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Experimental Investigation on the Effect of the Use of Steel Wire Meshes on Shear Transfer Strength of Reinforced Concrete Push-Off Specimens

Lect. Nibras N. Al-Chalabi
Civil Engineering Department
Al-Mustanseriya University

Abstract

Using push-off specimens with shear plan length of 200mm and depth of 100mm, the influence of the addition of relatively widely spaced layers of steel wire meshes on shear transfer strength of reinforced concrete was experimentally investigated in this study. Eleven push-off specimens were fabricated and were divided into three groups depending on the number of layers of wire meshes crossing the shear plan. The other studied parameters were the shear parameter of the conventional stirrups (ρf_y) and the angle of the plan of the steel wire mesh layers to shear plan of the push-off specimens.

The test results showed that the use of relatively widely spaced (about 40mm) steel wire meshes has only trivial effect on shear transfer strength of reinforced concrete, where the percentage increase in shear transfer strength was about 8% in best cases. While using steel wire meshes in combination with conventional shear reinforcement (stirrups) gave better results, the percentage increase was about 13% compared to specimens reinforced with the same amount of stirrups but without steel wire meshes.

الخلاصة

إستخدمت في هذا البحث نماذج خاصة (Push-off) ذات مستوى قص بطول 200 ملم وعمق 100ملم لدراسة تأثير إضافة طبقات متباعدة نسبياً من مشبكات أسلاك حديدية على مقاومة انتقال القص في الخرسانة المسلحة. تم استخدام 11 نموذجاً قسمت الى ثلاثة مجاميع إعتماداً على عدد طبقات مشبكات الأسلاك الحديدية. العوامل الأخرى التي تم دراستها هي مقدار معامل القص (ρf_y) لحديد القص التقليدي (الأترية) بالإضافة الى زاوية مشبكات الأسلاك الحديدية مع مستوى القص للنماذج.

أظهرت النتائج أن استخدام طبقات متباعده نسبياً (حوالي 40 ملم) من مشبكات أسلاك حديدية له تأثير متواضع على مقاومة انتقال القص للخرسانة المسلحة, حيث كانت نسبة الزيادة في مقاومة انتقال القص حوالي 8% في أفضل الحالات. بينما أظهرت النتائج أن استخدام هذه المشبكات مع حديد القص التقليدي (الأترية) يعطي نتائج أفضل, حيث أن نسبة الزيادة بلغت 13% مقارنة مع نماذج مسلحة بنفس الكمية من الأترية ولكن بدون مشبكات الأسلاك الحديدية.

Introduction:

It is known that the common type of shear failure in reinforced concrete members occurs by diagonal tension cracking. However, in some circumstances, reinforced concrete members may fail by direct shear transfer along a definable plan. Such type of failure occurs where crack presence along a definite plan or between concrete and steel (such as steel brackets fixed to concrete column), at interface between two types of concrete, at interface between concretes cast at different times, and commonly considered in the vicinity of connections of precast concrete structures.

Conventional steel reinforcement crossing the shear plan is used to prevent cracking along the shear plan or arrest the existing or potential crack and to resist the slippage of the two faces of the crack. Other reinforcing materials such as fibers and steel wire meshes can be used to contribute in shear transfer strength of reinforced concrete members.

The possibility of using of relatively widely spaced small diameter steel wire meshes as shear transfer sub-reinforcement in reinforced concrete members is examined in this study using push-off specimens.

Experimental Program:

The experimental program of this study consisting of preparation and testing of eleven push-off specimens, the specimen's length and width were 440 mm and 200 mm respectively, while the specimen thickness was 100 mm. Figure (1) shows the specimen detailing. The eleven push-off specimens were divided into three groups depending on the main variables, the number of steel wire meshes and stirrup legs as detailed in Table (1). Another variable is the angle of the steel wire meshes plan to shear plan which was in the order of (30^o, 45^o and 90^o).

The concrete mix was designed as grade 25, the mix proportion by weight was (1:1.5:3) of (cement: sand: gravel) and with water-cement ratio of 0.5. The cement was ordinary Portland cement, while the sand was from Rahhalia (Anbar Region) with maximum size 4.75mm and the gravel was crushed with maximum size of aggregate of 10 mm. Mild galvanized steel welded wire meshes with 6.3 mm square openings were used in this study. The diameter of the steel mesh wires was 0.8 mm, while the physical properties of the steel mesh wires (tested by reference 1) are given in Table (2).

