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SECTION 25. Technologies of materials for the light and textile industry.

THE SYNERGY INFLUENCE OF HAZARDS AT WORKSTATIONS AT A HEIGHT ON MEANS OF LANYARD MADE OF ROPE

***Abstract**: The construction workers use individual protection systems against fall from height in both for extra protection and as a single measure of protection when the work is short or for technical reasons other measures of protection are not possible. During the activities at height the hazards at workstations are acting not only to the worker, but also on personal protective system against falling from a height, damaging it. The anchor being a component of individual systems for protection against falls from height, which connects the body holding device and the anchor point to ensure the safety of users must retain the characteristics of protection throughout the period of use. Given the dangers at different workstations in construction, this article presents their influence on the protective characteristics of connecting means made of rope. It also presents the conclusions on the main causes of loss of the protection features of connecting means made of rope.*

***Key words**: means of coonection, ropes, danger/hazards, construction.*

***Language**: English*

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1. Introduction

The mean of lanyard being an essential component of all protection systems for protection against falls from a height, which together with other components (body support device and safe anchorage) is used in various sectors. The most important tasks of a lanyard means are:

• connect the body holding device to a safe anchor point;

• to support the user's body in the supported position;

• to support the wearer body in case of a fall.

Because it ensure the protection against serious or fatal accidents, maintaining of the characteristics of protection of lanyard means throughout the entire period of use is crucial.

Presently placing into the market of a lanyard means is governed by European Directive 89/686/EEC as amended and supplemented, those must meet the essential health and safety requirements throughout the entire life. In addition, to ensure adequate protection against the risks in question, must be able to withstand to the effects of the inherent environmental factors in the foreseeable conditions of use. Although this requirement exists in the European Directive 89/686/EEC it was not pursued because it was not translated into specific requirement standards by which full compliance is given the presumption of conformity of such a product.

Because over time occupational accidents due to falls from heights continued to appear, it is clear that the risk factors present in the working environment act not only on employees but also on personal protective equipment (abbreviated further PPE), influencing negatively its protection features. The lack from specific standards EN 1891, EN 358 and EN 354 of requirements that establish product performance taking into account the actual use conditions, led to the establishment of erroneous protection features or some false lifetime use, which proved to have repercussions on direct user. Accurate estimation of the life of a lanyard means made from rope is based on understanding the phenomena that adversely affect their protection features.

Studies on the effect of the mechanical factors or the synergistic effect of the various hazards of the protective characteristics of the constituent materials of the various components to the personal protective equipment against falls from height were made by Krzysztof and Marcin Baszczyński Jachowicz [1, p.

117, p. 123; 2, p 445; 3, p 21; 4, p. 2, p. 18. Although the analyzed studies have led to a better understanding of the size and pattern of accidents, however the allocation of a single specific cause for an accident or incident is rarely accurate and is often considered a flawed approach because it fails to identify the real causes. Regarding the synergistic action of risk factors to the characteristics of protection of lanyard means made of rope, studies are in an early stage. Thus, from the desire to correctly estimate the "life" of complex belt Krzysztof Baszczyński and Marcin Jachowicz conducted a study [32] in which they watched the influence of the synergistic action of weathering, light, mechanical factors and dust on different strap samples used to achieve them.

Due to the large number of work accidents recorded each year in construction [5] by the study carried out I wanted to draw attention of involved factors to the importance of identifying existing hazards in the workplace for the selection of the appropriate lanyard means made of rope .

2. Methodology

The methodology that was the basis of the survey was to identify the existing hazards at different workstations at a height in constructs to identify and develop accelerated test methods by which to determine the impact of hazards on the protective characteristics of different rope types.

Since in actual use conditions is likely that existing risk factors in the work environment to combine, in the study the synergistic effect was achieved by overlapping the factors effect for degradation through accelerated methods. Thus, samples of various diameters of rope were exposed to a sequence of degradation: weather conditions; dust and abrasive edges; moisture and cold. To track the effect of the degradation factors on the rope material, each exposure was followed by a static strength test according to EN 1891[6, p. 7] continued to break.

3. Rope samples and test methods

Considerind that the technology of manufacture of the ropes has reached a plateau, only one polymer is predominantly on the market – the polyamide; for the series of tests were acquired ropes of polyamide with different diameters made by different manufacturers (see Table 1).

