

An investigation on concrete columns with special reference to L and T sections with and without diaphragms

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An Investigation on Concrete Columns with Special Reference to L and T Sections With and Without Diaphragms

Une étude sur les colonnes en béton, traitant spécialement des sections en L et en T avec et sans cloison transversale

Eine Untersuchung an Stahlbetonstützen unter besonderer Berücksichtigung von L- und T-förmigen Querschnitten mit und ohne Querschotten

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1. INTRODUCTION:

Strength of columns having T and L shapes subject to biaxial bending is determined experimentally and compared with theoretical values of Hsu & Mirza (1). Efficiencies of T, L and rectangular column sections are also compared. Effect of end stiffening of T & L shaped columns by means of diaphragms has also been studied in the paper. One of the objects of this paper is to suggest a suitable method of design of non-rectangular column sections - T & L sections - for a practical designer's office using a desk calculator only.

2. PREPARATION OF THE SPECIMENS AND TESTING PROGRAMME:

Materials of the test specimens are ordinary portland cement, quarry sand & 6mm down (passing 6mm sieve size) crushed rock aggregates mixed in the proportion of 1:1.5:3 by weight with water cement ratio of 0.6. 6mm square black wire mesh with 0.6mm wire diameter, are used as reinforcement. Test specimens and concrete cylinders are cast with the same concrete and both cured under water.

Different shapes of specimens viz. T, L, rectangular and cruciform are prepared. Three sets of the test specimens are cast monolithically with end diaphragms of 6mm thickness to find the effect of diaphragm on column strength. Particulars of the specimens are given in Table 1. Length of each specimen is kept as 38.10 cm.

The first phase of the testing programme deals with uniform compressive load over the whole area and the second phase is conducted to study biaxial bending of the test specimens.

The stress strain curve of concrete is shown in Fig.1. The

ultimate strain is recorded as 31×10^{-4} .

3. TEST RESULTS AND DISCUSSIONS:

3.1. Under uniform compression:

Total results are shown in Table 1.

3.1.1. Effect of shape:

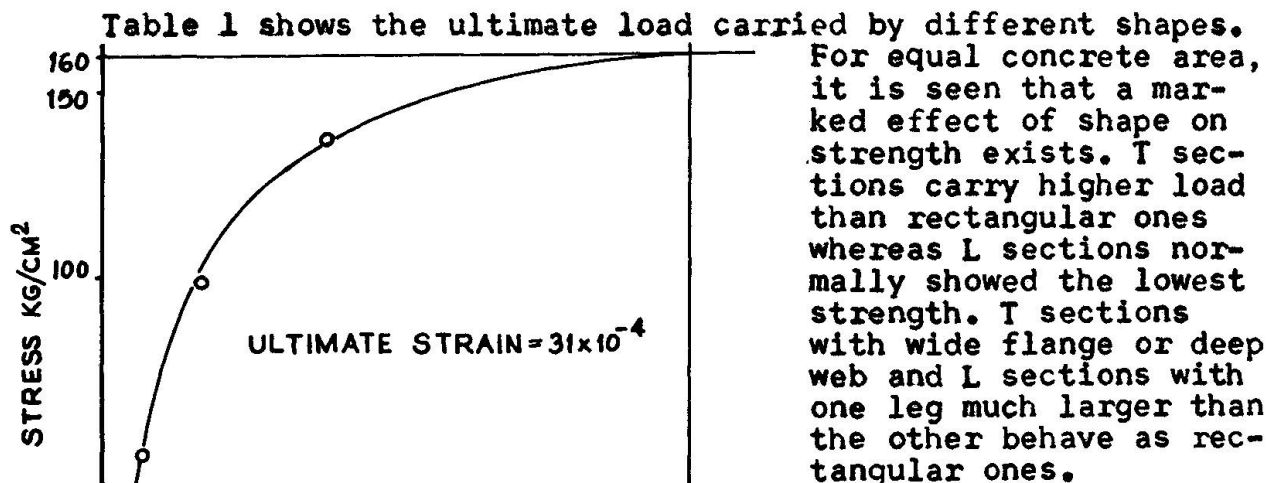


FIG.1. STRESS-STRAIN CURVE OF CONCRETE.

