EFFECT OF POSITION OF SINGLY REINFORCEMENT LAYER IN STEEL-CONCRETE COMPOSITE SECTION

Submitted in partial fulfillment of the requirements for the award of degree of

Master of Technology

In

DISASTER ASSESSMENT & MITIGATION

Submitted By

Rahul Karwasra

(2014PCD5434)

Under the guidance of

Dr. Sandeep Chaudhary

Associate Professor

Department of Civil Engineering

MALVIYA NATIONAL INSTITUTE OF TECHNOLOGY

JAIPUR (RAJASTHAN)

JUNE 2016

A

Dissertation Report

On

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "**EFFECT OF POSITION OF SINGLY REINFORCEMENT LAYER IN STEEL-CONCRETE COMPOSITE SECTION** " in partial fulfilment of the requirement for the award of the degree of Master of Technology and submitted in the Department of Civil Engineering, Malaviya National Institute of Technology Jaipur, is an authentic record of my own work carried out at Department of Civil Engineering, MNIT Jaipur during a period from June 2014 to June 2016, under the supervision of Dr. Sandeep Chaudhary, Associate Professor, Civil Engineering, MNIT Jaipur.

Date:

Rahul Karwasra

ID No. 2014PCD5434

This is to certify that the above statement made by the candidate is true to the best of our knowledge.

(Dr. Sandeep Chaudhary)

Associate Professor

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CERTIFICATE

This is to certify that the thesis report entitled,“ **EFFECT OF POSITION OF SINGLY REINFORCEMENT LAYER IN STEEL-CONCRETE COMPOSITE SECTION** “ which is being submitted by **Rahul Karwasra**, **ID: 2014PCD5434**, for the partial fulfilment of the degree of **Master of Technology** in **Disaster Assessment & Mitigation** in the Malaviya National Institute of Technology Jaipur, has carried out by him under our supervision and guidance.

Date:

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Date:

(Rahul Karwasra)

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CHAPTER - 1

INTRODUCTION

1.1 General

The Composite structure is composed by two or more than different types of materials which show distinct material properties and these composite material built from such as steel, concrete, wood, timber, etc. and composite material show best advantage of materials and produce stronger, lighter member, economical members from effective connection between two or more materials. Steel and concrete are most progressive and widely used construction material in the modern age. Composite material bonding of steel and concrete can load transfer effectively to the sub-structure which show like as single unit. In composite structural member combination of steel and concrete have an advantages of the high compressive strength of concrete, higher tensile and compressive strength of steel ensuing in stiffer and stronger structure.

Advantages of composite section are lightweight, reliable, efficient, building services friendly and economically regarding saving in labour cost and construction time and also steel-concrete composite construction ability to cover large column free area in building and longer span for bridge or flyovers which leads additional usable space in buildings. Compare to steel section, composite section having higher stiffness so that bending stresses and deflection are less in composite section. Steel-concrete beam is normally used in bridges and high rise buildings. Major experimental studies are conducted on shear strength and a relative slip of composite structure and those factors affecting them. The important desirability of composite construction is based on proficient connection of the steel to the concrete that connection provided by the mechanical shear connectors or epoxy adhesives. The connections are allows transfer of forces and composite members gives their distinctive behaviour.

In steel-concrete beam, the strength and behaviour of shear connection depend on two important factors that are –

1. Shear strength of shear connector
2. The resistance of composite concrete slab against longitudinal cracking.

Typically mechanical shear connector that is shown in a figure, and most common connector are shear stud connector that consists by a head and plain shank are connected to the steel element by welding.

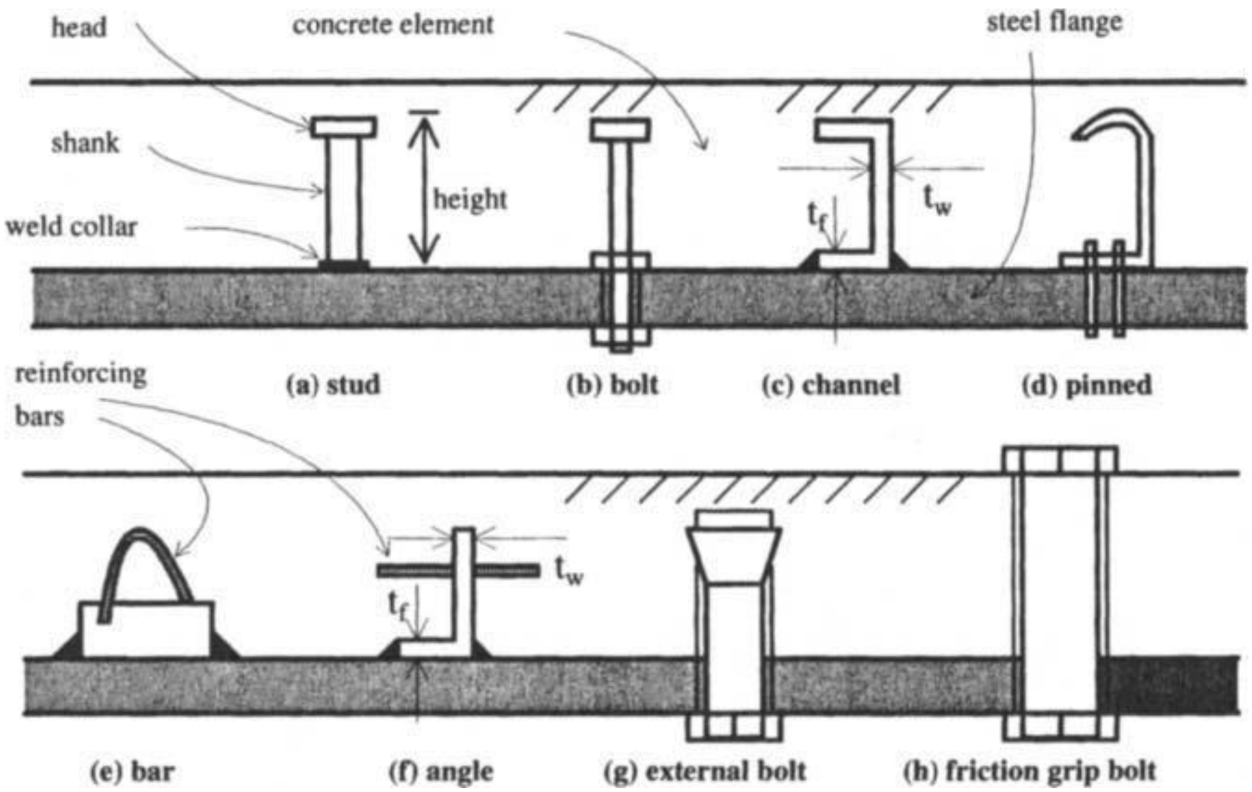


Fig. 1.1- Mechanical shear connectors (Oehlers & Bradford 1999)

Push-out test is used for determining the shear connector capacity and load slip curve behaviour of shear connectors. To determining the strength and safety of whole structure bonding between steel-concrete play a major role. Apart from adhesive bonding, the mechanical shear bonding demands more tests and experiments to be conducted.

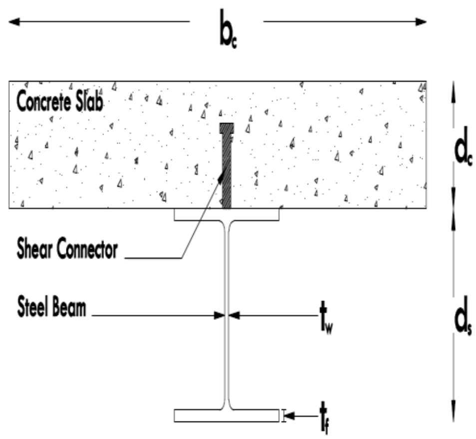


Fig: 1.2 Cross section of steel-concrete composite beam with shear stud connector

1.2 Shear Connector -

Shear connectors are used to resist horizontal shear between the steel concrete composite section. The mechanical connector used to facilitate concrete-steel members to composing behaviour.

Shear connector are also proposed –

1. Effectively transfers shear forces along contact surface interface without slip.
2. Prevents vertical separation of reinforced slab between steel and concrete due to uplift forces.

Shear connectors are usually classified into three categories-

- 1.2.1 Rigid type
- 1.2.2 Flexible type
- 1.2.3 Bond type

1.2.1 Rigid type connector –

These connectors are resulting their resistance from bearing pressure of the concrete. These connectors are intended to resist shear force through front side by shearing. These connectors are brittle failure due to concrete failure. These connections are very stiff in nature. They distributed equally bearing pressure over the surface because of the stiffness of the shear connectors. In these type of connectors, failure due to crushing of concrete.

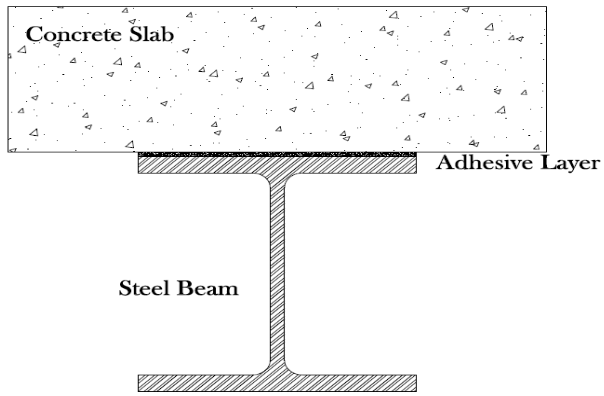


Fig. 1.3 Rigid shear connector using epoxy layer

1.2.2 Flexible type connector –

These type of connectors are like channel which welded to structural members of beams they develop their resistance from bending connectors. In generally failures occurs in connectors within yield stress which exceed ensuing in the slip between the prefabricated structural beam and flexible connector are shown in figure 1.4. Ductile failure occurs in that type of connector, and they maintain shearing strength equally with a lot of movement between concrete slab and steel beam. These connectors are fail due to yielding of connector or shearing at weld collar.

