FIS Specifications for Flex Poles (Edition November 2020)

Original Text: German

1 Field of Application and Basic Information

The following FIS specifications for flex poles are intended to ensure that flex poles all over the world will behave in the same manner, whether during training or in actual races. These specifications refer to a pole consisting of a base shaft firmly anchored in the snow base, a bending device at the level of the snow surface and an upright pole. The following specifications state the requirements for the material from which the pole is made, the bending device, and the manner in which the pole functions. The rules in ICR are valid.

A pole which satisfies all the following requirements must operate efficiently under a variety of conditions (e.g. at very low temperatures) over a period of at least three years (approx. 8000 passes). On the other hand, the requirements are set in such a way that bodily injury to the skier is avoided as far as possible. However, the fact that these requirements are satisfied or that these specifications are applied does not guarantee against the poles breaking or skiers being injured by them, and the FIS declines all responsibility in such case.

Any flex pole which has been subjected to the appropriate test (section 6) and which has been supplied with a test certificate to show that it has satisfied these requirements is automatically considered suitable for any FIS race.

The specifications establish merely the numerical limits for materials, dimensions and manner of function of the flex poles and do not lay down any rules for the mode of construction. Thus any suitable material may be used for the bending device and for the upright pole. It is essential to have not more than one bending device, placed at the level of the snow surface, as the dynamic behaviour of the flex pole is altered considerably if multiple bending devices are used. In principle, however, there is room for further development.

2 Definition of Terms

A flex pole as defined by these specifications consists of a base shaft, a bending device, and an upright pole (Fig. 1).

2.1 Bending Device

The bending device is the mechanism at the bottom of the pole at the level of the snow surface, which permits the pole to tip over and redress itself. The bending device allows the pole to bend either from a pivot point or over a defined zone.

2.2 Pivot Point

Where the bending device takes the form of a pivot point, the upright pole bends from this point right down to the snow surface (Fig. 2).

2.3 Flexible Zone

In this case, the upright pole bends within a short section so that the bottom of the upright pole remains above the snow surface (Fig. 2).

2.4 Tipping Resistance

The tipping resistance of the flex pole is the force perpendicular to the longitudinal axis of the upright pole required to deflect the upright pole (Fig. 3). It depends mainly on the flexural stiffness of the bending device, and is a decisive factor in the way the flex pole functions.

2.5 Flexural (bending) Stiffness

The flexural stiffness B is the resistance to a bending caused by a force acting perpendicular to the axis of the component in question (e.g. upright pole). The flexural stiffness is required to establish the deformation characteristics and is arrived at as the product of the elastic modulus and the bending moment of inertia.

$$B = EI = E\frac{\left(d_a^4 - d_i^4\right)\pi}{64}\left[kNm^2\right] \qquad \text{(formula 1)}$$

E Modulus of elasticity $\left[kN/m^2\right]$

d_a External diameter of the upright pole [m]

d_i Internal diameter of the upright pole [m]

2.6 Whiplash Effect

The whiplash effect is the result of the very fast acceleration of the upright pole, when the skier collides with it (Fig. 4).
As a result of the force of inertia produced mainly by the mass of the pole, the tip of the pole rebounds shortly after impact. A pronounced rebound with whiplash effect can cause injuries. The whiplash effect is less on a upright pole with a greater flexural stiffness and a low mass. However, a more rigid pole with the same mass will strike the skier harder. The tipping resistance has practically no influence on the whiplash effect.

2.7 Impact Strength

A very important property of the material used for the upright pole is the impact strength. It is the toughness of the material that is measured as it is subjected to a very high rate of load application. With polymer materials it depends on the temperature and in general it decreases as the temperature decreases. Requiring a minimum impact strength ensures that the pole will not snap or splinter when a skier collides with it or when it hits the ground. The impact strength is determined by the amount of energy required to fracture a test piece in an impact test with a striking pendulum.

2.8 Notched Impact Strength

This indicates the toughness of the material against a notching test tool and provides information as to its index of notch sensitivity.