3.1.2. Effect of end Diaphragms:

In a building, the columns in each floor are always bounded by the slabs at the top and bottom. Keeping this in view columns (L & T sections) are tested with end diaphragms of 6mm thickness. Table 2 shows that columns with end diaphragms have carried more load than columns without diaphragms. From the present series of tests (Table 2) it is seen that the percentage increase in strength is nearly 30 to 35.

TABLE.1. CYLINDER STRENGTH = 160 KG/CM²
 P_c = LOAD AT FAILURE
 P_A = CYLINDER ULTIMATE STRESS \times AREA OF CROSS SECTION

SPECIMEN MARKING	SPECIMEN	a CM	b CM	t ₁ CM	t ₂ CM	CONC. AREA CM ²	EQ STEEL AREA CM ²	AVERAGE P _c tonne	P _c /P _A
A ₁		5.08	5.08	2.22	2.22	17.7	0.47	1.810	0.641
A ₂		7.62	7.62	2.22	2.22	29.0	0.86	2.750	0.595
A ₃		7.62	5.08	2.22	2.22	23.8	0.75	2.800	0.758
A ₄		5.08	5.08	3.17	3.17	22.6	0.43	2.370	0.660
A ₅		7.62	7.62	3.17	3.17	38.4	0.75	6.150	1.020
A ₆		7.62	5.08	3.17	3.17	30.3	0.55	3.780	0.780
A ₇		7.62	5.08	1.27	1.27	14.6	0.78	1.950	0.840

TABLE 1 (CONT'D)

SPECIMEN MARKING	SPECIMEN	a CM	b CM	t ₁ CM	t ₂ CM	CONC AREA CM ²	EQ STEEL AREA CM ²	AVERAGE P _c tonne	P _c /P _A
T ₁		5.08	7.62	2.22	2.22	23.8	0.67	2.755	0.746
T ₂		7.62	5.08	2.22	2.22	23.8	0.67	3.250	0.880
T ₃		5.08	7.62	3.17	3.17	30.3	0.67	4.550	0.940
T ₄		5.08	5.08	2.22	2.22	17.7	0.63	2.280	0.816
T ₅		7.62	5.08	3.17	3.17	30.3	0.67	5.330	1.100
T ₆		5.08	5.08	3.17	3.17	22.6	0.51	3.100	0.870
T ₇		5.08	7.62	1.27	2.22	18.2	0.67	2.500	0.860
T ₈		7.62	7.62	1.27	2.22	24.9	0.86	5.520	1.400
T ₉		7.62	7.62	1.27	1.27	17.8	0.86	3.690	1.290
T ₁₀		10.16	7.62	2.54	1.27	29.1	1.17	7.300	1.580
T ₁₁		15.24	5.08	2.54	1.27	29.1	1.34	4.950	1.060
R ₁		7.98	—	2.22	—	17.7	0.47	1.740	0.620
R ₂		10.72	—	2.22	—	23.8	0.75	1.620	0.580
R ₃		7.13	—	3.17	—	22.6	0.43	3.600	0.740
R ₄		9.56	—	3.17	—	30.3	0.67	3.200	0.660
R ₅		11.43	—	1.27	—	14.6	0.78	1.355	0.580
R ₆		13.97	—	1.27	—	17.8	0.86	1.540	0.540

TABLE 2. DIMENSIONS ARE IN CM.

SPECIMEN MARKING		SPECIMEN	AVERAGE ULTIMATE LOAD tonne	PERCENT INCREASE IN LOAD FOR SPECI- MENS WITH DIAPHRAGM
A ₁	WITHOUT DIAPHRAGM		1.81	
A _{1S}	WITH DIAPHRAGM		2.44	35.15
A ₆	WITHOUT DIAPHRAGM		3.78	
A _{6S}	WITH DIAPHRAGM		4.90	30.05
T ₄	WITHOUT DIAPHRAGM		2.28	
T _{4S}	WITH DIAPHRAGM		2.96	30.20

3.1.3. Effect of Slenderness ratio:

The ratio l/r_{min} , being the most important design parameter in designing a column under uniform compression a plot of l/r_{min} against P_C/P_A for different shapes viz. T & L are shown in Fig.2 where P_C = Load at failure and P_A = cylinder ultimate stress X area of cross-section. From the curve it is observed that for a particular l/r_{min} ratio, T sections are about 30 to 40 percent more efficient than L sections.

