STRUCTURAL RIGIDITY AND OCCUPANT LOADING IN THE CASE OF THE SIDE COLLISION: RESULTS OF AN EXPERIMENTAL STUDY

by

R.Pasch, A.Kühnel, W.Wollert, J.Blödorn, H.Rattaj, H.Appel
Institute of Automotive Engineering,
Technical University of Berlin

INTRODUCTION

Up to now, investigations concerning the mechanics of the side collision have been performed almost without exeption only for standard factory model vehicles. Theoretical knowledge has been gained, and some structural conclusions have been drawn; These findings, however, have been experimentally investigated only in isolated cases. Within the framework of the UNI-CAR research project sponsored by the West German Federal Ministry of Research and Technology, considerable improvements in passive safety features of the automobile have been intended - in addition to work done on the remaining points of emphasis such as lowering of noise emission levels and reduction of consumption. Special structural measures were implemented on the UNI-CAR, particulary to afford increased safety in case of side collisions. These measures have been investigated singly and in their mutual interactions on an experimental basis. In the following, presentation will be made of these measures, and an elaboration will be presented of their effects.

MEASURES TAKEN AND CONSTRAINTS

In order to increase the rigidity of the passenger compartment with respect to side collisions, the following structural improvements were individually implemented (see Fig. 1):

- interconnection of the B pillars at main impact height by means of a strong lower cross brace over the tunnel. This bracing consists of a box profile made of autobody sheet steel and has a cross-sectional area of approx. 10,000 mm^2.

- interconnection of the B pillars at the height of the lower window edge by means of a less sturdy upper cross brace behind the front seats. The cross-sectional area of this bracing is approx. 2,500 mm^2.

- interconnection of the upper and lower cross braces in the middle, over the so-called belt upright. This belt upright contains the belt reels and the belt reversing fittings for the front-seat passengers (with reversed belt fastening points: i.e., in the middle rather than on the outside).

- provision in all four doors on two levels of door braces made of 120 x 50 mm box-shaped aluminium profiles with 4 mm metal thickness. These door guardrails are capped at the ends and are fastened to each other and to the surrounding car structure by means of tie rods (see Fig. 2).

For economic reasons dictated by functional and spatial considerations, certain compromises had to be complied with, which in turn led to constraints of confining nature in the design of the structural bracing. Owing to the encapsulation of the motor and the smooth underbody of the car, the tunnel also had to accommodate the exhaust pipe and system, a fact which made it especially large in size. For this reason, it was necessary to run the lower cross brace around the tunnel, with use being made of a rigid support ring. The consequence of this, naturally, was creation of a weak point. To enable the rearward slope of the front seats and to maintain the vertical configuration of the B pillar, we had to accept an offsetting of the upper cross bracing. As a result of the bending which became necessary here, this bracing will of course be more susceptible to buckling in the event that it is subjected to axially directed loading.

Since, for purpose of these tests, it would have been prohibitively expensive for us to use the handmanufactured UNI-CAR bodies, we consequently took the UNI-CAR improvements for greater lateral protection and applied them to a modern, four-door, mediumclass car with a passenger compartment similar in size to that of the UNI-CAR. Our experiments were then conducted with this car (see Figs. 3 and 4).

TESTS CONDUCTED AND CHARACTERISTICS OF THE TEST VEHICLES

A total of six tests have been conducted up to present. In each case, a car equipped with the reinforcing elements subject to testing was struck by a passenger car of the same type at an angle of 90 degrees and with a collision speed of 50 km/h (nonbraked). The impact point was the side of the struck vehicle, whereby the center front of the striking vehicle was aimed at the driver "H" point (seat reference point, or SRP). See fig. 5.

With regard to side protection, the cars used in testing exhibited the following variations:

1. Unmodified general car model (standard production)

2. Installation only of the lower cross brace, using bracing with 0.8 mm sheet metal thickness

3. Installation only of door guardrails

4. Installation of lower cross bracing using sheet metal members 0.8 mm and 1.25 mm thick, and of door guardrails

5. Installation of upper and lower cross bracing using sheet metal 0.8 mm thick, and of door guardrails

6. Installation of upper and lower cross bracing using sheet metal 1.25 mm thick, and of door guardrails

The striking and the struck vehicles were each occupied by two dummies. The following were measured: dummy accelerations, vehicle accelerations, and belt forces in the striking vehicle.

TEST RESULTS

In all tests run, film evaluation reveals approximately the same basic pattern of movement, as follows:

The striking vehicle penetrates into the side of the struck car, with the degree of penetration depending on the reinforcement involved. The occupant sitting in the target car is frequently struck directly by the intruding structure itself. Once the struck vehicle is laterally accelerated, this occupant will be slammed against the impacted side of his car. Simultaneously, the occupant sitting on the side of the car away from the impact will be thrown across toward the crash side. This latter occupant, however, has more free space for movement. If the impact-side occupant is then elastically rebounded by door upholstery, the consequence in almost all cases will be that the two occupants will be slammed into each other (interaction), by virtue of their now oppositely directed movements. If, in such cases, the occupants' heads strike together, this occurence alone can cause extremely serious injuries. This danger can be reduced by the installation of shoulder padding at the sides - also in the middle of the vehicle (see Fig. 6). By virtue of the following deceleration of the cars, up until their final positions, both of the occupants in the struck car will be thrown to the side away from the impact. As a result, another collision between the occupants (interaction) can take place - this time, however, with reduced force. In the tests conducted here, head contact did not take place: only shoulder-to-shoulder and head-to-shoulder collisions were recorded.

