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THE CONCORDANCE BETWEEN THEORETICAL AND EXPERIMENTAL MODEL FOR FORMWORKS MADE OF DISPERSELY REINFORCED CONCRETE WITH POLYPROPYLENE FIBERS

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Abstract: *The idea of concrete reinforcement using different types of fibers dispersed in its mass is very old. On the other side, polypropylene fibers used in concrete are something new. Practical applications of dispersely reinforced concrete with polypropylene fibers are various; one of them may be achieving the shuttering for lintels.*
A series of practical tests showed the efficiency of this type of items regarding their achievement, handling, commissioning and behavior under loads.The paper presents the concordance between the practical tests and theoretical model.

Key words: *concrete, reinforcement, polypropylene fibers.*

1. Generalities

There have been made thin wall elements made of dispersedly reinforced concrete with polypropylene fibers for use as shuttering for beams with rectangular section. Especially, these elements were designed to be used as formwork to achieve lintels.

The elements are U-shaped with top wings, having sectional dimensions of 250*mm* × 250*mm* and thickness of 25*mm*. The length of the element is 2200*mm*, imitating a real size element. Within them the reinforcement will be executed followed by the concreting of lintel.

These elements have been tested for bending loads, loading being made by interlocked bricks, imitating in this way the real situation of the lintel (Figure 1).

The tests have shown that the elements failed at 5.51*kN/m* force, having a deformation before failing of 2.5*mm* [3].

The failure was sudden, after the very first crack (Figure 2) [3].

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Fig. 1. *Lintel ready for testing*

Fig. 2. *Lintel during test and failure moment*

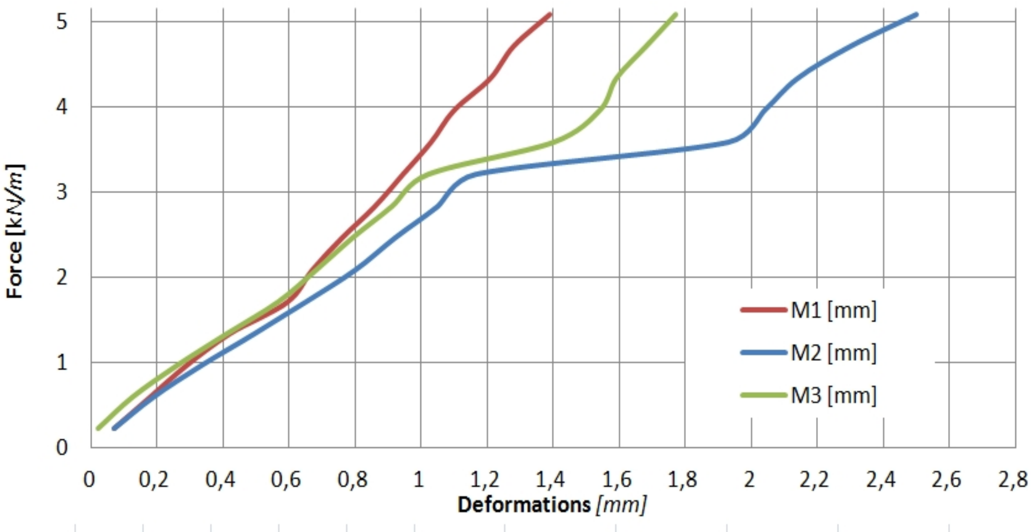

Fig. 3. *Force - deformation graphic for lintel [3]*

Obs.: M1, M2, M3 represents the three micro-comparators from left to right on the snapshot.

2. Lintel Estimated Bearing Capacity

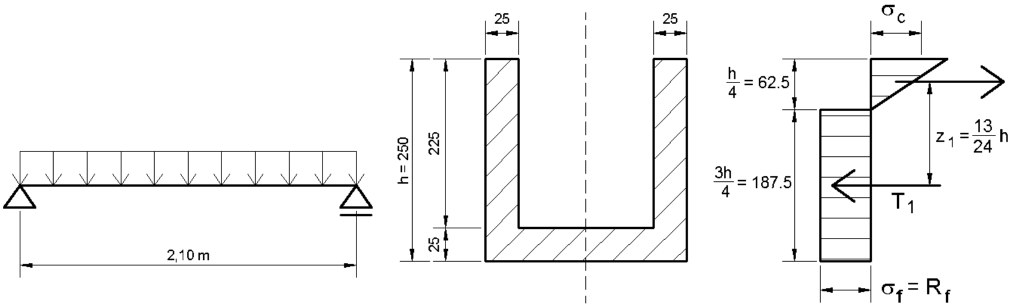

Fig. 4. *Lintel calculation scheme*

The resistant bending moment can be expressed by writing an equation of moments relative to the resultant of compressive stresses using the distribution scheme shown in Figure 4 [1], [4[, [5].

