ANEC-R&T-2007-CHILD-002

Report about a Round Robin Test

EN 1177:1997 Impact Absorbing Playground Surfacing
Test methods for determination of the Critical Fall Height

Within the framework of ANEC (European Association for the Coordination of Consumer Representation in Standardisation)

Dipl.-Ing. Adolf Russold
TÜV Austria

Page 1 to 18   Signature

Vienna, March 2007

1

Content of the Report:

1. Task of the Round Robin Test

1.1 Background:

In children´s playgrounds most of the injuries are caused by falls. It is considered that the most severe injuries are injuries to the head. The impact attenuating properties of surfacing are therefore of major importance to reduce the severity of those injuries.

That is why CEN/TC136/SC1 developed EN 1177, a standard that sets the test method by which the impact attenuation properties of a surface can be determined.

This method is considered to be the best model available to predict the likelihood of head injury resulting from falls. It gives a "critical fall height" for surfacing, which means the maximum acceptable fall height associated with different types of impact attenuating surfacing (IAS) materials in order to reduce the risk of head injuries.

The standard EN 1177 was published in 1997 and at that time, the test method was based on the results of the few test equipment available on the market (3 models). In the meantime also other models of test equipment have been developed and they are used not only by test houses but also by a variety of organisations and individuals with different backgrounds and level of experience. This has led to a

situation where serious disparities between test results were found which created uncertainty about the current safety level of the IAS that are used on playgrounds.

EN 1177 is under revision now and a working group of experts within SC1 has identified the need to analyse the factors influencing these differences. Probable reasons have been found like inaccuracy of measuring equipment (calibration) and of the measurement equipment for evaluation and calculation. To be able to improve requirements in order to give more certainty on the safety level of surfacing, TC 136/SC1 decided that a round robin test is carried out. Test houses were ready to carry out the tests at their own costs, but funding for the supervision by an independent body was needed and offered from ANEC.

ANEC outlined a tender to a R&T project for a round robin test for impact measurement on playground surfacing materials and the offer of TÜV Austria was chosen to prepare, organise and supervise this test, including the evaluation of the test results and possible improvements for the revision of EN 1177. The tests were carried out under the responsibility of Mr. Adolf Russold from TÜV Austria, who is also Convenor of the SC1- Working Group (WG 1) dealing with the revision of EN 1777. Project Advisor at ANEC is Mrs. Helena Menezes from APSI (Portuguese Association for Child Safety Promotion) .

1.2 Purpose:

The purpose of this R&T project was to carry out a round-robin test, involving test laboratories from different European countries, to investigate all relevant possibilities of uncertainties and define maximum tolerances to avoid major deviations in test results, leading to unsafe situations on playgrounds. According to the findings, additional requirements or specifications will be added to the standard EN 1177 during its revision, in order to improve the reliability of the test equipment. This will set up a quality standard for test equipment used by test houses as well as by other operators which, in turn, will ensure the safety level for IAS required by the playground standard.

1.3 Scope

At the moment the nominal value for the critical fall height shall be expressed according to EN 1177:1997 in metres to one decimal place without rounding.

This can lead to situations that in case of a difference of at least 110mm (0,11m) in the test results of different test-labs the nominal value confirmed in the test reports could differ in maximum by 200mm (0,2m), e.g. if one result is 1,79m and the other result is 1,90m (gives nominal critical fall heights of 1,7m in the one case and 1,9m

in the other case). The same nominal result in this situation would also be given with a much higher difference of 0,28m in the test results, e.g. 1,71m and 1,99m.

The task of the round robin test was to reduce the deviations in the results for the nominal critical fall heights (e.g. to maximal 0,1m, i.e. less tan 0,11m) and to improve the safety for users and operators of playgrounds by reliable test reports.

To reach this goal it was to investigate which improvements of the requirements on test equipment as given in EN 1177:1997 are necessary and possible, considering also the deviations given independently from the equipment by the inhomogeneity of the materials to be tested (synthetic tiles, compound material, loose fill material, etc.) to find the practical acceptable tolerance.

2. Test conditions

The tests have been carried out according to EN 1177:1997 on three different types of samples of synthetic tiles with different thicknesses, which are used as impact attenuating surfaces on playgrounds. From each type, two tiles of the same production (PI and PII) were tested to compare also uncertainties in the production:

Type 50mm : Sample PI and Sample PII- 50mm thickness
Type 75mm : Sample PI and Sample PII- 75mm thickness
Type 100mm: Sample PI and Sample PII- 100mm thickness

Tests on Samples PI: 4 specified drop heights on each of 3 points (P1, P2, P3), which have been marked on the sample
Tests on Samples PII: 1 specified drop height on each of 3 points (P1, P2, P3 – marked at the same positions as on sample P1)

On Samples PI the drop tests were carried out according to EN 1177:1997 from the lowest to the highest drop height
.

