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EFFECT OF FLANGE WIDTH ON SHEAR STRENGTH OF R.C T-BEAMS

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ABSTRACT
This search represented tests of reinforced concrete beams were tested in laboratory for shear strength. Beams consisted of six of reinforced concrete beams without stirrups, one with R-sec and five with T-sec, with variable flange width to web width ratio. All beams were loaded under two identical point load till failure. During loading of beams deflection was measured, steel strain at mid span, steel strain at mid shear span, stains at inclined strut, and strain at upper flange. Code equations usually does not account for the contribution of the flange of the T-sec while experimental research indicated enhanced shear strength for beams with flange.
Test results of this research indicated an enhance of shear strength ranging from 10-30% due to the contribution of the flange.

Keywords: Shear Crack, T-Beam, Deflection, Strains.

الملخص
هذا البحث يهدف الي تقديم نتائج اختبارات كمرات خرسانية مسلحة لقوي القص والتي تم اختبارها من خلال التجارب المعملية وهذه الكمرات تتكون من ستة كمرات خرسانية مسلحة واحدة علي شكل قطاع مستطيل والخمسة كمرات الاخري علي شكل قطاع تي مع اختلاف عرض الشفة مقارنة بعرض الجذع وجميع هذه الكمرات بدون تسليح كانات.
وتم تعريض الكمرات المختبرة لحملين متماثلين حتي حدوث الانهيار واثناء التحميل تم قياس الترخيم بمنتصف الكمرة والانفعال بالحديد في منتصف الكمرة والانفعال بالحديد بمنتصف بحر القص كما تم قياس الانفعال بمنطقة الضاغط والشداد علي المائل ايضا تم قياس الانفعال بالخرسانه اعلي منطقة الكمرة بالمنتصف.
ومن المعلوم انه توجد معادلات مستنتجه لمقاومة الكمرات لقوي القص متواجدة بالاكواد والمخصصة تحديدا للكمرات ذات القطاع المستطيل وتم عمل بعض الابحاث من خلال الدراسات السابقة لمقاومة الكمرات ذات قطاع تي لقوي القص . ومن خلال التجارب المعملية اتضح ان الكمرات ذات قطاع تي لها مقاومة اعلي لقوي القص من تلك الكمرات ذات القطاع المستطيل وخاصة كلما زادت نسبة عرض الشفة مقارنة بعرض الجذع وتراوحت نسبة هذه المقاومة لقوي القص من ١٠ % الي ٣٠ %.
الكلمات الدالة : القص- الترخيم – الاشغالات – كمرات ذات قطاع تى –عرض الشفة للكمرات

1. INTRODUCTION

The previous studies showed that the beams with T-sec had high shear strength compared to that of R-section. For instance, the standard national Indonesia Code (S.N.I) accounts for the effect of flange in shear as shown in the following equation,

$$V_c = \frac{1}{7}\left(\sqrt{f'_c} + 120\rho_w \frac{d}{a}\right) b_w * d \qquad (1)$$

Where, f'_c is cylinder compressive strength of concrete, ρ_w, ratio of longitudinal reinforcement (%), d is effective depth, a is shear span length, and b_w is width of web.

Rendy Thamrin, Jafril Tanjung, Riza Aryanti, modified the previous equation, by adding the effect of both width and thickness of the flange by the factor α, which was calculated in terms of equation (2), this factor α was added to Equation (1), to represent the effect of flange width and thickness on shear strength according to equation 3).

$$\alpha = 1 + \left(\frac{b_f\, h_f}{4d^2}\right) \tag{2}$$

$$V_c = \frac{1}{7}\left(\alpha\sqrt{f_c} + 120\rho_w \frac{d}{a}\right)\ b_w * d \tag{3}$$

Where, α is parameter taking into account the effect of flange in T section, b_f, is width of flange, d is effective depth, and h_f is height of flange.

