WIRE MESH IN EUROPE

HISTORY – QUALITY – PRODUCTION – APPLICATION

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SUMMARY

During the last 25 years a long and lively discussion has been going on in Europe concerning the ductility of reinforced concrete members and the necessary quality of reinforcing steel to guarantee a ductile and durable behaviour of reinforced concrete structures.

Even though this discussion is partially open, particularly with regard to seismic behaviour, for most of the reinforced concrete structures there are two ductility classes for which the "normal" reinforcing steel quality of hot rolled rebars and cold rolled wire mesh are sufficient to fulfil the requirements of the design codes.

A summary of these figures – beginning with the history until the application of today – is shown in this paper with the main focus on wire mesh.

HISTORY

After the first ideas of net-like laying of reinforcing steel since the beginning of the 20^{th} century the first "wire mesh" was produced in Germany in 1929 by "Baustahlgewebe", a company and trademark, whose industrial property belongs to the steel producing group of Badische Stahlwerke GmbH, Kehl, Germany.

The first technical approval in Germany followed in 1932. The wires at that time had a smooth surface (without ribs or any other profile) and were produced from steel out of blast furnaces and already spot welded. The quality was comparable to the wire mesh of today with yield strength of 550 MPa and tensile strength of 650 MPa. Ductile values like ratio or elongation were not required at that time and we therefore do not have any values. The range of diameters was from 2,0 mm up to 12 mm. After World War II, when Germany was vastly destructed, in the middle of the 20^{th} century (1950) rebuilding of the infrastructure and a triumphal procession of the wire mesh started. A technical improvement accompanied this procession with regard to the surface of the wires – profiled and/or ribbed – and a ductility definition of ratio R_m/R_e and a certain elongation after fracture.

Meanwhile the wire mesh was also introduced in other European countries. The share of wire mesh in the total reinforcement of European countries rose and reached its peak in the middle of the decade between 1990 and 2000 with values between 10 % (Spain) and 50 % (Germany) of the total reinforcement, the average value was about 30 %. In total figures about 5 million tons of wire mesh out of 16 million tons of total reinforcement were used within Europe.

Today the share of wire mesh is slowly decreasing (in Germany the value is about 30 %) due to the cheap blue-collar workers (semi-skilled) coming from Eastern Europe (e.g. Poland, Romania, Bulgaria, Ukraine) to Central and Western Europe and laying the reinforcing bars cheaper than the lightly more expensive wire mesh. But nevertheless, the wire mesh in Europe sustains its position particularly with regard to housing and large 2-dimensional flat concrete structures like floors and walls and badly approachable areas like the crown / calotte of tunnels (very important in the modern infrastructure).

Ductility of reinforced concrete structures

After a long lasting time of dispute and discussion during the development of the EUROCODE 2 with all different arguments of each country concerning the possible and necessary ductility of concrete structures with regard to the different qualities of reinforcing steel, the then existing CEB – comite euro-international du beton, Lausanne – published the available research results of the members from different European countries (e.g. Netherlands, Italy, Germany, Spain, UK) in the “Bulletin D’Information No 218” /5/ which formed the basis for a discussion during a meeting in Les Diablerets, Switzerland, in 1993. The results run into the EC2, 1994 /1/ and are now the background of the three defined ductility classes A, B and C. All the research work was carried out by universities; we as a reinforcement producer were involved as far as we defined our opportunity to produce different steel qualities in terms of ductility. The results (3 ductility classes) in EC2 are now compulsory in the European countries.

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

Figure 1: Properties of reinforcement – Eurocode 2

For the designers there are different possibilities for structural analysis. The importance for wire mesh is the linear analysis with limited redistribution of bending moments. Up to a moment redistribution of 20 % (in Germany 15 %) ductility class A (wire mesh, cold rolled) is possible, in any other cases class B and/or C must be used. This regulation was the result of the above mentioned research work. And the definition of the ductility values of class A ($R_m/R_e \geq 1{,}05$, $A_{gt} \geq 2{,}5$ %) means for wire mesh producers (cold rolled wire) a certain effort which was not necessary before.