On Sample PII only one of the drop heights used in the test of Sample PI was chosen to identify deviations caused by production and/or inhomogeneity of the products as well as by an influence of the sequence of the drop tests.

Measurements of the Head Injury Criterion HIC, the maximum acceleration at each impact a_{max} [g] and the time interval for the calculation of the time/acceleration curve Δt_{HIC} [msec], as defined in EN 1177:1997, were tabled in a prepared format (see page 8).

3. Methodology and performance:

11 test houses from 8 European countries with 12 test apparatus took part on this round robin test (listed in alphabetic order – see table).

Name	Adress	Country	Contact
AIJU Technology Center	Avenida de la Industria, 23 , 03440 Ibi (Alicante)	Spain	María Cruz Arenas
CST - Centre for Sports Technology Ltd	Unit 3: Greenwhich Centre Business Park, 53 Norman Road, London SE 10 9QF	United Kingdom	Greame Tipp
DTI Danish Technological Institute	Teknologiparken, Kongsvang Allé 29, DK-8000 Aarhus C, Denmark	Danemark	Kent Lemming
IBV - Instituto de Biomecanica de Valencia, Universidad Politéchnica de Valencia	Edificio 9 C, Camino de Vera s/n, E-46022 Valencia, Espania	Spain	Juan V. Durà
ISA Sport	Papendallaan 31, 6816 VD Arnhem, Netherlands	Netherlands	Gert-Jan de Kieft
ITC - Institute For Testing and Certification a.s.	Tř. T. Bati 299, CZ-764 21 Zlin	Czech. Rep.	Ludmilla Antosova
Laboratories Pourquery	Laboratoires Pourquery 93 boulevard du Parc d'Artillerie 69354 LYON cedex 07	France	Clément Charmasson
Labosport France	LABOSPORT TECHNOPARC 72100 LE MANS	France	Arnaud Louveau
TÜV Österreich	1015 Wien, Krugerstraße 16	Austria	Adolf Russold
TÜV Rheinland Product Safety	51105 Köln Am Grauen Stein	Germany	Berthold Tempel
VWA – Voedsel en Waren (2 test equipment)	Westelijke parallelweg 4 3331 EW, Zwijndrecht Netherlands	Netherlands	Dico van den Ouden

Requirement for the participating test houses was compliance with ISO/IEC 17025. From most of laboratories the certificates about accreditation are still missing.

3.1 Testing procedure

The test probes (in sum 3x2 tiles) have been sent in a container (fabricated with the dimensions of the tiles) from one test house to the next, so that all laboratories made the test on the same probes.

The first test was carried out by TÜV Austria to define the most representative drop heights for determination of the critical fall height at a HIC-value of 1000 as defined in EN 1177:1997.

The last test after tested by all participants was again made by TÜV Austria to compare the properties of the test probes with the condition at the first test with the same apparatus.

The results of the measurements of each laboratory were sent after each test to the supervisor for evaluation. The completed formats with all measurements as described above are included in Annex 1.

3.2   Evaluation of measurements

The evaluation of all measurements was carried out by the supervisor in accordance with EN 1177:1997.

For all tiles type PI the curves (HIC/ drop height) were drawn for each point tested (P1, P2 anP3), as shown in figure C.2 of the standard. In deviation to this figure the drop heights for this test have been chosen in advance (first test at TÜV Austria) in such a way, that two of the HIC values were expected above HIC 1000 and two values below HIC 1000. This gives more accuracy for measuring the critical fall height at HIC 1000 and will be an improvement of the standard which is already proposed (Draft prEN 1177:January 2006 clause 4.4.4).

Because the task of this round robin test was to investigate the accuracy of the apparatus, only 3 defined points on each tile were tested and the critical fall height for each of the 3 points on a tile was evaluated separately. These 3 critical fall heights are listed in the table of results for each tile (see page 9 of this report) and the differences between the results demonstrated.

Remark:For definition of the critical fall height of a whole surface consisting of single tiles the standard requires instead of this testing procedure that nine points on four tiles have to be measured. Only the curve giving the lowest drop height from all nine measurements defines the critical fall height. Because the curves in different points of a surface differ from each other (see the difference in critical fall heights in the table), the comparison of the final critical fall heights (the lowest for all points) would not allow to analyse deviations in single measurements any more.

The values for the critical fall height in each point tested were found graphically by measuring the height out of each (HIC/drop height) curve-diagram. The curves in the diagram were traced by a geometrical function connecting the measured HIC-values which give a nearly linear figure.

3.3 Test equipment and measurements

A format for the description of the test equipment was sent to each laboratory (see below).

