A

Dissertation report

on

EFFECT OF POSITION OF DOUBLE REINFORCEMENT LAYER ON COMPOSITE SECTIONS

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

Master in Technology

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Disaster Assessment of Mitigation

CIVIL ENGINEERING

Submitted by

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DECLARATION

I hereby certify that the work which is being presented in the dessertation report entitled "**Effect of Position of Double Reinforcement layer on Composite Sections"** , in partial fulfillment of the requirements for the award of the Degree of Master of Technology and submitted in the Department of Civil Engineering of the Malaviya National Institute of Technology Jaipur is an authentic record of my own work carried out during a period from August 2015 to June 2016 under the supervision of Dr. Sandeep Chaudhary, Associate Professor, Department of Civil Engineering, Malaviya National Institute of Technology Jaipur, India.

The matter presented in the report has not been submitted by me for the award of any degree of this or any other Institute.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Jayesh Kumar Teli

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INTRODUCTION

1.1 GENERAL

In the early 20th century, for bridge design composite structures were considered but in recent years, composite structures have been used widely in modern high-rise buildings. The flexural strength of composite beams widely affect by the force and ductility of the shear connectors between the steel beam and the concrete slab. The behavior of the shear connectors mostly applicable to the design for the connection between shear force impart and the degree of slip at the interface of the steel and concrete. The execution of the shear connectors, in a beam and in a push – out test specimen, will have a fundamental dissimilarity that influence the test results and dependability of test data. For example it has been evaluated by Slutter and Davis *et al.*(1999) states that the direct stresses which are available in concrete slab of a beam. It is generated by the bending, which is not present in push – out specimens and eccentricity of loading that can happen in push-out specimens, either because of minor error in the arrangement of the specimen or non uniformity of concrete, which frequently evaluate in low values of the average ultimate strength per connector.

In the past years for the design of a building, the choice is generally between a concrete structure and masonry structure. However, the failure of many RCC and low-rise building under earthquake makes the structural engineers to think about new type of materials. Use of composite construction is of more absorption due to its remarkable property of improving the overall performance of the building through modest changing the construction technology. Composite construction is a term, which refers to combination of two or more construction elements to exploit the mechanical properties of the each element. The most frequently and widely used combination of material is that of steel and concrete. These two materials are widely used for the fact that both the elements complement to and compatible with each other. These two materials have same degree of thermal expansion. They have also same degree of strength with concrete efficient in compression and steel in tension. Concrete also provides corrosion resistant to steel and thermal insulation at high temperature. Concrete also controls the slender steel from local buckling. These steel-concrete composite constructions are used in multistorey building as well as in long span bridges. A composite member is developed when a steel component such as I section beam attached to a concrete beam attached to a floor slab or bridge deck. Profile sheeting and partial thickness precast concrete are known as structural participating formwork. Composite construction is needed for medium or long span structure for which concrete deck is used for different purpose and where low or medium level of fire protection to steel is sufficient. Composite columns are also used widely to resist compressive load. This column may take the form of encased I-section, concrete filled rectangular section and concrete filled circular tube. Short composite column fails by crushing and their strength is governed by the cross section. Long columns tend to fail by geometrical nonlinearities and they fail by buckling. In framed structures, consist of composite beams, composite columns or both. In the composite member, mechanical shear connectors join steel flange and concrete slab. These shear connectors help in transfer of shear force from concrete to steel and vice versa. It also helps in vertical separation of concrete and steel components. These connectors are of different types such as stud shear connector, bolted shear connector, channel shear connector, bar shear connector, angle shear connector etc. The most widely used shear connector is welded stud shear connector. It consists of head and shank, which connected to steel element through welded collar. The bond between steel and concrete is achieved through mechanical shear studs. The mechanical properties of shear stud and their spacing determine the degree of shear connection. The shear flow forces have to be resisted by the shear strength of shear studs. The properties of shear studs are generally determined by the push-out test where shear load is directly applied to stud. The diameter of shank varies from about 13 mm to 22 mm with the common size being 19 mm. These composite structures have potential applications for protective structures, building cores, submerged tunnels, gravity sea walls, ship hulls, anti-collision structures, floating breakwaters in which resistance to blast loading and impact is of prime importance. There are also cases where composite structures are subjected to impact load due to drop of hammer or from a bullet striking composite armor. Now a day in sandwich structures lightweight concrete is used instead of conventional normal weight concrete. Conventional headed shear connector or angle bar shear connector does not perform well under impact. Concrete structures are often subjected to long-term static and short-term dynamic loading. Due to low tensile strength and energy, dissipating characteristic of concrete under impact resistance of concrete is poor. Current world events clearly indicated that protection to civilian and military structures from enemy or terror attack is highly essential. To meet these needs structure has to be made impact resistant. The most important constituent for the composite structure is the connection. As connections are responsible for the transfer of forces from one element to other, their performance under influence of the response of the structure. Hence connections should be strong enough to resist impact. Generally, headed stud connectors are used in composite construction that are best suited for flexure. However, under impact headed studs do not perform well and fail at a very small load. Therefore, there is another set of connectors that are known as J-hook connectors can be used instead of headed shear connectors. The hook of the double J-hook connector act as spring during impact loading because of which the structure can withstand load and does not undergo large deformation.

There is present day mode of composite beam was accepted to raise standard and economies material amount. In modern construction industry, composite beams and floor slabs system with profiled steel decking is regularly used instant of hard composite slab. The type of composite beam or slab system composed of a cold formed, profiled steel sheet. The metal decks are attached to the steel beam either using mechanical shear connector welded on the beam flange or adhesive bonding between profiled sheet and concrete. The steel deck functions not only as a everlasting formwork for a concrete slab, but also proceeds as tensile or positive reinforcement for the concrete slab. When profiled sheet used in a cellular combination, they allow the progress of electrical and communication resources. The centre of idea of composites is that the load is applied over a wide surface area of the matrix. Matrix then moves the load to the reinforcement, which being hard, increases the strength of the composite. It is well known that there are many matrix materials and fiber type, which can be grouped in countless way to prepare the desired properties. Composites are collected in countless other ways. One main group of composites is explained as laminar composites which is also called laminated composites or laminates. A laminate usually consists of two or more films of planar composites in which each film (also entitled lamina or ply) will be of the similar or different materials. Similarly, a sandwich laminate is a composite construction in which composite main layer is sandwich between either of metallic or composite face layers. The composite face layers shall be in the shape of laminates. Laminated and sandwiched composite structures are very tough and hard, and are normally proposed for lightweight structural demands.

1.2 COMPOSITE STRUCTURES

A composite member is described as composed of a rolled or a assembled structural steel form that is either engaged with concrete, protected by reinforced concrete or structurally connected to a reinforced concrete slab. Composite members are constructed such that the structural steel shape and the concrete move together to withstand axial compression or bending.

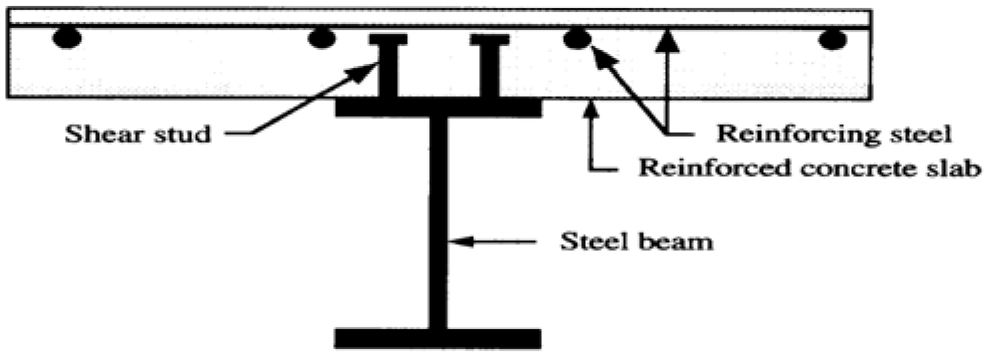


Fig. 1.1: Steel beam with and supporting a concrete slab (*IS 11384-1985*)

Advantages: Advantageous properties of both steel and concrete are employed in a composite structure. The advantages can be fully summarized as below:

- Advantages founded on the life-cycle-cost analysis alternate to initial cost only.
- Standard assurance of the steel material beside with accessibility of proper paint system convenient to different corrosive environment.
- Potential to cover wide column clear area in construction sites and wider span for bridges or flyovers which guide to more usable clearance.
- Reinforced cement concrete (RCC) slab is in the compression zone and steel joist is in tension. Hence, widely the useful utilization of the materials can be targeted.
- Effective seismic resistance i.e. top suited to withstand repeated earthquake loading, which needed a large amount of ductility and hysteretic energy of material orstructural frame.
- Composite sections have greater stiffness than similar property steel sections and thus bending stress except deflection are minor.
- Reduced beam depth shortens story height and similarly the cost of cladding in the buildings and it also degrades the cost of embankment in a flyover.

- Reduced depth permits the provision of lower cost for fire proofing of beams revealed faces.
- Cost of formwork is lower comparatively to RCC construction.
- Cost of handling and transportation is shortened for using crucial part of the structure fabricated in the workshop.
- Easy structural repair, modification and maintenance.
- Structural steel components has appreciable scrap value at the finish of useful life.
- Reductions in mostly weight of structure and therefore reduction in foundation value.
- Wider use of the material i.e. steel, which has property of durablity, fully recyclable on exchange and environment friendly.

Disadvantages: Disadvantages are given below

- High Cost
- Complex Repair Procedure
- Mechanical characterization of the composite structure is more complicated than that of a metal construction. distinctly metals, The composite materials are not isotropic, i.e. their properties are not the same in all directions. Besides , they require additional material parameters. For instance, one layer of a graphite or epoxy composite involves nine stiffness and strength constants for managing mechanical analysis. In instance of a monolithic material such as steel, one need only four stiffness and strength constants.

1.3 SHEAR CONNECTIONS

A component of a composite beam is the shear connection between the steel section and the concrete slab. This connection is accepted through mechanical stud which permits the shift of forces available in concrete to steel, and vice versa. It also withstands the vertical uplift forces at the steel concrete interface. Mechanical connectors are put in place on the top flange of the steel beam, normally by means of welding, before the slab casting. Such types of connections ensure that the two unlike materials that makes the composite action as one unit.