If one takes the above-listed sequence of variations in the reinforcement of the test vehicles in its given increasing order of passenger compartment rigidity, then one can expect lesser intrusions into the struck car with increasing reinforcement of the compartement (see Fig. 7). The test results confirmed this: the maximum outside deformation of 465 mm with the standard production car (Fig. 8) was reduced to less than half (225 mm) in the fully reinforced version of the car (Fig. 9). On the interior of the improved car as well, there was significantly more survival space remaining than in the conventional auto. According to linear evaluation of the 11 measuring points, the interior space of the fully equipped vehicle was reduced only by 11.1%; the production car, on the other hand, suffered a reduction of 27.3% of the original interior dimensions (see Fig. 10). Even with a maximum interior deformation of 215 mm, the occupant on the impact side will be hurled against the door padding in the reinforced car: In the production case, seating space is reduced by approximately half, without consideration being taken of the elastic deformation component involved.

If one studies the intrusions in the critical seat reference point height, then an even more favorable situation can be determined: the fully reinforced vehicle is deformed here by 165 mm, whereas the interior of the conventional auto is reduced by 400 mm at this point (see Fig. 11).

The increased rigidity of the struck vehicle of course means less favorable consequences for the striking car in terms of loading applied: this results above all in somewhat more severe frontal deformation. In the case of a reinforced struck auto, however, not the entire difference between production-car and reinforced-car deformations is transferred to the striking car: the overall deformation of both vehicles, indeed, demonstrates a decreasing tendency (see Fig. 12). This indicates a greater component of elastic deformation. This is also confirmed by greater skid distances determined with modified vehicles. Measurement of the side of the vehicle away from the impact revealed varying influences of the bracing elements on the overall vehicle: a cross brace results in transfer of the impact to the B pillar on the opposite side, whereby the car body as a whole is bent. Door braces will reduce this effect, by virtue of their tensile forces. The tie rods prevent sliding of the door braces over the pillars to the inside, once they have already been bent inward; the passenger compartment is protected in a manner as though a system of stressed cables were installed.

No significant tendencies can be detected from a study of the maximum values of vehicle deceleration (see Fig. 13). The loads subjected all range approximately around the same level; their durations are somewhat greater in the reinforced cases (same accelerations, greater deformation paths) than for the production cars.

The maximum accelerations determined for the occupants on the impact side (see Fig. 14) demonstrate no recognizable tendencies using the test setup chosen here, since no padding was used on the doors (a feature in fact otherwise required) in order to be able to study the isolated influence of the structural measures implemented. A greater impact on a reinforced passenger compartment (with greater skid distance, i.e., higher coasting speed of the struck vehicle after the crash) would therefore be expected to produce greater loads acting on the occupants. We were not able to produce confirmation of this hypothesis: apparently, the effects of the greater impact are partially nullified by the fact that, before the contact between dummy and side wall of the car, the penetration velocity for the modified vehicle has already decreased correspondingly greater than for the production model passenger compartment. If, now, the greater free space available in the reinforced car interior were provided with correctly installed padding, then considerably reduced dummy loads (especially pelvic values) could be expected.

With increasing passenger compartment rigidity of the struck vehicle, the maximum acceleration values for the occupants of the striking vehicle show a slight increase (see Fig. 15). These hardly reach 30 g, however, and are therefore not critical. Belt forces on these occupants also demonstrate an increasing tendency, but they do remain tolerable, with values under 2,000 N.

SUMMARY

On the whole, our tests have demonstrated that, for protection of auto occupants against side collisions, any measures taken for cross bracing of the passenger compartment will result in increased safety in the event of a side crash.

- More seating space is maintained by virtue of the bracing.

- The most beneficial effects are achieved by an integrated system featuring door guardrails and cross bracing for the passenger compartment. In conjunction herewith, the door guardrails are more effective under tension than under bending.

- The gain in safety by virtue of maintenance of more survival space in the struck vehicle significantly outweighs the deleterious effects of the somewhat greater loads on the occupants of the striking vehicle (brought about by greater accelerations upon impact with a reinforced target car body).

- The free interior passenger compartment space thusly maintained can, by means of suitable padding of the side door, be utilized to minimize occupant loading by allowing acceleration of the passengers up to lateral post-crash (struck) vehicle velocity over as great a padding deformation distance as possible.

The cross-bracing elements tested here will be used in the UNI-CAR. The UNI-CAR features an exsiting distance of approximately 300 mm between the car body shell and the outer seat edge; as a result, one can well expect that, in the case of a side crash of up to 50 km/h, the seating space of the compartment will remain fully intact, and that the wide door padding will be available to the passengers as a deformation path. In this manner, loads on the occupants in this vehicle will remain within tolerable bounds, even for more serious side collisions.

