



INTERNATIONAL SCIENTIFIC CONFERENCE

CIBv 2010

12 – 13 November 2010, Braşov

THE CHECKING ON EXPERIMENTAL MODELS OF CAPABLE LOAD ESTABLISHED BY THEORETICAL RELATIONS OF CALCULATION

Ioan TUNS*, Florin-L. TĂMAŞ*, Marius MĂNTULESCU*

* Transylvania University of Brasov, Faculty of Engineering
Corresponding author: Ioan TUNS, E-mail: ioan.tuns@unitbv.ro

Abstract: The reinforcing capacity expressed by capable load represents an important criterion of design exigency for buildings structural elements. Therefore the authors proposed in this paper to make a comparative analyze regarding results obtained on theoretical models of calculation with these determinate model at snatural size. Verification of the module in witch the actual designing norms according to SR EN 1992-1 satisfyingly reflects the observed behavior of the elements during the experimental tests, was also made.

Key words: reinforced concrete, capable load, experimental model, console.

1. INTRODUCTION

The study of bearing capacity of some deteriorated structural elements is a priority issue for a large number of specialists in this domain. This derives mainly from the fact that most industrial reinforced concrete structures (especially in our country) are aged and the demolition and replacement costs are high, often unreasonable or beyond the financial possibilities of the owner.

For these reasons, the approach in this paper of a subject concerning these issues is timely and of broad interest. The subject matter is aimed at verifying the capable load of experimental models initially determined based on calculation formulas.

Investigations also tried to determine the capable load of some reinforced concrete structural elements “console short” type, based on calculating relations used in the literature and verification of the results obtained in natural size experimental models tested by authors.

2. BEARING CAPACITY EVALUATION PROCESSES

2.1 Capable load determination based on calculation formulas

Examples of theoretical calculation were made on reinforced concrete short consoles whereat loads are transmitted by compression, the case most frequently encountered in construction practice.

They are usually supported by vertical elements of construction and are most commonly found in industrial structures.

To evaluate the bearing capacity a series of methods of calculation are set, based on observations and experimental studies on the mechanism of their failure. Thus, the verification formula to ensure a ductile-type failure of the console, according to [1] is:

$$P \leq b \cdot R_c \cdot \sin \alpha \quad (2.1)$$

where “b” represents width of the console and the significance of other terms is shown in Fig. 1:

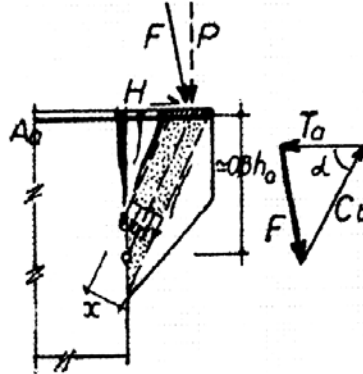


Fig. 1 Possible failure mechanism of a reinforced concrete short console

To determine the compressed diagonal width “x”, various formulas was proposed, such as:

$$x = 0,22 \cdot h_0, \text{ [CEB]} \quad (2.2)$$

$$x = 0,3 \cdot h_0 \cdot \cos \alpha, \text{ [DIN 1045]} \quad (2.3)$$

$$x = 0,4 \cdot h_0 \cdot \cos \alpha \quad (2.4)$$

$$x = 0,5l_p \cdot \sin \alpha + \frac{h_0 \sqrt{\frac{E_a}{E_b} \cdot \mu_a \cdot \operatorname{tg}(\alpha - 45^\circ)}}{\sin \alpha} \quad (2.5)$$

where: - l_p – length of bearing plate;
- A_a – aria of tensed longitudinal reinforcing bars.

$$\mu_a = \frac{A_a}{b \cdot h_0} \quad (2.6)$$

Another method of calculating the bearing capacity is based on the structural model proposed by Leonhardt and Monning and uses Steinle approximations [3]. The method involves considering the following simplifying hypothesis:

- Tangential stress caused by the clash between aggregates or wedge effect, is neglected;
- Local effects caused by reaction or loads, are neglected;
- Static equilibrium conditions are satisfied;
- Failure occurs by crushing of compressed concrete or tensed reinforcing bars break;
- The tensile stresses from concrete are neglected;
- Concrete strength considered is the cylindrical resistance;
- The mathematical model proposed is complemented by the geometrical one (this case refers to the reinforcement and reinforcing bars anchorage).

