DO TOUGHER STANDARDS LEAD TO BETTER HELMETS?

S. R. SARRAILHE

AERONAUTICAL RESEARCH LABORATORIES

DEPARTMENT OF DEFENCE

MELBOURNE AUSTRALIA

INTRODUCTION

Present day helmets for motorcyclists are highly effective in protecting the wearers, but there are continuing pressures and efforts for improvement. A further development is the increasing use of protective headgear in other activities, such as pedal cycling.

The performance of helmets is usually judged against one or other of the interrelated standards, Table 1, and so it is vital that these reflect the development of new designs and advances in knowledge. The use of certified helmets is mandatory in many instances. The test parameters set by the Standards, such as drop test height, are adjusted regularly but the most fundamental test, the shock absorption test, which uses a rigid headform to represent the head has remained virtually unchanged since inception. Recent work at the Aeronautical Research Laboratories suggests that this should be supplemented by other procedures to ensure a satisfactory balance between the properties of the shell and the liner. Typical helmet construction is shown in Fig. 1, the principal protective components are:

TABLE 1 INTER-RELATED PROTECTIVE HELMET STANDARDS

AS 1698-1974[1]	Australian Standard "Protective Helmets for Vehicle Users", AS 1698 - 1974 Standards Association of Australia. Sydney 1974.
ANSI Z90.1-1971[2]	Z905 1971, "Protective Headgear for Vehicle Users", American National Standards Institute Inc., New York, 1971.
Snell 75[3]	"Standard for Protective Headgear 1975", Snell Memorial Foundation, California, 1975.
Snell 70[4]	"Standard for Protective Headgear 1970", Snell Memorial Foundation, California, 1970.
ISO 1511[5]	Protective Helmets for Road Users. International Standards Organisation. Secretariat, British Standards Institution, London 1977.

(1) a strong shell, sufficiently rigid under potentially survivable loads to:

(a) maintain the shape of the head; and

(b) spread any concentrated impact load over the head.

(2) a shock absorbing liner intended to cushion the impact by:

(a) crushing to limit the impact force to a tolerable magnitude and while crushing to dissipate impact energy (e.g. during crushing the liner provides stopping distance);

(b) crushing to accomodate deflection of the shell at the point of impact; and

(c) spreading the load over the head.

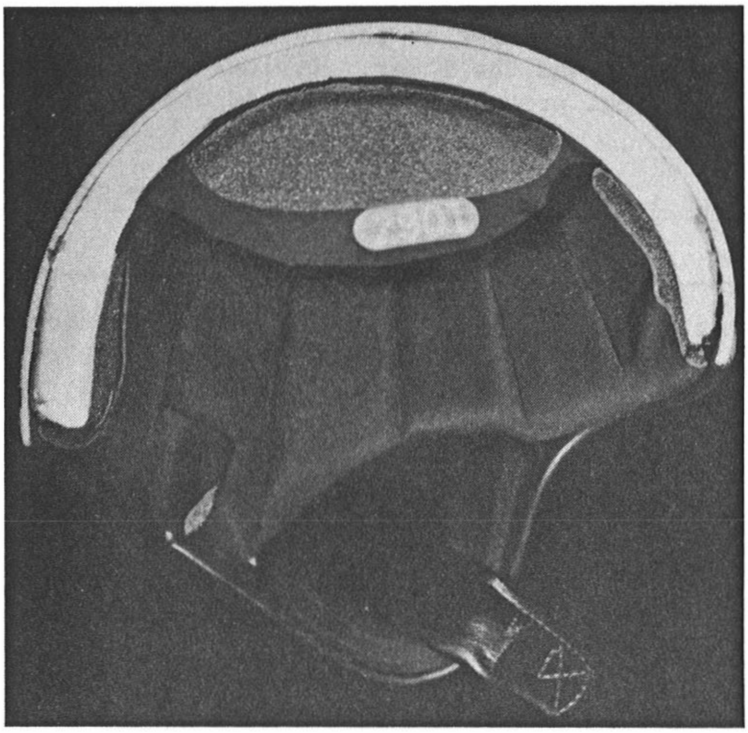

FIG. 1. Typical Helmet construction showing strong shell, crushable "shock absorbing" liner (styrofoam), comfort padding and lining and retention strap. The liner of some helmets designed to tougher standards is nearly twice the thickness shown here.

