International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume –04, Issue – 12, December 2019, PP – 38-43

Effect of Thickness and Steel Fiber Ratio on Punching Shear Failure of Column Footing

Zainab Talib Jafaar, Zinah Waleed Abass, Shaimaa Hasan Fadhil
Mustansiriyah University, College of Engineering, Civil Department
Baghdad – Iraq

Abstract: This study is conducted to investigate effect of footing thickness(100,120 140 mm) and steel fiber ratio (0,1,1.5 %) on punching shear failure of self-compacting concrete(SCC)pad footing. The specimens were supported on a bed of steel(car)springs and loaded by vertical centric force. The results showed that the first crack load and ultimate load, ductility and strength improve as the thickness increase and failed by punching shear failure. After adding steel fiber with different ratio the result showed that the first crack load , ultimate load , strength and ductility increase with increasing of steel fiber ratio and failed by flexural punching failure, Also, It is noticed that failure of all specimens without steel fibers was sudden and brittle as compared to those with steel fibers in which failure was gradually.
Keywords: punching shear, footings, reinforced concrete *SCC*, steel fiber.

Introduction

The punching shear failure is un desirable in the slab-column or the footing-column connection. Punching shear failure is also named as diagonal tension failure,which appears in the form of inclined cracks at concentrated load or column support regions. According to (ACI 318) the critical section for punching shear failure is taken at d/2 from the face of the column, where d is the effective depth of footing. To avoid punching shear failure, it must be checking that the ultimate upward shear force at the critical section in the footing less than the shear resistance of concrete for the given percentage of concrete. Otherwise, reinforcement must be provided to resist punching shear. This type of failure is catastrophic because no external visible signs are shown before the failure occurrence. Punching shear failure disasters have occurred several times in the last decade. Extensive studies have been conducted for punching shearfailure of the flat slab in the past decades to enhance thepunching shear strength of the slab-column connectionhave been studied by using prestressing technic[1-3], steel strips with high ductility[4], fiber reinforced concrete [5-8], but the study onthe punching shear failure of footing-to-column connection is still limited [9–11].

Hallgren et al.[9] studied the effect ofinclined bent-up bars as shear reinforcementpunching shear strength.Hegger et al.[10] investigated the punching shear failure of five reinforced concrete footings with different thickness and reinforcement ratios supported on sand, Lee et al. [12] studied a new method to improve the strength and ductility of the footing by inserting steel funnel-shaped to act as Punching Shear Preventers (PSP) into the footing.Shill et al.[13] investigated the punching shear behavior of RC column footing using broken burnt clay bricks as coarse aggregate. After the application of 690 kN load on the footing, some cracks were developed at a distance about (Effective depth in mm /2)from the face of the column. The cracks around the column were considered as punching shear cracks.Whereas the flexural steel has an influence on the punching shearstrength of RC footing

This study focused on punching shear behavior of the footing –to- column connection. A total number of five specimens were constructed and tested in order to investigate the effect of footing thickness (D) and steel fiber ratio (SF %) on the punching shear strength and failure mode of footing.

Experimental Part

Fivereinforced concrete footing specimens were constructed and tested ,all five specimens had the same reinforcing bar layout($\rho = 0.0036$) and square shape with side length (1000mm). The specimens were divided in two groups. The first group included three footing (S_1, S_2, and S_3) without steel fiber and with different thickness,(100, 120, and 140 mm) respectively. The second group included three footing (S_2,S_4, and S_5) with constant thickness (120 mm) and different steel fiber ratio (0, 1, and 1.5%)respectively. Alltest specimenswere casted in the same time. The self- compacting concrete (SCC)mix (cement 290 kg/m^3, water 160 liter/m^3 , sand 814 kg/m^3, gravel 910 kg/m^3, limestone 190 kg/m^3 and super plasticizer 1%) used in this study.
The specimens were supported on a bed of steel(car)springs and loaded by vertical centric force which is applied by using universal testing machine of the type (EPP300MFL system) with capacity of 3000kn was

used,applying the load in steps 5kn. During the experiments, the strains in the reinforcement and vertical displacements at the center of footing edge were measured every load step.