From the static equilibrium equation of the proposed calculation model [3], fig. 2, we have:

$$D \cdot x = V_u \cdot a + N_u \cdot \Delta h \quad (2.7)$$

where “x” represents the lever arm of the resultant efforts from the compressed diagonal related to the upper point of console and column junction;

$$x = 0,9a \cdot d / \sqrt{(0,9d)^2 + a^2} \quad (2.8)$$

where: - D – compression stresses resultant from buttress support;

$$D = 0,25b \cdot d (\beta_1 \cdot f_c') \quad (2.9)$$

- b – console width;
- d – effective depth of the console;
- f_c' – the concrete compression strength;
- β_1 – coefficient for multiplying the concrete compression strength; $\beta_1 = 0,65 \div 0,85$, respectively $\beta_1 = 0,85$ for $f_c' = 27,6$ MPa and reduced by 0,05 for each 6,9 MPa more than 27,6 MPa;
- V_u, N_u – shear force, respectively consoles transverse force (horizontal).

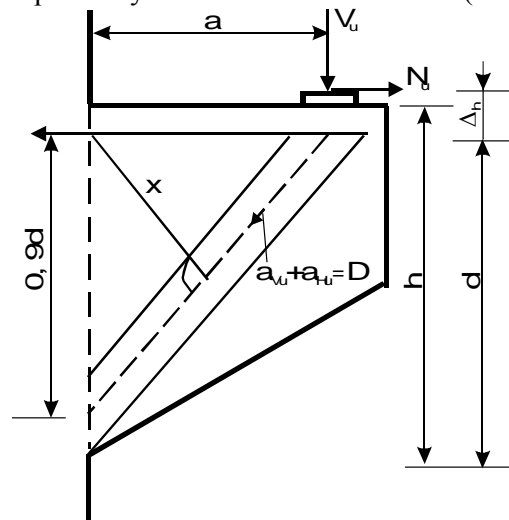


Fig. 2 Beam with counterbrace model

In the case of short consoles with horizontal stirrups, vertical stirrups, inclined reinforcing bars or horizontal and vertical stirrups combined, as transverse reinforcement, stiffness condition is written as follows:

$$Q \leq \varphi \cdot R_b \cdot b \cdot l_{sup} \cdot \sin\theta + Q_{sw} \quad (2.10)$$

and $Q_{sw} = T_{sw} + N_{sw}$,

where: - T_{sw} – the effort from inclined reinforcing bars, due to its stress along with compressed diagonal;

- N_{sw} – the effort from horizontal reinforcing bars, as a result of its stress along with compressed diagonal.

Substituting “ x ” and “ D ” with above formulas in equation 2.10 we have:

$$\frac{b \cdot d \cdot (f_c')}{V_u} = \frac{4,45}{\beta_1} \left(1 + \frac{N_u}{V_u} \cdot \frac{\Delta h}{a} \right) \sqrt{0,9^2 + \left(\frac{a}{d} \right)^2} \quad (2.11)$$

If $\frac{\Delta h}{a} = 0,3$, than equation determining the efforts of the transverse reinforcing bars is:

$$\frac{b \cdot d \cdot (f_c')}{V_u} = \frac{4,45}{\beta_1} \left(1 + \frac{0,3N_u}{V_u} \right) \sqrt{0,9^2 + \left(\frac{a}{d} \right)^2} \quad (2.12)$$

For value ratio $\frac{N_u}{V_u}$ from 0 to 0.2, the expression $\frac{b \cdot d \sqrt{f'_c}}{V_u}$ varies between (0÷6) %. In this case the terms that contain “ N_u ” and “ V_u ” from 2.11 equation can be neglected and we obtain:

$$\frac{b \cdot d \cdot f'_c}{V_u} = \frac{4,45}{\beta_1} \sqrt{0,9^2 + \left(\frac{a}{d}\right)^2} \quad (2.13)$$

This equation which determines the shear force of short consoles may be used as well to obtain the “ d ” value of effective depth.

