40 YEARS IN CAR SAFETY

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Joining the car industry more than 40 years ago, I dreamed of revolutionary engine concepts and unlimited road holding. But the true life answer was exciting enough.

In 1954 the Sindelfingen plant of Daimler Benz was responsible for the car body, development and final assembly of the Mercedes Benz cars. The neighbor of my office was Béla Barényi, who invented almost everything what you can invent in respect to car safety. His basic idea was: the result of any collision is the change of kinetic energy which causes deformation of material or vulneration of living structures involved (Fig.1.) The deformation energy is

$$eD = \frac{m_1 \; m_2}{2 \; (m_1 \; + m_2)} \Delta v^2 ,$$

where m_1 and m_2 are the involved masses and Δv is the difference of speed at the beginning of a central plastic collision. This amount of energy is not to avoid, but we can influence the relation of the parts of energy which goes to m_1 (eD1) or m_2 (eD2). Of course eD1 + eD2 = eD. If m1 is a small car and m2 a big one, we should try to give the bigger car the higher share of deformation energy, because it has got a bigger zone of possible deformation without harm to the occupants. Or if m1 is the head of a person and m2 the impacted part of the car: make the structure of the impacted part so, that the forces are of no harm to the head.

Daimler-Benz: Kraftfahrzeug, Festigkeit PS 854 157 vom 23.1.1951

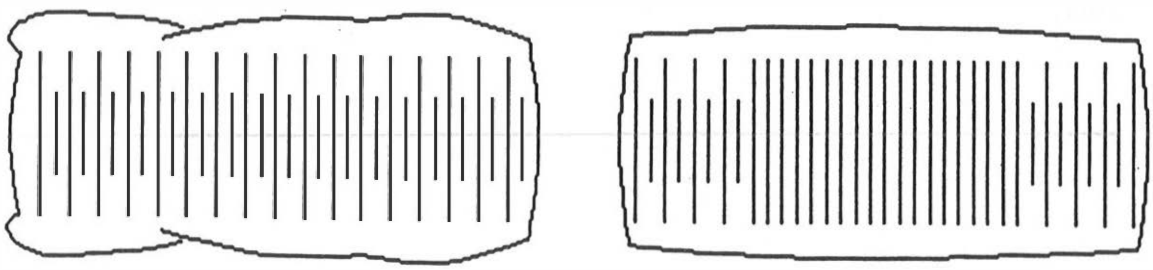

Fig.1: Bela Bareny's patent of heterogeneous strength in car bodys.

This simple principle was the striking experience for me.

But like all simple principles it is simple to understand but tricky in application. Take the car to car collision: a big car has a stronger structure than a small one. In a collision the deformation of the smaller car is bigger, which is the contrary of the desired behavior. So we started a programm for compatibility. With almost no success. The crash standards are written in speed against a massive barrier which makes the heavy car stronger than the light one and causes the advers effect in safety. We could improve the car-to-car collision and we should finaly improve the standards.

More complicated is the "second collision", the man-car collision. What is the speed of this collision? What are the forces in an head-dashboard impact? What energy can the various parts of the human body absorb? To answer this questions we had to leave the pure mechanical aspects and enter the field of biomechanics.

Suspension forces

In most car accidents have the passengers the chance to decelerate their body by transferring energy to the car-body and absorbing muscle energy. Of course are the suspending forces smaller than the forces in the second collision, but the spaces are much longer. Fig.2 gives the result of such an experiment. The sled decelerates in 0,2 sec from 9 to 0 m/s, a soft ride down. The test-specimen