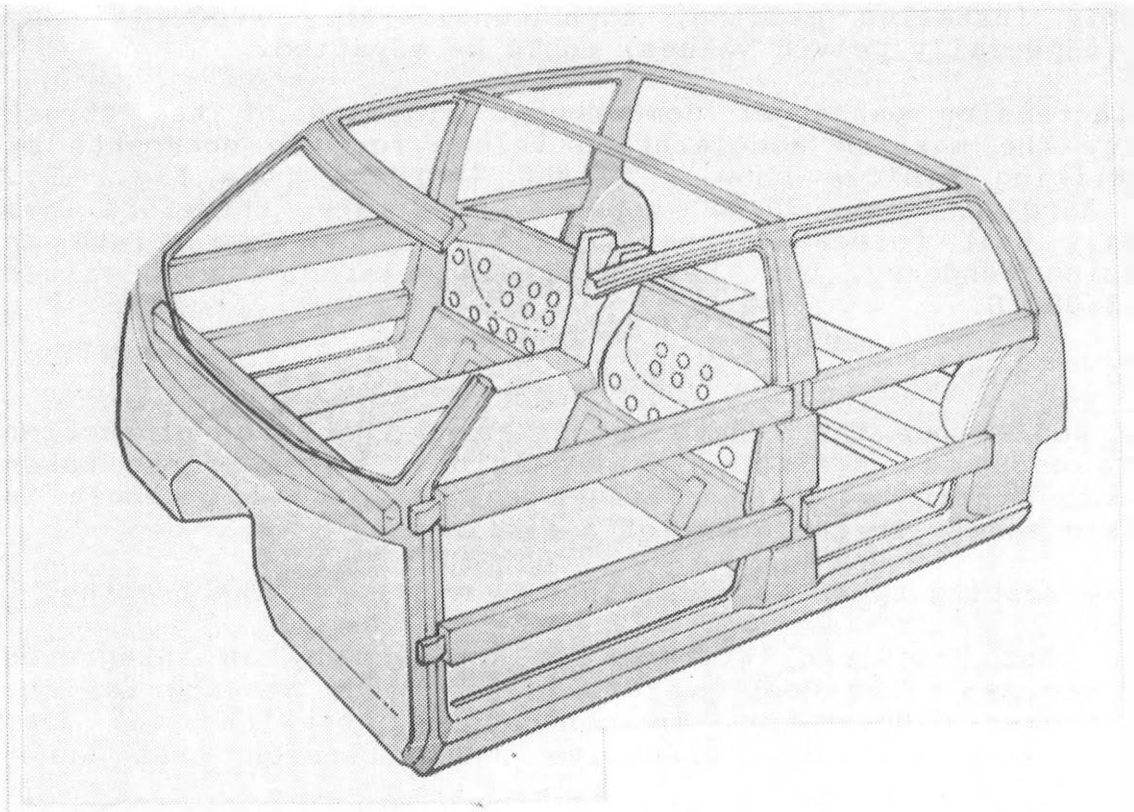


Fig. 1: Structural bracing of the passenger compartment

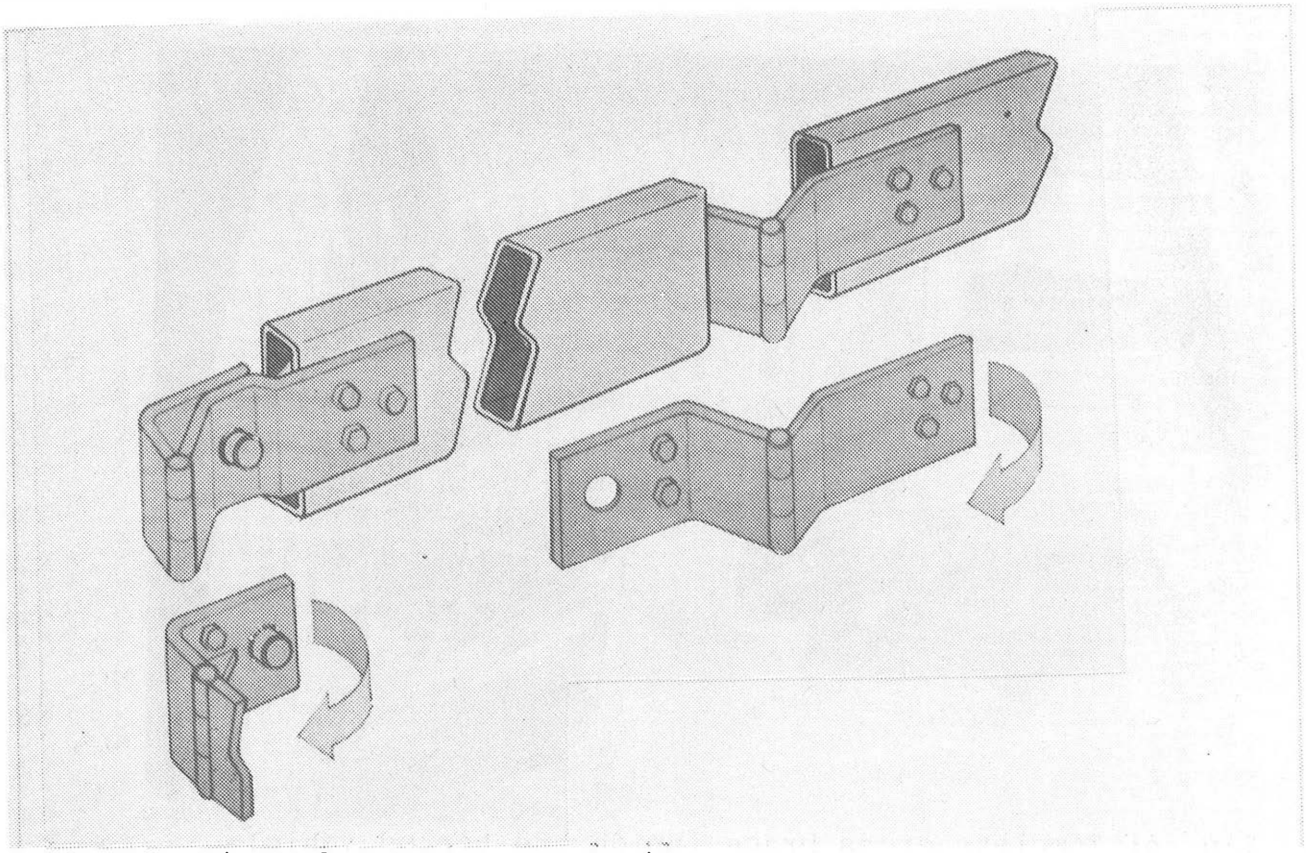


Fig. 2: Tie rods of the guardrails