2.9 Proportional Limit

The deformation behaviour of the upright pole is defined by determining the proportional limit in tensile and bending tests. This is the point up to which a material under stress retains its elasticity or linear elastic behaviour, or it is the greatest stress that a material is capable of sustaining without any deviation from the proportionality of stress to strain.

3 Units

Measurements, masses and mechanical values are expressed in this specification in terms of SI-Units.

Quantity	*Unit*
Strength, Proportional Limit	N/mm^2
Modulus of Elasticity	N/mm^2
Notched Impact Strength, Impact Strength	kJ/m^2
Flexural Stiffness	kNm^2

4 Requirements

4.1 General Remarks

The requirements for the mechanical values must be ascertained by means of a statistical analysis. 5 specimens are to be tested each time. From these, the mean $\bar{x}$ and the standard deviation s with (n-1) weighting of each quantity tested have to be calculated (see DIN 53398, part 1). The requirements laid down in the specifications are considered to be satisfied when the 95% confidence limit A of the mean, calculated according to formula 2, is greater or smaller than the value stipulated in the requirements. The 95% confidence limit A of the mean for 5 specimens is

A = $\bar{x} \pm \cdot 1.24 \cdot s$. (formula 2)

Unless otherwise indicated, all requirements for mechanical values must be satisfied within a temperature range of -20°C to +20°C. Furthermore, it must be guaranteed that the material is resistant to ultra-violet light.

4.2 General Requirements

4.2.1 Shape of the Flex Pole

The upright pole must have a uniform diameter and a uniform wall thickness. The maximal bending of the upright pole in the vertical position must not be larger than 1 cm. A protection of the bending device is not permitted. If the bending device turns out to be wider than the upright pole, there must be a progressive conical transition to the upright pole diameter.

4.2.2 Surface of the Upright Pole

The surface of the pole must be uniformly smooth.

4.2.3 Bending Device

The tipping of the upright pole can be achieved either by means of a pivot point or a flex zone. The maximum length of the bending device including the transition to the upright pole diameter is given in point 4.3.5. A flex pole with either pivot point or flex zone must meet the same requirements with respect to tipping resistance and must recover from a deflection of 120° (point 4.6.1). The bending device must be constructed in such a way that the proper functioning of the mechanism is not impaired by adverse weather conditions (snow, icing, low temperatures). All metal parts in the bending device must be made of materials designed to withstand corrosion.

4.2.4 Protection of the Upright Pole

The top of the upright pole must be sealed to ensure snow and rain do not enter the shaft. This must be rounded off and should protect the upright pole when knocked to the ground. The seal must not exceed the diameter of the upright pole. The seal must be light enough so as not to impair the dynamic functioning of the upright pole.
If the length of the bending device is less than recommended in 4.3.5, a gaiter can be fitted up to a height of 30 cm above the snow surface. The surface material of the gaiter must conform to the same standards as the upright pole. The gaiter must not exceed a diameter of 35 mm and must attach to the pole without sharp edges.

4.2.5 Replacement of Parts

It is essential that all connections between base shaft, bending device, and upright pole should be easy to open using standard tools, so that any of these parts can be replaced.

4.2.6 Construction of the Anchorage in the Ground

The safe and lasting anchorage of the pole in the snow base is an important condition for the functional efficiency of the flex pole during a race.

4.3 Requirements for Dimensions and Mass of the Flex Pole

4.3.1	*Length of upright pole above surface of snow*	*min. 1800 mm*
4.3.2	*Diameter of upright pole*	
	Type A (authorised to use in any FIS race)	*29-32 mm*
	Type B (authorised to use in any FIS race except World Cup races)	*25-28,9 mm*
4.3.3	*Thickness of wall of upright pole*	*min. 2 mm*
4.3.4	*Diameter in region of bending device*	*max. 35 mm*
4.3.5	*Length of flex zone including transition*	*max. 300 mm*
4.3.6	*Mass of the upright pole*	
	Type A (authorised to use in any FIS race)	*max. 300 g/m*
	Type B (authorised to use in any FIS race except World Cup races)	*max. 250 g/m*

4.4 Requirements for Basic Material used for Flex Pole

The requirements for the material from which the base shaft and the upright pole are made have been determined on the assumption that the material chosen is fundamentally suitable for the purpose. The pole manufacturer is not expected to carry out tests on the material. Proof that the requirements have been satisfied can be provided by the supplier of the raw material. In the case of materials which have properties depending of the orientation in the material (e.g. fibre-reinforced plastics) due attention must be paid to ensure that the required properties are maintained for the orientation perpendicular as well as parallel to the axis of the upright pole.

