EVERYTHING, WHAT LOOKS LIKE A HOLLOW BAR, IS NOT A TITAN HOLLOW BAR,

SUITABLE FOR REINFORCEMENT OF DRILLED AND PRESSURE GROUTED MICROPILES, SOIL NAILS OR ROOF BOLTS.

REQUIREMENTS FOR THE KIT OF LONGLIFE TITAN HOLLOW BARS.

Dipl.-Ing. Ernst F. Ischebeck

1. SCOPE

Hollow bars of ISCHEBECK TITAN are the most copied hollow bars in the world. Chinese say: "You can be happy, that your product is copied; that means acceptance of your product."
Hollow bars for geotechnical applications were developed ab. 25 years ago and created very successful, growing new markets in foundation business. The application of hollow bars for micropiles, soil nails and roof bolts was developed by ISCHEBECK GmbH, Ennepetal, Germany. Some registered patents from 1984 – DE3400182 and DE 3828335 – confirm this origin by ISCHEBECK.
In the meantime in the member countries of European Union (EU) standards for micropiles and soil nails are existing and are mandatory acc. to the "EU Construction Products Directive of 1992".

The most important standards are:

- EN 14199:2005 "Micropiles"
- EN 14490:2010 "Soil Nails"

In Germany since 1983 a National Technical Approval is required for drilled and pressure grouted micropiles. ISCHEBECK GmbH has done a lot of research to get the National Technical Approval Z-34.14-209 "Verpresspfähle TITAN", which contents design, calculation, application and execution of micropiles. The approval includes permanent, independent production control and identification marks on all components like hollow bars, couplers, hex nuts, spacers etc. to avoid mixing of component copies.
In the past technical approvals from Germany have promoted new construction products and their acceptance by consultants, contractors and owners.

e.g. The well known threadbars or GEWI-bar for micropiles, based on a solid, hot rolled bar with deformations, which can be used as continuous threads all over the length, was introduced by the DSI company, Munich, based on a National Technical Approval in Germany, which is still valid and accepted now all over the world.

In USA exist recommendations, design and construction guidelines for micropiles and soil nailing e.g.

- Hollow Bar Soil Nails (HBSN), Publication No. FHWA-CFL/TD-09-001, June 2009
- Hollow Core Soil Nails/State of the Practice-FHWA-SA-97-070, April 2006
- Micropile, Design and Construcion Guidelines, FHWA-SA-97-070, June 2000

In Switzerland SIA 267 "Geotechnical Design" requires for passive anchors ductile, tough

Dipl.-Ing. E. F. Ischebeck, Friedr. Ischebeck GmbH, Loher Straße 31-79, DE 58256 Ennepetal, export@ischebeck.de

steel quality like rebar quality B500B acc. SIA262, table 5. Because for the pricing of hollow bars, the steel quality is most important, a short course is given about the requirements for the steel quality of hollow bars, according to the above mandatory EU standards and USA-recommendations and guidelines. The requirements for the steel quality fortunately are identical in EU and USA.

2. REQUIREMENTS FOR THE KIT OF LONGLIFE TITAN HOLLOW BARS

The EU standards EN 14199:2005 "Micropiles", clause 6.2.1 and
EN 14490:2010 « Soil Nails », clause 6.2.2.2
require:

"Steel quality like rebar quality for reinforced concrete acc. to EN 10080 "Rebar" and 1992-1:2004 (Eurocode EC2) "Design of concrete structures"

In USA is required: "Reinforcing steel shall be deformed bars in accordance with ASTM A 615, AASHTO M 31."

"The carbon equivalency (CE) as defined in AWS D1.1, Section X15.1 shall not exceed 0,45 as demonstrated by mill certificates."

