belts are to be installed in busses only in "those seats with no passenger ahead", which means on seats in the very first row, which are in an exposed position, on seats next to the doors and on seats in front of tables. The bus manufacturers in Germany demand just like the **EU** Commission in Brussels that the installation and use of two point belts on all seats in touring coaches over 5 t have to be made compulsory. For small busses (3.5 to 5 t) manufacturers should be able to choose between two point and three point belts, and in mini-busses (up to 3.5 t) three point belts should be installed.

ACCIDENT ANALYSIS, COLLISION TYPES

First of all it must be remarked that the bus is one of the safest means of transportation. In Germany, for example, the risk of fatal injuries for bus occupants in relation to the transport service provided was only 9 % of that for passenger car occupants in 1992, see Figure 4 [15,16]. It should be noted that the relative high figure of aircraft fatalities cover commercial and private aircraft activities within the area of the Fed. Rep. of Germany.

Fig. 4 - Fatalities in reference to different means of transportation related to passenger kilometers travelled

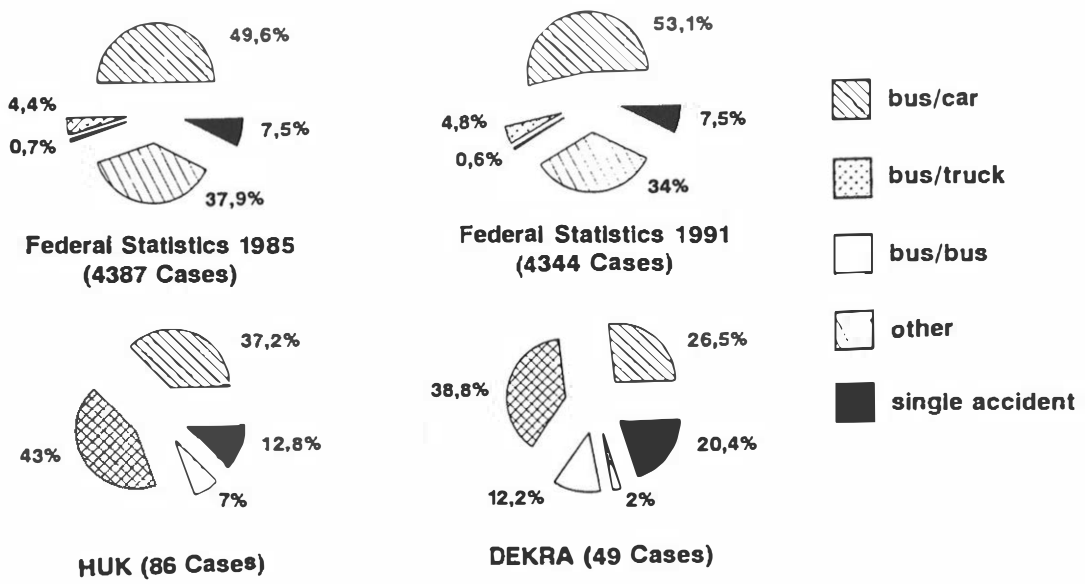


It is known that the most common collision type of busses is the frontal impact, followed by the frontal oblique impact, the rear-end collision and the overturn. Of these the most dangerous collision type is the overturn, which on an average involves more than four fatalities per accident [6, 10, 11].

The accident analysis used for this paper is based on an accident investigation carried out by the DEKRA as commissioned by the FAT (Forschungsvereinigung Automobiltechnik e.V.) [12]. The accidents, compiled between the years 1985 and 1993 and containing data for 48 accidents involving 50 busses, forms the data basis for the accident analysis of bus accidents, with the majority of them representing accidents reconstructed by motor vehicle specialists as part of the forensic clarification of the accidents. As far as the reliability of the evidence of these accident cases is concerned, it must be observed that these cases were investigated based on the assumption that there were injured bus occupants or such deformations of the vehicle as would make injuries of the occupants probable. For this reason the DEKRA data cannot correspond exactly to the general distribution of bus accidents. It is only relevant for accidents with severe consequences for the vehicle or its occupants. In order to ensure that the data record for these accidents is representative, comparisons with other accident investigations are carried out. The data, which form the basis for the comparisons were obtained from an evaluation of the federal statistic data made by the BASt (Bundesanstalt für Straßenwesen, Federal Traffic Institution) [11] and from an accident data record of severe bus accidents compiled by the HUK (Verband der Schadensversicherer, Association of Accident Insurances) between 1978 and 1985 [10].

Figure 5 contains a graphic representation of the distribution of the collision types in the various accident data collections. A comparison of the distribution of collision types for bus accidents occurring in the original West German states in the year 1991 (Federal Statistics) with that for the 48 accidents compiled by the DEKRA from 1985 to 1993 shows distinct differences. Single accidents of busses (10 cases or 20.4 %) and collisions with trucks (19 cases or 38.8 %) in particular have especially serious consequences for the vehicle and its occupants. Nearly 60 % of the 48 cases involve these two collision types alone. In comparison, they only make up 12.3 % in the Federal Statistics. Also in the Federal Statistics over half of the bus accidents are bus/car collisions (53.1 %), whereas in the DEKRA cases they constitute the comparably low percentage of 26.5 % (13 cases).

Fig. 5 - Types of bus accidents, different data sources



As the accidents contained in the DEKRA material were selected according to the aspect of the danger of injury to the bus occupants and the risk of injury to other parties involved in bus accidents (in particular passenger car occupants, pedestrians, riders of two-wheeled vehicles) was not taken into account, this explains the fact that the corresponding collision opponents are not represented at all or only underproportionately. A comparision of the Federal Statistics from different years with respect to collision types shows agreement to a very large extent.

The accident types of the DEKRA file and the HUK source, which both are containing severe bus accidents, are comparable. For this reason, it can be assumed that the 48 DEKRA accidents are representative for serious bus accidents with casualties for the bus occupants, but not for the bus accident situtation in general. If the collision type bus/car is disregarded, then 73.5 % of the DEKRA cases can be attributed to collision types which in the Federal Statistics of 1991 together comprise only 12.9 %, namely 7.5 % single accidents, 4.8 % bus/truck collisions and 0.6 % bus/bus collsions. This observation indicates that a relatively low number of accidents involving specific collision types lead to severe and fatal injuries of bus occupants.