Fig. 3: Door guardrails applied in the vehicle ready for test

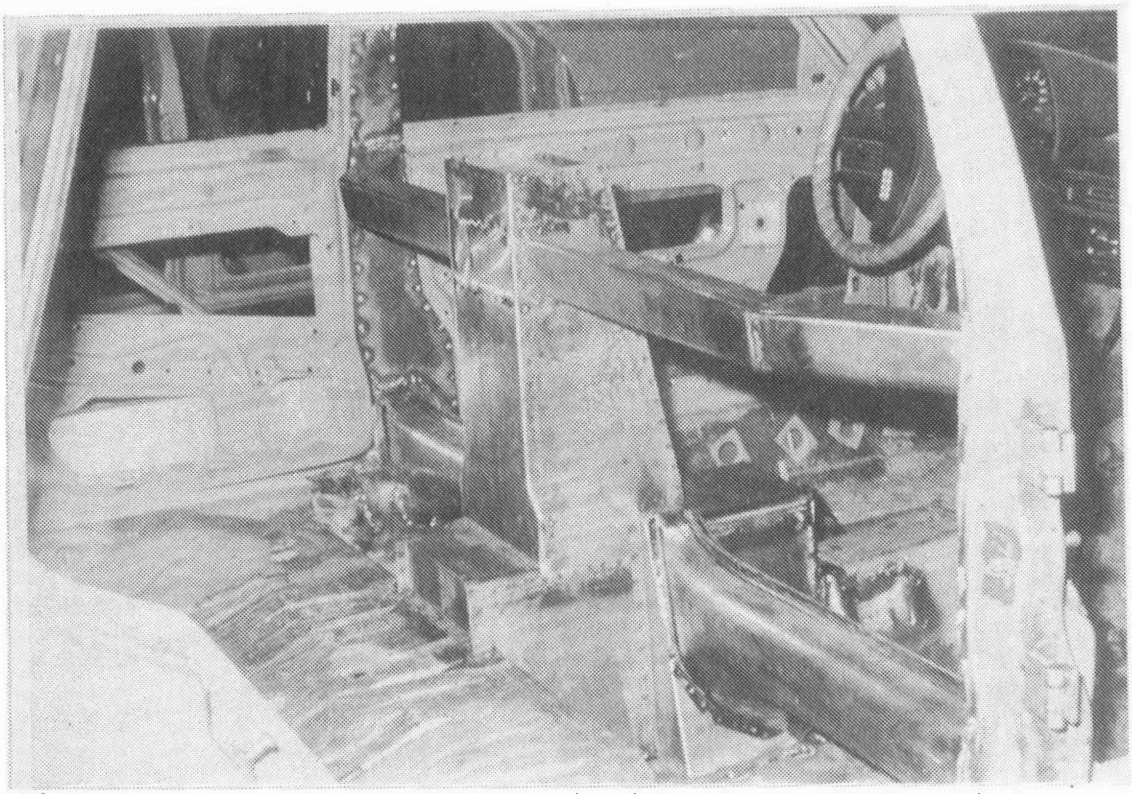


Fig. 4: Complete cross brace inside the tested vehicle