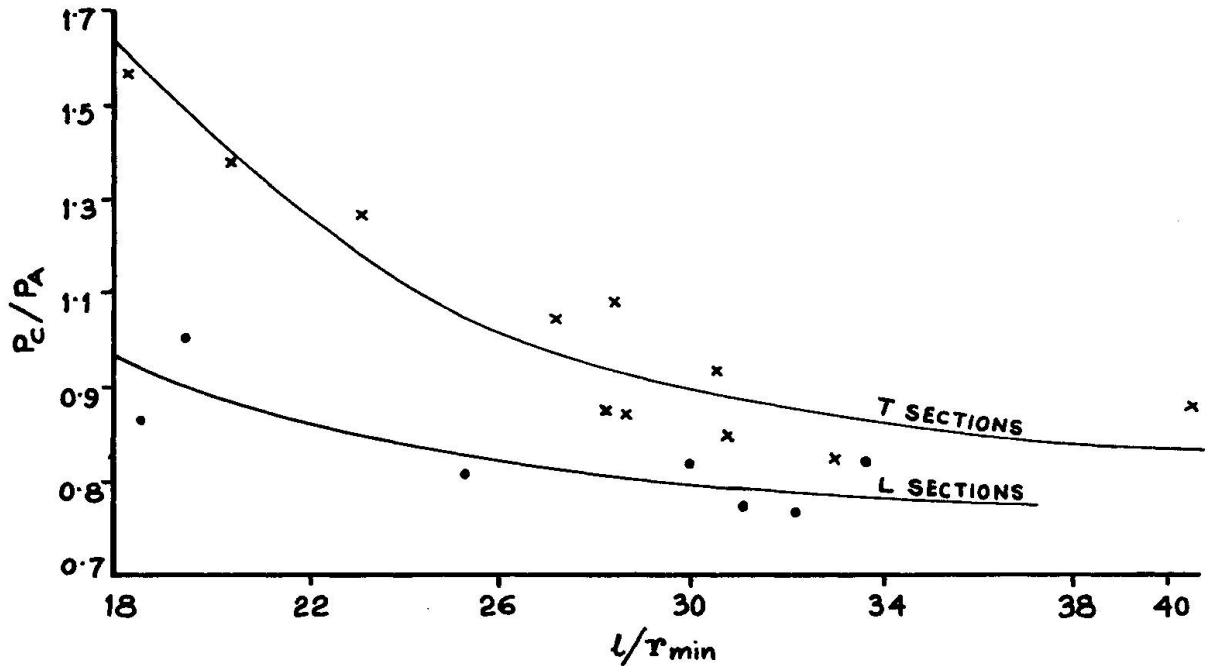


FIG.2 EFFECT OF l/r_{min} ON STRENGTH.

3.2. Bending Effect:

Specimens of different shapes viz. L, T, Cruciform were tested under bending and test results have been compared with the values obtained by the method of Hsu & Mirza (1) shown in Table 3.

TABLE. 3.

SPECIMEN MARKING	SPECIMEN	a CM	b CM	t_1 CM	t_2 CM	ECCENTRICITY(e)		AVERAGE P_C (EXPT) tonne	AVERAGE P_C (THEO) ¹ tonne
						e_x CM	e_y CM		
A _{1b}		5.08	5.08	1.27	1.27	1.0	1.0	1.02	1.21
T _{1b}		10.16	5.08	2.54	1.27	1.0	1.0	1.85	2.30
C _{1b}		10.16	10.16	2.54	2.54	3.175	3.175	2.97	2.66

