

SESSION A:

EARTH MOVING AND TRANSPORTATION MACHINERY

Analysis of zipline systems with large spans and low inclination angles

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ABSTRACT

This paper presents an overview of the engineering challenges associated with long-span zipline systems characterized by low inclination angles. In such installations, particularly when combined with shallow terrain profiles, wind and ice loads can cause significant rope sagging and lateral displacements. Consequently, it is necessary to verify the required safety clearances between the rope and the surrounding terrain, as well as any obstacles located along the route. Since there are currently no dedicated standards specifically governing zipline systems, the assessment was performed in accordance with standards applicable to cableways. Accordingly, relevant excerpts from these standards are presented and discussed. A numerical verification was then carried out using the example of a zipline constructed on Fruška Gora. In addition, the paper provides an overview of the wire ropes and trolleys commonly used in ziplines of this type.

KEYWORDS

Zipline, Large Span, Safety Clearance, Wind Load, Ice Load

1. INTRODUCTION

Although the zipline, which was sporadically used in the past, is a simple type of transport that can be used to bridge canyons and basins, the expansion of its usage and construction is associated with the end of the twentieth century, primarily due to the adrenaline experience of the user. At that time, a larger number of ziplines, which primarily served the purpose of leisure, began to be built, and the places where they were built, were not strictly defined. They appear in hilly areas, as well as in and within large economic facilities such as dams and all the way to the city centres. Lately, there is a noticeable “race” among builders who will build longer ziplines, and that’s how *Jebel Jais Flight* (2832 m), *Volo dell’angelo* (2213 m), *The Eye of the Jaguar* (2130 m) and *Crimean Hawk* (2022 m) were made, [1]. However, there are still no appropriate regulations and standards for designing a device of that type. In addition, there is a relatively small number of scientific papers dealing with load determination in ziplines.

Authors of the paper “Traveling along a zipline” [2], analyzed a heavy rope. Using geometric relationships, they determined the rope configuration for different positions of a concentrated load (the rider). Furthermore, they presented the trajectory curve for different mass ratios between the rider and the rope. However, all considerations are limited to the static case.

On the other hand, authors of the paper “Structural safety evaluation of zip line due to dynamic impact load” [3], use the finite element method to analyze the stress in the rope of an existing zipline with a span of 280 m. The steel rope has a diameter of 12 mm, and a load of 150 kg moves along it at a constant speed of 54 km/h. As a result, they obtain stress values in the rope that remain within the allowable limits for the selected rope type.

Paper “Dynamic computation and design of a world record death-ride” [4], describes the construction of a temporary zipline with a span of 1163 m in Belgium. The rope is discretized using 16 finite elements. The analysis is carried out in two stages. In the first stage, the rope is considered under self-weight and tension force, and its equilibrium configuration is determined. In the second stage, external loads are applied to the previously obtained rope configuration. In this study, the external loads include the person’s weight and aerodynamic drag forces. The authors place particular emphasis on the selection of an appropriate tension force, since it directly influences the natural frequency of cable oscillations and, consequently, the comfort and perceived quality of the ride.

2. ANALYSIS AND OVERVIEW OF STEEL ROPES USED IN ZIPLINE SYSTEMS

Standards for ziplines do not prescribe a mandatory steel rope construction for application in zipline systems. In short-span ziplines, general-purpose wire ropes (e.g. 6x7, 6x19, etc.) are commonly encountered; however, in long-span ziplines, there is a tendency to use locked-coil (closed) rope constructions. Locked-coil rope constructions are characterized by extremely high bending stiffness and relatively high self-weight, which necessitates the application of significant pre-tensioning forces. This, in turn, affects the required structural capacity of both the starting and terminal stations. As an intermediate solution, the use of compacted wire ropes has emerged. These ropes are characterized by a relatively smooth outer surface with reduced grooving, while at the same time being significantly more flexible and considerably lighter than locked-coil rope constructions, [5]. Examples of rope constructions used in ziplines are shown in Fig. 1.

