HELMET ATTENUATION OF THE HEAD RESPONSE IN OBLIQUE IMPACTS TO THE GROUND

by

B. Aldman, B. Lundell, L. Thorngren

Department of Traffic Safety, Chalmers University of Technology, Gothenburg

and

T. Turbell

Road User and Vehicle Division, National Swedish Road and Traffic Research Institute, Linköping, Sweden

Background.

Reports of investigations into two-wheeler accidents indicate that the head of the rider often impacts another vehicle, a fixed obstacle, and/or the ground (Ashton et al 1976). A number of different accident situations can be distinguished in these reports. What type of head impact the rider experiences to some extent depends upon whether he comes to rest near the place of the collision or continues, more or less in his initial direction, some distance from the point of first contact with the other vehicle. In single vehicle accidents a similar pattern can be seen since the driver may impact fixed obstacles or just slide along the road (Hight et al 1973, Newman 1976, Langwieder 1977).

Since both vehicles in a collision usually are moving in different directions, a contact between the head of the rider of the two-wheeled vehicle and some part of the other vehicle generally would be an oblique, rather than a perpendicular impact. If the head does not hit the other vehicle the reason is usually that the two-wheeler has collided with a low part of a car, the front or the rear, and then continues over that part and strikes the ground, or an obstacle, at some distance. The impact to the ground will then usually be oblique i.e. take place at an acute angle. This angle will be determined both by the rider´s horizontal velocity, at the time of the collision, and by his vertical velocity, determined by the height to which he was diverted as a result of the first collision. During the time the body is air-borne it may be tumbeling and there is generally no way of predicting its attitude at the time of impact to the ground.

Intuitively one would think, however, that in most situations where the head impacts the ground at an acute angle, the body would be moving in the direction of its long axis with the head as leading part and the face looking down. Another frequent attitude would then perhaps be one with the feet as leading part and the face turned upwards. In these situations a large relative movement of the helmet on the head at impact would seem possible because many helmets can easily slide in the forward or rearward direction on the head.

An intuitively less probable accident situation would be one where the body, while air-borne, moves sideways with its long axis perpendicular to the direction of travel at impact. Due to the shape of the head a large relative movement between helmet and head would seem to be less likely in this situation because a helmet cannot easily rotate around the head in this plane.

Helmets, worn by accident victims, often have marks and scratches which indicate contact with objects in the environment. Careful examination of such helmets will often disclose valuable information about the accident sequence. Although a perpendicular impact to a smooth, flat surface may not visibly damage an elastic outer shell, the liner usually is more or less permanently deformed in such contacts. Impacts on curved surfaces with small radii usually result in indentations in the shell as well as in deformation of the liner. Oblique impacts more often are identifiable by scratches on the surface of the shell and some deformation of the liner. Studies of such helmets worn in accidents indicate that oblique impacts where the body moves sideways at the time of impact are not uncommon, particularly not in single vehicle accidents (Figure 7).

From this short analysis it would seem that the head impact, in the majority of all two-wheeler collision, would be oblique rather than perpendicular to the impacted surface whether this surface is some part of a car, a fixed obstacle or the ground.

In a previous paper (Aldman et al 1976) a method was described for experimental studies of oblique impacts against a number of simulated road surfaces. It was also stated in that paper that a validation of the tests would be made using an instrumented dummy in free fall drop tests. This paper describes such validation tests which were performed at the National Swedish Road and Traffic Research Laboratory at Linköping, with the aim to simulate as realisticly as possible oblique head impacts to the ground in two-wheeler accidents.

Method.

An anthoropometric 50 percentile male test dummy, with the same instrumented head and rubber neck as in the tests reported in the previous paper, was used in drop tests with oblique ground impacts. The ground was covered with a new, unpolished ashpalt concrete surface Ab8t a type common in cities. Before impact the dummy was suspended in an automatic quick release mechanism at the side of a test cart. Figure 1. The height and the position of the dummy could be so altered that the dummy would impact the road at different attitudes. The horizontal velocity component had four different directions relative to the dummy:

- Parallel to the dummy´s sagittal plane and directed towards the feet or the head, referred to below as feet-first or head-first (F or H).
- Perpendicular to the dummy´s left or right side, referred to as left--side-first or right-side-first (L or R).