3.2.1. Theoretical Model:

The method of Hsu & Mirza is an iteration process based on Newton-Raphson technique where the axial load, moment in x & y directions have been expressed as functions of direct strain and curvatures in x & y directions as,

$$P = P(\phi_x, \phi_y, \epsilon_p)$$

$$M_x = M_x(\phi_x, \phi_y, \epsilon_p)$$

$$M_y = M_y(\phi_x, \phi_y, \epsilon_p)$$

The convergence of the calculated value at any cycle and the final value has been accelerated by using Taylor's expansion as,

$$P(c) - P(s) = u = -\left(\frac{\partial P(c)}{\partial \phi_x} \delta \phi_x + \frac{\partial P(c)}{\partial \phi_y} \delta \phi_y + \frac{\partial P(c)}{\partial \epsilon_p} \delta \epsilon_p\right)$$

$$M_x(c) - M_x(s) = v = -\left(\frac{\partial M_x(c)}{\partial \phi_x} \delta \phi_x + \frac{\partial M_x(c)}{\partial \phi_y} \delta \phi_y + \frac{\partial M_x(c)}{\partial \epsilon_p} \delta \epsilon_p\right)$$

$$M_y(c) - M_y(s) = w = -\left(\frac{\partial M_y(c)}{\partial \phi_x} \delta \phi_x + \frac{\partial M_y(c)}{\partial \phi_y} \delta \phi_y + \frac{\partial M_y(c)}{\partial \epsilon_p} \delta \epsilon_p\right)$$

where at any cycle y, iteration

$$P(c) = \sum_{k=1}^n (E_t)_k \epsilon_k a_k$$

$$M_x(c) = \sum_{k=1}^n (E_t)_k \epsilon_k a_k y_k$$

$$M_y(c) = \sum_{k=1}^n (E_t)_k \epsilon_k a_k x_k$$

the strain in kth element ϵ_k is given as

$$\epsilon_k = \epsilon_p + \phi_x y_k + \phi_y x_k$$

and $(E_t)_k$ = Tangent modulus at a given strain level.

As an example a T section has been shown here with element subdivisions in Fig. 3. A quadrilinear model of stress-strain curve has been considered as shown in Fig. 4 for the purpose of calculation. Tangent modulus of steel has been kept constant throughout because it is assumed that the strains in the steel will remain within the elastic limit. Fig. 5 giving the load values

at successive iteration, shows that the process converges very rapidly. Practically iteration is not needed after the third cycle. The deviation between second and third cycle is very

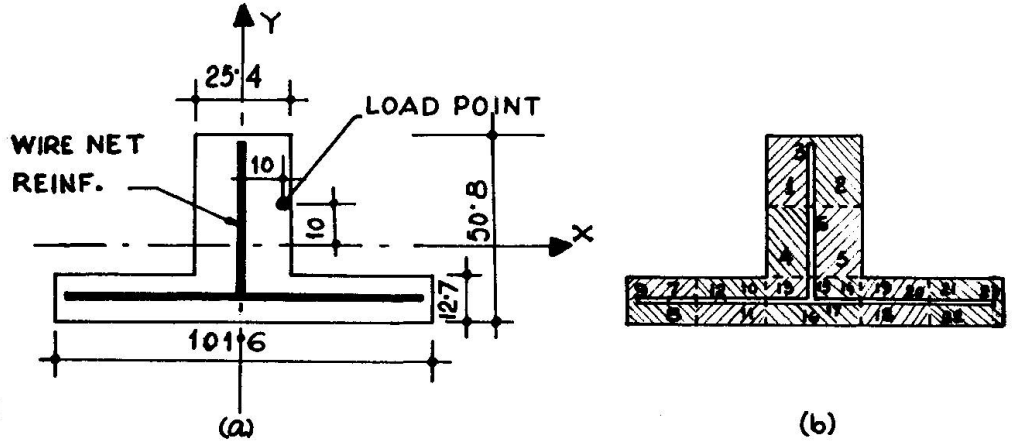


FIG. 3. ELEMENT IDEALISATION.