The moment redistribution ΔM possibility makes sense in heavy reinforced concrete structures like beams: if there is a lot of reinforcement in the beam-section above a column, you can e.g. badly fill in the concrete. There is the possibility to reduce this reinforcement by moment redistribution and relocate the reinforcement in the midspan, in which you have more space. In floors and walls, where wire mesh is mostly used, this situation is rarely given. Otherwise the possibility to redistribute bending moments is limited: in many cases you cannot redistribute the moments up to a limit of 15 % or 20 %. Therefore this ΔM-limit is very often no barrier for a wire mesh (cold rolled) application. In Germany we introduced this boarder in DIN 1045 /3/ in 2005: since then no situation/case is known where this value has been a problem: In our opinion it is a (mostly) theoretical value based on the scientific research, which is not standard in the daily use. Nevertheless, if it is required, you can use wire meshes with hot rolled wires: with this system you can produce ductility class B (see chapter “production”).

Annotation: Ductility class C (seismic) and wire mesh

Although it is possible according EC2, Appendix C, to design a wire mesh with ductility class C-steel (and also a production with class C-steel would be possible) an application does not make sense in our opinion: for seismic behaviour a large elongation of the steel is necessary due to the great deformation of seismic load. This elongation is prevented in a wire mesh because of the spot welded transverse wire in a certain distance: this cross wire prevents a greater deformation and an earlier break of the wire than in a bar without cross welded wire occurs. The necessary elongation cannot be activated.

Moreover, for seismic behaviour the beams and columns (H-beams) in a construction are the main members to dissipate seismic loads. Walls and floors are mostly stiffening elements.

QUALITY AND PRODUCTION

Cold rolled wire mesh (ductility class A)

Until 2005 the performance characteristics and the ductility requirement for cold rolled wires had been:

- Re = 500 MPa
- R_m/R_e = 1,03 when R_e > 550 MPa
- A_{10} = 8 % (elongation after break)

These values had been generally accepted in the European countries. No ductility class had been defined, no difference in structural analysis (moment redistribution) had existed. Bars and meshes had been applied in the same way.

With defining ductility classes – class A for wire mesh, cold rolled – the values changed:

- $R_m/R_e \geq 1,05$
- $A_{gt} \geq 2,5$ % (elongation at maximum load)

This change forced the producers to “higher” values, particularly for the ration R_m/R_e. The consequences for mesh producer were different: there must be a redefining of

- wire rod (chemistry, dimensions)
- rib geometry

Especially wire rod produced out of scrap requires a restriction of elements (micro elements) and a reduction of diameter: e.g. mesh wire 6 mm is cold rolled from wire rod diameter 6,3 mm in order to reduce the cross area reduction (6,3 → 6,0 = 10 % cross area reduction!)

An area reduction of more than 15 % would be problematic by reaching especially the ratio R_m/R_e. For fulfilling the requirements of the designers after EC2, ductility class A, this value is very important and the most critical one, whereas for the production process compliance with the value of elongation at maximum load A_{gt} is not a problem.

In the German standard DIN 488 /4/ the diameters ≤ 5,5 mm are not allowed for application in structural concrete members according to the design standard DIN 1045 /3/: when wire rod diameter 5,5 mm, without a special definition of chemistry, is cold rolled down to 5,0 mm it is not possible to ensure class A requirements especially concerning the ratio R_m/R_e. This would only be possible with special wire rod which is not commonly available and more expensive than “normal” wire rod for producing wire mesh ductility class A.

Another important aspect is the design of the rib pattern. Not only the relative rib area, as defined in EN 10080 /2/, but also the radius of the rib flank inclination (≥ 45 °) to the core of the wire is designed as smooth as possible: the ratio R_m/R_e is controlled very positively by this value. It must not be sharp but designed by a certain radius in order that the rupture in tensile test does not occur in this intersection. These rules generally apply for wire of ductility class B.

Wire mesh ductility class B

If wire mesh should replace reinforcement, e.g. bars with ductility class B (high ductility), the mesh must be produced with hot rolled and ribbed bars. These bars usually cover the requirements of ductility class B:

- $R_m/R_e \geq 1{,}08$
- $A_{gt} \geq 5$ %

In particular the adjustment of the welding process must be tuned to the other chemistry of these bars / wire having normally a higher content of carbon and manganese.