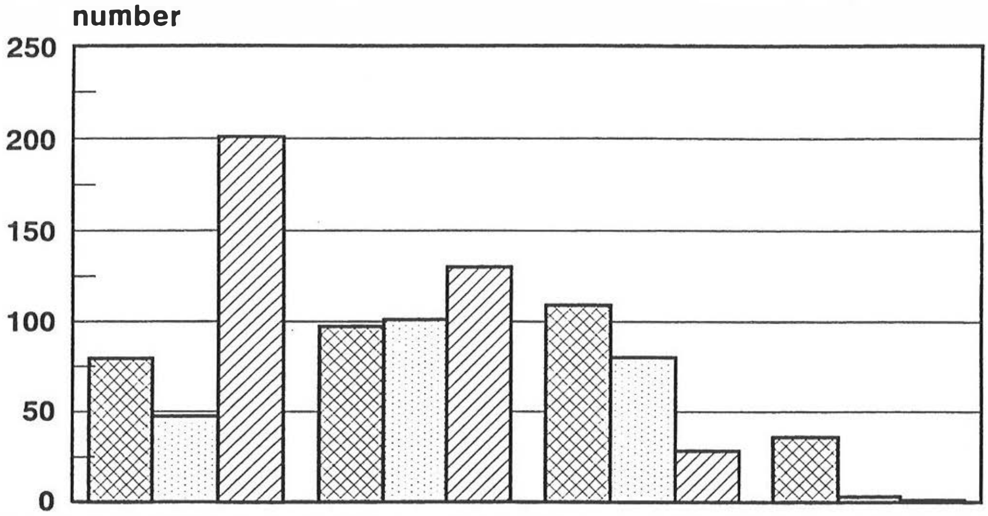
As with the collision types, the distributions of the accident locations in the Federal Statistics and in the accidents compiled by the DEKRA differ from each other. It becomes apparent that the vast majority of bus accidents occur within towns. In contrast, of the accidents recorded by the DEKRA only 16.3 % occurred within towns whereas accidents on federal superhighways as well as on federal, state and district roads show a higher representation when compared with the Federal Statistics. The bus occupants face the most risks in interurban and touring coach traffic, where the driving and collision velocities are correspondingly higher.

The analysis of accidents which are dangerous for the occupants will be carried out on the basis of the relevant collision types (see Figure 6). In addition to these, the collision type overturn/rollover will be introduced. A total of 8 out of the 48 accidents are of this collision type. One case must be accorded special status because of its specific causes of injury and is not regarded since it would influence the statistics considerably. It is astonishing that 50.2 % of all severely injured persons and even 90.0 % of all fatalities are to be attributed to the 8 accidents of the collision type overturn/rollover.

Before conclusions are drawn from this evaluation, the data material should be tested once again by a comparison with the accident data for severe bus accidents collected by the HUK-Association to ensure its representative character (see Figure 7). In the HUK-Association data material as well the majority of severely injured persons can be found in the collision types bus/truck and overturn/rollover. Particularly the fatally injured bus passengers are again to be regretted in the overturn/rollover accidents of busses. Therefore the DEKRA accidents can be considered representative with respect to the distribution of the severity of injury to bus occupants in serious accidents.

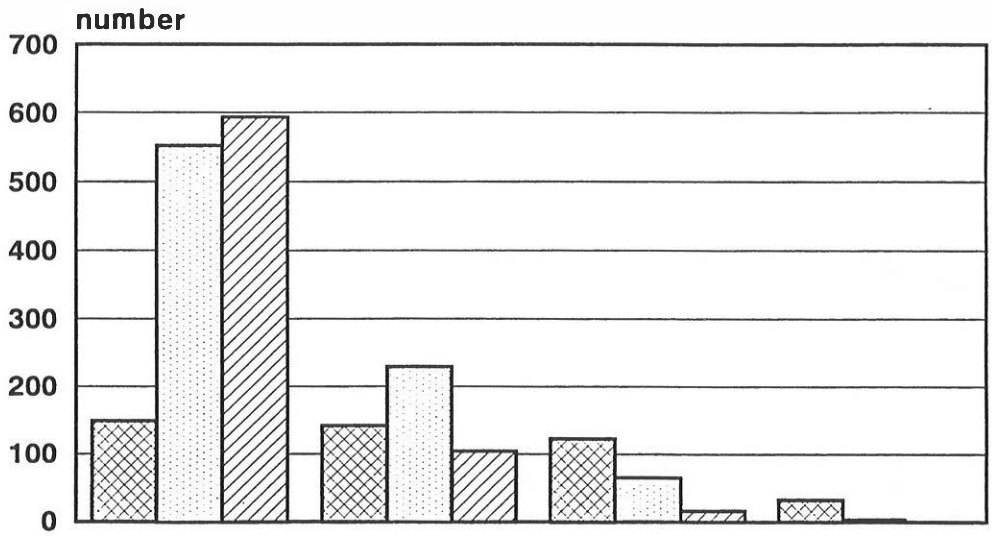
In summary it can be stated that overturn/rollover and, far behind, frontal impact are the most endagering collision types for bus passengers.

Fig. 6 - Injury severity in different collision types (48 DEKRA cases)



	uninjured	injured	severly injured	fatalities
Overturn/Rollover	79	97	109	36
Frontal Bus/Truck	47	101	80	3
Other Cases	201	130	28	1

Fig. 7 - Injury severity in different collision types (97 HUK cases)

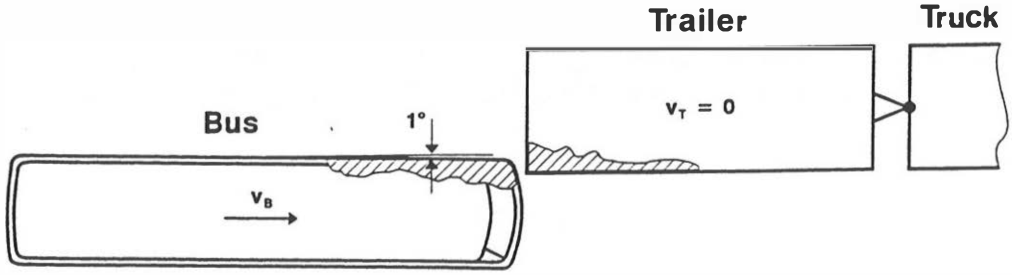


	uninjured	injured	severly injured	fatalities
Overturn/Rollover	150	143	124	34
Frontal Bus/Truck	552	229	66	5
Other Cases	593	105	18	1

THE COLLISION TYPE FRONTAL IMPACT OF BUS AGAINST TRUCK

In Figure 8 the impact of the left-hand side of a bus against a standing truck-trailer is recognizable as a typical frontal impact (Case No. 10753 of the Hanover Medical College). Of the 23 occupants 16 were injured, and most severely with AIS 3 the driver and some passengers sitting on the left-hand side. The longitudinal deceleration of the bus must have been under 5 g. The severe injuries were caused by the intrusions on the left-hand side.

Fig. 8 - Bus collision type: Frontal impact (example)



collision velocity v_B	=	97 km/h	acc. to Accident Analysis, Case No. 10753, MH Hannover
speed variation Δv_B	=	31 km/h	
equivalent energy speed EES_B	=	47 km/h	
collision angle	=	1°	
overlap	=	20 %	
VDI-code		06 F Y A W 9 50	

In a crash test at the DEKRA proving ground a bus impacted frontally against a fixed concrete barrier with an overlap of 30 % and at a speed of 31 km/h. With a deformation of 1.2 m and a crash duration of 200 ms, the deceleration was at 4 g on an average.

The evaluation of 10 frontal impact collisions bus/truck (5 rear-end and 5 head-on collisions) from the accident file [12] aimed at analysing the accident characterizations

relative impact speed,
overlap and
crash deceleration.