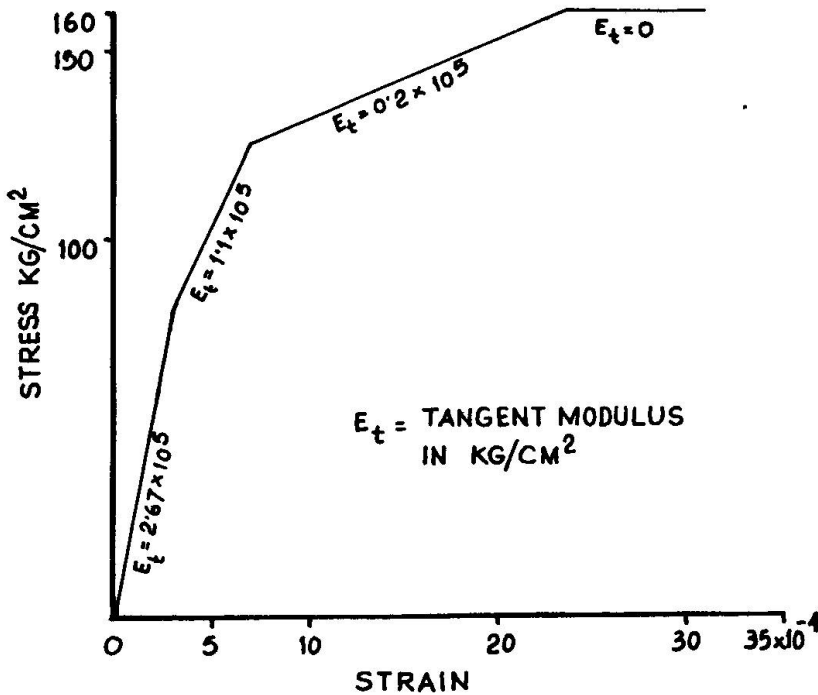


FIG. 4 IDEALISED QUADRI-LINEAR MODEL OF STRESS STRAIN CURVE OF CONCRETE (TAKEN FROM FIG. 1)

small and for practical purposes two iteration cycles are sufficient. The process is therefore, very much suitable in design office with only a desk calculator.

From Table 3 it is observed that the method is fairly good in estimating the ultimate load of compression members under biaxial bending.

Fig. 6 shows the photograph of some of the specimens after test.

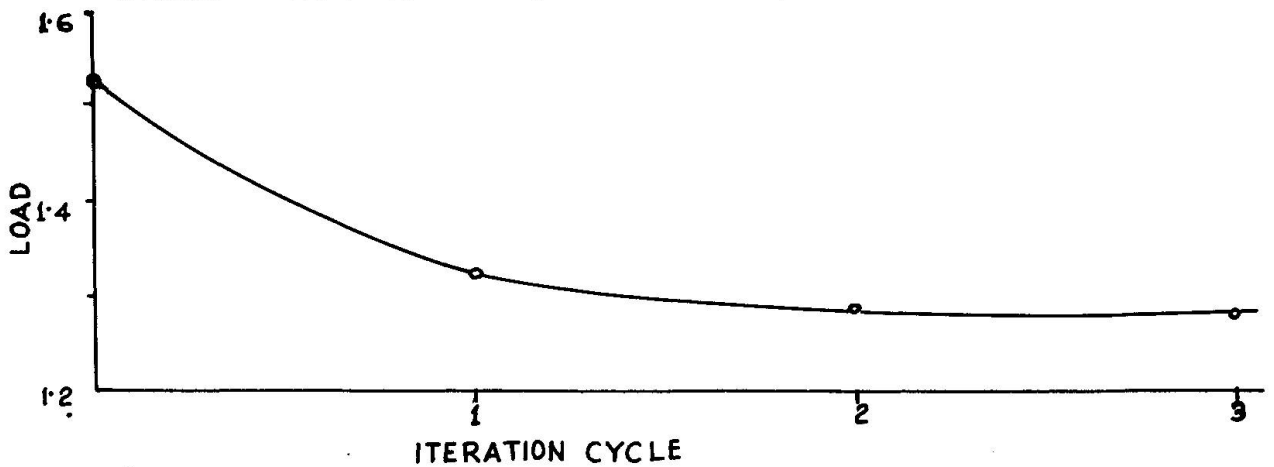


FIG. 5 CONVERGENCE OF ITERATION PROCESS.