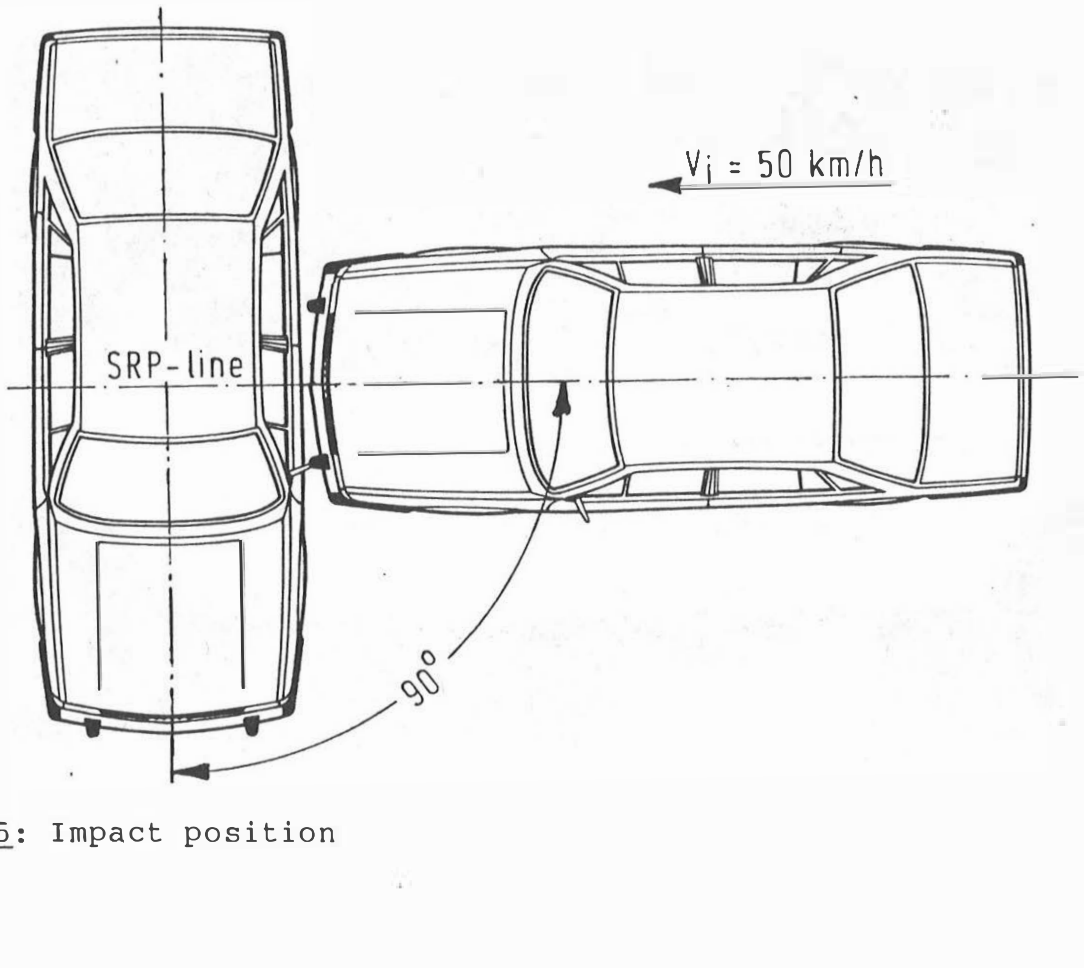


Fig. 5: Impact position

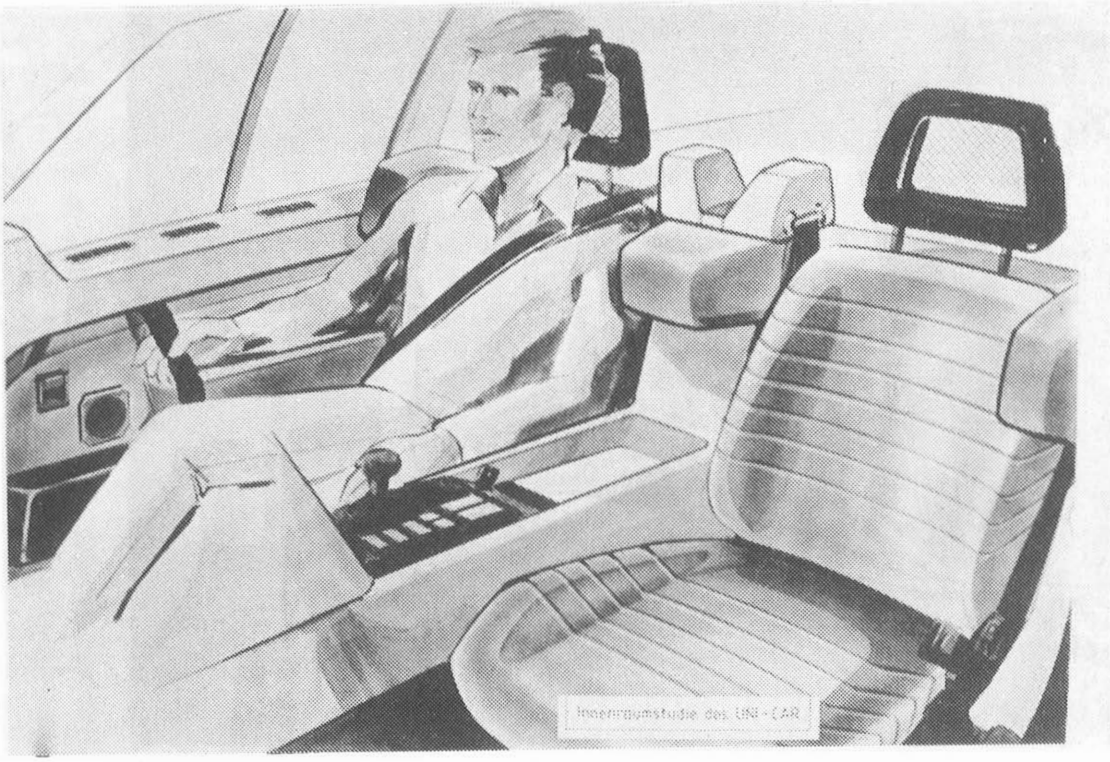


Fig. 6: Shoulder padding inside UNI-CAR

