REPORT OF TESTS CARRIED OUT ON ANCHORS IN THE MARINE ENVIRONMENT

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DE DEPORTES DE MONTAÑA Y ESCALADA

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REPORT OF TESTS CONDUCTED ON ANCHORS IN MARINE ENVIRONMENT

I. REASON FOR THE REPORT

More than a year ago the International Union of Alpinism Associations made clear, in its November 2015 world news release, the serious danger of anchors of the routes near the sea. It was noted that having anchors subjected to stress corrosion cracking (SCC) was the cause of a significant number of anchorage failures at very low load on different climbing routes, and that this type of corrosion is not visible. So they recommended to federations and teams, under a series of implicit recommendations in the document, to take corrective measures.

II. JUSTIFICATION OF THE TEST METHOD

1. Any study performed outside a controlled environment and without standard parameters generates a noise that must be taken into account. If we add to this that it is carried out in places of difficult access, it reduces the range of types of tests and techqniques available to study it.

Therefore, in order to obtain the largest number of test samples and to achieve a global understanding of the resistance and behavior of these anchors over time, and in order to minimize the errors in the test, **it was decided to simulate only the pull test destructive to extraction or flexotracción (see Note)**, that requires the standard EN959:2007, by using pull testing of anchors.

2. **Microscopic analyzes** have also been performed in the laboratory to identify the corrosion that has caused the loss of resistance or degradation of the different materials.

3. Apart from the object of the study, but of a fundamental nature, tests were carried out for the Evaluation of the **chemical composition of different types of anchors (PLX),** in order to assess its composition and evaluate if they can be a potential solution for the different corrosion problems located throughout the study. Finally, the **quality of the welds** of some anchors was studied.

III. AREA AND FIELD OF STUDY

The work used **201 resistance tests** to different types of anchors, both **carbon steel** and **304 stainless steel**, located at a distance of **11 to 0 km** from the coastline, installed for between **10 to 20 years**. A total of 11 schools, 19 sectors and 61 Provinces of Lanzarote, Gran Canaria, Mallorca, Menorca and Cádiz were looked at.

Translators note:
Flexotracción test means a tensile test that does not pull in the same line as the embedded anchor, but due to the anchor design (a hanger for instance) the load is applied off-centre and there is also a moment applied (an example is in the Annex Number 15)
Pull test is a tensile test where the load is completely in line with the embedded anchor (an example is a symmetrical P-type resin bolt, as shown in the Annex, Number 19)

1. MALLORCA

1.1 Climbing schools Visited: Sa Foradada, Banyalbufar, Port del Sòller, Son Xanquete. Cala Figuera tests were within the discarded trials due to the rock being of very poor quality.

1.2 Type of rock: Calizas Margas (type of limestone)

1.3 Closeness to the sea

Maximum Distance	Minimum Distance
3.5km	0.5km

1.4 Summary Tests

Anchor Type	Number tests	Time installed (years)	Average Resistance (kN)	Minimum Resistance (kN)	Maximum Resistance (kN)	Fraction of EN 959 Standard
Hanger + Bolt steel	16	15	18.61	13.5	27.0	93%
Hanger + Bolt Inox 304	14	16	18.34	11.0	24.5	83%
Discarded tests	27	-	-	-	-	-

The discarded tests are due to failure of the anchorage under circumstances not produced by corrosion or because they are Out of the scope of this study, (failure of the resin, failure of the rock, anchors of which there is no minimum sample (Spit anchors: a type of self drilling anchor, galvanic corrosion, improper installation etc.)

1.5 Conclusions

There is a minimum loss of noticeable strength between the 304 stainless steel anchors and the stainless steel anchors carbon. Of the carbon steel only 7% of them have failed below the resistance requirements which sets the standard, while the stainless ones have been much less suitable, producing failure below the requirements of the standard by 17%. In no case have the values obtained been cause for alarm, but **would hardly meet UIAA requirements for a minimum life of 50 years**.

The zones of Mallorca between 1.5 and 7 km of the coast would fit the location Zones 2 and 3 as determined by the UIAA. **Therefore, it is recommended to use duplex or superaustenitic anchors with release of stresses.** It is possible to make use of other types of lower resistance materials, requiring an in depth study of the specific area to be installed.

