`

FAILURE MECHANISM ANALYSIS AT STEEL CONCRETE COMPOSITE INTERFACE

A

PROJECT REPORT

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Under the supervision

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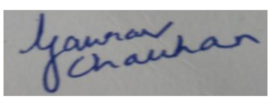
STUDENT'S DECLARATION

We hereby declare that the work presented in the Project report entitled "**Failure Mechanism at Steel Concrete Composite Interface**" submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of **Mr. Kaushal Kumar** and **Dr. Pankaj Kumar**. This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of our project report.



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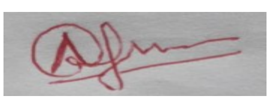

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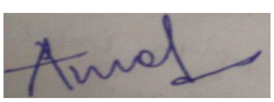

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CERTIFICATE

This is to certify that the work which is being presented entitled, "**Failure Mechanism at Steel Concrete Composite Interface"** in fulfillment of the requirements for the award of the degree of Bachelor of Technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Gaurav Chauhan (161612), Abhishek Thakur (161689) and Amol Srivastava (161604)** during a period from January 2020 to June 2020 under supervision and guidance of **Mr. Kaushal Kumar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

Following is project report on the failure mechanism of steel concrete composite. This report consist of a general understanding of composite structure their benefits and components. Different type of connectors, different type of failures and almost most of the studies conducted on composite structures in the literature review section of the report. The experimental part pertains mainly to figuring out failure load and failure pattern in case of two different grades of concrete on a composite of steel and concrete. The report also contains results related to experiments conducted for mix designs of these grades of concrete. The report ends with conclusion from final test results and overall experiments performed.

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LIST OF ACRONYMS

&	And
i.e.	That is
KN	Kilo Newton
MPa	Mega Pascal
mm	Millimetre
DIC	Digital Image Co-relation
LVDT	Linear Variable Differential Transformer
FEA	Finite Element Analysis
RCC	Reinforced Concrete Cement
M30	Concrete having 30 MPa Strength after 28 days
M35	Concrete having 35 MPa Strength after 28 days
M40	Concrete having 40 MPa Strength after 28 days
M50	Concrete having 50 MPa Strength after 28 days
Kg	Kilograms
G	Grams
UC	Universal Column section
Kg/m^3	Kilogram per meter cube
$f'ck$	target average compressive strength at 28 days
fck	characteristic compressive strength at 28 days

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1. INTRODUCTION

In this report we have covered the basic information on composite structures. Composite of steel concrete are widely used these days and especially for tall buildings. This report covers all the important aspects regarding the understanding of composite structures. It includes information on beams, columns, slabs and degree of interaction in composite structures. It also covers shear connectors and how adhesive connectors are replacing mechanical connectors these days. In the end the advantages and disadvantages of composite structures are mentioned. After this a detailed explanation on why there is a need to study the failure mechanism at steel concrete composite interface. Further we have mentioned the tests which have been conducted to study the failure mechanism. A detailed literature review as well as a summary of the same has been included in this report. The report includes various tests conducted on aggregates, the results obtained, and procedure followed for design mix. Then the experiments performed to make the specimens and conduct test and concluded with results.