The push-off specimens were concentrically tested at age of 28 days using a 300 kN capacity hydraulic testing machine. With each concrete, mix six standard 150×300 mm cylinders were prepared and tested as control specimens to find concrete compressive strength and static modulus of elasticity. The test results of control specimens are given in Table (3).

Results and Discussion:

The test results of the push-off specimens are recorded in Table (3), and shown in Figures (2) to (7).

Cracking patterns of push-off specimens:

The push-off specimens were over reinforced away from the shear plan to prevent failure other than along the shear plan (2). The failure was in general by longitudinal cracking along the shear plan. In most cases the crack initiated at the corner of the slots where shear plan starts and at loads of about 0.63 to 0.74 of the ultimate failure load. As load increased the crack propagated towards the opposite corner of the second slot. In some cases, only one primary crack was observed at final stages of loading along the shear plan. In other cases, two parallel primary cracks were observed along or adjacent to the shear plan. These cracks were mostly accompanied with few and short diagonal cracks. The crack width at failure load was recorded to be in the range of about 1.1 mm to 2.5 mm. Also, Crushing of concrete at corners of slots was noticed in some cases.

Effect of conventional steel stirrups:

The effect of the presence of conventional shear reinforcement (stirrups) which are vertical and have a yield strength of 345 MPa on shear transfer strength of the tested push-off specimens is illustrated in Figure (2). The results of this study completely confirm with many previous studies (2, 3, 4, 5) where it was recorded that as the shear reinforcement parameter (ρfy) increases the shear transfer strength increase. When steel stirrups were used perpendicular to shear plan with ρfy of 3.85 MPa, the shear transfer strength gained about 55% increase compared to specimens without stirrups.

As the shear parameter ρfy duplicated to 7.7 MPa, the shear transfer strength jumped to about 115% compared to specimens without shear reinforcement. Similar results were recorded in previous studies (4, 5). Where it was shown that when stirrups were used with ρfy of (3.66 and 7.32 MPa), the increase in shear transfer strength of push-off specimens was in the range of (59% to 61%) and (97% and 105%) respectively.

Effect of steel wire meshes:

Figure (3) and Figure (4) illustrate the effect of the use of small diameter (0.8 mm) steel wire meshes on shear transfer strength of concrete. Figure (3) shows the improvement in shear transfer strength (Vu) in (MPa) of push-off specimens due to the use of 2 layers and 4 layers of steel wire meshes as shear reinforcement on different angles to shear plan. It is observed that shear transfer strength of specimens reinforced with steel wire meshes as shear reinforcement was only slightly greater than specimens without any shear reinforcement.

The shear transfer strength in best case increased from 6.6 MPa for specimens without shear reinforcement to 6.9 MPa for specimens with two layers of steel wire meshes. When 4 layers of steel wire meshes were used, the shear transfer strength increased to 7.15 MPa. Figure (4) shows these results in terms of percentage increase in shear transfer strength, which shows that the best percentage increase in shear transfer strength was 4.5% for two layers of steel wire meshes and 8.3% for four layers. This mean that more layers of steel wire meshes are required along a shear plan length of 200mm to optimize the best use of steel wire meshes as shear reinforcement (direct shear).

However, a percentage increase of about 8% seems to be satisfactory for layer spacing of about 40mm. Note that because of the presence of heavy conventional steel reinforcement and coarse aggregates with maximum particles greater than wire mesh openings, it is practically difficult to use large number of closely spaced steel wire mesh layers in reinforced concrete members compared to ferrocement members.

Effect of steel wire meshes orientation to shear plan:

Figure (3) shows the effect of the angle of the wire mesh layers to the shear plan on the shear transfer strength of push-off specimens. Three angles of 30^o, 45^o and 90^o were depended to investigate this effect. It is shown in the figure that an angle of 45^o to shear plan gave higher shear transfer strength than angles of 30^o and 90^o. However, the difference is relatively small. The shear transfer strength of specimens with two layers of steel wire meshes and without stirrups was in the sequence of (6.8, 6.9 and 6.85 MPa) for angles of (30^o, 45^o and 90^o) respectively.