(a) Shear stud (commonly used) (b) Through bolts (Pavlovic *et al*. 2013)

Fig. 1.4 Flexible shear connectors

1.2.3 Semi rigid type –

These connectors are stiffer connector in nature. These connectors are fail due to crushing of concrete with partial damage in connectors.

Example - Perfobond and T perfobond shear connectors etc.

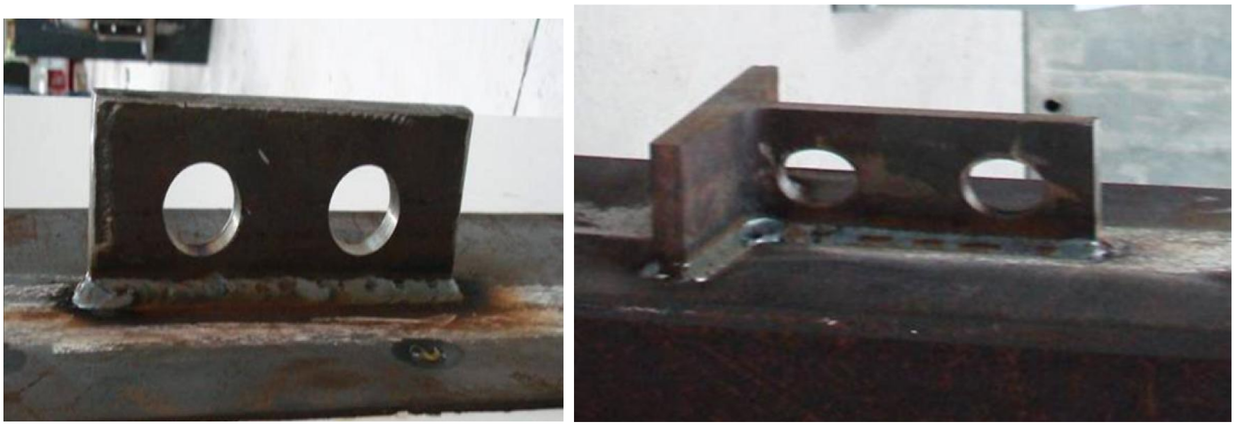


Fig1.5 - Perfobond and T perfobond shear connectors (Vianna et al., 2009)

1.3 Design strength of stud connector -

In design codes design strength of shear connector are -

As per Indian code design code on composite road bridge (*IRC* 22 1986)

i) For a ratio of $\frac{h}{d} < 4.2$

$$Q = 1.49 hd\sqrt{f_{ck}}$$

ii) For a ratio $\frac{h}{d} \geq 4.2$

$$Q = 6.08 d^2 \sqrt{f_{ck}}$$

Where –

Q = safe shear resistance in Newton of one shear connector

h = height of stud in mm

d = diameter of stud in mm

f_{ck} = strength of standard size cube at 28 days

As per *EUROCODE*-4 –

$$P_{DR} = 0.8f_u(\pi d^2/4)/\ \gamma_v$$

$$P_{DR} = 0.29\alpha d^2\sqrt{(f_{ck}\,E_{cm})}/\ \gamma_v$$

With

$\alpha = 0.2(\ h_{sc}/d + 1)$ for $3 \le h_{sc}/d \le 4$

$\alpha = 1$ for $h_{sc}/d \ge 4$

Where –

P_{DR} = Design shear resistance of stud per connector

γ_v = Partial safety factor which used in general taken as 1.25

d = Dia. of stud shank which should be between 16 mm to 25 mm

f_u = Ultimate tensile strength of stud material which should be less than 500 N/mm^2

f_c = Compressive strength standard sized cylinder at reaching a particular age

h_{sc} = Overall height of stud shank

E_{cm} = Elastic modulus of concrete in N/mm^2

Spacing of shear connector (*EN* 1994-1-1:2004)–

1) Shear connectors are provided all over length of beams at critical cross section as uniformly spaced.
2) Maximum spacing of shear connector in longitudinal direction –
    (a) 600 mm or
    (b) Three times thickness of slab
    (c) Four times height of connector

Whichever is the least.

3) The spacing of stud connector in any direction shall not be less than 75 mm

Dimension of shear connector (*EN* 1994-1-1:2004) –

a) Diameter of stud connectors welded to flange plate shall not exceed twice the plate thickness.

b) Height of the stud connectors shall not be less than four times their diameter or 100 mm.

c) The diameter of the head of stud shall not be less than one and half times the dia. of stud.

d) The length of weld joining other type of connectors to the flange plate shall not exceed half the thickness of flange plate.

e) Channel and angle connector shall have at least 6 mm fillet weld placed along the head and toe of channels/angles.

f) The clear distance between the edge of the girder and edge of the shear connectors shall not be less than 25 mm.

g) Surface of the shear connector which resists the separation between the units (ie. Under side of the stud or inner face of the top flange of a channel or inside of hoop shall extend not less than 40 mm clear above the bottom transverse reinforcement) not less than 40 mm into compression zone of the concrete flange.

h) Overall height of the connector including any hoop which is an integral part of the connector shall be at least 100 mm with a clear cover of 25 mm.

1.4 Push-out Test –

Push-out test is used in steel concrete composite section for determining the shear connector capacity and load slip curve behaviour of shear connectors. Push out test is commonly used in experimental study in laboratory test. Push-out test arrangement in two types based on direction of application of load which are apply on specimen that are horizontal or vertical push-out. In fig 1.6 and 1.7 shows vertical and horizontal push-out test. Push-out test classify the static strength, residual strength and fatigue endurance of shear connectors (Bro. and Westberg, 2004). Test arrangement includes a composite steel-concrete slab specimen and stud connectors. Loading system includes loading machine, load cell and load frame and dial gauge, LVDTs (Linear variable displacement transducer, strain gauge and computerized data acquisition system. Vertical push-out test is generally used and more consistent than the horizontal push-out test. Vertical push-out better organize over all unit and so that vertical test is commonly used and better used in cost and simplicity of test compare to horizontal push-out test.

Fig. 1.6 Vertical Push out test arrangement (Vianna *et al.* 2009)

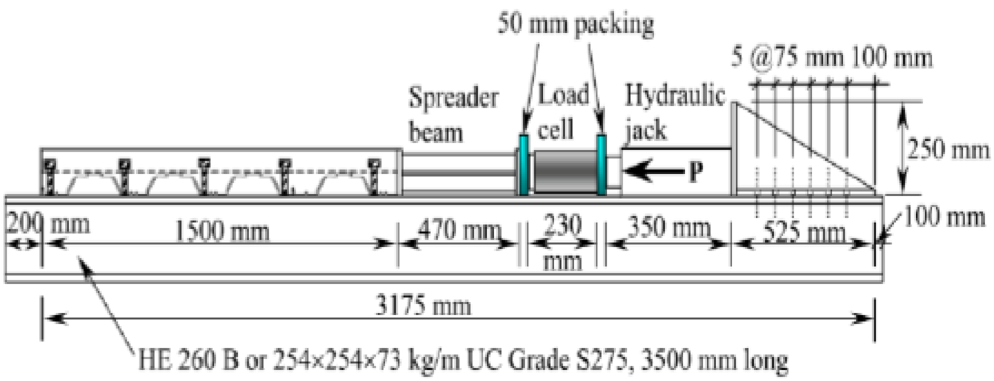


Fig. 1.7 Horizontal push-out test arrangement (Quereshi *et al.*,2011)

Push-out test

As per code (Eurocode 4)

- Push-out test specimen consists by steel beam with suitable size with welded shear stud connectors on both of the flanges.
- Before casting of slab shear connectors are to be placed embedded in suitable.
- Concrete slab reinforced with horizontal and transverse reinforcement bars.
- Code recommended that dimension of specimen and reinforcement must be modified as per beam for which test is being conducted.
- Prepared push-out test specimens are subjected loading.
- Initially load applied 5 to 40% estimated load in 25 cycle in cycle.

- Similarly, repetitive load was applied up to the specimen fail.

1.5 Objective and Scope of Thesis –

The aims of this thesis are experimentally investigate the effect of position of singly reinforcement parameter on shear stud in steel-concrete composite. The mainly works of experimentally determining the behaviour and design of headed shear connectors of composite steel-concrete members for strength, stiffness, and ductility. Experimental program based on the standard push out test. The objective of the study is replacement of concrete decks in steel-concrete composite bridges.

Objectives of this thesis are given below -

- Experimental analysis of the shear strength of shear stud connector at the lower strength of concrete (M25) after 28 days of curing.
- To analyze specimen without reinforcement with lower strength concrete.
- To analysis using singly reinforced cages (10 mm Dia) with different spacing from the flange of I-section steel beam side i.e. 20 mm, 40 mm, 60 mm, 80 mm.
- Evaluate load-slip behaviour of the connector at the lower strength of concrete.

1.6 Layout of Thesis –

Composition of this report is organized into four main chapters. **Chapter 1** represents introduction of composite structure, shear connectors, push-out test, objectives of thesis etc. **Chapter 2** describes comprehensive review of existing research work which relates to area of interest in this thesis. Composite steel-concrete bonded with headed shear stud connectors with different types of push-out test and different varying parameter studied in this chapter.

Chapter 3 explain experimental programme of this report which includes geometrical detail of mould, specimen holding assembly, material for push-out test specimen etc. **Chapter 4** represents results and discussion which show physical properties of materials which using casting of push-out test specimen.