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2. LITERATURE REVIEW

Composites are an up and coming lucrative construction type, there have been quite a few studies in this field and al lot of new works have come forward in the recent 10 years. Keeping this in mind we studied various research papers pertaining to this to each of which had its own abundance of knowledge to offer the most recent research in this field as of writing this review has been of *Zhao et al. (2019)* who conducted a study on strength tests they conducted on steel concrete composite interface and analyzed the results using Digital image correlation. DIC is a optical image based process in which they painted the specimen white and then bombarded it with black dots of 1mm dia placed 1mm apart. They conducted push out test on 6 specimens, 3 of M35 and 3 of M50 of dimensions $200\times100\times100mm^3$. Steel plate of $200\times120\times30mm^3$ was used. They used a 30mm thick steel plate to avoid buckling. Epoxy resin mortar was used as bonding interface layer. To prove the authenticity of DIC they conducted test on a sample using both DIC and normal strain gauge method using Linear Variable Differential Transformer (LVDT). They found out the results to be very similar thereby proving the authenticity of DIC. They used a 30mm thick plate to evade buckling [14]. The failure they observed was a de-bonding failure of concrete and connector as expected. Out of the six sample in two (1 M35 and 1 M50) of them the aggregates in these specimens got stripped of due to poor compaction of concrete. The ultimate load of composite with M50 had a 1.24 times greater value than the one with M35 implying higher grade of concrete gives higher strength [14]. They also observed that the values of bond strength that they calculated were lower when compared with bond strength values achieved by Si Larbi. They concluded that the higher grade of concrete had higher strength and stiffness in case of composite as well [14]. In case of interface ductility the load versus displacement curve was used to find out the ductility of the material and it was found out that the composite with concrete of higher grade was more brittle. Further it talks about analysis of interface failure which they did for both processes strain gauges and DIC separately. In case of strain gauges they were placed in 3 positions top middle and bottom and the specimen failed from bottom to top, the first crack appeared at bottom and after bearing 1.62 times the ultimate load at first crack the specimen failed. Similar results were obtained from DIC as well except for the case of top gauge the results

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of DIC differed but the overall stress strain curve was similar. This research paper served as the mother paper for our project.

QI Jing-jing at el. (2010) specified the effects of seismic loads on interface of steel concrete composites and especially on semi rigid connectors. For this they took into consideration a frame having 6 floors and 2 spans. This frame had a floor height of 3m and was built up of composite beams and columns. the analysis of the frame was conducting using MATLAB program. It was found out that in case of lower frequencies semi- rigid joints had a great effect in composites [8]. Although it was also observed that the same semi- rigid joint does not play any significant role in case of higher frequencies. It was also observed that if slip was considered than floor displacement was large as compared to a situation where the slip was not taken into account, also the seismic peak response value was greater for semi rigid connectors when compared with rigid ones this was because the global stiffness was greatly reduced by semi rigid joints as compared to the rigid ones [8]. It was inferred that the horizontal displacement increases if the joint rotational stiffness also increases and if we consider a case where semi rigid joint exists along with interface slip the horizontal displacement in such a case increases most rapidly and does not increases with the same rapid rate if we consider only [8]. Also the effects of semi rigid joints and slip interface on seismic response increases with increase in floors

Dae-Seock Shin et al. (2007) had derived a proper method and parameter to define the strength of the steel concrete composite interface. The author has only considered the strength of interface layer in bonded condition. It basically focuses on calculating two strength defining parameters friction angle and cohesion by applying the results of tests conducted by Cheiw et al. (1999)[7]. After this the paper covers the details of push out tests performed by Cheiw et al. on steel concrete composite by pressing a steel plate between two concrete blocks at a certain pressure in bonded and de-bonded conditions. The results of the test were 3 graphs plotted between shear stress and slip at 3 different restraining pressures of 0.5, 1 and 1.5[7]. Each bend indicated a comparable conduct that can be seen when all is said in done bond slip test; it fundamentally expanded until its flexible breaking point, and afterward it began to gradually diminish after the greatest normal shear stress [7]. Finally, it met to an incentive at remaining pressure condition. They expected that the interface nonlinear conduct is restricted to consummate plastic conduct; solidifying and mellowing impacts were ignored. This grinding point and attachment were gotten from the consequences of the test by breaking down pinnacle worry of failure [7]. The qualities