Clearly these functions overlap and the liner and shell should be designed to work together, for example it would be expected that shell rigidity and liner crushing force would be based on the same "design load".

In practice the crushing force of the liner must be selected to suit the "shock absorption" test. In this test a solid, virtually rigid, headform is fitted with a helmet and the assembly is dropped onto a rigid anvil, typically from a height of about 2 metres, Fig. 2. In the impact the deceleration of the headform must not exceed a given limit, typically 300 g. In this test the drop height effectively sets the lower bound for liner crushing force and thickness because the average force times the depth of crush must match the impact energy. The upper bound for force is set by the permissible deceleration of the headform and its mass. With typical values of 300 "g" and 5 kg the force is 15 kN.

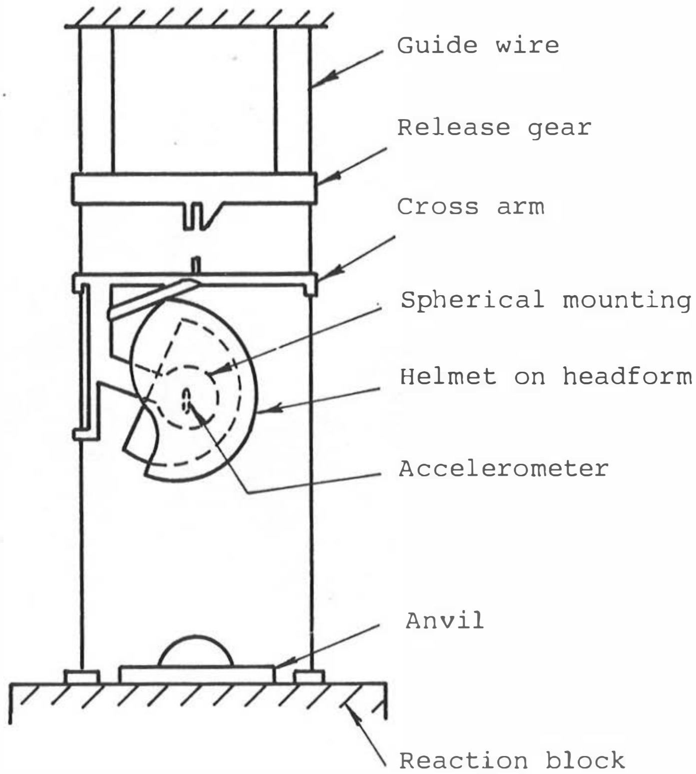

FIG. 2 Diagrammatic arrangement of standard test rig

The rigidity of the shell is not generally controlled in National standards. ISO Recommendation 1511 calls for a lateral compression test on an empty helmet but the loads are low.

Investigations at the A.R.L., including attempts to simulate impact damage which occurred in an accident[6], suggested that the rigid headform could reinforce the helmet and new procedures were developed to determine the behaviour of the helmet without the support of the headform. These tests consisted of slow or rapid lateral compression tests and they were carried out on a sample of typical helmets including ones with fibreglass or moulded plastic shells.[7]

New Test Procedures

Helmets were compressed slowly in a servo controlled electro-hydraulic testing machine, as shown in Fig. 3, or rapidly by a striker in a special impact facility, Fig. 4.

