Cihan University-Erbil Scientific Journal (CUESJ)

RESEARCH ARTICLE

Study of Shear Transfer in Modified Push-off Members Using Finite Elements Method: A Comparative Study

Sabih H. Muhodir

Department of Architectural Engineering, Cihan University-Erbil, Kurdistan Region, Iraq

ABSTRACT

This paper aims to investigate numerically the behavior of modified push-off specimens under the action of direct shear stress. Based on the tow-dimensional finite element model developed in this research, the contribution of the aggregate interlock to resist the shear stress along the shear plane, the effect of existing of the compressive stress acting across the shear plane, the effect of the parallel reinforcement in resisting shear stress, the effect of the shear reinforcement parameter, the strains in the concrete and steel, and the actual distribution of the shear stress along the shear plane were studied. To verify the accuracy and applicability of the suggested finite element model, a comparison between the results obtained in this study and those obtained experimentally by other authors was carried out. Comparison showed that the finite element results were in good agreement with the experimental results. It has been found that, for modified push-off specimens of groups without shear reinforcement across the shear plane the diagonal tension crack within the shear plane occurred at the load level which is closely to the ultimate shear strength respectively, while for specimens with both shear and parallel reinforcement, the first crack formed at about (33.7–53.0%) of the ultimate strength, also the investigation showed that the presenting of the shear reinforcement normal to the shear plane are significantly increased the shear transfer stress for all levels of loading.

Keywords: Shear, aggregate interlock, finite element method, interface, modified push-off

INTRODUCTION

Shear transfer may be of high importance in many types of reinforced concrete members including ordinary and deep beams, slabs, corbels and brackets, shear walls and shear diaphragms and containment vessels of various types. Shear transfer is generally considered as a major mechanism of load transfer along a concrete-to-concrete interface under the action of shear or under the combination effect of shear and normal force.[1-3] Although the mechanism of the shear transfer, the ACI-318-19 provisions[4] depends mainly on the relation between the shear transfer and the reinforcement crossing the shear plane (clamping force), as well as on the resistance generated from the friction between two sliding faces along the shear plane which is depending contact surface condition and on the coefficient of friction of the concrete used. To calculate the shear strength provided by the sear reinforcement perpendicular to the shear plane, the stress is assumed to have reached to its yield stress f_y. This leads to the fact that the concrete contribution to resist the shear calculated using the ACI code equations increases compared to that provided by the shear reinforcement which is expressed as $V_n = \mu A_v f_y$, where V_n = nominal shear strength, A_v is the area of reinforcement crossing the assumed shear plane to resist shear, and μ is the coefficient of friction.[5,6] Depending on the previously published test results Hsu[7-10] developed a formula to predict the shear transfer strength of reinforced concrete members:

$$v_u = 0.822(f_c^{/})^{0.406}(\rho f_y)^c \qquad (1)$$

Where:

v_u = unit Shear strength (MPa)

$$c = 0.159(f_{cc}^{/})^{0.33} \qquad (2)$$

$f_{cc}^{/}$ = concrete compressive strength of 150 mm cube and taken as $\dfrac{f_c^{/}}{0.85}$

To this end the present study is concerned with an attempt to verify the validity of the ACI shear friction provision and to investigate the influence of the direct shear stress acting parallel and transverse to the shear plane on the shear transfer strength using the finite element method (FEM) and to investigate their

Corresponding Author:
Sabih H. Muhodir, Department of Architectural Engineering, Cihan University-Erbil, Kurdistan Region, Iraq.
E-mail: sabih.alzuhairy @cihanuniversity.edu.iq

Received: June 05, 2022
Accepted: August 03, 2022
Published: August 27, 2022

DOI: 10.24086/cuesj.v6n2y2022.pp81-88

role in the influencing the strength and deformation using the typical and modified push-off specimens.

The main objectives of this study are the following:

1. Study the contribution of the aggregate interlock to resist the shear stress along the shear plane
2. Study the effect of existing of the compressive stress acting across the shear plane
3. Study the effect of the parallel reinforcement in resisting shear stress
4. Study the effect of the shear reinforcement parameter
5. Investigating the strains in the concrete and steel and the actual distribution of the shear stress along the shear plane.

FAILURE CRITERIA

For formulation the failure criteria for concrete under combined states of stresses, one must agree on a proper definition of failure. Such criteria as yielding, initiation of cracking, load carrying capacity, and extent of deformation have been used to define failure.[11,12] In this study, failure is defined as first crack loading and load carrying capacity of the reinforced concrete element.

In general, concrete failure can be divided into tensile and compressive types. With respect to the present definition of failure, tensile failure defined by the formation of major cracks and the loss of tensile strength in concrete normal to the crack direction, while in compressive failure many small cracks develop and the concrete element loses most of its strength.