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2. MENORCA

2.1 Climbing schools Visited: Cavalleria, sector Roquero

2.2 Type of rock: Calizas Margas (type of limestone)

2.3 Closeness to the sea

Maximum Distance	Minimum Distance
0 km	0 km

2.4 Summary of tests

Anchor Type	Number tests	Time installed (years)	Average Resistance (kN)	Minimum Resistance (kN)	Maximum Resistance (kN)	Fraction of EN 959 Standard
Hanger + Bolt steel	3	19	14.0	5.0	19.5	69%
Resin bolt Inox 304	8	19	12.78	3.0	28.0	57%
10mm carbon steel chain	1	19	-	-	31	100%
Discarded tests	6	-	-	-	-	-

The test of the chain was carried out a posterior (afterwards), by means of mechanical traction (tensile test).

The discarded tests are due to failure of the anchorage under circumstances not produced by corrosion or because they are Out of the scope of this study, (failure of the resin, failure of the rock, anchors of which there is no minimum sample (Spit anchors: a type of self drilling anchor, galvanic corrosion, improper installation etc.)

2.5 Conclusions

There is a notable loss of strength in the 304 stainless steel anchors and the dispersion values are considerable within even the same type of track. This is due to the stress corrosion that we have detected in the different analyzes under a microscope. The values obtained have been quite worrying. In principle, there is no imminent risk, since the tests have been carried out in climbs have been retrofitted, but the same type of material and anchor design has been used **must be replaced in a minimum period of 6 years**.

The areas of Menorca situated on the coastline would fall between Zone Type 1 and Zone 2 designated by the UIAA. So it is **recommended to make use of Titanium anchors**. It would need a study of greater depth to determine if the use of materials such as Duplex (PLX) or Superaustenitic with stress release treatment, were suitable.

3. LAS PALMAS DE GRAN CANARIA

3.1 Climbing schools Visited: Moya, Fataga, Cenobio.

3.2 Type of rock: Basalt

3.3 Closeness to sea

Maximum Distance	Minimum Distance
2 km	12 km

3.4 Summary of tests

Anchor Type	Number tests	Time installed (years)	Average Resistance (kN)	Minimum Resistance (kN)	Maximum Resistance (kN)	Fraction of EN 959 Standard
Hanger + Bolt steel	22	16	20.59	15	25	100%
Discarded tests	8	-	-	-	-	-

The discarded tests are due to failure of the anchorage under circumstances not produced by corrosion or because they are Out of the scope of this study, (failure of the resin, failure of the rock, anchors of which there is no minimum sample (Spit anchors: a type of self drilling anchor, galvanic corrosion, improper installation etc.)

3.5 Conclusions

The behavior of carbon steel in installed routes with an average of 16 years, and some of them with more than 20 years, installed to 2km of the coast gave really surprising values. Thanks to the way corrosion that occurs in this type of material, although values close to the requirement requirements which marks the standard, make the diameter and type of material used to date, **remain insufficient to reach a useful life of 50 years**, as recommended by the UIAA.

The zones of Las Palmas of Gran Canaria between 1.5 to 12 km of the coast would comprise, between Zone 2 and 3 as designated by the UIAA. So it is **recommended to use duplex (PLX) or superaustenitic anchors with stress release treatment**. It might be possible to use of other types of lower quality materials, but it needs an in-depth study of the specific area to be installed.

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4. LANZAROTE

4.1 Climbing schools Visited: Moya, Fataga, Cenobio

4.2 Type of rock: Basalt

4.3 Closeness to sea

Maximum Distance	Minimum Distance
0 km	0 km

4.4 Summary of tests

Anchor Type	Number tests	Time installed (years)	Average Resistance (kN)	Minimum Resistance (kN)	Maximum Resistance (kN)	Fraction of EN 959 Standard
Hanger + Bolt Steel	4	12	17.75	17	18.5	100%
Resin bolt - Steel	4	15	23.6	22	25	100%
Hanger + Bolt Inox 304	10	9	4.69	0.2	18	10%
Resin bolt – Inox 304	5	15	13.74	10	20	40%
Discarded tests	7	-	-	-	-	-

The discarded tests are due to failure of the anchorage under circumstances not produced by corrosion or because they are Out of the scope of this study, (failure of the resin, failure of the rock, anchors of which there is no minimum sample (Spit anchors: a type of self drilling anchor, galvanic corrosion, improper installation etc.)