Discussion of Experimental Results

1- Footing Punching Shear

First group (effect of footing thickness): This group consists of three specimens (S_1, S_2 and S_3) which are different in thickness(100 , 120 and 140) mm. The test results of these footings are illustrated in Table (1). During the testing procedure where the load was applied incrementally, springs became closed under the load of (50±1 kn) with no sign of failure was observed for all specimens. However, with load increasing first cracks started to appear in (S_1, S_2 and S_3) at (62.5, 64 and 66) kn respectively . The propagation of cracks was traced and marked without stopping the loading process till the final crack pattern was mapped in tension face as shown in figure (1). The results showed that the first crack load and ultimate load increase by increasing thickness of the specimens as shown in table (1) this behavior is good agreement with other[10,14,15]

Figure (2) shows the relationship between load and deflection at quarter span of the specimens. For each specimen, the general relationship between load and deflection for specimens is such that, initially almost linear elastic behavior at a low loading stage was observed. The load gradually increased up to failure, where after cracking the load and deflection curve is significantly changed. Also can be seen that the ductility and strength improve with increasing of thickness.

Table (1) Test Results of Specimens with Different Thickness

Specimens	Thickness D mm			First crack load (F.C.L) kN	Ultimate load (Pu) kN	Quarter span deflection at ultimate load mm
S_1	100	0.0036	21.2	62.5	88	1.41
S_2	120	0.0036		64	98	1.51
S_3	140	0.0036		66	113	1.62