The Mohr-Coulomb criterion in the present study was used as a load carrying capacity criteria, this is dating from 1900 and states that the failure is governed by the relation.[13]

$$|\tau| = f(\sigma) \tag{3}$$

Where the limiting shearing stress τ is depending only on the normal stress (σ) in the same plane and at the same point, and where the equation (1) is the failure envelope for the corresponding Mohr-Circle.[9] The simplest form of equation (1) can be written as:[13]

$$|\tau| = C - \sigma_n . \tan\emptyset \tag{4}$$

Where:

τ: The shearing stress

σ_n: The normal stress (tensile stress is positive)

C: Cohesion

$\emptyset$: The angle of internal friction (tan $\emptyset$ used in this study is equal to 1.4 –normal weight concrete).[14]

In the principal –stress coordinate, the failure criterion (sliding criterion) given by equation (2) takes the form: [14]

$$\frac{1}{2}\sigma_1(1+\sin\emptyset) - \frac{1}{2}\sigma_3(1-\sin\emptyset) - C.\cos\emptyset = 0 \tag{5}$$

For $\sigma_1 \geq \sigma_2 \geq \sigma_3$[10]

$$\frac{\sigma_1}{f_t^{/}} = \frac{\sigma_3}{f_c^{/}} = 1 \tag{6}$$

In general, the Mohr-Coulomb criterion is a two-parameter model[13] where any combination of parameters, such as ($\emptyset$, c), ($f_c^{/}$, $f_t^{/}$), experimentally observed will be adequate to characterized completely the material behavior, so it is sometimes convenient to use the parameters $f_c^{/}$and m, where

$$m = \frac{1+\sin\emptyset}{1-\sin\emptyset} = \frac{f_c^{/}}{f_t^{/}} \tag{7}$$

The coefficient m for concrete is considered to be 4.1,[13] then Equation (3) can be written as[14,15]

$$m.\sigma_1 - \sigma_3 = 2.C.\sqrt{m} = f_c^{/} \quad (8)$$

Where:

$$m = [\frac{\cos\emptyset}{1-\sin}]^2 = \frac{1+\sin\emptyset}{1-\sin\emptyset} \tag{9}$$

and;

$$f_c^{/} = \frac{2.C.\cos\emptyset}{1-\sin\emptyset} \tag{10}$$

Therefore, the value of (C) used in equation (2) can be obtained using equation (10) in terms of $f_c^{/}$and angle of internal friction ($\emptyset$).

The failure criteria given by equation (4) holds for member with shear reinforcement by adding the contribution of the shear reinforcement which can be given by the reinforcement parameter ($\rho.f_y$) to the normal stress (σ_n), therefore,

$$|\tau| = C - (\sigma_n - \rho f_y)\tan\emptyset \tag{11}$$

MATERIAL AND SPECIMENS CHARACTERIZATION

The dimension and reinforcement of the reinforced concrete members (modified push-of-specimens) were selected to be similar to those specimens, whose behavior being investigated experimentally by Al-Sharae.[15]

The overall dimensions of the modified Push-off-specimens that were used in this study are of length (L = 650 mm) × width (B = 400 mm) × depth (D = 150 mm). The length of the shear

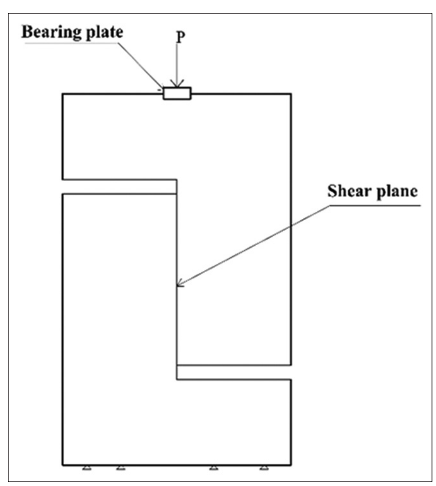

Figure 1: Typical push-off-specimen

plane remain constant for all specimens (i.e., the cross sectional area of the shear plane 150 mm × 300 mm) and the height of the slot is constant and equal to 25 mm as shown in [Figure 1]. In all specimens the shear reinforcement cross the shear plane at right angle. Additional reinforcement parallel to the shear plane is provided to prevent any failure other than along the specific shear plane. The specimens are loaded by concentrated (P), without moment. When the (p) applied concentrically in the modified push-off-specimen, the shear force along the shear plane will be (P. Cos ϴ) and a compressive normal force (P. Sin ϴ) across the shear plane. Five different values of (ϴ) was used to maintain different values of shear stress and transverse compressive stress (ϴ is the inclination of the upper point shear plane relative to the lower point). The details of specimens are summarized in [Table 1]. Therefore, the program of the shear transfer analysis is thus divided into the following three groups:

- Group SC
  Group with plain concrete specimens.
- Group SP
  Group reinforced with parallel to the shear plane reinforcement only as shown in [Table 1].
- Group SR (SR1, SR2, and SR3)
  Group with shear reinforcement placed at right angle to the shear plane as well as a parallel reinforcement is provided in the critical zone, [Table 1].