CHAPTER - 2

LITERATURE REVIEW

2.1 General

This chapter describes the history and the literature review on the properties of composite structure. composite beams are broadly used in the composite building structures. Shear connectors was used as bonding between concrete and steel section. The shear connector was used in the form headed shear stud. The researchers are studies on different experimental test conducted on push-out test and include information on the composite beams and slabs.

Viest *et al.* ,1956 identified headed stud behaviour by conducting 12 push-test and varying effective depth (stud height) to stud dia. ratio. The Viest evaluated three types of failures as failure of steel, concrete failure and mixed failure. In steel failure stud dia. reached its yield point and then failed, in concrete failure concrete surrounding the headed stud are crushed and in mixed failure included failure of both material and Viest anticipated the formula for determining the shear strength of studs.

Cem Topkaya *et al.*, 2004 studied of composite shear stud strength in early concrete ages of curing and examined composite action between prefabricated steel beam and concrete deck achieved by using welded headed shear studs. Behaviour of concrete at early ages is useful in understanding the behaviour of bridges during construction. 24 push out test were conducted at concrete ages ranging from 4 hours to 28 days. Result show load-slip curve and strength and also test result show that the maximum capacity decrease when slip increase. Stud deformed up to inter face slip limit at early concrete curing ages were able to development of their full strength at 28 days. Deformation observed excessive at early ages causes a decrease in stiffness of the stud.

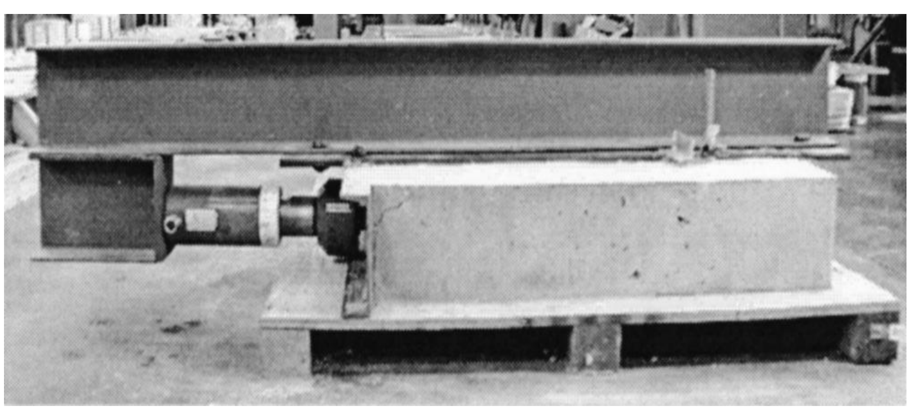


Fig 2.1– Side view of push-out test arrangement (Cem Topkaya et al.2004)

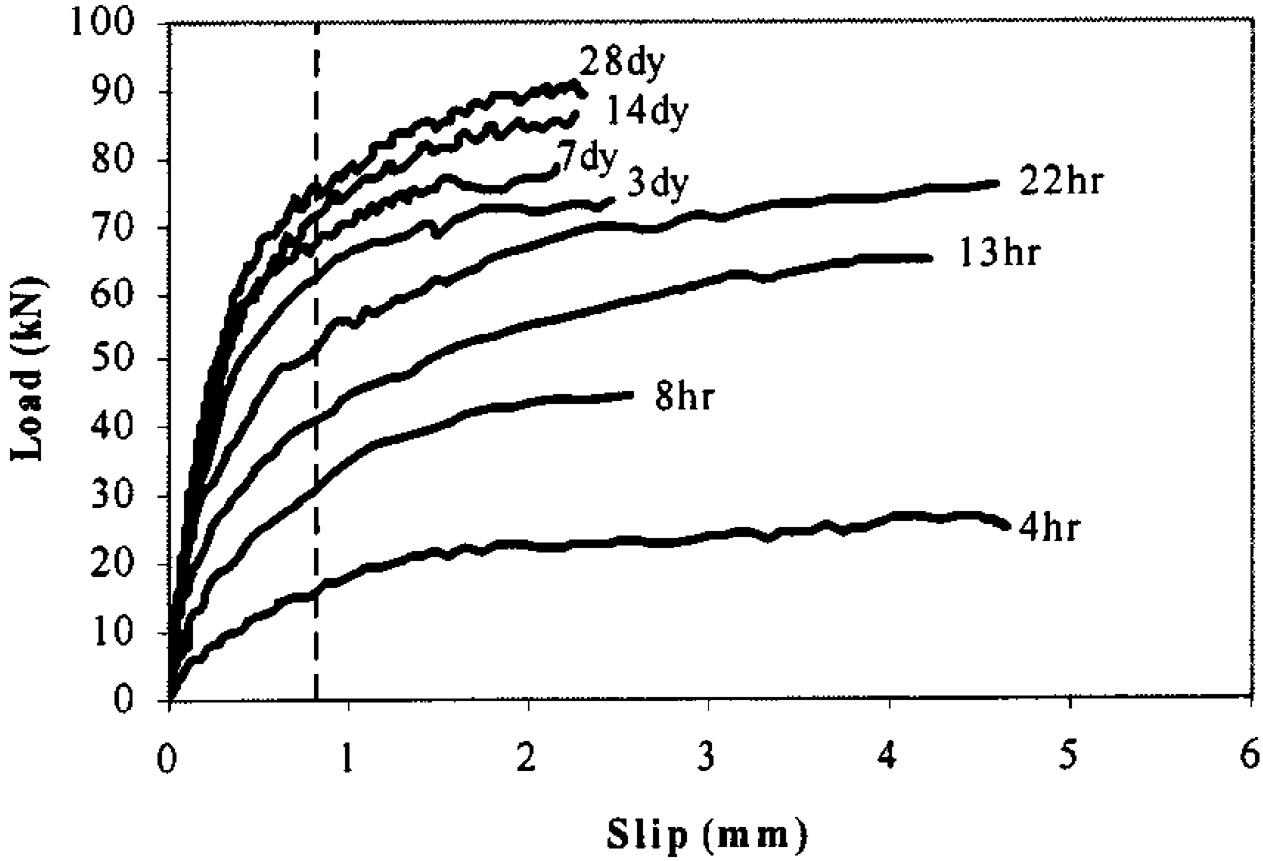


Fig. 2.3 Load-slip relationship from Push-out test (Cem Topkaya *et al*. ,2004)

Valente *et al*. ,2004 test conducted on the shear connector as headed stud, T-connector and perfobond connector and variation in diameter of a stud (19 mm, 22 mm, 25 mm) and transverse reinforcement (10 mm, 12 mm, 5 mm) with high strength lightweight concrete. Concrete slab dimension with 650 x 600 x 150 mm were used. The average compressive strength of concrete is M55 used. The push-out test was performed with headed stud, T-connector, perfobond rib connectors and test result showed load and deformation values compare to those verified with normal weight concrete. Observation of test results show when diameter of stud increase large damage on concrete slab due to cracking and crushing of concrete slabs without shear failure on studs. T connector specimen suffered from shear failure, localized near wed basis, right above the welded collar and concrete showed some cracking but not much damage as for 25 mm diameter studs. T connectors permit higher load values. When T connectors are compare to studs which show better stress distribution on concrete slab to avoiding concrete crushing due to higher loads. In initial part of test Perfobond connection much stiffer behaviour until the maximum load is reached and its show very small value of slip when compared to stud and T connectors. Increase in load capacity directly dependent on the transversal reinforcement area. When high strength light weight concrete compare with normal weight concrete which show load capacity is smaller and deformation values are higher which results in better ductility.

Dennis Lam *et al.* ,2005 examined design of composite beam with headed stud shear connectors and which generally used to transfer longitudinal shear forces across the concrete-steel bonding face. Using four different grade of concrete (M20, M30, M35, M50) specimens find load-slip behaviour and shear capacity of stud in composite beam were obtained. Slab was built by longitudinally and transversely reinforcement in two layers. Each layer consists of 6 longitudinal and 6 horizontal bars with 10 mm dia. according to requirement of Eurocode-4. Steel beam specification was 254 x 254 UC 73. Push-out test specimen with high strength concrete of 50 N/mm^2 used then no crack on surface of concrete slabs during test and after test cracks were observed at perpendicular to direction of loading on concrete surface. Results shows stud failure. Before yielding of concrete shear stud fully yielded. When concrete strength 20 Mpa used then conical concrete failure was observed around the stud. For test with 30 Mpa used then test show yielding of stud element was observed near collar. The shear connection are failed due to the combined concrete crushing failure and stud yielding. When concrete strength of 35 Mpa specimens used which failed in combined mode of failure that is stud yielding and concrete failure but tendency to the stud failure is high. Effective numerical model using the FEM to imitate the push out test was preferred. Using of test results model has validate and test date compared with common standard codes as BS5950, EC4, and AISC. Parametric studies are to examine variation in concrete strength and shear stud dia.