Eurocode EC 2, Table C1 and C2H summarizes the required properties for reinforcement:

① **Yield strength** is limited f_y = 400 to 600 MPa, because of strain compatibility. Strain of cementstone is limited to 0,03. High yield steels e.g. ARCO Termic oilfield tubes ISO 11960 or GEWI PLUS etc. with f_y > 600 MPa are not accepted.

② **Ductility** Characteristic strain at max force $\varepsilon_{uk} \geq 2,5$ or 5 % required.

③ **Bend/Rebend** test for checking ductility on site

④ **Shear bond** with relative rib area. f_R = 0,21 to 0,33 for Titan bars to limit crack width ≤ 0,1 mm

ANNEX C (Normative) **EN 1992-1-1:2004 (E)**

Properties of reinforcement suitable for use with this Eurocode

C.1 General

(1) Table C.1 gives the properties of reinforcement suitable for use with this Eurocode. The properties are valid for temperatures between -40°C and 100°C for the reinforcement in the finished structure. Any bending and welding of reinforcement carried out on site should be further restricted to the temperature range as permitted by EN 13670.

Table C.1: Properties of reinforcement

Product form		Bars and de-coiled rods			Wire Fabrics			Requirement or quantile value (%)
Class		A	B	C	A	B	C	-
Characteristic yield strength f_{yk} or $f_{0,2k}$ (MPa)		**400 to 600**						5,0
Minimum value of $k = (f_t/f_y)_k$		≥1,05	≥1,08	≥1,15 <1,35	≥1,05	≥1,08	≥1,15 <1,35	10,0
Characteristic strain at maximum force, ε_{uk} (%)		**≥2,5**	**≥5,0**	**≥7,5**	≥2,5	≥5,0	≥7,5	10,0
Bendability		Bend/Rebend test			-			
Shear strength		-			0.3 $A f_{yk}$ (A is area of wire)			Minimum
Maximum deviation from nominal mass (individual bar or wire) (%)	Nominal bar size (mm) < 8 > 8	± 6,0 ± 4,5						5,0

Note: The values for the fatigue stress range with an upper limit of βf_{yk} and for the Minimum relative rib area for use in a Country may be found in its National Annex. The recommended values are given in Table C.2N. The value of β for use in a Country may be found in its National Annex. The recommended value is 0,6.

Table C.2N: Properties of reinforcement

Product form		Bars and de-coiled rods			Wire Fabrics			Requirement or quantile value (%)
Class		A	B	C	A	B	C	-
Fatigue stress range (MPa) (for N ≥ 2 x 10[6] cycles) with an upper limit of βf_{yk}		≥150			≥100			10,0
Bond: Minimum relative rib area, $f_{R,min}$	Nominal bar size (mm) 5 - 6 6,5 to 12 > 12	**0,035** **0,040** **0,056**						5,0

Figure 1: Extract from Eurocode (EC) 2 "Design of concrete structures"

Dipl.-Ing. E. F. Ischebeck, Friedr. Ischebeck GmbH, Loher Straße 31-79, DE 58256 Ennepetal, export@ischebeck.de

2.1 Yield strength of reinforcement acc. EC 2

Yield strength f_y is limited to f_y = 400 to 600 MPa., because of strain compatibility between steel and cementstone. Strain of cementstone is limited to 3 ‰ (0,03%). Yield stress $f_y \leq 600$ Mpa means for longlife TITAN Hollow Bars after cold forming the threads, Yield stress $f_y \leq 600$ Mpa is required for the final product.

e.g. ARCO TERMIC heat treated hollow bars with f_y = 950 Mpa ≥ f_y = 600 Mpa don't fulfil the requirement.

Same is with oil field tubes acc. API Specification 5CT, ISO11960, N80,

f_y = 110 Ksi = 770 Mpa ≥ f_y = 600 Mpa, don't fulfil.

GEWI PLUS f_y = 670 N/mm² ≥ f_y = 600N/mm², all these steels are not accepted.