On the other hand, **Loannis P.Zaraaris, Maria K. Karaveziroglou, and Prodromos D.Zararis** showed that, in case of T-beams, it must be taken into account that the width of the compression zone and, consequently, the width of the area where the splitting of concrete occurs, defining as (effective width) of a T-beam in shear $Beff = \frac{A}{c}$,

Where A equals the area of compression zone, and c equals the depth of compression zone, where B_{eff} was calculated from equation (4).

$$B_{eff} = b_w \left[\frac{1 + 0.5 * \frac{h_f}{d}\left(\frac{b}{b_w} - 1\right)\frac{\square}{c}}{d}\right] \tag{4}$$

Where, b_w is width of web, h_f is thickness of the flange, and d is beam depth.

The shear strength of T-beams without shear reinforcement, becomes,

$$V_1cr = (1.2 - 0.2\, a/d\ d) *\ \ c/d\ \ f_1ct * B_1eff * d] \tag{5}$$

Where f_{ct}, is the splitting tensile strength of concrete, $f_{ct} = 0.3 f_C'^{\frac{2}{3}}$.

2. EXPERIMENTAL STUDY

Six R.C beams were subjected to identical concentrated loads up to failure; one of the tested beams had a rectangle section, while the other five beams had a T-section.

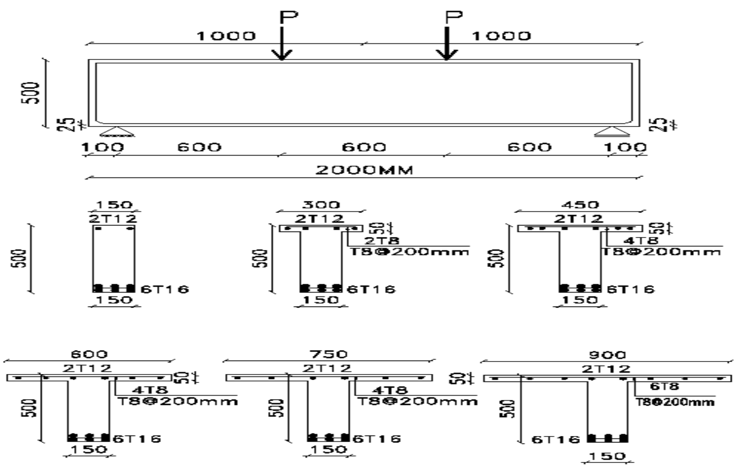

Figure (1): Dimensions and reinforcement of the tested beams.

Figure (1), shows the beams configuration, concrete dimensions and reinforcement details of beams. For all beams, the clear span was 1800 mm, total length was 2000 mm, the depth of beams was 500 mm, shear span was 600 mm and flange width was varied from 300 to 900 mm as shown in table (1).

Table (1) Properties of the tested beams

Beam I.D	Web Width mm	Flange Width mm	Flange Thickness mm	Height mm	Bottom R.F.T	Top R.F.T	Compressive strength (M.Pa)
a	150	-----	-----	500	6T16	2T12	19.00
b	150	300	50	500	6T16	2T12	20.20
c	150	450	50	500	6T16	2T12	19.80
d	150	600	50	500	6T16	2T12	20.10
e	150	750	50	500	6T16	2T12	19.40
f	150	900	50	500	6T16	2T12	19.90

Three cylinders were tested for each sample in the same day of sample test and the average values of f'_c as shown in table (1).

2.1 TEST SETUP

Figure. (2) shows the test set up, load was applied using hydraulic Jack of 700 (kN) capacity. The load was transferred by transfer beam to apply two identical concentrated loads.

The values of loads and deflections were measured using a load cell, and L.V.D.T , respectively. Steel strains were measured at mid-span and mid shear span. In addition, concrete strain was measured at the mid span and on the mid of the compression strut.

All data were measured and stored simultaneously using a data logger and a laptop.

Figure (2): Test setup and system of loading.

[1] Steel Frame. [2] Hydraulic jack. [3] Weight cell.
[4] Steel beam with two concentrated load. [5] Right concentrated load.
[6] Left concentrated load. [7] Tested concrete beam.
[8] Hinged support. [9] Roller support. [10] L.V.D.T

3. RESULTS AND DISCUSSION

3-1 CRACK PATTERN.

Flexural vertical cracks initated at the beam tensile side, with the increase of loads, flexural cracks propagated and started to incline, with further load increase, shear cracks appeared diagonally from concentrated load to support.
The failure mode varied between splitting failure and diagonal crushing.

