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RESEARCH ARTICLE

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PARAMETRICAL STUDY ON BEHAVIOR OF SHEAR STUD CONNECTORS FOR COMPOSITE BRIDGES

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ABSTRACT

Steel-Concrete composite beams have been used for an extensive time in bridge and building construction. Shear connector is important for steel concrete composite structures. It provides shear resistance in the steel-concrete interface. This study presents an investigation on behavior of shear stud connectors in composite beams. The composite section have been modeled in ANSYS with the help of finite element modeling and analyzed to study the performance of shear studs. Once the composite sections have been casted, it is made to undergo Standard Push out tests. The test is been carried out to analyze various parameters like load-slip behavior, axial shear resistance, ductility and also the failure modes of multi-stud shear connectors used will be detailed. And to find the design shear resistance values using various codal provisions for the comparison of test results. The effective and economical ways of using the shear stud connectors in Steel-Concrete composite sections will be discussed. Load-deflection curves, load-end slip curves, maximum shear resistance and failure modes were studied in detail.

Keywords: Steel-Concrete, composite, shear connectors, ANSYS, push-out test, resistance, ductility, slip, deflection, failure modes.

I. INTRODUCTION

The component that assures the shear transfer between the steel profile and the concrete slab in steel-concrete composite construction is the shear connector. Composite sections will get split or damaged due to shear forces and loading conditions if they are not provided with proper shear connections. If there were no connection, a beam and slab would bend easily. The presence of a shear connection prevents the slip between the two components and achieves a much stiffer and stronger beam. The transmission of shear forces and the intensity of stress in the steel beam, the weld that connects the shear connector to the flange of the beam, material of connector itself and the surrounding concrete of the slab, which all determines the strength, are highly dependent on the form of the shear connector. There are very different forms of means for composition that are used in practice. Steel-Concrete composite beams have been used for a considerable time in bridge and building construction. In this type of beams, concrete is assumed to take most of the entire compression load while steel takes all the tension. The two materials in the composite structure need to be firmly held together to make the structure rigid and strong. In steel and concrete composite beams the two materials are held together by

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means of headed shear connectors. Composite action can be obtained through mechanical connection commonly provided by headed shear studs or some other connectors. Therefore it is necessary to study about shear connections in composite sections before it is been practiced.

II. ANALYTICAL STUDY

A composite member with steel I section ISMB 250 as beam and concrete slab on both flanges of steel I section is connected with the help of various arrangements of shear stud connectors and the behavior of shear studs with respect to loading is studied with the help of ANSYS software. In this study three types of arrangement of shear studs are used they are single shear stud, square arrangement of shear studs with 3d spacing (48mm) and linear arrangement of shear studs with 2.5d spacing (40mm) in which the length and diameter of connectors are kept common as 100mm and 16mm for comparing the behavior of various arrangements of shear studs. As per BS EN 1994-2 Clause 6.6.5.7 gives minimum dimensions for headed shear studs. The minimum spacing in the direction of the shear force is 5d and the minimum spacing in the direction transverse to the shear force in 'solid slabs' is 2.5d. If the distance between headed studs are smaller than the prescribed minimum value of 5d, full shear resistance can be achieved by adopting the headed stud height in excess of 4d.

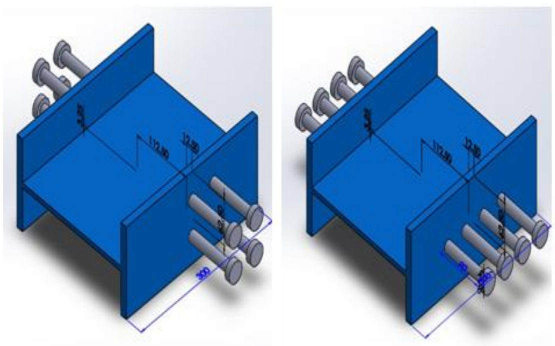

FIG-1: ARRANGEMENTS OF STUDS ON FLANGE PORTION OF I-BEAM USING SOLID-WORKS

SOLID 65 elements were used to model the concrete. **BEAM 188 elements** was used in reinforcements for RC Block. **SOLID 186 element** was used for steel I-beam.