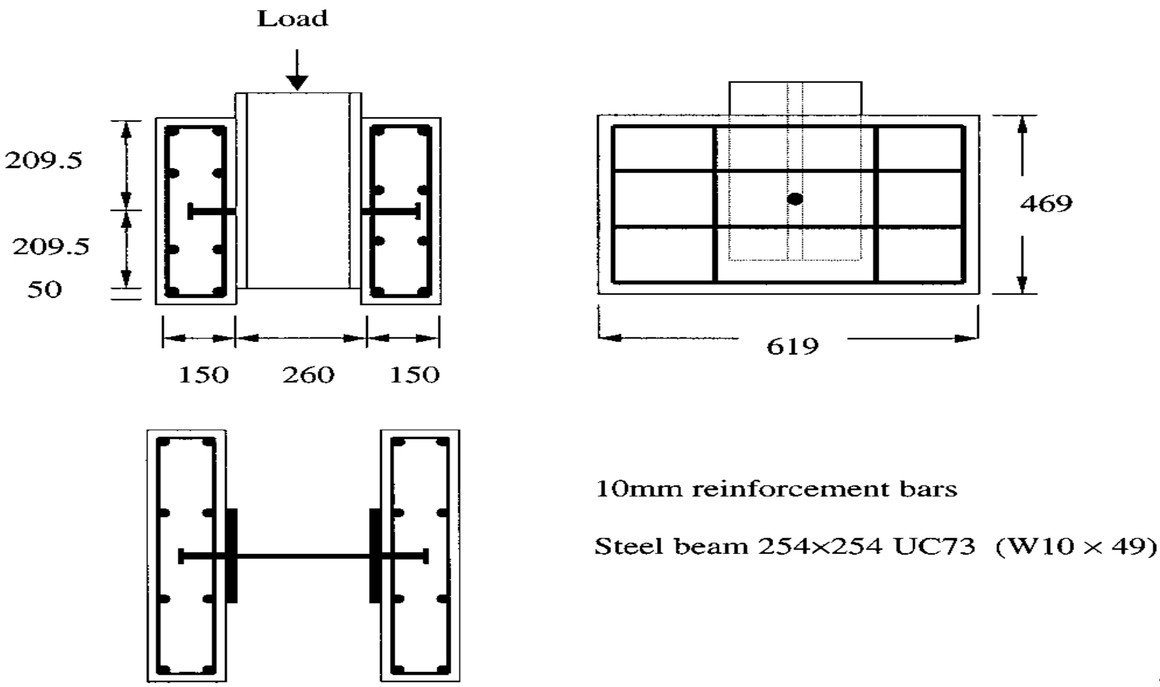


Fig. 2.3 Detail of Push-out test specimen (Dennis Lam *et al*. ,2005)

Qian *et al*. ,2006 experimental conducted studies on stud connections made with four different concrete materials that is plain concrete, reinforced concrete, strain hardening fibre-reinforced engineered cementitious composite (ECC), tension softening steel fibre reinforced concrete. Results were examined manipulate of concrete material ductility on a shear response of stud connection including failure modes, ultimate strength, load-slip capacity and structure reliability. 14 push-out test specimens conducted with using these four concrete material with different tensile strain capacity were examined. Results show that the ECC specimens achieved higher load capacity and slip capacity. ECC specimens 24% to 53% rise in load capacity and 220% rise in slip capacity were obtained. Concrete push-out specimen failed by brittle failure which shows lower ultimate strength. ECC material and plastic deformation of steel stud resulting in high load carrying capacity due to ductility ECC material effective in redistribute loads among the shear studs and also improve composite action between steel and concrete section.(**Qian *et al.* ,2006**).

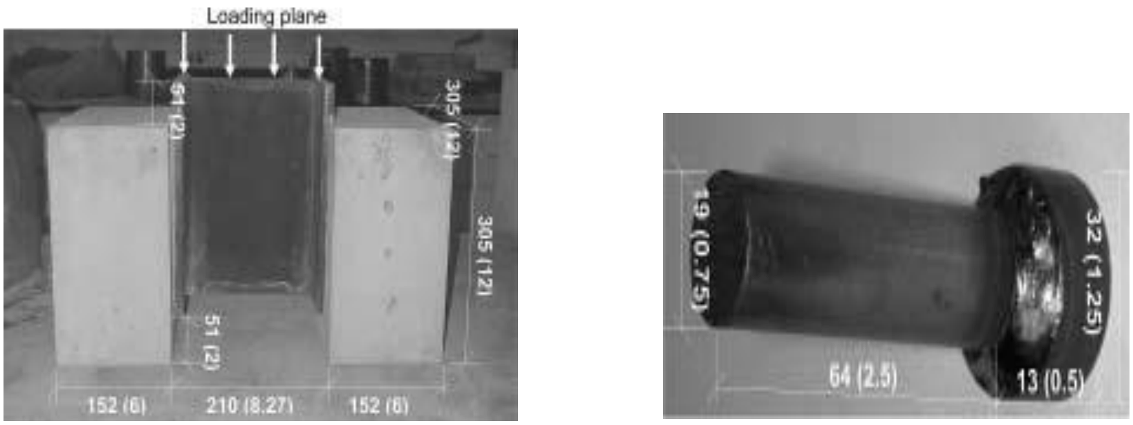


Fig. 2.4 Geometry of push-out specimen and shear headed stud (mm (inches)) (Qian *et al*. ,2006)

Luo *et al*. ,2008 experimentally conducted thirty push-out test on the stud shear connectors to evaluate effects of stud dia. and height, concrete strength and welding technique of stud, transverse reinforcement and type of steel beam of stud failure modes, load-slip curves and shear bearing capacity. Push out test results show that when the increase in concrete strength, stud dia. and height of stud then increase in stud shear bearing capacity. Reinforcement in the concrete slabs confined concrete around the stud and not take more load. Effect of steel beam was irrelevant on stud shear bearing capacity.(**Luo *et al*. ,2008).**

Weichen Xue *et al*. ,2008 studies on composite action of steel concrete composite slabs is achieved by stud shear properties. 30 push out test specimen conducted to examine the effect of dia. of a stud, height, concrete strength, transverse reinforcement, steel beam type and stud welding technique, load slip behaviour and shear bearing capacity of a stud. Push out test result analysed shear mechanism and result showed rise of stud shear bearing capacity and increase in concrete strength, strength dia. and height and decide from result stud welding quality of should be good controlled and reinforcement in the concrete slabs confined concrete around the stud and not take more load . Transverse reinforcement should also increase 10% when shearing capacity of a stud with ϕ13 mm used.

Three types of failure modes are observed from push-out tests after examined specimens. The first mode of failure splitting failure of concrete slab not observed of shearing off of headed stud and concrete fail in compression around stud before yielding and many cracks are found on a concrete surface that was in contact to steel beam. Due to sufficient transverse reinforcement concrete failure should be prevented and the second modes of failure was stud shank failure.

Concrete failure not observed and this failure was recognized as stud failure mode and tearing off the upper of flange was observed during test. The third modes of failure was seam welding failure. This observed due to standard welding technique.

Shim *et al*. ,2010 conducted push out test on shear studs embedded in the high strength concrete is carried out to examine the shear strength of stud connector and concrete strength behaviour. Evaluate the load-slip behaviour and shear capacity for appropriate design code. Push-out test on shear stud embedded in the high strength of concrete and In high rise building fibre reinforced concrete widely used. Results of FEM are compared with push out test and value given in design codes. Experimental test and design code values are compared maximum shear resistance then the distinction has arise. The reason is that reinforcements strengthened concrete specimens and thick welding part is affected in the test result but relations between two materials has not been utilize in equations. (**Shim *et al*. ,2010)**

Smith and Couchman *et al*. ,2010 conducted studies on strength and ductility of headed stud connectors. Examined the effects of such as mesh reinforcement position, transverse spacing between shear connectors, no. of shear connectors per trough and depth of slab on the resistance of the headed stud shear connectors. The observation of results also recommend that increase in resistance of 16% in pairs of shear connectors over using a single shear connector. Results show independent of the spacing evolution by using shear connectors in the groups of three.

Lam *et al*. ,2011 investigate three-dimensional FEM developed to studies the push-out test on behaviour of profiled sheeting. The concrete slab separation from steel deck, failure modes of concrete, buckling of the steel bridge and load slip behaviour corresponding with the experimental studies in laboratory. 64 double stud push out test specimens of studs placed next to the each other in beneficial position and staggered of studs by placing each of them in beneficial and adverse condition. Four single stud push out test specimen results compared with double studs of test specimen.The main variable in this was an effects of transverse spacing, shear connector position and concrete strength. Transverse spacing of 40 mm to 400 mm was tested. Results show that shear connector resistance to unaffected for transverse spacing less than 80 mm and greater than 200 mm.

Euro code 4 relations gives strength of double stud test result being 71 % of the single stud was valid for transverse spacing of 80 mm or lower than 80 mm. All push out test specimens failed in concrete conical or concrete crushing (M15, M20, M30) failure except push-out test with M40 concrete having staggered pairs of stud connectors outside 150 mm spacing which failed by the combination of concrete cone crushing and stud shearing failure. It concludes that shear connectors resistance of pair of shear connector placed in beneficial position is 94 % strength of a single shear stud when the transverse spacing in between studs is 200 mm or more than 200 mm. The favourable position of double shear stud strength is generally more than staggered pair of the shear connectors (**Lam *et al*. ,2011**).

WANG et al. ,**2011** studied behaviour of the shear resistance and shear stiffness of stud. Results showed that shear resistance and shear stiffness with large dia. and high strength are higher than normal studs used in the composite structure. In this experiment 12 push-out test specimen of stud connectors with different diameter and different strength of stud used. Concrete slab dimension 450mm x 450mm x 150mm used. Results also compare with standard design codes. Under load and cyclic load load slip curves of specimen are in each group have better in elastic phase. These results are better used in bridge structures.

Compare the experimental result with ultimate shear resistance from commonly used design codes. *EC*-4 design code of United State, *AASHTO LRFD*,give design strength of stud shear connectors achieve are welded automatically.

The formulas specific in design codes are conventional and can be used to determine the shear resistance of stud with large dia.and high strength.

(a) Concrete surface (b) Steel surface

Fig. 2.5 Failure mode of specimen (Wang *et al.* ,2011)

Prakash *et al.* ,2012 conducted modified the push out test to evaluate the shear strength of high strength steel (HSS) studs. Four specimens were tested, and values of shear strength were compared with *Eurocode* 4. Experimental results show that confinement of concrete in the region of HSS stud enhanced the compressive strength and splitting resistance of concrete. Firstly observed cracking in concrete slabs of push out test specimen at stud connector and ultimately failure arised with fracture of high strength stud connectors.

