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Effect of Mechanical Factors on the Protective Parameters of Textile Elements in Personal Equipment Protecting Against Falls from a Height

Abstract
Assurance of consistent protective parameters throughout the whole period of use is one of the more important problems associated with personal equipment containing textile elements that protects against falls from a height. The most important factors causing mechanical damage to such equipment are indicated in the paper, which also presents the methods and test stands used for conducting tests involving the application of loads to the equipment under static and dynamic conditions with simultaneous exposure to additional mechanical factors. Such factors comprised friction against steel and concrete elements of specially devised shapes, simulating the effect of the worksite edge during a fall arrest. The results obtained demonstrated that an additional factor such as friction against an obstacle significantly decreases the mechanical strength, creating unfavorable conditions for a fall arrest. Thus, it can be concluded that if personal protective equipment protecting against falls from a height is to be used under conditions including potential exposure to additional mechanical factors, it must be characterised by special protective properties.

Key words: *fall arrest, personal protective equipment, webbing, fibre rope, static strength test, performance test, lanyard, energy absorber.*

Introduction

The variety of conditions and activities characteristic of worksites located at heights leads to situations in which, despite its numerous disadvantages, personal equipment protecting against falls from a height [1 - 4] cannot be eliminated by appropriate organisational measures or group protections. One of the most important problems associated with such equipment is the assurance of appropriate protective parameters throughout the whole period of use.

In recent years, some European institutes concerned with the safety of humans in the work environment, such as HSL in the UK [5] have conducted studies associated with the loss of protective parameters by personal equipment protecting against falls from a height during the period of its use. In 2006-2007, the Central Institute for Labour Protection - National Research Institute Department of Personal Protective Equipment assessed, within the framework of a realised project [6, 7], such equipment withdrawn from use in civil engineering, power engineering and telecommunications companies. The study demonstrated damage of various types in many items of equipment. Most of the damage was due to mechanical factors such as friction, cuts, punctures, etc. and affected connecting and shock-absorbing components (e.g. lanyards and work positioning lanyards [8], textile energy absorbers [9 - 11], as well as self locking arresters on flexible anchorage lines [12]) made of textile materials such as fibre ropes and webbing.

Analysis of the methods and conditions of work at worksites located at a height revealed that such damage is inflicted mainly as a result of contact with objects of sharp and hard edges in two situations:
- during 'normal' work,
- during a fall arrest.

The first situation usually takes place when a component of the system (e.g. a lanyard) is tied around a sharp-edged construction element of the worksite and is gradually damaged as the user moves around.

The second situation is encountered when, during a fall arrest, a component of the system protecting against falls from a height (e.g. a lanyard, or a flexible anchor line) comes into contact with a dangerous object and undergoes mechanical damage as a result of acting dynamic forces. An example of such a situation is presented in ***Figure 1***.

If we compare the two cases above, it is notable that the second one is much more dangerous from the user's point of view, which is due to the fact that the damage inflicted in the first case can be identified during standard inspections of the equipment carried out by the employer, and the damaged equipment can be withdrawn from use. In the second case, damage

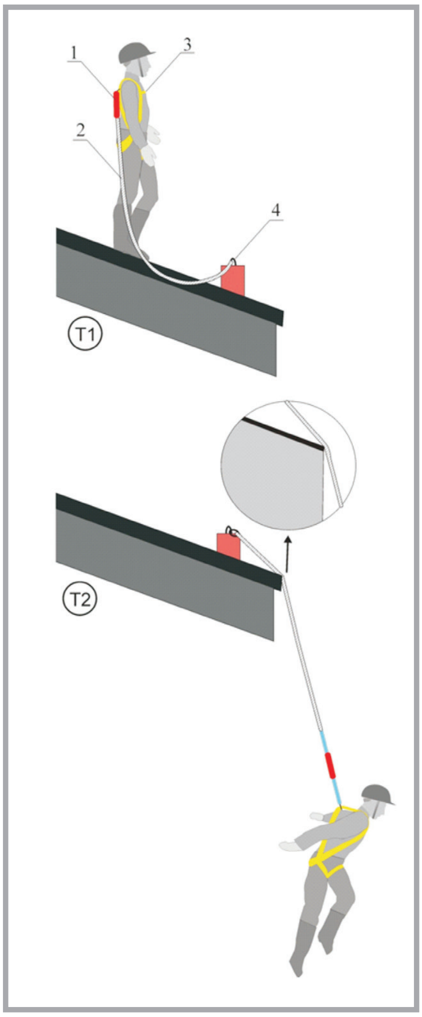

***Figure 1.** Energy absorber with a lanyard arranged horizontally - an example. **Notes**: T1 - state before fall, T2 - state after fall, 1 - energy absorber, 2 - lanyard, 3 - full body harnesses, 4 - anchor point.*

takes place when the equipment is working and the user is unable to counteract it. For this reason some European institutes, such as BGIA in Germany [13] and CIOP-PIB [14, 15] have conducted studies associated with the loss of protective parameters by personal equipment during a fall arrest. The present paper is based on data obtained within studies at the Department of Personal Protective Equipment of CIOP-PIB and concerns equipment containing textile elements that protects against falls from a height.