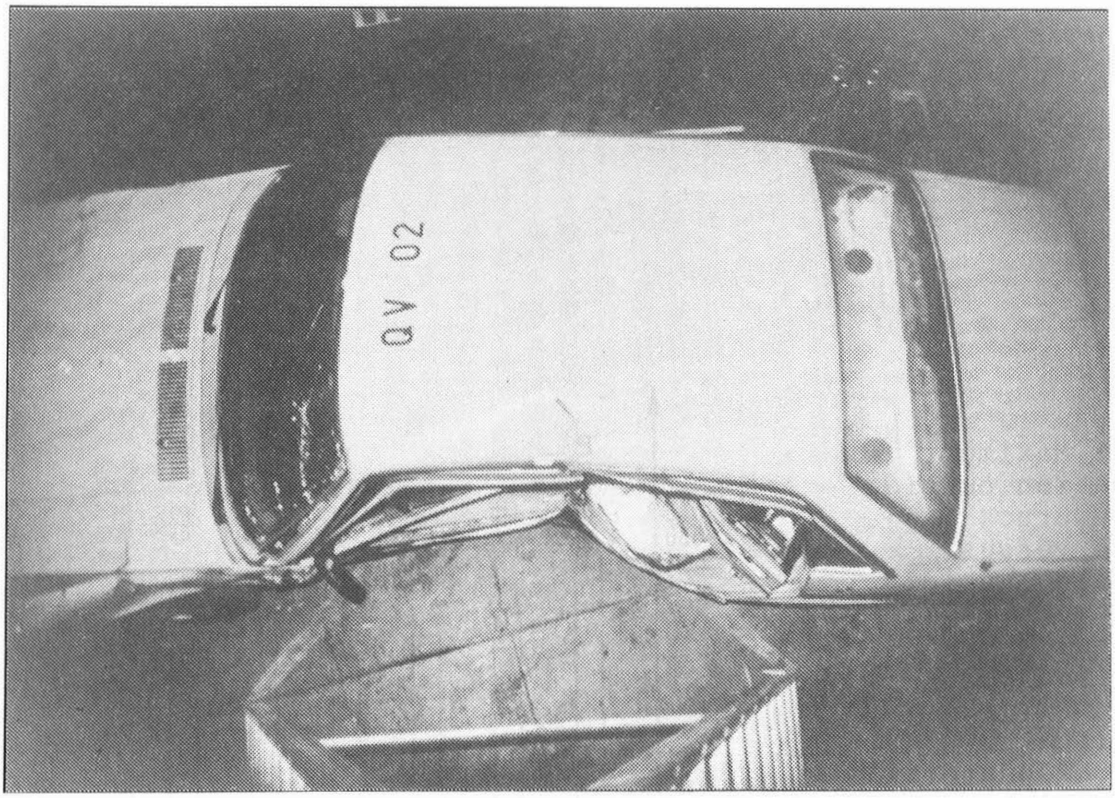


Fig. 8: Standard production car after side collision

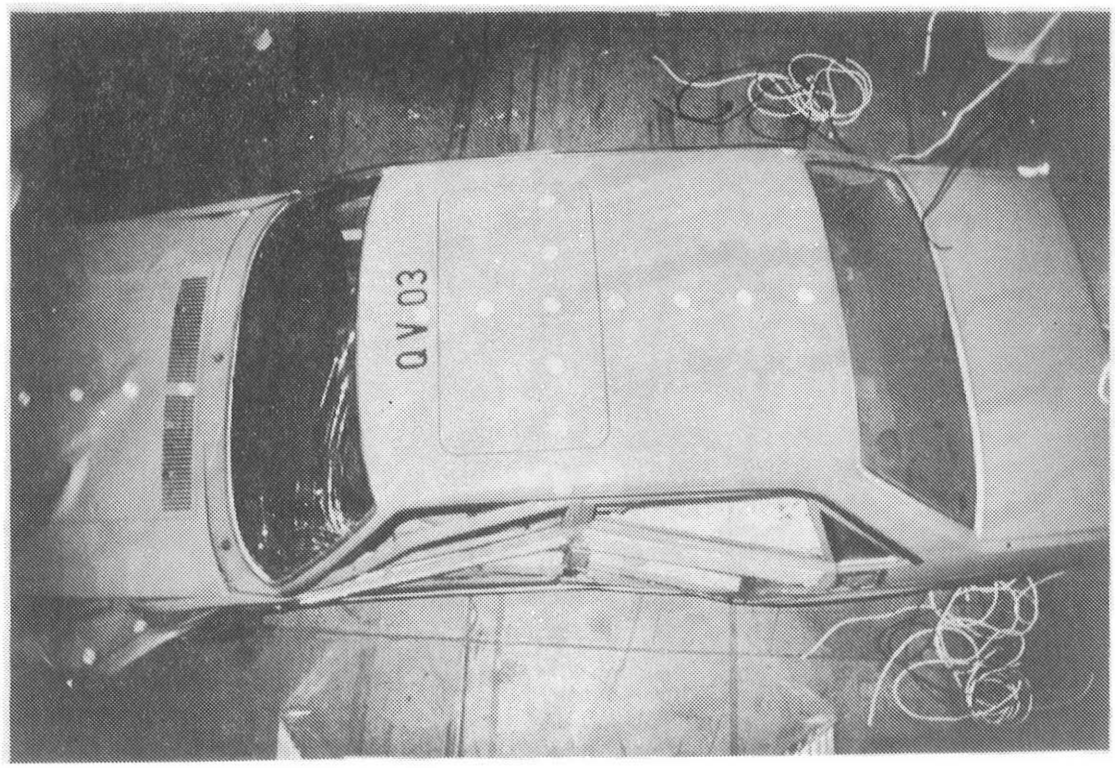
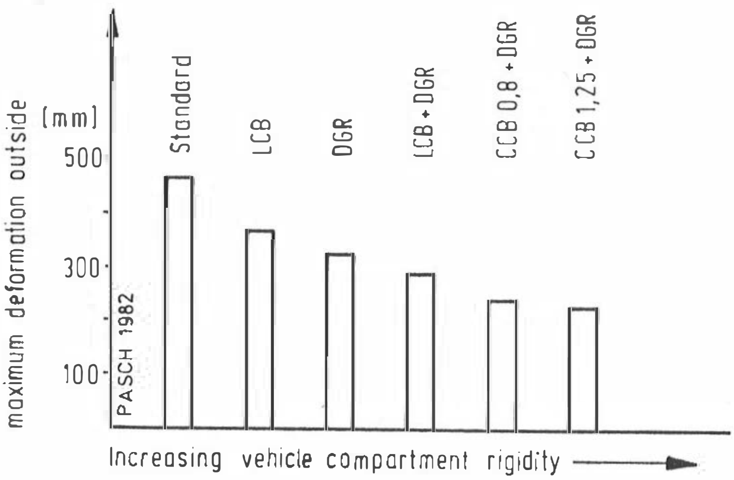