For specimens with four layers of steel wire meshes, the shear transfer strength for the same sequence of angles were (6.95, 7.17 and 7.02 MPa) respectively. Figure (4) shows the same results in terms of percentage increase in shear transfer strength compared to specimen without stirrups and wire meshes. From the observation of the two figures it can be concluded that the orientation of steel wire meshes to the shear plan (between 30^o and 90^o) has only minimal effect on shear transfer strength of push-off specimens.

Combined effect of stirrups and steel wire meshes:

As discussed previously in this paper, the use of conventional steel stirrups improves shear transfer strength significantly reaching more than 100% increase when ρfy of 7.7 MPa was used. On the other hand, the use of steel wire meshes had only slightly increased shear transfer strength by about 12%.

The combined effect of stirrups and steel wire meshes was studied using specimens reinforced with two legs of stirrups (ρfy =3.85MPa) and with two layer or four layers of steel wire meshes. Figure (5) shows the combined effect of two legs of stirrups with two or four layers of steel wire meshes.

Figure (6) shows the percentage increase in shear transfer strength due to the use of steel wire meshes with two legs of stirrups. It was recorded that shear transfer strength of push-off specimen with two legs of stirrups only was 10.25MPa. When two layers of were added, the shear transfer strength raised to 11.05MPa with a percentage increase of about 8% compared to specimens reinforced with legs of stirrups only. When the number of steel wire meshes layers crossing the shear plan was duplicated to four, the shear transfer strength increased by about 13% compared to specimens reinforced with legs of stirrups only reaching about 11.6 MPa.

Comparing these percentages of increase with the percentages of increase due to the use of two or four layers of steel wire meshes without stirrups (3.8% and 6.4%) respectively, it is noticed that the use of steel wire meshes in combination with conventional steel stirrups gave higher percentages of increase in shear transfer strength. This leads to a conclusion that the use of steel wire meshes as a partial replacement of conventional steel stirrups gives better results (higher shear transfer strength) than pure reinforcing with steel wire meshes. Figure (7) shows a comparison between the percentage increase in shear transfer strength due to the use of steel wire meshes with and without steel stirrups.

Conclusions:

Within the limits of the studied parameters in this experimental study, the following can be concluded.

1. The use of steel wire meshes has a limited effect on shear transfer strength of push-off specimens. For shear plan length of 200mm, the use of four layers of galvanized steel welded wire meshes crossing the shear plan led to a maximum increase in shear transfer strength of about 8% only compared to specimens without any shear reinforcement.

2. The use of steel wire meshes in combination with conventional steel stirrups resulted in higher percentage increase in shear transfer strength (about 13%) compared to specimens reinforced with steel wire meshes only (less than 7%).

Table (1): Push-off Specimens Properties.

Specimen No.	No. of Wire Mesh Layers	No. of Shear Legs	Shear Parameter r(ρf_y) (MPa)	Angle of Wire Meshes
R0 R2 R4	0	0 2 4	0 3.85 7.7	- - -
A0-90 A0-45 A0-30 A2-90	2	0 0 0 2	0 0 0 3.85	90 45 30 90
B0-90 B0-45 B0-30 B2-90	4	0 0 0 2	0 0 0 3.85	90 45 30 90

Table (2): Physical Properties and Chemical Composition of Steel Wire Meshes[1].

Diameter mm	Physical Properties			Chemical Composition			
	f_y MPa	f_u MPa	E GPa	M_n %	Al%	Si%	Fe%
0.8	170	240	85	0.1584	< 0.35	0.26	84.63

Table (3): Test Results of Push-off Specimens and Control Specimens.

Specimen No.	Failure Load (kN)	Shear Transfer Strength (MPa)	f'_c (MPa)	E_c (GPa)
R0 R2 R4	132 205 283	6.6 10.25 14.15	25.2	28
A0-90 A0-45 A0-30 A2-90	137 138 136 221	6.85 6.9 6.8 11.05	26.0	28
B0-90 B0-45 B0-30 B2-90	140.5 143 139 232	7.02 7.15 6.95 11.6	26.7	28