The effect of edges on the tensile strength of fibre ropes and webbing under static conditions

Testing methodology and the test stand

Webbing and fibre ropes made of polyamide or polyester fibers are the basic textile elements of personal protective equipment protecting against falls from a height. In order to determine the effect of edges on their tensile strength, a test stand was designed, presented in ***Figure 2***.

A Zwick type Z100/SW 5A universal tensile machine was the main element of the test stand. One end of the test webbing or fibre rope sample is mounted in a grip (6) located on the mobile beam of the machine (1). The sample comes in contact at a straight angle with the edge of a rounded steel bar (5) with a given radius (i.e. 0,5 mm; 1,0 mm and with a non-finished edge obtained by guillotine cut). The other end of the test webbing or fibre rope sample is mounted in the lower grip (2) coupled with a force transducer (3), mounted on the fixed beam of the machine (4).

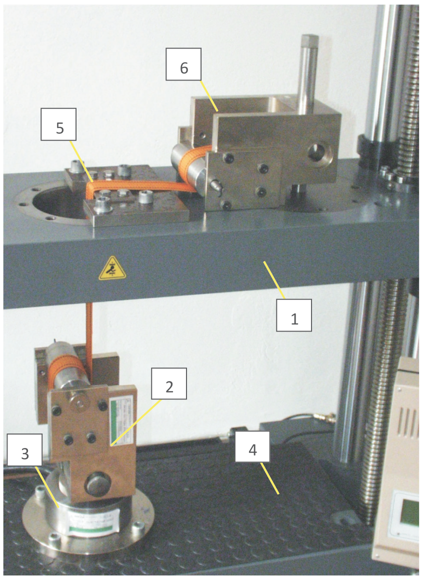

Figure 2. *Zwick type Z100/SW 5A universal tensile machine equipped for tests of webbing and fibre ropes. Notes: 1 - mobile beam of the machine, 2 - lower grip for webbing, 3 - force transducer, 4 - fixed beam of the machine, 5 - test edge, 6 - upper grip for webbing.*

In accordance with the methodology of testing applicable to textile elements of personal protective equipment protecting against falls from a height described in EN 364:1992 [16], the samples were stretched at a 50 mm/min velocity. During the loading process, the middle segment of the sample interacted with the edge of the steel bar (5), which caused additional damage.

Test objects

The objects of the tests were ca. 1.5 m long segments of webbing and fibre ropes used for the production of lanyards, energy absorbers, self locking arresters on flexible anchorage lines and full body harnesses [17, 18]. The characteristics of these materials are presented in ***Table 1***.

Test results and their analysis

The results obtained are presented in graphic form in ***Figure 3***. The graphs represent mean values (from tests of five