Fig. 9: Fully reinforced car after side collision

Fig. 7: Maximum deformation outside at the struck vehicle versus increasing vehicle compartment rigitity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete crossbrace



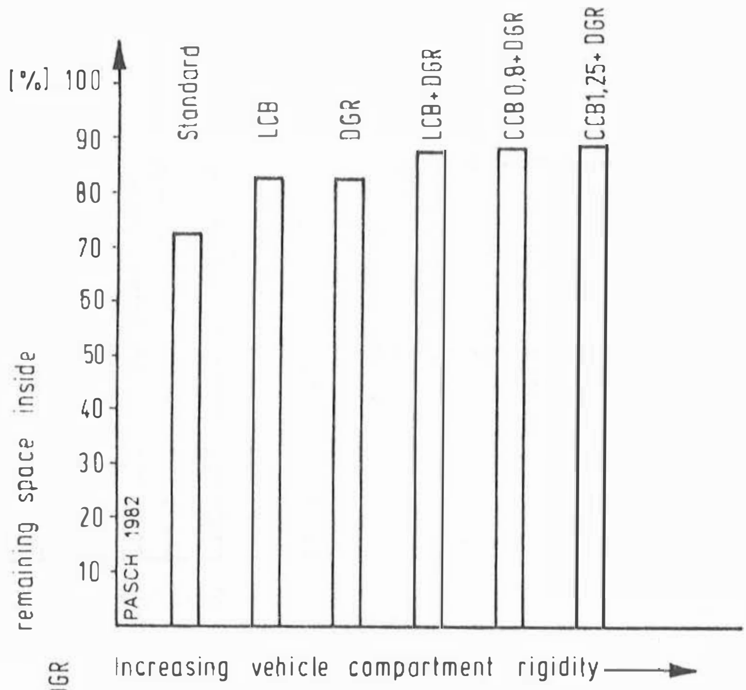


Fig. 10: Remaining space inside the struck vehicle versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete crossbrace

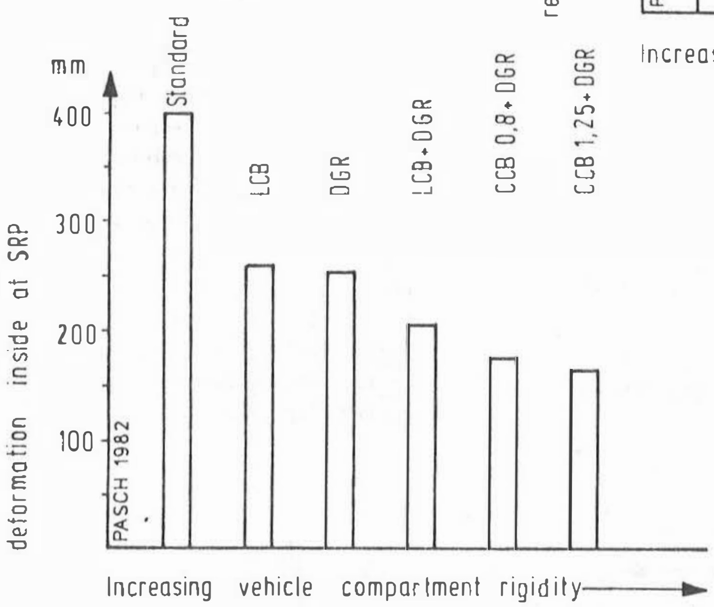


Fig. 11: Deformation inside at SRP of the struck vehicle versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete crossbrace

Fig. 12: Deformation of both cars versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete crossbrace