Beam (a) R- section-diagonal crushing failure

Beam (b) flange width equal 300 mm- diagonal crushing failure

Beam (c) flange width equal 450 mm-splitting failure

Beam (d) flange width equal 600 mm-splitting failure

Beam (e) flange width equal 750 mm-splitting failure

Beam (f) flange width equal 900 mm-splitting failure

Figure (3): Failure modes and cracking pattern of the beams

Figure (3) shows that failure type was splitting shear failure for all beams.
Failure mode for beam (a and b) was diagonal crushing. The decrease of flange width shifted the failure mode from splitting failure to diagonal crushing.

3-2-LOAD DEFLECTION BEHAVIOR.

Generally, the first part of the curve was linear up to the value of the cracking load (P_{cr}), beyond the value of (P_{cr}) the curve had a nonlinear behavior up to the ultimate load value.
As shown in figure (4), the increase of the flange width (B_{eff}) increased the ultimate load and corresponding deflection value. The value of load increase varied from (290) to (380) kN.

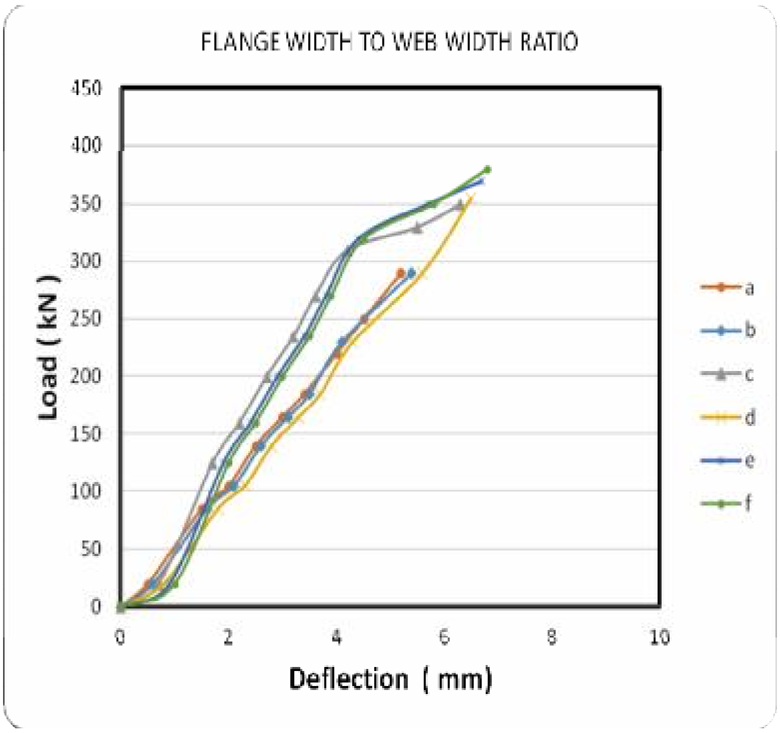

Figure (4): load deflection curve of the tested beams.

The increasing of shear strength ranged from 10-30 % compared that R-sec

Table (2): Results data of the tested beams.

Beam Model	P_{crack} (kN)	M at shear crack (kN.m)	$P_{failure}$ (v_{exp}) (kN)	M at shear failure (kN.m)	Δ_{max} (mm) Deflection
a	120	36	290	87	5.50
b	150	45	330	99	6.00
c	170	51	345	103.5	6.30
d	180	54	355	106.5	6.50
e	190	57	370	111	6.70
f	200	60	380	114	6.80

Table (2), showed the relation between loads at cracking and failure loads, and the deflection for all the tested beams.
the increase of the flange width (B_{eff}) incrased the ultimate load and corresponding deflection value. The value of load increase varied from (290) to (380) kN.

3-3 COMPARISON BETWEEN EXPERIMENTAL AND ANALYTICAL MODELS.

Experimental results were compared with the analytical models as shown in figures from (6) to (9), confirmed that the flange width at T-sec beams had high shear strength compared that R-sec.