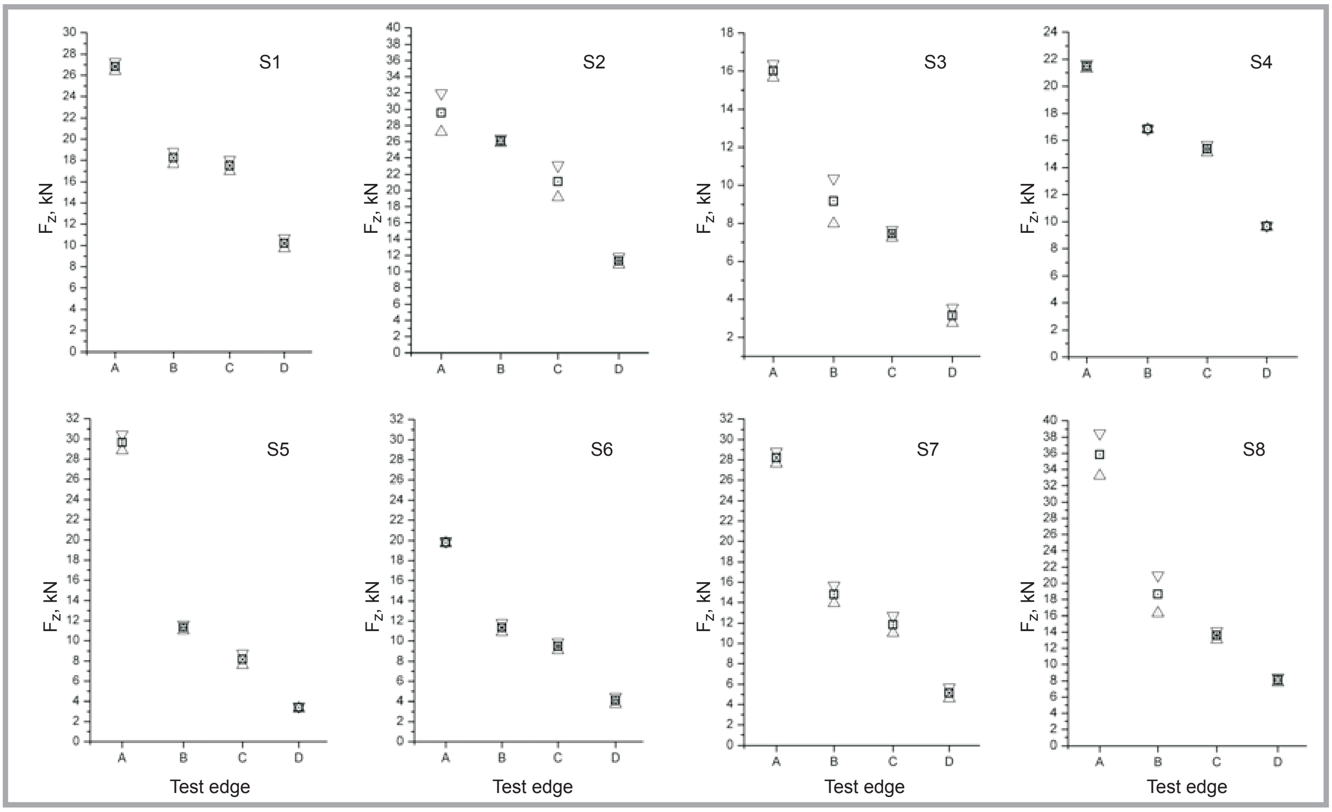

Figure 3. *Results of static strength tests. Notes: Kind of edge: A - without an edge, B - steel bar - radius of the edge: 1 mm, C - steel bar - radius of the edge: 0.5 mm, D - steel bar after cutting with a cutter, without grinding, sharp edge up; □ - F_z mean value of the breaking force, △ - F_z - s (where s – standard deviation), ▽ - F_z + s.*

samples) of the maximum tensile forces before break F_z, with the means increasing and decreasing by standard deviations.

As the first result presented in the graphs (marked as A in ***Figure 3***), regarded as the reference level, the tensile force at break obtained in the test of the 'normal" tensile strength without the edge of the steel element (marked as (5) in ***Figure 2***) is given. It follows unequivocally from the data presented that the contact of textile material samples with the edge of steel elements during the stretching process reduces their tensile strength, which is understood here as the maximum tensile force value before break. Moreover, the value of the tensile force at break decreases with a decrease in the radius of the edge interacting with the material sample. Analysis of the results presented in ***Figure 3*** can lead to the following most important observations:

- using a steel element with the edge radius r = 1.0 mm (B) caused a decrease in the mean value of force F_z within the range of 10 to 62%,
- using a steel element with the edge radius *r* = 0.5 mm (C) caused a decrease in the mean value of force F_z within the range of 28 to 75%,
- using a steel element with an edge obtained by a guillotine cut caused a decrease in the mean value of force F_z within the range of 58 to 87%,
- among the textile materials tested, webbings, marked in ***Table 1*** (see page 116) as S2 and S4, proved to be the most resistant to the loading method described,
- in the case of samples S3, S5, S6 and S7, the value of F_z was lower than 6 kN i.e. a value which under the actual conditions of a fall arrest [9, 12, 19] may act on connecting and shock-absorbing components.

The effect of edges on the process of a fall arrest by textile lanyards and shock absorbers

The task of personal protective equipment protecting against falls from a height during a fall arrest is to prevent the user from hitting the ground, or construction elements of the worksite, as well as to reduce the forces and accelerations acting on the user's organism to safe values. Equipment compliant with the appropriate standards, harmonised with