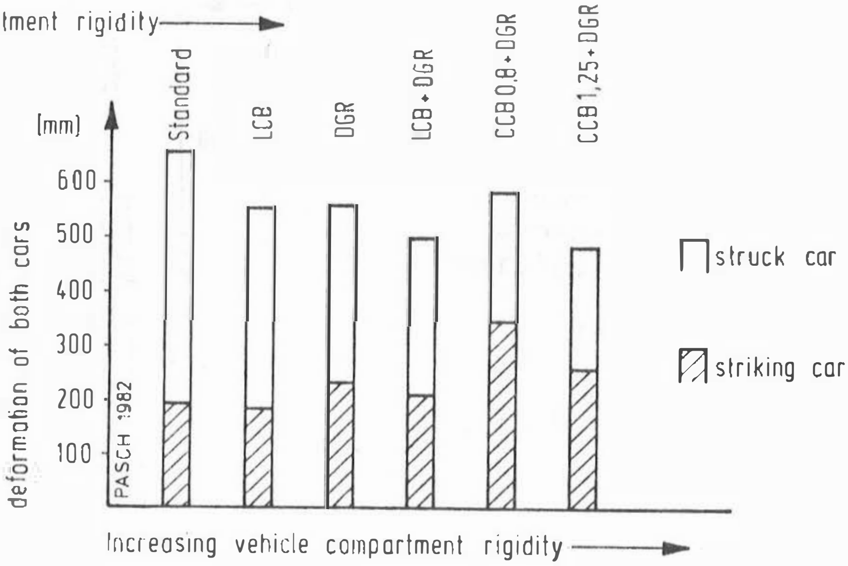
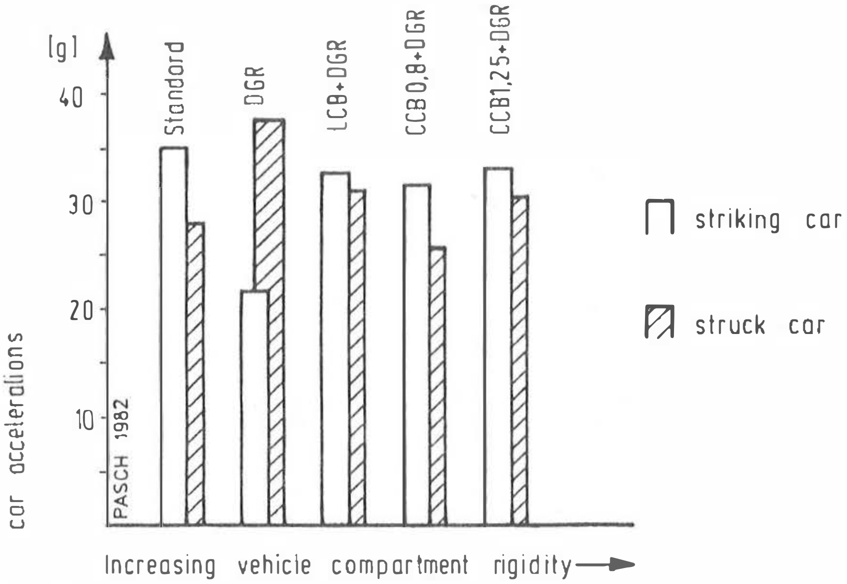


Fig. 13: Car accelerations versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete



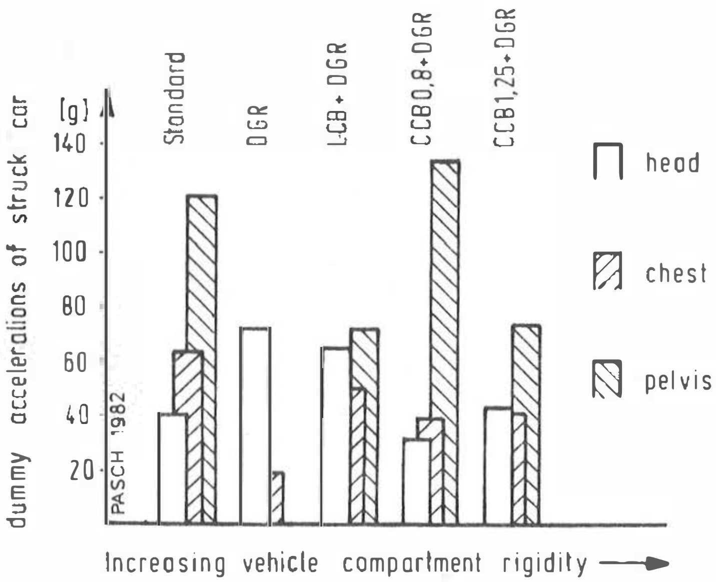
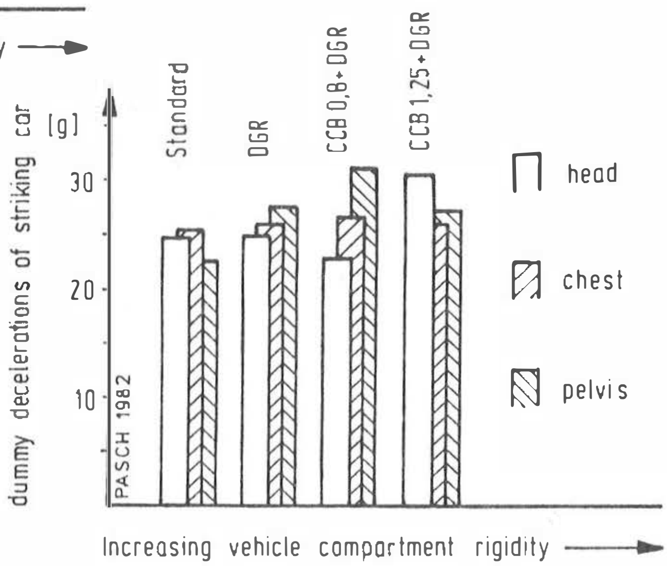


Fig. 14: Dummy accelerations of struck car versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete crossbrace

Fig. 15: Dummy decelerations of striking car versus increasing vehicle compartment rigidity
standard: unmodified car
LCB: lower crossbrace
DGR: door guardrails
CCB: complete



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