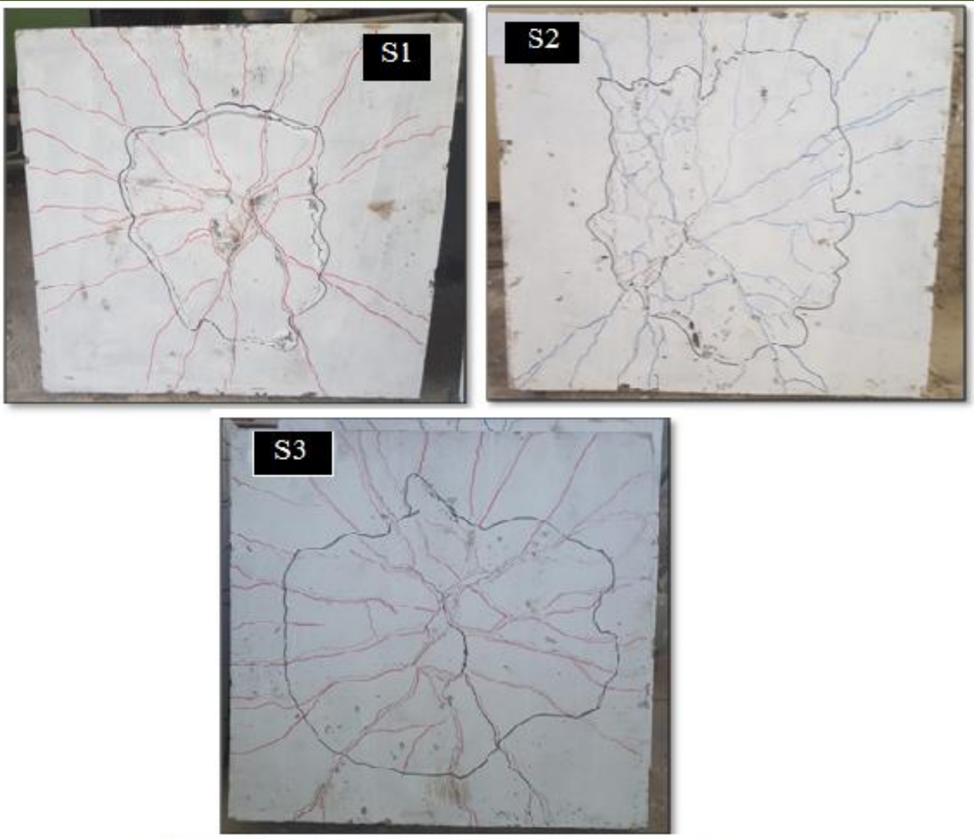

Figure (1): Crack pattern of footings with different thickness

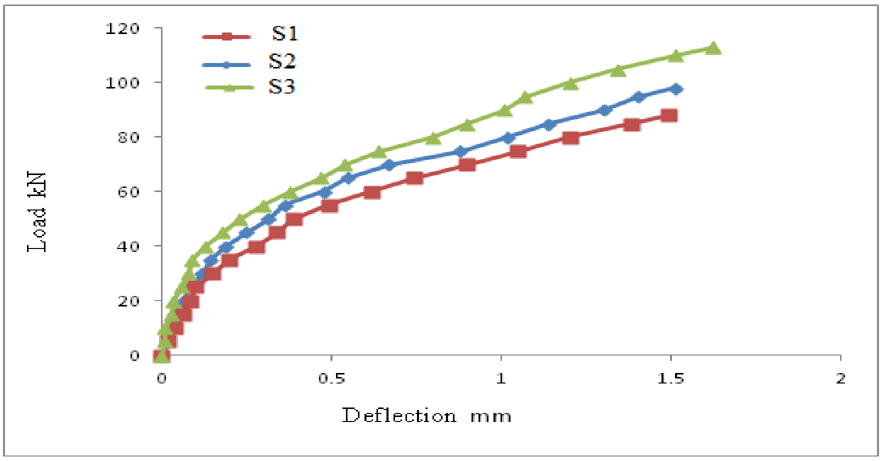

Figure (2) Load - deflection curve of specimens with different thickness

Second group (effect of steel fiber): This group consists of three specimens with different steel fiber volume ratio(S_2, S_4 and S_7) with constant thickness (120mm). The test results are given in Table (2). With increasing in applied load on specimens did not observe any crack before the springs closed as the previous case . Later, the first cracks started to appear in (S_2, S_4 and S_5) at (64,65.6 and 67.02) knrespectively . The radial cracks started to appear and extended from the center towards the slab edges in tension face as shown in figure (3). The results showed that the first crack load and ultimate load increase by increasing steel fiber volume ratio of the footing specimens as shown in table (2) similar behavior have been obtained by [16-18]. Figure (4) shows the relationship between load and deflection at the quarter span of the specimens is such, initially almost linear elastic behavior at a low loading stage was observed. The load gradually increased up to failure, where after cracking the load and deflection curve is significantly changed. Also can be observed a significant increase in strength and ductility with increasing of steel fiber ratio.

Table (2) Test Results of Footing with Different Steel Fiber Ratio

Specimens	Thickness D mm			First crack load (F.C.L) kN	Ultimate load (Pu) kN	Quarter span deflection at ultimate load mm
S_2	120	0.0036	21.2	64	98	1.51
S_6			24	71.5	150	1.75
S_7			25	72.5	159	1.97