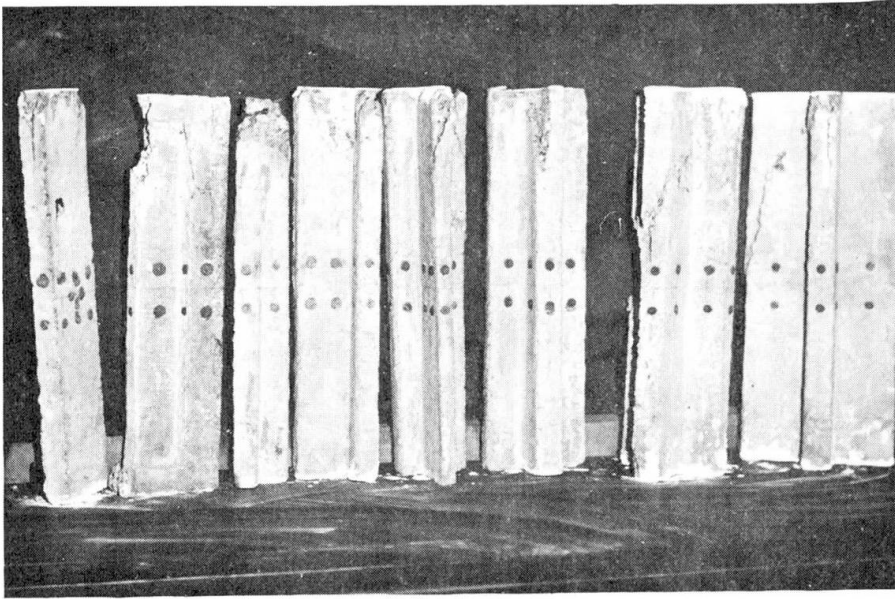


FIG.6 SOME OF THE SPECIMENS AFTER TEST

4. CONCLUSION:

Within the scope of the present series of experiments conclusions are,

1) T sections are about 30 to 40 percent more efficient than L sections.

2) Rectangular sections carry less load than T sections but more load than L sections.

3) The increase in column strength ranges from 30 to 35 percent for columns with end diaphragms in case of T and L sections.

4) The iteration procedure given by Hsu & Mirza (1) is a highly convergent one and is fairly good in estimating the ultimate load carrying capacity of compression members under biaxial bending.

5) In case of biaxial bending also, T sections carry more load than L sections.

REFERENCE:

1. Cheng-Tzu Hsu and M. Saeed Mirza "Structural Concrete - Biaxial Bending and Compression". Technical note, ASCE Vol.99 No. ST2 Feb. 1973.

SUMMARY

Strength of columns having T and L shapes subject to biaxial bending is determined experimentally and compared with theoretical values of Hsu & Mirza (1). Efficiencies of T, L and rectangular column section are also compared. Effect of end stiffening of T and L shaped columns by means of diaphragms has also been studied in the paper.

RESUME

On détermine expérimentalement la résistance des colonnes en forme de T et de L soumises à une flexion biaxiale, et on effectue une comparaison avec les valeurs théoriques de Hsu et Mirza (1). On compare également les colonnes à section en forme de T, de L, et de rectangle. Ce rapport étudie également l'influence d'un raidissage aux extrémités des colonnes en T et en L au moyen de cloisons transversales.

ZUSAMMENFASSUNG

Zahlenmässige Schätzungen für den Wert der grössten Druckstauchung von Beton bei der Bruchbeanspruchung von Stahlbeton-Stützenquerschnitten unter Einwirkung verschiedener Kombinationen von Normalkraft und Biegemomenten wurden vorgenommen. Die Ergebnisse zeigten, dass die grösste Druckstauchung durch eine Reihe von Faktoren, wie die Kombination von Normalkraft und Biegemoment, den Verlauf des Spannungs - Dehnungs - Diagramms von Beton, die Streckgrenze der Bewehrung, den Bewehrungsgehalt usw. beeinflusst wird.