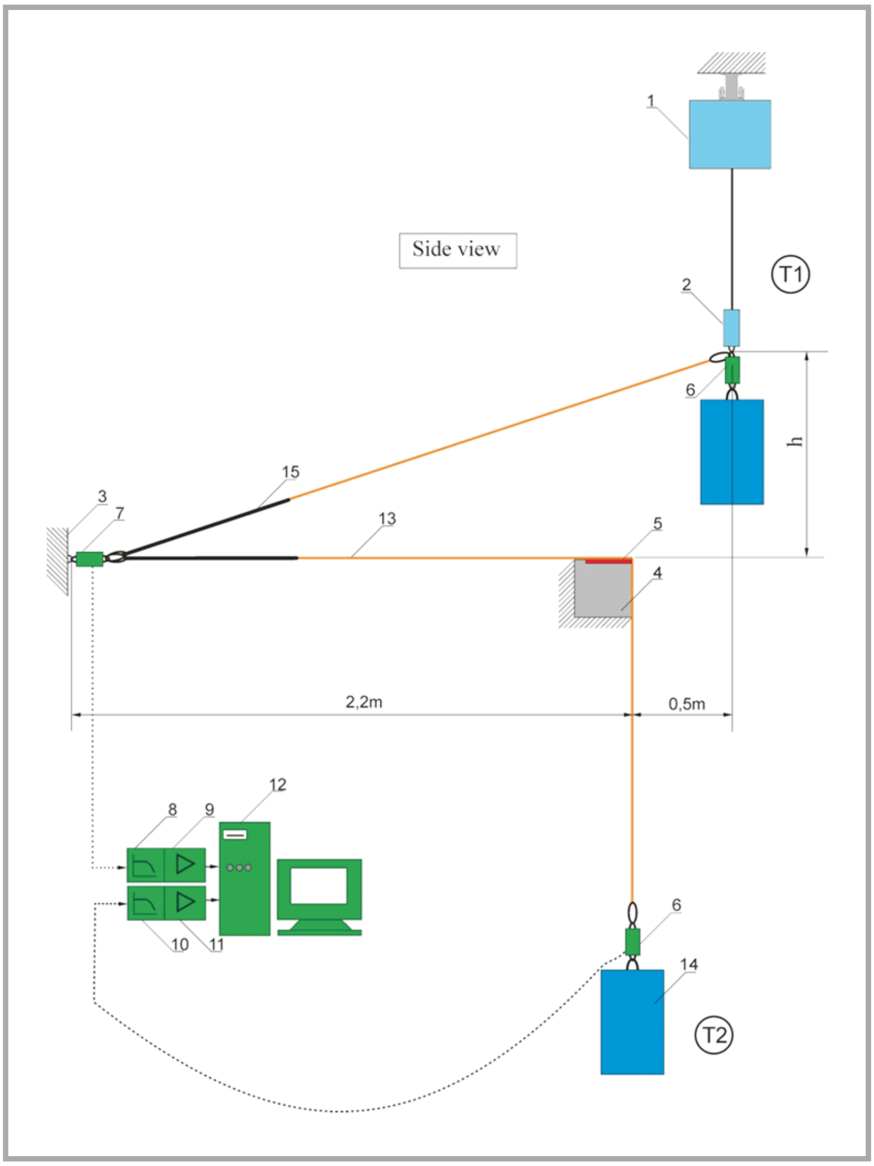

Figure 4. *Performance test equipment and test method. Notes: T1 - state before fall, T2 - state after fall, 1 - power winch for lifting and lowering the test mass, 2 - quick release device, 3 - rigid construction, 4 - test beam (basic part), 5 - upper part of the test beam, 6 - force transducer F_R (Hottinger, Germany), 7 - force transducer F_N (Hottinger, Germany), 8,9,10,11 - low-pass filters with amplifiers (Hottinger, Germany), 12 - KUSB 3116 type measuring system (Keithley, USA) with personal computer, 13 - test object, 14 - test mass, 15 - chain.*

Table 1. *Samples of webbing and fibre ropes used for strength tests.*

Symbol	Material and construction	Dimensions	Type
S1	polyamide webbing	width of 45 mm	TS325/45mm
S2	polyamide webbing	width of 45 mm	TS326/45mm
S3	polyamide webbing	width of 20 mm	TS608/20mm
S4	webbing: - polyamide mantle - aramide core	width of 45 mm	-------------
S5	three strand polyamide fibre rope	diameter of 12 mm	PA12-A-Z/K6/200
S6	polyamide mountaineering dynamic rope	diameter of 11 mm	TRUST
S7	polyamide mountaineering static rope	diameter of 10 mm	PRO-STATIC
S8	rope: - polyamide mantle - polyamide core	diameter of 14 mm	PA14-K-16

Directive 89/686/EEC, e.g. [20], guarantees correct functioning during this process. Conformity with these requirements is checked during laboratory tests constituting an element of the certification process for the CE marking of per-

Table 2. Upper parts of the test beam simulating the edge of a workplace.

Type	Material	Dimensions, mm			Additional information about the edge
		height	width	length	
K1	steel sheet type ST3S	2	300	2000	the steel sheet after cutting with a cutter, without grinding, sharp edge down
K2	steel sheet type ST3S	2	300	2000	the steel sheet after cutting with a cutter, without grinding, sharp edge up
K3	concrete	60	200	1800	-----------