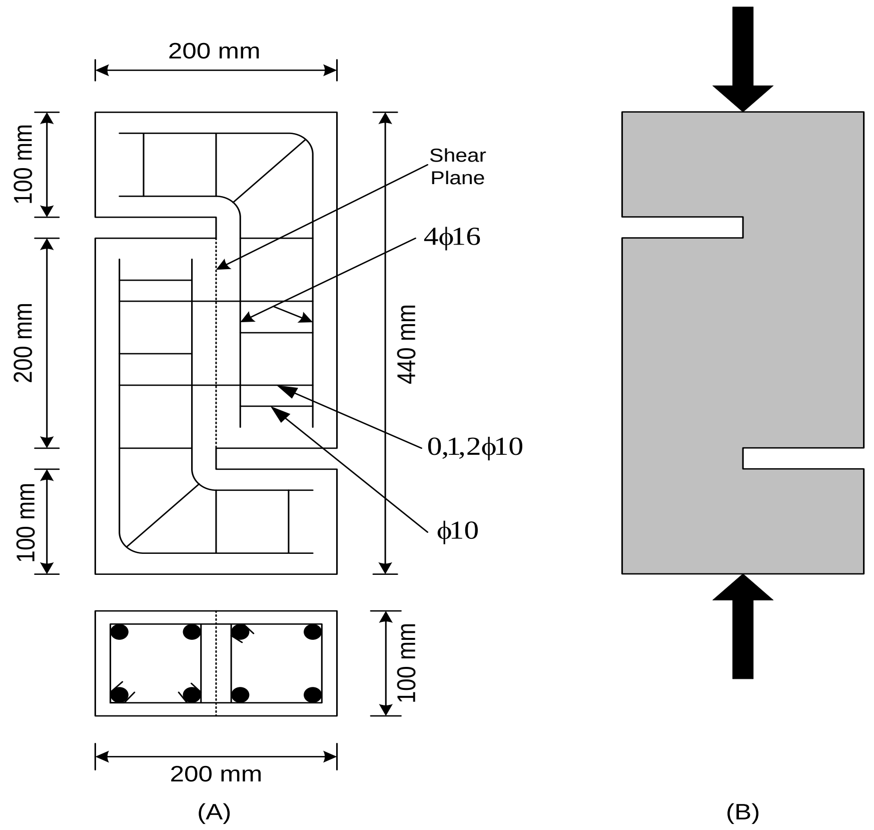


Figure (1) (A) Dimensions And Reinforcement Details Of Push-Off Specimen. (B) Loading Arrangement Of Push-Off Specimens.