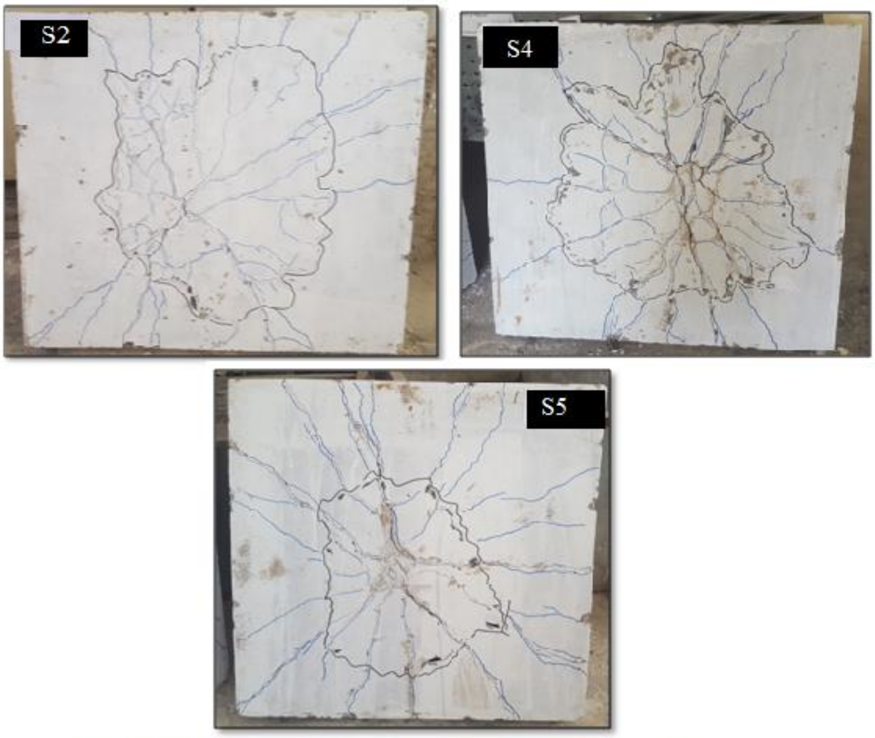

Figure (3): Crack pattern of footings with different steel fiber ratio

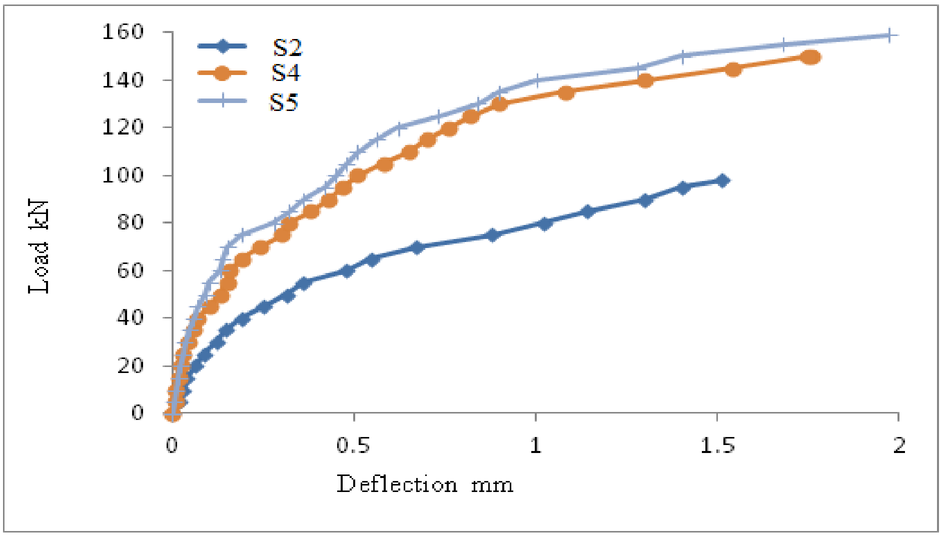

Figure (4) Load-deflection relationship of the footings with different steel fiber ratio

2- Mode of Failure

The punching failure is divided into two different types. The first one is shear failure that occurs suddenly with a small deflection. This type of failure is frequently observed in the footing or slab with a large flexural reinforcement ratio. The second type of failure mode is the flexural failure. This failure takes place when the flexural reinforcement ratio is small, and the footing or slab is failed by the yielding of the reinforcing bar [12,19,20]. To classify the failure mode of the specimens, the ultimate strain in the flexural reinforcing bar have been evaluated by strain gage which installed at the bottom of reinforcing bar as shown in table (3). It can be noted that the ultimate strain of flexural reinforcing bar of (S_1,S_2, and S_3) increases as the thickness increase but did not reach the yield strain. Thus, it failed by punching shear failure. With adding steel fibers the ultimate strain of flexural reinforcing bar of (S_4 and S_5) exceeded the yield strain and failed by flexural punching failure, which may be due to increasing the elasticity of concrete. It is worth pointing out here that the failure of all specimens without steel fibers was sudden and brittle as compared to those with steel fibers in which failure was gradually.Table (3) also shows that the area of the failure punching zone increase with increasing specimens thickness while decreasing with increasing of flexure reinforcement ratio

Table (3) Ultimate Strain and Mode of Failure

Specimens No.	Ultimate Strain in Reinforcing Bar	Yield Strain (ε_y)	Mode of Failure	Failure area (mm^2)
S_1	345.5	577	shear	211800
S_2	350.1		shear	363840
S_3	360.0		shear	374500
S_4	854.0		flexure	360730
S_5	860.0		flexure	246360

Conclusion

In this study the influence of thickness and steel fibers ratio of foundation was investigated experimentally**,** It was observed that**:**

1- The specimens reinforced with steel fibers exhibits more ductile than without steel fibersin which failure wassuddenly.
2- The area of failure zone depend on thickness and steel fiber ratio in specimens.
3- the mode of failure turned from punching shear to flexural punching after adding steel fibers.

References

[1]. M. F. Ruiz, Y.Mirzaei, and A.Muttoni, “Post-Punching Behavior of Flat Slabs”, ACI Structural Journal, Vol.110, No. 5, (2013)pp.801–811.

[2]. T. Cl´ement, A. P. Ramos, M. F. Ruiz, and A. Muttoni, “Designfor Punching of Prestressed Concrete Slabs”, Structural Concrete,Vol.14, No. 2, (2013)pp. 157–167.