TABLE 1: DETAILS OF SPECIMEN TO BE MODELLED IN ANSYS

Width of both top and bottom flange of steel I section	125mm
Depth of steel I section	250mm
Thickness of top and bottom flange of steel I section	12.5mm
Thickness of web of steel I section	6.9mm
Size of concrete slab	300x150x150mm
Grade of concrete slab	M30
Grade of steel	Fe415

A. LOADING AND BOUNDARY CONDITIONS

Before applying load on the composite member boundary conditions are need to be provided, the bottom end of the both concrete slab attached to the flange of the steel I beam are fixed. Then the load is applied on the face of web.

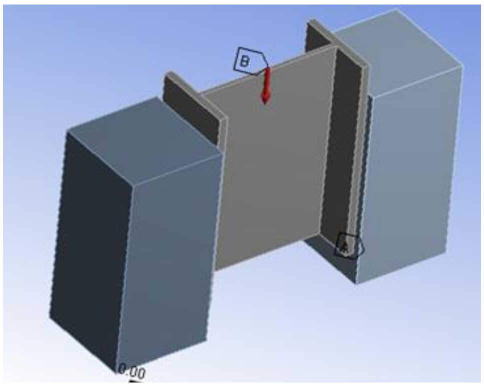

FIG-2: LOADING AND BOUNDARY CONDITIONS

B. BEHAVIOR OF SINGLE SHEAR STUD CONNECTOR

The figure-3 shows the total deformation of single stud Push-Out Model in ANSYS. Load is applied at central portion of the web. Deformation of push-out model can be identified by contours as shown in figure. Red portion on the web indicates the maximum deformation at centre and gradually it goes down towards the depth of the I-section. Due to transmission of load from I-beam to concrete through stud connectors, concrete portion attached to the flange part of I-beam gets damaged.

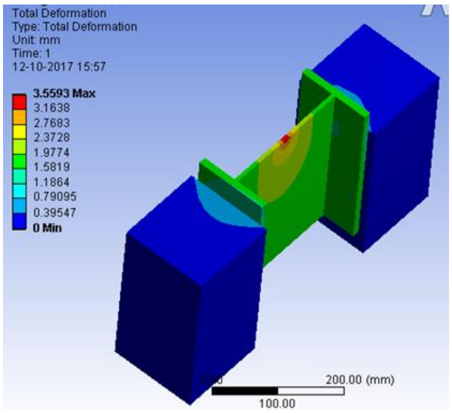

FIG-3: TOTAL DEFORMATION OF SINGLE STUD (PUSH-OUT MODEL)

C. BEHAVIOR OF SQUARE ARRANGEMENT OF SHEAR STUD CONNECTORS

The figure-4 shows the total deformation of square arrangement of studs (Push-Out Model) in ANSYS. Load is applied at central portion of the web. Deformation of push-out model can be identified by contours as shown in figure. Red portion on the web indicates the maximum deformation at centre and gradually it goes down towards the depth of the I-section. The total deformation seems to be lesser compared to single stud push-out model. Due to transmission of load from I-beam to concrete through stud connectors, concrete portion attached to the flange part of I-beam gets damaged.

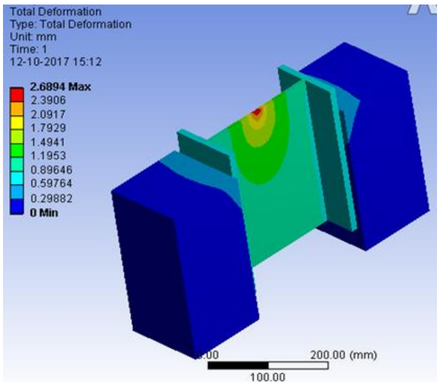

FIG-4: TOTAL DEFORMATION OF SQUARE ARRANGEMENT OF STUDS (PUSH-OUT MODEL)

D. BEHAVIOR OF LINEAR ARRANGEMENT OF SHEAR STUD CONNECTORS

The figure-5 shows the total deformation of square arrangement of studs (Push-Out Model) in ANSYS. Load is applied at central portion of the web. Deformation of push-out model can be identified by contours as shown in figure. Red portion on the web indicates the maximum deformation at centre and gradually it goes down towards the depth of the I-section. The total deformation of linear arrangement of studs seems to be slightly lesser compared to square arrangement of studs due to influence of stud spacing.

