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MATERIALE, ELEMENTE ŞI STRUCTURI COMPOZITE PENTRU CONSTRUCŢII

PREZENT ŞI PERSPECTIVE

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Aspects regard reinforcement optimization in reinforced concrete elements

Aspecte privind optimizarea armăturilor în elementele din beton armat

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ABSTRACT

Under tensile stresses the plain concrete, an artificial hard and brittle conglomerate, with mechanical properties similar to nature stone, behaves inadequately. This is manifest, especially by its reduced strengths and ultimate strains. In exceeding them, concrete develops cracks, being no longer able to sustain loads.

In order to make up for the above mentioned drawbacks, it was necessary to associate concrete with reinforcements, especially under the form of steel bars. The assembly concrete-steel, know as reinforced concrete, is a composite material, having higher characteristics than plain concrete. It is made up following the principle that compressive stresses be taken by the concrete and tensile stress by the steel reinforcement.

Along a member, the reinforcements are placed in such a way as to follow the directions of the unit tensile stresses, produced by the action of diferent types and combinations of loads. Mastering the reinforcing technology assumes a good knowledge of concrete stress distribution and of the influence that reinforcing variants may exert on the strength and cracking capacity of the members.

1. GENERAL CONSIDERATIONS

Under tensile stresses the plain concrete, an artificial hard and brittle conglomerate, with mechanical proprietiers similsr to natural stone, behaves inadequately. This is manifest, especially by its reduced strenghths and ultimate trains. In exceeding them, concrete develops cracks,being no longer able to sustain loads.

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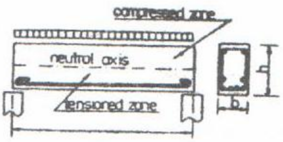

Fig. 1. — Reinforced concrete beam supported at extremities.

Beams are structural members subject to bending, characterized by the existence of a tensioned and a compression area separated by a neutral area. The reinforcing of the tensioned area, within a certain section, implies to solving of two problems: the selection of the optimum bar diameter and the achievement of certain distribution of these bars on section so that the reinforcement gravity centre be placed as close as possible to the extreme stressed fibre, thus being observed a series of constructive conditions imposed by standards.

2. CHOISE OF BAR DIAMETER

Although a long experience has been accumulated within decades of calculations and reinforced concrete structure making, up to now there has not been created a methodology allowing to establish the optimum value of bar diameters, depending from the technical and economic criteria, conditioning the structure assembling.

Among these building regulation, only the minimum and maximum permissible values are provide for thus, the longitudinal structure bars for beams are chosen from the standardized assortment (ranging from 10 to 70 mm) without any restriction as to the geometric and mechanical characteristics of their section.

This operation with obvious implications on structural member making is essentially based on the experience and institution of the constructor.

The automation of reinforced concrete member dimensioning imposes to renounce to the method applied so far and the use of an algorithm able to include as many criteria as possible in the conditioning of the optimum diameter.

Since the relation between bar diameter and some of the cross section geometrical and mechanical characteristics cannot be expressed by mathematical relation, it has been considered that the most indicated way to evidence the influence of these parameters on bar diameter value as a result of a vast designing experience.

The results of the analysis undertaken may be synthesized as follow:

a) The section hight exert an essential influence on the reinforcement diameter – the diameter values increase hight increases (Table 1), there existing, however, a limit (a maximum diameter which cannot be exceeded) for each hight value (Table 2).

Table 1 - Current Diameter Function of Beam Hight

H, [mm]			200	250	300	350	400	450	500	550	600
DIN, [mm]			12	12	14	14	16	16	18	20	20
H, [mm]	650	700	750	800	900	1000	1100	1200	1300	1400	1500
DIN, [mm]	20	22	22	25	25	25	28	28	32	32	36

Table 2 - Maximum Dianeter Function of Beam Hight

H, [mm]	200	250	300	350	400	450	500	550	600	650	700
DMAX, [mm]	16	16	18	18	20	20	22	25	25	28	28
H, [mm]			750	800	900	1000	1100	1200	1300	1400	1500
DMAX, [mm]			28	32	36	36	36	40	40	40	40

b) The choice of bar diameter on the section hight to breadth, on the reinforcing percentage, on the type of steel and on the quality of concrete. Their influence may be evidenced by means of some coefficients, the importance of which, within the process of finding the optimum diameter, has been estimated after a probabilistic interpretation of a large amount of data. This resulted from an investigation conducted among specialists with a vast designing experience, as well as from the survery of existent documentation. By noting: CM Ø – the H/B ratio influence coefficient; CM 1 – reinforcing percentage influence coefficient; CM 2 – steel type influence coefficient; CM 3 – concrete quality influence coefficient, it may be admitted that the global influence exerted by these parameters may be estimated with help of the coefficients affected.