Similar relations for calculating the shear force of reinforced concrete short consoles are given in some other technical publications [4], [5], [6], as follows:

$$\frac{b \cdot d \cdot f'_c}{V_u} = \frac{2,97}{\beta_1} \left[1 + 0,61 \left(\frac{d}{a}\right)^2 \right] \left(\frac{a}{d}\right) \quad (2.14)$$

$$\frac{b \cdot d \cdot f'_c}{V_u} = \frac{2,8}{\beta_1} \left(1 + \frac{a}{d} \right) \quad (2.15)$$

$$\frac{b \cdot d \cdot f'_c}{V_u} = \frac{3,57}{\beta_1} \quad (2.16)$$

It can be concluded that this method of calculating the shear force is quite simple, covering an area of use for value ratio $\frac{a}{d}$ from 0.1 to 1.

The process is applicable to the short consoles with horizontal, inclined or combined reinforcing bars, loaded centric or eccentric way.

Applying the calculation formulas on experimental model presented in figure 3, with characteristics of the materials according to 2.2 subsection, lead to value for capable load ranging from 37.7 tf and 51.8 tf.

2.2 Capable load determination on experimental models

Short consoles for the experimental study are made of reinforced concrete with longitudinal reinforcing bars and transversal stirrups [7].

Characteristic and calculation strength on concrete and reinforcing bars, used in design calculation are:

- for concrete Bc 20 (C 16/20) class:
 - $R_c = 12.5 \text{ N/mm}^2$;
 - $\overline{R_c} = 1.75 \cdot R_c = 21.88 \text{ N/mm}^2$;
 - $f_{ck} = 16 \text{ N/mm}^2$;
 - $f_{cd} = f_{ck} / 1.5 = 10.67 \text{ N/mm}^2$;
- for OB 37 transversal stirrups bars:
 - $R_a = 210 \text{ N/mm}^2$;
 - $\overline{R_a} = 1.35 \cdot R_a = 283.5 \text{ N/mm}^2$;
- for PC 52 longitudinal bars:
 - $R_a = 300 \text{ N/mm}^2$;
 - $\overline{R_a} = 1.35 \cdot R_a = 405 \text{ N/mm}^2$;
 - $f_{yd} = 300 \text{ N/mm}^2$.

Applying the calculation formulas and composition general rules provided by Romanian standards, geometric dimensions and amount of reinforcing bars for experimental models investigated was obtained.

Aspects related to shape and dimensions of experimental elements are presented in figure 3.