Draft Formate HIC-Round Robin

1. Testing Laboratory: Name and address: Legal status: (accreditation certificate, ...) Supervisor for the test:
2. Test Equipment acc. EN 1177 Headform: mass and shape   mass in grams: - drawing with measurements   position of accelerometer - guided headform   ☐ - free fall headform   ☐ - radius at impact area   r in mm
Accelerometer: Number (1 axial, 3 axial) - Type - Position - Sensitivity   (pC/g, mV/g) - uncertainty / protocol for calibration
Measuring equipment: Amplifyer: - type - sampling rate (frequency) - filter … - uncertainty complete
Height measurement - equipment/type - uncertainty
Speed measurement (if applicable) - equipment/types - uncertainty
Validation of HIC calculations - method - uncertainty

TEST PROTOCOL Round Robin Test for HIC 2006

INSTITUTE:

Name:
Address:
Date of receipt:
Date of test:
Date of sending : to: ……………
Test equipment (Id.No.)
Name of responsible tester:
Tempterature at the test:
rel. humidity at the test:

RESULTS:

TYPE 50mm

HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec]
Tile P I
Drop height H1= 1200mm
Drop height H2= 1400mm
Drop height H3= 1600mm
Drop height H4= 1800mm
Drop height H5= 1200mm
Tile P II
Drop height H= 1400mm

TYPE 75mm

HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec]
Tile P I
Drop height H1= 1800mm
Drop height H2= 2000mm
Drop height H3= 2200mm
Drop height H4= 2400mm
Drop height H5= 1800mm
Tile P II
Test points
P1 P2 P3
Test points
P1 P2 P3
Drop height H= 2000mm

TYPE 100mm

HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec] HIC a_{max} [g] Δt_{HIC} [msec]
Tile P I
Drop height H1= 2500mm
Drop height H2= 2700mm
Drop height H3= 2900mm
Drop height H4= 3100mm
Drop height H5= 2500mm
Tile P II
Drop height H= 2700mm
Remarks:
Δt_{HIC} [msec] ... t_2-t_1 for HIC-calculation
Each drop test for tiles I shall start at each test point with the lowest drop height and shall be continued immediately with the next drop height. The last
drop height shall be the same as the first drop height. The time difference between each drop test shall be lower than 2 min.
All time/acceleration curves to be recorded.
Test points
P1 P2 P3
3-HIC-round_robin_test_protocoll_engl(1) 31.01.2007

Test protocols with results and HIC/ time curves see Annex 1 and Annex2.

4. Results and further investigations

Table 1:   Single critical fall heights for each point

Critical fall heights [m]	Type 50 mm			Type 75 mm			Type 100 mm		
	50-P1	50-P2	50-P3	75-P1	75-P2	75-P3	100-P1	100-P2	100-P3
Lab. No. 1	1,41	1,41	1,41	1,98	1,96	1,98	2,76	2,76	2,67
Lab. No. 2	1,42	1,45	1,45	2,05	2,05	2,05	2,80	2,85	2,85
Lab. No. 3	1,55	1,58	1,58	2,28	2,30	2,30	*3,40*	*3,40*	*3,40*
Lab. No. 4	1,43	1,45	1,46	2,04	2,08	2,08	2,82	2,83	2,87
Lab. No. 5	1,46	1,46	1,46	2,08	2,05	2,08	2,83	2,83	2,83
Lab. No. 6	1,47	1,47	1,48	2,12	2,11	2,15	2,92	3,00	3,02
Lab. No. 7	1,42	1,47	1,46	2,08	2,13	2,09	2,87	2,93	2,88
Lab. No. 8	1,43	1,45	1,44	2,13	2,02	2,08	2,88	2,92	2,89
Lab. No. 9	1,48	1,50	1,50	2,15	2,14	2,13		3,15	3,11
Lab. No. 10	1,50	1,52	1,48	2,15	2,15	2,08	2,85	2,90	2,87
Lab. No. 11	1,52	1,50	1,51	2,17	2,10	2,08	2,88	2,85	2,83
Lab. No. 12									
max. difference [m]	O,10	0,07	0,07	0,13	0,13	0,10	0.08	0,10	0,06
max. deviation in %	7,0%	4,8%	4,9%	6,4%	6,4%	4,8%	2,9%	3,5%	2,1%
max. difference [m]	0,14	0,17	0,17	0,30	0,34	0,32	*0,64*	*0,64*	*0,64*
max. deviation in %	9,9%	12,1%	12,1%	15,2%	17,3%	16,1%	*23,2%*	*23,2%*	*23,2%*

The table shows the results for the critical fall heights in the measured points (P1,P2 and P3) for the 3 types of tiles PI evaluated in Annex 2.
The measured values on tile PII are listed in the test protocols in Annex 1. They are in the same range as the values on PI and are not considered in Table 1.