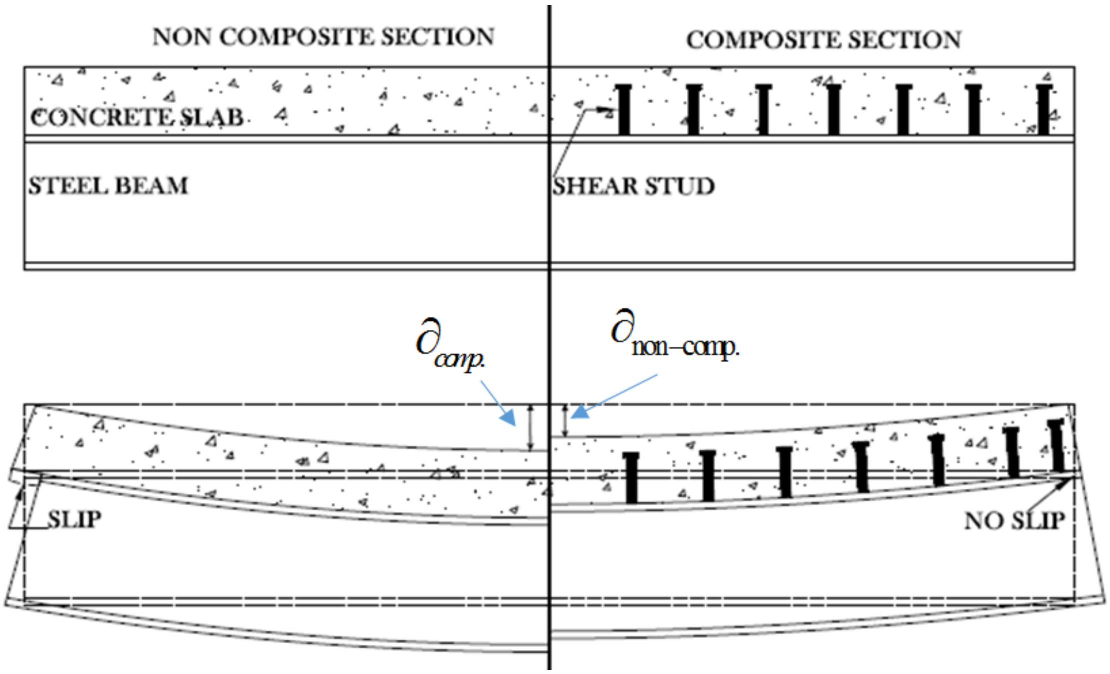


Fig. 1.2: Composite action in flexural members

Shear connections ensures composite action. It effectively transfers shear forces at the interface and prevents vertical separation between steel and concrete due to uplift forces. Shear connectors may be mechanical or adhesive bonding. On the basis of behavior they are classified into three main types :

1.3.1 FLEXIBLE SHEAR CONNECTORS

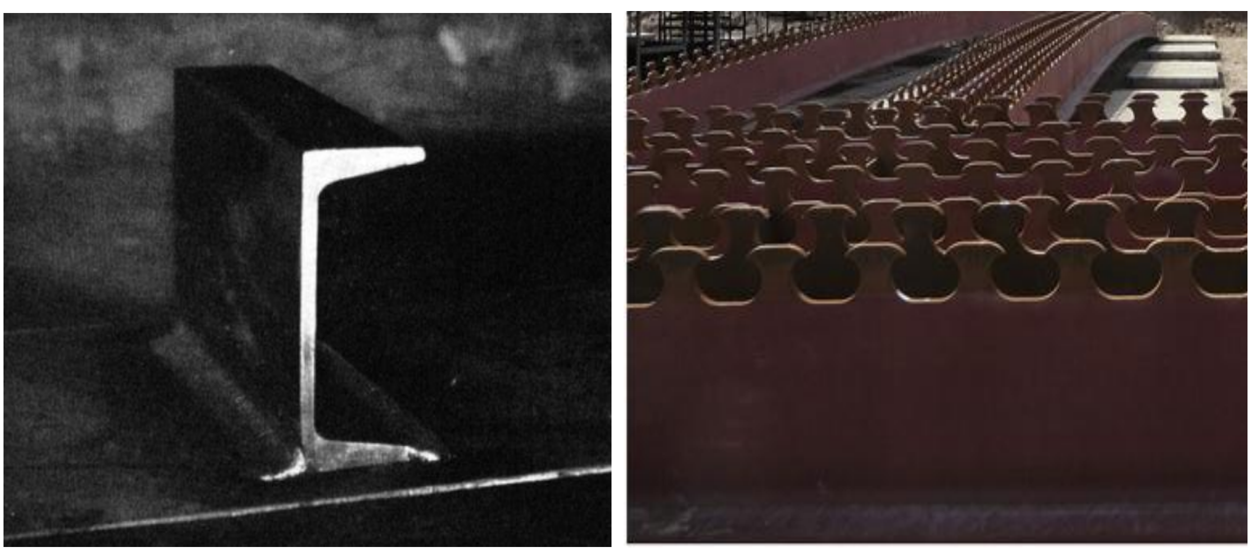
Usually they undergo appreciable shear deformations before yielding. They may fail due to yielding of connector or shearing at weld collar. Examples: Shear studs, through bolts etc.

Shear studs (commonly used) Through bolts(Pavlović *et al.* 2013)

Fig. 1.3: Flexible shear connectors

1.3.2 SEMI-RIGID SHEAR CONNECTORS

They are stiffer connectors and may fail due to crushing of concrete with partial damage in connectors. Examples: Channel shear connectors, Puzzle shaped shear connectors



Channel shear connector (Viest 1951) Puzzled shape shear connectors (Lorenc *et al.* 2014)

Fig. 1.4: Semi-rigid shear connectors

1.3.3 RIGID SHEAR CONNECTORS

They provide Very stiff connection and Offers negligible slip. It also provides brittle failure due to concrete chipping or failure a surface of steel flange. Example: Adhesive connection using epoxy or polyurethane.

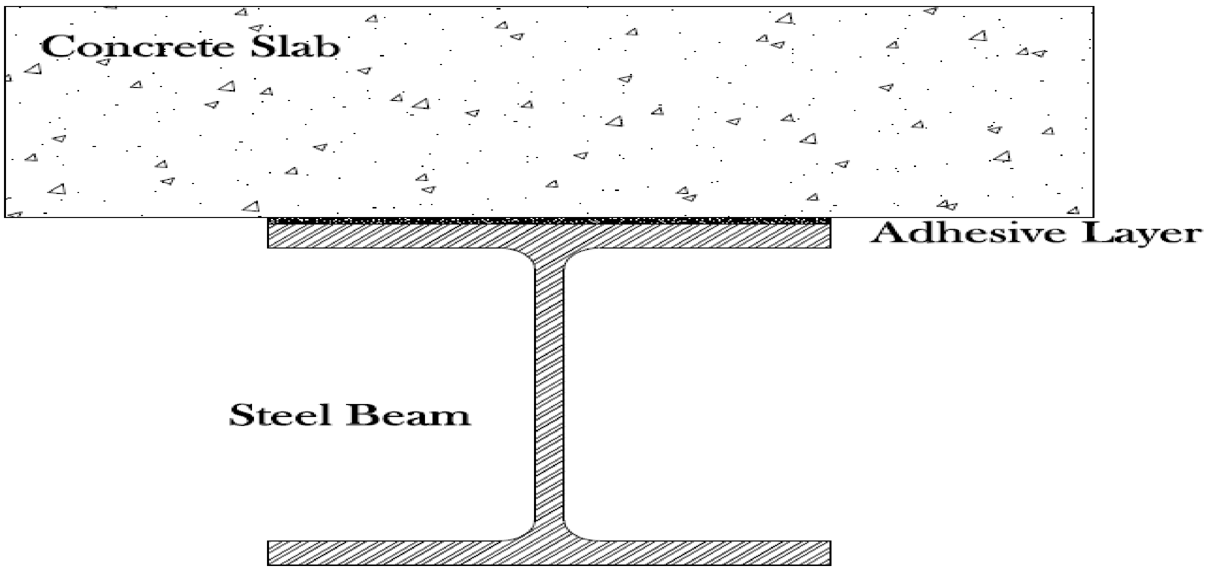


Fig. 1.5: Rigid shear connectors

1.4 BACKGROUND AND MOTIVATION FOR RESEARCH

Even though composite steel and concrete members have been studied effectively since the late 1960's, the limit states and design methods w.r.t strength and serviceability are yet being explored. The main research has concentrated on the strength and behavior of composite beams with or without profiled steel decking. Push -out tests are done in order to evaluate the behavior of headed stud shear connectors. When headed stud shear connectors are used in design, one must be able to decide their ability to withstand the longitudinal forces that appear between the steel and concrete. Hawkins and Mitchell (1984) stated that it is difficult to predict the strength of headed stud shear connectors. The reason is that when the embedded headed stud shear connector approaches failure, the behavior is very complicated because of the inelastic changes due to deformation in the stud under the grouped effects of shear, bending and tension. The concrete enclosing the headed stud shear connectors are projected to cracks due to high splitting forces happened by headed stud shear connectors and that a non-ductile failure will happen. If the strength of the concrete is very high, the headed shear stud fracture will happen prior to concrete failing.

Grant *et al.* (1977) researched that the position of the headed stud shear connector influenced the strength of the stud and on the stud load bearing side is different. The strong and weak position is shown. The position of the stud in the rib is unconsidered in the existing strength equations used in the AISC (1999), British standards institution (2004) and AS 2327.1 (2003) because when the stud strength equations were evolved from Grand *et al.* (1977), the experimental studies widely used the studs welded in the mid of the deck rib.

Hicks (2007) studied a full-scale composite steel-concrete beam and experimented companion push tests. The beam showed excellent ductility with the slip capacity overreached the value given by existing international standards. The study of behavior of headed studs in push-out test specimens provides unchanging approximates of strength and they do not display the ductility that the beam tests exhibit.

1.5 PUSH OUT TEST ON SHEAR CONNECTORS

Indian design code on composite road bridges (*IRC 22 1986*)

$$Q = 1.49hd\sqrt{f_{ck}} \qquad (h/d<4.2) \qquad (1.1)$$

$$Q = 6.08d^2\sqrt{f_{ck}} \qquad (h/d<4.2) \qquad (1.2)$$

Where:-

Q is safe shear resistance of a connector in newtons

H is overall height of stud in mm

D is diameter of stud in mm

F_{ck} is the strength of a standard size cube at 28 days

According to *Eurocode -4*

$$P_{DR} = \frac{0.8 f_u \pi d^2 / 4}{\gamma_v} \qquad (1.3)$$

Or

$$P_{DR} = \frac{0.29 \alpha d^2 \sqrt{f_c E_{cm}}}{\gamma_v} \qquad (1.4)$$

With

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

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

Where:-

P_{DR} is design shear resistance per connector

Y_V is partial safety factor, generally taken 1.25

d is diameter of stud shank, which should be between 16mm to 25mm

f_u is ultimate tensile strength of stud material which should be less than 500MPa

f_c is compressive strength standard sized cylinder at reaching a particular age

h_{sc} is overall height of stud shank

E_{cm} is elastic modulus of concrete in MPa

Load slip curves are used to evaluate parameter like stiffness, ductility and ultimate bearing capacity of connectors. Horizontal push out test is performed as per IS 11384 (1985) and vertical push out test is performed as per *EUROCODE-4*(commonly used).

Push-out test as per Eurocode-4: Push out specimen consist of steel beam of suitable size with welded shear connectors both the flanges. Shear connectors are embedded in concrete by casting slabs of suitable size around them. Concrete slab is restricted with 10mm horizontal and transverse reinforcement bars. Code recommends that dimensions of specimen and reinforcement must be modified as per the beam for which the test is being conducted. The prepared specimen is subjected to loading. Initially load is cycled 25 times between 5 to 40% of expected capacity. Subsequently monotonous load should be applied such that the specimen fails in not less than 15 minutes. The longitudinal slip between each concrete slab and the steel section would be studied continuously during loading or at each load increment. The slip would be studied at least until the load has fallen to 20% lower than the maximum load. As close as possible to each group of connector, the transverse separation between the steel section and each slab should be measured.