The energy absorbed in the collision is

$$W_B + W_T = \frac{1}{2}\frac{m_B \cdot m_T}{m_B + m_T}(1-k^2)(v_B - v_T)^2$$

W_B, W_T	Deformation energies of bus, truck
m_B, m_T	Masses of bus, truck
k	Restitution coefficient (0.25 - 0.70)
v_B, v_T	Speeds of bus, truck before the collision.

The mean crash deceleration $\bar{a}_B$ of the bus can be determined from the specific deformation energy W_{Bsp} of the bus and the crush s_B of the bus :

$$W_{Bsp} = \frac{W_B}{m_B} = \frac{m_B \cdot \bar{a}_B \cdot s_B}{m_B}$$

$$\bar{a}_B = \frac{W_{Bsp}}{s_B} \quad .$$

For this it is presupposed that the acceleration versus time remains constant and that appropriate assumptions about the distribution of crash energy W_B/W_T for bus and truck can be made.

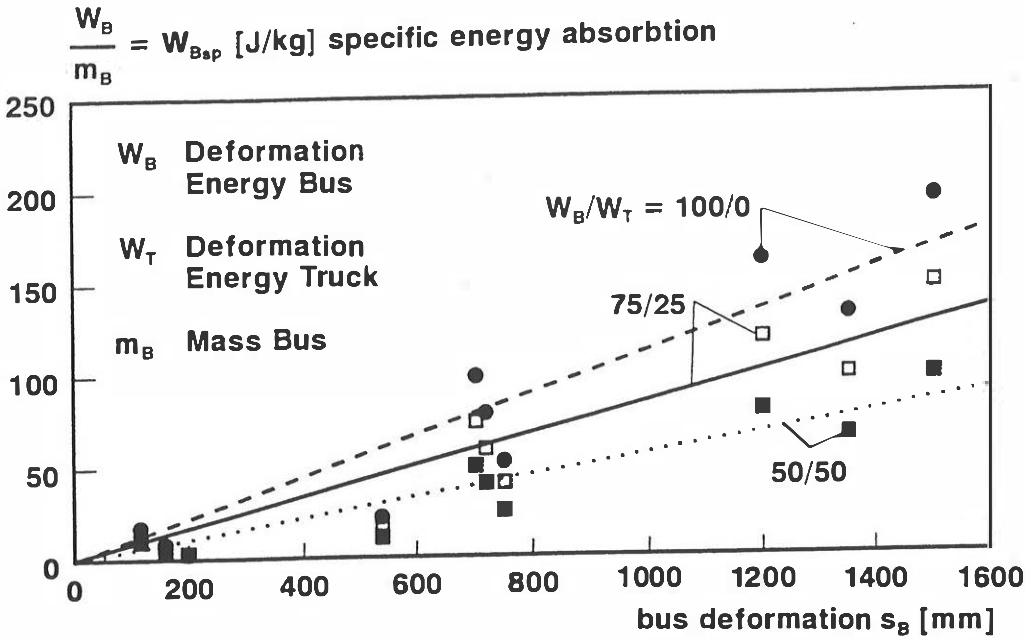
In Figure 9 the specific energy W_{Bsp} is shown versus the bus deformation for the 10 collisions. Here the two extreme values

W_B/W_T = 100/00 and 50/50 [% / %]

are added to the probable distribution of the deformation energies

W_B/W_T = 75/25 [% / %].

Fig. 9 - Specific energy absorption in bus/truck collisions
(5 head-on, 5 rear-end collisions)



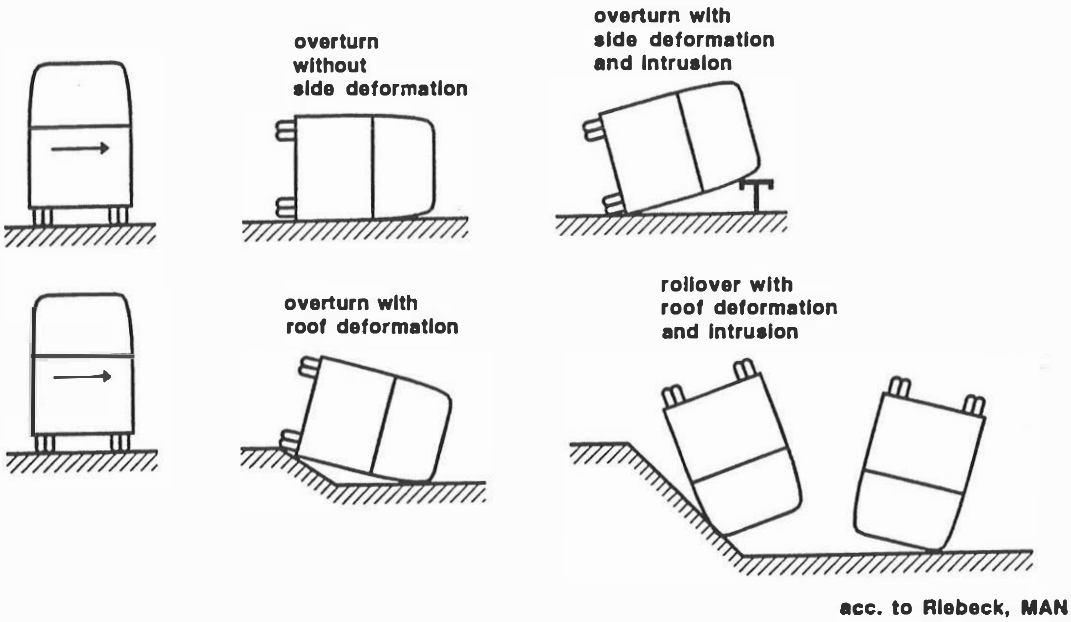
The regression line for the ten accidents with the distribution of 75/25 has a slope of approximately 8 g. This deceleration is higher than the deceleration measured in [12] because in the real accidents there often is an overlap higher than 30 %. The overlaps lay between 60 and 70 % on an average.

THE COLLISION TYPE OVERTURN/ROLLOVER

The most important subclassifications of the collision type overturn/rollover are represented in Figure 10. Lateral skidding caused by a combination of longitudinal and transverse motion occur in 75 % of the cases in a driving state without braking at a relatively high medium speed of 62 km/h. Lateral skidding and/or driving down an incline or into a ditch lead to the following overturn types:

1 Overturning onto the flat side
2 Overturning onto local obstacles, for example guardrails
3 Overturning into a depression without rolling over
4 Overturning into a depression with rolling over.