This table needs to be commented as follows:
A. Red markings:
   - Lab. No. 1 had the lowest critical fall heights (highest HIC-values)
   - Lab. No. 3 had the highest critical fall heights (lowest HIC-values) and
     had on tile type 100mm no HIC-value above HIC 1000
     (the curves were extrapolated to find the value for the critical fall height)
   - Lab. No. 6 had on type 100mm only one point with HIC above 1000
   - Lab. No. 9 had on type 100mm no HIC-value above HIC 1000
     (*extrapolation of P1-curve not possible*)
   - Lab. No. 12 made wrong measurements and was not included in evaluation

   These results show bigger differences in the fall heights than the intended task (i.e.max. 0,34m>>0,11m) and therefore further investigations for improvement of the measuring system have been carried out.

B. Green markings:
    Majority of results, based on formally correct measurements. The max. deviation

is here 0,13m which is closer to the task of 0,11m, but nevertheless possible improvements on the accuracy were investigated for all results.

4.1   Consequences from Table 1:

Although the test points P1, P2 and P3 have been marked on the tiles before the test, the repeatability and characteristics of the values measured show deviations within the same apparatus (see evaluation in Test Protocols Annex 1). Reasons and degrees of variations have been investigated as follows:

4.1.1   Behaviour of surfacing material:

Anticipating that the measuring process remains unchanged for a given apparatus, deviations in the results can occur as well from inhomogeneities in the tested material as from a certain compression effect caused from the former test impacts. Hitting not exactly the same point of the marked test position at each drop test, which is in practice always given, can in addition lead to some deviations in the results, which depend on the structure of the surfacing material.

Test results within each apparatus (dispersions of measurements Annex 1): For these comparisons no extra table was created.

1.   Compression effect from former impacts:

The differences between 2 repeated HIC-values, measured from drop height H1 on tile PI, varies in a range between −7% lower value and +20% higher value at the second impact on the same point. Apart from these single extremes there are generally slightly increased HIC values (+0% to +5%) with single higher measurements as well in + as in −direction, but without a reasonable systematic in the sequence, which could be a consequence of compression.

2.   Inhomogeneity of material:

The dispersions of HIC-values, measured over the surface Tile PI (in the points P1, P2, P3), expressed by HICmax/ HICmin in %, vary in a range between 0% and max. 16%. Most of these dispersions are below 10%. The sequence of dispersions cannot be explained by inhomogeneities alone.

3.   Final comparison test (Lab. No. 4-2):

The final test after the round robin showed deviations of HIC to the initial test (Lab. No. 4-1) between max. +4/ -5%. Compared with the dispersions within one test procedure (see pt. 2) this result confirms that no change of the test tile during the test procedures of the round robin has occurred.
Note: A negative value (lower HIC-value) in the repeated test is not probable because it would mean a softening of material instead of a compression.

4. **Comparison tests on tiles PII:**

The tests for one drop height H2 in the points P1, P2, P3 of each tile PII are differing from the comparable values on tile PI in a range between max. --14% and +16%, with a tendency of about - 5% lower HIC-values than on tile PI. This result shows the difference in the production of the tiles and can be neglected, when compared with the dispersions within the tiles PI.

.

Conclusion:

1. The compression effect on the same point in a series of drops can be considered as negligible, because the dispersions of HIC-values measured are within the range of the uncertainties of all the other measurements over the surface and the tendency of +5% is therefore no clear indication for a relevant compression effect.

2. The inhomogeneity of the material does not show a relevant influence on the variable +-dispersion of the results in the different points of the surface tested and can be neglected too for the further investigations.

3. The final comparison test after the whole round robin test procedure does not show a relevant change of properties on the tested material.

4. The tests on the second tiles PII of the same production do not show relevant differences to the tiles PI.

4.1.2 Uncertainties of the measurement system

As the dispersions of measurements shown in 4.1.1 are not caused mainly by the material, this leads to the conclusion that they have to be considered as uncertainties in measurements of the apparatus.

Reasons for possible dispersions in the results, caused by the test apparatus itself as defined now in EN 1177:1997 , were identified at the meeting of the participants of the round robin test on 22 January 2007. Improvements by giving more precise definitions for the measurement system of the apparatus have been found and partly confirmed by further investigations. They will be proposed for the revision of the standard (see pt. 4.1.4 measuring equipment).

Unfortunately it was not possible to receive more detailed information about the measurement systems and about accuracies of instruments used from the majority of participants. For this reason it was not possible to calculate an uncertainty budget and to find a more precise estimation for the results of improvements which have been proposed for the revision of the standard EN1177.

4.2 Acceptability of the final result in a Test Report:

The dispersions in the single measurements for the HIC values are not fully relevant for the final determination of the critical fall height, which is the end result of a complete impact test for the impact attenuation of a surface.