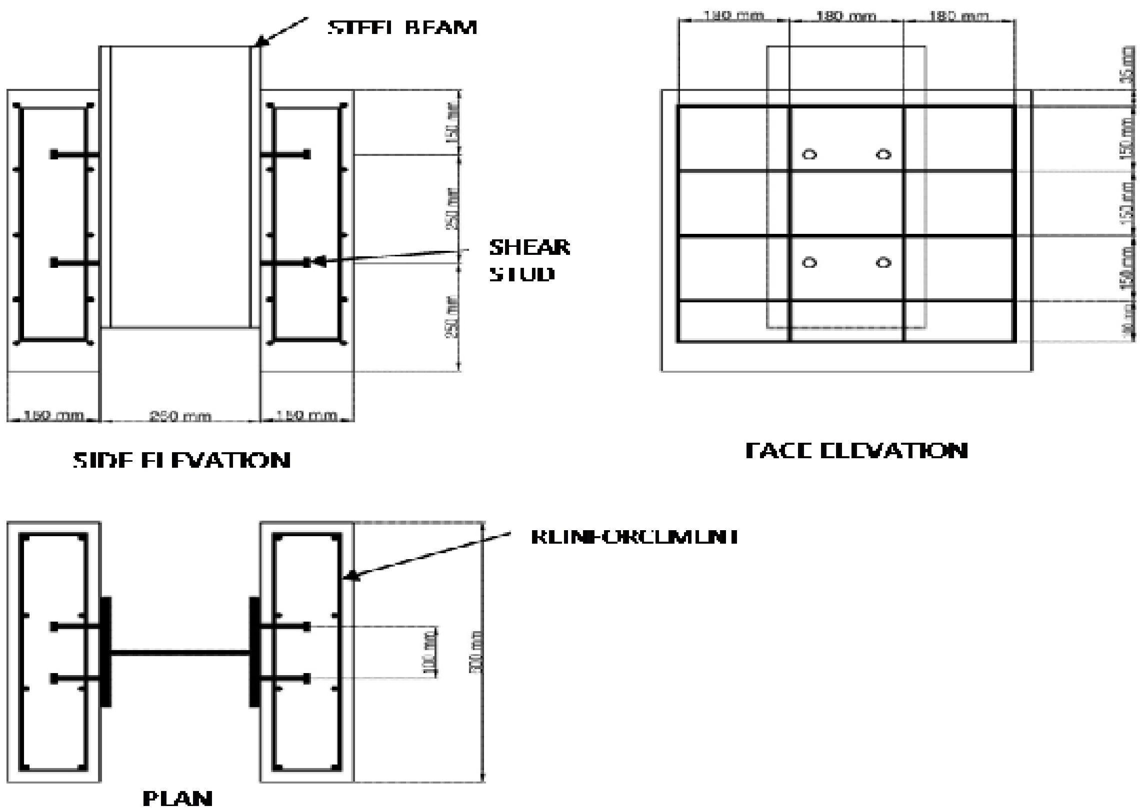


Fig. 1.6: Standard push out test specimen as per *Eurocode 4*

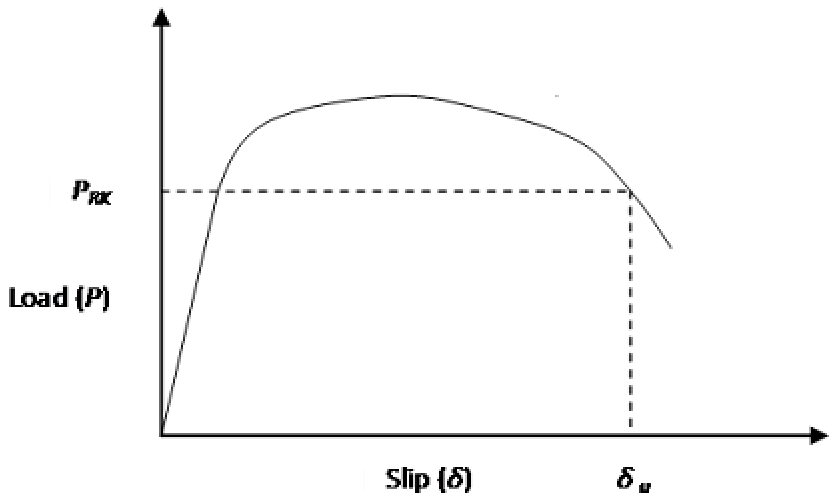


Fig. 1.7: Load- slip curve for push-out test

Bearing capacity of a connector is defined as the ratio of ultimate failure load and number of connectors. Ultimate slip is the maximum slip at the interface and shear stiffness is defined as the secant modulus at a load level of 50% of the peak load.

1.6 OBJECTIVE OF THESIS

The main objective of this research study is to explore the feasibility between stud welded on steel girder and concrete. The main aim of the study is the rapid substitution of concrete decks in concrete-steel composite bridges. The study is designed to define the feasibility of bonding between concrete and stud as shear connector in composite bridges by an experimental program. Under the limit state of serviceability, the bonding joint should have sufficient stiffness to minimize interlayer slip. The bond must be strong enough to permit the complete development of the plastic capacity of the concrete and steel sections without failure of the joint. Investigate the feasibility of bonding concrete decks to steel beams in composite bridges using stud welded to steel girder made in the experimental program established on the standard push-out test.

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1.7 ORGANIZATION OF THE DISSERTATION REPORT

This dissertation is organized as follows:

Chapter 1 discusses detailed information of the steel concrete composite bonded with steel. *Chapter 2* discusses about the different types of push-out test and literature review is presented. *Chapter 3* presents the experimental program for push out test specimen arrangement, load setup with requisite equipment and unlike approaches for single member preparation are reported. *Chapter 4* discusses the result of physical properties of materials needed for specimen's preparation and load slip values for unlike push-out test specimens.

Chapter 5 is the summary of finding this research; push-out test experimental value and other viewing which are developed in this study.

Chapter: 2

LIERATURE REVIEW

2.1 INTRODUCTION

Composite steel–concrete beams are the new form of the composite construction methods. In U.S. a patent by an American engineer extended the shear connectors at the top flange of universal steel section to block longitudinal slip. This was the initial stage of the evolution of fully composite in steel and concrete. Concrete encased steel sections were initially evolved in order to answer the trouble of fire resistance and to safeguard that the security of the 9steel section was extended throughout loading.The steel section and concrete act combindely to withstand axial force and bending moments. Composite construction as we realize it currently was initially used in both buildings and on the bridges in U.S. over decades ago.

Test results on steel concrete composite beams were indicated since early 19th century . Many details of composite structural associated between steel beams and concrete have been indicated and researched in Canada and as prior as 1922. These studies similar to the behaviour of 12 conventional concrete slabs on steel I – beam. Such experimental tests are not evaluated here for the re-evaluated. The tests researched below include data on the composite beams and slabs which use stay in place form.

2.2 LITERATURE REVIEW

Johnson R.P (1994) does the first work for composite construction initiated by the full scale research by Dr. Chapman and Prof. Johnson R.P which led to prepare a book with a idea conducted of composite structures of steel and concrete. In his book he outlined design methods for composite structures for both buildings and bridges.

Nie et al. (2004) studied the static loading were evaluated on sixteen steel concrete composite beam and 2 steel beam to shear withstanding mechanism and strength of the composite beams. The important experimental parameters were the shear span/aspect ratio of the simply supported beam and width & thickness of concrete flanges. Based on strain calculations, stresses in steel beam were analyzed using speculations of elasticity & plasticity and vertical shear that steel beam withstand was determined. The shear resistances of concrete flange were achieved by subtracting steel shear contributions from the complete load applied. It was established to the concrete flange which would sustain 33-57 percentage of the complete ultimate shear given to composite beams specimen. Opposite to the classic assumption of ignoring the concrete, shear contribution in most of the design codes and description. The shear strength equations that considered the shear benefactions of both steel beams and concrete flanges is suggested.

Lam et al. (2005) used headed stud shear connectors which are normally prefer to move longitudinal shear forces over the steel Concrete bonding face. Current information of the load, displacement behavior and shear capacity of shear stud in the composite beams are restricted led to information given from the experimental push out tests. For this cause, a constructive numerical model using the FEM to simulate push out test was prepared. The model has proved against experimental test results & compared with information given in the present code of practice i.e. BS5950, EC4 and AISC. Parametric studies using FEM model were explored to variation in concrete strength & shear stud dia. The FEM had given better information to the different mode of failures given during experimental testing.

Abbas *et al.* (2005) studied experimentally strength & behavior of shear stud connectors in composite beams constructed of steel plate and reinforced concrete slabs using push out tests. The connectors behavior is examined in terms of load-displacement relationship from which stiffness of the stud connector can be evaluated. A series of 7 push out tests examined on full-scale specimen having the similar basic dimensions, shown in Fig 1. Each specimen consist of UB 254 mm x 147 mm x 43 mm, 560 mm long joined to two 460 mm x 300 mm x 150 mm concrete slabs by means of 2 pair of stud connectors, welded to both sides of flanges of steel beams. Specimens had various stud dia. and unlike concrete strength. The concrete slabs was reinforced with 10 mm and joined to universal steel beams by 2 groups of 65 mm long, 13 mm dia. & 19mm. 100 mm headed studs welded manually to flange of the universal steel beams on each side. Specimens had various stud diameter, and different concrete strength. Vertical slip of the slab relative to the steel beam was measured at the level of the connectors by means of dial – gauges with least count of 0.01mm.

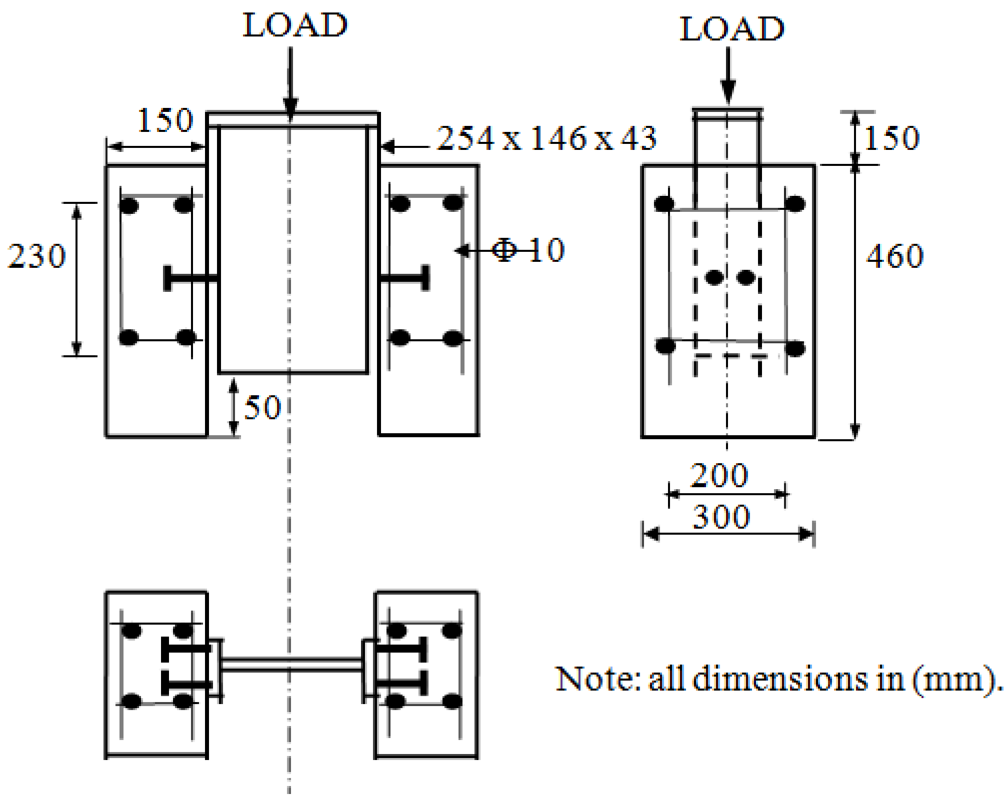


Fig. 2.1: Push-out on shear connector (Abbas *et al.(2005)*)

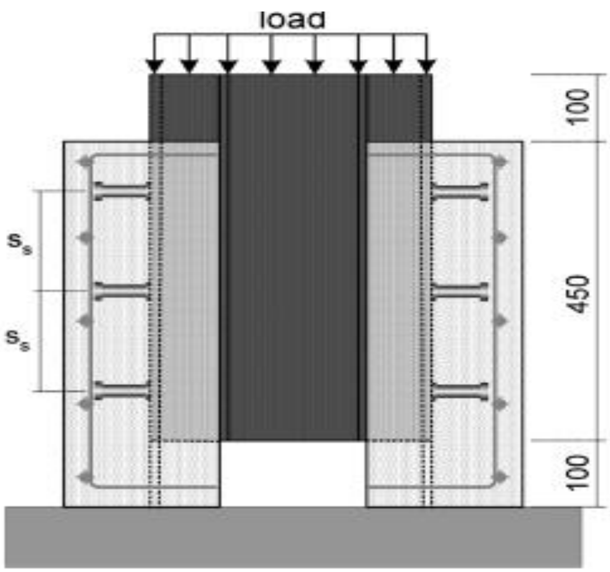
Results shows that shear strength of stud shear connectors are affected by the shank dia. of stud shear connectors, compressive strength of the concrete & slip on the interface of steel beams and concrete slabs. At low loads, the stud shear connectors record a small value of slip. At about (80%) of the ultimate load, large slip value are recorded while the concrete slabs showed signs of crack and distress in the form of diagonal cracking. With further load increase, the specimen failure normally occurred by the concrete slab slowly developing cracks. Load – slip curves indicate approximately linear behavior up to around (70%) of the ultimate load. Failure usually is being preceded by the horizontal cracking of the slabs at connector's level at about 60-85% of the ultimate load. It can be seen that, the ultimate shear capacity is greater when compressive strength of concrete is higher & also large dia. studs extend their peak load higher than smaller diameter.