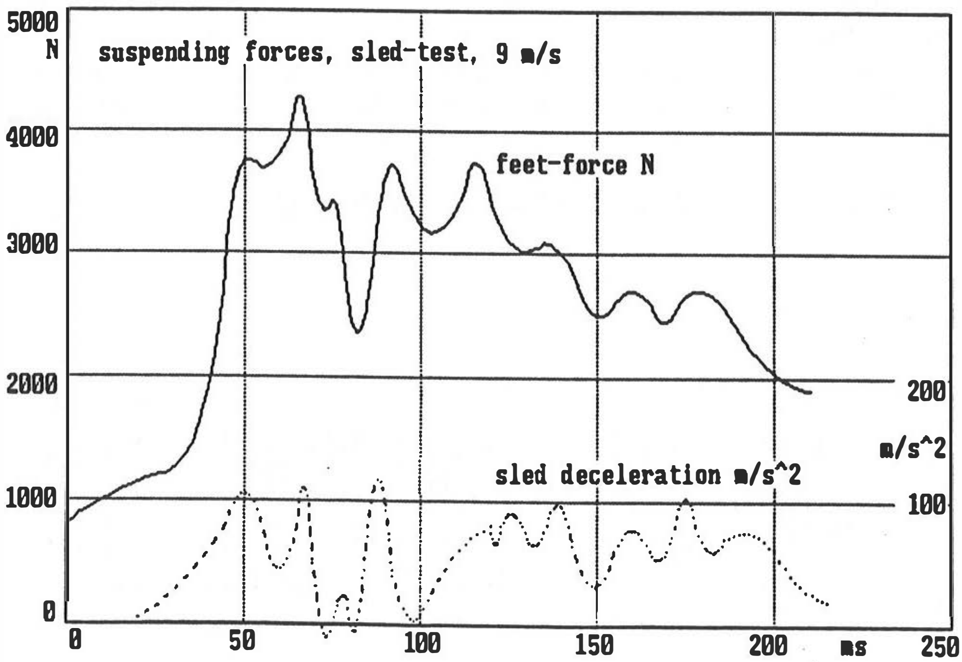

Fig.2: Suspending forces of legs and arms in a sled-test.

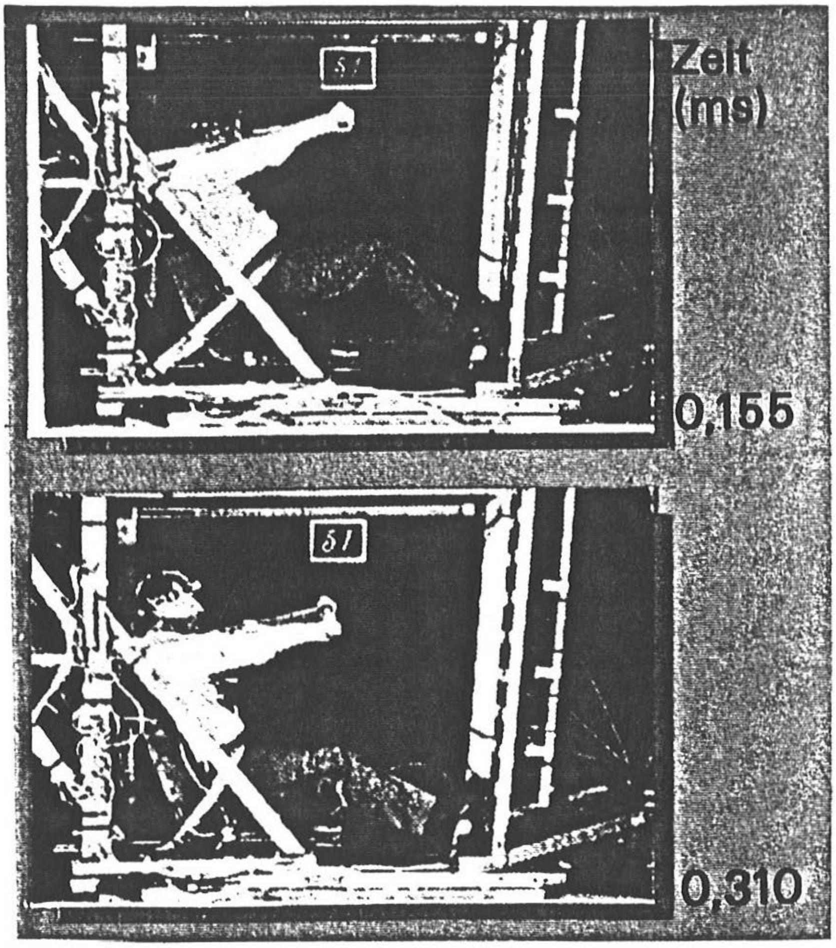

Fig.3: Arm- and leg- forces as well as sled- and head- decelleration are measured in this sled test.

The lap-belt is not loaded.

stems legs and arms against the footrest and a pair of handels. The forces in the legs exeeds 4 000 N. A momentum of well over 400 Ns is transferred. The overall-momentum of the body is about 80*9 = 720 kgm/s or Ns. Other parts are transferred by the suspending arm forces and the seat. In contradiction to the always stated opinion, that suspending arm- and leg-forces are of negligible order, in this case they transfer all energy to the energy-absorbing device of the sled. Of course, it is a low-speed, low-deceleration test. But in a true accident the forces might be higher and another amount of energy is absorbed by bending arms and legs. Assume a 30 mpg = 14 m/s speed change. Kinetic energy of a 80 kg body is 8000 Nm. If the suspending forces are 4000 N, the deceleration-space 0,5 m and the bending space of the same size, about half of the energy is taken out befor the second collision occures.