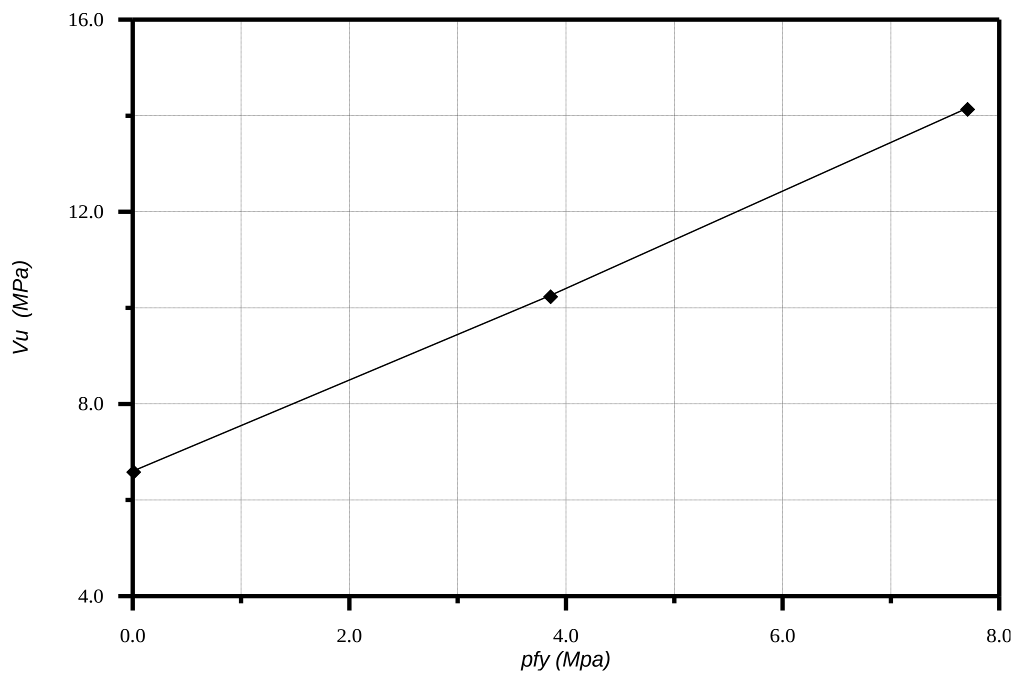
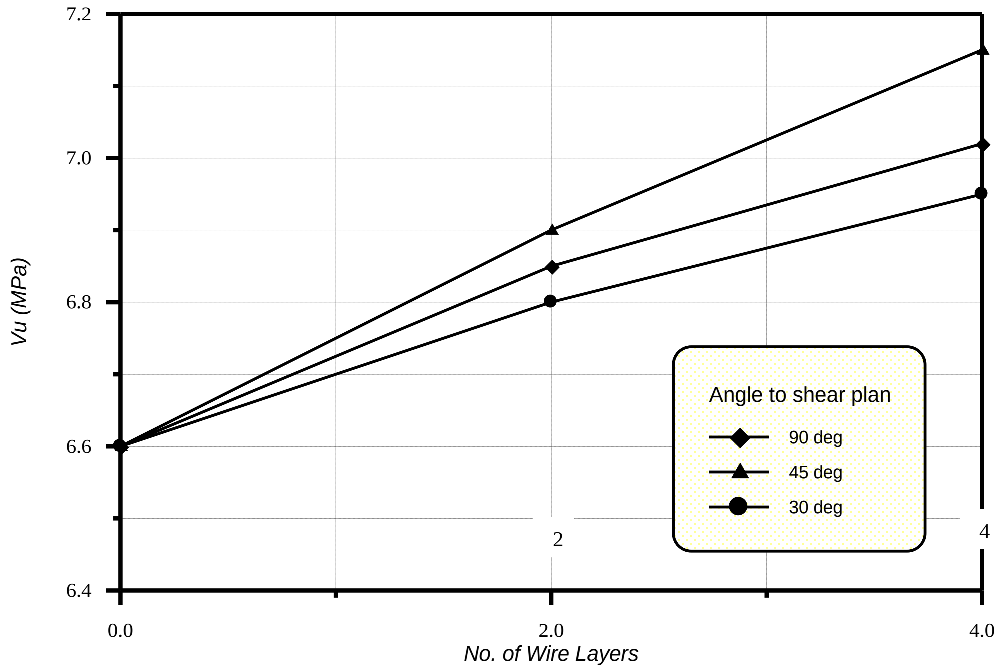
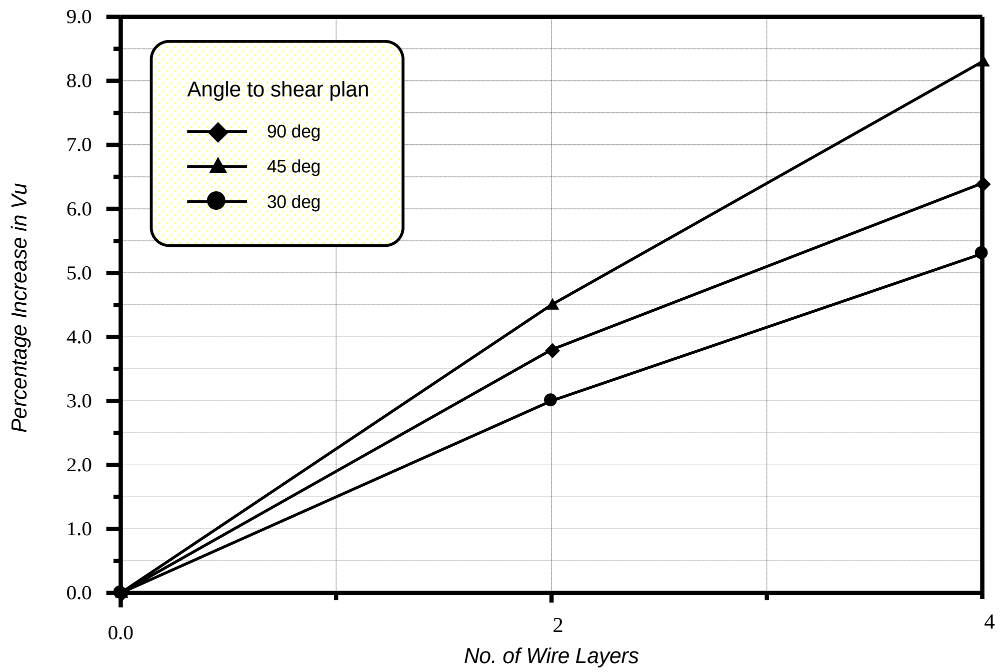