Typical patterns of cracking in the concrete slabs consisted of horizontal, and diagonal. Horizontal cracks developed first, at the side surface of the concrete slab, near the location of studs, as shown (see pictures). Yield of the stud involved shown, of course considerable local crushing of the concrete where it was subjected to very high bearing stress near the root of the stud. Measurable slip occurred in all test when the increment of load was applied, and increased at an accelerating rate as the test progressed, failure usually being preceded by horizontal cracking of the slabs at connectors level at about 60 – 85% of the ultimate load.

Fig2.2: Cracks of the concrete slab near the position of the studs shear connector (Abbas *et al.(2005)*)

Fig.2.3: Bending of shear due to horizontal shear (Abbas *et a.(2005)*)

Jeong *et al.* (2005) examined the behavior characteristic of steel concrete interface & analysis method to simulate interface behavior by using push out test experimental results for steel concrete composite beams. In order to determine the partial interaction behavior of steel concrete interface, such interface is given by a no. of interface elements.



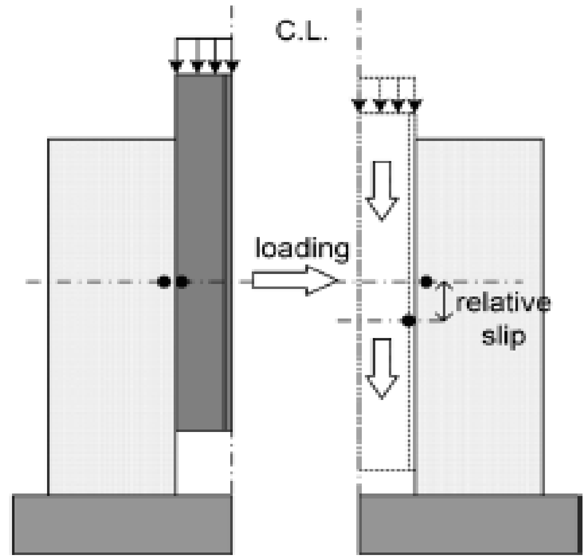


Fig2.4 Specimen (Jeong *et al.2005*) Fig2.5 Measurement of relative slip (Jeong *et al.2005*)

The results of experimental push out test gave that the degree of interaction depending on stud space had no outstanding influence on relative displacements but on ultimate loads only. Hence as degree of interactions is higher, the ultimate load and initial tangential stiffness are inclined to rise. The load relative slip curve changes the linear elasticity approx. upto 90% of ultimate load regard less of the degree of interaction. The magnitude of relative slip are approx. 0.16d at linear elasticity limit, 0.30d at ultimate load where interaction failures is started and 0.77d at interaction perfect failures where d is the dia. of the stud.

Xue *et al.* (2008) studied Stud shear connector which is widely used shear connectors in steel concrete composite beams. The Composite activities of steel beams & concrete slabs is attained by stud shear properties directly. 30 push-out tests on stud shear connectors were guided to evaluate the outcomes of stud dia. and height, concrete compressive strength, stud welding technique, transverse reinforcement and steel beam types on stud failure modes, load-slip curve and the shear bearing capacity. 30 push out tests were examined out with unlike parameters i.e. stud dia. and height, concrete compressive strength, stud welding technique, steel beam type and the type of transverse reinforcements in accordance with Table 2.1

Table 2.1 Test Specimen (Xue *et al.2008*)

Specimen	Number of specimens	Shank diameter (mm)	Concrete	Dimension a×b×c (mm)	Steel beam	Stud welding technique	Transverse reinforcement
STUD1-3	3	Φ13	50	360×80×200	I20b	High pressure fusion welding	Two layers
STUD3-6	3	Φ16	50	454×100×254	Welded I steel beam		Two layers
STUD7-9	3	Φ16	50	400×100×200	I20b		Two layers
STUD10-12	3	Φ16	50	454×100×254	Welded I steel beam		Two layers
STUD13-15	3	Φ19	50	494×120×254	Welded I steel beam		Two layers
STUD16-18	3	Φ19	50	494×120×254	Welded I steel beam		Two layers
STUD19-20	2	Φ13+	50	420×110×200	I20b	Weld all around	Two layers
STUD21-22	2	Φ13+	50	420×110×200	I20b		Four layers
STUD23-24	2	Φ13+	50	420×110×200	I20b		Two layers
STUD25-26	2	Φ16+	50	440×120×200	I20b		Two layers
STUD27-28	2	Φ16+	50	440×120×200	I20b		Four layers
STUD29-30	2	Φ16+	50	440×120×200	I20b		Two layers

A transparent influence of concrete compressive strength and stud dimensions on the capacity was examined. The results determine that increases of stud shear bearing capacity with increase in concrete compressive strength, stud dia. and height. The amount of transverse reinforcement in concrete slabs had a very light influence on stud shear bearing capacity of the stud of 13 mm. The increase was 10 percent. The effect of steel beams type on stud shear bearing capacity was unqualified.

Karkare et al. (2011) researched the strength & behavior of shear stud connectors in composite beams madeup of steel plates and reinforced concrete slabs was examined using push out tests. Extensive parametric studies were carried out & a mathematical model was prepared to forecast the shear strength of connectors. The experimental results showed close relations with the model developed. This type of work were carried out in Structures Lab. of the University of Baghdad, Iraq. Many test specimens with different stud sizes and different strengths of concrete were examined under push out tests. The connectors behavior is analyzed in term of load slip relationships, from which stiffness of stud connectors can be evaluated. The experimental resulted are compared with mathematical model and with other accepted models developed by other researchers.

Souici et al.(2012) analyses the behavior of steel concrete composite beam with shear connections realized by either the traditional welded studs or a newly bonded solution based. Experimental push out tests were carried out on 5 composite beams. The distribution of bonded face shear stress depends on various parameters among which distribution of shear forces throughout beam axis. The fully interface bonded connection gives a continuous transmission of shear forces between steel beam & the concrete slabs. The full connection between concrete & steel by shear stud is difficult to predict. The connections standard between two materials considerably depend on the no. of shear studs. This assumptions can only be given if concrete is untracked. The variation of neutral axis position depend on applied load & strain state of steel beams. The strain distribution along longitudinal & vertical directions is unlike in the bonded composite beam and connected composite beams. The distributions of interface slip is also influence by the solution given for shear connection. The experimental results are examined & equate with those obtained by this theory.

Prakash et al. (2012) paper presents modified push out tests examined for determination of shear strength & stiffness of High strength steel (HSS) stud. The HSS stud having ultimate strength of 900MPa and yield strength of 680MPa is evaluated in the modified push out specimens. The reinforced concrete slab of push out specimen which provided dimension which as recommended by BS5440 Part-5 but with expanded transverse reinforcement for greater splitting strengths. Enhancement of splitting strength was considered due to confinement of concrete with hoop types of transverse reinforcements at smaller spacings. Manders model was considered to evaluate the enhancement in splitting strength due to rise in the confined compressive strength of concrete. At this type of study shall be considered in high lighting the significance of confined concrete compressive strength while designing push out specimens. Experimental results test value of shear strengths of HSS stud is found to degrade in between extreme bound given by the *eurocode* 4 formulae. Further measurements are given by addition of steel fibre concrete in surrounding of HSS stud clouded in RC slab of push out specimen.

Han et al. (2015) studied static behavior of stud shear connectors clouded in elastic concrete. 18 push-out tests were examined to give the load slip behavior, bearing capacity & ultimate slip of shear stud. Push-out test specimens include rolled H section steel beam of size 200mm×200mm×8mm×12mm. The size of concrete slabs used was 460mm×400mm×160mm. The slab of concrete were grouped into four different categories of crumb rubber contents with 0%, 5%, 10% and 15%. There was also group of 5% (S) with greater compressive strength. Two dia., 16mm & 19mm were given and the height of the studs were 90mm & 110mm respectively.

Table2.2 The parameter of push out specimen (Han *et al.* 2015)

<table>
<tr><th>Specimens</th><th>Concrete strength grade</th><th>Rubber content</th><th>Size of studs</th><th>Reinforcement</th></tr>
<tr><td>PS 1-3</td><td rowspan="6">C30</td><td>0%</td><td rowspan="5">Diameter is 16mm, 90mm long</td><td rowspan="6">Horizontal
10Φ@100
10Φ@95(1.5%)

Vertical
10Φ@110(1.45%)</td></tr>
<tr><td>PS 4-6</td><td>5%</td></tr>
<tr><td>PS 7-9</td><td>10%</td></tr>
<tr><td>PS 10-12</td><td>15%</td></tr>
<tr><td>PS 13-15</td><td>5%(S)</td></tr>
<tr><td>PS 16-18</td><td>5%</td><td>Diameter is 19mm 110mm long</td></tr>
</table>

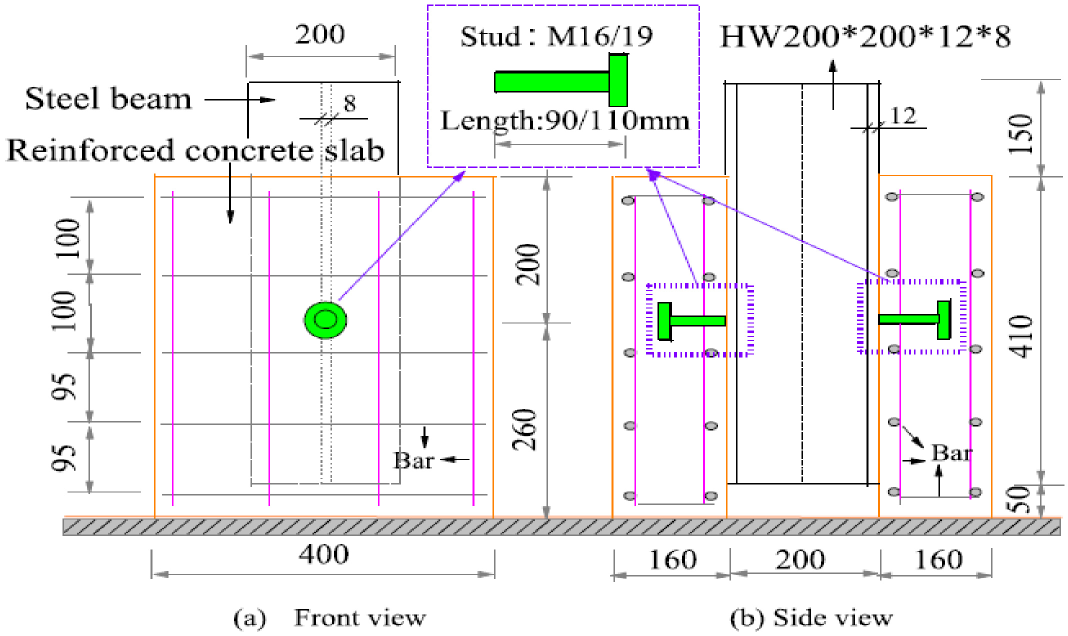


Fig2.6 Push out specimen (a) Front view (b) Side view (Han *et al. 2015*)

Experimental test results evaluate that the ductility of stud improve outstandingly with increasing rubber content. When the rubber content extends 10%, the shear studs has comparatively high bearing capacity, better deformation & better ductility. The specimens with 5% rubber contents elastic concrete, shear studs show large ductile behavior embedded in lower strength elastic concrete and dia. has low influence on the ductility & stiffness of the studs. Studs shank failure is the important failure modes in the push-out tests and damage is ductile.