EN 1177:1997 requires to draw the relevant HIC/ drop height- curve created only from all highest HIC- values in 9 drop tests to evaluate the critical fall height at HIC 1000. This method eliminates the measured lower HIC-values, so that the relevant result for the critical fall height is the lowest value from all measurements. This provides more safety for the user on the playground. As an additional safety this lowest value shall be rounded down to the lower decimal of a meter (e.g. 1,59m is reported as 1,5m).

In this round robin test only 3 defined points have been measured (instead of 9 points as required in EN 1177:1997, including also joints of tiles), to have precise conditions for the main task of this test, which was to compare the accuracy of apparatus. Following the standard also for this special case and taking the lowest values from these drop tests, Table 1 would lead to final results for the critical fall height as given in Table 2. Following the task of this test, these values have not been rounded down to the lower decimal to show the real differences.

Note: It should be considered that when carrying out the complete test according the standard (testing more points and also the joints between the tiles) the final results could be lower than found for these 3 points!

Table 2: Critical Fall Height acc .EN 1177

Critical fall height in {m} (acc. EN 1177:1997)	Type 50mm 50-P1	Type 75 mm 75-P1	Type 100 mm 100-P1	
Lab. No. 1	1,41	1,96	2,67	lowest
Lab. No. 2	1,42	2,05	2,80	
Lab. No. 3	1,55	2,28	*3,40*	highest
Lab. No. 4	1,43	2,04	2,82	
Lab. No. 5	1,46	2,05	2,83	
Lab. No. 6	1,47	2,12	2,92	incorrect
Lab. No. 7	1,42	2,08	2,87	
Lab. No. 8	1,43	2,02	2,88	
Lab. No. 9	1,48	2,13		incorrect
Lab. No. 10	1,48	2,08	2,85	
Lab. No. 11	1,50	2,08	2,83	
Lab. No. 12				
Max. difference in [m]	0,08	0,11	0,08	
	0,14	0,32	0,73	
Max. deviation in %	5,6%	5,4%	2,9%	
	9,9%	16,3%	27,3%	

12

These results show that although the dispersions in the HIC- measurements within one test apparatus will be compensated to the safe direction, it remains the situation that the differences between the different apparatus lead to end results with higher differences than intended.

4.2.1 CONSEQUENCES OF THE ROUND ROBIN TEST FOR IMPROVEMENTS

The first step was to look for the measurement systems in the different apparatus and for the sources of differences in measurements. Table 3 shows the min. and max. a-values as well as HIC-values measured from all drop heights on each test tile and gives below the maximal dispersions from all apparatus in %, marking the Labs in the same way as above.

Table 3: HIC and acceleration [a]- measurements

	Type 50 mm				Type 75 mm				Type 100 mm			
	HIC*min*	a*min*	HIC*max*	a*max*	HIC*min*	a*min*	HIC*max*	a*max*	HIC*min*	a*min*	HIC*max*	a*max*
Lab. No. 1	677	134	1703	226	807	130	1450	178	856	121	1261	148
Lab. No. 2	705	137	1611	223	774	129	1327	172	803	117	1148	142
Lab. No. 3	588	131	1388	215	613	118	1085	161	*584*	*102*	*866*	*127*
Lab. No. 4	637	134	1589	228	729	127	1351	177	768	116	1158	146
Lab. No. 5	682	142	1530	223	764	132	1320	175	806	120	1153	146
Lab. No. 6	657	140	1504	222	735	130	1253	171	743	117	1071	140
Lab. No. 7	656	139	1616	233	719	130	1303	176	742	117	1125	145
Lab. No. 8	678	139	1280	208	747	130	1340	176(184)	782	118	1147	143
Lab. No. 9	600	132	1508	225	632	122	1248	174	711	113	994	136
Lab. No.10	657	141	1524	221	694	127	1223	168	737	118	1188	145
Lab. No.11	642	133	1472	205	703	125	1282	171	791	117	1153	144
Lab. No.12												
Dispersion %	14	7	33	14	28	8	19	6	9	3	6	3
Dispersion %	16	8	33	14	32	12	34	11	47	19	46	17

This comparison shows that the max. HIC-values, which are relevant for the determination of the critical fall height, vary between 6% and 33% even in the green area, but between 33% and 46% in the red area (for the min. HIC- values this goes up to 47%).
On the other hand the dispersion of the acceleration-values [a] is much lower. The a*max*-values vary between 3% and 14% in the green area and between 11% and 17% in the red area (for a*min*-values up to 19%).

Conclusion:
The differences in the HIC- values are caused by a minor dispersion of acceleration [a] measurements and a much bigger part of dispersions in the acceleration/ time curve

[g]/ [t] respectively in the evaluation of this curve acc. the formula for HIC, as defined in EN 1177.