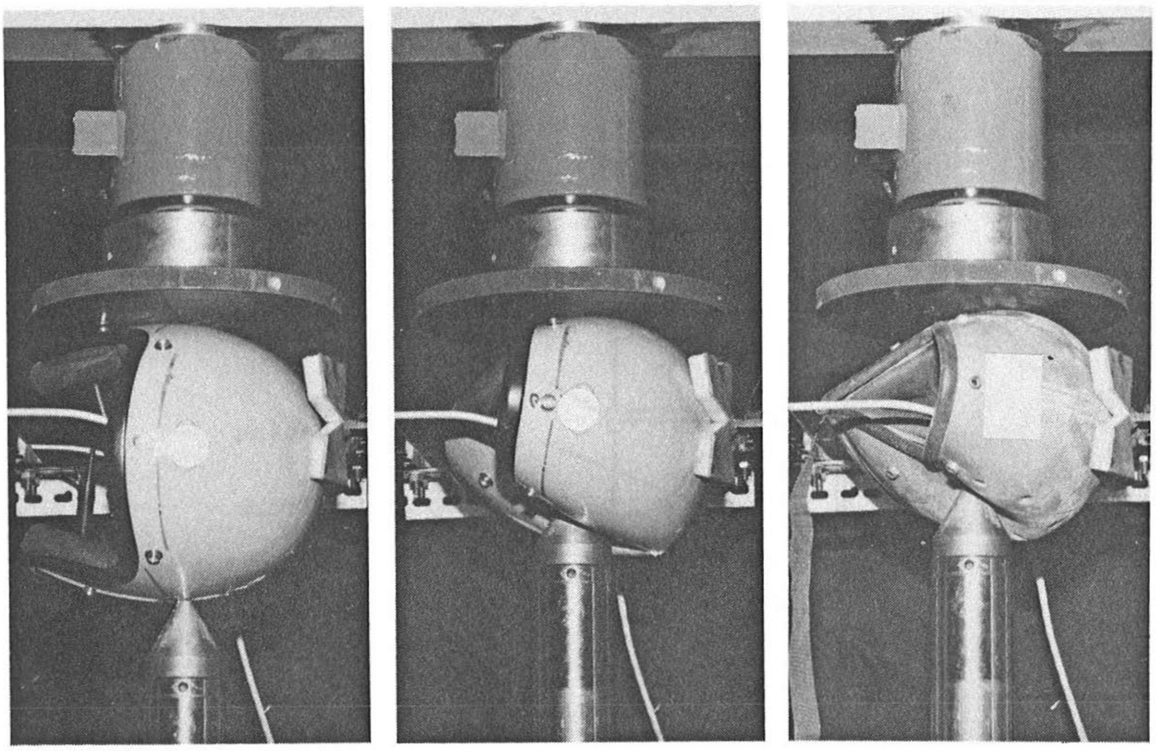

FIG. 3 Slow compression tests

Left: Fibreglass helmet unloaded
Centre: Fibreglass helmet loaded 4.5 kN
Right: Polycarbonate helment loaded 3.5 kN