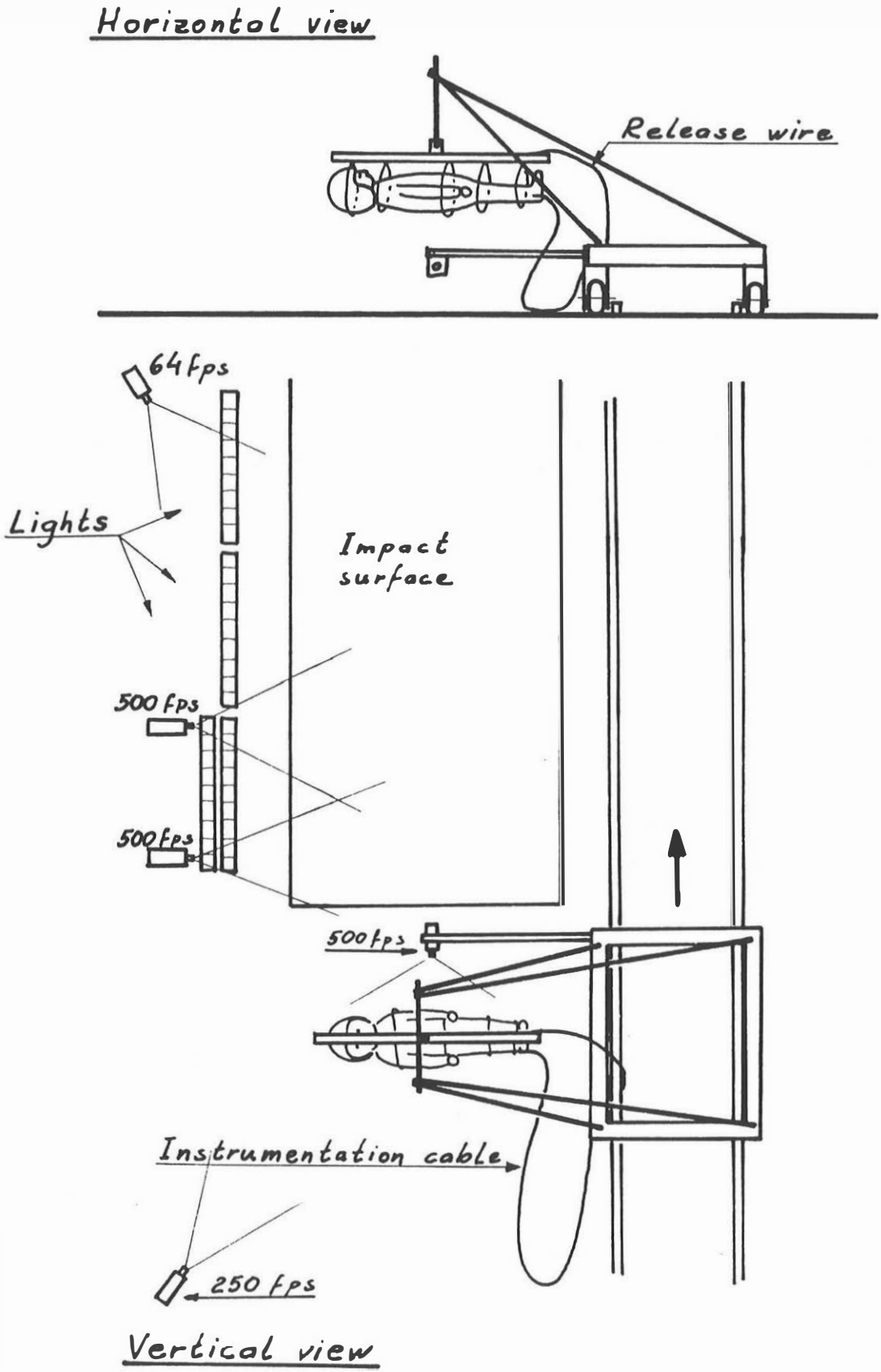
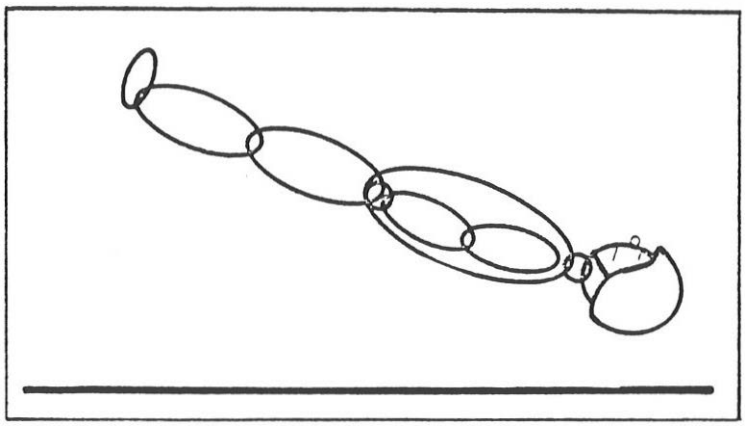