Fig. 10 - Bus collision type: Overturn, rollover

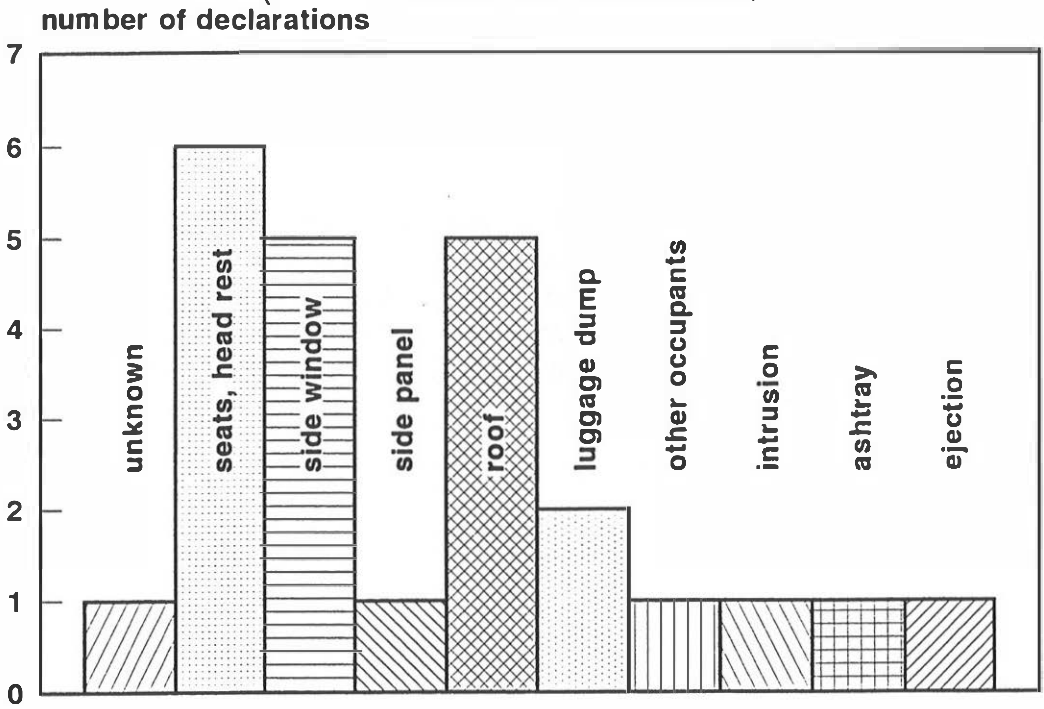


It is evident that in particular both impacting against guardrails owing to the intrusions and rolling over on account of denting of the roof can lead to disastrous consequences.

LOCATIONS OF INJURIES IN THE COLLISION TYPE VERTURN/ROLLOVER

For accidents of the collision type overturn/rollover the parts which in the accident investigators' reports are declared to be the cause of the injuries should be studied more closely so that information on the occupant kinematics during the accident can be obtained (see Figure 11). At the same time this enables conclusions to be drawn about the most advantageous design of individual construction elements with regard to safety and about the reduction of the danger of injury by installating and using belts.

Fig. 11 - Locations of injuries
(9 DEKRA cases overturn/rollover)



Seats/head rests, side windows and the roof area are mentioned especially often. Impacting against the seats is basically inevitable because the seat is the element which the bus passenger is in closest proximity to. However, as seats are also named as a cause of injury in almost all of the other collision types in which occupants have in part only minor injuries, it seems likely that seats only lead to minor injuries in most cases. That the roof area is often mentioned, which includes the overhead racks for carry-on luggage and to a certain extent the side windows, is on the other hand an indication that the occupants are thrown around during the overturning process. The padding of these constrution elements could contribute to improving the passive safety of busses. This also applies to ashtrays, which are often designated as a cause of injury in the other collision types. The side windows were mentioned five times, which leads to the conclusion that when the bus overturned, some persons were partially flung out, subsequently suffering considerable injuries from glass fragments and contact with the road surface. One further cause mentioned is the "being catapulted out of the bus", with which a total of six casualties is connected.

The following points, which were of importance for the occupant simulation of these accidents, could be gathered from the accident assessments:

- In seven out of eight cases the bus turned on its side. Only in one case did the bus roll over so that turning on its side can be considered representative.

- When the bus did not fall against a fixed obstacle such as a guiderail, the side structures were homogeneously deformed, with only slight crushing being observed.

COMPUTER SIMULATION OF THE OCCUPANT KINEMATICS AND OCCUPANT DYNAMICS

Computer simulation is carried out for the frontal impact and the overturn. The respective bus kinematics are defined as smooth motion. The occupant simulations are carried out with 3D-MBS models for the occupants (Hybrid III, 50 % male dummy and 5 % female dummy) and for the construction elements (seat, seat back, side, roof). The belts are incorporated as FE-models. The following parameters are varied:

- Restraint (no belt, 2 pt. belt, 3 pt. belt)
- Spacing of seats (720 - 850 mm)
- Belt slack (0, 40, 60, 80, 120 mm)
- Resistance of seat anchoring
- Resistance of seat backs
- Belt strain (8, 10, 12, 14 %)
- Belt force limitation (2000, 2500, 3000 N)
- Height of side panel (600 - 750 mm)
- Arm rests (yes, no).

The two essential questions to be posed are:

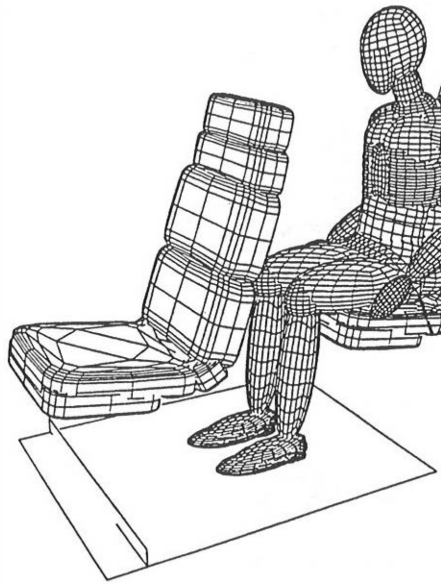
1. Which restraint should be given preference?
2. Which forces arise at the anchor points of the belts?

SIMULATION OF THE FRONTAL IMPACT

The Madymo model is depicted in Figure 12. The dummy sits on a seat and there is another seat in front of it which allows the impact against the back of the front seat to be tested. The bus motion is described by using the following representative accident characterizations [14]:

Speed variation	Δv	=	32 km/h
Average deceleration (constant)	a	≈	5 g
Duration of the crash pulse	Δt	≈	186 ms.