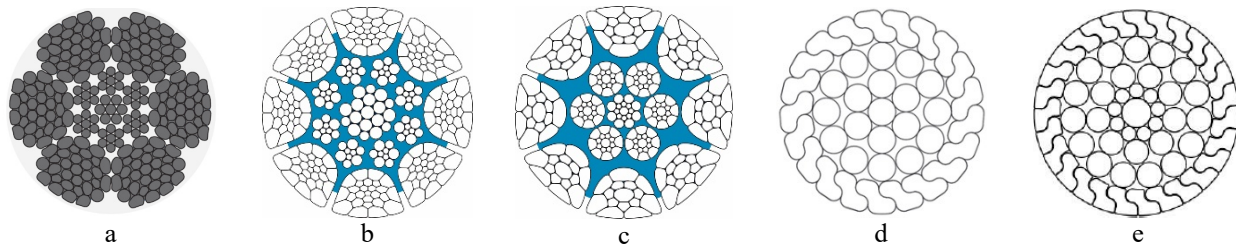


Figure 1: Rope constructions used for ziplines

Figures 1a, 1b and 1c show compacted wire ropes, whereas the Figs. 1d and 1e show locked spiral ropes.

3. ANALYSIS AND OVERVIEW OF TROLLEYS USED IN ZIPLINE SYSTEMS

Movement of persons along the rope is enabled by wheeled trolleys to which safety harnesses are attached. In practice, different types of wheels are used depending on the field inclination angle and applied loads. Figure 2a-c shows common types of wheels available in the product range of various manufacturers. The use of wheels made of plastic materials, or steel wheels with plastic or rubber inserts, is advantageous from the perspective of reducing the contact pressure on the steel rope, thereby positively influencing its service life. The use of such trolleys is common in shorter ziplines with steeper gradients.

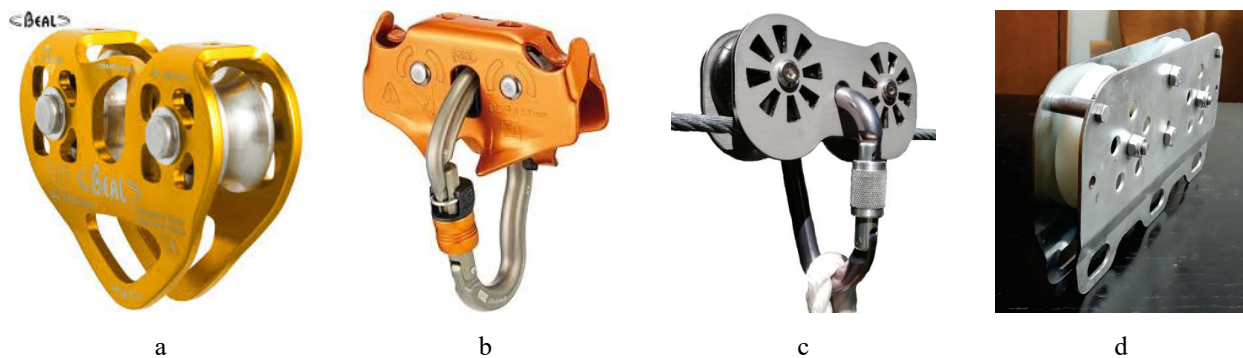


Figure 2: Types of trolleys

For this specific zipline system, specially designed trolley was developed and manufactured (Fig. 2d), featuring significantly larger wheel diameters in order to reduce the influence of bearing resistance.

In ziplines with a low field inclination angle, it often occurs that persons, under certain conditions, do not reach the end of the route. Among other factors, the riding position (Fig. 3) has a significant influence. In ziplines with a low inclination angle, even a prone position is not always sufficient to ensure reaching the end of the track. For example, simply extending the arms - an action commonly performed by users experiencing increased adrenaline - significantly increases the exposed surface area to airflow and wind. This leads to a substantial increase in aerodynamic drag and, consequently, to stopping before reaching the end of the route.



Figure 3: Various riding positions

If conventional trolleys were used in such ziplines, frequent manual retrieval would be required, which is time-consuming. Therefore, in such cases motorized trolleys with electric drive systems powered by batteries are used. Examples of such trolley systems from various international manufacturers are shown in Fig 4.