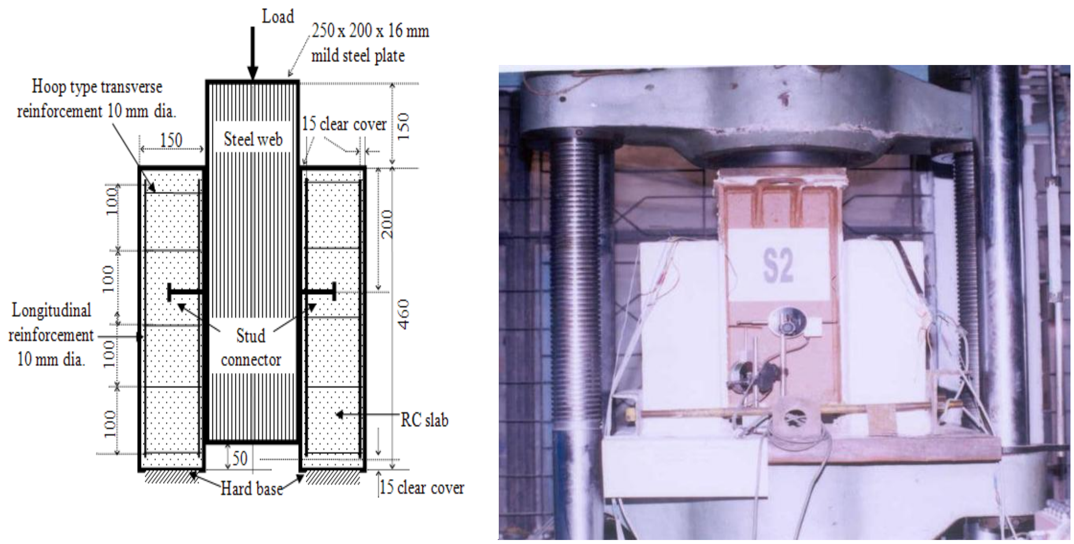
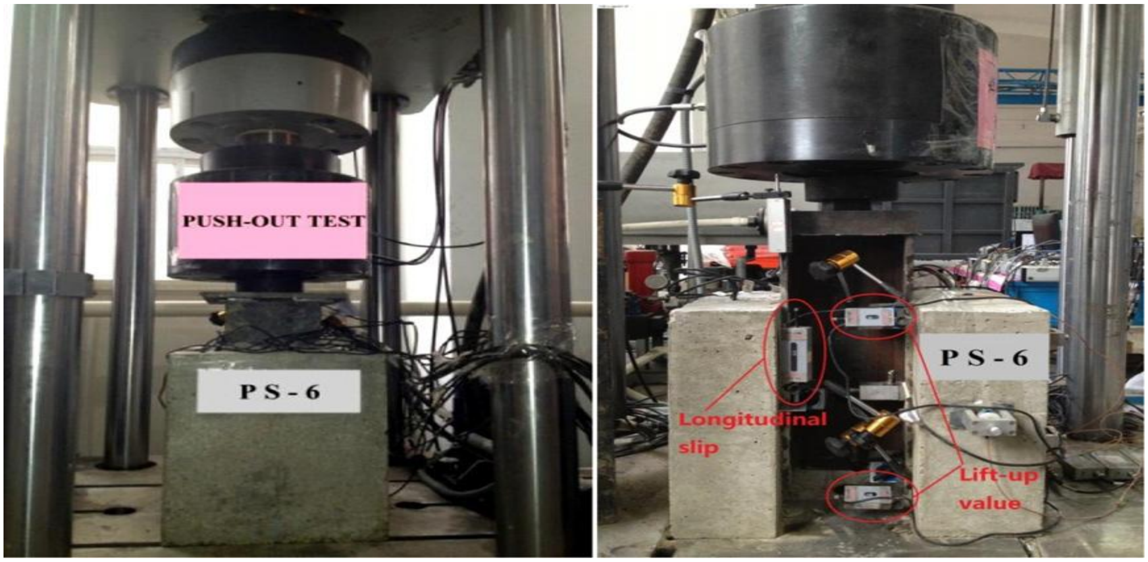


Fig. 2.6 Details of reinforcement for push-out test and push out test specimen under loading condition (Prakash *et al.*,2012)

Qinghua *et al.* ,2015 studied about a static behaviour of shear stud connector embedded in elastic concrete. Experimentally 18 push out tests were organized to evaluate the load slip behaviour, ultimate slip and bearing capacity of shear stud. Static behaviour of shear stud connector embedded in elastic concrete with four different rubber content of 0%, 5%, 10%, 15% with M30 concrete grade was used. H-section steel beam used as size of 200mm x 200mm x 8mm x 12mm and concrete slab with size 460mm x 400mm x 160mm and stud with 16mm and 19mm diameter and with a height of 90mm and 110mm respectively. When rubber content increases then deformation capacity and ductility of studs are improve and stiffness decreases rapidly when rubber content used is 15% and shear stud in elastic concrete with 10% rubber content has show a comparatively bearing capacity which show the more deformation and ductility.



(a) Front View (b) Side View

Fig. 2.7 Loading device and push out test specimen arrangement (Qinghua *et al.* ,2015)

CHAPTER-3

EXPERIMENTAL PROGRAMME

3.1 Geometrical Detail of Mould –

Mild steel mould is used to concrete specimen casting. Mould fabricated from 10 mm mild steel plates. Mould was assembled from 6 different plate component. The entire assembly was fixed on a 12 mm thick mild steel platform. The verticality of mould was checked from using magnetic plate level. Cutting of plates, grinding and assembly works for plates were done in fabricator workshop. The dimension of H section mould is 355 x 155 x 500 mm.

Fig. 3.1 Different component of mould

Fig. 3.2 Tightening of mould

Fig. 3.3 Magnetic level for checking verticality

3.2 Specimen Holding Assembly –

Holding of an assembly of fabricated consisting of two horizontal 5 mm thickness of mild steel plates which placed on each side of plates P1 and P2 beside width of the slab. It hold two plates on either side handled by the help of tie rod. Whole assembly arrangement and component of push-out test specimen are shown in figure –

Fig. 3.4 Specimen holding assembly

3.3 Material for Push-out test Specimen –

3.3.1 Reinforcement bar –

Steel and reinforcement mostly used in construction industries. Reinforcement cement concrete material is an important part of the composite material. For strengthening of concrete section reinforcement bar is provided. Reinforcement bar is preventing failure of concrete from the crushing failure and sudden failure. Reinforcement bar which we used are manufactured by SAIL “Steel Authority of India”. Reinforcement bar of Fe 500 is used .

Reinforcement bar of 10 mm diameter was used in singly reinforced cage. 10 mm dia.bar were used for transverse and longitudinal reinforcement. 10 mm diameters of 4 no. bars used as longitudinal having 400 mm and six no. of transverse bars of 10 mm diameter having 300 mm length was provided for singly reinforced cage. Singly Reinforcement cages are shown in below –

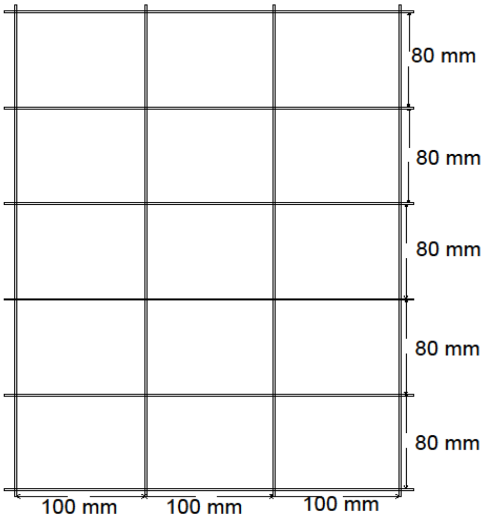


Fig -3.5 Layout of reinforcement layer used in preparing cages

3.3.2 Steel section classification –

Steel section was selected as per Eurocode 4 (1992).Code define for standard push-out is UCS (Universal Column Section) 254 x 254 x 89kg. Since only single stud was to be welded on each side of flange hence smaller section UC 203 x 203 x 52 Kg was in use. So we used in push-out test specimen are UC 203 x 203 x 52 kg section. Geometrical specifications of standard and selected steel section are in below table-

Table 3.1 Geometry specification of steel section

Section	**Weight/L (Kg/m)**	**H (mm)**	**B (mm)**	**t_w (mm)**	**t_r (mm)**	**R (mm)**
UC 203 x 203 x 53 kg	52	206.2	204.3	7.9	12.5	10.2

Preparation Steel section –

UCS manufactured by the "Jindal Steel and Power "was used for preparing of 13 meter length steel section.Gas cutting welding cut universal section at significant marked lines. The required length of a steel beam in each specimen was 450 mm. Marking is done by markers with carefully by the help of right angle and scales.

Fig. 3.6 Measuring of Steel Section Beam

Fig. 3.7 Cutting of Steel Section with Gas Cutter

3.3.3 Headed Shear Stud –

Headed shear studs are mechanical connectors that are usually welded to UC steel section get embedded in concrete for bonding between steel and concrete section. Studs dimension and its strength have a direct effect on the ultimate shear strength of the composite structure. We used a shear stud with size of 19 mm x 100 mm. These stud supplied by “Nelson Stud Welding” company. These shear stud welded to UC steel section by Mig (Metal Inert Gas) Welding at welding workshop. Welding metal are fed from the spool and mixture of inert gases like Hi (helium), Ar (argon) and CO_2 (Carbon dioxide) shields the arc. In this welding process continuous weld with no slag, uniform and no post-operation.