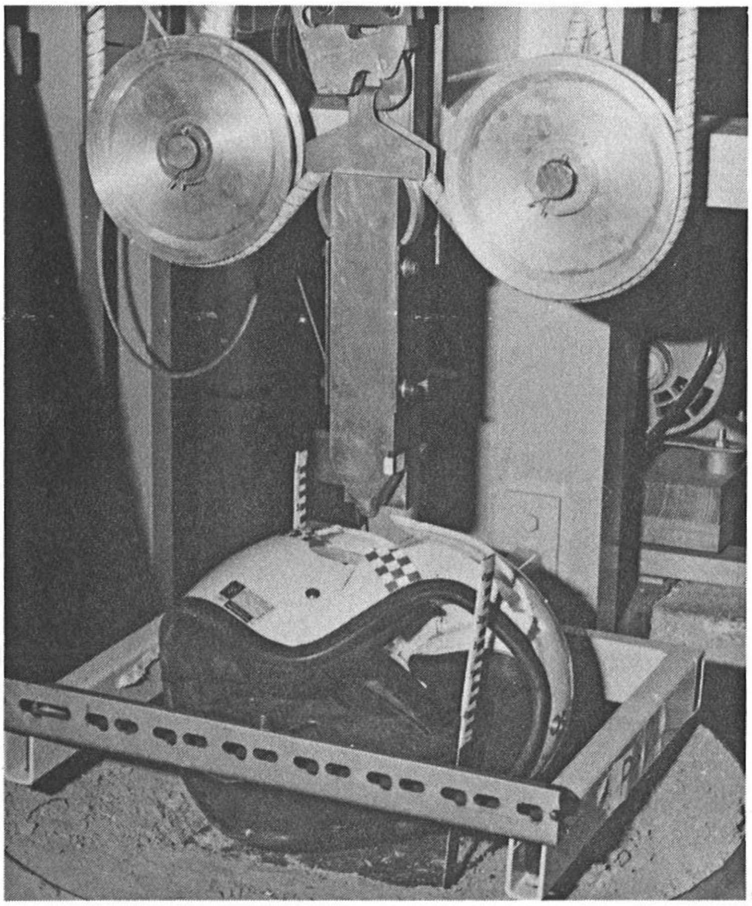

FIG. 4 Rapid Compression test rig.
(Helmet deliberately embrittled by application of solvent. Test energy 387 J)

In either type of test the helmet was empty and the load was applied just above the "test line" (as defined in the standard). The position of the indenter on the shell is evident in Fig. 5.

The indenter had a flat contact surface 10 mm diameter and the helmet was located by pads arranged to minimise interference with the deflection of the shell.

The load transmitted through the helmet to the anvil, and the deflection of the helmet at the indenter were recorded.

The compression conditions were selected to flex the shell until the opposite sides touched one another as shown on Fig. 3.

During the slow compression test the testing machine was programmed to compress the helmet 90 mm at a rate of 10 mm per second. This compression was held for 10 seconds and then reduced at 10 mm per second. The load deflection curve was plotted automatically. The energy to compress the helmet ranged from 140 to 280 joules.

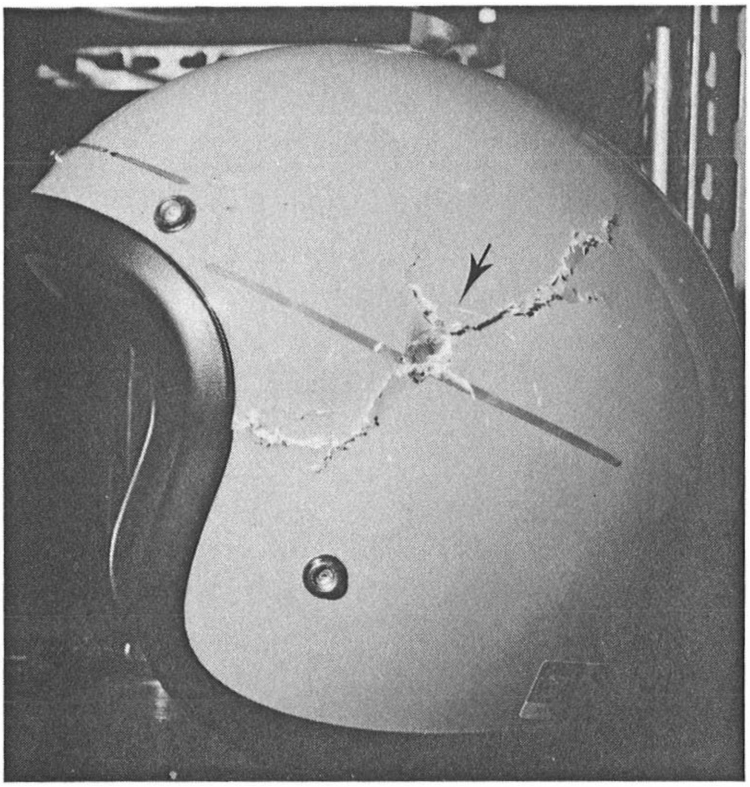

FIG. 5 Location of the indenter (arrowed) and cracks in a fibreglass helmet after a slow compression test. The "test line" as defined in the standard is drawn on the helmet.