In the case of thermoplastics, the following requirements must have been tested previously on specimens taken from the moulding material during the manufacturing process. In the case of fibre-reinforced plastics, the properties can be checked on test-plates made during each manufacturing process. The following minimum requirements must be met:

4.4.1	*Short-term Tensile Strength*	*min. 55 N/mm^2*
4.4.2	*Tensile Modulus of Elasticity*	*min. 1900 N/mm^2*
4.4.3	*Tensile Proportional Limit*	*min. 45 N/mm^2*
4.4.4	*Notched Impact Strength*	
	- at room temperature	*min. 30 kJ/m^2*
	- at -20° C	*min. 12 kJ/m^2*

4.5 Requirements for the Upright Pole (semi-finished product)

The following requirements are valid for the production version of the upright pole and are checked on the pole or parts of the pole.

4.5.1 Proportional Limit in Short-term Bending Test

The proportional limit is tested during the short-term bending test and must measure at least 40 N/mm^2. Slight deviations are permissible in the linear graph of the stress-strain curve if purely elastic behaviour is determined during the removal of the load, that means the stress-strain curve passes through the origin. Keeping below the proportional limit ensures that a pole will bend back perfectly after strong deformation through bending, as happens e.g. when a racer collides with a pole.

4.5.2 Fracture Behaviour of the Upright Pole

A sufficient wall thickness of the upright pole must be provided so that under normal operating conditions no fracture of the pole due to impact from the skier can occur. This requirement must be considered particularly for the tip of the pole. When the pole fractures due to impact, the material of which the pole is made must not splinter or show any brittleness in the required temperature range (ductile fracture behaviour). This is a qualitative test for the impact strength of the upright pole. In order to prevent any danger of injury care must be taken to ensure that the pole only snaps without breaking off completely.

4.5.3 Flexural Stiffness of the Upright Pole

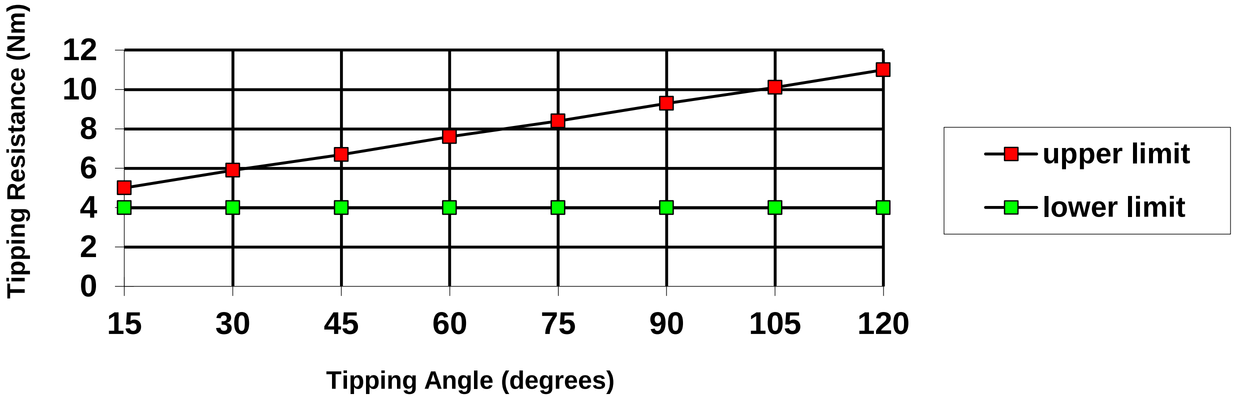
The flexural stiffness of the upright pole is calculated according to formula 1 (point 2.5) as the product of the modulus of elasticity and the bending moment of inertia. The modulus of elasticity must be determined according to point 5.2. The flexural (bending) stiffness of the upright pole must be between:
min. 0,022 kNm^2
max. 0,055 kNm^2.