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were then utilized in affectability examination to compute unrelated firmness coefficient. Toward the end the aftereffects of numerical investigation were contrasted and trial results and were seen as all around coordinated. Pankaj Kumar et al. (2019) led tests to contemplate the impact of fortification specifying on execution of composite associations with headed studs. In this paper they first notices the upsides of utilizing composite structures for example high solidarity to weight proportion when contrasted with traditional Reinforced Cement Concrete (RCC)[13]. The creator at that point discusses the steel solid interface and that its quality decides the quality of the composite structure, the interface layer must have the option to oppose and move the worries among steel and cement. The presentation of the interfacial association relies upon the kind of loading [13]. It at that point moves its concentration to composite shafts and discusses considers that reason that the shear connectors when given in hoarding district prompts compelling usage of reinforcement[13]. . It likewise clarifies the expansion in rib width to thickness proportion of steel shaft lessens altogether with increment in measure of fortification, prompting a decrease in general avoidance and discusses change in disappointment mode with the adjustment in measure of longitudinal support. For a solitary layer of fortification, the splits were seen to go around the stud, while for twofold layer of support, the breaks were seen to run corresponding to long edge. It was accounted for that the flexibility of association is expanded with increment in the measure of transverse fortification. They threw example with no fortification, single layer twofold layer and triple layer support and investigated the outcomes. The outcomes indicated that the commitment of unreinforced segment to the association unbending nature is negligible; a definitive quality of association expanded with increment in quality of cement and slip diminishes with increment in quality of cement. If there should arise an occurrence of single layer fortification it was discovered that the shear limit of the headed stud association diminishes with increment in separation of the support with the base of the stud. Solid pulverizing disappointment was seen in examples with single layer support at 50mm and 70mm from the foundation of stud yet not in the event of 100mm [13]. The shear quality of connectors expanded with increment in quality of solid, disappointment for this situation was smashing of cement around the headed studs.

Pankaj Kumar et al.(2017) have composed this survey paper relating to utilizations of auxiliary cements in cement and steel-solid composite and components affecting the presentation of

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composite associations . in this paper the creator starts with referencing that auxiliary glues like Polyvinyl Acetate (PVAC) were utilized to fill the holes in precast individuals yet later its use was constrained to inner use because of its poor obstruction against ecological actions[10]. At that point the creator makes reference to that nowadays the use of auxiliary glues have expanded in regions like retrofitting and they have additionally supplanted shear connectors since they offer expanded homogeneity in stress appropriation, alongside a diminished formwork, quickened development speed, quality affirmation and improved weakness life of individuals. The creator starts the paper with referencing the utilization of cements in fix of CC and RCC structures [10]. It underscores that the cements with low thickness can without much of a stretch infiltrate into pores and breaks and gives parallel dependability and had solidness and avoidance equivalent to those of a standard chunk. Quality of fixed individuals likewise relies upon the weight with which the epoxy is infused and it is legitimately relative to strength [10]. . It at that point likewise reveals to us that how mechanical connectors utilized in steel solid composite development have poor exhaustion life, causes pressure fixation and can't give a high level of collaboration in this way inferring the need of glues. There are two sorts of glues utilized in steel solid composite associations epoxy tars that show high connection yet fragile disappointment and polyurethane that displays malleable conduct with halfway communication. The quality of a steel solid composite relies upon fortified territory geometry of the example while example geometry has unimportant impact on its bond quality. Further the paper discusses impact of previously mentioned parameters on the quality of bond. First it discusses the impact of thickness of association, as per creator at a similar burden higher shear stresses were watched for lower bond thickness [10]. The glue thickness in lower quality cement doesn't impact the bond quality essentially, while in higher quality solid, it prompts a radical change in the disappointment mode. We discovered that expansion in glue layer thickness diminishes the association productivity yet builds adaptability and holding stays unimportant up to a bond layer thickness of 2mm [10].

Further studies were conducted on bonded steel concrete composite structures in which they mechanical behavior of the composite structure was observed. For the experiment the author a total of 4 composite beams consisting of a precast concrete slab on a steel girder and bonded the two with adhesive and concluded with results that indicated that epoxy resin was better than poly-urethane as an adhesive [6]. . After arriving at this conclusion it was necessary to decide the

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optimum thickness of the adhesive layer which was done with the help of another study that was conducted on composites bonded with epoxy resin in 3 different layer depth 3mm, 5mm and 2mm [11]. It was concluded in this research that 3mm was the optimum bond thickness. 2mm bond thickness caused partial interaction and 5mm layer caused bond layer failure whereas in case of 3mm the failure was a concrete interface failure which was considered desirable.[11]

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3. SUMMARY OF LITERATURE REVIEW