No dummy nor dead test specimen acts like an alive passenger. Some think, that also the alive body will react differently. To make this clear, we undertook some test with living (narcotized) animals.

Energy-absorption by the tissue

During the impact of a human body to car interior or car exterior there is a split of energy: one part goes to the body, causing injuries or not, the other to the car structure. What is the critical amount of energy the various parts of the body can take?

For linear an rotary head acceleration we had the head injury criteria connected to the name of Larry M. Patric. For experiments with all body parts we used a double pendulum apparatus, Fig.4. ("We" means several institutes of the Freie Universität and the Technische Universität of

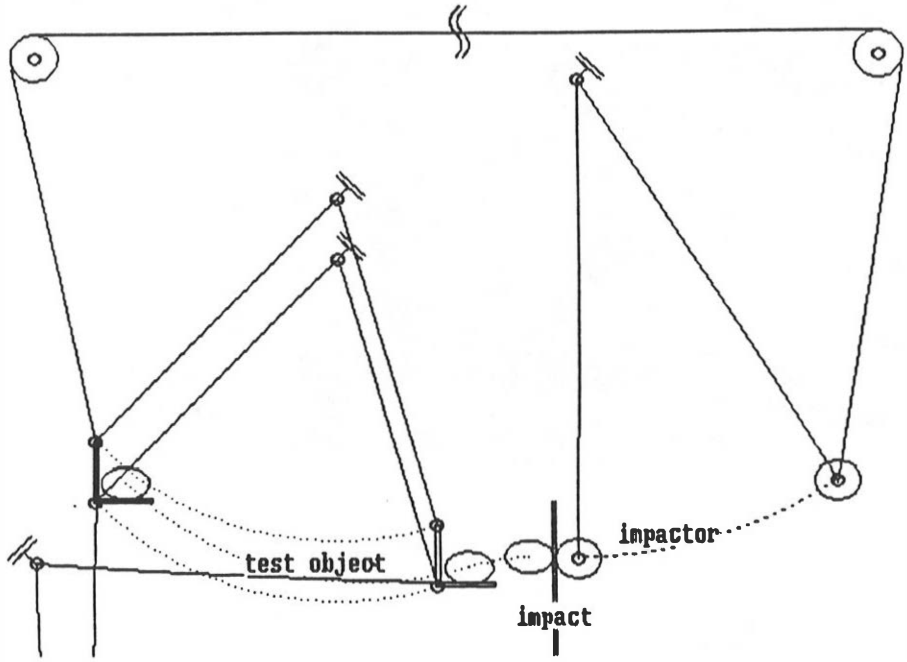

Fig.4: Double-pendulum for research in vulneration mechanics. (Together with Pathologisches Institut des Klinikums Westend, FU-Berlin, Prof. Dr. V.Becker)

Berlin during the years 1966 to 1970. All common research was stopped by the unlucky Berliner Universitätsgesetz of 1968, which never became effectiv since.) On the left pendulum lays the body, on the right the impactors for the specific investigation: for head, chest, abdomen, knees, legs etc. Both pendulums are pulled up in different directions according to the masses. Both start the movement at the same time. The left pendulum is stopped shortly befor impact. The body moves on and hits the approaching impactors of a given stability with the desired speed. At the end of the collision the speed is very small: all energy is absorbed by the impactor and the body. The aim of this tests was to absorb a maximum of energy without vulneration.

During the tests we run into the problem of the deviation of strenght depending on, age, sex and health condition. To minimize the efford we reduced this research to ribs, Fig. 5. Force and deformation for breaking the ribs vary in a wide field. We could not definitely clear the influence of accidental selection and the time after mortem.

Body-parts we used also for research on neck-spine and eyes, Fig. 6 and 7. Eye-vulneration was in the days of toughend glass a problem.