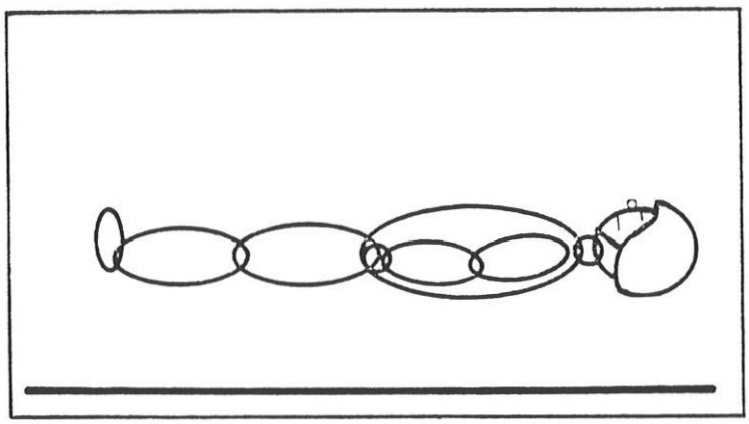
Figure 1. Test site.

Figure 2.



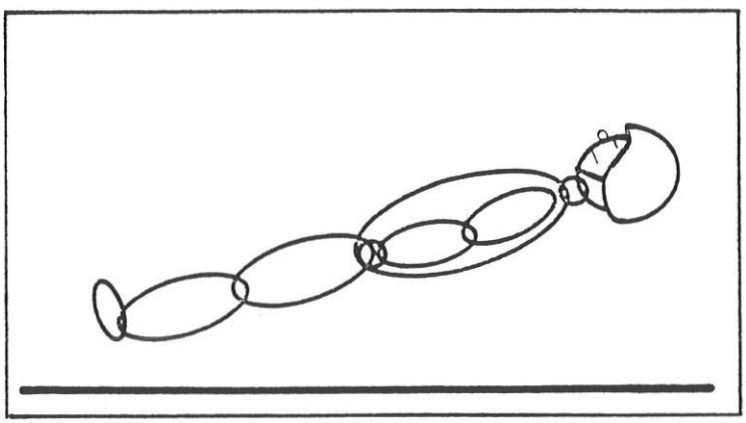
This attitude was used in twelve tests, nine of these with the left-side-first (L), two with head-first (H) and one with the feet-first (F).

Figure 3.



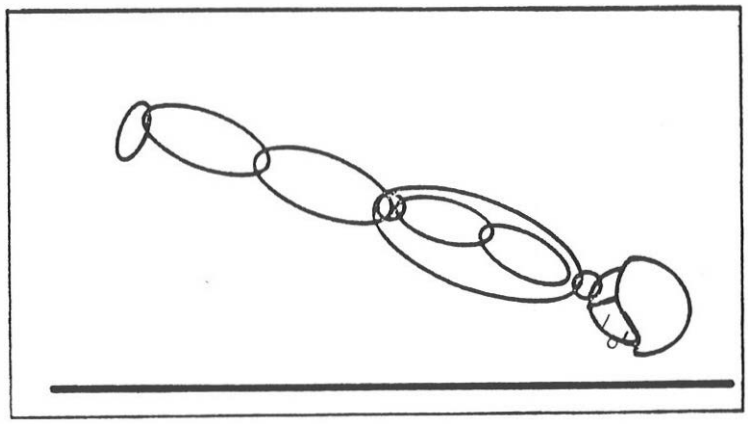
This attitude was used in four tests, three with the left-side-first (L) and one with the head-first (H).