From reading the above mentioned research papers we concluded that there is a need for study in the area of failure mechanism at steel concrete interface. The latest research done in this field was done on two grades of concrete M30 and M40. It has been already established that the most optimum adhesive layer thickness is 3 mm therefore we will be using 3mm thick adhesive layer. Also the from the literature we infer that the adhesive connections are better than mechanical connectors. The test conducted in most of the cases is push out test as we shall also conduct the same. The literature also focuses on different types of failures encountered at the interface and we shall be working on the same to define type of shear failure at the interface. The literature mentions the lack of experimental results pertaining to the failure mechanism analysis at the interface therefore we shall be conducting the experiments on 2 different grades of concrete i.e. M30 and M40 using the same steel section and adhesive layer of 3mm thickness.

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4. COMPOSITE STRUCTURES

4.1 COMPOSITE CONSTRUCTION OVERVIEW

One of the most up and coming methods of construction is the composite construction. A composite structure involves two phases the concrete part and the steel part. Although composites in general refers to as the mixture of two or more material and there are many types of composite in the market these days but the most widely used composites are the steel concrete composite structure[1]. Composite structure can be seen in numerous places. These structures have the benefits of both materials i.e. concrete in compression and steel in tension [1].

Although composite construction has prevalent for a very long time now especially in the construction of tall buildings where the lower storey are made of RCC and the higher storey have frames of steel, but nowadays composite elements have also started to come out as an option like composite beams, columns and slabs. Composite do not only have an edge over the conventional RCC construction in terms of the strength they provide but also in terms of various other factors that we will cover in this chapter as we go ahead.

The most important factor that should be taken into consideration while designing composite structures is the degree of interaction. It has been seen in many prevalent cases that the connection provided between the steel and concrete interface is usually with the help of shear connectors or mechanical connectors. The connection although is good but since mechanical connector need to be I huge numbers unlike the practical norms to provide full interaction therefore it is witnessed that the shear connectors do not bring out the most of the composites. With enough research at hand adhesives have started to replace the shear connectors in composite structures and are proving to be a better replacement.

The composite way of construction is going to the way of the future civil works. These are not only more efficient but also have a better reuse value since one half of the construction is steel and more than 90 percent of steel used in all sorts of construction works is usually reusable. The idea is getting a lot of popularity and recognition in construction circles and soon enough shall take over the world.

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4.2 ADVANTAGES OF COMPOSITE CONSTRUCTION

Quicker Construction

The speed of construction in case of a composite structures us much higher as compared to RCC structures. [1] Since composite construction requires placement of steel decks which can be quickly done with a help of a machine and reduces labor time. [1] Also many a times steel sections in composite structures also provides formwork for concrete works thereby reducing time of construction by a great deal.

Safe strategy of development

The decking as mentioned above acts like a scaffolding and also helps to safeguard workers from falling construction objects in case of an accident. [1]

Better strength and stiffness

Composites provide better stiffness and strength compared to RCC. This is because of their design properties which enable concrete to act in compression and steel to act in tension. They also provide better bending moment resistance

Easier to transport

The steel decking used in composite structures is precut and in segments therefore easier to carry over long distances in large numbers. One lorry will ship in path over a thousand meter square of decking. Along these lines, a littler assortment of conveyances are typically required in contrast with various sorts of development. [1]

Auxiliary solidness

The decking will go about as a proficient sidelong restriction for the pillars, as long as the decking fixings are intended to hold the necessary weight and fixed thus. The decking also acts as a resistance to shear forces or wind loads providing better overall structural stability. The connectivity of beam to deck and deck to column or column to beam/base is also very proficient and fairly easy. [1]

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More floor to floor room

The composite beam for the same load has a lesser depth than a RCC beam this helps in increasing floor to floor height [1]. This helps in providing more spacious accommodation and therefore in cases of continuous beams composite beams are more preferred.

