FIELD ACCIDENT DAMAGE AS A BASIS FOR CRASH TESTS

J.L.G.Hardy, G.M.Mackay, S.J.Ashton and P.F.Gloyns
Department of Transportation and Environmental Planning,
University of Birmingham, U.K.

ABSTRACT

Analysis of a representative at-the-scene sample, and also a retrospective study of serious injury accidents, is used to establish the pattern of damage configurations in injury producing accidents. Suggestions for improving frontal impact testing are made on this basis, and an important conclusion is that the ¼ overlap offset barrier test should be adopted. Some observations concerning barrier design and impact testing of occupant contact areas are also made.

INTRODUCTION

Some recent work (1,2) has suggested that the overall crash-performance of passenger cars in accidental collisions is not adequately predicted by current crash testing, because some collision configurations which are common in occupant-injury accidents are not reproduced by the experimental tests.

This paper suggests more realistic test types on the basis of field data, outlines a procedure for establishing appropriate speeds for these tests, and comments on some related aspects of interior design. Because of the relatively small size of the samples available, only the problem of frontal impact testing is considered.

METHODOLOGY

Two separate samples of cars involved in collisions have been examined to this end.

The first comes from an at-the-scene study structured to be representative of urban and rural accidents in the U.K. This study has been reported in detail elsewhere (3).

The second sample is the result of a more recent retrospective study of serious injury accidents involving current model cars and car derivatives less than three years old. Because of the way in which this study has been structured (4) it is not representative of all serious injury car occupant accidents. The sample is biased towards certain models of car, and towards frontal impacts. In addition it is thought to have a slight bias towards higher energy accidents; however it is judged that the sample correctly represents the damage distribution in serious injury frontal impacts in the U.K.

AT-THE-SCENE SAMPLE

At present, most crash tests involving damage to the front structure of the vehicle result in the principal force component at impact being parallel to the longitudinal axis of the vehicle. The at-the-scene sample is examined to establish whether or not the majority of frontal collisions have a similar impact direction.

The distributions of impact directions and impact areas for the passenger cars and car derivatives in this sample are summarised in Table 1. 77.2% of the 352 frontal impacts lie within the 11 o'clock to 1 o'clock band of impact directions (see Figure 1).

RETROSPECTIVE SAMPLE

This rather larger sample of serious injury accidents has been used to indicate the relative frequency of different damage configurations in the real world. From the original sample of 700, cases were selected on the following basis:

a) At least one occupant with an overall injury severity of 2 or higher on the AIS scale (5). This selects moderate or greater injury levels. Injury to be attributable to the frontal impact.

b) No occupant ejection.

c) No seat belt use by occupants.

d) Impact direction between 11 o'clock and 1 o'clock.

These criteria were used to select a sample representative of the more severe injury-producing frontal impacts occurring in the field.

The 184 cases remaining were then examined individually, and a judgement made as to which type of crash test would most closely reproduce the damage which occurred in the impact. Not all possible tests were included, the types being restricted to the following:

a) Front distributed barrier.

b) Offset barrier; subdivided in ¼, ½ and ¾ overlap conditions.

c) 15^{o} angled barrier.

d) Front central pole.

Table 2 illustrates these test types and shows the percentage of the sample judged to be best represented by each test.

During this analysis, it became evident that only a very small proportion of the cases classified as "front distributed barrier" or "15° angled barrier" were best represented by a flat rigid barrier. In most cases of this type, the load had not been spread evenly over the contact area by the object struck; typically in a car-to-car head-on collision, the stiffer parts of one vehicle had penetrated the other. Such stiff members are often clearly seen protruding beyond the front of the damaged strucutre after the impact (see Figure 2). It is possible that some kind of deformable or energy-absorbing barrier might reproduce this type of damage more faithfully than the rigid barrier.

DISCUSSION

The analysis of the at-the-scene sample illustrates the predominance of the 11 o'clock to 1 o'clock range of impact directions in collisions involving the front structure of the vehicle. Other field work (2,6,7) is in general agreement with this, and it is concluded that a high proportion of frontal impact crash testing should reproduce this condition.

However, the crash tests chosen to represent this range of impact directions should also reproduce the most common field damage configurations and current testing is less satisfactory from this point of view.

For the range of impact directions under consideration, the most common damage configuration found in the retrospective sample approximated to that produced by a ¼ offset overlap barrier test. About 25% of the cases in the sample were judged to fall into this category. It is suggested, therefore, that the ¼ offset overlap barrier be adopted for frontal impact crash testing. The importance of this test type is reflected in a recent proposal for a safety vehicle specification (8). In view of the expense and difficulty of carrying out multiple tests, it is suggested that a vehicle which performs adequately in both the front distributed barrier test and the ¼ overlap barrier test might be expected to perform adequately in ½ and ¾ overlap barrier tests as well, and so there should be no need to perform all four tests. In addition, unless the vehicle structure was markedly assymetrical it would probably not be necessary to carry out a ¼ overlap test on both sides, as one test on the driver's side only would suffice.