2.2 Ductility

Ductility is divided into 3 classes with A = 2,5 %; B = 5,0 % and C = 7,5 %. Characteristic strain at max force $\varepsilon_{uk} \geq$ 2,5, 5 % or 7,5 % is required.

Longlife TITAN Hollow Bars fulfil all **A** with $\varepsilon_{uk} \geq$ 2,5 %.
All the larger sizes (larger TITAN 40/16) fulfil **B** $\varepsilon_{uk} \geq$ 5 %. (Agt ≥ 5 %)

Ductility means in the stress-strain diagram (Figure 2) for the steel, that after overloading the yield stress there is no further load increase, Ductility means, deformations without breaking, plastic, visible deformation until rupture.

Ductility is required to overcome imperfections (e.g.excentricities) and design calculation following the design-method elastic-plastic and plastic-plastic.

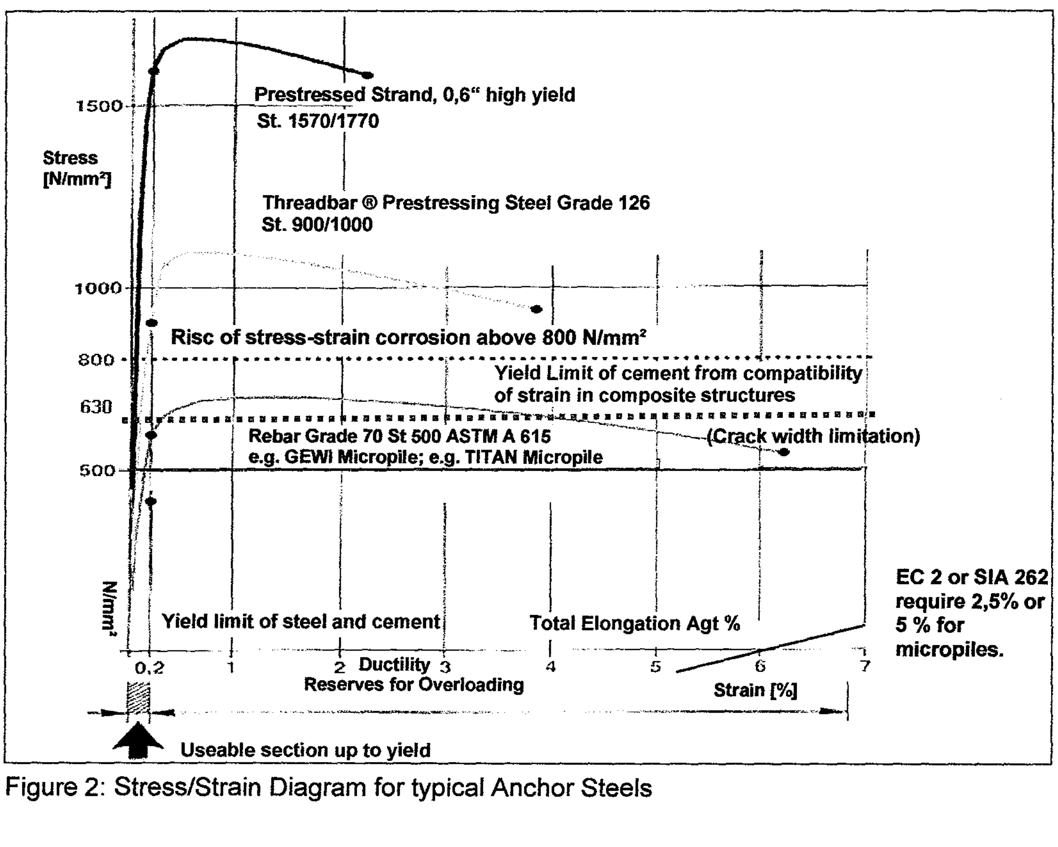


Figure 2: Stress/Strain Diagram for typical Anchor Steels

2.3 Bend / Rebend test for checking sufficient ductility on site

Sufficient ductility of hollow bars can be checked easily on site by a bend / rebend test (Figure 3):
Bending around 180° (U-shape) over a pin diameter D ≥ 6 x diameter of hollow bar e.g. for TITAN 30/11 D = 6 x 30 mm = 180 mm. If there are visible cracks or the hollow bar breaks, there is not enough ductility as required in detail in ASTM A 615. “Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement”.