[3]. T. Cl´ement, A. P. Ramos, M. F. Ruiz, and A.Muttoni, “Influence of Prestressing on the Punching Strength of Post-Tensioned Slabs”, Engineering Structures, Vol.72, (2014)pp. 56–69.

[4]. K. Pilakoutas and X. Li, “Alternative Shear Reinforcement for Reinforced Concrete Flat Slabs”, Journal of Structural Engineering,Vol. 129, No. 9, (2003)pp. 1164–1172.

[5]. P. J.McHarg, W. D. Cook,D.Mitchell, and Y. S. Yoon, “Benefitsof Concentrated Slab Reinforcement and Steel Fibers on Performance of Slab-Column Connections”,ACI Structural Journal, Vol.97, No. 2, (2000)pp. 225–234.

[6]. M.Y. Cheng and G. J. P. Montesinos, “Evaluation of Steel Fiber Reinforcement for Punching Shear Resistance in Slab Column Connections. Part I.MonotonicallyIncreased Load”, ACIStructural Journal, Vol. 107, No. 1, (2010)pp. 101–109.

[7]. M. H.Harajli,D.Maalouf, andH. Khatib, “Effect of Fibers on the Punching Shear Strength of Slab-Column Connections”, Cementand Concrete Composites, Vol. 17, No. 2, (1995)pp. 161–170.

[8]. L. N. Minh, M. Rovˇn´ak, T. T. Ngoc, and T. L. Phuoc,“Punching Shear Resistance of Post-Tensioned Steel Fiber Reinforced Concrete Flat Plates”, Engineering Structures, Vol. 45, (2012)pp.324–337.

[9]. M. Hallgren, S. Kinnunen, and B. Nylander, “Punching Shear Tests on Column Footings”, Nordic Concrete Research, Vol. 21, No.3, (1998)pp. 1–22.

[10]. J. Hegger, A. G. Sherif, and M. Ricker, "Experimental Investigations on Punching Behavior of Reinforced Concrete Footings",ACI Structural Journal, Vol. 103, No. 4, (2006)pp. 604–613.

[11]. J. Hegger, M. Ricker, and A. G. Sherif, "Punching Strength ofReinforced Concrete Footings", ACI Structural Journal, Vol. 106,No. 5, (2009)pp. 706–716.

[12]. S.S. Lee, J. Moon, K. S. Park, and K.W.Bae,"Strength of Footing with Punching Shear Preventers", Scientific World Journal, Vol. 2014, (2014)pp1- 15.

[13]. S. K. Shill, M. M. Hoque, M. Shaifullah, "Punching Shear Behavior of RC Column Footing on Stabilized Ground",International Journal of Engineering Technology, Management and Applied Sciences, Vol. 3,September (2015)pp.264-253.

[14]. K. F. Sarsamand H. F. Hassan, "Punching Shear Failure Characteristics of Flat Slabs Using Reactive and Modified Powder Concrete with Steel Fibers", Journal of Engineering and Development, Vol. 17, No.5, November(2013)pp.124- 140

[15]. G.Birkle , W.H.Dilger, "Influence of Slab Thickness on Punching Shear Strength", ACI Structural Journal, V. 105, No.2,March-April (2008)pp.180- 188.

[16]. A. M. Shaaban, andH. Gesund, "Punching Shear Strength of Steel Fiber Reinforced Concrete Flat Plates", ACI StructuralJournal, Vol.91, No.3, (1994)pp.406-414.

[17]. G. J.P. Montesinos, "Shear Strength of Beams with Deformed Steel Fibers" Concrete International, Vol. 28, No. 11, November (2006) pp. 57-66.

[18]. A.H. Aziz , S.S. Kareem ,B.Sahib, "Experimental Study for Punching Shear Behavior in RC Flat Plate with Hybrid High Strength Concrete", Journal of Engineering and Development, Vol. 17, No.3, August (2013)pp.95-109.

[19]. H. Marzouk and A. Hussein, "Experimental Investigation on the Behavior of High-Strength Concrete Slabs", ACI Structural Journal, Vol. 88, No. 6, (1991) pp. 701–713.

[20]. S. Guandalini, O. L. Burdet, and A.Muttoni, "Punching Tests of Slabs with Low Reinforcement Ratios" ACI Structural Journal, Vol.106, No. 1, (2009) pp. 87–95.