It has been found in practice (2) that a 15° angled barrier test adds little to the information gained in the front distributed barrier and so the 15° angled barrier test could also be omitted. Thus a ¼ overlap test, a front distributed barrier and a central pole impact should test the front structure adequately.

The damage configuration in about 15% of frontal impacts within the range of impact directions under consideration did not fall into any of the chosen categories. This group was composed of some under-run and offset pole impacts in addition to a number of cases not conforming to any test type, and a few cases where the impact direction was uncertain.

For each case in the retrospective sample an attempt was made to decide at what speed the appropriate test would have to be carried out to most closely reproduce the damage, i.e. an Equivalent Test Speed (ETS) was assigned to each case. Because of the lack of relevant test data, however, the results were judged to be too imprecise. Further test work in various configurations and at various speeds is a necessary preliminary for such an analysis to be accurately performed.

Optimising crash-performance in both front distributed and ¼ overlap offset barrier collisions is likely to be difficult, but field experience indicates that many present designs could be improved considerably before the inherent design conflicts become apparent. In particular, some designs of 'A' pillar area and front suspension systems lead to large amounts of interior crush in the ¼ offset situation. Front doors which are weak in compression also contribute to the reduction of the passenger compartment volume in this type of impact. The cases shown in Figure 3, 4 and 5 illustrate these points.

INTERIOR DESIGN

Impact direction in real accidents is continuously variable in a horizontal plane, occupant trajectories with and without restraint are different, and occupant size and initial posture also vary; thus the locus of all points at which the occupants may strike the interior covers a large area. It is therefore important that vehicle interior design is not dictated entirely by the standard crash-tests. The areas within which the majority of injury-producing occupant contacts occur could be defined by analysis of in-depth field studies, and separate tests then specified for these areas. The possible effects of static and dynamic deformation of the inside of the passenger compartment should not be ignored in specifying these tests.

CONCLUSIONS

1) Much current and proposed crash testing does not reflect the pattern of impact types in the real world.

2) It is suggested that the ¼ overlap offset frontal barrier be adopted in conjunction with the central pole and the front distributed barrier as appropriate crash tests for frontal impacts.

3) Some consideration must be given to the design of barriers for crash-testing in order that they should more closely represent real accidents.

4) In order to elucidate appropriate tests for impact conditions other than frontal, a large representative sample of real accidents must be collected. This does not need to be an in-depth study, but the numbers required would be large; of the order of several thousand.

5) In order to establish appropriate test speeds, the proposed tests should be carried out on a number of vehicles, and the sample of real accidents re-analysed on the basis of the data thus obtained.

6) Separate testing of occupant impact areas should be carried out instead of simply testing those areas struck by a dummy in specific crash tests.

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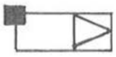
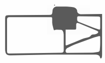
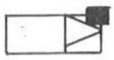
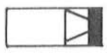
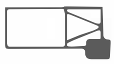
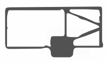
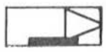
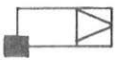
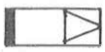
DIRECTION OF IMPACT (CLOCK CODE)

AREA OF DAMAGE

	9	10-11	12	1-2	3	4-5	6	7-8	Unknown
	7	2						2	1
	18	5	1					3	1
	15	7	3					3	
	4	13	33	1	1			1	5
	2	5	164	11	1				20
		6	54	27	3				1
			8	7	19	8			1
			7	9	32	6	1		
			1	3	8	5			1
				2	1	3	52	5	

Figures represent numbers of cases in each cell (N = 599)

TABLE 1

Table of area damaged by impact direction for the at-the-scene sample

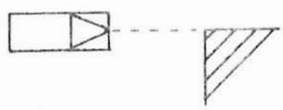
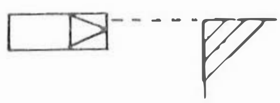
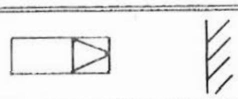
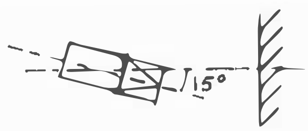
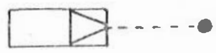
Equivalent Test	%	%	
Offset 0-¼ left	7.6	25.5	
0-¼ right	17.9		
¼-½ left	6.5	17.9	
¼-½ right	11.4		
½-¾ left	2.7	11.9	
½-¾ right	9.2		
Front Distributed	12.5	18.4	
15° Angled - left	1.6		
- right	4.3		
Front central concentrated	11.4	11.4	
Unclassified frontal	14.7	14.7	Including underun and offset pole impacts

TABLE 2 (N = 184)

% Distribution of Equivalent test type for frontal impacts in the retrospective sample