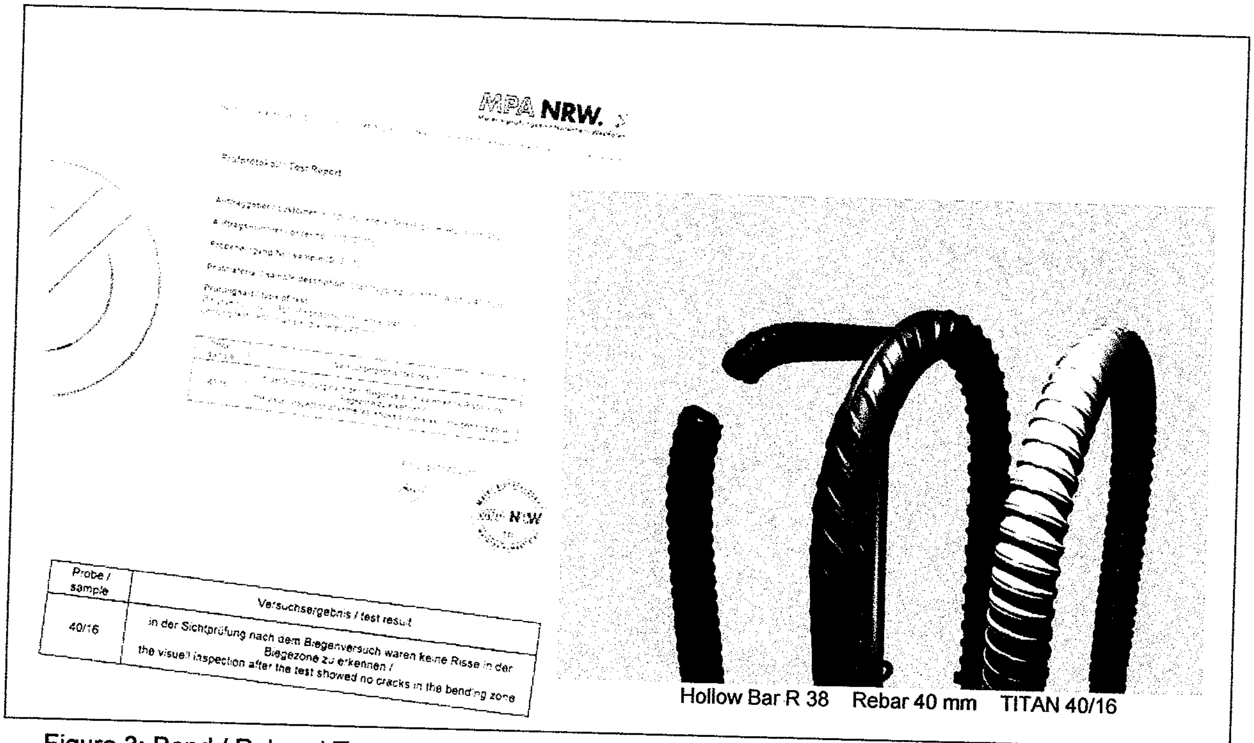
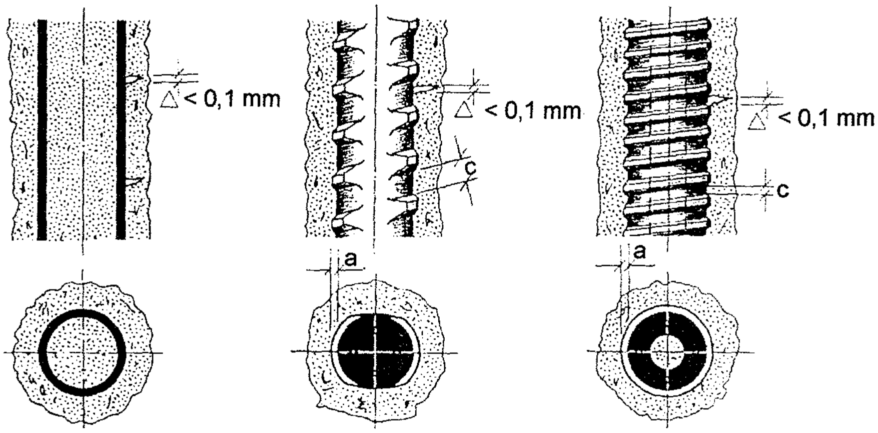