c) The methodology recommended for the finding of longitudinal reinforcement optimum diameter (DØL) consists in taking, in an early stage, an initial value (DIN), function of section height, and multiplying it by a serries of influence coefficients:

$$DØL = DIN \cdot CMØ \cdot CM1 \cdot CM2 \cdot CM3$$

Table 3 - H/B Ratio Influence Coefficients

H/B	1.25	1.50	2.0	2.5	3.0	3.5
CMØ	0.8	0.9	1.0	1.05	1.1	1.2

Table 4 - Reinforcing Percentage Influence Coefficients

AP, [%]	0.5	0.8	1.0	1.2	1.5	2.0
CM1	0.8	0.9	1.0	1.1	1.2	1.3

Table 5 - Steel Type Coefficients

Steel Type	OB 37	PC 52	PC 60
CM2	0.9	1.0	1.20

Table 6 - Concrete Quality Influence Coefficients

	B_c 10	B_c 15	B_c 20	B_c 25	B_c 30	B_c 35
CM3	1.1	1.06	1.0	0.98	0.97	0.95

In Tables 3…6, for intermediate values, a linear interpolation is being made.

When a dimensioning program is drawn up, it has to be taken into account that some of the design parameters (H, H/B,AP) are not known in the stage of bar diameter measuring. It is,therefore, necessary to resort to an iterative calculation the concordance between these and the resulted ones.

Since bar diameter can represent but a standardized value,enclosed in the assortment offered by industry, the algorithm includes the probability that, in case of some fractionary or intermediate magnitudes, to automatically choose, from the vectors of diameter considered, the adequate value.

The process of selecting the bar diamer in a reinforced concrete beam has to meet the economic requirement of covering the necessary reinforcement area resulted from calculation, with as little material in excess as possible (as a rule the choice of diameter and number of bars is made with a surplus of steel).

In order to undertake an anlisys, from this point of view, the suggested methodology foresses the posibility to define a number of 3…5 diameters in the vicinity of the optimum one (function of DØL position within standardized diameters vector, these are found on one side or the other of DØL, only to the left or only to the right of DØL). For each diameter considered, the area of bars is calculated, as well as the number of bars covering the total reinforcement area and the difference between this and the one corresponding to a whole number of bars. The minimum difference values leads to finding the most economic diameter.

3. DETERMINING POSITION OF REINFORCEMENT GRAVITY CENTRE

Within structural and crack growth analysis of reinforced concrete beams, it is of utmost importance to known the position of the gravity centre. The point of application of the unit stress resultant in the tensioned reinforcement which coincides with its gravity centre condition, the magnitude of the inside couple (Z), the behaviour of the section at exterior loads.

The position of the reinforcement gravity centre as related to the extreme stressed fibre is determined using a static moment equation depending on: total using of a static moment equation number of bars composing the reinforcement (NTB), section breadth (B), bar diameter (D), as well as on a series of prescriptions of making which enable the practical realization of the members distance between bars (DB), thickness of concrete covering layer (AB).

On a rectangular bar cross section having the breadth (B), bars can be disposed on three rows, on the last row the distance between bars (DBU) being twice as much as the admissible distance on the first two (DB) (Fig.2). This constraint is imposed by the condition of an easier penetration of concrete between bars. Depending on the number of rows on which bars are disposed the position of reinforcement gravity centre as related to adjacent extreme fibre is found using the relations:

a) If bars are disposed on a row:

$$DP1 = AB + 0{,}5D;$$

b) If bars are disposed on two rows:

$$DP2 = [NBR \cdot (AB + 0{,}5D) + NBR2 \cdot (AB + DB + 1{,}5D)] / NTB;$$

c) If bars are disposed on three rows:

$$DP3 = [NBR \cdot (DB + 2 \cdot (AB + D) + BNR3 \cdot (AB + 2DB + 2{,}5D)] / NTB,$$

Where: NBR represent the maximum admissible number of bars on the first two rows; NBU - the maximum admissible number of bars on the first last rows; NTB – total number of bars; NBR2 – incomplete number of bars extant to the second row; NBR3 - incomplete number of bars for the third row.

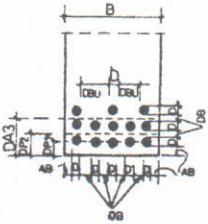

Fig. 2. — Disposition of bars on beam width.

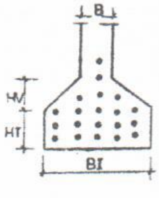

Fig. 3. — Disposition of bars in the splayed basis of a reinforced concrete beam.

The algorithm found determines in a early stage, for a certain amount of reinforcement, the total number of bars (NTB) having the diameter chosen on the basis of before mentioned methodology.

Depending on the beam breadth, it will be studied if these bars may be disposed on one, two or three rows, using the corresponding calculations for each case.

If the reinforcement resulting from the earlier calculation is too strong and exceeds the disposing posibilities offered by a certain section with geometrical characteristics, the decrease of bar diameter will be introduced in the programe. If this provision does not solve the problem, the gradual breadth increase will be resorted to until NBMAX, where:

$$NBMAX = 2NBR + NBU$$

Similary, there has been found a calculation procedure for bar is splayed on a relatively small area.

Under this situation the distance between the inside forces increases, thus leading to a more rational use of reinforcement and a reduced steel comsumption (Fig.3).

4. CONCLUSIONS

The two methodologies presented herein represent contributions to the computerization of reinforced concrete beam design, being part of an ing these structural members.

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