To study the effect of steel parameter ($\rho.f_y$), different steel ratios were used by changing the diameter of the shear reinforcement crossing the shear plane. The detailing of all groups is summarized in [Table 1]. The properties of concrete and reinforcement used in this study are tabulated in [Tables 2 and 3] respectively.

FINITE ELEMENT DESCRIPTION

In the finite element formulation, the choice of a proper element is very important and effects on the accuracy of the final results of the analysis. In the current study a nine nodded

Table 2: Properties of bars used[15]

Bar diameter ϕ (mm)	Area (mm²)	f_y (MPa)	Strain ε_y
8	50.27	410	0.002
10	78.54	412	0.002
12	108.54	410	0.002

Table 1: Details of specimens[15]

Spec. identity	ϴo	k-factor	Parallel rein.	Transvers rein.
SC00	0	0	None	None
SC10	10	0.174	None	None
SC20	20	0.34	None	None
SC30	30	0.5	None	None
SC45	45	0.707	None	None
SP00	0	0	4ϕ12	None
SP10	10	0.174	4ϕ12	None
SP20	20	0.34	4ϕ12	None
SP30	30	0.5	4ϕ12	None
SP45	45	0.707	4ϕ12	None
SR100	0	0	4ϕ12	6ϕ8
SR110	10	0.174	4ϕ12	6ϕ8
SR120	20	0.34	4ϕ12	6ϕ8
SR130	30	0.5	4ϕ12	6ϕ8
SR145	45	0.707	4ϕ12	6ϕ8
SR200	0	0	4ϕ12	6ϕ10
SR210	10	0.174	4ϕ12	6ϕ10
SR220	20	0.34	4ϕ12	6ϕ10
SR230	30	0.5	4ϕ12	6ϕ10
SR245	45	0.707	4ϕ12	6ϕ10
SR300	0	0	4ϕ12	6ϕ12
SR310	10	0.174	4ϕ12	6ϕ12
SR320	20	0.34	4ϕ12	6ϕ12
SR330	30	0.5	4ϕ12	6ϕ12
SR345	45	0.707	4ϕ12	6ϕ12

Table 3: Concrete properties[15]

Spec. identity	Cylinder compressive strength (MPa)	Modulus of rupture (MPa)
SC00	22.9	1.78
SC10	22.9	1.78
SC20	22.1	1.73
SC30	22.1	1.73
SC45	23.2	1.82
SP00	23.4	1.85
SP10	24.6	1.83
SP20	22.5	1.89
SP30	21.8	1.89
SP45	21.8	1.89
SR100	23.4	1.74
SR110	23.4	1.61
SR120	24.2	1.61
SR130	21.8	1.84
SR145	21.8	1.84
SR200	23.4	1.87
SR210	23.4	1.61
SR220	24.2	1.61
SR230	21.8	1.84
SR245	23.4	1.87
SR300	21.8	1.61
SR310	21.8	1.61
SR320	23.4	1.84
SR330	23.4	1.84
SR345	24.2	1.87

two-dimensional isoparametric quadrilateral elements with two degrees of freedom per node, as shown in [Figure 2], were used for all constituent materials (concrete and steel) in the modified push-off specimens' analysis.

In generating the finite element, mesh certain assumptions were made to simplify the complex geometry and to reduce the size of the mesh, such as, the interface between the concrete and steel was assumed.

RESULTS AND DISCUSSION

Cracking and Ultimate Strength

Three groups of specimens (SC, SP, and SR) were analyzed using finite element model suggested in this paper to study the shear transfer strength in the modified push-off specimens. In this study, the modulus of rupture (f_{cr}) and the Mohr-Coulomb criterion were used as a first cracking and ultimate strength criteria, respectively. Using the finite element model, it was found that, the group (SP) behaved to same manner to the specimens of group (SC). Results of the finite element analysis are shown in [Table 4].

For specimens with both shear and parallel reinforcement (groups SR), the first crack formed at about (33.7–53.0%) of the ultimate strength. Depending on the first crack criterion, these cracks occurred first almost at mid-length of the shear plane approximately. As lad increased, more cracks began appear throughout the shear plane with rapid propagation away from the mid-length of the shear plane approximately. Furthermore, it can be seen that the ultimate strength is increased as the external compressive stress (σ_{nx}) and reinforcement parameter (ρf_y) are increased. In general, characterized failure for specimens with shear and parallel reinforcement is ductile failure.

Al-Sharae,[15] in his experimental study found that, for modified push-off specimens with (Φ = 10 mm) as a main shear reinforcement, the diagonal tension crack within the shear plane occurred at about (51–55%) of the ultimate shear strength. Comparison of the results obtained in this study using FEM with those obtained experimentally by Al-Sharae[15] shows a good agreement as shown in [Table 4].