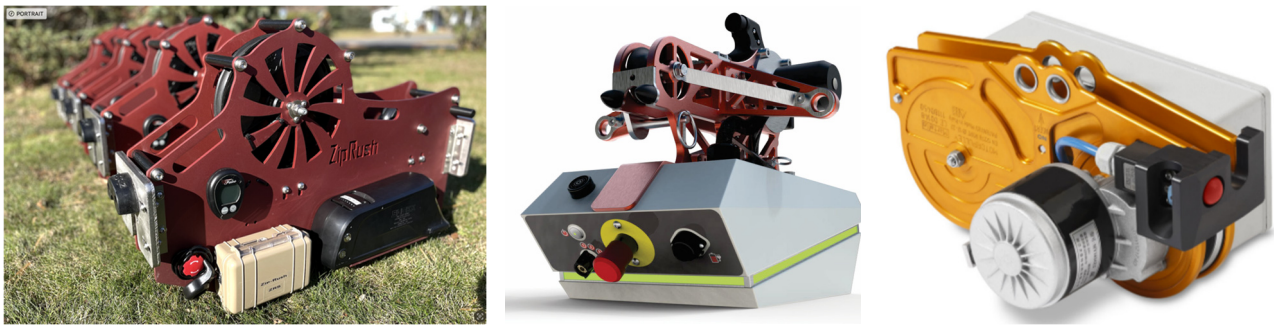


Figure 4: Motorized trolleys

4. DETERMINATION OF STEEL ROPE SAFETY CLEARANCES DURING OPERATION AND OFF-SEASON CONDITIONS

In order to determine the required safety clearances between the steel rope and the surrounding terrain, it is necessary to know both the terrain configuration and the loads acting on the rope. Defining the loads for zipline systems is particularly challenging due to the absence of regulations that directly address this type of installation. The standards EN 15567-1:2015+A1 and EN 15567-2:2015 [6-7] are not applicable, although they mention ziplines; however, this refers only to short installations within adventure parks. Consequently, the assessment of long-span zipline systems must be based on a combination of other relevant regulations. The most comparable installations to which zipline designers may refer are cableway systems. However, the actual operating conditions differ significantly in certain aspects, and strict application of cableway standards often leads to inappropriate design parameters for ziplines. The most significant differences are outlined below:

- Cableways are typically designed for operation in winter conditions in high-altitude regions with significantly low temperatures and strong winds, whereas ziplines are used under favorable meteorological conditions and are taken out of service during the winter season.
- Cableways are designed for the simultaneous transport of a large number of persons (high capacity), whereas ziplines are used for individual transport of persons; therefore, the safety requirements and operating conditions are significantly different.
- Ziplines are often located in relatively sheltered areas (urban environments or between tree canopies), whereas cableways are generally more exposed to wind action, as at least part of their route is typically located in open terrain (“clear areas”).

In the following sections, an overview and application of the regulations defined in the cableway standards EN 12930:2015 and EN 12929-1:2015+A1 will be presented [8-9], while section 4.3 will provide a more detailed determination of the safety clearances themselves. The determination of safety clearances will be demonstrated on the example of a specific zipline constructed on Fruška Gora, considering the case of installing a steel rope “Fatzter Integra” with a diameter of 16 mm, whose cross-section is shown in Fig. 1e. The terrain configuration of the specific zipline is shown in Fig. 5.

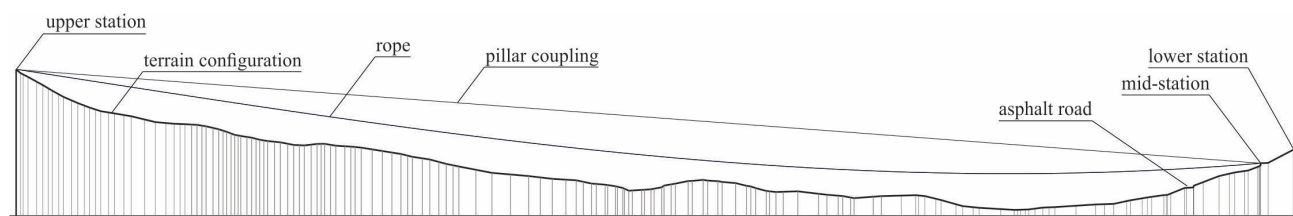


Figure 5: Terrain configuration

4.1. Loads According to Standard EN 12930:2015 (E)

4.1.1. Actions from Wind

The resultant wind force shall generally be calculated in accordance with EN 1991-1-4 on the basis of formula (1):