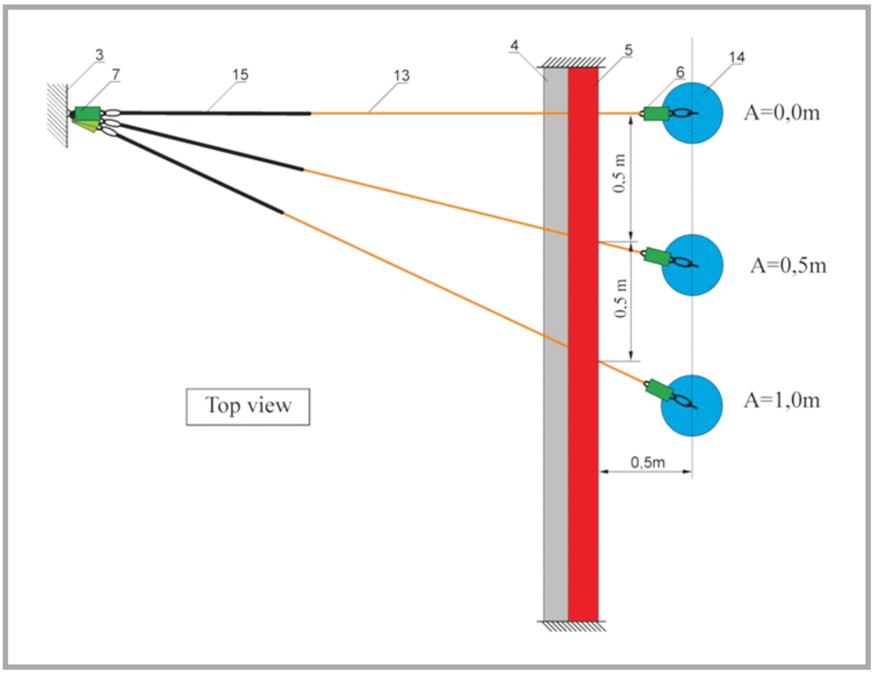

Figure 5. *Performance test equipment and test method. Notes: 3 - rigid construction, 4 - test beam (basic part), 5 - upper part of test beam, 6 - force transducer F_R (Hottinger, Germany), 7 - force transducer F_N (Hottinger, Germany), 13 - test object, 14 - test mass.*

Figure 6. *Examples of damage to lanyards. Notes: conditions of performance tests: K3; h = 2.5 m; A = 0.0 m; 1 - lanyard made of TRUST type mountaineering dynamic rope, 2 - lanyard made of type PA12-A-Z/K6/200 fibre rope, 3 - lanyard made of PRO-STATIC type mountaineering static rope.*

sonal protective equipment. Typical tests of such connecting and shock-absorbing components of personal protective equipment as lanyards, textile shock absorbers, self-locking arresters on flexible anchorage lines are conducted under conditions in which the equipment does not come into contact with external mechanical objects which may cause additional damage during the fall arrest of a rigid test mass of 100 kg.

Testing methodology and the test stand

To investigate the case in which connecting and shock-absorbing components come into contact with objects that may affect their protective parameters, a test stand was designed, presented in ***Figures 4*** and ***5***.

The stand consists of a rigid construction (3) mounted on the wall of the laboratory premises. The test object, e.g. a lanyard (13), is connected to this construction by a force transducer F_N (7) and a chain (15). The other end of the lanyard is connected by a force transducer F_R (6) with a rigid test mass, (14) of 100 kg weight. A transverse test beam (4) is mounted parallel to the laboratory wall, which is of rigid construction (3) due to specially prepared sockets in the load-bearing walls of the building. The test beam construction ensures that its bending rate does not exceed 1 mm under a vertically acting load of F = 20 kN. The beam length, measured between the supports, amounts to ca. 3.0 m. The upper part of the test beam (5) is a changeable element, e.g. concrete beam or flat steel bar simulating the edge of the worksite with which the connecting and shock-absorbing component (13) comes into contact during the fall arrest of the rigid test mass (14).

For testing purposes, the transverse beam was equipped with three types of the upper element, simulating the edge of the worksite, characterszed in ***Table 2***.

The test stand consists of a power winch (1), whose hook is connected to a quick release device (2). The power winch allows to raise and lower the rigid test mass (14) to the height required in relation to the test beam (4), and the quick release device (2) allows its release and consequent fall. The stand is equipped with an electronic system enabling to measure the courses of forces acting at both ends of the test object (13) when it is arresting the fall of the rigid test mass (14). This system is composed of force transducers (6) and (7), manufactured by Hottinger, with a 20 kN measurement range, amplifiers (Hottinger) cooperating with them, low-pass analogue filters with frequency characteristics consistent with the requirements of EN 364:1996 [16], and a type KUSB 3116 measurement chart (Keithley) connected to the USB port of a computer. The measuring system commences the measurement and recording of the courses of forces acting on force transducers (6) and (7) at the moment when the rigid test mass starts falling down (14). The force signals are sampled at a 10 kHz frequency, and the time of their recording amounts to ca. 5 s, which covers the total time of arresting the fall of the rigid test mass by the test object. As a result of the test, two data files with the time courses of the acting forces are saved in the computer memory and subsequently processed by means of Origin v. 7.5 software.

The testing method applied on the test stand presented involves dropping the rigid test mass (14) from a given height - *h*. After the elimination of clearance of the test component (13) connected in

Table 3. Performance test results of the lanyards.