Maintainability

Steel used in composite structure can be completely reused [1]. Since more steel is used in composites this means that reuse value is also higher

Simple establishment of administrations

Since a lot of steel is used in composite structures therefore it is easier to install connections like water pipes, electricity and LAN cables [1]

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4.3 COMPOSITE BEAMS

Composite shafts, subject essentially to twisting, incorporate a steel area acting compositely with one or 2 blocks of cement. The 2 materials are reinforced together by the methods for of mechanical shear connectors. These are as of now combined with the methods for headed stud shear connector as adhesives are not at present a lot in common. [3] Thus, composite beams, even with little steel areas, have high firmness and might convey huge masses on long ranges. In the event that there is any sort of slip brought about in the composite, at that point both steel and solid act independently which nullifies the whole point of having a composite in the absolute in front of the rest of the competition. On the off chance that the estimation of this slip is decreased and full collaboration is accomplished then the steel and cement can act conjointly and consequently give better quality. The heap bearing limit relies upon the degree to which the slip is decreased in a composite creation it the most significant factor of all. [3] The level of association relies upon the level of shear connector utilized.

The focuses referenced beneath relate to composite beam properties:

• As far as opposition is concerned a distinction is seen among complete and incomplete shear association. The collaboration is alluded to as full association if the obstruction of the shaft is characterized by its twisting opposition and not its even obstruction. [3]

• If there should be an occurrence of full cooperation the solidness of the pillar is higher when contrasted with halfway connection of cement and steel in a composite. Incomplete collaboration for the most part happens if there should arise an occurrence of studs or welds which don't frame a total association not at all like cements that bond immovably, this offer ascent to the slip in the event of a composite pillar. [3]

• Composite shaft have their own arrangement of advantage one such advantage is that they give a more noteworthy burden bearing limit and solidness when contrasted with the standard fortified solid bars. Since the composite pillar gives a more prominent quality the profundity of a composite bar is likewise normally lower when contrasted with a strengthened one. Since a piece of the material utilized is steel hence the shaft likewise has a huge reuse esteem making it eco-accommodating and cost effective.[3]Since the pillars have lower profundity thusly they additionally encourage more noteworthy floor statures.

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Components for which composite beams are checked:

- Resistance of significant cross-areas
- Resistance to parallel torsion clasping
- Resistance to shear clasping and transversal powers
- Resistance to longitudinal shear

Basic cross-segments include:

- Sections of most elevated twisting
- Supports
- Sections exposed to concentrated burdens or responses
- Positions any place a quick revision of cross-area occurs, aside from a correction on account of breaking of cement.

It is seen if there should arise an occurrence of bars full and halfway interaction is just restricted to shafts with plastic miss happening. Composite bars are presently being generally used because of their predominance over regular RCC shafts.

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4.4 COMPOSITE COLUMNS

Composite columns like the name suggests are designed of concrete and steel sections combined. The composite columns just like composite beams have a greater stiffness as compared to RCC columns. There is a minimal requirement of reinforcement in these columns as compared to RCC. Designing these composite columns however is no easy task as the process is quite complicated but it has on field benefits as it significantly reduces the width of the column [4]. There can be made broad classification of the composite columns as mentioned below:

Composite columns can be classified in three different categories:

• Concrete incased steel columns:

In these types of composite columns there is a steel section generally an I-section or H-section at the core and surrounded with concrete and reinforcement.

• Concrete stuffed steel tubes:

Steel casings in cylindrical or cubic form are placed and filled with concrete in order to obtain these kinds of columns

• Rolled section columns partially incased in concrete:

In this type of composite the steel section is somewhat partially filled with concrete or in some cases concrete is filled in the pores of a steel section.

When these columns are designed it is important to bear in mind that the interaction is assumed to be as full interaction. For ensuring full interaction it is advised to use mechanical connectors with proper design methods [4]. The joints must be provided in areas of high load concentrations which is usually the ends in case of a column. It must also be endure that the connector at the ends are distributed properly and evenly so as to ensure maximum load transfer for this various steel tools are used such as gusset plates headed studs etc.

The second type of composite columns namely concrete stuffed steel tubes are also gaining popularity. The core of these tubes is generally made up of high strength concrete encased in steel tubes. The load transferring mechanism is that beams transfers load over to columns therefore if possible then welding must be used to connect beam with column to ensure maximum load transfer without slip [4]. Also in cases of these columns fire resistance can be ensured if the concrete column is reinforced length wise. Although every necessary efforts are made still it is

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not quite possible to attain a fire resistance equivalent to a conventional RCC beam. It is also generally witnessed that no shear connections are usually provided between columns and end plates in compression [5].