Fig. 3.8 Headed Shear Stud

Fig. 3.9 Steel Beam with Welded Shear Stud

3.3.4 Cover Block –

Cover block used for maintain spacing from an inner surface of a mould. In the casting of specimen three type of cover block used that is 20 mm,40 mm,60 mm are used from steel section side. cover block are used in a bottom side of the mould.

(a) 20 mm cover block

(b) 40 mm cover block

(c) 60 mm cover block

Fig. 3.10 Different Types of Cover Block used in Casting of Specimen

3.4 Concrete Specimen Preparation –

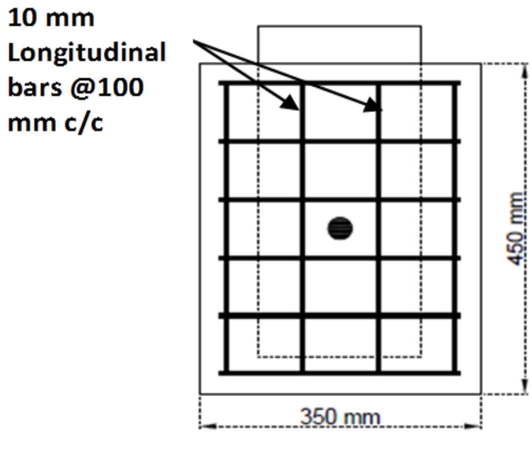
To reach the desired grade of concrete, some standard cube test were conducted. Concrete specimen were cast in MNIT laboratory and which test results are present in next chapter. Compressive strength test was done on a cube of size 150 mm x 150 mm and concrete grade is constant for all specimens which cast with or without reinforcement. The normal strength of M25 grade concrete was used.

3.5 Push-out test Specimen –

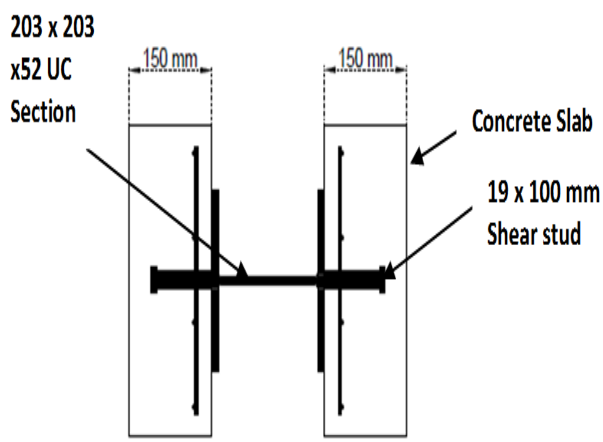
Five different type of specimen were cast. For each type two identical specimen cast to examined average reading. Each type of specimen consists of two identical specimens. M25 concrete grade was constant for all specimens. For each specimen three cubes of 150 mm x 150 mm were cast with simultaneously casting to a push-out test specimen. Shear stud welded on each side of I-section steel beam flange at a height of 200 mm above a bottom of beam. Tightening of a mould by wedges and carefully checking verticality by levelling tube. Concrete specimen size with 450 mm x 350 mm x 150 mm was cast with or without reinforcement. These two concrete slabs attached to a side of the flange. When reinforcement singly reinforced cage used to a casting of specimen these singly reinforced cages are used with different four type of spacing from steel section side i.e., 20 , 40 , 60, and 80 mm. Mould was vibrated after half filling by needle vibrator.

Table 3.2 Different Group of Push-out Specimen-

Specimen	Concrete Grade	Reinforcement	Spacing provided from steel section side
SP1RE0	25	Without Reinforcement	---
SP2RE0			
SP1RE1	25	Singly Layer	20 mm
SP2RE1			
SP1RE2	25	Singly Layer	40 mm
SP2RE2			
SP1RE3	25	Singly Layer	60 mm
SP2RE3			
SP1RE4	25	Singly Layer	80 mm
SP2RE4			



FACE ELEVATION



PLAN FROM TOP

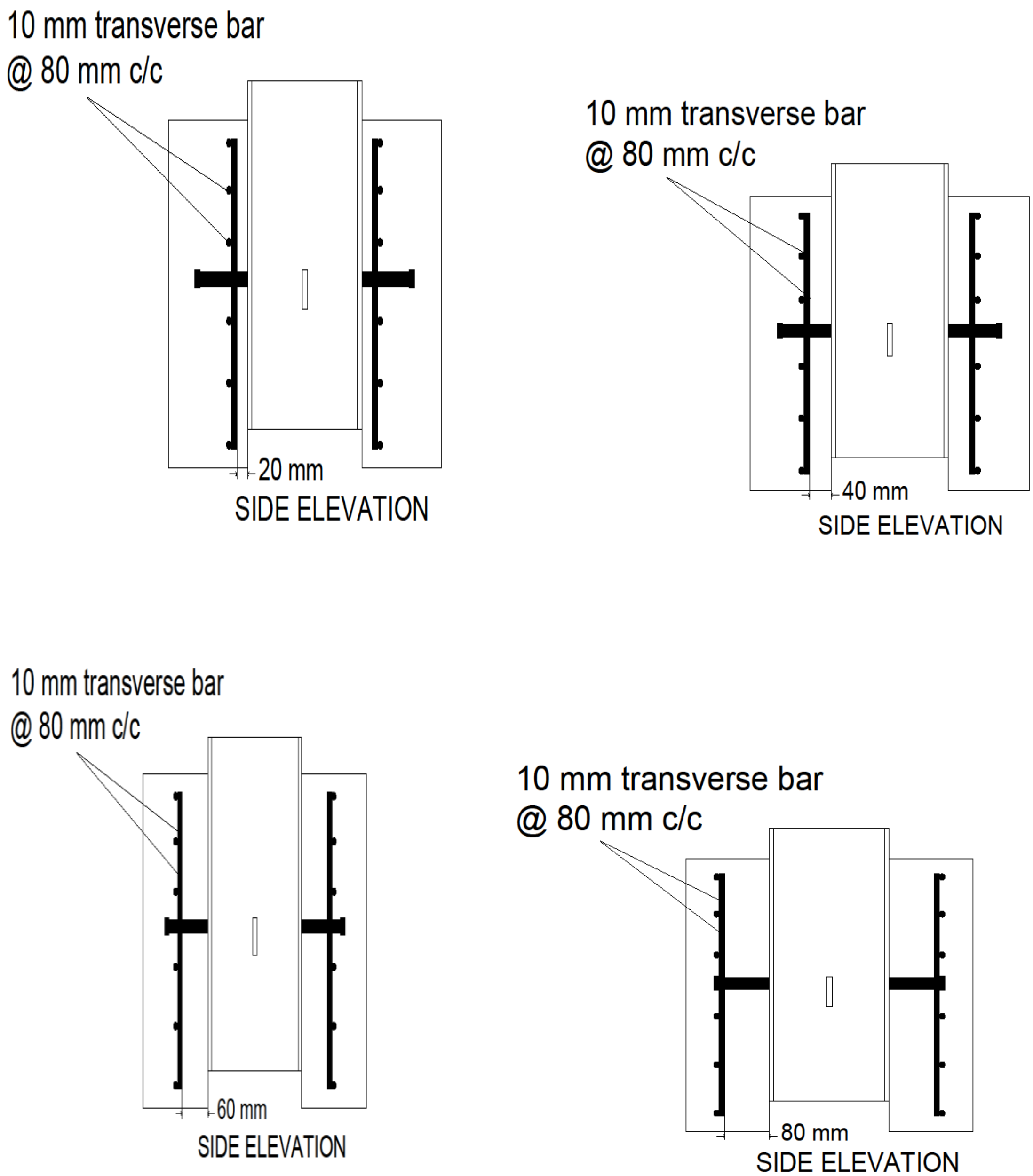


Fig. 3.11 Single Layered Specimen with Different Spacing from steel section side

3.6 Push-out Test Specimen Preparation –

Preparation of push-out test specimen cast one at a time. For each specimen three cubes of 150 mm x 150 mm were cast with simultaneously casting to a test specimen. To reduce resistance of friction between steel section and concrete oil was placed over entire section. After than tightening of a mould by wedges and carefully checking verticality by levelling tube. Singly reinforced cage used to a casting of specimen. These singly reinforced cages are used with different four type of spacing from steel section side i.e., 20, 40, 60, and 80 mm. Mould was vibrated after half filling of concrete by needle vibrator. After 24 hours demolding process take place after demolding prepared specimen were dumped in curing tank for 28 days. Specimen dumped into curing tank by the help of gantry girder. The whole process is shown in below –

Fig. 3.12 Oiling of Steel section

Fig. 3.13 Mould with or without reinforcement

Fig. 3.14 Pouring of concrete and compaction carried out with needle vibrator

Fig. 3.15 Finished push-out test specimen

Fig. 3.16 After demolding of push-out test Specimen

Fig. 3.17 Curing of Specimen

CHAPTER - 4

RESULT & DISCUSSIONS

4.1 General –

Physical properties of materials which used in push-out test specimen are carried out in MNIT laboratory by equipment. The consistency of cement, initial and final setting time, sieve analysis of fine and coarse aggregate, a specific gravity of cement, fine aggregate, and coarse aggregate and compressive strength of concrete, water absorption test are carried out in a laboratory. Mix design was carried out to achieve desired compressive strength.

An experimental test results are discussed in current chapter.

4.2 Raw Materials –

Following raw materials was used in casting of push-out test specimen –

1. Coarse aggregate: An aggregate having sizes 10 mm and 20 mm were used in this study with 50:50 ratio. Aggregate was purchased locally and tested for specific gravity, water absorption and gradation using sieve analysis.
2. Fine aggregate: Fine aggregates are transported from locally available river bed. And sand tested for specific gravity, water absorption and sieved analysis as per Indian Standards.
3. Cement: Ambuja Plus PPC cement obtained from locally cement traders and tested for specific gravity, consistency, initial and final setting time.
4. Reinforcement Bar: Reinforcement bar were 10 mm diameter bars are used for the preparation of reinforcing of steel cages.
5. Water: Water were used from the locally availability of in laboratory for experimental purpose.