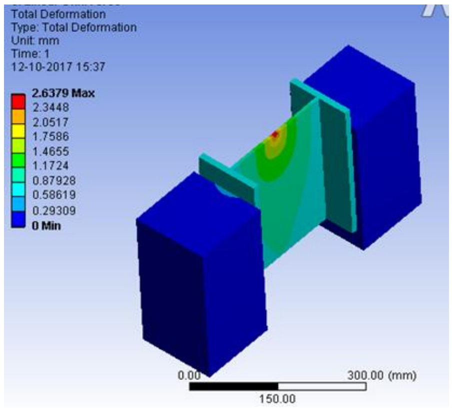

FIG-5: TOTAL DEFORMATION OF LINEAR ARRANGEMENT OF STUDS (PUSH-OUT MODEL)

E. ANALYTICAL RESULTS AND DISCUSSION

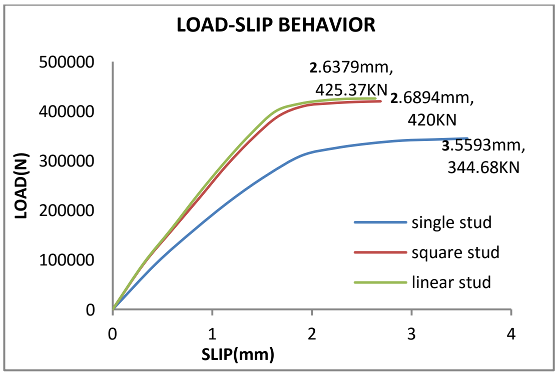

FIG-6: COMPARISON CHART OF ANALYTICAL RESULTS OF SINGLE & MULTI-STUD SHEAR CONNECTORS

Figure-6 shows the comparison of load slip behavior, it represents how single and multi-stud shear connectors behave with respect to loading. As the load is applied on the push-out specimens, slip b/w the steel and concrete occur. The static behavior of shear stud connectors can be explained through load-slip curves. It consists of three different parts. First part is the elastic part in which it reaches almost 50% of the maximum load value. The slip is very small and the shows large shear stiffness. Second part is the plastic part in which the curves show a new branch with a softer slope with increasing load. The slip increases rapidly while load increases slowly and the stud shear stiffness reduces continuously. After the maximum load is reached, the specimens fail suddenly and the load-slip curves do not show an evident descending part.

TABLE 2: ANALYTICAL RESULTS OF SINGLE STUD AND MULTI-STUD SHEAR CONNECTORS

S.NO	SHEAR STUD CONNECTORS		ULTIMATE CAPACITY IN KN	SLIP IN mm
1	SINGLE STUD		344.68	3.56
2	MULITI -STUD	SQUARE TYPE	420	2.68
		LINEAR TYPE	425.38	2.63

Table-2 represents the results obtained by analysing the composite member with single and multi-stud shear connectors. Among the two different arrangements of multi-shear stud connectors, linear arrangement of studs with 2.5d spacing have more load carrying capacity than square arrangement of studs with 3d spacing. The ultimate strength of multi-stud is about 18% larger than single stud. The slip of single stud specimen is about 25% larger than multi-stud specimens. These results may be useful in the design of steel-concrete composite bridges.

Normally, decreasing stud spacing resulted in lower ultimate strength. For that we provided confined reinforcements that enhance the shear strength of the shear connection. Behavior, ductility and shear resistance of the connection realized with a group of headed studs depends on the height of headed studs in the group.

III. EXPERIMENTAL PROGRAM

Two reduced-scale composite specimens are built and tested accordance with the Eurocode 4 – Part 1.1 to determine various parameters like Structural Behavior, Axial shear strength and ductility. Also, to study the load-deflection curves, load-end slip curves, maximum shear resistance and failure modes subjected to imposed loads. And to find the shear resistance values using various design codes for the comparison of test results.