Table 1

Rope samples purchased

No.	Static rope type A	Rope diameter, mm	Characteristics	Code
1		10	- the mantle structure has woven strands 40 (8 strands khaki, black strands 32) - the core is made up of 14 twisted strands with a diameter of 0.63 mm	10 NK
2		10	- the mantle structure has colored braided strands 40 (4 strands of black and blue strands 36) - the core is made up of 16 twisted strands with a diameter of 1.86 mm	10 AN
3		10,5	- the mantle structure has 40 strands braided black - the core is made up of 14 twisted strands with a diameter of 1.82 mm	10,5 N
4		10,5	- the mantle structure has 16 colored wires twisted (2 wires blue, one red thread, one thread yellow, gray 12 threads) - the core is made up of 40 twisted strands with a diameter of 0.63 mm	10,5 TRI

No.	Static rope type A	Rope diameter, mm	Characteristics	Code
5		10,5	- the mantle structure has 54 colored wires interlaced (6 wires khaki and black yarn 48) - the core is made up of 16 twisted strands with a diameter of 1.82 mm	10,5 NK
6		11	- the mantle structure has colored strands woven 48 (6 strands of black and blue strands 42) - the core is made up of 16 twisted strands with a diameter of 1.68 mm	11 AN
7		11	- the mantle structure has colored strands woven 48 (6 strands khaki and black strands 42) - the core is made up of 16 twisted strands with a diameter of 1.68 mm	11 NK

To determine how the hazards from the work environment, act during a year, the protective characteristics of the lanyard means made of rope, sets of specimens for each type of rope were exposed to different types of degradation through accelerated methods. Since for lanyard means the static resistance is representative and closely linked to its durability, each degradation was accompanied by a determination of static resistance according to EN 1891 continued to break. In parallel, samples of rope coded as 10.5 TRI were used for a year by workers in construction in various activities at height.

Prior to the exposure of the ropes to the series of degradation, all samples were conditioned at (23 ± 2) ^{0}C and at a relative humidity of (50 ± 5)% for 168 hours. The conditioning was carried out in a climate chamber Feutron provided with a ventilation system, which allows to ensure uniform temperature and humidity conditions, in the whole enclosure.

3.1. The degradation to weathering

Key variables that influence the weather are ultraviolet radiation, temperature and water /humidity. In setting test parameters was taken into account the position that Romania has in the world [(7)]. With a moderate climate, with sunshine yearly on a horizontal surface less than or equal to 5 GJ/m2 [8, p. 8, p 9], calculations determined that 1 year of sunlight is equivalent to an exposure in the laboratory to an energy radiation equal to 201 MJ/m^2. Applying the principle of similarity to the achievement aging of the ropes was used method of ISO 4892-2 [9, p.7].

Thus, sets of specimens of each type of rope were exposed for 400 hours to artificial sunlight using a test chamber Q-Sun Xenon Xe-1 equipped with a lamp Xenon arc (see Figure 1). A day filter was installed between the irradiance source and the sample and the was set at (0.51 ± 0.02) W / (m2·nm) for wavelength of 340 nm.

Specific exposure conditions were:

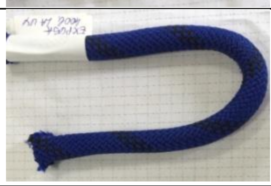
- Standard panel temperature: (65±3) ^{0}C;
- the temperature in the test chamber: (38±2) ^{0}C;
- relative humidity: (50±10) %;
- radiation - Narrowband: (0,51±0,02) W/(m^2·nm) wavelength 340 nm;
- exposure period: 400 hours;
- The number of cycles of exposure: 200 (1 cycle: 102 min. Drying; 18 min. sprayed with water).

Figure 1- Aging equipment for determining exposure to artificial radiation (xenon) - Q-SUN xenon

Results of the appearance of the ropes after exposure for 400 hours in the UV radiation are shown in Table 2.

Table 2

Notice recorded after exposure of ropes for 400 hours to UV radiations

Type of rope	**Photos before exposure**	**Photo after exposure**	**Observations**
10 NK			− discoloration − rope surface is slightly sticky
10 AN			− slight dulling − rope surface is slightly sticky
10,5 N			− without discoloration
10,5 TRI			− severe discoloration − rope surface is frosted
11 AN			− discoloration − rope surface is slightly sticky

Encoded ropes 10.5 N 11 NK 11 NK showed no changes in the appearance. Since encoded rope 10,5 TRI showed a marked discoloration in order to observe any structural changes that occurred, it was analyzed under a microscope (see Figure 2).