APPLICATION

All European countries using wire mesh have a certain system of standard meshes:

- length
- width
- diameters
- spacing

All these figures vary from country to country but they all consider the design standards which are almost the same as in the EC 2.

In addition to the standard meshes very often scheduled meshes are used: In this case the dimension (length, width, spacing) can vary in certain limits:

- length up to 14 m and width up to 3 m (or more) (depending on terms of transport)
- diameter up to 16 mm (cold rolled wire) and up to 25 mm (hot rolled bar) (spacing according to design code from 50 mm up to 350 mm (or more))

Below you will see the German standard mesh programme:

Mattentyp	Querschnitte längs cm² / m	Querschnitte quer cm² / m	Länge / Breite m	Gewicht je Matte / je m² kg	Mattenaufbau in Längsrichtung und Querrichtung: Stababstände mm	Stabdurchmesser Innenbereich mm	Stabdurchmesser Randbereich mm	Anzahl der Längsrandstäbe (Randeinsparung) links	rechts	Überstände Anfang / Ende links / rechts mm
Q188A	1,88	1,88		41,7 3,02	150 150	6,0 6,0				75 25
Q257A	2,57	2,57		56,8 4,12	150 150	7,0 7,0				75 25
Q335A	3,35	3,35	6,00 2,30	74,3 5,38	150 150	8,0 8,0				75 25
Q424A	4,24	4,24		84,4 6,12	150 150	9,0 9,0	7,0	4	4	75 25
Q524A	5,24	5,24		100,9 7,31	150 150	10,0 10,0	7,0	4	4	75 25
Q636A	6,36	6,28	6,00 2,35	132,0 9,36	100 125	9,0 10,0	7,0	4	4	62,5 25
R188A	1,88	1,13		33,6 2,43	150 250	6,0 6,0				125 25
R257A	2,57	1,13		41,2 2,99	150 250	7,0 6,0				125 25
R335A	3,35	1,13	6,00 2,30	50,2 3,64	150 250	8,0 6,0				125 25
R424A	4,24	2,01		67,2 4,87	150 250	9,0 8,0	8,0	2	2	125 25
R524A	5,24	2,01		75,7 5,49	150 250	10,0 8,0	8,0	2	2	125 25

Figure 2: German standard mesh programme

A special design of scheduled mesh is often used: the “mesh” with only longitudinal wires held together with spot welded cross wires, spacing 0,80 m – 1,00 m in order to fix the longitudinal wires. This mesh e.g. is called “one axis mesh” in Germany. For the reinforcing of e.g. a floor you need two types of such meshes: one mesh in x-direction and the other mesh in y-direction. You can also see this form of mesh as “welded” or “assembled” bars. In Germany more than 50 % of the scheduled meshes are designed and produced according to this system.

Durability of concrete structures

Beside the requirements of serviceability, strength and stability throughout the defined design working life of reinforced concrete construction, the concrete cover of the reinforcement is a very important construction detail. The environmental conditions – chemical and physical conditions to which the structure is exposed – are the main input for defining the concrete cover. The normal reinforcing steel – bar or wire mesh – is low carbon steel, not stainless steel. Therefore the behaviour against corrosion due to carbonation and/or chloride and chemical attack depends on thickness, density and quality of the concrete cover. Due to a lot of defects of reinforced concrete constructions, since 1980 the German design code has redefined twice the thickness of the concrete cover to higher values. These values are also given in the EUROCODE EC 2 /1/. Depending of the exposure classes the thickness of the concrete covers ranges from (10) 15 mm up to 65 mm. Also the quality of the concrete is important: this value is defined by the concrete class (strength class).

The two extreme conditions and the respective concrete cover are:

XC1 = dry or permanently wet (inside buildings with low air humidity or permanently submerged in water) concrete cover 20 mm

XD3/XS3 = bridges, pavements, park slabs exposed to containing chlorides or marine structures concrete cover up to 65 mm (and more if necessary)

These values are the basis for buildings with a design life of 50 years. If other periods of designed lifetime are requested, higher values of concrete cover or a special treatment must be defined.