According to that, the tests are designed to provide fundamental information on the behavior of composite slabs with realistic geometric and material characteristics. Experimental program include a set of specimens subjected to axial shear test. A description of the specimen details and testing arrangement is included henceforth. Diameter and height of the shear stud connector used was 16mm and 100mm respectively.

A. *FABRICATION OF SPECIMENS*

The Fabrication of steel-concrete composite specimens was carried out as per BS EN 1994-2:2005.The overall height of the stud should not be less than 3d, where d is the diameter of the shank. The spacing of studs along the direction of shear force should not be less than 5d; the spacing in the direction transverse to shear force should be not less than 2.5d in solid slabs and 4d in other cases. The distance between the edge of the connector and the edge of the plate or flange to which it is connected shall not be less than 25mm. The diameter of the head of the stud should not be less than 1.5d and thickness of the head shall not be less than 0.4 times the shank diameter.

The stud connectors are connected on I-Section (ISMB125x250) using welding as shown in fig 7(a). Shear stud connectors were fixed at 48mm spacing c/c for square arrangements as shown in fig 7(b). For linear arrangements, the stud spacing was 40mm c/c as shown in fig 7(c). There are 4 numbers of 16mm diameter studs welded on either side of the flange. The wooden mould for casting the concrete block was fabricated with the reinforcement rods of 4 bars, 8mm in diameter is placed at a distance of 100mm and 5 bars of 6mm diameter is kept as hoop reinforcement at a spacing of 120mm along transverse direction.

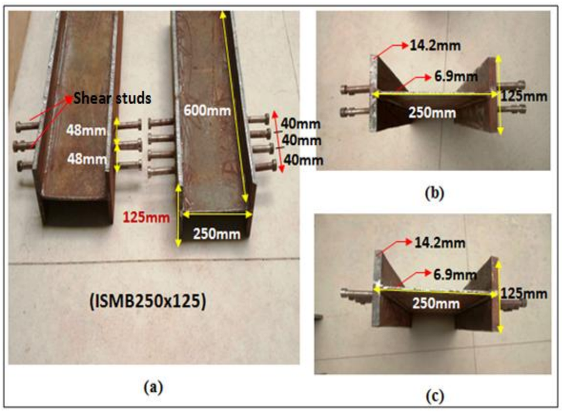

FIG-7 (A) STUD TYPE CONNECTION (B) SQUARE ARRANGEMENT (C) LINEAR ARRANGEMENT

B. *CONCRETE PROPERTIES*

Concrete used for the specimens is of normal weight, designed for compressive strength of 30 N/mm^2. The Compressive strength of cube was obtained by testing 150mm concrete cubes. The split tensile strength was obtained by testing 300x150mm concrete cylinders. Three samples in each cube and cylinder were tested, using the compression testing machine and the values of the actual concrete compressive strength are summarized. For experimental work M30 Grade of concrete, M-sand as fine aggregate, Crushed angular aggregate (20mm), Portland Pozzolana Cement (PPC) were used. Concrete proportion used in the mixture is 1:1.53:2.5 (cement/ fine aggregate/coarse aggregate). All the concreting works were carried out in the laboratory according to IS10262-2009. The design compressive strength of concrete was 30MPa.

C. PREPARATION OF COMPOSITE SPECIMENS

The concrete blocks were reinforced with minimum reinforcement using 6mm & 8mm diameter steel rods, with a minimum spacing of 25mm. The Push-out specimen of I-section (ISMB 125x250) was casted with two concrete blocks of size 600x150x150 mm on either side or with both the flanges as shown in fig 8.

FIG.-8 CASTING OF PUSH-OUT SPECIMEN

After the specimens are casted, they are demoulded and left for curing. The curing is done by placing the push-out specimens under atmospheric air conditions. To gain maximum strength the specimens are left for 28 days curing.

D. DESCRIPTION OF PUSH-OUT TEST SET-UP

Strength of shear connector will be determined by using push-out test. The axial shear strength of stud for both linear and square arrangements is calculated in this test. Each test consists of a push-out specimen which has two identical reinforced concrete blocks attached to the flanges of a steel I-section beam (ISMB250) by means of shear connectors.