Test object	Upper part of the test beam	h, m	A, m	F_R, kN	F_N, kN	Δ_F, kN	Arresting of the fall of the test mass	Damages of the test object
Lanyard made of three strand polyamide rope type PA12-A-Z/K6/200, diameter of 12mm	K1	0.5	0.0	4.92	3.02	2.08	Yes	Absence of the damages
	K1	1.5	0.0	8.45	6.63	2.21	Yes	Partial damage of one strand of the rope
	K1	2.5	0.0	11.59	9.72	1.99	Yes	Partial damage of two strands of the rope
	K1	0.5	0.5	3.90	2.24	1.75	No	Cutting of one strand of the rope
	K1	1.0	0.5	4.85	3.09	1.78	No	Cutting of three strands of the rope (Figure 8.3)
	K1	1.5	0.5	3.85	2.52	1.44	No	Cutting of three strands of the rope
	K1	0.5	1.0	4.63	2.75	2.07	Yes	Partial damage of two strands of the rope
	K1	1.0	1.0	3.96	2.36	1.74	No	Cutting of three strands of the rope (Figure 9.3)
	K2	0.5	0.0	3.88	2.19	1.77	No	Cutting of three strands of the rope
	K2	1.5	0.0	3.05	1.89	1.42	No	Cutting of three strands of the rope
	K2	2.5	0.0	2.87	1.65	1.29	No	Cutting of three strands of the rope
	K2	0.5	0.5	3.43	1.68	1.75	No	Cutting of three strands of the rope
	K2	0.5	1.0	2.97	1.49	1.57	No	Cutting of three strands of the rope
	K3	0.5	0.0	4.15	2.45	1.95	Yes	Partial damage of three strands of the rope
	K3	1.0	0.0	6.26	4.58	1.94	Yes	Partial damage of three strands of the rope
	K3	1.5	0.0	8.11	5.61	2.73	Yes	Partial damage of three strands of the rope
	K3	2.5	0.0	8.95	6.60	2.47	No	Cutting of three strands of the rope (Figure 7.2)
Lanyard made of mountaineering dynamic rope type TRUST, diameter of 11mm	K1	0.5	0.0	3.76	2.25	1.65	Yes	Damage of the surface of the mantle
	K1	1.0	0.0	4.73	2.89	2.09	Yes	Cutting of the mantle
	K1	1.5	0.0	5.47	3.16	2.47	No	Cutting of the mantle and the core
	K1	2.5	0.0	5.14	2.87	2.34	No	Cutting of the mantle and the core
	K1	0.5	0.5	4.11	2.98	1.20	Yes	Cutting of the mantle and part of the core
	K1	1.0	0.5	4.60	3.33	2.11	Yes	Cutting of the mantle and part of the core (Figure 8.1)
	K1	1.0	1.0	4.18	2.80	1.73	No	Cutting of the mantle and the core (Figure 9.1)
	K2	0.5	0.0	3.33	1.76	1.66	Yes	Cutting of the mantle and part of the core
	K2	1.0	0.0	3.63	2.20	1.96	Yes	Cutting of the mantle and part of the core
	K2	1.5	0.0	3.74	2.65	1.80	No	Cutting of the mantle and the core
	K2	0.5	0.5	3.09	2.10	1.65	Yes	Cutting of the mantle and part of the core
	K2	1.0	0.5	3.51	2.36	1.45	No	Cutting of the mantle and the core
	K2	0.5	1.0	3.01	2.55	1.67	No	Cutting of the mantle and the core
	K3	0.5	0.0	3.28	1.87	1.96	Yes	Cutting of the mantle and part of the core
	K3	1.5	0.0	4.70	3.92	2.05	Yes	Cutting of the mantle and part of the core
	K3	2.5	0.0	6.35	5.25	1.92	Yes	Cutting of the mantle and part of the core (Figure 7.1)
Lanyard made of mountaineering static rope type PRO-STATIC, diameter of 10mm	K1	0.5	0.0	5.82	3.63	2.60	Yes	Damage of the surface of the mantle
	K1	1.5	0.0	9.33	7.44	2.04	Yes	Cutting of the mantle
	K1	2.5	0.0	12.31	10.22	2.66	Yes	Cutting of the mantle and part of the core
	K1	0.5	0.5	4.34	2.76	1.83	Yes	Cutting of the mantle and part of the core
	K1	1.0	0.5	5.34	3.40	2.43	No	Cutting of the mantle and the core (Figure 8.2)
	K1	1.0	1.0	5.47	3.37	2.13	No	Cutting of the mantle and the core (Figure 9.2)
	K2	0.5	0.0	4.47	2.47	2.06	No	Cutting of the mantle and the core
	K2	1.0	0.0	4.47	2.57	2.11	No	Cutting of the mantle and the core
	K2	0.5	0.5	4.51	2.83	1.74	No	Cutting of the mantle and the core
	K2	0.5	1.0	4.38	2.79	1.65	No	Cutting of the mantle and the core
	K3	0.5	0.0	6.08	4.58	1.91	Yes	Cutting of the mantle and part of the core
	K3	1.5	0.0	9.07	7.89	2.32	Yes	Cutting of the mantle and part of the core
	K3	2.5	0.0	7.77	7.11	2.32	No	Cutting of the mantle and the core (Figure 7.3)

series with an extension chain (15), the fall arrest process begins, during which the test object rubs against the edge (5) of the transverse beam. The result of the test is the observation whether or not the rigid test mass has been released, as well as the courses of the F_R acting at the end of the component connected to the rigid test weight and of the force F_N acting at the end connected by a chain to the rigid construction of the test stand. The baseline conditions of the test include the following: the type of the upper part of the transverse beam (5), the height of the free fall of the rigid test mass *h* and shift *A*, presented in ***Figure 5***. In the case of $A = 0.0$ m, the test object, as a result of elongation, moves during the fall arrest only in a direction perpendicular to the beam, whereas if $A > 0.0$ m it also moves in a parallel direction.