Figure 1 shows a correct acceleration/time curve as given in the standard EN 1177 and the formula for calculation of HIC by evaluating this curve. The dimensions for accelerations are given in [g= gravity 9,81m/s^2] and for time t in [ms].

Figure 1: Impact acceleration / time curve
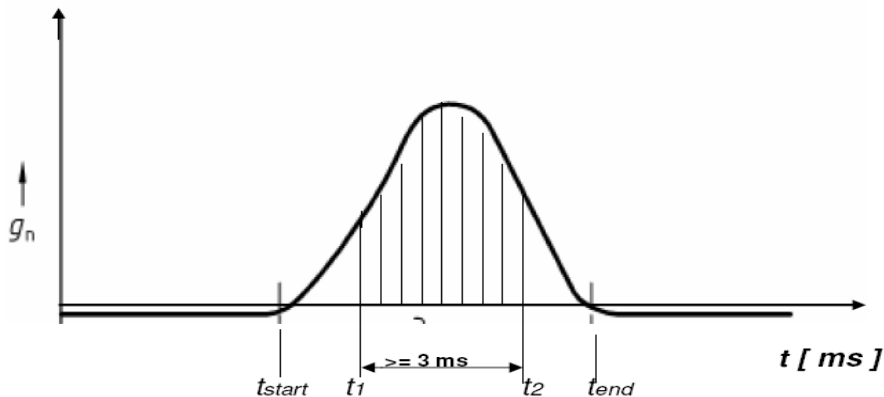
$$HIC = \left[\left(\frac{\int_{t_1}^{t_2} a \times dt}{t_2 - t_1} \right)^{2,5} \times (t_2 - t_1) \right] max$$

4.2.2 IMPROVEMENTS FOR HIC-MEASUREMENTS:

The following improvements for the impact measuring equipment have been identified following the results of this round robin test. As explained in pt. 4.1.2, it is not possible at the moment to give exact values for the final result from these improvements, which are therefore restricted to single estimations.

1. The accelerometer measurement system must be able to measure all relevant frequencies for tracing the exact [g]/ [t]- curve. It is necessary to define also the lower limiting frequency to get sufficient lower response and to reduce the amplitude error by overshooting the baseline after the impact and underestimating the g-max.and HIC- score, as shown in Figure 6.8. This error is bigger in particular for longer pulse durations. An accelerometer with a time constant of 2s or greater and appropriate signal conditioning will generally meet this requirement. The example for such overshooting is out of a data sheet from a manufacturer of such measuring instruments and shows such incorrect curves (full lined), which will lead to wrong HIC- values.

Also the amplitude accuracy at higher frequencies and requirements for the filter need to be defined to avoid wrong incorrect curves caused by the "ringing"-effect (right curve).

More details about such requirements are in ISO 6487, to which a reference will be made in the revised EN 1177.
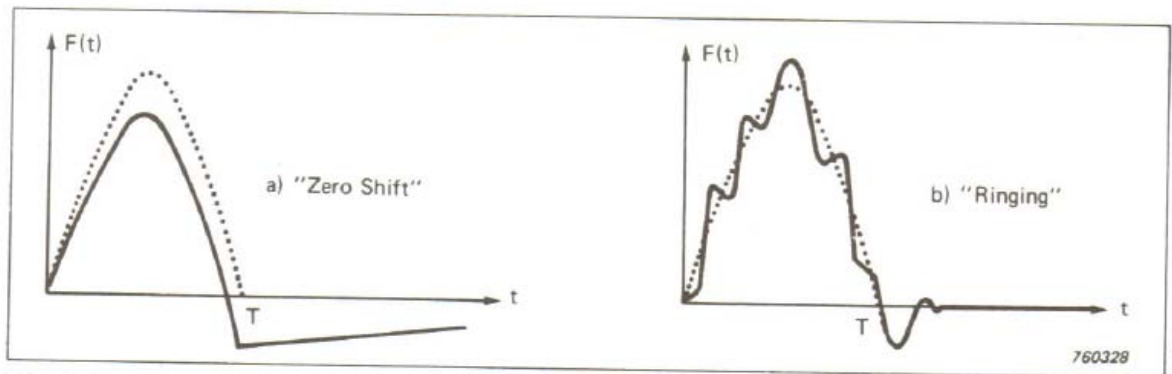

Fig.6.8. Vibration measurement system response to half sine wave pulse of length T.
a) "Zero Shift" limits the low-frequency response of the system.
b) "Ringing" limits the high frequency response of the system

Source: Brüel & Kjaer, Denmark

Additional tests made by C.S.T. after the round robin test have confirmed these overshooting measurements to minus g-values (in the Fig. named F(t)), which are not existing in reality and which therefore are amplitude errors caused from insufficient low frequency response of the measurement system.