In all cases thickness and density of the concrete cover are the basis for a durable reinforced concrete construction. This will become more and more important by a higher impact of CO_2 and other chemical elements (sulphate) in the air.

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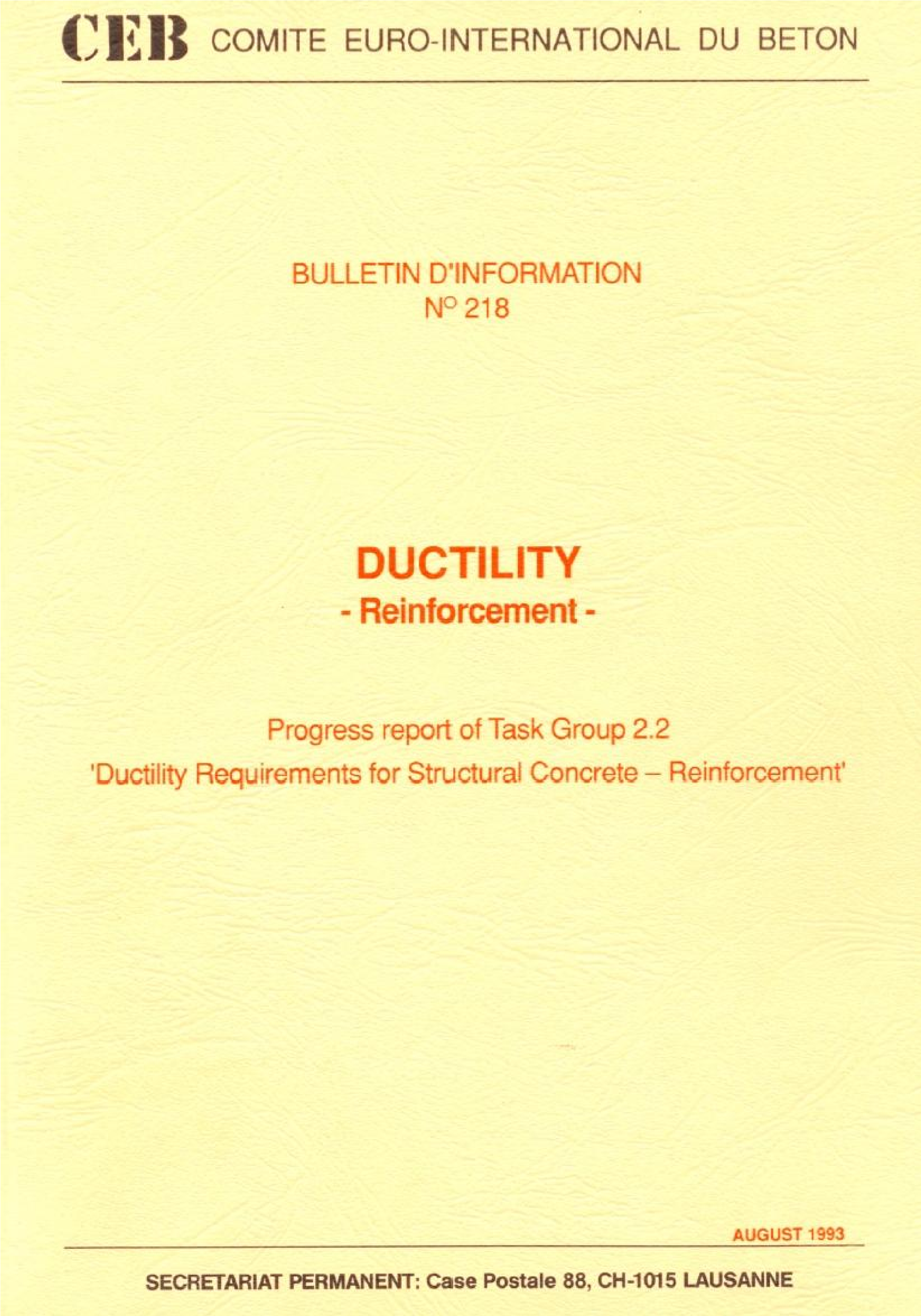
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