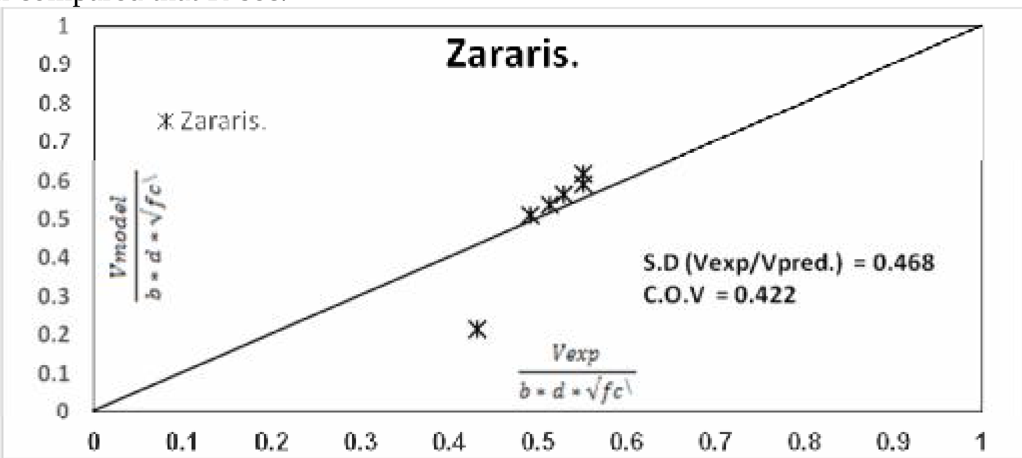

Figure (5): Comparison between experimental and Zararis models

Table (3): Comparison between experimental and Zararis equation

Beam Model	$Vexp$ kN	$\frac{Vexp}{b*d*\sqrt{fc}}$	$Vmodel$ kN	$\frac{Vmodel}{b*d*\sqrt{fc}}$	$\frac{Vexp}{Vmodel}$	$\frac{Vexp}{Vmod}$ mean
a	145	0.432	72	0.215	2.01	1.10
b	165	0.491	171	0.51	0.965	
c	172.5	0.514	180	0.537	0.912	
d	177.5	0.529	189	0.563	0.939	
e	185	0.551	198	0.59	0.934	
f	185	0.551	207	0.617	0.893	

Zararis model was over estimated to the experimental values about percentage equal 10 % according to the effective of flange width at T-sec, while was under estimated for R-section about percentage equal 50% .