Occupants unrestrained and not ejected

At least one occupant AIS ≥ 2

Impact direction between 11 o'clock and 1 o'clock

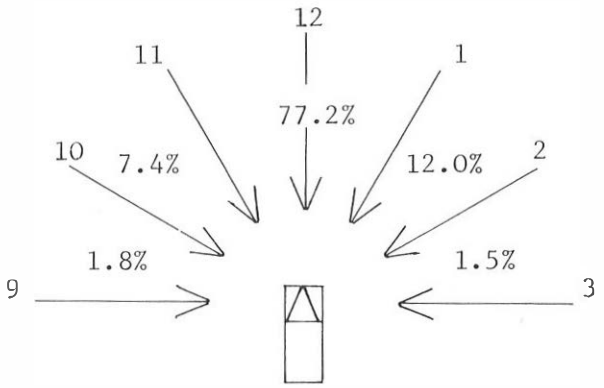


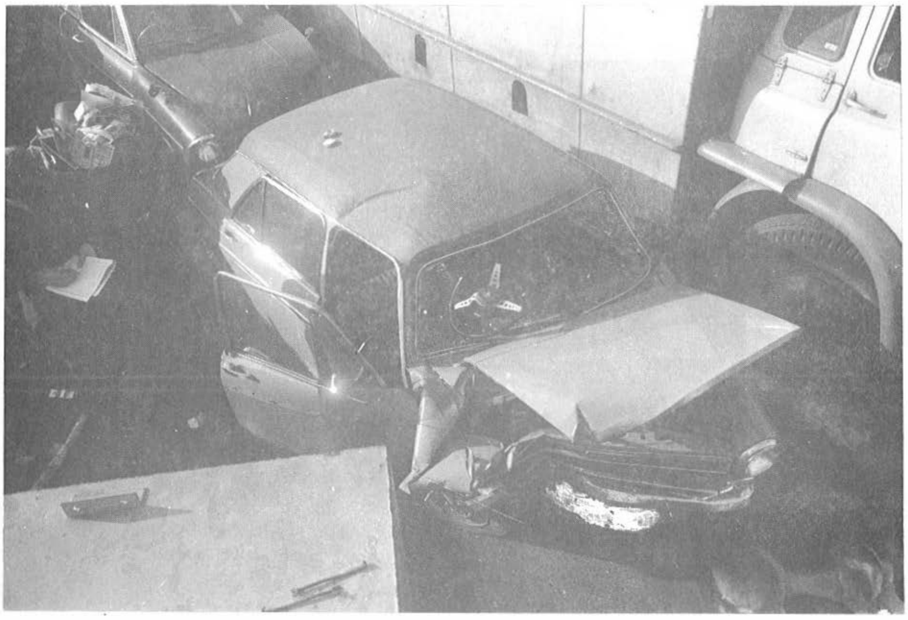
FIGURE 1

Proportions of Impact directions on the clock code for accidents involving damage to the front structure of the vehicle (Drawn from Table 1)

FIGURE 2

Note stiff members protruding beyond softer structure

(a)



(b)

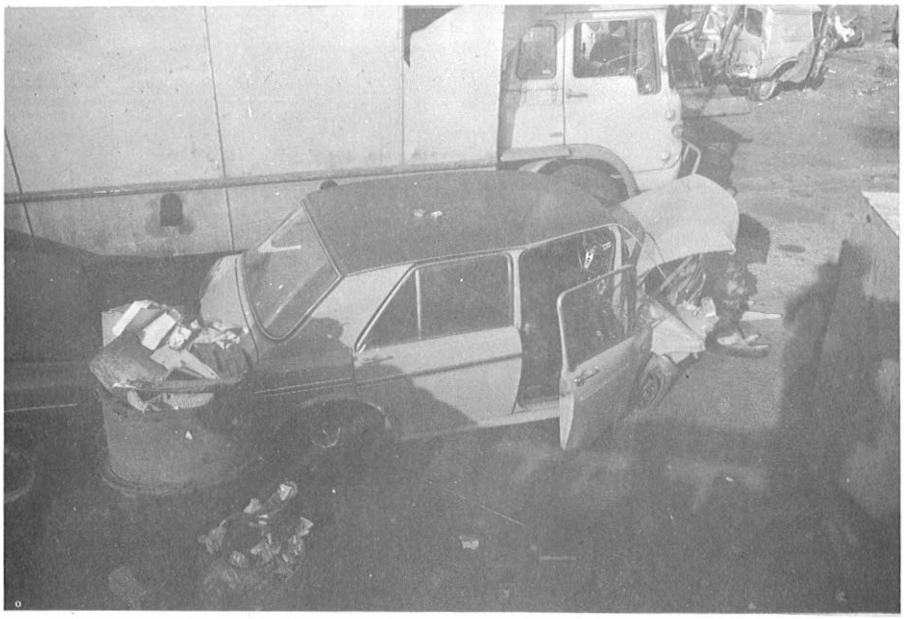


FIGURE 3

Rearward movement of facia due to compression of front door in $\frac{1}{4}-\frac{1}{2}$ overlap impact

(a)

(b)

FIGURE 4

Gross reduction of left front passenger's seating area through rearward movement of 'A' pillar in a $\frac{1}{4}$ overlap situation.

(a)

(b)

FIGURE 5

A sideswipe accident. The right front road wheel moved back through the floor, (b) leading to a compound comminuted fracture of the driver's right ankle.