The lower limit for the frequency measurement is therefore proposed for the revision of the standard with 0,3 Hz to keep this error below 5% for pulse durations up to about 30ms.
Note: This limitation was made for practical reasons to allow the mostly used piezo electric gauges, which reach at 0,3Hz the limit of accuracy. Very soft impact materials (e.g. loose fill material) can have longer pulse durations up to 50ms which can cause amplitude errors up to 10%.

2. **Calibration of measuring equipment:**

    Only calibrated measuring instruments shall be used for the measurement of the drop height (in case of free fall head forms) respectively of the velocity before the impact (in case of guided head forms) and for the measurement of the acceleration (accelerometers).

The usual measurement uncertainties for such instruments are proposed for the revision of the standard EN 1177 and periodical calibration will be required. For accelerometers a guide on acceptable calibration levels will have to be elaborated in future, taking ISO 6487 into consideration.

3. **Release system for the headform:**

   The release system shall not create any significant rotation of the headform which can affect the vertical acceleration values measured at the impact point.

   A comparison test at the beginning of each test series to identify such effects is proposed for the revision of the standard.

4. **HIC – calculation:**

   An independent check for the computer algorithm by imposing a half sinus curve and comparing the result with the result of the computer is proposed for the revision of the standard.

4.2.3 CONSEQUENCES ON THE FINAL RESULTS FOR THE CRITICAL FALL HEIGHT:

The improvements proposed are expected to lead to lower dispersions in the HIC-values than found in the round robin test. This means in practice dispersions of ca. 5% for short pulse durations and up to 10% for longer pulse durations up to 50ms in case of soft impact attenuating material.

The consequences of such dispersions in the HIC- values on the critical fall height depend on the inclination of the HIC/drop-height curve and lead to different deviations in the final result.

This influence is demonstrated in Figure 2 on the simple example for an anticipated deviation of 10% in HIC-values (shown in this figure for HIC 1000 and HIC 1100) within one and the same curves of Lab. No. 4-1. This simplification is possible because the "curves" are nearly linear and would have the same effect for another "curve" with 10% higher HIC-values.

We can see that in such a case the difference in the fall height would be ca. 6cm for the steep curve ("harder" tile Type 50mm), but ca. 17cm for the flat curve ("softer" tile Type 100mm). The red arrows show the difference in the result.
It shows also that these differences in the critical fall heights are always based on the same dispersion of HIC (in this case 10%) and in both cases would have the same acceptable safety tolerance.

Note: These differences become bigger on flatter curves, e.g. in case of loose fill surfacing material, which was not subject of this test.

Figure 2: Critical fall height for HIC 1000 and HIC 1100
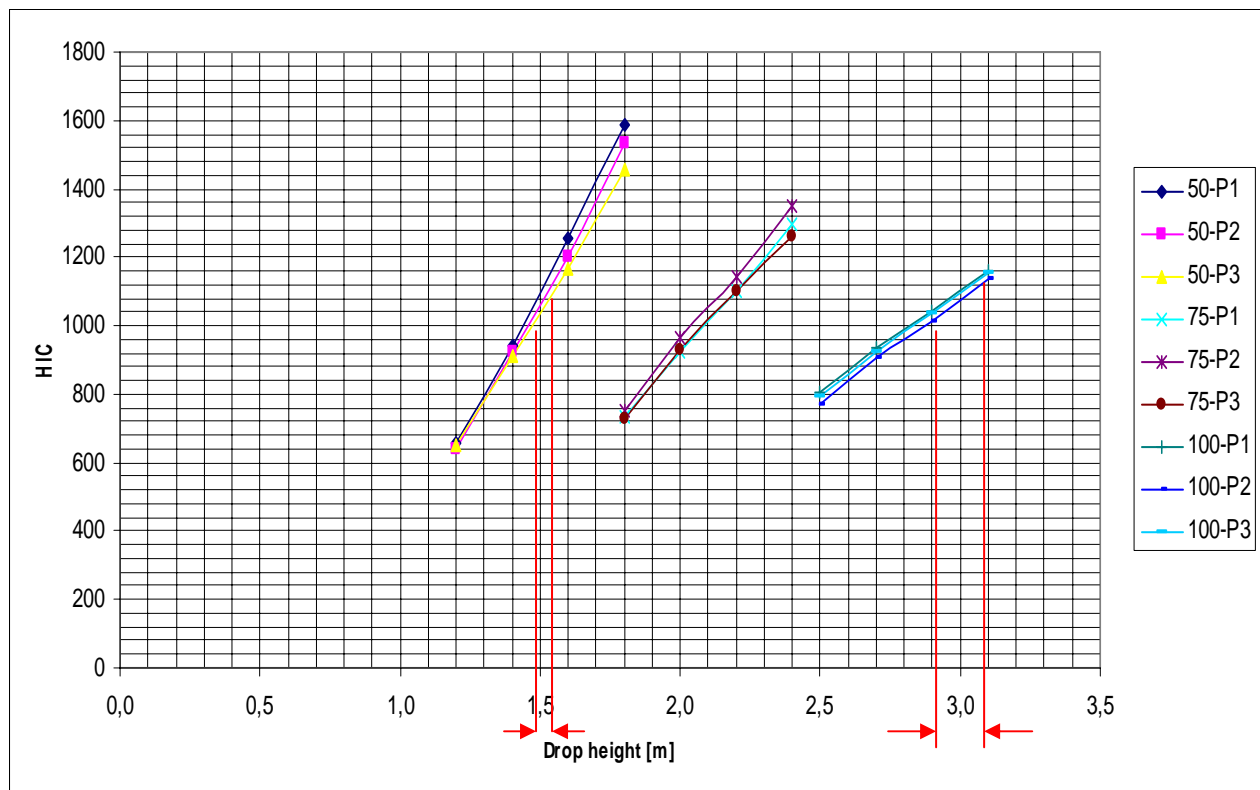
This result shows that the improvement of reducing the dispersions in the HIC- values cannot solve the formal problem that the final result for the critical fall height can differ more than 0,1m in case of soft material, as it was the original task of this project. It is to say that this task was also a wish from the market to avoid different classifications in test reports of playground surfacing.