4.5 Conclusions

The behavior of carbon steel has performed much better than steel Stainless 304, due to the different forms of corrosion that affect them. In the different samples of steel Stainless steel 304 in which microscopic analysis has been performed, **stress corrosion cracking (SCC) has been detected**. This is a very worrying factor to which the local climbing community has been alerted.

The areas of Lanzarote situated on the coastline would fall between Zone Type 1 and Zone 2 designated by the UIAA. So it is **recommended to make use of Titanium anchors**. The use of materials such as Duplex (PLX) or Superaustenitic with stress release treatment, would need a study in greater depth of the area to be carried out. Although the information we have is scarce, **we do not know how sulfur chlorides contained in basaltic rocks can react with Titanium**.

5. CADIZ

5.1 Climbing schools Visited: Bolonia

5.2 Type of rock: Arsenica

5.3 Closeness to sea

Maximum Distance	Minimum Distance
7 km	6.5 km

5.4 Summary of tests

Anchor Type	Number tests	Time installed (years)	Average Resistance (kN)	Minimum Resistance (kN)	Maximum Resistance (kN)	Fraction of EN 959 Standard
Hanger + Bolt Steel	8	10	20.5	18	22	100%
Resin bolt – Inox 304	7	12	22	22	22	100%
Discarded tests	14	-	-	-	-	-

The discarded tests are due to failure of the anchorage under circumstances not produced by corrosion or because they are Out of the scope of this study, (failure of the resin, failure of the rock, anchors of which there is no minimum sample (Spit anchors: a type of self drilling anchor, galvanic corrosion, improper installation etc.)

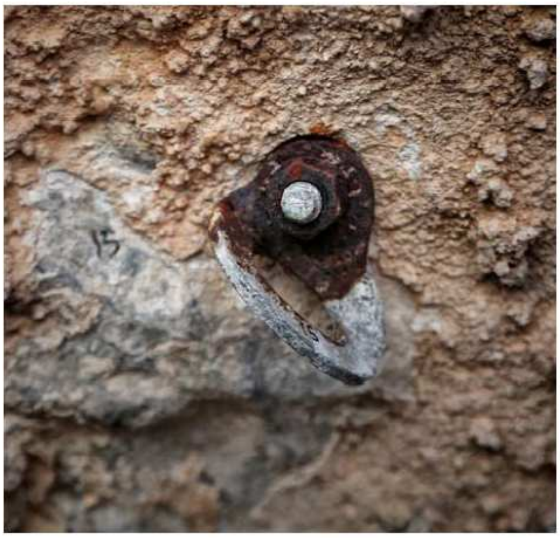
5.5 Conclusions
A complex and particular case can be considered regarding the data obtained, since the limitation of Strength of the rock and the area of protection it contemplates, prevented us from carrying out maximum breaking tests Of the resistance of the anchors, making only maximum loads of 22 kN, well above the mark rule. However, the values obtained from the behavior of stainless steel 304 have been quite satisfactory, as a consequence of their location, the time of installation and the particularity of which is a of the less aggressive rocks of the peninsula. Subsequent and on-the-spot evidenced signs of corrosion, but it is **not recommended to use this type of 304 stainless steel in the future**.

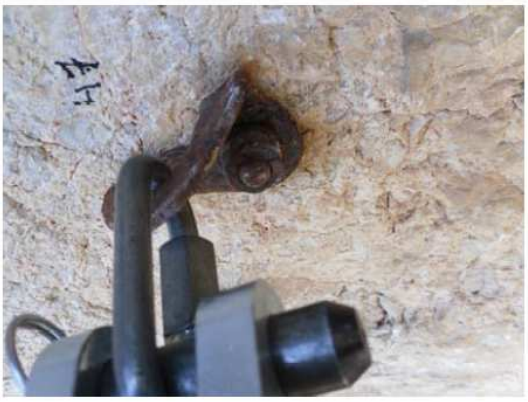
The areas of Bolonia situated 7 km from the sea would fall within the type of Zone 3 as called the UIAA. So it is **recommended to use 316 L stainless steel anchors**.