Figure 4.



This attitude was used in one test with the left-side-first (L).

Figure 5.



This attitude was used in two tests, one with the head-first (H) and one with the right-side-first (R).

The horizontal velocity component was approximately 8.3 m/s in the major part of the tests. In four tests it was 4.0, 4.2, 11.4 and 14.0 m/s respectively.

The falling height of the lowest part of the dummy was approximately 1.4 m, giving a vertical velocity component of 5.2 m/s, in all tests but one, in which it was 1.0 m (4.4 m/s).

Linear and angular head accelerations were recorded and the impact sequence was covered by several high speed cameras. All tests were performed indoors at ambient room temperature.

Only one type of helmet of only one size was used throughout the test series. This type of helmet had a polycarbonate shell and a liner of expanded polystyrene. Special efforts were made to press the helmet firmly on to the dummy´s head before each drop. The same procedure was used for each test and a rather high force (≈ 500 N) was used for this purpose. This force was maintained while the chin strap was fastened and placed in identically the same position at each test by means of a chin cup. Each helmet was used only for one test.

Results.

A summary of the results is shown in table 1 below. A total of 19 tests were made, two of these are not included in table 1 because they were performed merely to test the dummy release mechanism and no recordings were made. In one of the tests, where the dummy was dropped in the attitude shown in figure 5 and with the right side leading, the impact to the ground was directly to the dummy´s face and the chock was not attenuated by the helmet.

Attitude according to fig. no	Horizontal motion attitude	m/s	Vertical velocity m/s	Peak linear acceleration g's	Peak angular acceleration rad/s^2	No of tests
2	L	8.1-8.4	5.2	120-150	5500-11400	4
3	"	8.2-8.3	5.2	138-162	6000-12300	3
4	"	8.4	5.2	150	8700	1
2	H	7.8	5.2	140	7700	1
2	F	8.4	5.2	120	12400	1
5	H	8.3	5.2	105	4800	1
5	R	8.4	5.2	240	19000	1
2	L	8.4	4.4	120	7200	1
2	"	4.0-4.2	5.2	134	7000-7400	2
2	"	11.4-14.0	5.2	130-135	10000-10200	2

Table 1.

The results in the first two lines of table 1 are quite similar. For both impact attitudes there is a great variation between the individual results. One possible explanation for this would be that the dummy in some of the tests, during its free fall, had rotated somewhat around its longitudinal axis. In that case one shoulder could well impact the ground earlier than intended, i.e. slightly before or simultaneously with the head. Such a rotation was seen in some of the films but the moment of shoulder impact is obscured by the clothing used to protect the torso at impact.

Even if the impact attitudes illustrated in figures 2-5 are not easily distinguished in the results it seems reasonable to assume that the results recorded reflect the real accident situation quite well.

Another factor contributing to the scatter in the results could be the characteristics of the simulated road surface. In the surface layer of new asphalt concrete the stone material may not be quite evenly distributed and this could be assumed to have a notable effect on the friction between the road surface and the helmet shells. In previous experiments this circumstance had been found to influence the peak value of the angular acceleration at impact and a certain amount of the observed scatter in these values could probably be attributed to the fact that the head impacts to the ground were distributed over a large area of the asphalt concrete surface.

Also in this respect it is assumed that the test situation reflects quite well what happens in real accidents.

The recorded linear and angular accelerations are quite similar to those reported in the previous paper where the same helmeted head was dropped against simulated road surfaces mounted on a rotating disc.

Since very few experiments of a similar nature as those reported here seem to have been performed, it is difficult to assess the realism of this kind of simulation. This in particular is the case for the kinematics of the dummy during impact. Theoretically one would assume that a human body would have behaved differently in some respects under similar conditions.