For specimens of groups (SC) and (SP), the first crack formed at about (87–95.02%) and (82.4–90.5%) of the ultimate strength, respectively, as shown in [Table 5]. Increasing in stiffness of group (SP) as compared with that of group (SC) can be attributed of the presenting of the parallel reinforcement within the critical zone. Al-Sharae,[15] in his experimental study found that, for modified push-off specimens of groups (SP and SC), the diagonal tension crack within the shear plane occurred

Table 4: F.E.M results of the modified push-off-specimen

Specimen's Identity	F.C.L* (KN)	F.L** (KN)	F.C.L/ F/L (%)
SC00	143.18	154.0	93
SC10	162.1	170.4	95.36
SC20	185.13	193.0	95.28
SC30	210	227.32	93.2
SC45	267.6	307.76	87
SP00	147.58	163.05	90.5
SP10	165.32	187.6	88.12
SP20	196.3	218.0	90
SP30	219.74	250.2	87.83
SP45	273.43	331.45	82.4
SR100	122.34	256.3	47.78
SR110	145.70	318.63	45.72
SR120	183	368.0	49.73
SR130	210.8	412.02	44
SR145	254.37	480.49	53
SR200	128.5	312.84	41
SR210	160	400.0	40
SR220	225.63	469.3	48.1
SR230	247.2	538.8	46
SR245	322.35	656.81	49
SR300	136.55	406	33.7
SR310	184.84	533.0	34.6
SR320	248.9	631.7	39.4
SR330	309.3	741.63	41.71
SR345	395.34	869.7	45.5

F.C.L: First crack loading, **F.L: Failure loading

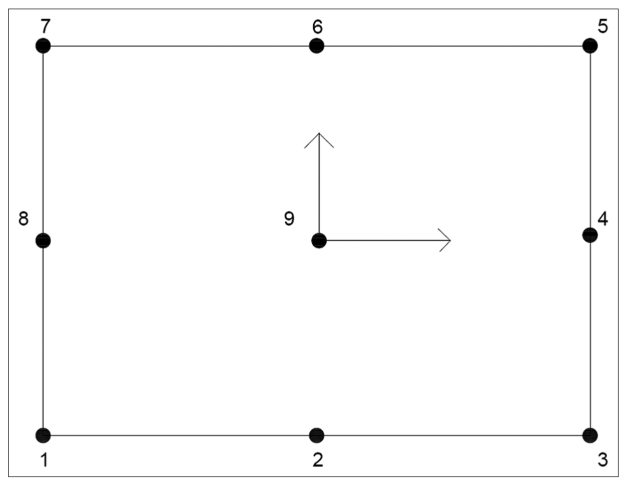

Figure 2: Typical two-dimensional isoparametric element

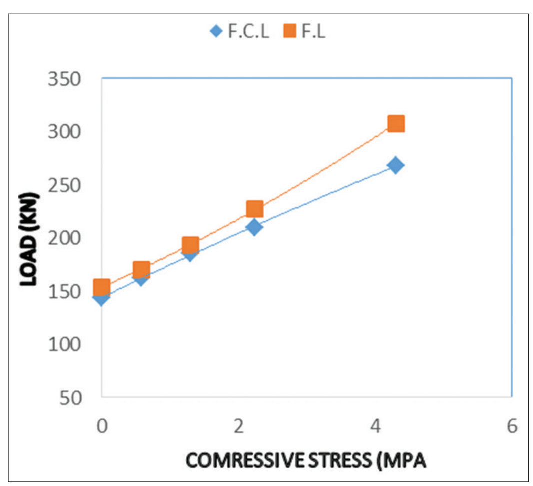

Figure 3: Load – normal compressive stress curve- group (SC)

Table 5: First crack loading and failure loading using F.E.M. and the experimental results by Al-Sharea[15]

Specimen's Identity	F.L (KN) EXP.[15] (1)	F.L (KN) F.E.M (2)	$\left(\frac{1}{2}\right)$	F.C.L. (KN) EXP.[15] (3	F.C.L (KN) F.E.M (4)	$\left(\frac{3}{4}\right)$
SC00	154.0	166.77	0.92	143.18	156.96	0.91
SC10	170.4	181.84	0.94	162.1	169.71	0.95
SC20	193.0	201.12	0.91	185.13	180.5	1.03
SC30	227.32	220.72	1.03	210	194.5	1.08
SC45	307.76	249.30	1.06	267.6	255.06	1.05
SP00	163.05	183.44	0.88	147.58	179.52	O.82
SP10	187.6	220.72	0.85	165.32	215.82	0.76
SP20	218.0	245.25	0.88	196.3	235.44	0.83
SP30	250.2	274.68	0.91	219.74	259.96	0.84
SP45	331.45	333.54	0.99	273.43	311.95	0.87
SR200	312.84	284.49	1.10	128.5	147.15	0.87
SR210	400.0	372.78	1.08	160	196.2	0.81
SR220	469.3	451.26	1.04	225.63	245.25	0.91
SR230	538.8	549.36	0.98	247.2	294.3	0.84
SR245	656.81	608.22	1.09	322.35	333.45	0.96
			σ_{n-1}=0.0849			σ_{n-1}=0.095