$$F_w = q \cdot c_f \cdot A_{ref} \quad (1)$$

where:

q - dynamic pressure;

c_f - force coefficient;
 A_{ref} - reference area for c_f

The values specified in the EN 1991-1-4 and in the national construction standards can differ in accordance with cableway-specific circumstances. Provided no other regulations have been specified in EN 1709, EN 1908, EN 1909, EN 12397, EN 12408, EN 12927 (all parts), EN 12929 (all parts), EN 13107, EN 13223, EN 13243 and EN 13796 (all parts), the following dynamic pressure values shall apply:

- in operation, a minimum value for dynamic pressure $q = 0.25 \text{ kN/m}^2$ shall be used. For specific cableways a higher value may be necessary.
- out of operation, the minimum value for dynamic pressure is $q = 1.20 \text{ kN/m}^2$, provided that particular local installation circumstances of the cableway or national cableway-specific provisions or directives do not stipulate other values.
- the dynamic pressure acts as a uniformly distributed load over the total slope length l^* . Out of operation, the dynamic pressure may be reduced in accordance with equation (2).

$$q_{red} = \beta \cdot q \quad (2)$$

where:

q_{red} - reduced dynamic pressure acting on the slope length l^* of the span;
 β - reduction coefficient;
 q - dynamic pressure.

The reduction coefficient β is:

- 1.00 at $l^* = 0 \text{ m}$;
- 0.65 at $l^* = 600 \text{ m}$;
- 0.50 at $l^* \geq 2\,000 \text{ m}$.

With a slope field length l^* between 0 m and 600 m or between 600 m and 2 000 m, β shall be established by linear interpolation.

For slope field length $l^* = 1430 \text{ m}$, the reduction coefficient amounts to:

$$\beta = 0.5 + (0.65 - 0.5) \cdot \frac{2000 - 1430}{2000 - 600} = 0.56$$

so the reduced dynamic pressure amounts to:

$$q_{red} = 0.56 \cdot 1200 = 672 \text{ N/m}^2$$

4.1.2. Actions from Ice

An ice load on the rope shall be taken into account if the ice curtain cannot be removed in good time by moving or driving the rope in another manner. Where an expert opinion establishes no other ice load on the rope, an ice sheet with a density of 600 kg/m^3 and an ice thickness of:

- 20 mm for ropes with a nominal rope diameter $\leq 10 \text{ mm}$;
- 25 mm for ropes with a nominal rope diameter $\geq 100 \text{ mm}$;

shall be assumed.

With a nominal rope diameter between 10 mm (corresponding to an ice load of 11.1 N/m) and 100 mm (corresponding to an ice load of 57.8 N/m), the ice load shall be established by means of linear interpolation. If required by local climatic conditions, a greater ice thickness or greater density shall be assumed. In the case of favourable climatic conditions, lower values may also be taken.

For a $\varnothing 16 \text{ mm}$ rope, the ice load amounts to $q_i = 14.2 \text{ N/m}$. This load corresponds to an ice accretion thickness of $\delta_i = 20.3 \text{ mm}$, yielding an overall iced rope diameter of $d_i = d + 2 \times \delta_i = 56.6 \text{ mm}$. Based on the previously determined values, the total distributed load of the iced $\varnothing 16 \text{ mm}$ rope is:

$$q_z'' = q + q_i = 14.8 + 14.2 = 29 \text{ N/m}$$

where:

$q = 14.8 \text{ N/m}$ - weight of the bare rope,
 $q_i = 14.2 \text{ N/m}$ - weight of ice.