E. TESTING PROCEDURE FOR AXIAL SHEAR TEST

The assembly was subjected to a vertical (axial) push load on the steel beam as shown in fig.9. The shear load, produced along the interface between the concrete slab and the steel beam flange due to this vertical load, was transferred to the concrete slabs through shear connectors. The load should first be applied in increments up to 40% of the expected failure load and then cycled 25 times between 5% and 40% of the expected failure load. Subsequent load increments should then imposed such that failure does not occur in less than 15 minutes. The longitudinal slip between each concrete slab and the steel section should be measured continuously during loading or at least until the load has dropped to 20% below the maximum load. As close as possible to each group of connectors, the transverse separation between the steel section and each slab should be measured.

The Universal Testing Machine used for testing had a capacity of 100 tons. The specimens were tested until the failure. The testing was done in order to obtain the load-slip curve. The dial gauges were fitted on the top surface of I-section to find deflection and on the concrete top to find the slip.

FIG-9 PUSH-OUT TEST SETUP

Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen. The machine itself can record the displacement between the cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other elastic components of the testing machine and its driving systems including any slipping of the specimen in the grips.

F. FAILURE MODES ON LINEAR ARRANGEMENT OF STUDS

When push-out test is conducted the following failure modes are obtained for linear type of stud push-out model and the test results are shown in table 3.

FIG-10 FAILURE MODE ON CONCRETE

Figure-10 represents the failure of linear arrangement of studs (push-out specimen) while conducting standard push-out test, it shows failure of concrete and slip between I-section & Concrete.

FIG-11 CRACKS DUE TO FAILURE AND STUD DEFORMATION

Figure-11 shows the various forms of cracks such as shear cracks, longitudinal cracks, structural cracks and stud bending deformation due to failure of Push-out specimen.

G. FAILURE MODES ON SQUARE ARRANGEMENT OF STUDS

When push-out test is conducted the following failure modes are obtained for second specimen and the test results are shown in table 3.

FIG-12 CRACKS DUE TO FAILURE

Figure-12 shows the various forms of cracks such as shear cracks and structural cracks due to failure of Push-out specimen. In this type, there is no slip between the I-section and concrete.

H. TEST RESULTS AND DISCUSSION

When comparing the experimental results of linear arrangements of studs and square arrangement of shear stud connectors. Square arrangement of shear stud connectors gives better results. They have more load carrying capacity (i.e. it had better shear resistance) compared to linear one. The table-3 represents the results obtained by testing the push-out specimens with two different arrangements of shear stud connectors. The ultimate strength of square arrangement (Push-out model) is about 27% larger than linear one.

Figure 13 & 14 shows the load-deflection and load-slip behavior of push-out specimen with studs connected in linear arrangement; it represents how this type behaves with respect to loading.

The yield load of the specimen is about 108.154KN. The ultimate load & failure load of the specimen seems to be 125.76KN and 112.92KN respectively. Once the failure load reaches sudden load drop is occurred with the sound of separation between the concrete and steel. The ultimate slip of concrete was measured manually and it was found to be 3.8mm. The ultimate deformation of I-section seems to be less than 2mm. The ultimate deformation of the specimen was 4.5mm. The slip of the specimen was considered up to the first crack load and after reaching the ultimate load the specimen fails due to slippage.

Behavior, ductility and shear resistance of the connection realized with a group of headed studs depends on the height of headed studs in the

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group. Normally, 16mm diameter studs are considered as ductile studs and it mainly depends on stud height. It must be greater than 4.25d; here it seems to be 6.25d i.e.100mm. From the test result, ductility ratio for linear type specimen was found to be 1.8.

TABLE -3: COMPARISONS OF TEST RESULTS OF PUSH-OUT SPECIMENS

S.NO	PARAMETERS	PUSH-OUT SPECIMENS	
		LINEAR TYPE	SQUARE TYPE
1.	First Crack Load	119.74KN	135.26KN
2.	Yield Load	108.154KN	148.14KN
3.	Ultimate Load	125.76KN	172.26KN
4.	Breaking Load	112.92KN	117.54KN
5.	Ultimate Slip	3.8mm	4.54mm
6.	Ultimate Deformation	4.5mm	6.2mm
7.	Ductility ratio	1.8	1.63

Figure 15 & 16 shows the load-deflection and load-slip behavior of push-out specimen with studs connected in square arrangement; it represents how this type behaves with respect to loading.