4.3 Physical Properties of raw materials–

4.3.1 Cement:

4.3.1.1 Consistency Test –(*IS* : 4031 (part-4) -1988)

The standard consistency of cement paste is defined consistency of cement paste which permits the penetrates of vicat plunger of size 10 mm and height of 50 mm into cement mould up to the depth of 33 to 35 mm from top of vicat mould. In order to find the initial and final setting time of cement, strength and soundness of cement a parameter known as "Standard Consistency " is used. It is designated by 'P'. This test includes computation of the percentage of water at which cement paste of standard consistency is produced. Observation of standard consistency of cement are tabulated below –

Table 4.1 Observation of standard consistency test

S.No.	Weight of Sample (gm)	Weight of Water (gm)	Weight (%)	Penetration (mm)
1.	400	105	27	23
2.	400	113	29	28
3.	400	121	31	32
4.	400	129	33	35

Percentage of water required for this test is (P) = 33%.

4.3.1.2 Setting time test-

Setting time of cement is used to detect the deterioration, due to storage of the cement. Initial setting time is defined as the time elapsed between the movement of water is added into it to the time its start loosing its plasticity. In order to perform this test take 400 gm cement paste with 0.85P. In initial setting time test Square needle is used to released it from a top of the mould and note the time required by the needle to show the penetration of 33 to 35 mm from a top. This time is referred as an initial setting time of cement. And this is 95 minute for using cement in the experiment.

Final setting time of cement is defined as the time elapsed between the movement of water is added into it to time at which cement has completely lost its plasticity. In order to find a final setting time of cement the preparation of mould same as above done but instead of using a square needle, a needle with annular collar is used. Final setting time is taken as the time at which central needle makes the impression over the mould. And this is 630 minute for using cement in the experiment.

4.3.1.3 Specific Gravity (*IS*: 4031 (Part –11) – 1988)

The Le Chatelier Flask determines specific gravity of cement. Observations table of specific gravity as shown in table 4.2.

Table 4.2 Observations of specific gravity

	Sample 1	**Sample 2**
Weight of empty flask (W1) (gm)	48	48
Weight of flask + cement (W2) (gm)	98	98
Weight of flask + cement + kerosene (W3) (gm)	156.5	157
Weight of flask + kerosene (W4) (gm)	127	127
Specific gravity of cement (g/cc)	3.08	3.16
Average Specific Gravity of cement (g/cc)	3.12	

4.3.2 Aggregate:

4.3.2.1 Sieve Analysis for fine aggregates as per code.

Sieve analysis is used to estimate the particle size distribution of granular materials. Particle size or grading distribution is relevant to the material perform in use. For sieve size analysis take 1kg of fine aggregate and 2 kg of each 20 mm coarse aggregate and 10 mm coarse aggregate. Observation in tabular form of sieve analysis of fine aggregate, 10 mm coarse aggregate and 20 mm coarse aggregate are given below respectively.

Table 4.3 Observation sieve analysis of fine aggregate

IS Sieve (mm)	Mass Retained (gm)				Cumulative Mass Retained (gm)	% Cumulative Mass Retained (gm)	% Passing
	Sample 1	**Sample 2**	**Sample 3**	**Mean**			
4.75	38	42	51	43.6	43.6	4.36	95.64
2.36	39	36	42	39	82.6	8.26	91.74
1.18	181	170	161	170.6	253.2	25.32	74.68
0.600	231	233	225	229.6	482.8	48.28	51.72
0.300	377	373	379	376.3	859.1	85.91	14.09
0.150	81	88	93	87.3	946.4	94.64	5.36
0.075	36	39	34	36.3	982.7	98.27	1.73
Pan	17	19	15	17	999.7	99.97	0.03
Total	**1000**						

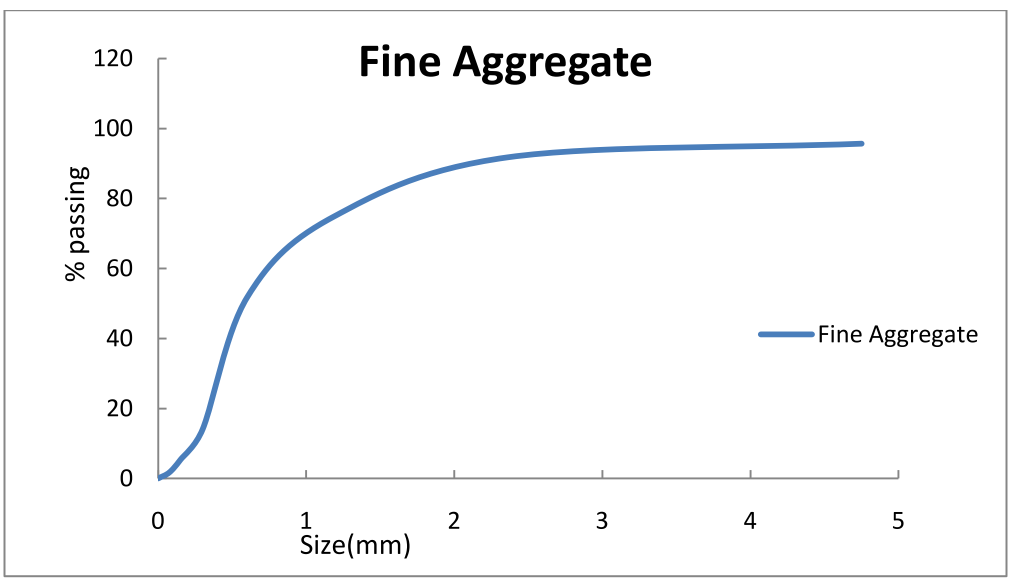


Fig. Gradation curve for fine aggregate

Table 4.4 Observation of sieve analysis of 10 mm coarse aggregate

IS Sieve (mm)	Mass Retained (gm)				Cumulative Mass Retained (gm)	% Cumulative Mass Retained (gm)	% Passing
	Sample 1	Sample 2	Sample 3	Mean			
20	0	0	0	0	0	0	0
10	201	135	177	171	171	8.55	91.45
4.75	1485	1495	1394	1458	1629	81.45	18.55
Pan	314	370	429	371	2000	100	0
Total	2000						

Table 4.5 Observation of sieve analysis of 20 mm coarse aggregate

IS Sieve (mm)	Mass Retained (gm)				Cumulative Mass Retained (gm)	% Cumulative Mass Retained (gm)	% Passing
	Sample 1	Sample 2	Sample 3	Mean			
40	0	0	0	0	0	0	0
20	359	516	290	388.3	388.6	19.43	80.57
10	1628	1461	1682	1590.3	1978.9	98.94	1.06
4.75	11	21	27	19.6	1998.5	99.92	0.08
Pan	2	2	1	1.6	2000	100	0
Total	2000						

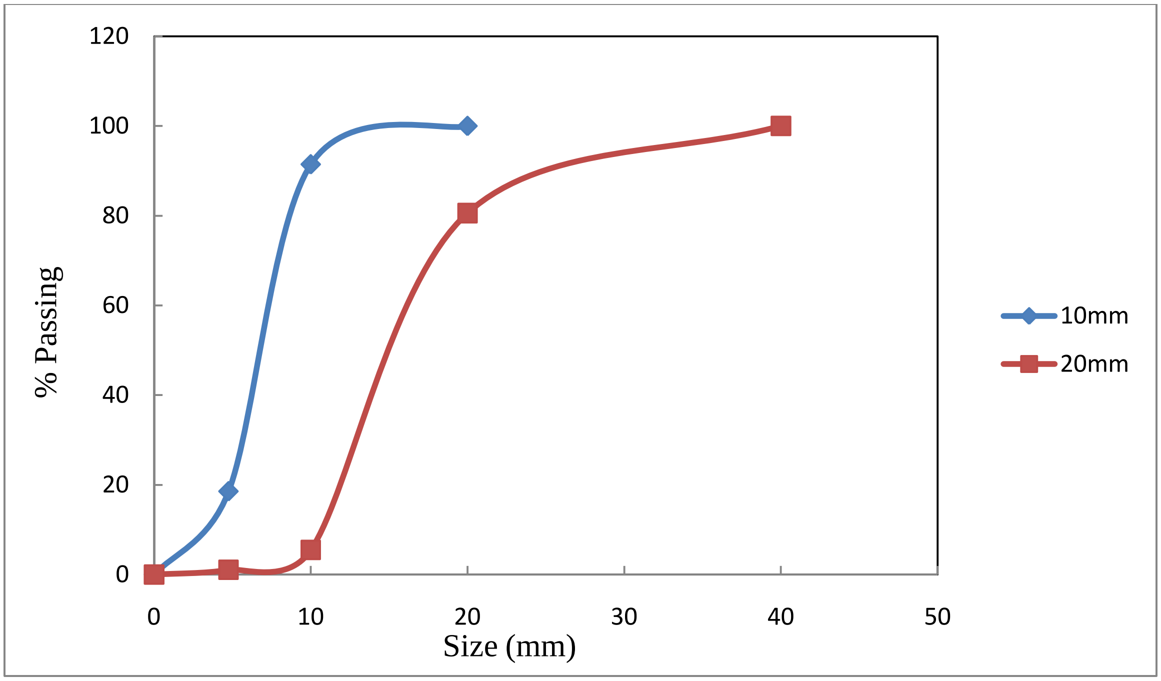


Fig. Gradation curve for coarse aggregate (10 mm and 20 mm)