Nevertheless these differences in the critical fall height will not affect the safety of the surfacing. Provided that all improvements on the measuring system are made as proposed, in any case of such differences the values for HIC would not differ more than 10%, which seems to be an acceptable tolerance for the safety of the user. In particular for soft materials (e.g. loose fill surfacing) a bigger tolerance than 0,1m in the critical fall height results will be expected and can be accepted therefore.

It is to state that under such complex conditions no uncertainty budget could be calculated. The practical results of the proposed improvements will have to be investigated in a further round robin test.

5. SUMMARY

Tasks of the round robin test:

Task 1 of this round robin test was to improve safety of surfacing on playgrounds by improving the accuracy of the test method described in EN 1177:1997 in its revision. It was intended to reach a difference of not more than one decimetre (100mm) in the final results of the critical fall height.

Task 2 was to determine the measurement uncertainty of the measuring equipment by calculation of the uncertainty budget as a basis for task 1.

Task 3 was to improve the standard EN 1177:1997 using all the results and their consequences by concrete amendments for the revision of this standard.

Results:

TASK 1 was considered for accredited test laboratories as well as for other operators. Subject of this round robin test was to compare test laboratories only.

11 European test houses with 12 partly different types of test equipment were participating in this test, which was running from May 2006 to January 2007.
All tests have been carried out on the same samples in a defined test procedure, laid down by the independent supervisor of the test. The samples were tested before and after the round robin test to identify any changes from transport or testing. The results were evaluated by the supervisor and analysed with the participants in a separate meeting with a follow up meeting of CEN/TC136/SC1/WG1 and the advisor of ANEC.

This task could be reached for the test equipments by identifying the reasons for major deviations in the test results received, leading to necessary improvements in the measurement requirements which will be proposed for the revision of the standard.

Nevertheless the originally intended tolerance of one decimetre (100mm) in the final result for the critical fall height needed to be replaced by the real safety criteria, which is the tolerance in the measured HIC-values. This tolerance is proposed for the revision of EN 1177 with 5%, but must be expected up to 10% for long pulse durations (soft materials) when improving the existing apparatus according the given proposals. This is an acceptable tolerance for the safety of users and the resulting differences in the critical fall height given in the test report, even if more than 0,1m, will always be in compliance with this HIC-tolerance.
Remark: Deviations caused by inhomogeneities in the material cannot be prevented by an improvement of the test method.

TASK 2 was not possible to fulfil for the reason of the complex system of the measuring chain and the unknown uncertainties in this system, for which the

improvements have been elaborated. The effects of these improvements need to be further investigated in connection with further additional tests. Although this was not within the scope of this round robin test, one of these additional tests could be carried out to define the frequency range of the measurement equipment more detailed. However further investigation will remain necessary.

TASK 3 could be fulfilled as far as at this stage possible, using the findings of this round robin test for the revision of standard EN 1177:…as proposed in par. 4.2.2 of this report.
The proposed revision is attached as Annex 3.

Anyway this project was an important approach for clarification and improvements of the measuring equipment in apparatus for testing impact attenuating surfaces, to reach the task for more reliable test reports and increase the safety of the playground user.
The supervisor thanks ANEC for supporting this project.

TÜV AUSTRIA   Vienna, 30 March 2007
Dipl.- Ing. Adolf Russold