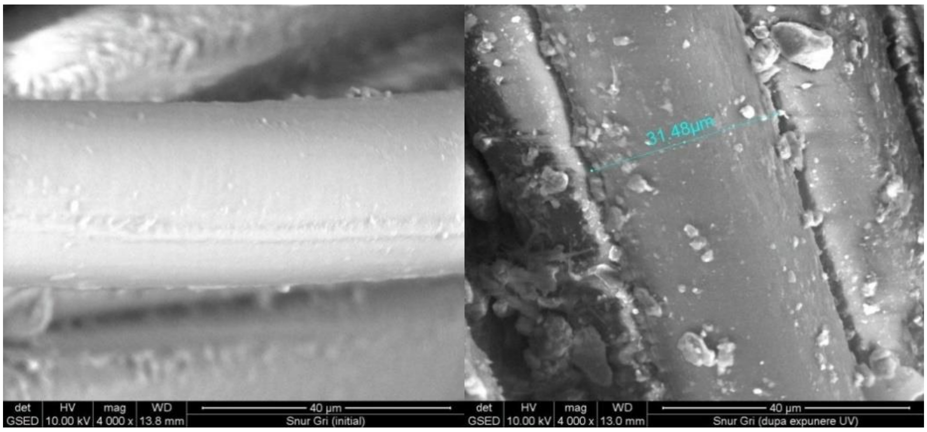


Figure 2 – The microscopic analysis of TRIM 10.5 rope before and after exposure to UV

As shown in Figure 2, following exposure to UV radiation, surface of the rope (mantle) has been damaged, which stresses that under the action of UV radiation the polymer structure undergoes various changes that can influence their physical and chemical properties. This is demonstrated by the results recorded in Table 3.

3.2. The exposure to dust

The idea that particles of dust on most construction workstations could pass through the mantle of the rope and get to the core strands reducing their integrity, determined the need to monitor the influence of this phenomenon on the tensile strength of the ropes.

Method on dust exposure was modeled after the pr. EN 354: 2006 [10, p. 18] and consisted in the exposure of the test specimens of rope to 1000 cycles of abrasion in a sand bath through a roller system. The device used to carry out this degradation being provided with a drum that performs a oscillatory motion at an angle of 90^0, to permit back and forth movement of the test specimen, through sand, over a length of 100 mm.

The device (see Figure 3) has been set so that, for each cycle the specimen to be passed through the sand bath twice (back and forth). As the abrasive material was used special sand with a grain size ranging between 0.1 mm and 1.0 mm (see Figure 4). The abrasive material has been changed at the beginning of each test.

After completion of the test / degradation, samples were visually inspected and then subjected to the static strenght test, continued to break.

Figure 3 - Device used to dust degradation

Figure 4- Abrasive material - sand

3.3. The exposure to abrasive edges

Since the rope connecting means are used in various individual protection systems for working at height, one of the criteria by which the user can decide whether connecting means is defective or not is the mantle damage. If for limiting systems we can not speak about a true contact for the connecting means with the abrasive edges, in terms of positioning systems and access on rope such situations are common. The need to monitor the effects of unprotected edges on the protective characteristics of the ropes was determined by the conclusions of interviews with construction workers that frequently use access and positioning systems on the rope and admitted that there are situations (especially when the rope was new) the protection of the rope at the edges contact area was omitted. To track the effects of the unprotected edges on the protective characteristics of the ropes, it was simulated such action by switching under load (120 kg) samples of rope over the abrasive edge of concrete (with roughness of 18 micrometres and an edge radius of curvature of 2 mm) (see Figure 5). Rope samples were subjected to 5 passes over edge. A crossing over the edge consist in raising and lowering the ground of a mass of 120 kg.

Figure 5 - Exposure to abrasive edges

3.4. Conditioning to moisture and cold

Given that during cool weather unforeseen circumstances may arise the activity at height can be done the test will be made in accordance with section 5.2.2. / EN 354: 2011 and consists of dipping the sample of anchor in water fresh at least 1 h at a temperature of (23 ± 5) °C and then, within 90 s after removal from the water, has been placed in the cold room for at least 4 hours at a temperature of (-4 + 0 / -2) °C.

After completion of the test / degradation, the specimens are subjected to the tensile strength.