In the rapid compression (impact) test a three kilogram striker was arranged to impact the helmet at 13 m/s. The resulting impact energy of 254J was comparable to that in the slow compression tests, but is much greater than in any conventional approval test (eg. the Australian Standard requires an impact energy of 90J). The test parameters were chosen to ensure destruction of the helmet so that the conditions at the point of failure, or the maximum load and deflection could be measured. To achieve the rapid impact the striker was accelerated down the rail, towards the helmet, by a rubber shock cord. The compression of the helmet was indicated by a photo-electric device which sensed the movement of the striker by detecting a series of stripes 8 mm apart on a transparent strip attached to the striker. The resulting "blips" were displayed, together with the impact force on a storage oscilloscope. The maximum deflection was typically about 80 mm.

RESULTS

The load/deflection curves for slow compression and points representing maximum force and compression in the rapid compression tests are shown in Fig. 6 for the most and least rigid helmets. The rapid compression test results were close to the slow compression test curves.

It is seen that a load of 1.5 kN could produce a lateral compression of about 50 mm.

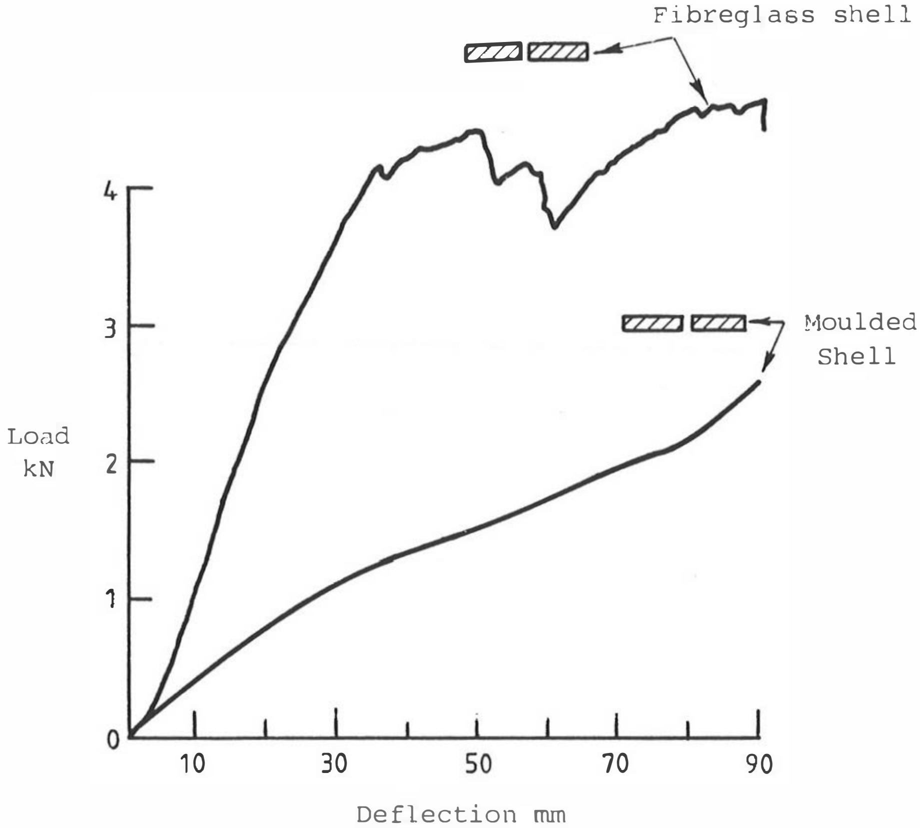

FIG. 6 Load deflection curve for lateral compression

Curves: slow compression
Bars: rapid compression

DISCUSSION

The 1.5 kN load to produce the large deflection of 50 mm is only one tenth of the impact force used to control the selection of the crushing properties of the shock absorbing liner.

Without the support of the solid headform, a force 15 kN would produce a totally unacceptable deflection of the shell. Helmets are shown compressed by about 4 kN on Fig. 3.

There is therefore a vast disparity between the loads that the shell can withstand and the loads effectively used to design the shock absorbing liner.