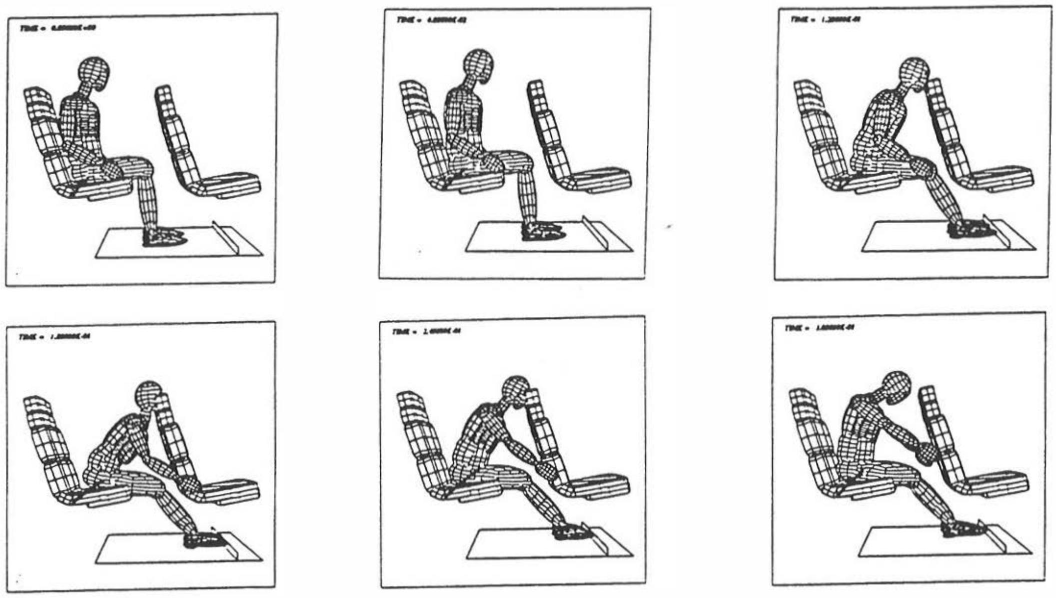
Fig. 12 - MADYMO model for simulation of the frontal impact



dummy hybrid III 50% male, 2 pt. belt, seat distance 850mm

The simulation results show that with use of a 2 pt. belt the jack-knife effect on the hip joint leads to a head impact against the back of the seat ahead (see Figure 13). When the padding of the seat back is inadequate, this leads to high contact forces, head decelerations and neck bending angles in the derived representative accident characterizations. In the worst-case studies, head decelerations with a HIC > 1000 can be simulated. In order to reduce these loadings to a negligible level, it is necessary to pad the seat backs on their back side in the area of the head-rests. The padding should contain sheet metal or foam rubber of high density because in this case the padding thicknesses of 2.5 to 5 cm already present are sufficient for providing protection against head impacts. These measures should be carried out with respect to the specifications defined in the ECE-R 80 concerning occupant safety in frontal impacts so that the level of occupant safety is not decreased by introducing belts as compared with today's standards.

Fig. 13 - Kinematics of a Hybrid III 50 % male dummy during frontal impact, 2 pt. Belt



10% belt strain, 60mm belt slack, no belt force limiter

When no belt is used, the neck and head strike against the upper edge of the seat back in the row ahead (see Figure 14). The loadings are dependent on the construction of the seat back. The best restraint is provided by the 3 point belt, see Figure 15.

Fig. 14 - Kinematics of two Hybrid IIIs 50 % male dummies during frontal impact, no belt

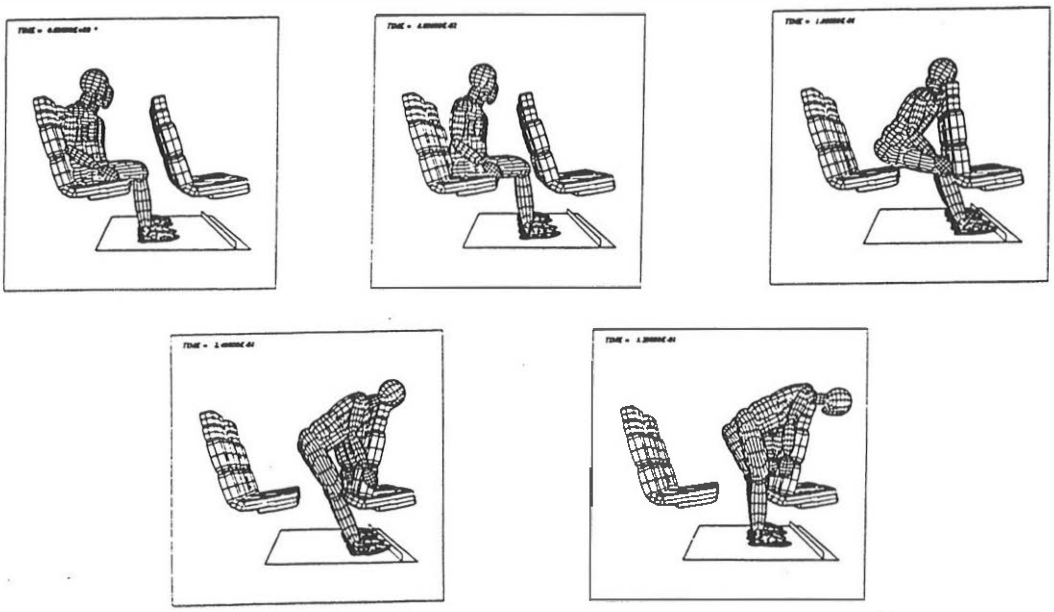
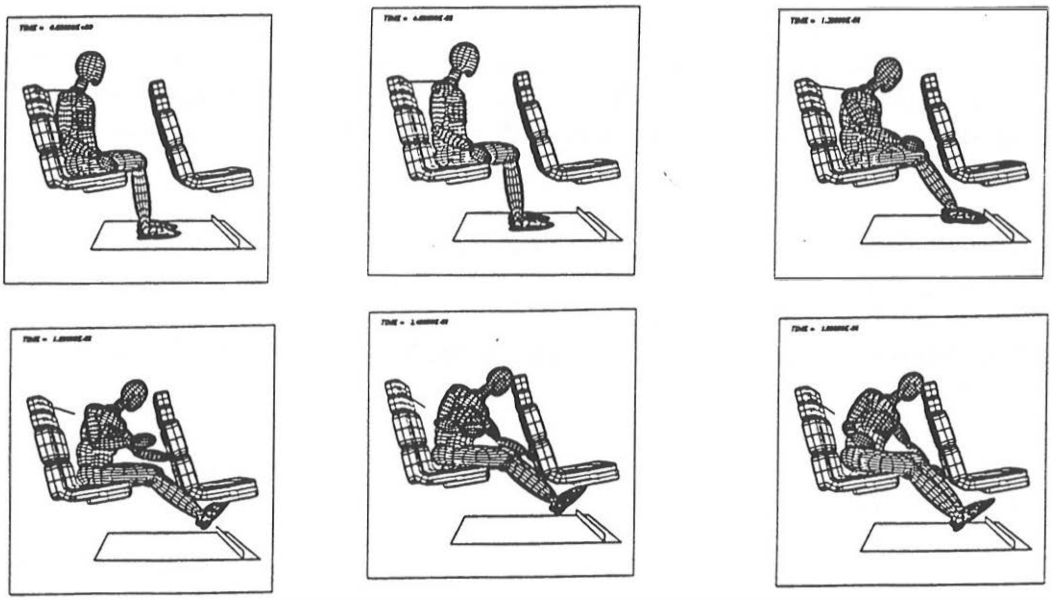