The yield load of the specimen is about 148.144KN. The ultimate load of the specimen obtained was 172.26KN. This type of specimen carries a maximum load than previous one. The failure load of the specimen was found to be 117.46KN. The ultimate slip of concrete was measured manually and it was found to be 4.54mm. The ultimate deformation of I-section seems to be less than 1mm. The ultimate deformation of the specimen also found to be greater than linear one. The slip of the specimen was considered up to the first crack load and after reaching the ultimate load the specimen fails due to slippage. The ductility ratio of this type of specimen was 1.63.

By comparing the load and deflection values of both the specimen, square arrangement of specimen was found to be 27% greater than linear type i.e. it has better shear resistance.

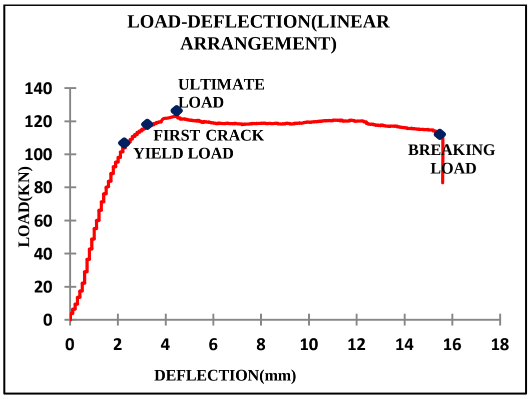

FIG-13 LOAD-DEFLECTION BEHAVIOR OF LINEAR ARRANGEMENTS OF STUDS

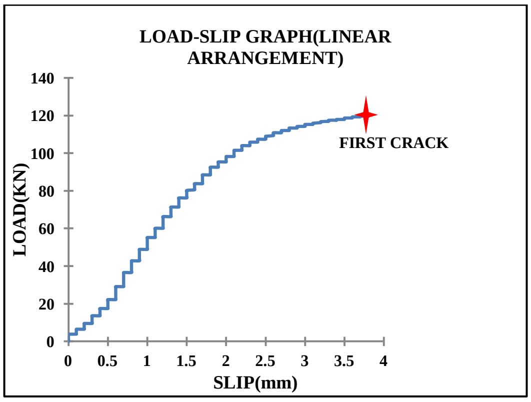

FIG-14 LOAD-SLIP BEHAVIOR OF LINEAR ARRANGEMENTS OF STUDS

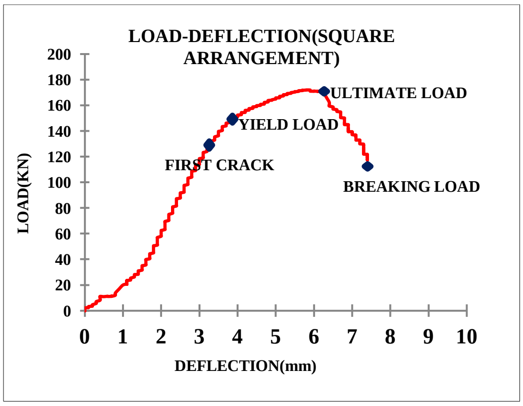

FIG-15 LOAD-DEFLECTION BEHAVIOR OF SQUARE ARRANGEMENTS OF STUDS

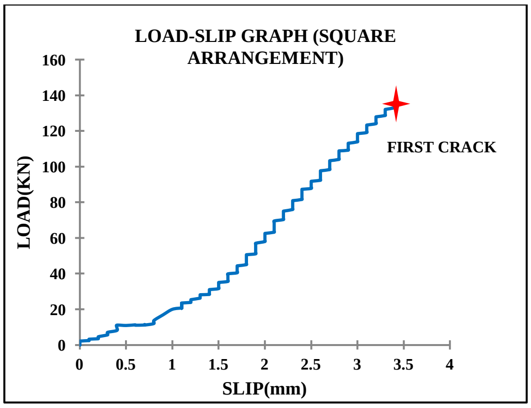

FIG-16 LOAD-SLIP BEHAVIOR OF SQUARE ARRANGEMENTS OF STUDS

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I. *DESIGN SHEAR RESISTANCE*

We compare the experimental results with the ultimate shear resistance calculated from common used design codes. The following are the various design code methods to find shear capacity.