Test objects

The test stand presented was used for the testing of the following types of personal protective equipment protecting against falls from a height:

- lanyards made of type PA12-A-Z/K6/200 three strand polyamide fibre rope, 12 mm in diameter [17],
- lanyards made of TRUST type mountaineering dynamic rope, 11 mm in diameter [21],
- lanyards made of PRO-STATIC type mountaineering static rope, 10 mm in diameter [22],
- textile energy absorbers with lanyards made of three strand polyamide rope, 12 mm in diameter.

Table 4. Performance test results of the energy absorbers.

Upper part of the test beam	h, m	A, m	F_R, kN	F_N, kN	Δ_F, kN	Arresting of the fall of the test mass	Damages of the lanyard
K1	1.0	0.0	4.45	2.53	2.08	Yes	Partial cutting of two strands (Figure 10.1)
K1	1.5	0.0	4.49	2.81	2.15	Yes	Partial cutting of two strands
K1	2.0	0.0	4.27	2.60	1.73	No	Cutting of three strands
K1	0.5	0.5	3.68	2.10	1.72	Yes	Partial cutting of two strands
K1	1.0	0.5	4.25	2.44	1.84	Yes	Partial cutting of two strands
K1	0.5	1.0	3.15	1.66	1.62	Yes	Partial cutting of two strands
K1	1.0	1.0	3.85	2.17	1.78	No	Cutting of three strands (Figure 10.2)
K2	0.5	0.0	3.58	2.18	1.53	No	Cutting of three strands
K2	1.0	0.0	3.25	1.92	1.47	No	Cutting of three strands
K2	2.0	1.0	2.76	1.59	1.28	No	Cutting of three strands (Figure 10.3)
K2	0.5	0.5	3.38	1.78	1.69	No	Cutting of three strands
K2	0.5	1.0	3.01	1.56	1.63	No	Cutting of three strands
K3	0.5	0.0	4.64	2.73	2.18	Yes	Damage of the surfaces of three strands
K3	1.0	0.0	4.79	2.99	1.98	Yes	Damage of the surfaces of three strands
K3	2.0	0.0	4.65	2.43	2.29	Yes	Damage of the surfaces of three strands
K3	2.5	0.0	4.21	2.56	1.87	Yes	Damage of the surfaces of three strands
K3	3.0	0.0	4.83	2.33	2.51	Yes	Damage of the surfaces of three strands

Test results and their analysis

The results of the tests are presented in ***Tables 3*** and ***4***.

To sum up the results presented, the following observations and conclusions can be made:

- In ca. 50% of cases, the friction of the lanyards and textile energy absorbers against the edge of the transverse beam caused that the protective equipment failed to arrest the fall of the rigid test mass. Such an effect was due to cuts inflicted by the upper edge of the beam. Examples of damage occurring as a result of the friction of lanyards and shock absorbers are presented in ***Figures 6, 7, 8,*** and ***9***;
- The cutting of the connecting and shock-absorbing components by the edge of the upper part of the transverse beam depends on its type, the radius of the edge and on the direction in which the object moves against it during the fall arrest;
- Most of the cases of the cutting of the connecting and shock-absorbing component tested and consequent failures to arrest the fall of the rigid test mass were associated with the use of the upper part of the beam of the type denoted in ***Table 2*** as K2;
- The complete cutting of the connecting and shock-absorbing component was more frequent in cases where the initial displacement of the rigid test mass met the condition A > 0, caused by the movement of the lanyard during the fall arrest both in a perpendicular and parallel direction in relation to the beam edge;
- In all cases, the friction of the lanyards against the beam edge caused that they broke sooner, i.e. at a lower height of free fall of the rigid test mass, in comparison with standard tests of resistance to dynamic loads, where the lanyard does not come in contact with any objects [16];
- The maximum values of force F_R measured by the force transducer connected to the rigid test mass were always higher than force F_N, measured at the anchorage point. These differences, in the case of lanyards, fell within the (1.17 ÷ 2.5) kN range, and in the case of textile shock absorbers – within the (0.46 ÷ 2.5) kN range. The effect observed resulted from the occurrence of a friction force between the test object and the edge of the transverse test beam.

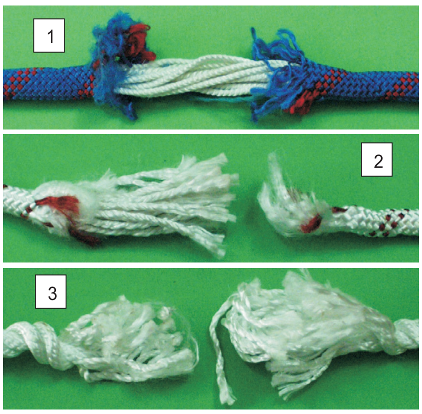

Figure 7. *Examples of damage to lanyards. Notes: conditions of performance tests: K1; h = 1.0 m; A = 0.5 m; 1 - lanyard made of TRUST type mountaineering dynamic rope, 2 - lanyard made of PRO-STATIC type mountaineering static rope, 3 - lanyard made of type PA12-A-Z/K6/200 fibre rope.*