Annex A

PHOTOGRAPHS OF DIFFERENT SAMPLES OF TESTS BY ZONES

1. MALLORCA





1. Flexotraccion test of number 15: carbon steel, resistance 18.5 kN, rupture failure by the plate.

2. Flexotraccion sample of number 41: carbon steel, resistance 10.5 kN, rupture failure by the plate.

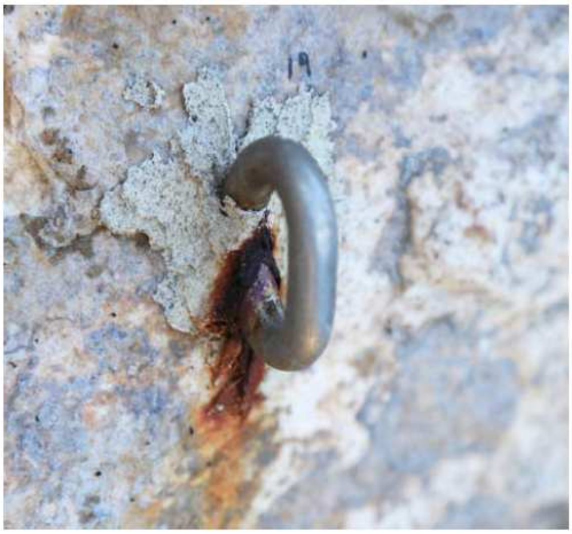
3. Flexotraccion test of number 45: galvanic corrosion, resistance 17 kN, break failure by parabolt.

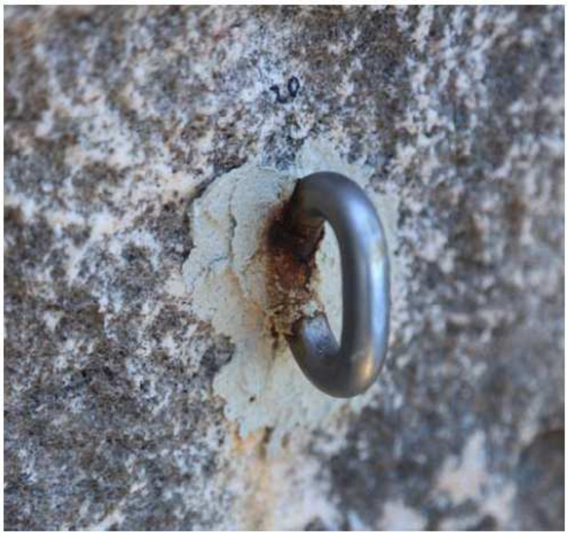
4. Flexotraccion test of numeral 47: carbon steel, resistance 16 kN, breakage failure by parabolt

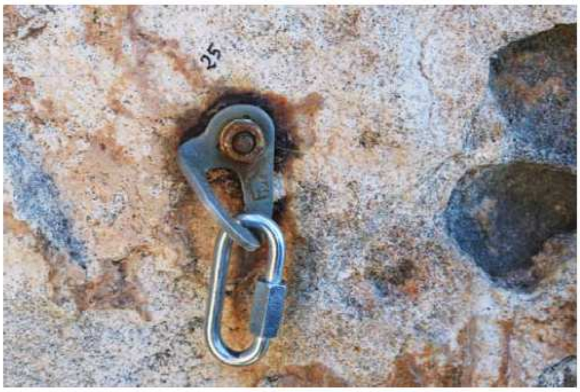
Annex A

PHOTOGRAPHS OF DIFFERENT SAMPLES OF TESTS BY ZONES

2. MENORCA







1. Axial test sample number 19: stainless steel 304, resistance 3 kN, breakage failure by welding.

2. Axial test of sample number 20: stainless steel 304, resistance 24.5 kN complete extraction.

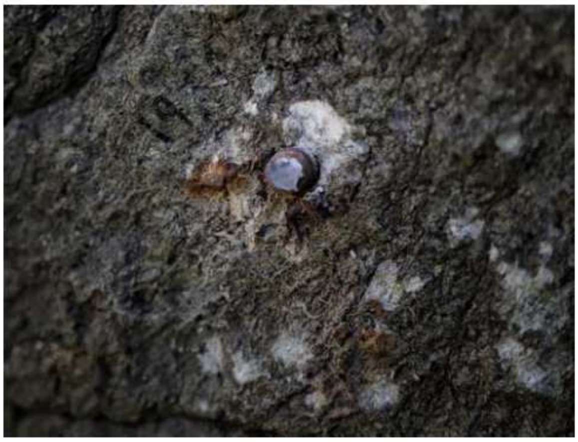
3. Flexotracción test sample number 25: stainless 304, resistance 6 kN, break failure by the parabolt.