3.5. The static strength / the breaking strength

Because the static resistance establishes the relationship between external forces and effort (internal forces) and the relationship between effort and tension; by determining its was monitored the ropes capacity to resist to all demands arising in the entire lifespan. The test method for determining the static strength is described in standard EN 1891 and consists in the exposure of the test specimen (which may be part of the system or part of it) for 3 minutes at a force of 15 kN. It is considered that the requirement for static strength is satisfied if during that time when the force was applied, the specimen does not break.

The test equipment used to perform the static strength test is a traction machine in accordance with 4.1 of EN 364: 1992 (see Figure 6).

Figure 6 - Static test machine for tensile, compression, shear and bending materials, type H50K-S with interchangeable cells

The results of test series are presented in Table 3.

Table 3

The influence of the risk factors on the ropes breaking strength

Rope code	Breaking strength, N, after exposure						
	t = 23 ° C, UR= 50 %, 168 hours	t = 23 ° C, UR= 50 %, 168 hours + 1000 abrasion cycles	t = 23 ° C, UR= 50 %, 168 hours + 1hour immersion in water + 4hours conditioning t= - 4 ° C	t = 23 ° C, UR= 50 %, 168 hours + 400 hours at UV radiation, 0,51 W/(m2·nm), λ=340 nm	t = 23 ° C, UR= 50 %, 168 hours + 1000 abrasion cycles + abrasive edges	t = 23 ° C, UR= 50 %, 168 hours + 1000 abrasion cycles + abrasive edges + 1hour immersion in water + 4hours conditioning t= - 4 ° C	t = 23 ° C, UR= 50 %, 168 hours + 400 hours at UV radiation, 0,51 W/(m2·nm), λ=340 nm +1000 abrasion cycles + abrasive edges + 1hour immersion in water + 4hours conditioning t= - 4 ° C
10 NK	16.550	15.413	16.400	13.987	15.960	15.700	13.373
10 AN	16.260	15.931	15.542	14.340	16.117	15.663	14.230
10,5 N	17.820	17.227	16.973	17.030	17.200	16.600	15.893
10,5 TRI	20.375	16.400	16.427	16.100	16.388	16.143	16.087
10,5 NK	16.620	15.480	15.487	14.800	14.193	14.085	12.877
11 AN	16.987	18.020	16.290	15.840	17.280	16.227	15.275
11 NK	18.494	18.100	16.317	16.827	17.997	16.260	16.143

Analyzing the results recorded in Table 3, it can be seen that the magnitude of synergistic risk factors on the tensile strength of various types of wire exposed to combinations of degradation depends on the number of risk factors, the diameter of the rope and not least the lack treatments applied ropes.

Thus, satisfactory results in relation to the requirements of European harmonized standards have the ropes coded 10.5 N, 10.5 TRI 11 AN and 11 NK, which means that these cords have undergone various treatments, which makes them resistant to the water, UV protection, and not least to the abrasion resistance.

4. The method validation

Also, by comparing the tensile strength of rope samples (10.5 TRI) exposed for 1 year in real conditions of use (see Table 4), on a site with those derived from the exposure of same rope type at all degradation "stacked" (table 3), we can say that the results are similar.

Tabelul 4

The breaking strength results after exposure of the rope 10.5 TRI to synergistic effect of the identified risk factors and the real conditions of use for 1 year

degradation type	Breaking strength, N			
	Epr. 1	Epr. 2	Epr. 3	The average value
Synergy created in the laboratory by the accelerated degradation overlay	16.460	15.900	15.900	16.087
Exposure for 1 year on site in real conditions of use	15.700	16.600	15.720	16.007

This proves both the correct identification of hazards existing at workstations at height in the construction, and the development of a right protocol for test simulation in the laboratory of the synergistic action of risk factors present in the workplace.

5. Conclusion

Results obtained from tests showed that the means of protection against falls from height made of rope lose some of the protection features in use. The main factors causing this process are the synergistic action of ultraviolet radiation and risk factors. As can be seen from the results obtained after carrying out series of tests synergistic effect has a greater negative effect on the characteristics of protection than that caused to the rope by the action of the individual hazards. The risk of injury/accident or occupational disease, defined as the combination of the probability and consequences of a dangerous characteristic event occurred is much higher than that due to a single risk factor.

Therefore, to maintain safe and healthy jobs, special attention should be paid to risk assessment. Identifying all existing factors at workstations is essential in determining the characteristics of the components that PPE must have for work at height.

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