Figure 3: Bend / Rebend Test

2.4 Minimum relative rib area f_R min. > 0,056 for bar size > 12 mm

The min. relative rib area factor f_R is important for the shear bond between hollow bar and cementstone and avoids splitting of the bond, when f_R is $f_R \geq 0,056$. For longlife TITAN Hollow Bars f_R is $f_R = 0,21$ to $0,33 > 0,056$.

Smooth tubes with $f_R \sim 0$ or hollow bars with R-threads (Rope threads from tunnelling acc. ISO 10208 are not accepted (Figure 4).



Smooth Steel Tubes	**Micropile GEWI**	**Micropile TITAN**
relative rib area factor	relative rib area factor	relative rib area factor
	$f_R = 0{,}56 \times \frac{a}{c}$	$f_R = \frac{a}{c}$
$f_R = 0$	$f_R = 0{,}074$	$f_R = 0{,}21 : 0{,}33$
accepted steel stress **75 N/mm²** to avoid splitting and axial cracks	accepted steel stress **230 N/mm²** to avoid splitting of cementstone and axial cracks acc. Z-32.1-2	accepted steel stress **500 N/mm²** to avoid splitting of cementstone and axial cracks acc. Z-34.14-209

Figure 4: Technical Development of Improving Shearbond of Micropiles

2.5 Charpy V-notch test (CVN)

Longlife TITAN Hollow Bars are first used as drilling tool, then as tremie pipe for grouting and finally as load bearing reinforcement for tension or compression loads. Overloading and predamage of hollow bars during the use as drilling tool has to be avoided.

Drill operators know, that drill tools are forged from high yield, tempered, ductile Chrom-Nickel alloy steels to withstand roto-percussion drilling and torques by deviation. Hollow bars from Cr-Ni-alloys would be too expensive and would not fulfil the requirements for rebar.

Dipl.-Ing. E. F. Ischebeck, Friedr. Ischebeck GmbH, Loher Straße 31-79, DE 58256 Ennepetal, export@ischebeck.de