1. IS11384-1985 (IS CODE)

In IS code, the design shear resistance is expressed as Eq. (1), where Ls is length of welded shear surface; fck is characteristic compressive strength of concrete; At is Cross-sectional area of transverse reinforcement in composite beams in cm^2/m; fy is Yield strength of steel in N/mm^2 and n is Number of times each transverse reinforcement crosses the shear force.

Design Shear resistance per metre run of beam

$$= 0.232 \times Ls \times \sqrt{fck} + 0.1At \times fy \times n$$

(Or) **(1)**

$$0.623 \times Ls \times \sqrt{fck}$$

a. Linear Stud shear resistance per metre run of beam = **204.7 KN**

b. Square Stud shear resistance per metre run of beam = **245.686 KN**

2. EUROCODE 4 – 1994

In Eurocode 4, the design shear capacity of stud is expressed as Eq. (2), where γ_v is partial factor; Fu is the ultimate strength of a stud but not greater than 500MPa; α is factor; fc' is characteristic compressive strength of concrete and Ec is the young's modulus of concrete.

$$(P_{Rd}) = \frac{0.8 \times Fu \times \pi \times \alpha^2}{4\gamma_v} = \mathbf{231KN} \quad \mathbf{(2)}$$

$$(P_{Rd}) = \frac{0.29 \times \alpha^2 \times \sqrt{fc'} \times \sqrt{Ec}}{\gamma_v} = \mathbf{214.52KN}$$

Take whichever is lesser (i.e.) $\mathbf{P_{Rd}}$ **= 214.52KN**

3. AASHTO LRFD - 2007 (AMERICAN CODE)

In AASHTO, the nominal stud shear resistance is expressed as Eq. (3), where As is the area of stud cross section; fc' is specified compressive strength of concrete used in design; Ec is the young's modulus of concrete and Fu is the minimum tensile strength of stud.

$$(P_u) = \varphi \times 0.5 \times As \times \sqrt{fc'Ec} = 78.44KN$$

$$(P_u) = \varphi \times As \times Fu = 78.615KN$$

$$(P_u) = \varphi \times 0.5 \times As \times \sqrt{fc'Ec} \leq \varphi \times As \times Fu \quad \mathbf{(3)}$$

$$\mathbf{78.44KN \leq 78.615KN}$$

4. JSCE – 2007 (JAPANESE CODE)

In JSCE, the allowable shear capacity of stud is expressed as Eq. (4), where d is the shank diameter, H is stud height and σ_{ck} is the design strength of concrete.

$$(Q_a) = 9.4d^2 \times \sqrt{\sigma_{ck}} \left(\frac{H}{d} \geq 5.5\right) \quad \mathbf{(4)}$$

$$(Q_a) = 1.72dH \times \sqrt{\sigma_{ck}} \left(\frac{H}{d} < 5.5\right)$$

Here Stud Height (H) = 90mm

Stud Diameter (d) = 16mm, H/d= 5.625

Therefore,

Allowable Shear resistance (Q_a) = 13.180KN

Stud Yielding Force is 3 times greater than Allowable Shear Resistance.

Ultimate Stud shear Resistance is 6 times greater than Allowable Shear Resistance. **(i.e. 79.08KN)**

5. GB50017-2003 (BEIJING – CHINESE CODE)

In GB50017-2003, the design stud shear capacity is expressed as Eq. (5), where As is the cross-sectional area of one stud, Ec is the young's modulus of concrete and f is the design tensile strength of stud and γ_f is the ratio of minimum ultimate tensile strength to yield strength.

$$(N_v^s) = 0.43 \times As \times \sqrt{fcEc} = 82.016KN$$

$$(N_v^s) = 0.7 \times As \times \gamma_f = 110.06KN$$

$$(N_v^s) = 0.43 \times As \times \sqrt{fcEc} \leq 0.7 \times As \times \gamma_f \quad \mathbf{(5)}$$