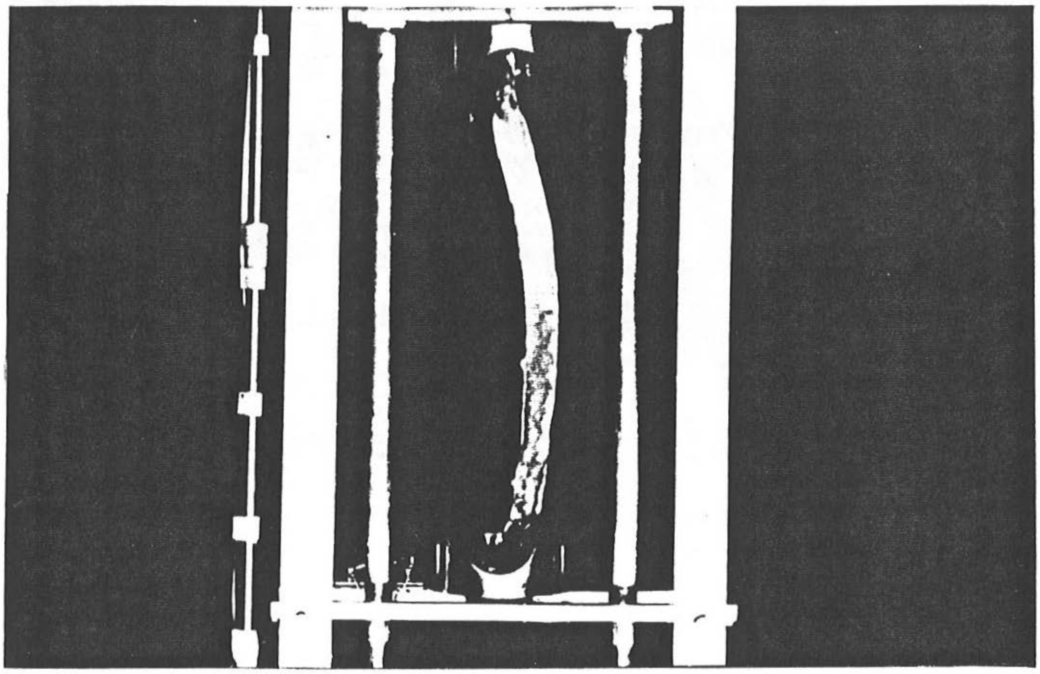

Fig. 5: Strength of human ribs (together with Institut für gerichtliche und soziale Medizin, FU-Berlin, Prof.Dr.W.Krauland.)

Fig.6: Human eyes in a dummy head, which is coverd with leather for experiments with glass lacerations (together with Augenklinik der FU-Berlin, Prof.Dr.H.F.Tiburtius).

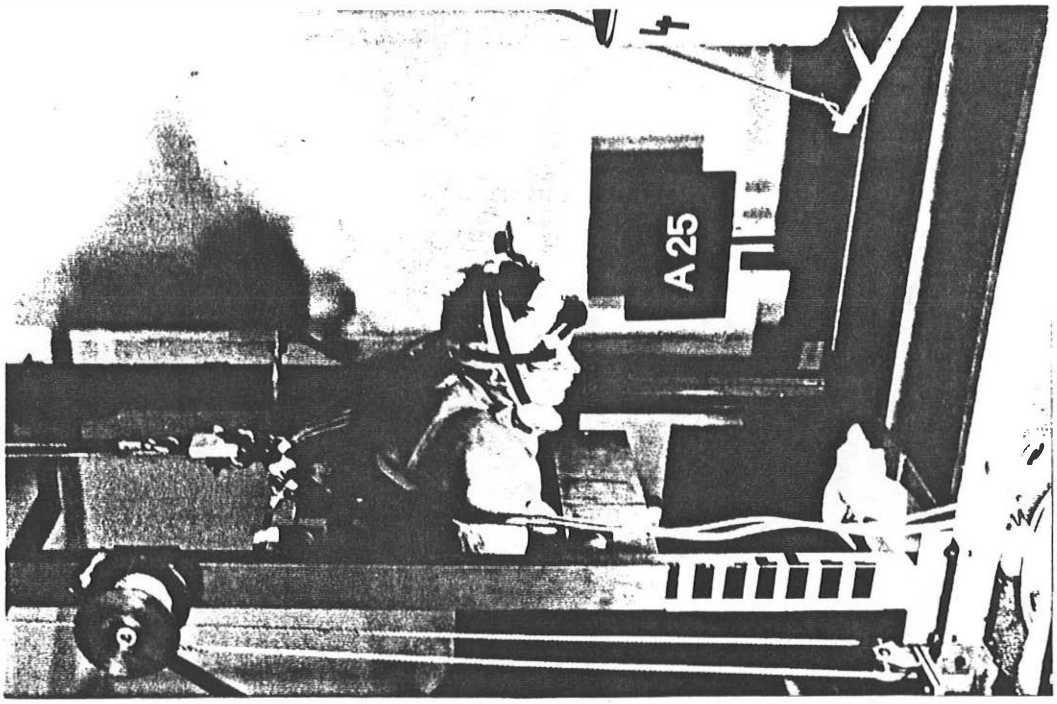

Fig. 7: Wip-lash-tests (together with 3. Anatomisches Institut der Fu-Berlin, Prof.Dr. H.-J.Clemens).

