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Influence of Steel Bars on Structural Behaviour of Reinforced Concrete

Influence des barres d'armature sur le comportement du béton structural

Einfluss neuer Bewehrungsstähle auf das Tragwerksverhalten

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1. INTRODUCTION

Due to the evolution of manufacturing processes, reinforcing steel bars possessing new mechanical characteristics, different from those of traditional ones, are now available on the market. Therefore Model Code 90 and Eurocode 2 take into account two classes of ductility, related to characteristic elongation at maximum load, and characteristic tensile strength to yield stress ratio (class A with $\varepsilon_{uk} \geq 5\%$, $(f_t/f_y)_k \geq 1.08$ and class B with $\varepsilon_{uk} \geq 2.5\%$, $(f_t/f_y)_k \geq 1.05$).

The different ductility characteristics, greatly affect the structural behaviour in the plastic range.

2. TESTS ON STEEL BARS.

Experimental tests have been carried out by strain controlled procedure on two types of high bond bars with 12mm diameter:

- -hot rolled bars, which can be classified as class A (30 specimens);
- -cold rolled bars, which can be classified as class B (50 specimens).

	Steel class A			Steel class B		
Measured charact.	Mean value	Stand dev.	Char. value	Mean value	Stand dev.	Char. value
f_y(N/mm^2)	587	24.14	540	596	6.22	583
f_t(N/mm^2)	672	19.94	633	641	4.12	633
f_t/f_y	1.150	0.021	1.108	1.076	0.008	1.061
A_5 (%)	17.85	1.58	14.74	15.10	1.08	12.97
A_{10} (%)	12.58	1.27	10.08	10.03	0.91	8.24
ε_u(a)(%)	7.00	0.98	5.06	4.18	0.76	2.68
ε_u(b)(%)	6.29	0.81	4.69	4.47	0.85	2.80
ε_u(c)(%)	7.66	1.21	5.27	5.28	1.09	3.13

Table 1 Characteristics of steels

The determination of ε_u has been performed in three ways:
(a) by means of extensometer;
(b) by measuring the deformation after failure outside the necking zone and away from the grips (adding the elastic deformation f_t/E);
(c) by measuring the deformation after failure of a 5 diameter (A_5) and a 10 diameter (A_{10}) base, including the necking zone, as follows:

$$\varepsilon_u = 2A_{10} - A_5 + f_t/E.$$

3. TESTS ON REINFORCED CONCRETE BEAMS.

Plastic rotation capacity of the beams was taken as a parameter to evaluate the influence of steel type. Midspan deflection controlled tests were carried out on 28 simply supported r.c. beams with various steel percentages, loaded by one load applied at midspan or by three symmetrical loads (Fig. 1). Beam depth was 400mm for 13 specimens and 600mm for 15 specimens; depth to width ratio was two whereas the span was 4000mm and 6000mm, respectively.

Plastic rotation, Θ_p, is obtained by integration, along the plastic zone, l_p, of the difference between mean curvature $1/r_m$ and that obtained at the yield limit of steel, $1/r_{my}$, according to:

$$\Theta_p = \int_{l_p} (1/r_m - 1/r_{my})\, dz$$

Bending moment versus plastic rotation curves, referred to the beams with 600mm of depth, are plotted in Fig. 2. Total plastic rotations, evaluated at 90% of the maximum bending moment in the descending branch of the moment-rotation diagram, are reported in Fig. 3 versus the x/d ratio, x being the compressive depth calculated at ultimate limit state assuming the design values for materials and d being the effective depth.

The existence of two branches, theoretically given, was confirmed by the tests performed so far. These branches, qualitatively shown in Fig. 3, depend on steel class, beam depth and form of bending moment diagram.

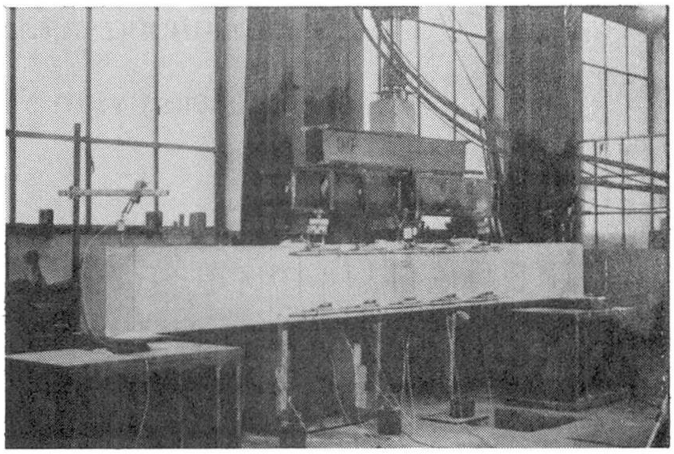

Fig. 1 Testing apparatus for three symmetrical loads

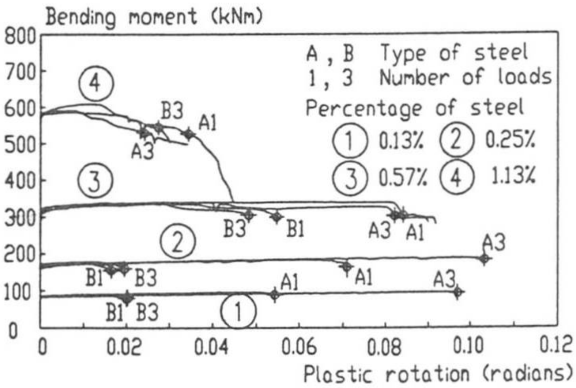

Fig. 2 Bending moment versus plastic rotation, varying the steel percentage, for beams with depth of 600mm

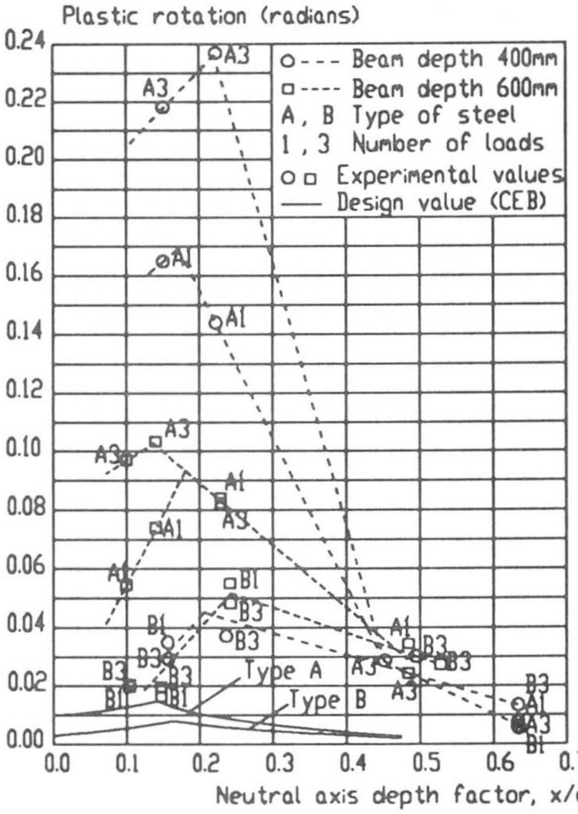

Fig. 3 Total rotation versus x/d ratio

4. CONCLUSIONS

Compared to the traditional reinforcing steel bars the $(f_t/f_y)_k$ value requested by European Codes seems significantly reduced. As a consequence a reduced structural ductility can be observed, in particular when low percentages of class B steel are used. This behaviour may be significantly unfavorable in presence of imposed deformations (e.g. settlement of supports) and can reduce the possibilities of load effect redistribution.