4.6 Requirements for the Flex Pole System

The following requirements are intended to ensure that the flex pole functions efficiently as a whole.

4.6.1 Tipping Resistance

The tipping resistance is found by using a spring balance applied at 90° to the pole axis at a point 1 m above the centre point of the bending device. The tipping resistance must be at least 4 Nm for tipping angles between 15 and 120 degrees. The upper limit of the tipping resistance is detailed below.



tipping angle (degrees)	upper limit of the tipping resistance (Nm)
15	5,0
30	5,9
45	6,7
60	7,6
75	8,4
90	9,3
105	10,1
120	11,0

4.6.2 Flexural Fatigue Behaviour of the Bending Device

The bending device and the adjoining region of the pole must stand up to 10 000 deflections according to the test described in point. 5.3 without sustaining any visible damage. This requirement can be tested at room temperature on devices made of metallic materials. For those where polymers have been used the tests must be carried out at a temperature of -20°C. The requirements for the tipping resistance as given in point 4.6.1 must be fully satisfied after testing the flexural fatigue behaviour of the bending device.

4.6.3 Standstill of Pole Tip after Tipping

The tip of the pole must not incline more than 2.5 degrees, 15 seconds after tipping through 90 degrees. If it is not possible to keep within this time limit an appropriate mechanism to dampen the vibrations must be built into the bending device. A permanent inclination of max. 2,5 degrees is permissible once the pole is at a standstill.

5. Tests

The section describes the test methods used to check that the requirements in sections 4.4, 4.5 and 4.6 have been satisfied. They are based as far as possible on standardised testing methods. The proposed test methods are ISO-Norms, DIN-Norms and ASTM-Standards.

5.1 Tests for the Requirements of Point 4.4

The flex pole manufacturer is not expected to test these requirements. If test data, established by a third party are taken, these requirements should have been tested previously by the following methods:

Short-term Tensile Strength (4.4.1), Tensile Modulus of Elasticity (4.4.2), and Tensile Proportional Limit (4.4.3)

At least 5 test-pieces must be tested according to ISO 527 (DIN 53455, ASTM D 638).

Notched Impact Strength (4.4.4)

At least 5 test-pieces must be tested according to ISO 179 (DIN 53453, ASTM D 256, Charpy-Test).

5.2 Tests for the Requirements of Point 4.5

Proportional Limit in Short-term Bending Test (4.5.1)

At least 5 test-pieces must be subjected to bending tests following ISO 178 (DIN 53452, ASTM D 790). The test-piece has to be cut out from the upright pole and loaded as described in Fig. 5. The length of the test-piece to be clamped has to be 800 mm.

Flexural Stiffness of the Upright Pole (4.5.3)

A test-piece with a length of 300 mm is taken from the upright pole and tested according to ISO 527 (DIN 53455, ASTM D 638) (tensile test). Instead of the tube shaped test piece a piece shaved from the upright pole can be taken as well. At least 5 pieces must be tested at temperatures of -20°, 0° and 20°C. In order to consider the short-term loading of the pole the loading velocity must be at least 1 mm/s. Upright poles with different stiffness along the pole have to be tested section by section.

5.3 Tests for the Requirements of Point 4.6

Tipping Resistance (4.6.1)

This is measured by a spring balance at a height of 1 m above the centre of the bending device on at least 5 poles, in three different directions at an angle of 120 degrees apart in the horizontal plane. The mean is found for the evaluation from these 15 readings. The spring balance remains perpendicular to the axis of the pole throughout the entire process. Fig. 3 shows the test method.

Flexural Fatigue Behaviour of the Bending Device (4.6.2)

This can be tested by any suitable method. The maximum deflection of the pole section with which the bending device is tested should be + and - 60° out of the vertical, with a positive and a negative swing following each other alternately. Thus, in each case the pole must be subjected to 5000 deflections in each direction. Each time one third of these oscillations can be carried out in three different directions at an angle of 120° apart in the horizontal plane.