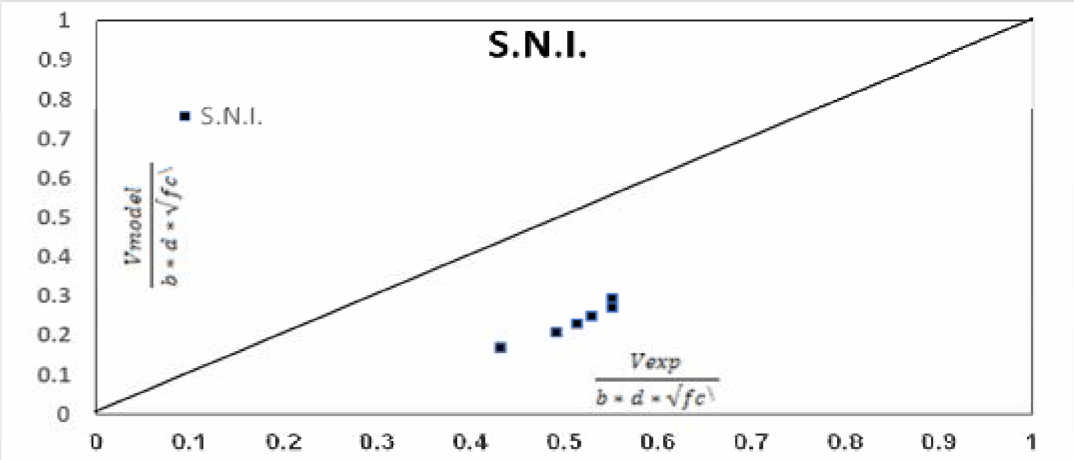

Figure (6): Comparison between experimental and analytical models

Table (4): Comparison between experimental and S.N.I equation

Beam Model	$Vexp$ kN	$\frac{Vexp}{b*d*\sqrt{fc}}$	$Vmodel$ kN	$\frac{Vmodel}{b*d*\sqrt{fc}}$	$\frac{Vexp}{Vmod}$	$\frac{Vexp}{Vmod}$ mean
a	145	0.432	57	0.169	2.54	2.156
b	165	0.491	70	0.208	2.35	
c	172.5	0.514	77	0.229	2.05	
d	177.5	0.529	84	0.250	2.11	
e	185	0.551	91	0.271	2.03	
f	185	0.551	99	0.295	1.86	

S.N.I modified model was under estimated to the experimental values about percentage from 42 to 50 %, according to effective of the flange width at T-sec.

3-4 EFFECT OF FLANGE WIDTH ON SHEAR STRENGTH OF THE TESTED BEAMS.

Figure (7) shows the relation between shear strength and the flange width according to experimental results.

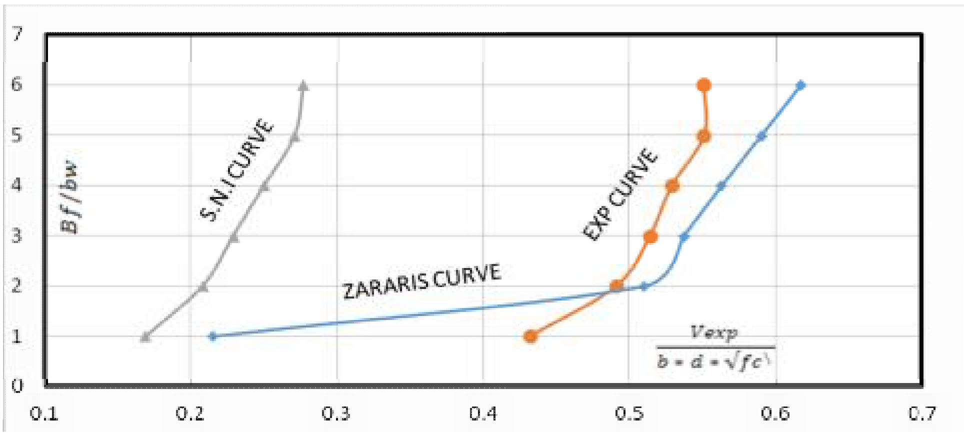

Figure (7): The relation between the flange width to web width ratio to the experimental and the analytical shear strength.

The relation between the flange width over web width to the experimental results was linear and increased gradually. When the flange width was equal $(B_{eff} = 2_{bw})$, shear strength was increased about 10% compared that R-section. When the flange width was equal $(B_{eff} = 3_{bw})$, shear strength was increased about 19% compared that R-section. When the flange width was equal $(B_{eff} = 4_{bw})$, shear strength was increased about 23% compared that R-section. When the flange width was equal $(B_{eff} = 5_{bw})$, shear strength was increased about 28% compared that R-section, while shear strength was remained constant after that which showed that, the shear strength was constant at $(B_{eff} = 6_{bw})$.

Zararis curve had results approaching real to the experimental results, and was over estimated to the experimental values about percentage equal 10 % according to the effective of flange width at T-sec, while was under estimated for R-section about percentage equal 50%, while S.N.I modified model had results were conservative to the experimental results and was under estimated to the experimental values about percentage from 42 to 50 %, according to effective of the flange width .

5.The SUMMARY AND CONCLUSION

Six R.C beams were subjected to two identical concentrated loads up to failure, one of the tested beams had a rectangle section, while the other five beams had
a T-section, which was noted the following conclusions:.

- The increase of the effective flange width over web width (B_1eff/b_1web) from $(B_1eff/b_1web) = 1$ to $(B_1eff/b_1web) = 6$ increased shear strength. The increase ranged from 10 to 30 % .
- The experimental results were compared with the Zararis model, and modified Stnandard National Indonesia analytical models.

Zararis model was over estimated to the experimental values about percentage equal 10 % according to the effective flange with, and S.N.I modified model was under estimated to the experimental values about percentage from 42 to 50 %, according to the effective flange width.

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