In comparison with some cadaver tests, where the body falls to the ground with a horizontal velocity component, this dummy seems to be somewhat more elastic with a tendency to bounce somewhat more easily then the cadavers do at ground contact. This, in combination with a road surface with rather high friction, also implies that the dummy was perhaps more inclined to roll after impact rather than to slide along the road surface. This was particularly the case when the body moved sideways.

The influence of this dummy characteristic on the response of the helmeted head could be rather complex. In general one would expect several, more distinctly separated and more violent, secondary head impacts to the ground than in real life accidents.

In the test series reported here the accelerometer signals were recorded on magnetic tape and the recordings were extended long enough to include subsequent head impacts to the ground. In figure 6 one of these extended records is shown.

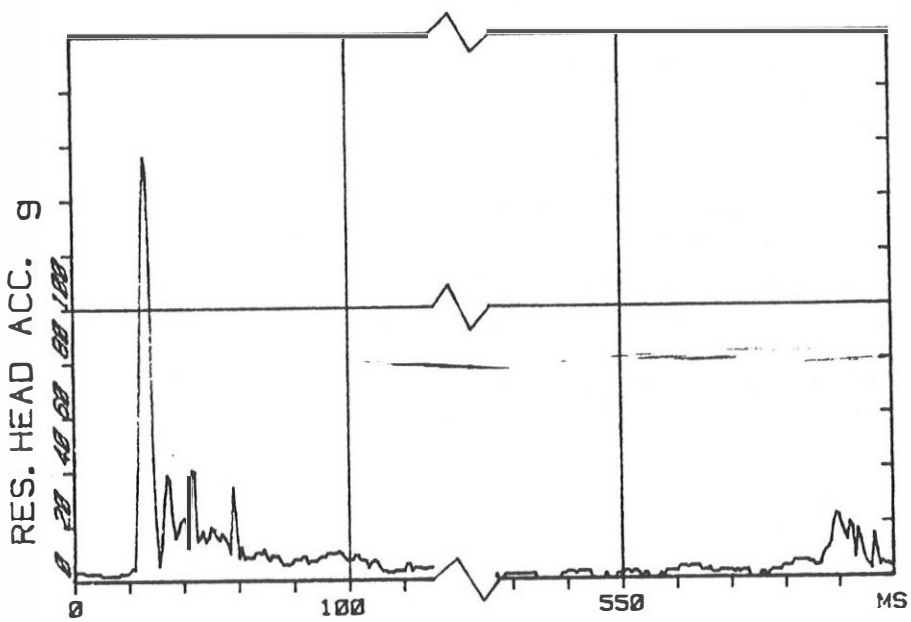


Figure 6.Resultant linear acceleration from first and second ground impacts.

It seems quite obvious from these recordings that secondary head impacts are considerably less violent than the first ground contact.

Upon impact the road surface made very clear imprints on the surface of the helmet shells and therefore it was quite easy to identify the location of the various blows. The imprints consisted of a number of scratch marks stained with asphalt and so the direction of movement could also be identified for each contact. In spite of the fact that the shoulder part of the dummy was rather stiff compared to a human body, the imprints were often located in the lower parts of the helmet shells particularly in the front and in the back depending upon the impact situation. As a matter of interest it was observed that each one of the primary impacts was located or at least reached below the line indicated in the ISO 1511 standard as the lower limit for impact testing (figure 8).

In the tests where the body moved sideways during impact one would anticipate less torsional load imposed on the neck because the dummy rotated more than expected. This would imply a weaker influence from this link between head and torso on the kinematics of the head. In this respect the dummy could be considered to err on the safe side. However, in the tests where the body moved in its longitudinal direction during impact a large relative movement between the head and the helmet could occur and still the rubber neck could to some extent be either compressed or extended and in this situation one would assume the simulation to be less realistic. These problems are dealt with in a subsequent paper where a comparison is also made between accelerations recorded in different types of oblique impact tests.

Conclusions.