The passiv-restraint problem

Although the airbag was invented in 1951 it was discussed in the late sixtees. The air-bag standard was written in 1970, but it took 20 years before it was clear that the correct question is not belt or bag but belt or belt plus bag. In this 20 years we discussed a legal question: is it legaly possible to mandate the use of a belt? My suggestion from beginning was to order the use of a belt <u>or</u> a bag and leave the decision of the preferred device to the user. We shall see the true results of the benefits on the road soon.

The Experimental Safety Vehicle

In 1970 US-Secretary Volpe started this program together with his colleages in other contries. After the big succes of the landing on the moon the US goverment tried to bring the space- companies and space-engineers into car-accident-research. The specifications for the ESV's call for 50 mpg crash speed instead of 30, which makes the kinetic energy 2.78 times higher. The equivalent dropping height went from 9.2 to 25.3 m. A passiv restraint system was needed. I started in this days to work for Volkswagen. The ESV was the first consolidating task for the new founded Volkswagen Forschung (research group). After some preliminary testing we decided on passiv belts for chest and knees with force limiters for all 4 occupants. A circular, foam-filled diagional-belt moves pneumatically driven along the door rim when the door is opened or closed. With a given deceleration of the car it is preloaded. The knee-belt is covered in the lower dash-board. On the same signal it surroundes the knees with a load of some 100 N.

Belt forces are limited by torsion bars to a non-vulnerating level, Fig. 8. This solution brings the chest-decelleration in a 50 mph-crash down to 40 g, the head-decelleration to 50 g, Fig 9.

The concept of the Volkswagen Experimental Safety Vehicle, the ESVW, was well aware of weight and fuel economy, which led to a car not to far from production. But the interest of the project ceased away.

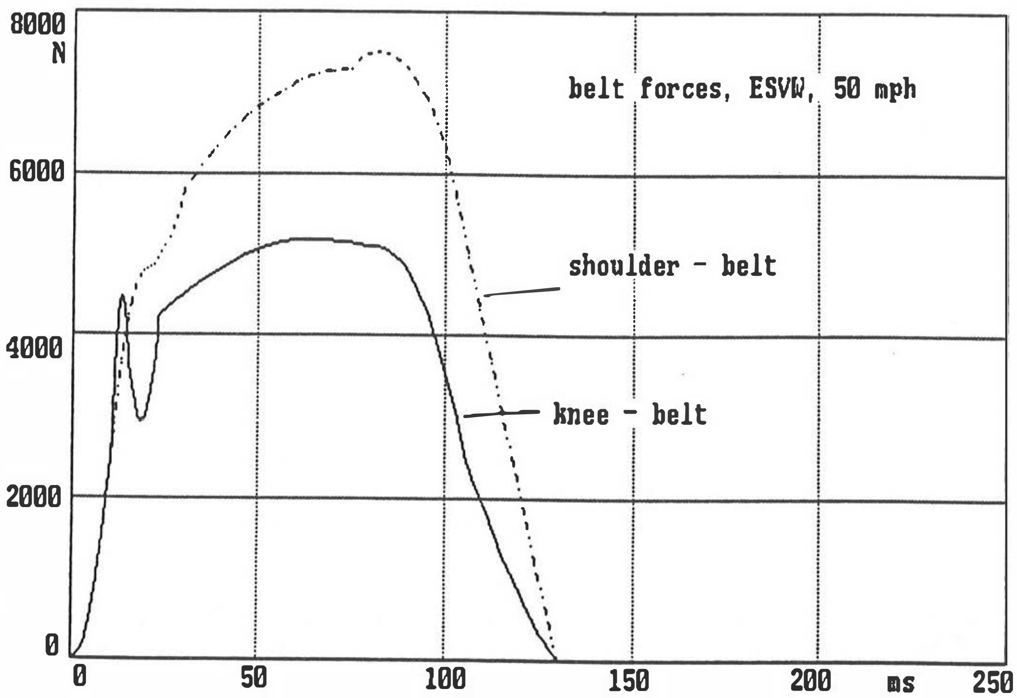

Fig.8: Belt forces at a 50 mph crash test with the ESVW-belt system.