Based on the previously defined values, the wind load can be determined:

In operation:

$$q_v = q \cdot c_f \cdot A_u = 250 \cdot 1.2 \cdot 0.016 = 4.8 \text{ N/m}$$

For reduced dynamic pressure (out of service):

$$q_v^u = q_{red} \cdot c_f \cdot A_u = 670 \cdot 1.2 \cdot 0.016 = 12.9 \text{ N/m} - \text{wind load acting on the bare rope,}$$

$$q_v^l = q_{red} \cdot c_f \cdot A_l = 670 \cdot 1.2 \cdot 0.057 = 45.8 \text{ N/m} - \text{wind load acting on the iced rope.}$$

4.1.3. Combined Actions from Wind and Ice

The following cases with simultaneous action from wind and ice shall be assumed:

- a) in operation:
 - 1) wind force in accordance with 2.1, ice load at 40 % of the value in accordance with 2.2, and;
 - 2) wind force at 80 % of the value in accordance with 2.1, ice load in accordance with 2.2;
- b) out of operation:
 - 1) wind force at 65 % of the value in accordance with 2.1, ice load at 40 % of the value in accordance with 2.2, and;
 - 2) wind force at 40 % of the value in accordance with 2.1, ice load in accordance with 2.2.

Zipline systems are not designed to operate under icing conditions; therefore, the analysis/check is carried out only for case b) as follows:

- 1) wind force at 65 % and ice load at 40 %

$$q_k^h = 0.65 \cdot 45.8 = 29.8 \text{ N/m} - \text{horizontal wind load,}$$

$$q_k^v = q_u + 0.4 \cdot q_l = 14.8 + 0.4 \cdot 14.2 = 20.5 \text{ N/m} - \text{vertical load.}$$

- 2) wind force at 40% and full ice load

$$q_k^h = 0.4 \cdot q_l^l = 0.4 \cdot 45.8 = 18.3 \text{ N/m} - \text{horizontal wind load,}$$

$$q_k^v = q_u + q_l = 14.8 + 14.2 = 29 \text{ N/m} - \text{vertical load.}$$

Thus, the resultant loads are:

- 1) wind force at 65 % and ice load at 40 %

$$q_r = \sqrt{(q_k^v)^2 + (q_k^h)^2} = \sqrt{20.5^2 + 29.8^2} = 36.2 \text{ N/m}$$

$$\operatorname{tg} \alpha_r = \frac{q_k^h}{q_k^v} = \frac{29.8}{20.5} = 1.45 \rightarrow \alpha_r = \arctg(1.45) = 55.5^\circ$$

- 2) wind force at 40% and full ice load

$$q_r = \sqrt{(q_k^v)^2 + (q_k^h)^2} = \sqrt{18.3^2 + 29^2} = 34.3 \text{ N/m}$$

$$\operatorname{tg} \alpha_r = \frac{q_k^h}{q_k^v} = \frac{18.3}{29} = 0.63 \rightarrow \alpha_r = 32.2^\circ$$

4.2. Loads According to Standard EN 12929-1:2015+A1:2022 (E)

4.2.1. Actions from Wind

The lateral deviation of the ropes as a result of the wind is to be calculated with a reduced dynamic pressure q' :

$$q' = q \cdot \left(\frac{l^{*'}}{l^*} \right)^2 \quad (3)$$

where

q - minimum dynamic pressure

- in operation: $q = 0.20 \text{ kN/m}^2$;

- out of operation: $q = 1.20 \text{ kN/m}^2$;

l^* - slope length of span;
 $l^{*'} -$ notional field length.

The dynamic pressure q' acts as a uniformly distributed load over the total slope length of span l^* . The notional field length $l^{*'}$ is calculated from the slope field length l^* by means of the following equation:

$$l^{*' = l^* \cdot \delta \quad (4)$$

where δ is the reduction coefficient and amounts to:

- 1.00 at $l^* \leq 200$ m;
- 0.65 at $l^* = 900$ m;
- 0.50 at $l^* \geq 2\,000$ m.

With a slope field length l^* between 200 m and 900 m or between 900 m and 2 000 m, δ shall be established by linear interpolation. When establishing the lateral deviation, the increase in the lateral windage areas of the ropes as a result of an ice curtain shall be taken into consideration. Where an expert opinion establishes no other values, an ice sheet with an ice thickness of:

- 20 mm for ropes with a nominal rope diameter ≤ 10 mm;
- 25 mm for ropes with a nominal rope diameter ≥ 100 mm;

shall be assumed.