It may be argued that the test loading of the shell, at the two opposite sides of the helmet, was more severe than the impact of a helmeted head, when the impact loading outside is reacted by an evenly distributed inertia loading inside. However, comparison made using standard stressing formulae for similar shapes shows that the difference in the loading onto the shell is far less than the disparity between the stiffnesses of the liner and shell.

The relative stiffness of liner and shell is not detected in the standard impact test, because the rigid headform allows the small area of liner under the impact point to transfer the load directly from the anvil to the headform.

In a real impact, with a less-than-solid head, the shell is likely to deflect, with possible distortion of the head, before substantial crushing of the liner can occur. This appears to be consistent with the results of accident studies which indicate that although helmets are highly effective in protecting their wearers from head injury, the liner is seldom crushed to any extent. For example, Dr. Hurt[8], in his study of over 900 accidents measured the depth of crush in about 200 helmets and reported that 95% of these had crushed by less than 5 mm and the maximum crush was about 10 mm, (Table 2).

The report also showed that average liner thickness was 21 mm with a maximum of 29 mm, (Table 3.) It would appear that there is little to be gained by the use of the thicker liners when such a small proportion of the thickness is used.

The depth of crushing in these accidents was much less than has been measured in standard tests at ARL, and this suggests that the "survivable accident" impacts were generally less severe than the standard impact tests.

A study was made by Slobodnik[9] in which accidental damage to aircrew helmets was duplicated in the laboratory and accident injury correlated with the corresponding impact deceleration measured in the test. This indicated that the maximum permitted value (for aircrew helmets) should not exceed 150 g.

It is considered that although the conventional test procedures have resulted in highly successful protective device the protection will not be improved by increasing the energy in the impact test. Furthermore the best performance in an accident may not be achieved by optimizing the helmet to the artificial conditions of the test where a solid headform is used, and the permitted deceleration is 300 to 400 g.

In particular, extrapolation of test parameters may be inappropriate for:-

1. helmets intended to give extra protection when bulk or mass are not critical;
2. helmets for active sports where bulk and mass are critical; and
3. helmets which use new materials or methods of construction.

TABLE 2 HELMET LINER CRUSH AT IMPACT SITE

crush less than: inches	mm	adjusted cumulative frequency%
0.1	2.5	86
0.19	5	95.4
0.35	9	99.5
0.44	11	100

REF: from Hurt and others - Table 9.8.13
900 accidents investigated
liner crush known in 216 cases

TABLE 3 HELMET LINER THICKNESS

liner thickness inches	mm	cumulative frequency%
.84	21	49.6
1.13	29	94.9
1.44	37	100

REF: from Hurt and others - Table 9.4.6
236 helmets measured.

RECOMMENDATIONS

It is recommended that the basic mechanism of protection, the tolerance of a helmeted head to impact and the test procedures for assessing protective performance should be reviewed.

It is proposed that:

(1) a shell stiffness criterion be established (perhaps at a median value for current fibreglass helmets) and a test introduced into the standard;

(2) the crushing strength of the liner should be correlated to the shell rigidity; and

(3) unless and until a suitable non-rigid headform can be developed, impact tests should continue with a solid headform, but the permitted deceleration (or impact load) should be reduced drastically (ie. far more than the 400 to 300 g reduction that has already been made in some standards).

CONCLUSIONS

(1) The standards encourage selection of grade of "shock absorbing" material liner that is too hard relative to the rigidity of the shell.

(2) An increase in the specified test impact energy, by an increase in drop height or requirements for repeated impacts at the same point may exacerbate the imbalance.

(3) Accident surveys indicate that the liner may be too hard to crush and fulfil its cushioning function in the majority of accidents.

(4) Test procedures and requirements should be reviewed and revised to introduce tests for shell rigidity. In particular the permitted impact load (or deceleration) should be reduced to increase effectiveness of the liner in accidents and restore a balance between the rigidity of the shell and the crushing strength of the liner.

(5) Optimization of a helmet to unrealistic test requirements may not produce the best helmet in the real world.

ACKNOWLEDGEMENT

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