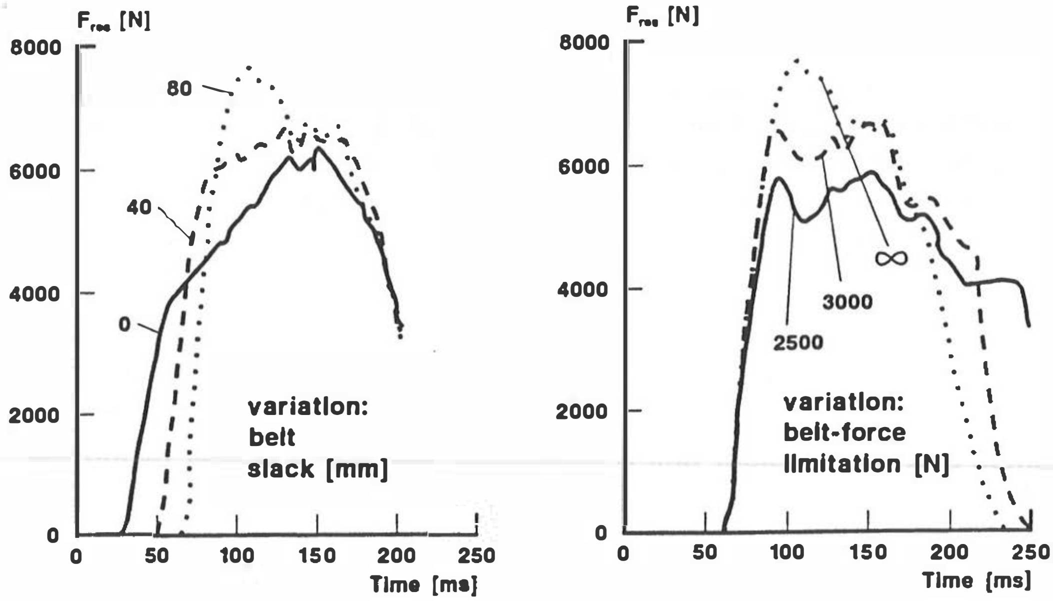
Fig. 15 - Kinematics of a Hybrid III 50 % male dummy during frontal impact, 3 pt. belt



10% belt strain, 60mm belt slack, no belt force limiter

To serve as an example, the time history of the resulting belt forces of a 2 pt. belt is shown in Figure 16.. On the left-hand side the belt slack and on the right-hand side the force limitation are varied. The resulting belt force is approximately 6000 N.

Fig. 16 - Frontal impact resultant belt force versus time



(2pt belt, 850mm seat distance, 8% belt strain, 80mm belt slack)

SIMULATION OF THE OVERTURN

First the overturning of the bus structure is simulated by means of a two-dimensional model so that the characterizations for the acceleration of the occupants and the rotation movement of the bus structure during the overturn process are maintained. The overturning motion was simulated under the following conditions, which were defined based on data from the accident assessments:

- overturning motion from a strictly transverse motion of the bus
- starting velocity of 50 km/h
- maximum tilting angle of 98°
- maximum deformations of the side structure of 150 mm during the overturning process.

The differentiated curves of the transverse and vertical accelerations of the bus can be found in the report [14].

On the basis of the accident characterizations obtained from the overturn simulation, it was possible to simulate the occupant kinematics and kinetics during the overturning action for different combinations of dummies with their interactions. Figure 17 shows four dummies sitting in a row of seats with roof and side as possible contact surfaces. To serve as examples, some of the important simulation results are described:

- The analyses of motion sequences show (see Figure 18, top) that the occupants not wearing belts are thrown around when the bus overturns. They first move in a lateral direction, then towards the roof; after that the dummies on the offside fall onto the dummies on the impacted side.

- By using 2 pt. belts the occupants are fixed securely on their seats. Only the occupants sitting directly next to the window on the impacted side face the danger of being partially catapulted out of the bus when the upper body is shifted to a horizontal position after a window has been destroyed. The degree of the horizontal positioning of the upper body and the severity of the head impact against the road surface connected with this are influenced critically by the height of the side panel, see Figure 18, center.

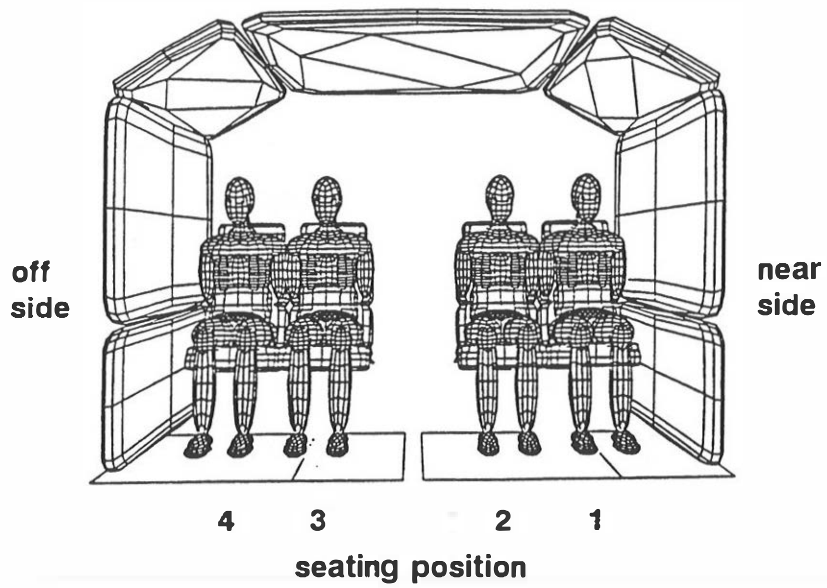
- The 3 pt. belt shows a definite disadvantage as far as ensuring that the bus occupants are fixed securely in their seats is concerned. If one assumes that the shoulder belt is positioned over the shoulder facing the nearest side window, then the offside occupants slide out of the shoulder belts during the overturning process. After a side impact the dummies slide completely out of the belts because of the extreme belt slack resulting from the sliding of the shoulder belt slack through the d-ring (see Figure 18, bottom).

- The resulting belt forces are greater with the 3 pt. belt than with the 2 pt. belt; they are lesser for the occupants on the impacted side than for those on the offside, see Figure 19.

- By using a belt force limiter, the maximum resulting belt force for the offside occupants wearing a 2 pt. belt decreases from just under 14 000 to approximately 7000 N, see Figure 20.

- The simulation of the occupant kinematics of a passenger sitting directly next to the impacting side wall and wearing a 2 pt. belt shows that the height of the side panel has a considerable influence on the motion of the occupant when the side window is destroyed by a side impact. From a side panel height of approximately 800 to 850 mm onwards above the floor of the bus the horizontal positioning of the upper body is prevented for the most part by the shoulder resting against the side wall. If the road surface is taken into consideration in the simulations, then the occupant's head and, with lower side panel heights, the occupant's head and shoulder strike against the street surface (see Figure 21). With side panel heights from 800 mm on, the loadings resulting from the head impact are not serious (≈100), whereas with lower side panel heights HIC-values which are only slightly under the limit of 1000 (see Figure 21) can be analysed from the simulations. The restraining effect could also be achieved by fixing a shoulder-rest on the window columns at the corresponding height (see Figure 22).