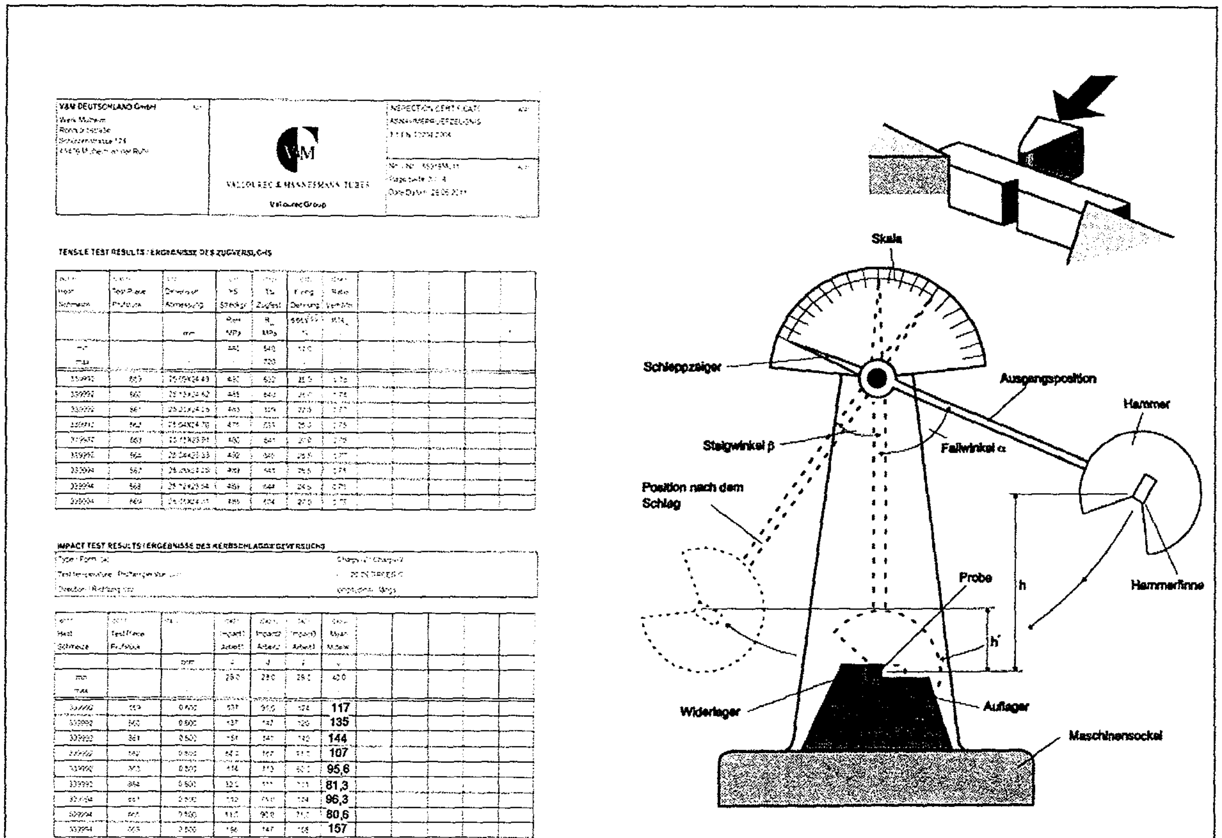


Figure 5: Charpy-Impact Bending Test

IMPACT TEST RESULTS / ERGEBNISSE DES KERBSCHLAGBIEGEVERSUCHS

Type / Form (C40)	Charpy-V / Charpy-V
Test temperature / Prüftemperatur (C03)	- 20 DEGREES C
Direction / Richtung (C02)	longitudinal / längs

(B07.1) Heat Schmelze	(C00.1) Test Piece Prüfstück	(C41)	(C42.1) Impact1 Arbeit1	(C42.1) Impact2 Arbeit2	(C42.1) Impact3 Arbeit3	(C43.3) Mean Mittelw.
		qcm	J	J	J	J
min max		- -	28.0 -	28.0 -	28.0 -	40.0 -
339992	859	0.800	137	91.0	124	**117**
339992	860	0.800	137	147	120	**135**
339992	861	0.800	151	141	140	**144**
339992	862	0.800	64.0	167	91.0	**107**
339992	863	0.800	114	113	60.0	**95,6**
339992	864	0.800	32.0	111	101	**81,3**
339994	867	0.800	110	75.0	104	**96,3**
339994	868	0.800	81.0	90.0	71.0	**80,6**
339994	869	0.800	166	147	158	**157**

Figure 6: Charpy-V Figures of 80 Joule for Longlife TITAN Hollow Bars

In order to avoid over overloading of the longlife TITAN hollow bars during drilling, ISCHEBECK is using since the beginning steel quality of fine-grain structural steel S460 NH according to EN10210 “Seamless Tubes”. This material has the highest available Charpy impact bending resistance with > 80 Joule, measured at – 20 °C. The success of Longlife TITAN Hollow Bars is based on this tough and ductile steel since 25 years (Figure 6).