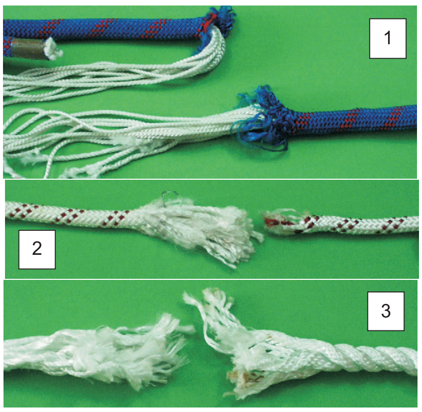

Figure 8. *Examples of damage to lanyards. Notes: conditions of performance tests: K1; h = 1.0 m; A = 1.0 m; 1 - lanyard made of TRUST type mountaineering dynamic rope, 2 - lanyard made of PRO-STATIC type mountaineering static rope, 3 - lanyard made of type PA12-A-Z/K6/200 fibre rope.*

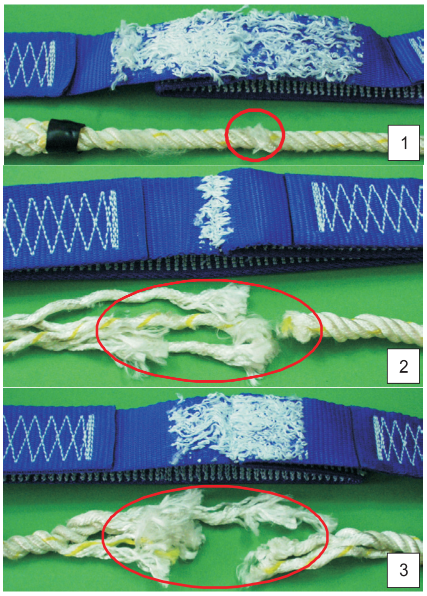

Figure 9. *Examples of damage to energy absorbers with lanyards. Notes: conditions of performance tests: 1 - K1; h = 1.0 m; A = 0.0 m; 2 - K1; h = 1.0 m; A = 1.0 m; 3 - K1; h = 2.0 m; A = 1.0 m.*

Conclusions

Analysis of the results of the laboratory tests has led to the following conclusions:

- Pressure on a rope or webbing sample, directed perpendicular to its length, exerted by an additional element, causes a significant decrease in its tensile strength under static conditions;
- The extent of mechanical strength loss depends on the sample type (material and construction), and on the element exerting pressure during the stretching process (edge radius and material);
- In the case of the element with the sharpest edge (case D in ***Figure 3***), the tensile force at break was for some webbing and rope samples lower than 6 kN, the value which can occur and is acceptable under the actual conditions of use of protective equipment during a fall arrest;
- The EN 354:2002 standard [8] concerning lanyards contains a requirement that if the equipment is made of textile materials, it must be able to carry a load with a static force of 22 kN value for 3 min. However, compliance with this fundamental requirement does not guarantee appropriate mechanical strength of the equipment in case of additional mechanical factors, e.g. sharp edges;
- If the connecting and shock-absorbing components come into contact with a sharp-edged transverse element during a fall arrest, it can lead to serious damage, including a complete break;
- The extent of damage is dependent on the material and construction of the connecting and shock-absorbing component, as well as on the material and shape of the element with which it interacts. The extent of damage is increased significantly if the connecting and shock-absorbing component moves against the transverse obstacle not only in the perpendicular but also in a parallel direction;
- Friction between the connecting and shock-absorbing component and a transverse obstacle causes the momentary values of the force acting at the anchorage point - F_N to be lower than corresponding values of force F_R acting on the object whose fall is being arrested. The difference between F_N and F_R is more significant the higher the friction force acts between the component and the obstacle edge. This phenomenon may lead to a situation in which the shock absorber, anchored on one side of the obstacle, is unable to reduce the force acting on the user (on the other side of the obstacle) during a fall arrest to a value lower than 6 kN.

Relating the above conclusions from laboratory tests to the actual use of individual systems protecting against falls from a height, it should be stated that the connecting and shock-absorbing components should be installed so as to have no contact with any construction elements, especially those with sharp edges, during a fall arrest. This problem is particularly important in the situation where a man falls outside the worksite, and the component slides along its edge. If it is impossible to eliminate contact between the protective equipment and worksite elements, devices characterised by a higher resistance to destructive mechanical factors should be used. For appropriate identification of such equipment, additional requirements and testing methods should be applied for the purposes of the certification of conformity with directive 89/686/EEC [20]. Compliance with these requirements should be checked in addition to the basic criteria if the manufacturer declares that the equipment has additional resistance to the effects of destructive mechanical factors. A step in this direction has been made this year in the European Union by Vertical Group VG-11, an association of notified bodies dealing with the testing and certification of personal equipment protecting against falls from a height, which has created two *Proposal for enquiry* documents: CNB/P/11.074 [23] and CNB/P/11.075 [24]. These documents contain preliminary proposals for the requirements and methods of testing lanyards with fall arresters and self-locking elements with flexible anchorage lines, which can be used in the case of friction against worksite elements occurring during a fall arrest. These documents, after appropriate revisions and approval, will be applied to certify equipment protecting against falls from a height.

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