For the given parameter values, the reduction factor is obtained by linear interpolation:

$$\delta = 0.5 + (0.65 - 0.5) \cdot \frac{2000 - 1430}{2000 - 900} = 0.58$$

the lateral deviation (deflection) of the rope due to wind action should be calculated using the reduced dynamic pressure:

$$q' = 1200 \cdot \left(\frac{1430 \cdot 0.58}{1430} \right)^2 = 403.7 \text{ N/m}^2$$

4.2.2. Actions from Ice

With a nominal rope diameter between 10 mm and 100 mm, the ice thickness shall be established by linear interpolation. If required by local climatic conditions, a greater ice thickness shall be assumed. In the case of favourable climatic conditions, lower values may also be applied.

4.2.3. Combined Actions from Wind and Ice

To establish the lateral deviation of the ropes, the following cases shall be assumed:

- a) in operation
 - 1) 100 % dynamic pressure without ice sheet;
 - 2) 100 % dynamic pressure at 40 % of the ice thickness;
 - 3) 80 % of the dynamic pressure at 100 % of the ice sheet;
- b) out of operation
 - 1) 100 % dynamic pressure without ice sheet;
 - 2) 65 % dynamic pressure at 40 % of the ice thickness;
 - 3) 40 % of the dynamic pressure at 100 % of the ice sheet.

According to calculations for the simultaneous action of wind and ice, the most unfavorable resultant load is determined as follows:

$$q_v^u = q_{red} \cdot c_f \cdot A_l = 403.7 \cdot 1.2 \cdot 0.016 = 7.8 \text{ N/m} \text{ - wind load acting on the bare rope,}$$

$$q_v^l = q_{red} \cdot c_f \cdot A_l = 403.7 \cdot 1.2 \cdot 0.057 = 27.6 \text{ N/m} \text{ - wind load acting on the iced rope.}$$

For the simultaneous action of ice and wind, the following cases shall be considered:

- a) in operation: usage of zipline is not foreseen under icing conditions.
- b) out of operation

- 1) 100 % dynamic pressure without ice sheet

$$q_k^h = 7.8 \text{ N/m} \text{ - horizontal wind load,}$$

$$q_k^v = q_u = 14.8 \text{ N/m} \text{ - vertical load,}$$

thus, the resultant loads are:

$$q_r = \sqrt{(q_k^v)^2 + (q_k^h)^2} = \sqrt{7.8^2 + 14.8^2} = 16.7 \text{ N/m}$$

$$\operatorname{tg} \alpha_r = \frac{q_k^h}{q_k^v} = \frac{7.8}{14.8} = 0.53 \rightarrow \alpha_r = \arctg(0.53) = 27.8^\circ$$

2) 65 % dynamic pressure at 40 % of the ice thickness

$$q_k^h = 0.65 \cdot 27.6 = 17.9 \text{ N/m} - \text{horizontal wind load,}$$

$$q_k^v = q_u + 0.4 \cdot q_l = 14.8 + 0.4 \cdot 14.2 = 20.5 \text{ N/m} - \text{vertical load,}$$

thus, the resultant loads are:

$$q_r = \sqrt{(q_k^v)^2 + (q_k^h)^2} = \sqrt{20.5^2 + 17.9^2} = 27.2 \text{ N/m}$$

$$\operatorname{tg} \alpha_r = \frac{q_k^h}{q_k^v} = \frac{17.9}{20.5} = 0.87 \rightarrow \alpha_r = \arctg(0.87) = 41.1^\circ$$

3) 40 % of the dynamic pressure at 100 % of the ice sheet

$$q_k^h = 0.40 \cdot 27.6 = 11 \text{ N/m} - \text{horizontal wind load,}$$

$$q_k^v = q_u + q_l = 14.8 + 14.2 = 29 \text{ N/m} - \text{vertical load,}$$

thus, the resultant loads are:

$$q_r = \sqrt{(q_k^v)^2 + (q_k^h)^2} = \sqrt{29^2 + 11^2} = 31.1 \text{ N/m}$$

$$\operatorname{tg} \alpha_r = \frac{q_k^h}{q_k^v} = \frac{11}{29} = 0.38 \rightarrow \alpha_r = \arctg(0.38) = 20.8^\circ$$

4.3. Determination of the Safety Clearances

In the present case, the safety clearances will be verified at five characteristic points along the zipline route, shown in Fig. 6. For points T1-T4, the safety clearances during operation shall be greater than 1.5 m, as follows:

- For the operational condition of the zipline, considering a person length of 2 m, a person mass of 140 kg, and a snow cover thickness of 0.5 m, the calculated sag values shall be increased by 10%.
- During periods when the zipline is out of service (off-season conditions), no safety clearance is required.
- The clearance above the road shall be greater than 6 m at all times.