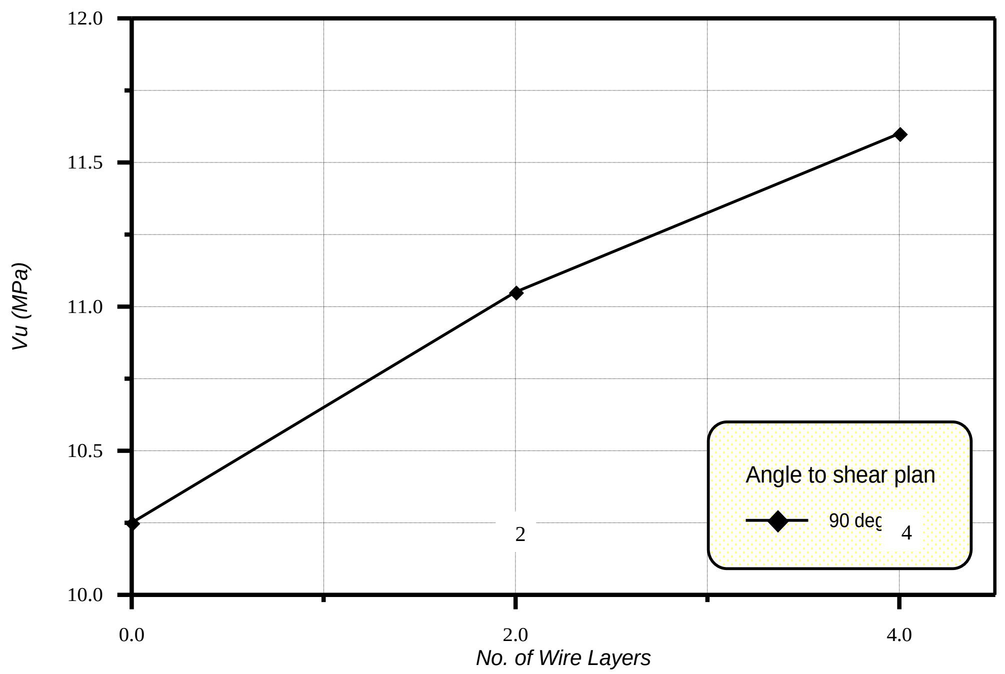
Fig (2) Effect Of Stirrups On Shear Transfer Strength Of Push-Off Specimens.



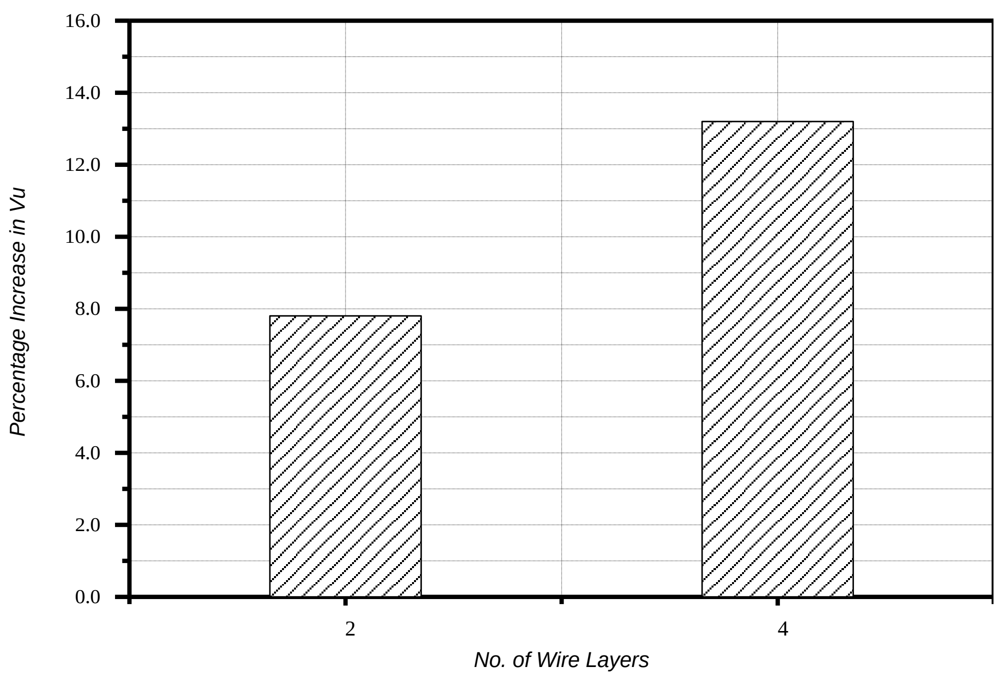
Fig(3) Effect Of Number Of Steel Wire Mesh Layers, Different Angles