For comparison, other fine grain structural steels according to EN 10210, e.g. S355, have a Charpy impact bending resistance of only 27 Joule (20 ft lbf) at + 20°C and no resistance at all at – 20°C (- 4°F).

For oilfield tubes acc. ISO 11960 API specification 5CT and for grades H40, J55, K55 and N80 no CVN-Charpy impact bending resistance is guaranteed (Figure 7).

3. PROPERTIES OF OILFIELD TUBES ACC. ISO 11960 – ESPECIALLY GRADES H40, J55, K55, N80 – DON’T FULFIL THE REQUIREMENTS FOR LONGLIFE TITAN HOLLOW BARS.

Oilfield tubes acc. ISO 11960 for transport of oil and gas are the largest application for seamless steel tubes. Especially for the grades H40, J55, and N80 the standard ISO 11960 opens the chance to suppliers to market their de-qualified charges for very low prices.

Specification for Casing and Tubing

API Specification 5CT
Eighth Edition, July 1, 2005

ISO 11960:2004, Petroleum and natural gas industries—Steel pipes for use as casing or tubing for wells

EFFECTIVE DATE: JANUARY 1, 2006

API Specification 5CT / ISO 11960

Table E.6 — Tensile and hardness requirements

Group	Grade	Type	Total Elongation under load %	Yield strength ksi		Tensile strength min.	Hardness[a] max.		Specified wall thickness	Allowable hardness variation[b]
				min.	max.	ksi	HRC	HBW	in	HRC
1	2	3	4	5	6	7	8	9	10	11
1	H40	—	0.5	40	80	60	—	—	—	—
	J55	—	0.5	55	80	75	—	—	—	—
	K55	—	0.5	55	80	95	—	—	—	—
	N80	1	0.5	**80**	**110**	100	—	—	—	—
	N80	Q	0.5	**80**	**110**	100	—	—	—	—

80 Ksi = 560 N/mm²
110 Ksi = 770 N/mm²

7.5 Charpy V-notch test – Absorbed energy requirements for pipe

7.51 Grades H40; J55, K55, and N80 Type 1 There ist no mandatory CVN impact requirement.

Additional requirements for PSL-2 and PSL-3 products are specified in Annex H.

NOTE See A.10 (SR16) for optional CVN impact energy requirements.

7.5.2 Grade M65

The minimum full-size transverse absorbed energy requirement shall be 20 J (15 ft·lb). The minimum full-size longitudinal absorbed energy requirement shall be 41 J (30 ft·lb).

Table E.5 — Chemical composition, mass fraction (%)

Group	Grade	Type	C		Mn		Mo		Cr		Ni	Cu	P	S	Si
			min.	max.	min.	max.	min.	max.	min.	max.	max.	max.	max.	max.	max.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	H40	—	—	—	—	—	—	—	—	—	—	—	0.030	0.030	—
	J55	—	—	—	—	—	—	—	—	—	—	—	0.030	0.030	—
	K55	—	—	—	—	—	—	—	—	—	—	—	0.030	0.030	—
	N80	1	—	—	—	—	—	—	—	—	—	—	**0,030**	**0,030**	—
	N80	Q	—	—	—	—	—	—	—	—	—	—	0.030	0.030	—
2	M65	—	—	—	—	—	—	—	—	—	—	—	0.030	0.030	—
	L80	1	—	0.43[a]	—	1.90	—	—	—	—	0.25	0.35	0.030	0.030	0.45
	L80	9Cr	—	0.15	0.30	0.60	0.90	1.10	8.00	10.0	0.50	0.25	0.020	0.010	1.00
	L80	13Cr	0.15	0.22	0.25	1.00	—	—	12.0	14.0	0.50	0.25	0.020	0.010	1.00
	C90	1	—	0.35	—	1.20	0.25[b]	0.85	—	1.50	0.99	—	0.020	0.010	—
	C90	2	—	0.50	—	1.90	—	NL	—	NL	0.99	—	0.030	0.010	—
	C95	—	—	0.45[c]	—	1.90	—	—	—	—	—	—	0.030	0.030	0.45
	T95	1	—	0.35	—	1.20	0.25[d]	0.85	0.40	1.50	0.99	—	0.020	0.010	—
	T95	2	—	0.50	—	1.90	—	—	—	—	0.99	—	0.030	0.010	—