- The results from these tests with a complete anthropometric dummy are in accordance with results from a test method where a rail-guided dummy head impacts a rotating disc. However, when a complete dummy is used the impact situation is more complex and the scatter between individual tests greater.
- The linear accelerations were within the expected range and the angular accelerations often reached high levels.
- The primary impacts reached or were located below the line indicated in the ISO 1511 standard as the lower limit for impact testing. It was also found that the secondary impacts gave considerably lower accelerations than the first impact and that they rarely were located at the same site as the primary impact.
- The findings indicate that present standards for approval of crash helmets in some respects do not reflect the course of events in real accidents.

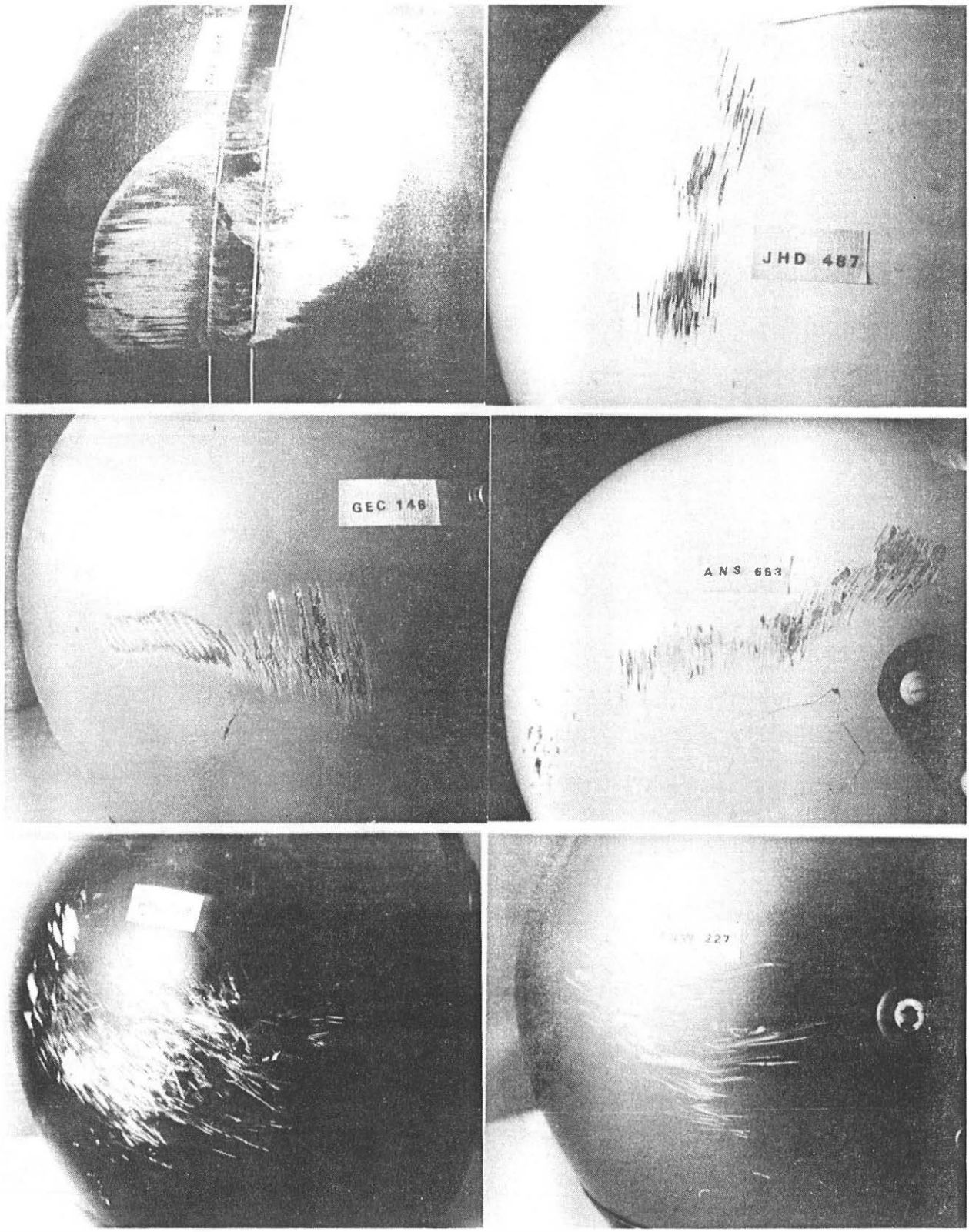


Figure 7. Helmets worn in real accidents.