82.016KN < 110.06KN

6. KOREA BUILDING CODE – 2004

In KBC, the design stud shear capacity is expressed as Eq. (6), where Ra is the resistance factor of stud shear connectors, Ec is the young's modulus of concrete, fc' is specified compressive strength of concrete used in design, As is the cross-sectional area of one stud and Fu is the minimum tensile strength of stud.

$$(P_u) = 0.5Ra \times \sqrt{fc'Ec} = 85.01KN$$

$$(P_u) = As \times Fu = 92.48KN$$

$$(P_u) = 0.5Ra \times \sqrt{fc'Ec} \leq As \times Fu \quad \mathbf{(6)}$$

85.01KN < 92.48KN

7. CANADIAN BRIDGE STANDARDS - 2006

In CBC, the design stud shear capacity is expressed as Eq. (7), where Ec is the young's modulus of concrete, fc' is specified compressive strength of concrete used in design and As is the cross-sectional area of one stud.

$$(Q_a) = 0.5As \times \sqrt{Ecfc'} = 85.012KN$$

$$(Q_a) = 448 \times As = 90KN$$

$$(Q_a) = 0.5As \times \sqrt{Ecfc'} \leq 448As \quad \mathbf{(7)}$$

85.12KN < 90KN

J. COMPARING THE EXPERIMENTAL SHEAR RESISTANCE WITH DESIGN SHEAR RESISTANCE

When comparing the maximum shear resistance value obtained from experimental test and design code, difference is appeared. As compared with the shear resistance value by experimental test and Indian code, only slight variation was found. The design resistance values obtained from Korean and Canadian Building Code was similar. And the design value from Chinese code seems to be nearer with previous codes. Design values obtained from Japanese Code and American Code was same. The values obtained from Indian code and Eurocode is moreover in range.

As a result, Indian Code seems to be more efficient than other design codes. The reason for the difference appeared is that the concrete specimens were strengthened by reinforcements and thick welding part affected in the test result. But the shear resistance of the stud calculated by design codes is determined separately by the concrete or by the stud. The interaction between the two materials has not been applied in equations.

IV. CONCLUSION

Push-out specimens were built and tested accordance with the Eurocode 4 – Part 1.1 and the following conclusions are made based on the test results.

- From the analytical results, the load-slip curves show an initial almost linear relationship, and then the curves develop a new branch with a softer slope. After the maximum load is reached, the specimens fail suddenly and the load-slip curves do not show an evident descending part.
- The ultimate strength of multi-stud specimens is higher than that of single stud specimen. The ultimate strength of multi-stud is about 18% larger than single stud. The slip of single stud specimen is about 25% larger than multi-stud specimens. These results may be useful in the design of steel-concrete composite bridges.
- The single-stud and multi-stud specimens have varying stiffness, and the spacing of studs has little influence in the stiffness in the multi-stud. Normally, decreasing stud spacing resulted in lower ultimate strength. For that we provided confined reinforcements that enhance the shear strength of the shear connection.
- Behavior, ductility and shear resistance of the connection realized with a group of headed studs depends on the height of headed studs in the group.
- From the test results, square arrangement of shear stud connectors has better axial shear resistance than linear one. The ultimate strength and deformation of Square arrangement of stud (Push-out model) is about 27% larger than linear one. But linear arrangement of specimen is more ductile than other one from the outcome.
- As compared with the shear resistance value by experimental test and various design codes, Indian code slightly coincides with the test results and seems to be more efficient than other codes. The reason for the difference appeared is that the concrete specimens were strengthened by reinforcements and thick welding part affected in the test result. But the shear resistance of the stud calculated by design codes is determined separately by the concrete or by the stud. The interaction between the two materials has not been applied in equations.

V. FUTURE SCOPE

- Further researches in numerical and experimental investigation of composite deck slabs using multi-stud shear connectors under static and cyclic loading.
- Design longitudinal shear strength values of deck slabs obtained from (m-k and PSC) methods are to be compared later.

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