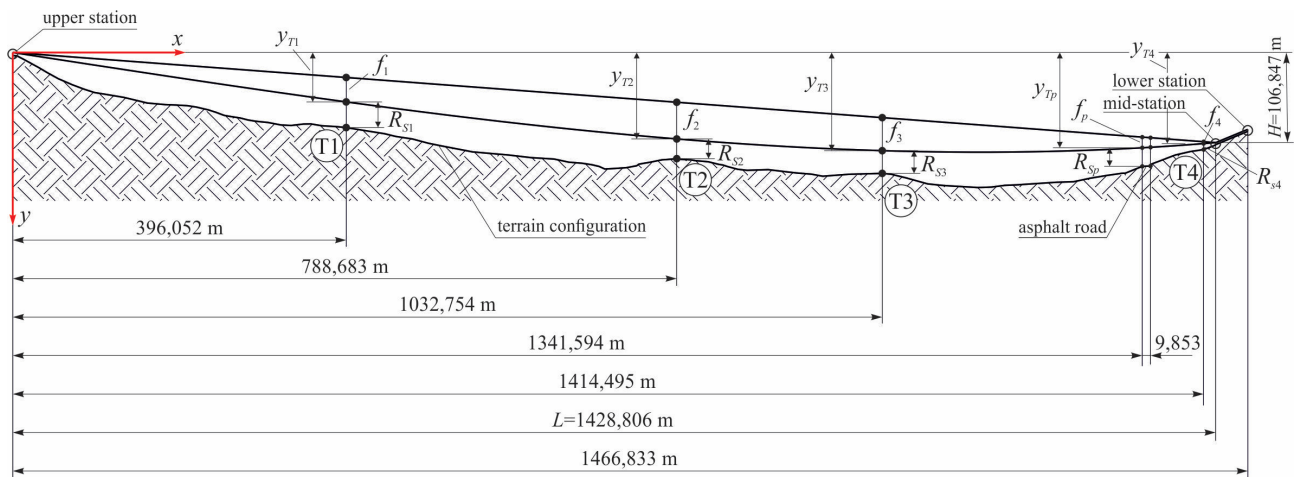


Figure 6: Terrain profile with safety clearances

The terrain parameters for the characteristic points were obtained from the topographic survey shown in Fig. 5.

The value of the safety clearance, (R_s), is determined as the difference between the vertical distance from the horizontal axis (x -axis) to the terrain elevation and the value of (y), where the value of (y) is calculated as follows, [10]:

$$y = x \cdot \operatorname{tg} \beta + \frac{x \cdot (l - x)}{2 \cdot H} \cdot \left(\frac{q_r}{\cos \beta} + 2 \frac{Q}{l} \right) \quad (5)$$

where:

- y - vertical distance from the horizontal x -axis,
- x - horizontal distance from the upper support,
- β - field inclination angle,
- l - span length,
- H - horizontal component of the rope force,
- q_r - self-weight of the rope including ice and wind loads,
- Q - person load.

The horizontal component of the rope force (H), for the case of a rope tensioned by a weight, is determined from the following system of equations:

$$H - \left[G - \left(f_{\max} - \frac{h}{2} \right) \cdot q_r \right] \cdot \cos \beta = 0 \quad (6)$$

$$f_{\max} = \frac{l^2}{8H} \cdot \left(\frac{q_r}{\cos \beta} + \frac{2Q}{l} \right) \quad (7)$$

where G is weight of the tensioning weight and $f_{\max}$ is maximum rope sag.