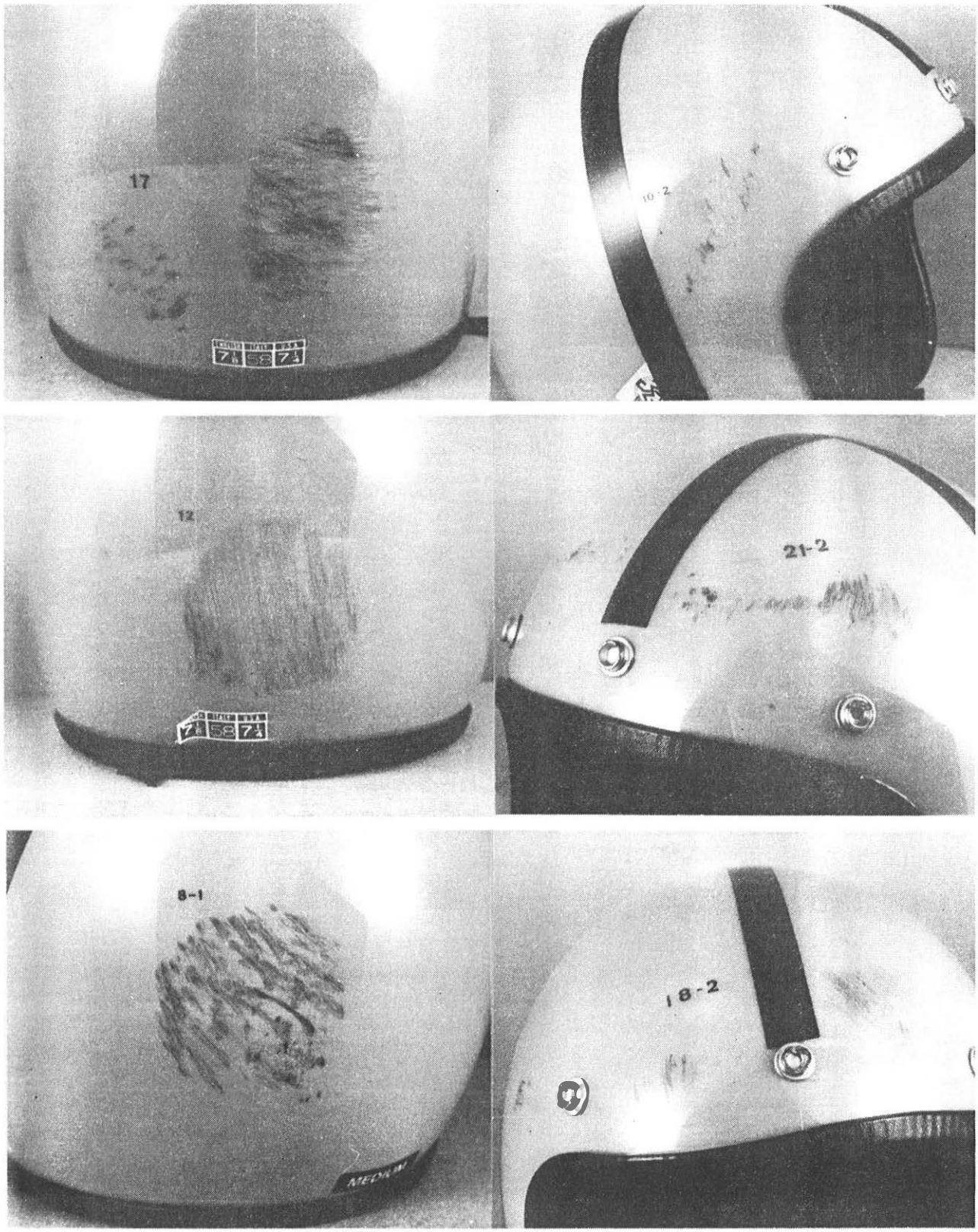


Figure 8. Helmets used in simulation tests.

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