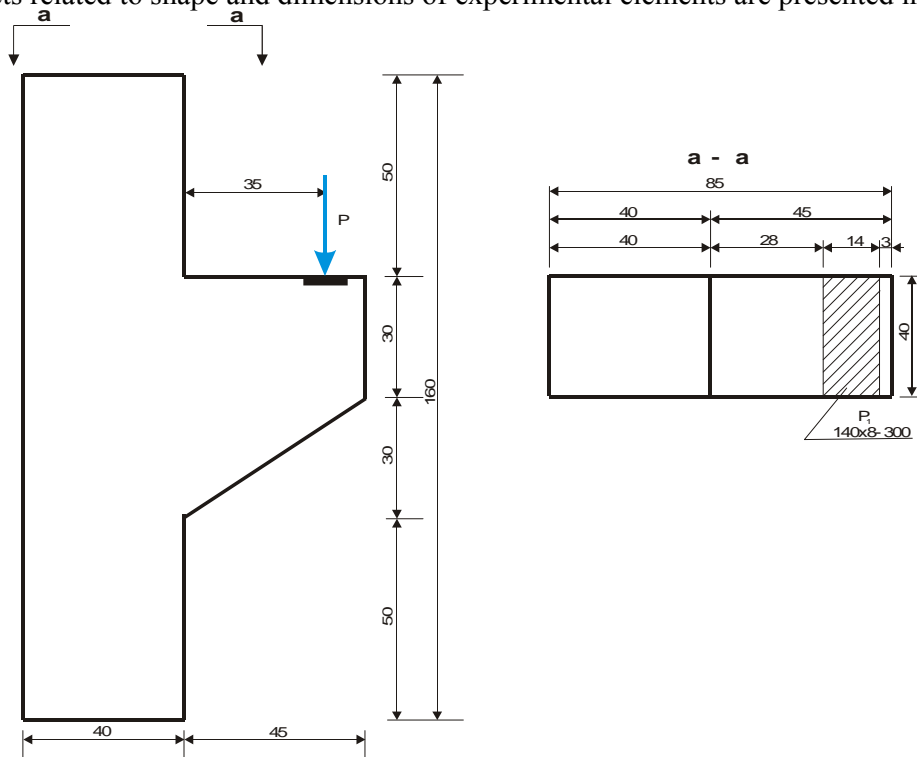


Fig. 3 Geometric shape and dimensions of the experimental models

The experimental program was carry out on three models to scale, with shape and dimensions according to figure 3 and labeled CS 1-1, CS 1-2, CS 1-3.

For consoles, CS 1-1, CS 1-2, CS 1-3 (tested to failure), their breakdown has occurred at a force of 48 tf for consoles CS 1-2, CS 1-3 and 50 tf for CS 1-1 console.

Cracks appearing and development (figure 4) show that they occur in number from two to three, which then spreads into new crack, smaller in terms of length and opening..

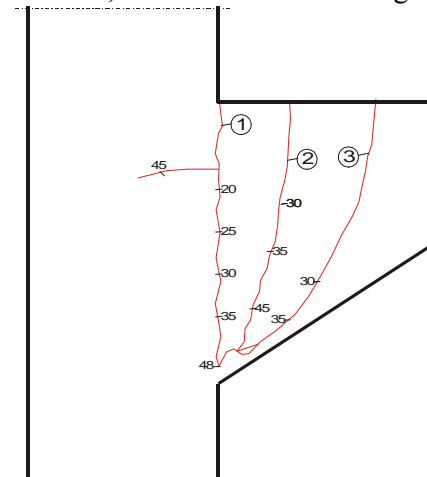


Fig. 4 CS-1 console mapping cracks

The first crack appear under a vertical load of 15 tf for CS 1-1 console and 20 tf for CS 1-2 and CS 1-3 consoles, at the joint point with the column.

The second and third cracks are observed at a load value of 30 tf, are inclined at an angle of about 45°, from under or near the metal bearing plate and reaches the lower corner of console-column junction.

Consoles failure occurred by pronounced cracks openings, the opening and spread of branches resulted from existing cracks and concrete crushing near the lower corner of the console-column junction (figure 5).



Fig. 5 Crushed concrete at the lower corner of console-column junction

3. CONCLUSIONS

Applying formulas for the determination of bearing capacity of investigated consoles led to values between 37.7 tf and 51.8 tf.

After practical tests conducted on the same models capable load values between 48 tf and 50 tf were obtained.

Closed values of investigated consoles capable load, based on the calculation formulas proposed by prestigious specialists in the field and confirmed by tests conducted on models at scale, indicates a high degree of confidence that they posed to evaluate the bearing capacity of some damaged structural elements for which were established by in situ and laboratory investigations the geometrical and material characteristics.

Having assessed the bearing capacity of deteriorated structural elements may be established rehabilitation procedures designed to restore the damaged condition of affected resistance.

REFERENCES

1. MĂNOIU O., *Some aspects of the design of columns short consoles supporting roof elements*, Building 1980.
2. SOLANSKI H., SABNIS M. G., *Reinforced Concrete Corbels, Simplified*, ACI Structural Journal, vol. 84, page 428-432.
3. NIEDENHOFF H., *Investigations on the Load Bearing Behavior of Corbels and Short Consoles*, Dr. Eng. dissertation Technische Hochschule Karlsruhe, 1961.
4. MEHMEL A., BEKER G., *Shear Design of Short Consoles*, Der Bauingenieur, Heidelberg, V40, nr.6, 1965, page 224÷231.
5. STEINLE A., *The problem of minimum dimensions of Corbels*, Beton und Stahlbetonbau, Berlin, V70, nr.6 1975, page 150÷153.
6. TUNS I., *Study of reinforced concrete short consoles*, PhD thesis, Technical University "Gh Asachi Iasi, 2003.