$$M_{cap} = M_{Rd} = T_1 \cdot z_1 \quad (1)$$

where:

$$z_1 = \frac{13}{24} \cdot h = 0.5416 \cdot 250 = 135\ mm,$$

$$T_1 = A_{bi} \cdot n_f \cdot R_f \cdot A_f$$

in which:

$$A_{bi} = 2 \cdot 25 \cdot 187.5 = 9375\ mm^2$$

(stretched concrete area)

$$n_f = N \cdot P_1 \cdot P_2 \cdot C_v$$

(number of fibers involved in effort taking over, per unit area)

in which:

$$N = \alpha \cdot \frac{v_f}{A_f}$$

(total number of fibers that cross the unit area [5])

$P_1 = 50\%$

(probability that all the fibers which cross the unit area to be perpendicular to the breaking surface; P_1 varies between 0 – 100%; it can be accepted $P_1 = 50\%$)

$P_2 = 50\%$

(probability that all the fibers which cross the unit area to be symmetrically positioned to the breaking surface – meaning that half of their length to one side, respectively the other side of the breaking section, to ensure the anchorage condition)

$C_v = 0.89$

(coefficient for homogeneity variation; during the experimental tests, it was determined a variation between 89 – 113%; it can be considered the minimum value of 89%)

where:

$\alpha = 0.41$

(fibers orientation factor, according to the literature [5])

$$v_f = \frac{V_f}{V_b} \cdot 100$$

(volumetric percentage of reinforcement)

$$V_f = \frac{m_f}{\rho_f}$$

(volume of fibers)

$m_f = 0.9\ kg$

(mass of fibers inserted into the unit volume – 1m^3, according to the recipe [2])

$\rho_f = 910\ kg/m^3$
(polypropylene fibers density [2])

$V_b = 1.0\ m^3$
(volume of concrete)

then:

$$V_f = \frac{0.9}{910} = 0.989 \cdot 10^{-3}\ m^3$$

$$v_f = \frac{0.989 \cdot 10^{-3}}{1,0} \cdot 100 = 0.0989\ \%$$

$$A_f = \frac{\pi \cdot d_f^2}{4}$$

(fiber cross-sectional area)

$d_f = 0.034\ mm$
(fiber diameter [2])

$$A_f = \frac{\pi \cdot 0.034^2}{4} = 0.907 \cdot 10^{-3}\ mm^2$$

results:

$$N = 0.41 \cdot \frac{0.0989}{0.907 \cdot 10^{-3}} = 45\ buc/mm^2$$

$n_f = 45 \cdot 0,5 \cdot 0,5 \cdot 0.89 = 10\ buc/mm^2$

$R_f = 300\ MPa$
(fibers tensile strength [2])

than:

$T_1 = 9375 \cdot 10 \cdot 300 \cdot 0.907 \cdot 10^{-3}$

$T_1 = 25375\ N$

and

$M_{cap} = M_{Rd} = 25375 \cdot 135 = 3436210\ Nmm$

$\mathbf{M_{cap} = M_{Rd} = 3.436}$ ***kNm***

3. Lintel Loading Capacity

$$M_{cap} = M_{Rd} = \frac{p_{cap} \cdot l_c^2}{8} \tag{2}$$

$$p_{cap} = \frac{M_{cap} \cdot 8}{l_c^2} = \frac{3.436 \cdot 8}{2.1^2} = 6.233\ kN/m$$

$\mathbf{p_{cap} = 6.233\ kN/m}$

4. Moment Due to External Loads

$$M_{ext} = M_{Ed} = \frac{p_{ext} \cdot l_c^2}{8} \tag{3}$$

where:

$p_{ext} = g_p + g_c$
(total value of external loads)