Fig. 17 - MADYMO model for simulation of overturn



Possible and probably advantageous is another geometry of the seat integrated 3pt. belts. When the upper anchor point is placed in each case not nearest to the window, but to the middle aisle than the "sliding out effect" of the offside occupants will not occur. This seat belt arrangement was not simulated here.

Fig. 18 - Motion sequence of four dummies Hybrid III 50 % male during overturn

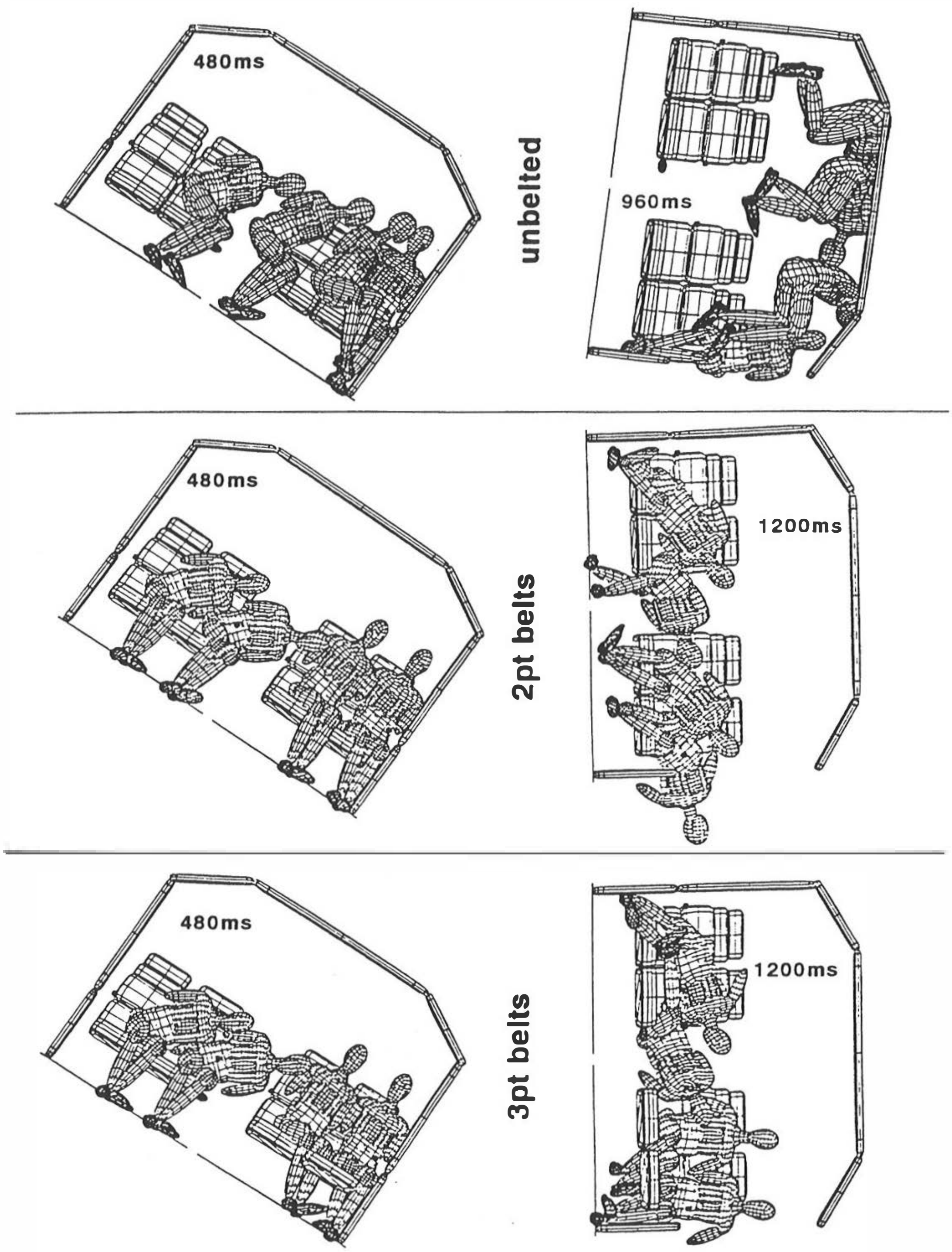


Fig. 19 - Maximum resultant belt forces during overturn

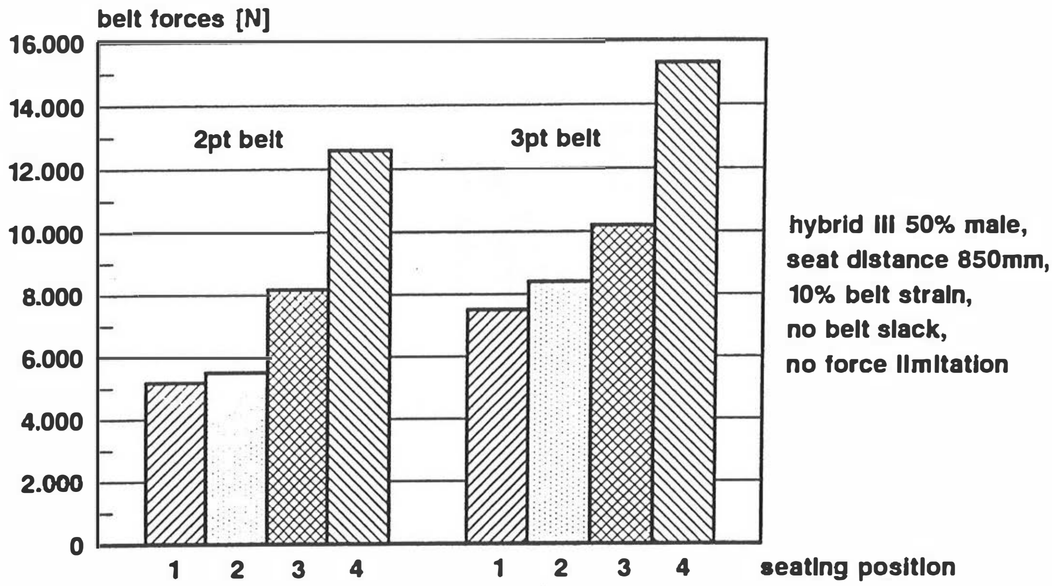


Fig. 20 - Resultant belt force for the offside occupant verus time

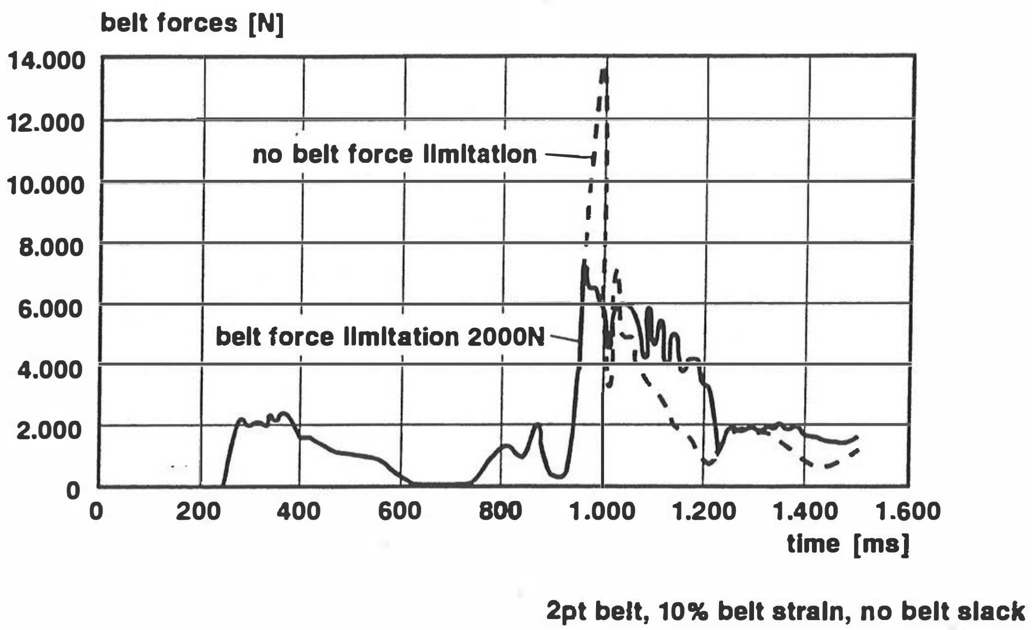


Fig. 21 - HIC caused by head impact with road surface influence of side panel

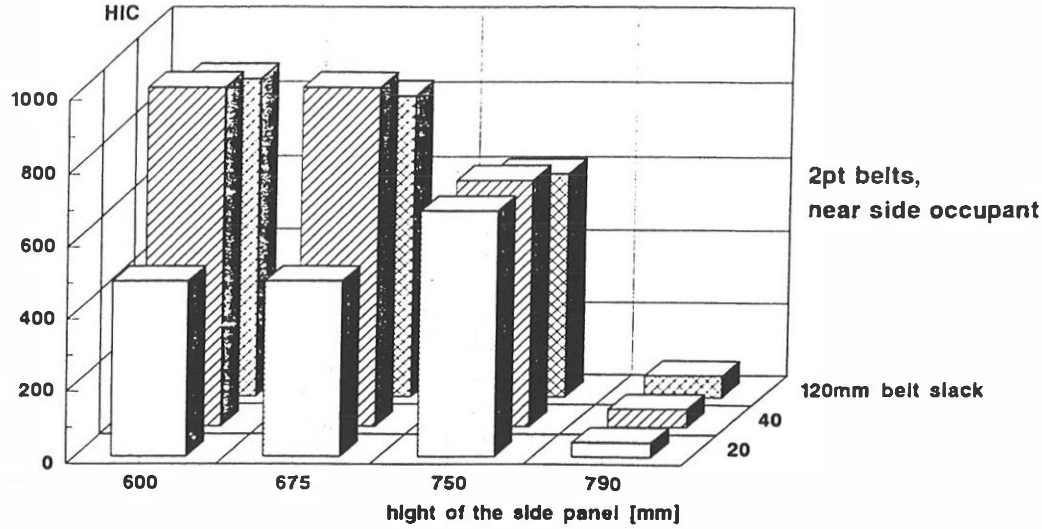
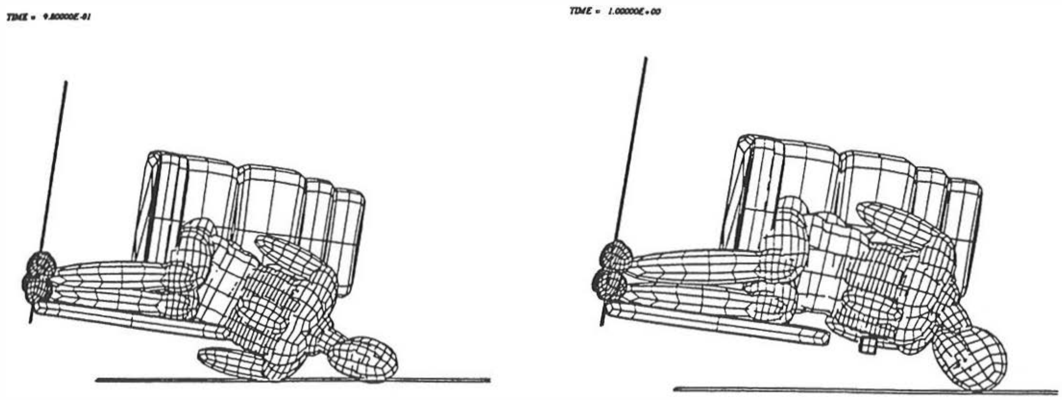


Fig. 22 - Different head kinematics and head loadings for various heights of the side panel (collision type overturn)



CONCLUSION

The accident analysis of severe bus accidents shows that the frontal impact, but most of all the overturn/rollover of busses cause severe and fatal injuries to bus occupants. With the aid of occupant simulations for these collision types, to what degree belts can reduce the danger of injury to bus occupants was analysed. The simulations show that passive safety especially in accidents of the collision type overturn/rollover can be considerably improved by belts, with the 2 pt. belt being sufficient for fixing the occupants securely in their seats. Even in comparison with 3 pt. belts, facing the shoulder belt to the nearest window, there are advantages of the 2 pt. belt, since they are garanteeing that occupants do not slide out of the belts. On the otherhand 3 pt. belts facing the shoulder belt to the aisle, should avoid this disadvantage; they are not investigated here.

