THE PEDESTRIAN LEGFORM IMPACTOR ACCORDING TO EEVC WG 17 - RESULTS OF AN ACTUAL RESEARCH AND POSSIBILITIES FOR THE IMPLEMENTATION WITHIN REGULATIONS ON PEDESTRIAN PROTECTION

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ABSTRACT

AN INVESTIGATION WITH THE EEVC WG 17 PEDESTRIAN LEGFORM IMPACTOR at the Federal Highway Research Institute in order to find causes for possible measured value variations was initiated after a test series with different legform impactors showed partially unacceptable scatters regarding the bending angle, shearing displacement and acceleration. Several sets of impact tests were performed and the standard deviation of the repeatability and reproducibility was assessed. Results of tests under idealised impact conditions were first validated by a comparison to real vehicle tests. A recently drawn up handling guideline will improve the reproducibility of component tests with the legform impactor.

INTRODUCTION

Variations in the bending angle, the knee shearing displacement and the acceleration have become apparently in a former round robin test series conducted by another test laboratory with EEVC WG 17 legform impactors of various test laboratories and car manufacturers (Mlekusch et al., 2004). One part of this study was a series of inverse tests where a suspended legform was hit by a linearly guided honeycomb impactor. The intention was to exclude the possibility of variations resulting from differing impact positions, impact angles or velocities.

The aim of the present investigation done at BASt was to analyse these results and to localise the causes of the variations which occurred. Therefore, it seemed to be appropriate to limit the observations solely to the legform impactor and to conduct an inverse series of tests, using a similar test design as in the study mentioned above.

TEST SET-UP

The legform impactor was suspended using a guide roller from a fixed frame bolted to the floor (Fig. 1). The guide roller was engaged in a pivoted retaining bolt, prestressed with a spring (Fig. 2).

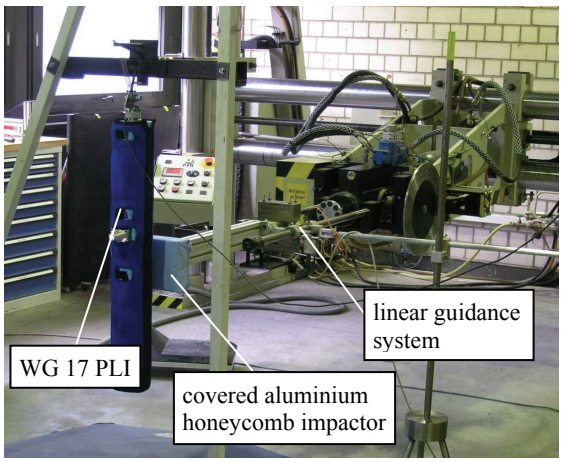

Fig. 1 - Test set-up

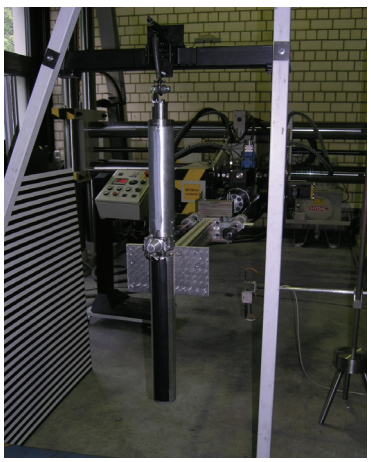

Fig. 2 - Suspension of the legform impactor (foam, skin and honeycomb removed)

An impactor with a non-precompressed honeycomb face (compression strength: 75 psi = 517 kN/m^2) was guided linearly and accelerated against the legform impactor. To prevent damage from the legform impactor skin the honeycombs were covered with a thin paper cloth as it was alike in the former test series. In order to obtain the required measuring ranges, the impactor mass was 16.52 kg, analogously to the formerly conducted tests.

The legform impactor was provided with standard equipment (EEVC WG 17 report). For the velocity measurement a light barrier system was used.

TEST PROCEDURE

The guided honeycomb impactor (uncompressed honeycombs) was propelled against the legform. The impact velocity was 42 km/h, the same as in the reference round robin. The honeycomb impactor was located with its upper edge at mid knee height (Fig. 3 and 4) during the impact.