Standstill of Pole Tip after Tipping (4.6.3)

The tip of the pole is deflected 90° out of the vertical. The test is evaluated visually using a stop watch.

6. Quality Assurance and Scope of Checks

6.1 Suitability Test

Whenever a new flex pole is developed or if a pole does not have a test certificate, a suitability test must be performed on the product by an authorised testing institution. The results of the test must be recorded on a test certificate, confirming that the requirements prescribed for the suitability test have been satisfied. The test certificate must contain a construction diagram and a material declaration for the upright pole. The document must certify that all the requirements under section 4 have been satisfied. A copy of the test certificate must be submitted to the FIS.

6.2 Tests at Races

At the time of a race, spot-checks may be carried out by the FIS at any time to ensure that the requirements under points 4.2, 4.3 and 4.6.1 are being satisfied.

Fig 1: Flex pole - definitions

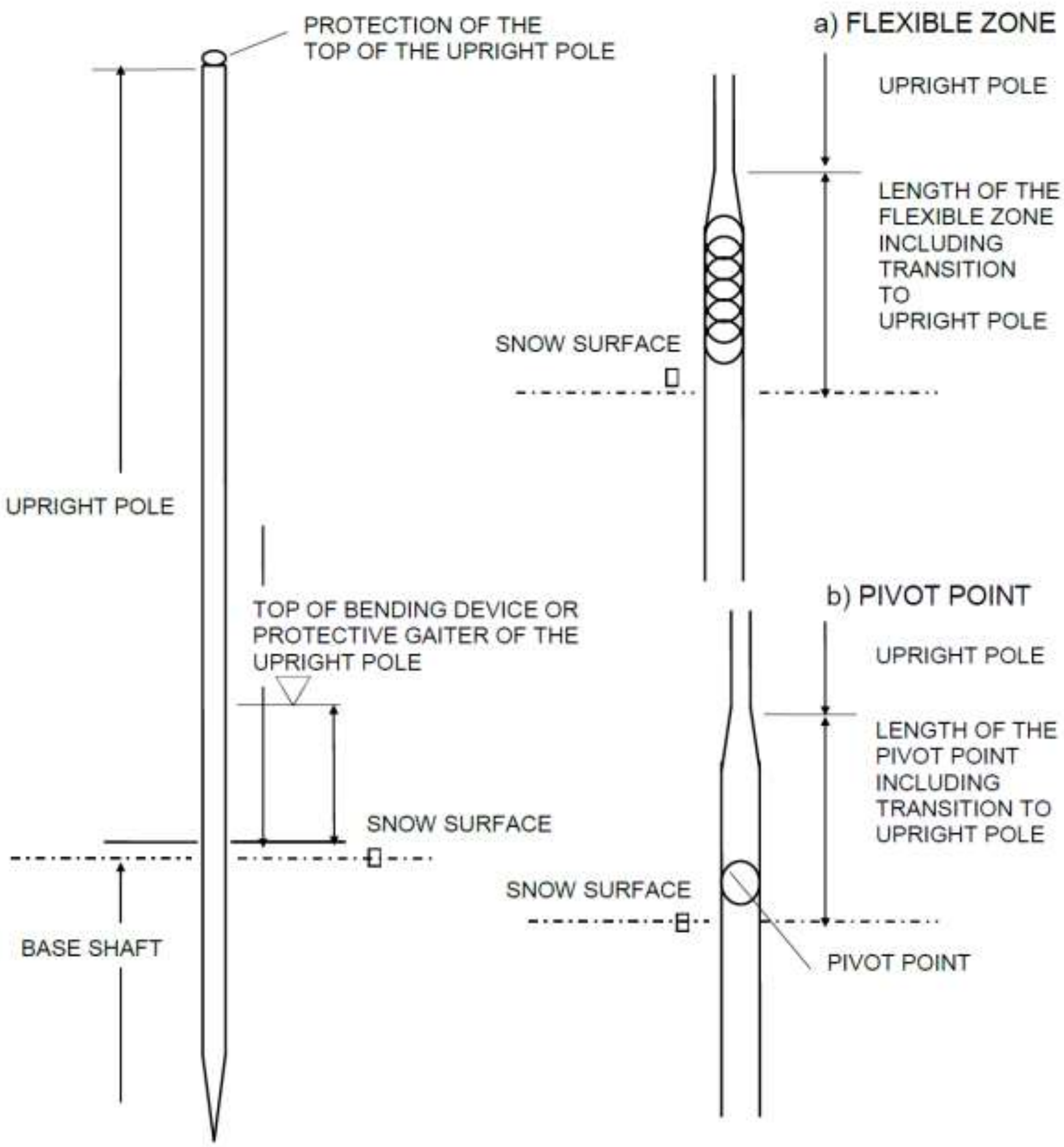


Fig 2: Function of pivot point and flexible zone systems

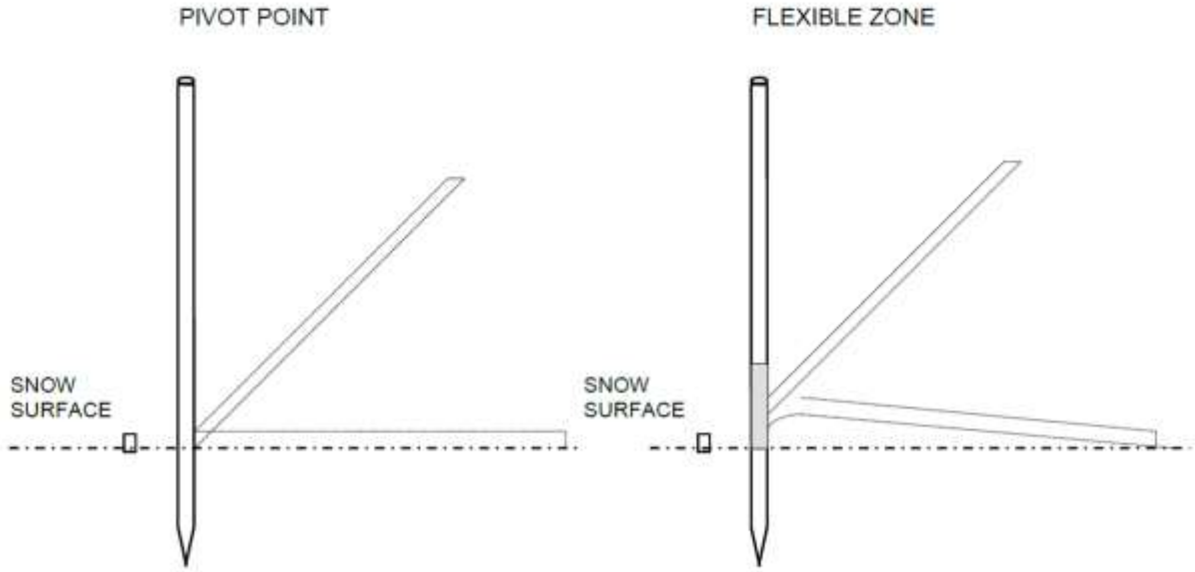


Fig. 3: Definition and testing of tipping resistance

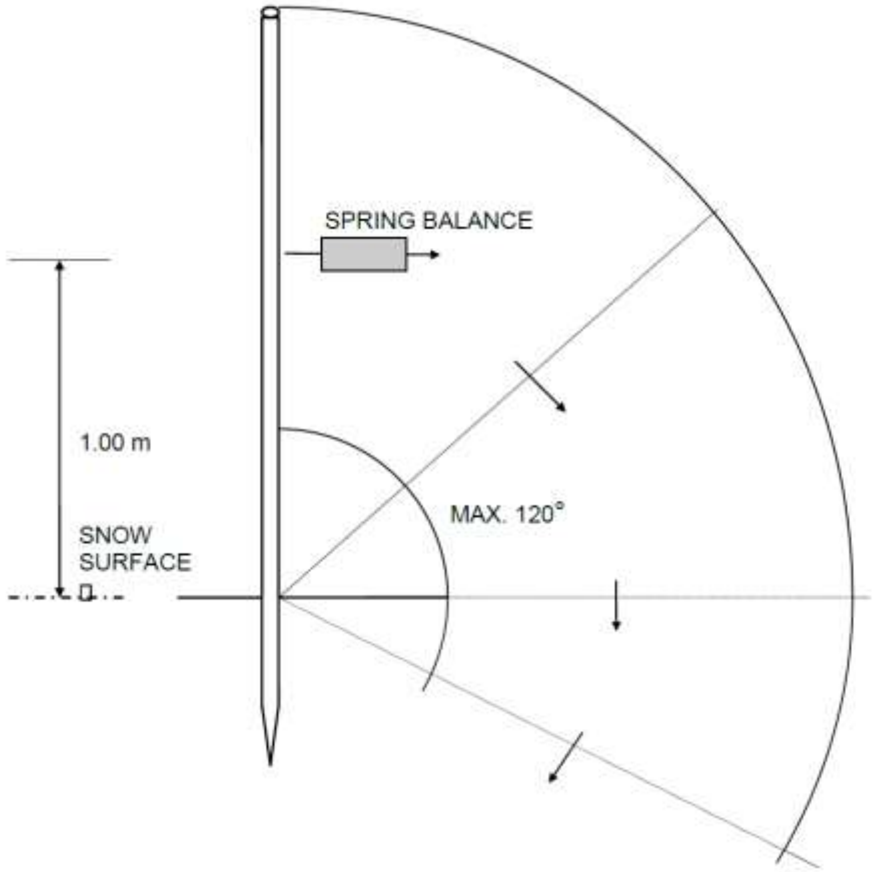


Fig. 4: Definition of whiplash effect

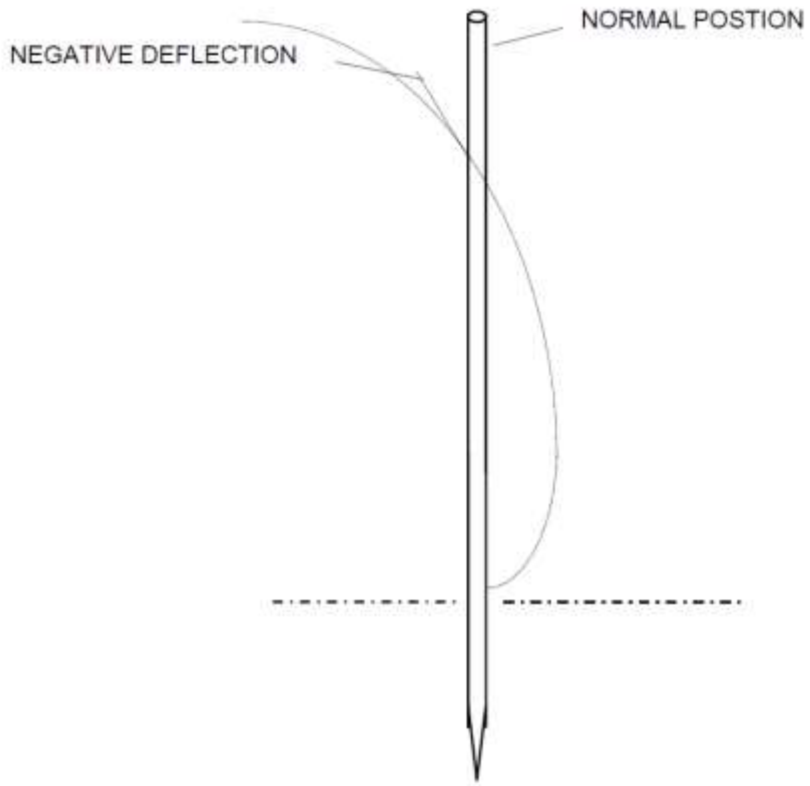


Fig. 5: Fixation for the measurement of the short-term bending test