Chapter: 3

EXPERIMENTAL PROGRAM

3.1 GEOMETRICAL DETAILS AND FABRICATIONS

3.1.1 MOULD FABRICATION

Mild steel mould was prepared for concrete specimens casting. 10mm mild steel plates accessible in MNIT material concrete laboratory was used for mould preparation. Useful cutting, grinding & assembly work for plates were made very accurately in fabricator workshop. Fabricated mould & mould preparation process for concrete shown in fig 3.1

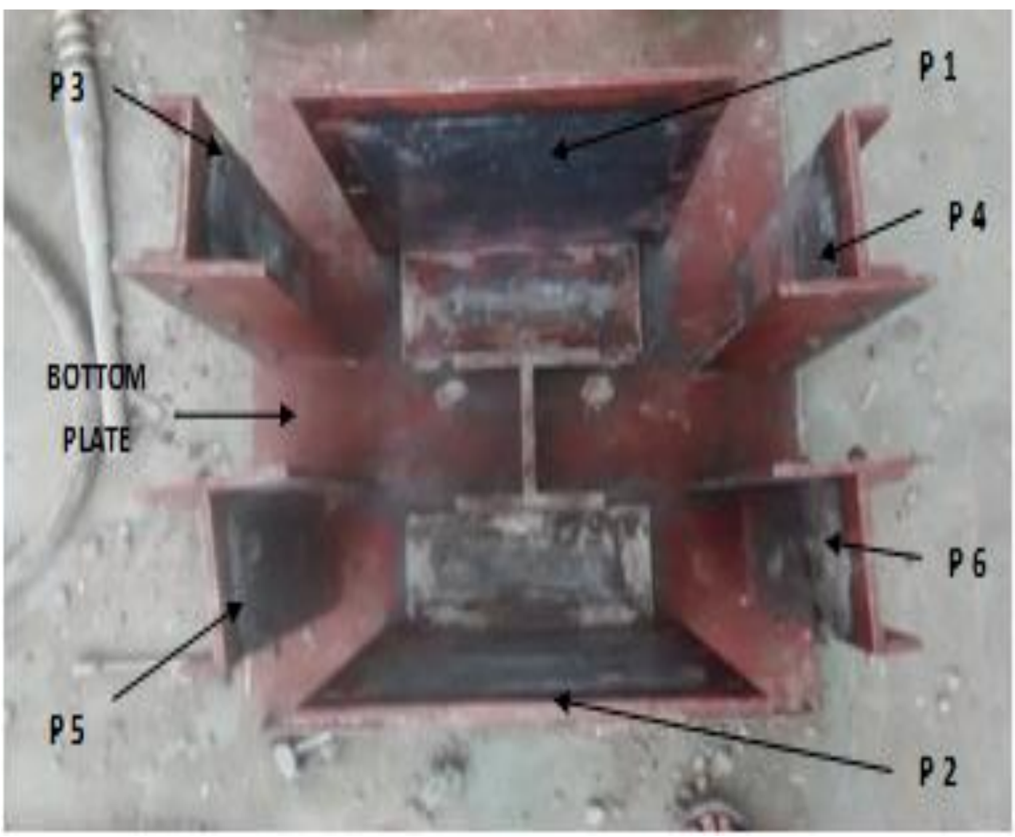


Fig.3.1: Different components of the mould

Moulds were fabricated from 10 mm mild steel plates. Mould was assembled from 6 different plate components. Entire assembly was fixed on a 12 mm thick mild steel platform Verticality of mould was checked using magnetic plate level. The dimension of H-section mould is 355×155×500 mm.

Fig. 3.2 Tightening of plates

Fig. 3.3 Magnetic level for checking verticality

Fig. 3.4 Full assembled mould

3.1.2 SPECIMEN HOLDING ASSEMBLY

Newly cast concrete had a tendency of exerting higher pressure on vertical plates therefore making transverse deflections of the mould holding assembly was prepared comprising of 2 horizontal mild steel plate of thickness 5mm which could be placed on either side of Plates P1 & P2 along width of slab. 2 tie rods join these horizontal plates.

Fig. 3.5 Specimen holding assembly

3.2 MATERIAL FOR PUSH OUT SPECIMEN

3.2.1 STEEL

Construction industries widely use steel & reinforced cement concrete as composite materials. Reinforced cement concrete is main part of composite materials. RCC are having 2 ingredients. One is concrete & second one is steel or reinforcement bar. Reinforcement bars are given for strengthening of concrete sections. Reinforcement bars prevented concrete failure from crushing & instant failure. Reinforcement bars which was used by us are manufactured by SAIL *"Steel Authority of India"*

Reinforcement bars of 10 mm were used in concrete slabs casting. 10 mm dia. bar were used for longitudinal reinforcements & 10 mm dia. bar were used for transverse reinforcements. 10mm dia. bars were used as hoop stirrup or shear stirrup to prevent the buckling or crushing of slabs.

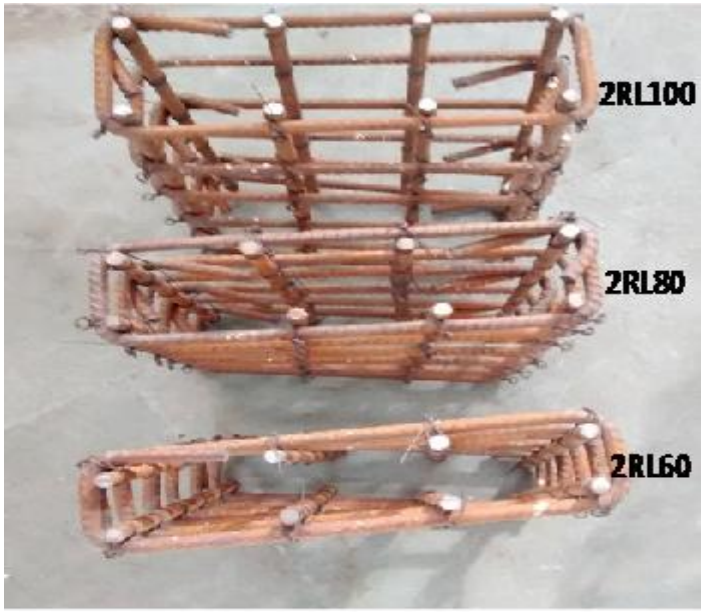
8 longitudinal bars of 10mm dia. & 400mm in length were given along length of slab. Six transverse reinforcements of 10 mm dia. & 300mm in length were provided. Shear stirrups of 10mm dia. were provided at spacing of 60mm, 80mm & 100mm centre to centre. Longitudinal and Transverse bar cutting, bending & cage formations procedure are shown in below figure 3.6.

(a)Reinforcement Cutting

(b) Shear Stirrups

(c) Marking on longitudinal bars for proper arrangement of all bars

(d) Reinforcement cage formation



(e) Final shape of Reinforcement Cage

Fig. 3.6 Reinforcement Bars Process

Reinforcement cages were prepared from 10 mm bars. Double layered types of reinforcement cages were prepared. Layout of reinforcement in each layer was kept constant. Shear stirrups were bent at 135 degree at the corners.

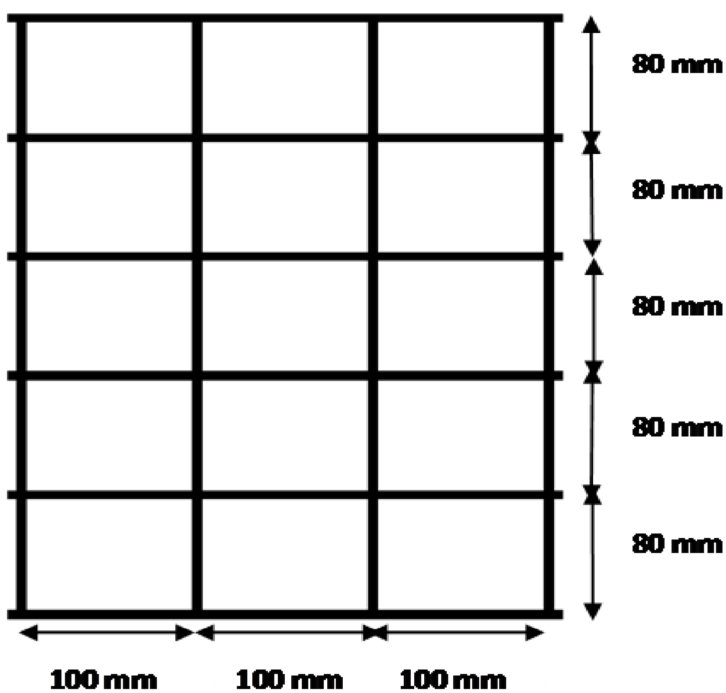


Fig. 3.7 Layout of a reinforcement Layer used in preparing cages

Three different types of reinforcement cages of double layered were used. In this three different sizes of doubled layer reinforcement were used. The spacing of shear stirrups taken were 60mm, 80mm and 100mm centre to centre of cage respectively.

Table 3.1 Different types of reinforcement cages

Category	Reinforcement cage coding
Double Layer	2RL100
	2RL80
	2RL60

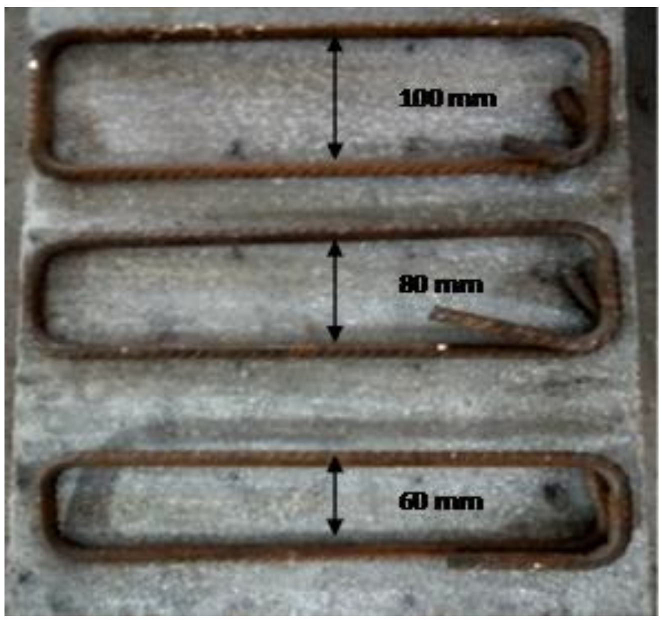


Fig. 3.8 Different types of shear stirrups used in the cages

3.2.2 STEEL SECTION SELECTION

Steel section geometry was selected on basis of EUROCODE 4 (1992). EC 4 (1992) suggests to use Universal Column Section 254×254×73 kg was used in the current study. This was closely available. Many researchers have used smaller steel sections. Since only single stud was to be welded on each side of flange hence smaller section UC 203×203×52 kg was employed.