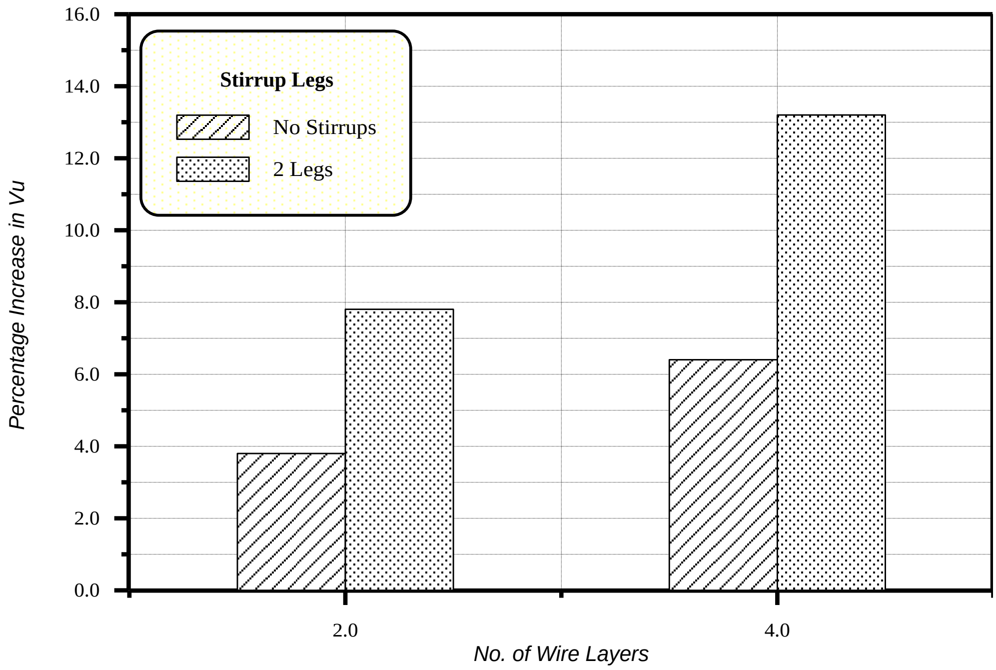
Fig(4) Percentage Increase In Shear Transfer Strength Due To Use Of Steel Wire Mesh Layers.



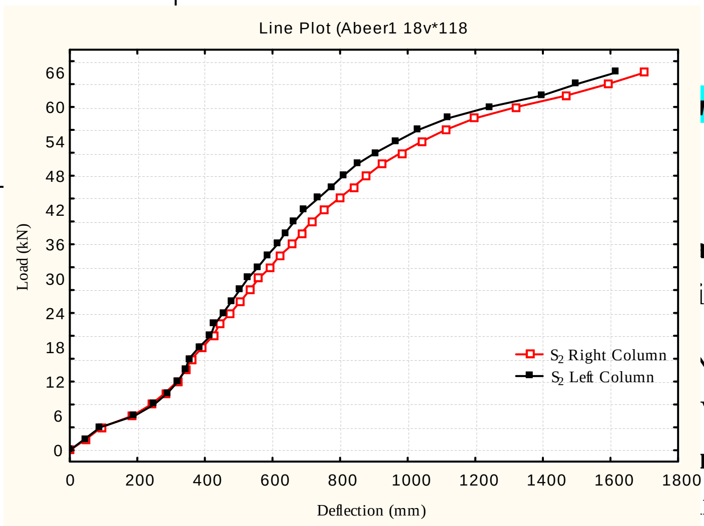
Fig(5) Combined Effect Of 2legs Of Stirrups And Different Layers Of Wire Meshes.



Fig(6) Percentage Increase Due To Wire Mesh Layers For Specimens With 2 Legs Of Stirrups



Fig(7) Percentage Increase Due To Wire Mesh Layers For Specimens Without Stirrups And With 2 Legs Of Stirrups



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