Figure 7: Extract from ISO 11960 Oilfield Tubes for Grades H40, J55, K55, N80

- The extract of ISO 11960 shows no guaranteed properties for above grades.

- Table E.5 Chemical composition shows a blank field for above grades

- Table E.6 shows very wide range for the yield stress, e.g. for N80 from 80 $_{Ksi}$ to 110 $_{Ksi}$, which is 110 $_{Ksi}$ = 770 Mpa, which is much more than accepted for rebar by EC 2.

- Table E.6, Total elongation under load 0,5 %, which is much less than the required min class A ≥ 2,5 % for rebar acc. EC 2.

- 7.5.1 Grades H40, J55, K55 and N80
  There is no mandatory DVN-Chary Impact requirement. These grades are not accepted for Longlife TITAN Hollow Bars as drill tools.

4. SUMMARY

Longlife Titan Hollow Bars are successful used for foundations e.g. as micropiles, soil nails, raft-shaft foundations etc.

Foundations are extreme expensive to repair. Therefore the existing execution standards:

EN 14199:2005 "Micropiles" and
EN 14490:2010 "Soil Nails"

have to be carefully followed, concerning design, execution and material (steel and cement quality).

Concerning the steel quality for the kit of Longlife TTITAN Hollow Bars is required:

1. Yield stress of the final product between 400 to 600 MPa.
2. Min ductility class A ≥ 2,5 % Agt
3. Bend / Rebend test on site to U-shape
4. Relative rib area factor f_R ≥ 0,056 for best shearbond
5. Charpy V-notch test (CVN) with ab. 80 Joule for – 20 °C to have enough toughness for drilling operation.

CHECKLIST

Kit for Longlife TITAN Hollow Bars.

To be able to compare offers for hollow bars, concerning price and mandatory required technical datas, it is necessary to ask the supplier and compare prices and technical datas acc. to following checklist:

1. Yield load Fy of finished hollow bar
2. Ultimate load Fu of finished hollow bar
3. Elongation (ductility) Agt up to ultimate without reduction in cross-section of finished hollow bar
4. Cross section, calculated by the weight per m of the hollow bar
5. Mill certificate for the steel tube, delivered by steel mill
6. Manufacturing standard of steel tube
7. Deformations (ribs) to increase shear bond, according to which standard
8. Test for ultimate load Fu of 2 coupled hollow bars
9. Charpy impact bending resistance in Joule for the steel tube
10. Guaranteed technical datas based on
    - Test reports from independent laboratories
    - Permanent tests of production control
    - Quality management system ISO 9001
11. Permanent visible identification of all hollow bar components for product liability reasons
12. Prices for steel tubes
    - Low carbon steels (0,2 % C; 1,5 % Mn) with not sufficient ductility Agt after cold forming actually are ab. ./. 20 % cheaper than TITAN hollow bars
    - Oilfield tubes acc. to ISO 11960 with high carbon steel ab. 0,4 % C are actually ab. ./. 40 % to 60 % cheaper than TITAN hollow bars.

Dipl.-Ing. E. F. Ischebeck, Friedr. Ischebeck GmbH, Loher Straße 31-79, DE 58256 Ennepetal, export@ischebeck.de