$g_p = (2 \cdot 0.025 \cdot 0.225 + 0.025 \cdot 0.25) \cdot 1.0 \cdot \gamma_b = 0.0175 \cdot 24$

$g_p = 0.42\ kN/m$
(tare weight of the element)

$g_c = 5.09\ kN/m$
(weight of the bricks used to load the element, determined by direct weighing and measurement)

results:

$p_{ext} = 0.42 + 5.09 = 5.51\ kN/m$

$\mathbf{p_{ext} = 5.51}$ ***kN/m***

$l_c = 2.10$ m
(calculation opening of the element)

than:

$$M_{ext} = M_{Ed} = \frac{5.51 \cdot 2.10^2}{8}$$

$\mathbf{M_{ext} = M_{Ed} = 3.035\ kNm}$

The difference between $M_{Ed} = 3.035$ *kNm* and $M_{Rd} = 3.436$ *kNm* can be attributed to the variation factor (dishomogeneity) and, also, to the method of making the elements, manually, in wooden formworks likely to deform.

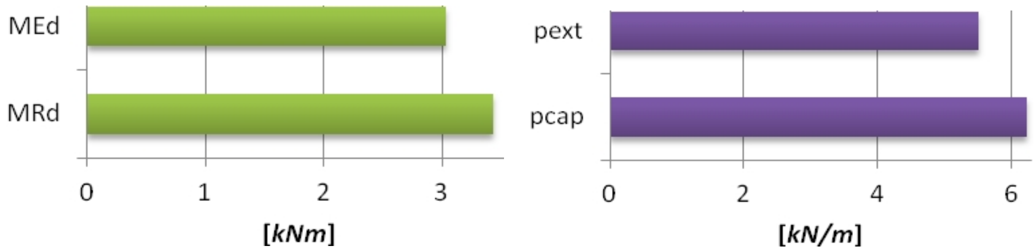

Fig. 5. *Comparison between theoretical and actual capacity of the lintel*

Practical conclusion is that such elements are effective because: their handling is an easy one, there are no problems for the final fitting position, provides the concrete protective coating for reinforcement that will be assembled inside and they are sufficiently strong to support the weight of concrete from inside and of the layers of bricks above, optionally with a single support pillar mounted on the midspan.

Unlike the lintels made in wooden or metal formworks, these ones eliminate the labor and materials necessary for formworks achievement, eliminate the labor for taking off the formworks and provides faster commissioning, practically the day after the concrete is put inside, the masonry can be continued.

5. Economic Efficiency of Lintels Made of Dispersely Reinforced Concrete with Polypropylene Fibers

As a conclusion regarding the economic efficiency of such prefabricated lintels, compared to the classic executed ones, by shuttering, an estimative price analysis have been made. This analysis is shown in Table 1.

Price analysis for lintels Table 1

No.	Symbol	Article name	UM	Quantity		U.P. [lei]	Value [lei]	
				Fiber concrete	Regular concrete		Fiber concrete	Regular concrete
1	CB02XC	Beams formworks, excluding supports	m^2		1.55	25.5 2	0.00	39.56
2	CB11XA	Supporting with extendable metal poles	buc	1.00	2.00	3.60	3.60	7.20
3	CB07XL	Metal molds for the production of precast	m^2	0.02		320. 00	6.75	0.00
4	CA04XD	Fiber concrete preparation	m^3	0.03		232. 00	6.96	0.00

		and pouring in metal molds						
5	CA04XC	Reinforced concrete preparation and pouring in beams	m^3	0.10	0.14	205.00	20.50	28.70
6	CC02XC	Production and installation of reinforcement in beams	kg	12.30	12.30	2.50	30.75	30.75
7	NL	Purchase and installation of PVC spacers	buc		4.00	0.01	0.00	0.04
8	CP15XA	Installation of concrete prefabricated slabs	buc	1.00		3.20	3.20	0.00
9	TRA	Concrete transport with mixer at 10km	T	0.24	0.29	5.20	1.25	1.51
10	TRA	Transport of precasts at 10km	T	0.07		18.60	1.30	0.00
Total value [lei]							**74.31**	**107.75**
Manufacturing cost saving [lei]								-33.44
Manufacturing cost saving [%]								**31.04%**

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