In the case of a rope anchored at both ends, the value of the horizontal component (H) is determined from the following system of equations:

$$H - \left[S_A - \left(\frac{h}{2} + f_{\max} \right) \cdot q_r \right] \cdot \cos \beta = 0 \quad (8)$$

$$f_{\max} = \frac{l^2}{8H} \cdot \left(\frac{q_r}{\cos \beta} + \frac{2Q}{l} \right) \quad (9)$$

where S_A represents the maximum force at the upper support, which is typically determined as follows:

$$S_A = \frac{S_{kid}}{\nu} \quad (10)$$

where ν is safety factor and S_{kid} is breaking load.

By substituting the values for the example zipline on Fruška Gora, the values of the safety clearances are obtained and are given in Table 1, while Table 2 presents the values for the descent of a person with the maximum design mass (140 kg) under operational conditions.

Table 1: Safety clearances (R_S [m]) for iced rope

ν	T_1	T_2	T_3	T_p	T_4
3.15	-13.535	-23.136	-6.820	13.831	5.751
2.25	7.053	2.276	13.768	19.720	6.770

Based on the obtained results, it can be concluded that, for a rope safety factor of $\nu = 3.15$, in icing conditions according to the cableway standard EN 12930:2015, the rope would penetrate into the ground at Point 1 by 13.5 m, at Point 2 by 23.1 m, and at Point 3 by 6.8 m, which is unacceptable. Since this standard allows, for iced rope conditions, a reduction of the safety factor to $\nu = 2.25$, the minimum safety clearance between the rope and the ground is obtained at Point 2, where it amounts to 2.3 m. This ensures sufficient clearance even in the presence of snow accumulation not exceeding values typical for the Fruška Gora area (0.2÷0.3 m).

Regarding the safety clearance during the movement of a person with a trolley ($Q=140$ kg), the obtained values are significantly higher than the prescribed requirements. For example, above the road, considering a rider height including the safety harness of 2 m, the clearance amounts to 19.3 m.

Table 2: Safety clearances (R_S [m]) for operational conditions ($Q=140$ kg)

T_1	T_2	T_3	T_p	T_4
12.462	8.952	19.177	21.268	7.038

For the assessment of extreme conditions involving the simultaneous action of wind and ice, the lateral deflections of the rope will be determined in accordance with EN 12929-1:2015+A1. The maximum lateral deflection of the bare rope under wind load amounts to:

$$b_u = f_{\max} \cdot \sin \alpha_r = 52.7 \cdot \sin 27.8^\circ = 26.7 \text{ m}$$

while the maximum lateral deflection of the iced rope under wind load amounts to:

$$b_u = f_{\max} \cdot \sin \alpha_r = 85.9 \cdot \sin 41.1^\circ = 56.5 \text{ m}$$

5. CONCLUSIONS

Although at first aspect it seems that any „attractive“ location can be used for the installation of a zipline, it often turns out to be extremely unfavorable from a technical point of view, mainly due to:

- ensuring sufficient inclination angles, which is often the case with ziplines of long lengths (leading to frequent or constant stay of people on the zipline),
- very „shallow“ terrain of the route (problem of ensuring safety distances),
- a significant problem arises due to climatic conditions and meeting the „harsh conditions“ for ice and wind loads when the zipline is not in use (out of season), because most often the method of tensioning with a weight with an extremely large stroke must be applied, which is why it is necessary to create a tensioning station with a large depth of the „well“ for the movement of the weight.

Even more unfavorable conditions are the limit values of lateral deflections of the rope due to the effect of wind, according to the EN standard 12929-1:2015+A1, which can have large values for long ziplines. This paper shows that at the mid-span of the considered zipline, the lateral deflections are 26.7 m for a steel rope without ice and as much as 56.5 m for an iced steel rope. As already mentioned, in ziplines with large spans and small height differences between the starting and ending stations, the problem of persons remaining on the line arises, even up to several hundred meters. In such situations, in the design phase, it is always a good idea to propose the use of motorized trolleys as an option (two pieces are enough for one zipline line), which enable:

- safe arrival of persons to the exit station,
- return of the trolley with safety belts to the starting station without the need to transport the trolley and the equipment by special means of transport.

In cases where designers have favorable conditions from the point of view of the zipline route (large inclination angles), then problems arise with high incoming velocities of persons. Then the use of brakes is necessary, which requires a separate analysis that is not an integral part of this work.

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