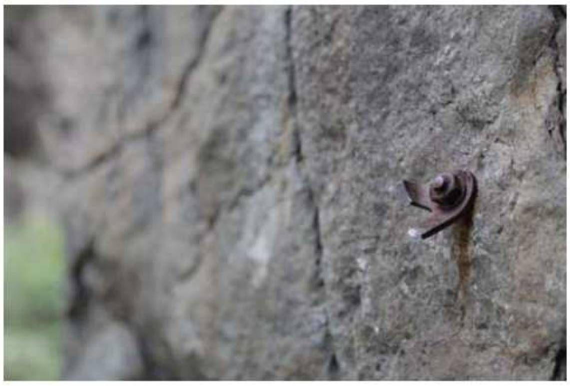
4. Detail image of break of sample number 25.

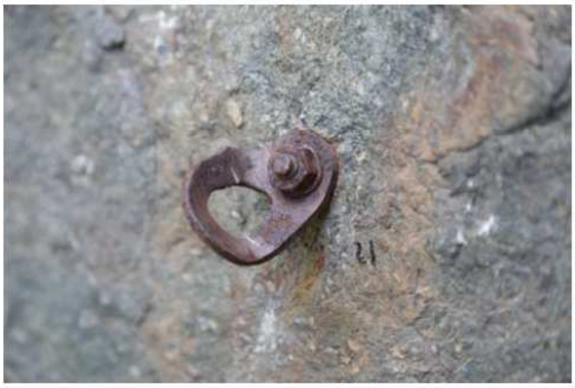
Annex A

PHOTOGRAPHS OF DIFFERENT SAMPLES OF TESTS BY ZONES

3. LAS PALMAS DE GRAN CANARIA







1. Flexotraccion test sample number 19: carbon steel, resistance 20 kN, break failure by parabolt.

2. Detail image of breakage of sample number 19.

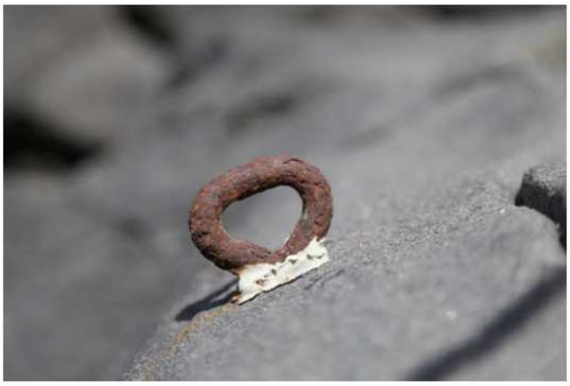
3. Flexotraction test sample number 20: carbon steel, resistance 20.5 kN, rupture failure by the plate.

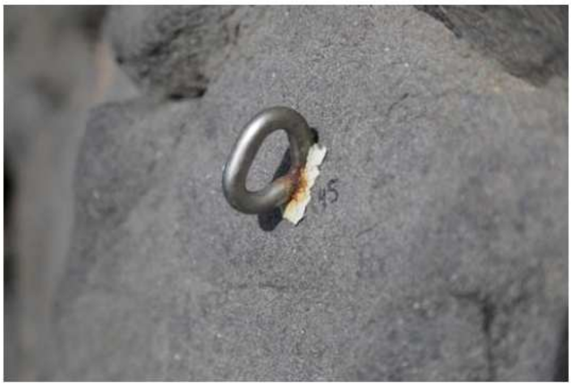
4. Flexotraction test shows number 21: carbon steel, resistance 21 kN, rupture failure by the plate.