Are we on the right track?

Passiv safety is the big success in car safety. Passiv safety minimizes the advers consequences of a crash. On the first glance has the active safety the higher attraction. Is'nt it wiser to avoid a crash instead of only lowering the consequences? The experience in respect of the reduction of casualities and vulneration with active safety is disillusioning. Almost all benefits of active safety are taken away by increasing the power of traffic, increasing speed, traffic density, riscier driving. We "consume" the added active safty. Better road grip, better breakes, better traffic information all leaves safety where it was before the introduction of new measures of active safety.

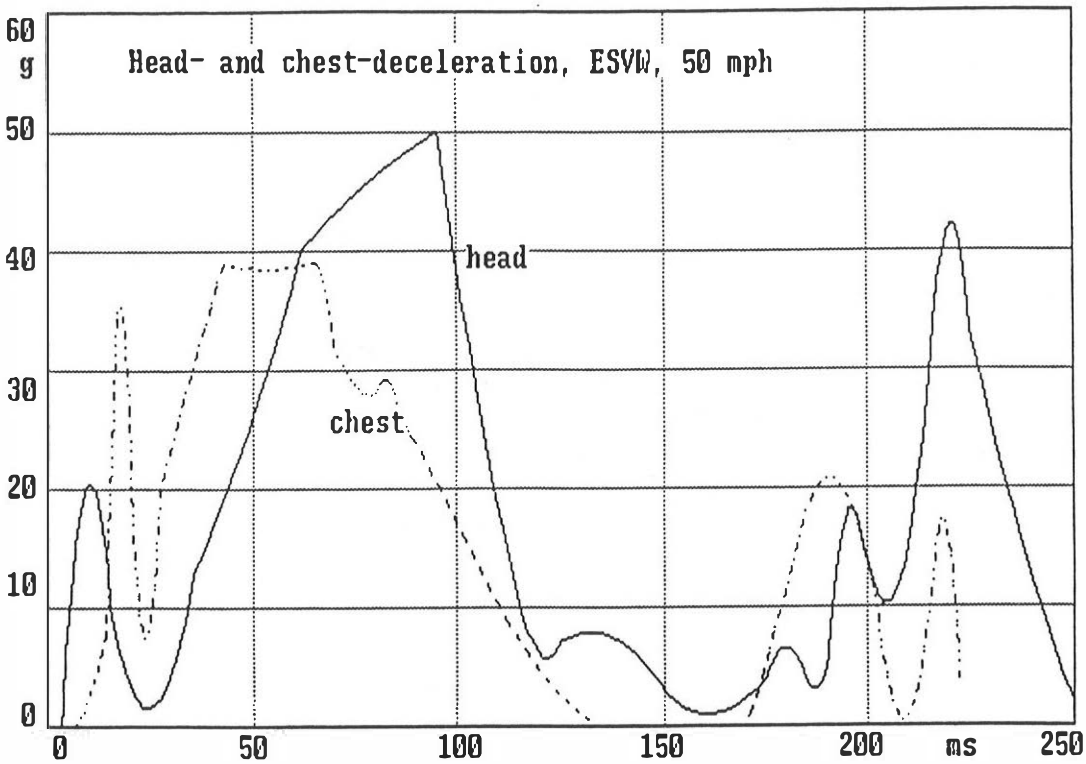

Fig.9: Decelleration of head and chest at a 50 mph crash test with the ESVW-belt system.

In the contrary: worsening the road grip, as it happens on icy roads, makes the probability of vulneration and death smaller. Their is a saying, that tyres of wood reduce the number of death. More accidents but less vulneration and death.

Of course, this is not a serious measure for the increase in road-safety. The speed of the traffic is one aim of evolution. It can not suffer, must not suffer. Look at the evolution of nature: fast moving animals have no passiv safety. A bird, hitting a glass window, can lose his life as well as a hare hitting a plow in his course. The nature trusts in the intelligence of the animals, tries to solve the problem more with software then hardware solutions. Hardware solutions are possible: bulls and bocks have tough skulls for the absorption of crash energy. But not from fast moving but for the fight for predominance.

I think, that passive safety is not the ultimate measure in road safety. It is not economically to transport mass for safety measures. Software solutions are immateriell and thus the final answer. Not tomorrow but in some decades we will create sufficient intelligence of crash avoidence to take some of the heavy, energy consuming mass out of the cars, which we have installed in the last 40 years with some succes.