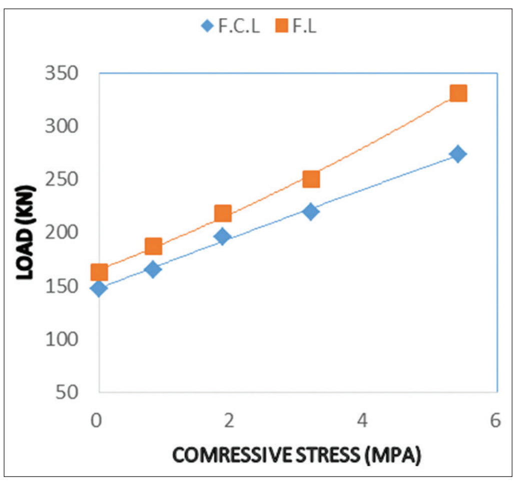

Figure 4: Load – normal compressive stress curve- group (SP)

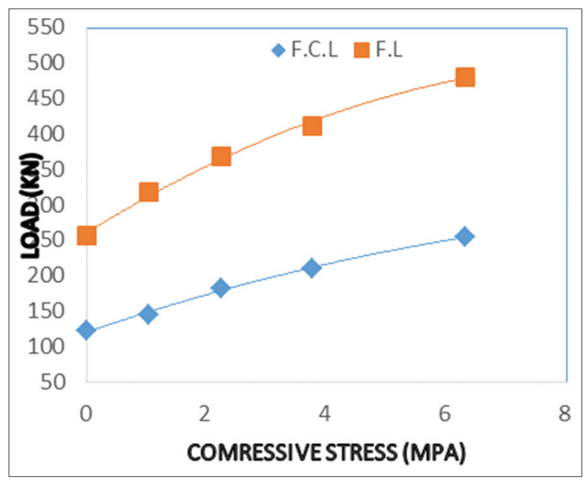

Figure 5: Load-normal compressive stress curve - group (SR1)

at about (76.0–95.0 %) and (93.0–98.0%) of the ultimate shear strength respectively, and this can be attributed to the absence of the shear reinforcement across the shear plane. [Table 5] shows the comparison of the results obtained by this study and those obtained experimentally by Al-Sharae.[15] In general, the agreement between the results is very good for some specimens and unstable for other specimens of groups (SP and SC). In general with help [Tables 4 and 5], it can be conclude that, the failure load increases with increase of the normal compressive stress (σ_{nx}) and reinforcement parameter (ρf_y) regardless of the specimen's group. Furthermore, it can be concluded that, the reinforcement parallel to the shear plane has a little effect on the shear transfer strength.

[Figures 3-7] show that the cracking loads versus normal compressive stress for groups (SC, SP, SR1, SR2, and SR3), respectively. From these figures, it can be noted that the reserve in strength after the formation of cracks is increased with increasing the external compressive stress (σ_{nx}). Furthermore, a large reserve in strength is obtained in the specimens reinforced with parallel and shear reinforcement, and is reduced a great deal when only plain concrete is present in the shear plane. The same behavior is obtained experimentally by Mattock and Hawkins[11] and Al-Sharae.[15] Comparisons of [Figures 3 and 4] show that the strength of specimens with the parallel reinforcement is higher than those of specimens made with the plain concrete only, but the reserve in strength is small, and in both groups failure occurred almost at a load closer to the first cracking load. Furthermore, it can be observed from [Figures 5-7] that the increase in strength with increase in (σ_{nx}) tends to stable for specimens in groups (SR).

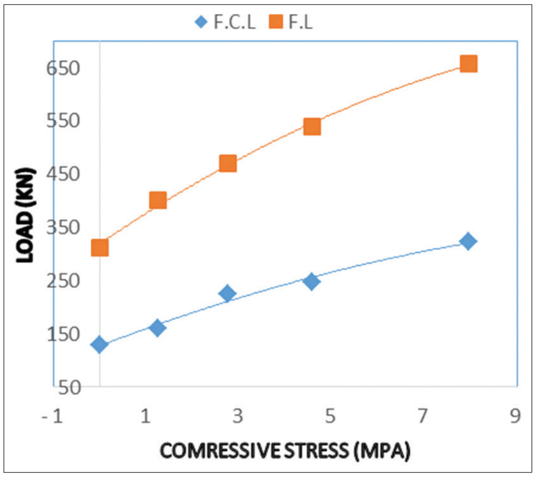

Figure 6: Load-normal compressive stress curve - group (SR2)

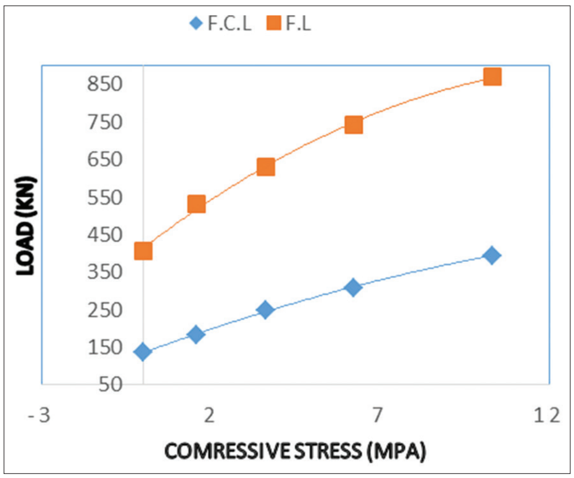

Figure 7: Load-normal compressive stress curve-group (SR3)