As belts help to reduce the danger to occupants in the accident types with the highest number of severely and fatally injured bus occupants, their use in touring coaches can generally be considered an effective measure for improving safety in touring coach transportation. Of course it is not only necessary to install the belts, but also to make their use mandatory because otherwise it cannot be assumed that they will be used by everyone. As an accompanying measure for improvement of occupant safety by introducing the 2 pt. belts, padding the back-side of the seat backs in the area of the head rests and raising the side panels on the side walls or fixing a shoulder-rest to the window columns of the side wall have been found to be advisable. The first measure pertains to the head impact against the seat back which with the 2 pt. belt results from the occupant kinematics during the restraint phase of the frontal impact. The second measure is supposed to protect the occupants sitting directly next to the impacting side wall from having their upper bodies partially catapulted out of the bus in the case of an overturn. In addition, the busses should be furnished with laminated safety glass in some of the side windows. The possibility of quick escape must be maintained.

Loss of comfort and the present difficulty of enforcing the use of belts are not acceptable as reasons against making belts obligatory in busses. The disadvantages, that after an overturn occupants wearing belts are left hanging in the air and can hardly free themselves without danger and also cannot be as easily rescued by helpers, are of more import. These disadvantages, however, do not outweigh the advantages gained by requiring the general use of belts in busses.

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