4.3.2.2 Water Absorption and Specific Gravity: (*IS*: 2386 (Part 3) 1963)

Take 2000 gm aggregate for water absorption test. Specific gravity and water absorption test are usually used for strength prediction of aggregate. Observation table for specific gravity and water absorption of fine aggregate and coarse aggregate of 10 mm and 20 mm are given below –

Table 4.6 Observation of specific gravity and water absorption for fine aggregate

S.NO.	Weight Combination	Weight (gm)		
		Sample 1	Sample 2	Sample 3
1.	Weight of Pycnometer (W1)	651	651	651
2.	Weight of Pycnometer + Aggregate (W2)	1151	1151	1151
3.	Weight of Pycnometer + Aggregate + Water (W3)	1819	1826	1833
4.	Weight of Pycnometer + Water (W4)	1519	1519	1519
5.	Weight of Saturated Surface Dry Aggregate in Air (W5)	1024	1026	1029
6.	Weight of Oven Dry Aggregate (W6)	1000	1000	1000
7.	Specific Gravity = (W2-W1)/(W2-W1)-(W3-W4)	2.5	2.59	2.68
8.	Water Absorption = ((W5-W6)/W6)x100	2.4	2.6	2.9
9.	Average Specific Gravity	2.59		
10.	Average Water Absorption(%)	2.64		

Table 4.7 Observation of specific gravity and water absorption for 10 mm coarse aggregate

S.NO.	**Weight Combination**	**Weight (gm)**		
		Sample 1	**Sample 2**	**Sample 3**
1.	Weight of Pycnometer (W1)	651	651	651
2.	Weight of Pycnometer + Aggregate (W2)	1151	1151	1151
3.	Weight of Pycnometer + Aggregate + Water (W3)	1827	1831	1836
4.	Weight of Pycnometer + Water (W4)	1519	1519	1519
5.	Weight of Saturated Surface Dry Aggregate in Air (W5)	1002	1003.5	1002.5
6.	Weight of Oven Dry Aggregate (W6)	1000	1000	1000
7.	Specific Gravity = (W2-W1)/(W2-W1)-(W3-W4)	2.6	2.63	2.73
8.	Water Absorption = ((W5-W6)/W6)x100	0.2	0.35	0.25
9.	Average Specific Gravity	2.66		
10.	Average Water Absorption(%)	0.26		

Table 4.8 Observation of specific gravity and water absorption for 20 mm coarse aggregate

S.NO.	**Weight Combination**	**Weight (gm)**		
		Sample 1	**Sample 2**	**Sample 3**
1.	Weight of Pycnometer (W1)	651	651	651
2.	Weight of Pycnometer + Aggregate (W2)	1151	1151	1151
3.	Weight of Pycnometer + Aggregate + Water (W3)	1833	1836	1838
4.	Weight of Pycnometer + Water (W4)	1519	1519	1519
5.	Weight of Saturated Surface Dry Aggregate in Air (W5)	1001.5	1002.5	1002
6.	Weight of Oven Dry Aggregate (W6)	1000	1000	1000
7.	Specific Gravity = (W2-W1)/(W2-W1)-(W3-W4)	2.68	2.73	2.76
8.	Water Absorption = ((W5-W6)/W6)x100	0.15	0.25	0.20
9.	Average Specific Gravity	2.72		
10.	Average Water Absorption(%)	0.20		

4.4 Concrete Mix Design:

Concrete mix design is an important parameter for every casting of concrete. In this experiment M25 grade of concrete was carried out as per *IS* 10262: 2009 design code guidelines. M25 grade concrete design strength is

$$F_m = 1.64\sigma + f_{ck}$$

Where -

F_m= Design Strength of Concrete in N/mm^2

$f_{ck} =$ Characteristic Strength of Concrete in N/mm^2

σ = Standard Deviation

For M25 grade of concrete design strength is 31.56 MPa.

Table 4.9 Observation of concrete mix proportion

S.No.	Material	Mass (Kg)	Proportion
1.	Cement	350	1
2.	Fine Aggregate (Sand)	567	1.62
3.	10 mm Aggregate	686	1.96
4.	20 mm Aggregate	630	1.80
5.	Water	175	0.5

4.5 Size of Test Specimen-

For the desired grade of concrete cube test are performed to desired strength. Trial test are carried out on cube size of 150 mm x 150 mm mould. Before casting of concrete cube oiling of cube mould done. And after 24 hours casting of cubes mould were demoulded and cube specimen cured for 3 days, 7 days and 28 days. For each trial mix 9 cubes were cast.

Fig. 4.1 Concrete Cubes

4.6 Compaction Factor Test (*IS*: 1199-1959)

This test is used for low workable concrete for which slump test is not suitable. The principle of this test is based on calculate the degree of compaction which achieved by the standard amount of work done through allowing the concrete to be fall through standard height. The degree of compaction called "compaction factor". It is the ratio of a weight of partially compacted concrete to a weight of fully compacted concrete. Observation observed during test are shown in table –

Table 4.10 Observation of compaction factor test

S.No.	Weight Combination	Sample (Kg)
1.	Weight of Cylinder (W_1)	19.05
2.	Weight of Partially Compacted Concrete + Cylinder (W_2)	30.3
3.	Weight of Partially Compacted Concrete(W_2- W_1)	11.25
4.	Weight of Fully Compacted Concrete + Cylinder (W_3)	31.65
5.	Weight of Fully Compacted Concrete (W_3- W_1)	12.6
6.	Compaction Factor = (W_2- W_1) / (W_3- W_1)	0.89

4.7 Compressive Strength (*IS*: 516-1959)

Compressive strength test of concrete is a most important test to find idea about all the characteristics of concrete. The specimens of size 150mm x 150mm x 150mm were cast and tested at 3 days, 7 days and 28 days of the curing period. Result of compressive strength test is below in table –

Table 4.11 Observation of compressive strength test

Age (Days)	Axial Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
3	440	19.55	18.88
	410	18.22	
	425	18.88	
7	555	24.66	24.07
	520	23.11	
	550	24.44	
28	695	30.88	31.32
	690	30.66	
	730	32.44	

4.8 Push-out test results –

4.8.1 Without reinforcement of push-out specimen

Table 4.12 Without reinforcement of push-out specimen

S.No.	Specimen Designation	Ultimate Load (KN)	Ultimate Slip (mm)	Failure Pattern
1	SP1RE0	102.24	------	Concrete crushing failure
2	SP2RE0	103.32	-----	Concrete crushing failure

4.8.2 20 mm spacing provided from steel section side (Singly layered)

Table 4.13 Observations for 20 mm spacing provided

S.No.	Specimen Designation	Ultimate Load (KN)	Ultimate Slip (mm)	Failure Pattern
1	SP1RE1	124.62	11.96	Stud Failure
2	SP2RE1	123.93	12.10	Stud Failure

4.8.3 40 mm spacing provided from steel section side (Singly layered)

Table 4.14 Observations for 40 mm spacing provided

S.No.	Specimen Designation	Ultimate Load (KN)	Ultimate Slip (mm)	Failure Pattern
1	SP1RE2	124.23	11.98	Stud Failure
2	SP2RE2	123.12	12.24	Stud Failure

4.8.4 60 mm spacing provided from steel section side (Singly layered)

Table 4.15 Observations for 60 mm spacing provided

S.No.	Specimen Designation	Ultimate Load (KN)	Ultimate Slip (mm)
1	SP1RE3	122.6	12.35
2	SP2RE3	121.8	12.53

4.8.5 80 mm spacing provided from steel section side (Singly layered)

Table 4.16 Observations for 80 mm spacing provided

S.No.	Specimen Designation	Ultimate Load (KN)	Ultimate Slip (mm)
1	SP1RE4	112.34	14.21
2	SP2RE4	111.63	14.63

4.9 Discussion –

4.9.1 Effect of reinforcement on bearing capacity of stud –

Specimen type	Design strength of stud as per EUROCODE 4 (KN)	Average ultimate bearing capacity from experiment (KN)
Without Reinforcement	80.23	
Single layer 20 mm spacing from steel section	80.23	124.26
Single layer 40 mm spacing from steel section	80.23	123.67
Single layer 60 mm spacing from steel section	80.23	122.20
Single layer 80 mm spacing from steel section	80.23	111.98

Ultimate bearing capacity of stud in single layer 20 mm spacing from steel section and 40 mm spacing from steel section are nearly same. Bearing capacity of stud in single layer 60 mm spacing from steel section are 1.18% lower than using above single layer reinforcement. Ultimate bearing capacity of stud in single layer 80 mm spacing from steel section side is 8.36% lower than using singly layer 60 mm spacing from steel section side.

4.9.2 Effect of reinforcement on ductility of shear stud –

Specimen type	**Average ultimate slip (mm)**
Without Reinforcement	
Single layer 20 mm spacing from steel section	12.03
Single layer 40 mm spacing from steel section	12.11
Single layer 60 mm spacing from steel section	12.44
Single layer 80 mm spacing from steel section	14.42

Average slip of single layer of 20 mm and 40 mm spacing from steel section side are almost same. Connection using with singly layer 80 mm spacing from steel section are more ductile but ultimate bearing capacity of stud decreasing due to concrete crushing. Slip increase with when singly layer position are away from steel section side due to not confinment of stud with in stud zone.

CHAPTER - 5

CONCLUSION

- Ultimate bearing capacity of stud decrease when reinforcement layer position away from steel section side.
- Ductility of connection increase with increase with position of reinforcement layer from steel section side due to confinment of concrete not occure near stud zone.
- Load capacity directly dependent on the confinment of concrete in stud zone.
- Design equations given in Eurocode-4 underestimates the bearing capacity of the headed shear studs. It does not take the effect of reinforcement and welding technique into account.

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