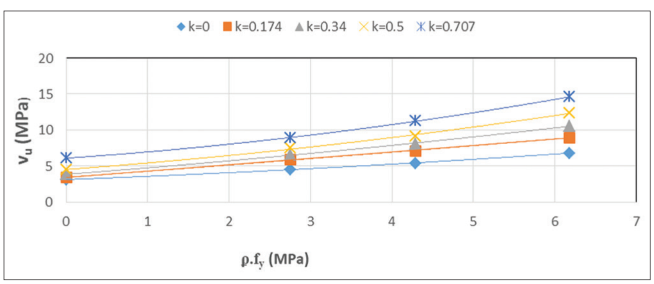

Figure 8: Effect of the reinforcement parameter ($\rho.f_y$) on the shear transfer stress (v_u)

In general, it can be concluded that the external compressive force will add clamping force, which resist the shear force; therefore, the shear transfer strength will increased with increasing this force.

Effect of the Reinforcement Parameter ($\rho.f_y$)

The reinforcement parameter ($\rho.f_y$) can be changed by varying either the reinforcement ratio (ρ), the reinforcement yield strength (f_y) or both. If the area of the shear plane constant (as

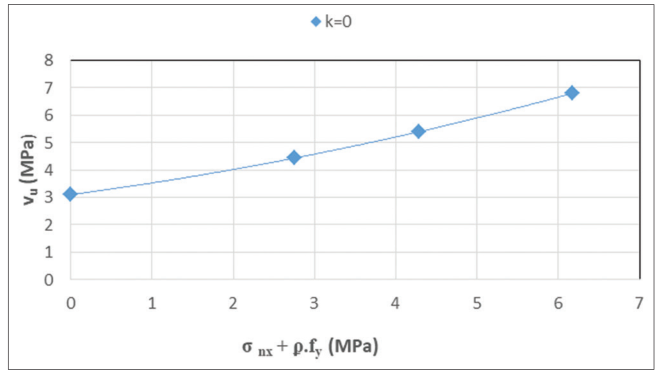

Figure 9: Max. shear stress-total normal compressive stress relationship (k=0)

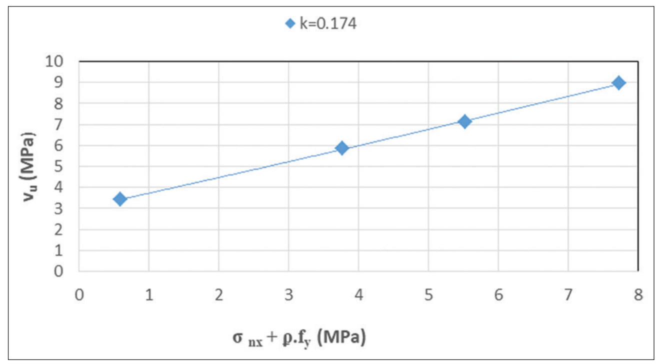

Figure 10: Max. Shear stress-total normal compressive stress relationship (k=0.174)

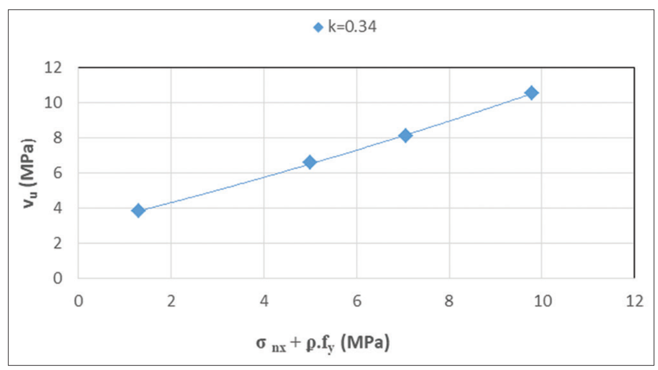

Figure 11: Max. Shear stress-total normal compressive stress relationship (k=0.34)

in this study), the reinforcement ratio (ρ) can be changed by changing the bar size and/or spacing between the bars crossing the shear plane. Mattock and Hawkins[9] stated that the way in which steel ratio chanced does not affect the relationship between shear stress and the reinforcement parameter ($\rho.f_y$). To study the effect of reinforcement parameter ($\rho.f_y$), three ratios of steel reinforcement have been used (2.75, 4.92, and 6.18) using three different bar diameters. (Ø8 mm, Ø10 mm, and Ø12 mm).