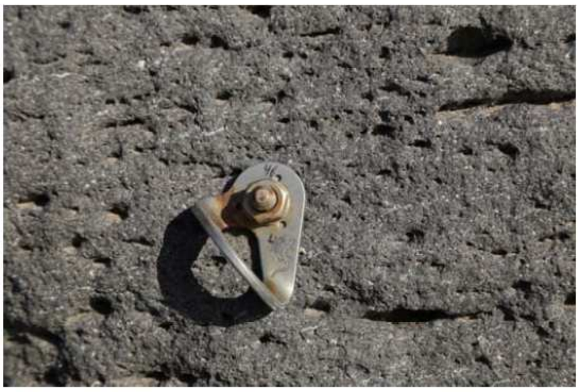
Annex A

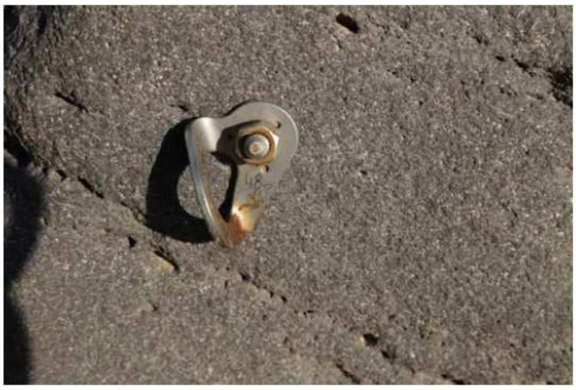
PHOTOGRAPHS OF DIFFERENT SAMPLES OF TESTS BY ZONES

4. LANZAROTE









1. Axial test, sample number 41 carbon steel, resistance 25 kN, complete extraction.

2. Axial test, sample number 45 aceroinox 304, resistance 10 k, breaking side opposite to welding.

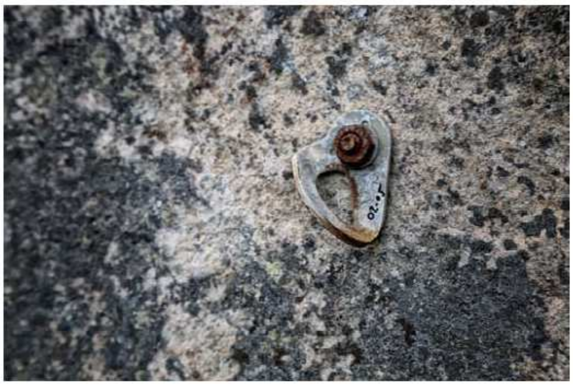
3. Test flexotracción sample number 46 stainless 304, resistance 4 kN, breaking failure by the parabolt.

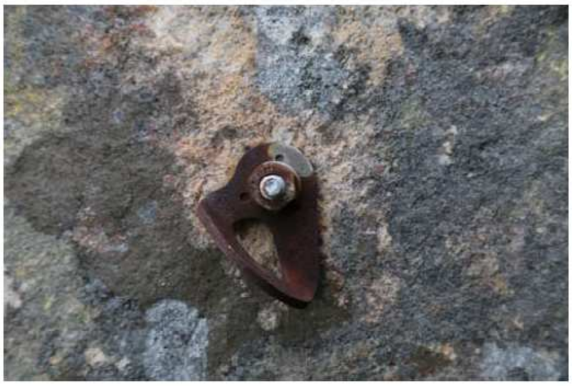
4. Test flexotracción sample number 48 stainless 304, resistance 3.5 kN, breakage failure by the plate.

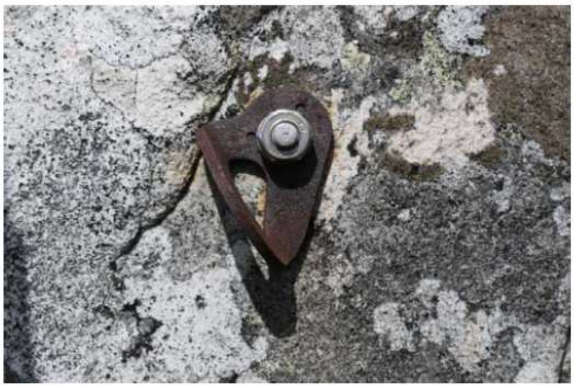
Annex A

PHOTOGRAPHS OF DIFFERENT SAMPLES OF TESTS BY ZONES

5. CADIZ







1. Flexotraction test shows number 2 carbon steel, resistance 19, breaking failure by parabolt.

2. Flexotraction test shows number 5 carbon steel, resistance 20 kN, breaking failure by parabolt.

3. Flexotraction test shows carbon number 7, resistance 22 kN.

4. Flexotraction test shows number 12 carbon steel, resistance 22 kN.

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