Table 3.2 dimension of I-sections

Section	Weight/L (kg/m)	H (mm)	B (mm)	t_w (mm)	t_f (mm)	R (mm)
UC 203×203×52	52	206.2	204.3	7.9	12.5	10.2
UC 254×254×89	88.9	260.3	256.3	10.3	17.3	12.7

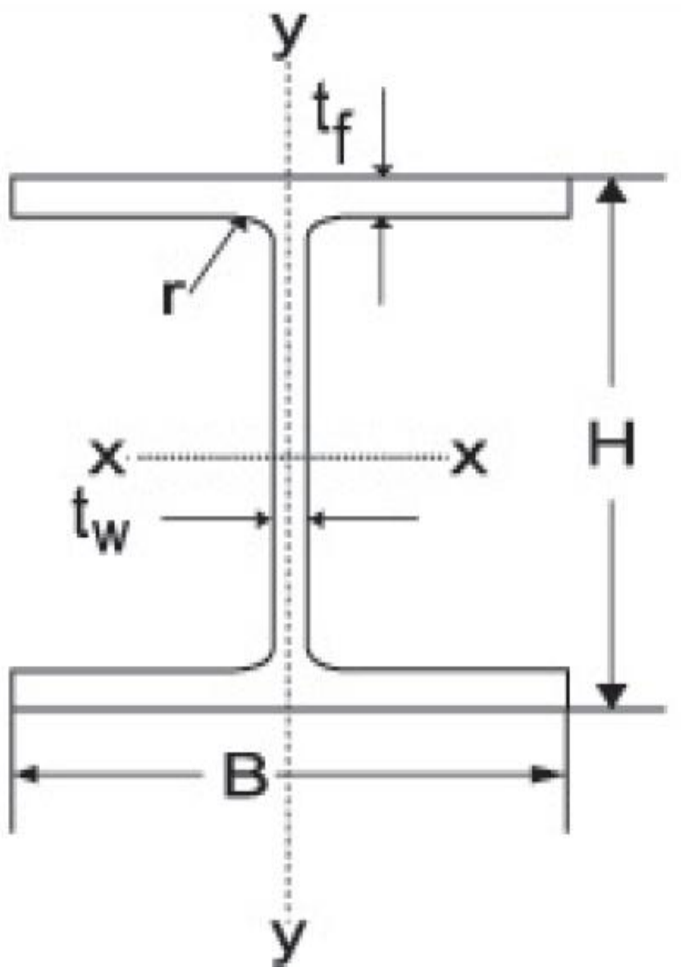


Fig. 3.9 Rolled steel UC section

3.2.3 UC SECTION PREPARATION

The Standard sections were supplied by *"Jindal Steel & Power"* were 13 m in length. Required length of steel beam in each specimen was 450 mm. The whole process of section preparation shown in below figure 3.10

(a) Measuring of steel beam Section by right angle

(b) Cutting of steel section by gas cutter

Fig. 3.10 Process of UC section Preparation

3.2.4 SHEAR STUD

The dimension of shear studs used was 19×100mm which were supplied by *"Nelson Stud Welding"* company. It proportionate with the thickness of the concrete slab.

Fig. 3.11 Dimension of stud used

MIG (Metal Inert Gas) welding techniques were found that the most suitable techniques for welding. Metal is continuously loaded from spool & mixtures of inert gases like helium, argon and carbon dioxide penetrate the arc. The Advantage is Continuous weld with no slag, uniform and no post operations. One stud was welded on each flange of steel section.

Fig. 3.12 I-sections used

3.2.5 CONCRETE

(a) Cover Blocks or Spacer

The important objective of using cover blocks was retaining proper spacing from inside surface of mould. It was to secure desired gap during vibration of concrete slabs casting. Cover block of 20mm and 40mm were provided near the flange and on the sides. Cover blocks were tightened to reinforcement bars with help of steel wire. Cover blocks have proper groove for proper holding the reinforcement bars. Cover block provide spacing of 20mm. The spacing of 40mm is provided by tightening two cover blocks together and tightening them to the reinforcement bars.

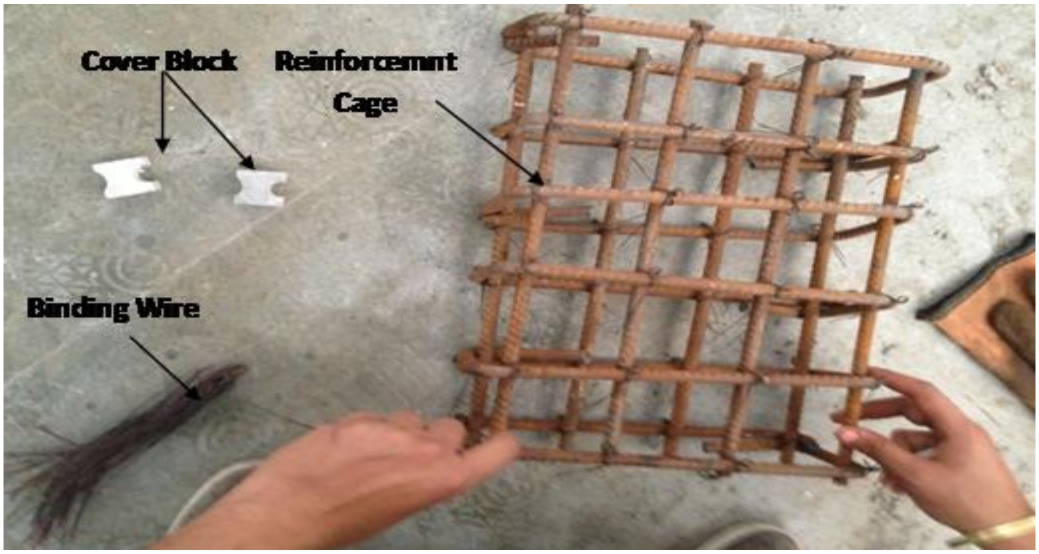


Fig. 3.13 Various components for installing cover blocks

Fig. 3.14 20mm cover block provided

Fig. 3.15 40mm cover blocks provided

(b) **Concrete specimen preparation**

Reinforced cement concrete specimens were casted in MNIT laboratory. Some standard cube tests were also performed to achieve a desired grade. Tests results are shown in chapter 4. Quality of concrete was ensured by done experimental tests on material which are used for concrete casting and fresh concrete. Concrete grade was kept constant in all the specimens. Normal strength M25 concrete was used.

(c) **Push out specimen**

Three different group of specimens were prepared. Each group of specimen consist of two identical specimens. Concrete grade was kept M25 in al the specimen. Three different reinforcement cages were used in in three different groups. Steel beam of size 450mm×350mm×150mm was casted simultaneously. One shear stud was welded at the middle of each flange of the section at a height of 200mm above the bottom of the beam. Two reinforced concrete slabs of height 450mm, width 350mm and depth 150mm were attached on each side of the flange. Concrete specimen were casted in two parts. Mould was vibrated after half filling by needle vibrator.

Table3.3 Different groups of push out specimen

Specimen name	Concrete grade	Reinforcement	Side Cover provided from I section side
25a2RL100	25	Double layered	20mm
25b2RL100			
25a2RL80	25	Double layered	20mm
25b2RL80			
25c2RL80	25	Double layered	40mm
25d2RL80			
25a2RL60	25	Double layered	20mm
25b2RL60			
25c2RL60	25	Double layered	40mm
25d2RL60			

Doubly reinforcement with shear stirrups 100mm centre to centre is shown in below figure 3.16. The position of first layer from stud welded side or cover provided is 20mm. This group specimen with 100mm centre to centre spacing consist of two identical specimen having 20mm cover which is defined as 25a2RL100 and 25b2RL100.

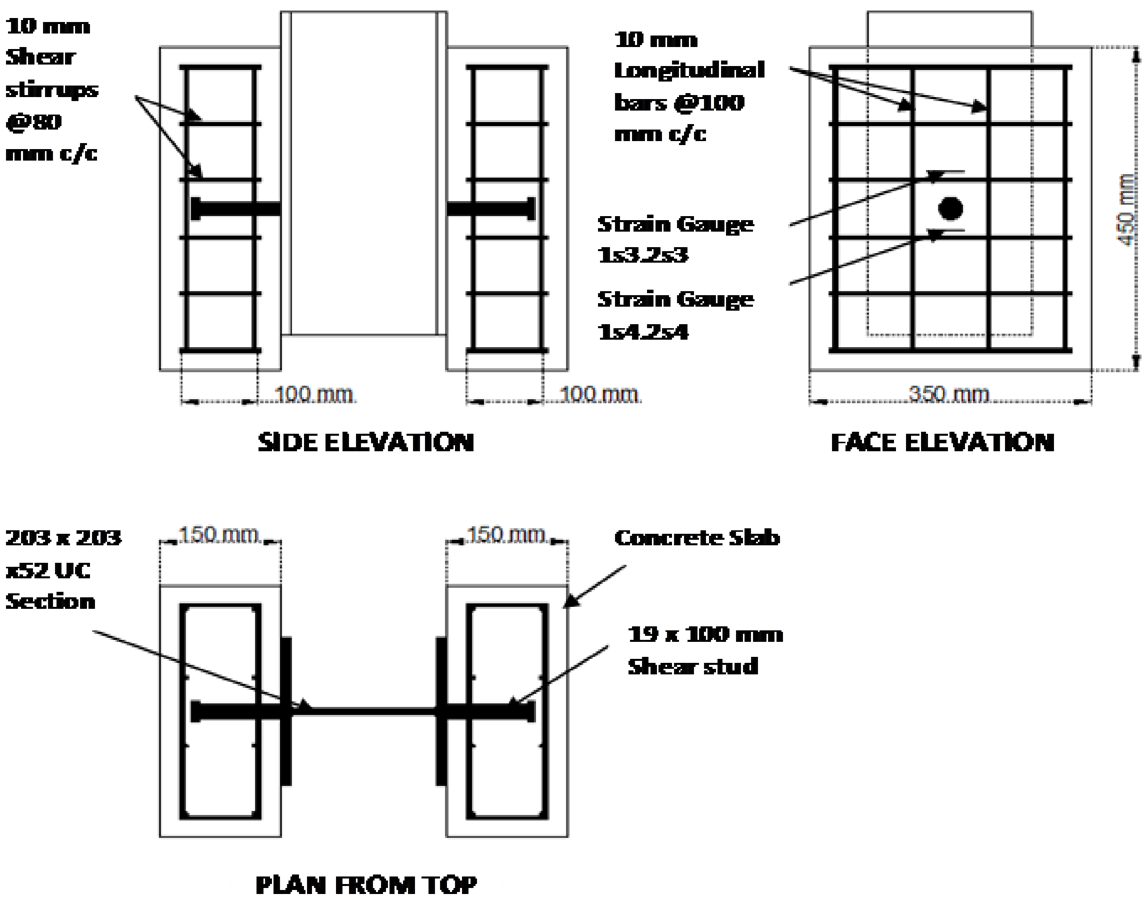


Fig. 3.16 Double layered specimen (25a2RL100, 25b2RL100)

Doubly reinforcement with shear stirrups 80mm centre to centre is shown in below figure3.17. The position of first layer from stud welded side or cover provided is 20mm and 40mm. This group specimen with 80mm centre to centre consist of two identical specimen having 20mm and 40mm cover. Two identical specimen of 20mm cover is defined as 25a2RL80 and 25b2RL80 and of 40mm cover is defined as 25c2RL80 and 25d2RL80.