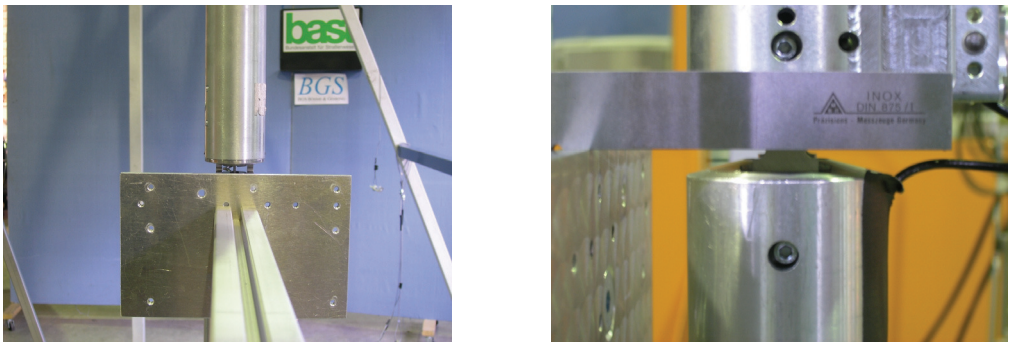

Fig. 3 and 4 - Impact height of the honeycomb impactor (foam, skin and honeycomb removed)

During the complete series of tests the vertical impact accuracy was ± 2 mm. The ambient temperature was between 21 and 23 °C.

Tests were performed with three different legform impactors. All of them were calibrated beforehand both quasi-statically and dynamically. Moreover, complete sensor calibrations were performed in each case. This was intended to verify the repeatability of the results with the same legform impactor and the reproducibility with different legform impactors. A total of 11 tests were conducted with the same legform impactor in order to determine the repeatability, out of which five were also taken into account when determining the reproducibility. The total number of tests for the determination of the reproducibility was 15. Altogether, 21 tests were performed and foams of six sheets were used.

The legform impactors were inspected both before and after each test. They were found everytime in good condition.

TEST RESULTS

PENDULUM TESTS: As the aluminium honeycombs used for the tests were not pre-compressed, their influence on the results was determined in an initial series of four tests with a pendulum impact. The deceleration of the pendulum was measured and the variation was identified for this purpose (see Table 1).

	v [m/s]	Deceleration [g]
Average value	**5,70**	**64,75**
Max. deviation in % from av. value	**0,26**	**3,47**
Standard deviation	**0,02**	**1,71**
in %	**0,30**	**2,64**

Table 1: Pendulum tests for determining the deceleration

As the maximum deviation from the average value did never exceed twice the standard deviation, this was proved to be a sufficient assessment criterion besides the single standard deviation. Nevertheless, due to existing requirements for the vehicle development the three times standard deviation was used as a second assessment criterion during further examinations.

TESTS OF REPEATABILITY: In the next step, a total of 11 impact tests with the honeycomb impactor were conducted on the same legform impactor under the above mentioned test conditions (Table 2). Here, foams out of three sheets were used.

	v [m/s]	Bending [°]	Shearing [mm]	Acceleration [g]
Average value	**11,73**	**16,71**	**-5,40**	**-152,47**
max. deviation in % from av. value	**0,75**	**1,85**	**3,70**	**6,77**
Standard deviation	**0,05**	**0,18**	**0,10**	**6,55**
in %	**0,41**	**1,09**	**1,85**	**4,29**
3 Sigma in %	**1,24**	**3,26**	**5,56**	**12,88**

Table 2 - Repeatability results - impactor #1 (11 tests)

TESTS OF REPRODUCIBILITY: In the following step, sets of five further impact tests were performed with a second and a third legform impactor under otherwise identical test conditions. These tests showed results similar to those of the first impactor. Finally, the results of the three impactors were combined in order to determine the reproducibility of the tests (Table 3):

	v [m/s]	Bending [°]	Shearing [mm]	Acceleration [g]
Average value	**11,75**	**16,63**	**-5,49**	**-153,49**
max. deviation in % from av. value	**0,71**	**6,46**	**9,36**	**6,12**
Standard dev.	**0,04**	**0,55**	**0,32**	**5,18**
in %	**0,33**	**3,30**	**5,80**	**3,38**
3 Sigma in %	**1,00**	**9,89**	**17,40**	**10,13**

Table 3 - Reproducibility results - impactors #1, #2 and #3 (5 tests each)

In order to validate the round robin tests, the ranking in accordance with dummy requirements was taken for the assessment of the standard deviation S: S ≤ 3% - good, 3% < S < 7% - acceptable, 7% < S < 10% - marginal, S > 10% - not acceptable. The following overall assessment (Table 4) was achieved:

		Bending [°]	Shearing [mm]	Acceleration [g]
Repeatability	Standard dev.	0,18	0,10	6,55
	in %	**1,09**	**1,85**	**4,29**
	Assessment	**GOOD**	**GOOD**	**ACCEPTABLE**
Reproducibility	Standard dev.	0,55	0,32	5,18
	in %	**3,30**	**5,80**	**3,38**
	Assessment	**ACCEPTABLE**	**ACCEPTABLE**	**ACCEPTABLE**

Table 4 - Repeatability and reproducibility assessment

VEHICLE TESTS: With regards to the validation of the repeatability tests, 10 legform tests against real cars performed at BASt, with a total of eight vehicles currently on the market, were compared to the assessment of the repeatability of all three legform impactors (L1, L2 and L3). These vehicle tests were conducted in each case at symmetrical points of the vehicle front structure resp. points with identical structure beneath. Thus, the vehicle structure beneath the tested points 1 and 1', 2 and 2' etc. was comparable. The ranges of the measured values of those test points are shown in Table 5:

Vehicle	Test points	Δ v [m/s]	Δ Bending [°]	Δ Shearing [mm]	Δ Acceleration [g]
A	1, 1'	**0,09**	**0,5**	**0,1**	**25,2**
B	2, 2'	**0,10**	**0,1**	**0,3**	**28,8**
C	3, 3'	**0,11**	**0,3**	**0,5**	**27,0**
D	4, 4'	**0,20**	**0,6**	**0,2**	**7,2**
D	5, 5'	**0,15**	**0,4**	**0,5**	**5,2**
E	6, 6'	**0,08**	**1,4**	**0,8**	**15,9**
F	7, 7'	**0,00**	**1,5**	**0,5**	**6,8**
G	8, 8'	**0,10**	**0,5**	**0,0**	**7,5**
G	9, 9'	**0,06**	**1,0**	**0,3**	**11,8**
H	10, 10'	**0,00**	**1,5**	**1,0**	**1,9**
Mid range		**0,09**	**0,8**	**0,4**	**13,7**

Table 5 - Ranges in repeatability results of vehicle tests

As demonstrated in Table 6, the mid ranges of all 10 relevant minimum and maximum values for bending angle, shearing displacement and acceleration, resulting from the vehicle tests, go with the overall results, i.e. the ranges of the three inverse series of repeatability tests. Therefore, the results of the inverse tests can be considered as being validated.

Range for:	**Δ Bending [°]**	**Δ Shearing [mm]**	**Δ Acceleration [g]**
L1	**0,6**	**0,4**	**20,3**
L2	**1,3**	**0,3**	**11,8**
L3	**1,1**	**0,5**	**12,8**
Vehicle tests	**0,8**	**0,4**	**13,7**

Table 6 - Comparison of the ranges of the impactors with those of the legform tests to real cars

DISCUSSION

The series of tests with the EEVC WG 17 legform impactor, performed at BASt, showed for the repeatability good to acceptable results, and regarding the reproducibility acceptable results. Concerning to the determination of the acceleration during the tests, it should be considered that the irregular structure and cut of the aluminium honeycombs already showed a standard deviation of acceleration of more than 2.5 % in the earlier performed pendulum tests. In total, the test series conducted with the EEVC WG 17 legform impactors proved that those tests are both repeatable and reproducible. An analysis of the former test series showed amongst others, that the assessment of the results is not always acceptable due to partly missing test data or impact deviation. Furthermore, one of the used legform impactors could not be calibrated. Finally it has to be pointed out, that the condition of the foam is of significant influence on the test results (Lawrence et al., 2004).

CONCLUSIONS

The study described in this paper could not confirm the results of the formerly performed round robin tests with the EEVC WG 17 legform impactor. Possible causes for the sometimes relatively high variations in the former tests could be related to the different handling of the impactors and foam on the one hand and to calibration procedures and corridors on the other hand. To ensure the highest possible repeatability and reproducibility of the test parameters, concomitant with a least possible uncertainty of results, special care while dealing with the legform impactor has to be taken. Therefore, BASt has drawn up a handling guideline (Gehring et al., 2004) that should achieve this quality. It refers to the certification of the legform impactor, additional verifications on the occasion of certification, additional verifications before each test, the test preparation and execution and the storage and transport of the foam pieces. Examples are the verification of the total mass and centers of gravity, the wiring and the correct assembly. It is recommended that the EU Directive on Pedestrian Protection will be amended by these aspects. Further investigation in form of parameter studies, real car tests and the development of a new calibration method is needed.

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