[Table 6 and Figure 8] presented the results of analysis using F.E.M of specimens of groups (SR1, SR2, and SR3). These results are studied and compared to determine the effect of this parameter. It was found that, for given values of ($k = sin\Theta$), the specimens with higher reinforcement parameter had

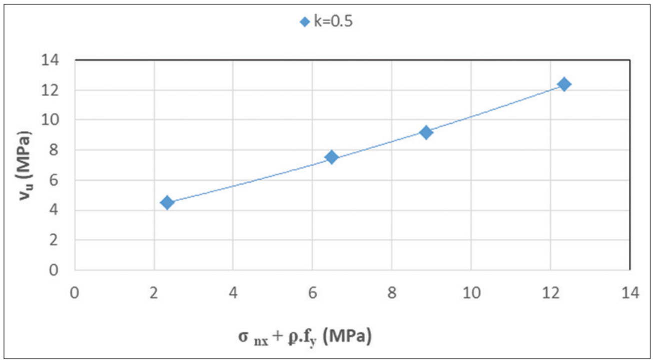

Figure 12: Max. Shear stress-total normal compressive stress relationship (k=0.5)

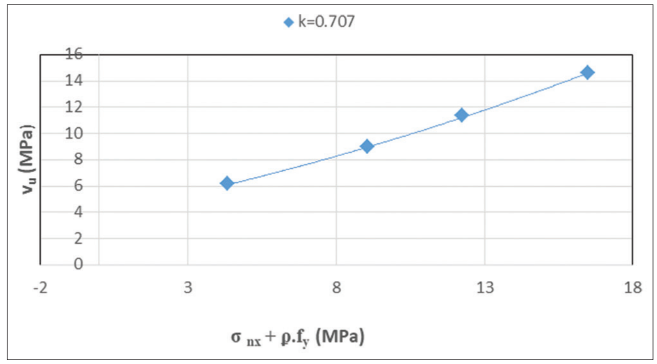

Figure 13: Max. shear stress -total normal compressive stress relationship, (k=0.7070)

Table 6: Results of (vu) using finite element method

Specimen's Identity	$f_c^{/}$ (MPa)	$\rho.fy$ (MPa)	σ_n (MPa)	$\sigma_n+_\rho.f_y$ (MPa)	v_u (MPa)
SC00	22.9	None	Zero	Zero	3.10
SC10	22.9	None	0.592	0.592	3.41
SC20	22.1	None	1.31	1.31	3.83
SC30	22.1	None	2.25	2.25	4.49
SC45	23.2	None	4.32	4.32	6.10
SP00	23.4	None	Zero	Zero	3.85
SP10	24.6	None	0.82	0.82	4.69
SP20	22.5	None	1.86	1.86	5.43
SP30	21.8	None	3.20	3.20	6.39
SP45	21.8	None	5.41	5.41	7.65
SR100	23.4	2.75	Zero	2.75	4.53
SR110	23.4	2.75	1.02	3.77	5.88
SR120	24.2	2.75	2.25	5.00	6.58
SR130	21.8	2.75	3.75	6.50	7.50
SR145	21.8	2.75	6.30	9.05	8.90
SR200	23.4	4.29	Zero	4.29	5.40
SR210	23.4	4.29	1.24	5.53	7.10
SR220	24.2	4.29	2.77	7.06	8.09
SR230	21.8	4.29	4.58	8.87	9.16
SR245	23.4	4.29	7.97	12.26	11.27
SR300	21.8	6.18	Zero	6.18	6.80
SR310	21.8	6.18	1.55	7.73	8.95
SR320	23.4	6.18	3.61	7.79	10.55
SR330	23.4	6.18	6.19	12.37	12.37
SR345	24.2	6.18	10.3	16.48	14.57

higher shear strength than specimens without or with lower reinforcement parameter. Results presented by [Figure 8 and Table 6] show that the presenting of the shear reinforcement normal to the shear plane are significantly increased the shear transfer stress by (46.2%, 74.02%, and 119.4%) when groups (SR1, SR2, and SR3) are compared to the unreinforced specimens of group (SC) for k=0 (i.e., σ_{nx} =0). This increasing in the shear strength can be attributed to the clamping force which is developed in the reinforcing bars within the yield range when diagonal cracks appear.

Effect of Total Normal Compressive Stress ($\sigma_{nx}+\rho f_y$)

[Figures 9-13] and [Table 6] show the effect of total normal compressive stress ($\sigma_{nx}+\rho f_y$) on the shear transfer strength.

Table 7: Comparison of v_u Using F.E.M and v_u Experiment

Specimen's Identity	v_u, F.E.M. (MP) (1)	v_u, Experim[15] (MPa) (2)	$\left(\frac{2}{1}\right)$
SC00	3.10	3.69	1.19
SC10	3.41	3.98	1.17
SC20	3.83	4.46	1.16
SC30	4.49	4.87	1.09
SC45	6.10	6.54	1.08
SP00	3.85	4.06	1.05
SP10	4.69	4.84	1.03
SP20	5.43	5.45	1.01
SP30	6.39	6.04	0.94
SP45	7.65	7.34	0.96
SR200	5.40	6.26	1.16
SR210	7.10	7.91	1.12
SR220	8.09	9.76	1.22
SR230	9.16	11.92	1.30
SR245	11.27	13.52	1.21
			σ_{n-1}=0.102

With reference to this figure, it can be noted that the presence of external normal compressive stress (σ_{nx}) and shear reinforcement within the shear plane enhanced dramatically the shear transfer strength of the specimens used when compared with the those without shear reinforcement or those include parallel reinforcement only. Furthermore, it can be concluded that the external normal compressive stress is additive to the reinforcement parameter (ρf_y) finally it can be concluded that, if a certain shear stress is to be resisted, the area of shear reinforcement can be reduced by an amount equal to the external compressive force (σ_{nx}) divided by (f_y).