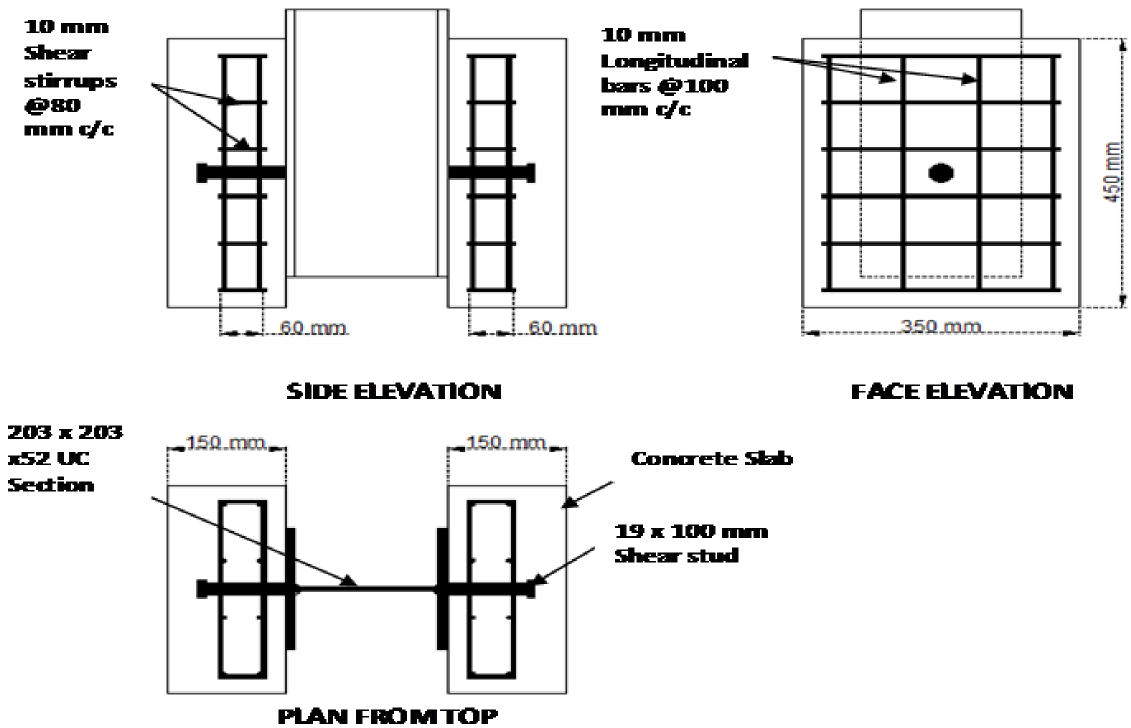


Fig.3.17 Double layered specimen (25a2RL80, 25b2Rl80, 25c2RL80, 25d2RL80)

Doubly reinforcement with shear stirrups 60mm centre to centre is shown in below figure3.18. The position of first layer from stud welded side or cover provided is 20mm and 40mm. This group specimen with 60mm centre to centre consist of two identical specimen having 20mm and 40mm cover. Two identical specimen of 20mm cover is defined as 25a2RL60 and 25b2RL60 and of 40mm cover is defined as 25c2RL60 and 25d2RL60.

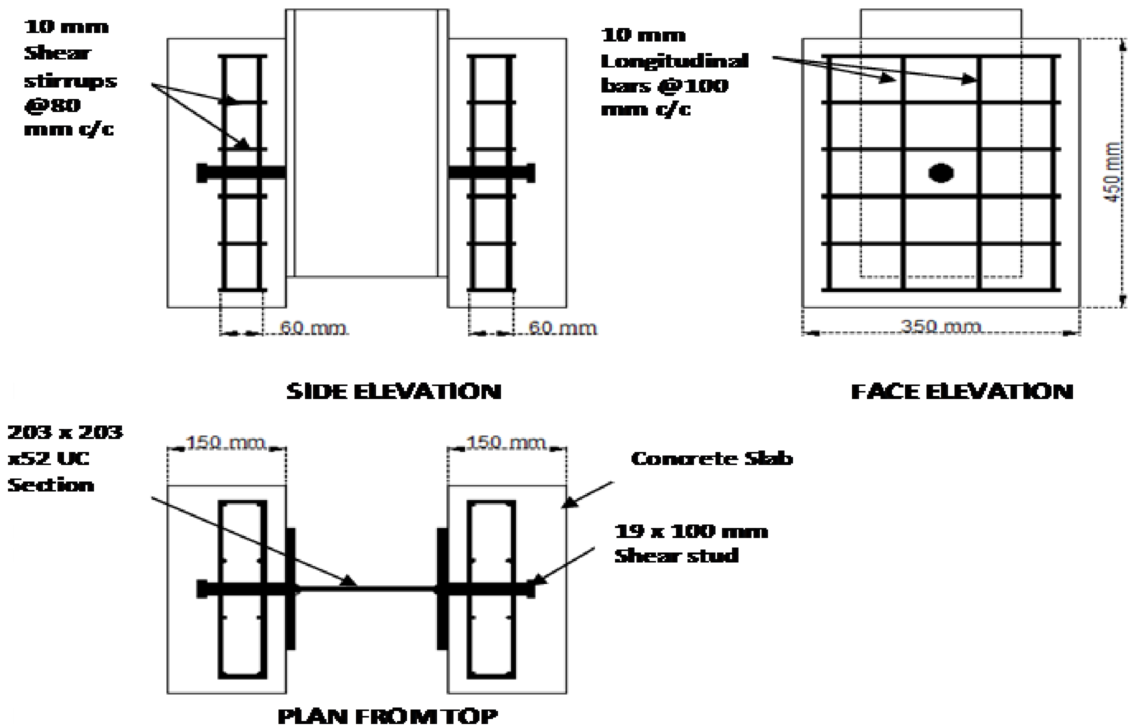


Fig. 3.18 Double layered reinforcement (25a2RL60, 25b2RL60, 25c2RL60, 25d2RL60)

(d) Preparation of pushout test specimen

The preparation of all push out test specimens followed a similar process. In this One specimen was casted at a time. Firstly the proper oiling of the mould and supporting I-section was placed and it was to be levelled by leveling tube. Then proper oiling of the I-section was to be done so to avoid frictional resistance. Then the double layer reinforcement cage was fitted in between the stud and after that procedure the section with reinforcement was placed in proper position in the mould. After that the concrete of M25 was poured in the mould and it was half filled it was vibrated with needle vibrator so that compaction was carried out. Then the mould was fully filled. After 24hrs demoulding process takes place and after it was demoulded prepared specimen were dumped in the curing tank for 28 days with the help of gantry girder.

The whole process of oiling, casting and demoulding is shown in below figure

Fig.3.18 Oiling of Flange section to avoid Frictional resistance

Fig. 3.19 Steel beam with reinforcement

Fig. 3.20 steel beam and reinforcement placed in position

Fig. 3.21 Pouring of concrete in the mould

Fig. 3.22 Compaction carried out with the help of needle vibrator

Fig. 3.23 fully filled mould

Fig. 3.24 Demoulding of specimen

Fig. 3.25 lifting of specimen by gantry girder

Fig. 3.26 Curing of specimens in tank

Chapter: 4

RESULTS AND DISCUSSION

4.1 GENERAL

Physical properties test of raw material is to be performed in MNIT laboratory. The various test performed were cement consistency test, initial and final setting time test of cement, sieve analysis of fine and coarse aggregates, specific gravity of cement, specific gravity of fine aggregate and coarse aggregate, compressive strength of concrete and water absorption test in the laboratory. Based on this initial or physical test on raw materials concrete mix designs were done for proper grade of concrete strength. After deciding the mix proportion of different ingredients of raw materials the concrete mix were prepared for section casting. The experimental test and their test results are shown in below chapter.

4.2 RAW MATERIAL USED FOR TESTING

Cement : The aggregate of nominal size of 10mm and 20 mm were used in the ratio 50:50 respectively in concrete mix design. Aggregate were brought locally and tested for specific gravity, water absorption and gradation using sieve analysis as per Indian standards.

Fine aggregate (Sand) **:** Sand are transported from locally available river bed and sand tested for specific gravity, water absorption and sieve analysis as per Indian standards.

Cement : Ambuja plus PPC cement obtained from locally cement traders and tested for specific gravity, consistency and initial and final setting time.

Reinforcement Bar: Reinforcement bar were 10mm diameter bars are used for preparation of reinforcing of steel cages.

Water: locally available water in laboratory were used for experimental purpose.

4.3 PHYSICAL PROPERTIES

4.3.1 Cement:

(a). Standard 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 10mm and height of 50mm into cement mould upto depth of 33 to 35mm 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 percentage of water at which cement paste of standard consistency is produced. Observation of standard consistency of cement are tabulated below-

Table4.1 Standard Consistency Test

S.NO	Weight of Sample (mm)	Weight of Water (mm)	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 normal consistency cement (P) = 33%

(b) Initial and Final setting time of cement (IS 4031 (Part 5) -1988)

Setting time of cement is used to detect the time required for stiffening of cement paste to a defined consistency. Initial and final setting time test are conducted by using vicat's apparatus. In order to perform this test take 400gm cement paste with 0.85P. In initial setting time test square needle is used to released it from top of mould and note the time required by the needle to show the penetration of 33 to 35 mm from top. This time noted is 95minutes which is referred as initial setting time of cement.

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 with annular collar needle is used. The final setting time recorded is 630 minutes.

(c) Specific gravity (IS 4031 (Part 2)-1988)

Specific gravity is determined by Le Chatelier Flask. Specific gravity of cement is found by replacing the weight of kerosene by weight of cement.

Table 4.2 Specific gravity of cement

Particulars	Sample 1	Sample 2
Weight of empty flask (W_1)(gm)	48	48
Weight of flask + Cement (W_2)(gm)	98	98
Weight of flask + Cement + Kerosene (W_3)(gm)	156.5	157
Weight of flask + kerosene (W_4)(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 :

(a) Sieve analysis (IS 2386 (Part1)-1963)

Sieve analysis determines the particle size distribution of granular material. Sieve analysis is performed on 1kg of fine aggregate (sand) and 2kg of each 20mm coarse aggregate and 10mm coarse aggregate. Observation for sieve analysis of fine aggregate, coarse aggregate of 10mm; 20mm are shown in the following tables 4.3, 4.4 and 4.5.

Table 4.3 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
0.6	231	233	225	229.6	482.8	48.28	51.72
0.3	377	373	379	376.3	859.1	85.91	14.09
0.15	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						

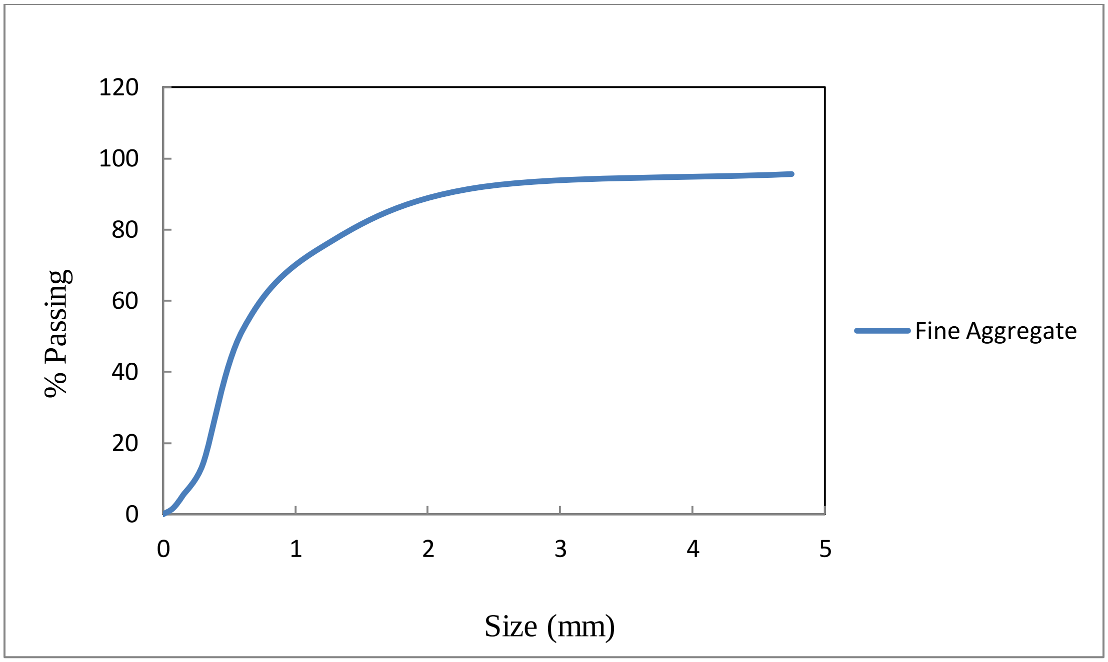


Fig. 4.1 Gradation for fine aggregate

Table 4.4 Sieve analysis of 10mm coarse aggregate

IS sieve(mm)	Mass Retained (gm)				Cumulative Mean Retained (gm)	% Cumulative Mass Retained (gm)	% passing
	Sample 1	Sample 2	Sample 3	Mean			
20	0	0	0	0	0	0	100
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 Sieve Analysis of 20mm 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	100
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						

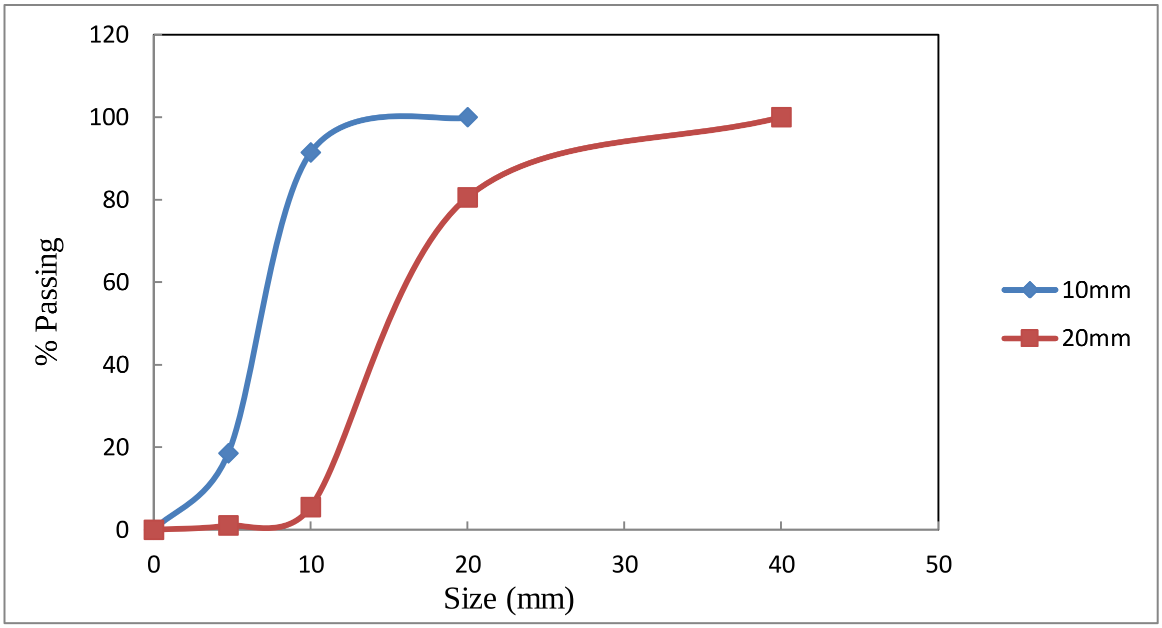


Fig. 4.2 Gradation curve for 10mm and 20mm

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

A sample of 2000kg was used for water absorption tests. Water absorption test was experimented for proper strength prediction. Aggregates which are having large water absorption , more porous in nature. Observations given for specific gravity & water absorption of fine aggregates, coarse aggregates of 10 mm and 20 mm are shown in Table

Table 4.6 Specific gravity and water absorption for fine aggregate

S.NO	Weight Combination	Sample 1	Sample 2	Sample 3
1	Weight of Pycnometer(W_1)(gm)	651	651	651
2	Weight of Pycnometer + Aggregate(W_2)(gm)	1151	1151	1151
3	Weight of Pycnometer + Aggregate + Water(W_3)(gm)	1819	1826	1833
4	Weight of pycnometer + Water (W_4)(gm)	1519	1519	1519
5	Weight of saturated surface Dry aggregate in air(W_5)(gm)	1024	1026	1029
6	Weight of Oven Dry aggregate(W_6)(gm)	1000	1000	1000
7	Specific Gravity = $(W_2\text{-}W_1)/(W_2\text{-}W_1)\text{-}(W_3\text{-}W_4)$(g/cc)	2.5	2.59	2.68
8	Water Absorption = $((W_5\text{-}W_6)/W_6)\times100$	2.4	2.6	2.9
9.	Average Specific Gravity (g/cc)	2.59		
10.	Average Water Absorption(%)	2.64		

Table 4.7 Specific Gravity and Water Absorption for 10mm Coarse Aggregate

S.NO	Weight Combination	Sample 1	Sample 2	Sample 3
1.	Weight of Pycnometer(W_1)(gm)	651	651	651
2.	Weight of Pycnometer + Aggregate(W_2)(gm)	1151	1151	1151
3.	Weight of Pycnometer + Aggregate + Water(W_3)(gm)	1827	1831	1836
4.	Weight of Pycnometer + Water (W_4)(gm)	1519	1519	1519
5.	Weight of Saturated Surface Dry Aggregate in Air (W_5) (gm)	1002	1003.5	1002.5
6.	Weight of Oven Dry Aggregate (W_6)(gm)	1000	1000	1000
7.	Specific Gravity = $(W_2-W_1))/(W_2-W_1)-(W_3-W_4)$ (g/cc)	2.6	2.63	2.73
8.	Water Absorption = $((W_5-W_6)/W_6)\times100$	0.2	0.35	0.25
9.	Average Specific Gravity (g/cc)	2.66		
10.	Average Water Absorption(%)	0.26		

Table 4.8 Specific Gravity and Water Absorption for 10mm Aggregate

S.No	Weight Combination	Sample 1	Sample 2	Sample 3
1	Weight of Pycnometer(W_1)	651	651	651
2	Weight of pycnometer + aggregate (W_2)	1151	1151	1151
3	Weight of Pycnometer + aggregate + Water(W_3)	1833	1836	1838
4	Weight of Pycnometer + Water (W_4)	1519	1519	1519
5	Weight of Saturated Surface Dry Aggregate in Air(W_5)	1001.5	1002.5	1002
6	Weight of Oven Dry Aggregate(W_6)	1000	1000	1000
7	Specific Gravity = $(W_2-W_1)/(W_2-W_1)-(W_3-W_4)$	2.68	2.73	2.76
8	Water Absorption = $((W_5-W_6)/W_6)\times100$	0.15	0.25	0.20
9	Average Specific Gravity	2.72		
10	Average Water Absorption(%)	0.20		

4.3.3 Concrete mix design

For every casting of concrete mix design is an important parameter. In this experiment M25 grade of concrete was carried out as per *IS 10262 : 2009* design code guidelines. After determine physical properties of raw material desired concrete mix design was done and proportion were obtained from trial of cube test. And for M25 grade concrete design strength is

$$F_m = 1.64\sigma + f_{ck} \quad (4.1)$$

Where:-

F_m= Design Strength of Concrete (Mpa)

f_{ck} = Characteristic Strength of Concrete(MPa)

σ = Standard Deviation

For M25 grade of concrete design strength is 31.56 MPa.

Table 4.9 Concrete mix design

S.No	**Material**	**Mass(Kg)**	**Proportion**
1.	Cement	350	1
2.	Fine Aggregate(Sand)	567	1.62
3.	10mm Aggregate	686	1.96
4.	20mm Aggregate	630	1.80
5.	Water	175	0.50

4.4 SIZE OF TEST SPECIMEN-

For desired M25 grade of concrete cube test are performed to desired strength. Trial test are performed 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 casted.

Fig. 4.3 Concrete Cubes

4.5 COMPACTING FACTOR TEST *(IS: 1199-1959)*

The compacting factor defined as ratio of the weight of partially compacted concrete to weight of the fully compacted concrete. Observation for compacting factor test are shown in Table 4.10

Table 4.10 Compacting Factor Test

Particulars	**Compaction Factor**
Weight of Cylinder(kg)	19.05
Weight of Partially Compacted concrete + Cylinder(kg)	30.30
Weight of Partially Compacted Concrete W (kg)	11.25
Weight of Fully Compacted Concrete + Cylinder(kg)	31.65
Weight of Fully Compacted Concrete	12.60
Compacting Factor(W/W)	0.89

4.6 COMPRESSIVE STRENGTH TEST *(IS: 516-1959)*

The specimen of 150mm×150mm×150mm of 7 and 28 days age were tested after their removal from curing tanks. The rate of loading would be 140kg/cm^2/min. The compressive strength is determined by dividing axial load at failure by cross-section area of specimens.

Table 4.11 Compressive Strength Test

Age(days)	Axial Load	Compressive Strength	Average Compressive Strength (MPa)
7	440	19.55	18.88
	410	18.22	
	425	18.88	
14	555	24.66	24.74
	520	25.11	
	550	24.44	
28	695	30.88	31.32
	690	30.66	
	730	32.41	

4.7 PUSH-OUT TEST RESULTS

Table 4.12 Specimen with 100mm cage

Specimen	Ultimate load per stud(P_u) in kN	Ultimate slip (S_{max}) in mm	Failure pattern
25a2RL100	127.54	13.81	Stud failure
25b2RL100	127.59	13.77	Stud failure

Table 4.13 Specimen with 80mm cage

Specimen	Ultimate load per stud(P_u) in kN	Ultimate slip (S_{max}) in mm	Failure pattern
25a2RL80	129.62	12.10	Stud failure
25b2RL80	129.50	12.16	Stud failure
25c2RL80	130.15	12.69	Stud failure
25d2RL80	130.05	12.90	Stud failure

Table 4.14 Specimen with 60mm cage

Specimen	**Ultimate load per stud (P_u) in kN**	**Ultimate slip (S_{max}) in mm**	**Failure pattern**
25a2RL60	130.19	11.7	Stud failure
25b2RL60	130.27	11.4	Stud failure
25c2RL60	136.02	11.8	Stud failure
25d2RL60	135.82	11.9	Stud failure

Chapter 5

CONCLUSIONS

5.1 CONCLUSIONS

- The increase in size of doubly reinforcement cages in concrete slabs around headed shear studs leads to confinement of concrete.
- Slip decreases due to this confinement of concrete and hence ultimate load will increase.
- Ductility of the connection decreases with increase in size of double reinforcement cages. Substantial decrease occurs if concrete is highly confined near the root.
- Position of reinforcement gives an indication that stress in the reinforcement layer near the bearing side is higher as compared to the reinforcement layer away from the interface.

Future Scope:

- Development of mathematical model for estimation of bearing capacity of shear stud based on experimental results, which takes into account the reinforcement detailing in slab.
- Simulation of finite element models with different reinforcement detailing could be used to obtain an equation for accurate estimation of bearing capacity of shear stud.

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