Efficiency of the FEM

To verify the accuracy of the finite element model suggested in this study to the shear transfer analysis, the obtained results are compared with those obtained experimentally by Al-Sharae.[15] The experimental results obtained by Al-Sharae,[15] ($v_{u,\ test}$) and that obtained by the finite element, ($v_{u,\ cal.}$) are summarized in [Table 7].

The standard deviation value (σ_ (n-1)) for (v_ (u, Test)/v_ (F.E.M)) is 0.102, this indicates that the predicted shear strength using FEM is very effective and gave a clear picture about the behavior of the push-off specimens.

CONCLUSIONS

Based on the results presented in this study, the following conclusions can be stated.

1. The two dimensional isoparametric element used in the mesh of the FEM is quite efficient in idealizing the field of displacement and the state of stresses in the modified push-off specimens with and without shear reinforcement.
2. Specimens with shear reinforcement (i.e., group SR) ad a ductile failure, while the specimens without shear reinforcement (i.e., groups SC and SP) had a brittle failure.
3. The parallel reinforcement has a little or ignored effect on the shear transfer strength.
4. An externally applied compressive normal strength which acting transversely to the shear plane is additive to the reinforcement parameter ($\rho.f_y$) in the calculation of the shear strength.
5. Shear strength is increased with increasing the total compressive stress. ($\sigma_n + \rho.f_y$).
6. FEM results showed a good agreement with those obtained experimentally by other authors.

REFERENCES

1. L. Ahmed and A. Ansell. Direct shear strength of high strength fiber concrete. *Magazine of Concrete Research*, vol. 62, no. 5, pp. 379-390, 2010.
2. P. M. D. Santoa and E. N. B. Julio. A state-of-the-art review on shear friction. *Engineering Structures*, vol. 45, no. 1, pp. 435-448, 2012.
3. K. H. Yang, J. I. Sim, J. H. Kang and A. F. Ashour. Shear capacity of monolithic concrete joints without transverse reinforcement. *Magazine of Concrete Research*, vol. 64, no. 9, pp. 767-779, 2012.
4. K. A. Harries, G. Zeno and B. Shahrooz. Toward an improved understanding of shear-friction behavior. *ACI Structural Journal*, vol. 109, no. 6, pp. 835-844, 2012.
5. K. N. Rahal. Simplified design and capacity calculation of shear strength in reinforced concrete membrane elements. *Engineering Structures,* vol. 30, no. 10, pp. 2782-2791, 2008.
6. American Concrete Institute. *ACI Committee 318, Building Code Requirements for Structural Concrete* (*ACI 318-19*) *and Commentary*. American Concrete Institute, Farmington Hills, MI, USA, 2019.
7. T. T. C. Hsu. Unified approach to shear analysis and design. *Cement and Concrete Composites*, vol. 20, no. 89, pp. 419-435, 1998.
8. B. J. Al-Sulayvani and J. R. Al-Feel. Effect of direct compressive stress on the shear transfer strength of fibrous concrete. *Al Rafidain Engineering*, vol. 17, no. 2, pp. 65-75, 2009.
9. S. Mahmoodreza and B. E. Ross. Database evaluation of interface shear transfer in reinforced concrete members. *ACI Structural Journal*, vol. 114 no. 2, pp. 383-394, 2017.
10. M. Soltani, B. E. Ross and A. Khademi. A statistical approach to refine design codes for interface shear transfer in reinforced concrete members. *ACI Structural Journal*, vol. 115, no. 5, pp. 1341, 2018.
11. A. H. Mattock and N. M. Hawkins. Shear transfer in reinforced concrete-recent research. *PCI Journal*, vol.17, no. 2, pp. 55-75, 1972.
12. R. N. Khaldoun. Shear-transfer strength of reinforced concrete. *ACI Structural Journal*, vol. 107, no. 4, p. 346, 2010.
13. W. F. Chen. *Plasticity in Reinforced Concrete*. McGraw Hill, New York, 1982.
14. E. Hinton and D. R. J. Owen. *Finite Element Programming*. Vol. 90. Academic Press, Inc., Cambridge, p. 345, 1977.
15. A. J. Al-Sharae. *Experimental and Analytical Study of Shear Transfer in Reinforced Concrete Members Made with Abu-Ghar Limestone as a Coarse Aggregate*. M.Sc. Thesis, University of Basrah, Iraq, 1999.