All in all composite columns are one of the most important composite structure and widely used due to their greater load transfer capacity and better performance under compression

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4.5 CONTINUOUS BEAMS AND SLABS

In cases of continuous beams it is generally noticed that composite beams are preferred over conventional RCC due to better strength, longer sections without breaks and better bending resistance. As we know that slabs are also a form of a continuous beam therefore composite slabs are also in trend like decks in bridges. [4] When it comes to continuous beams composites have certain advantages over conventional RCC that provides them an edge:

- They have a greater load resistance due to more evenly distributed bending stresses
- They also have a greater stiffness than RCC beams
- They also have significantly lower depths for the same amount of loading hence providing more space.

One point that must be kept in mind while designing continuous beams is that in case of continuous beams the composite encounters greater hogging moments therefore reinforcement can be provided in these regions.

`

5. CONNECTORS

5.1 SHEAR CONNECTORS

Shear connectors or mechanical connectors are one type of connectors that are used to connect concrete and steel in composite structure. These types of connector are more prevalent and widely used in composite construction due to easy availability and enough research data proving their effectiveness and ensuring their connecting ability. One of the most important factors in case of composite structures is the interaction of the bonding layer. This is why it is important that the shear connectors provide interaction as close to full interaction as possible. For this to occur it is necessary that shear connectors fall in certain parameter. [5].The name shear connector comes from the fact that these connector are generally provided to counter longitudinal shear.

The shear connectors must fulfill the following criteria's:

- They must be able to transfer the direct shear at the base.
- The link created by these connectors inside concrete should be a tensile link.
- It is also very necessary according to the modern norms that these connectors are feasible, economical and eco- friendly.

The general perception towards a composite beam is that the steel section takes the bending load while the concrete part deals with the compression but the most important factor that binds the two often goes unnoticed. It must be ensured that if a complete utilization of the bending resistance of steel is required then the connector used must be as few as possible also keeping in mind the economical aspect of the situation [12].

Although this type of approach may reduce the number of stud connectors and may also facilitate bending resistance but must be kept in mind that this also causes the slip to increase and the interaction to become partial thereby reducing the resistance of the beam. Also a similar kind of problem comes across in case of a composite slab decking. It may also be noticed that due to the insertion of metallic studs into concreted its lateral expansion gets hindered which in turn causes frictional resistance and therefore can cause partial interaction and lower transfer of load from one component of the composite to another [5].

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5.2 ADHESIVE CONNECTORS

Structural adhesives are the ways forward I the growing need of a substantial connector for a composite structure. Although mechanical connectors are more widely used but adhesives is also gaining ground with newer research in this field showing their capabilities. Unlike mechanical connectors adhesives provide a much greater degree of interaction. In case of shear connectors you need to increase the amount of connectors to get an ample connection with a good degree of interaction this however is not the case with adhesive. Also providing a large number of shear connectors causes hindrance to placement and compaction of concrete whereas adhesive connectors overcome these limitations. Adhesive connectors quite clearly are better option here and are starting to get more widely used. Although there are still questions about the performance during disaster conditions such as in case of a fire out break but these queries have stayed out of the scope of research yet and need further study

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5.3 DEGREE OF INTERACTION

5.3.1 FULL INTERACTION

Full interaction refers to when the two halves of the beam are joined together by an infinitely stiff shear connection. The two individuals at that point nearly carry on as one. Slip and slip strain are zero, and it is typically expected that plane segments stay plane. Likewise this happens when there is a finished burden move from steel to cement or the other way around with no misfortunes or with no kind of distortion to the connector/interface layer

5.3.2 PARTIAL INTERACTION

Partial interaction is a more realistic condition where the slip is not equal to zero. This means that the load does not get completely transferred from one element to another due to connection inaccuracies and deformations. This kind of state is responsible for 3 types of failures in composite structure which will be talking about in detail further. Although we try to attain full interaction but we usually only are able to come close to it. Nevertheless partial interaction must be reduced to whatever extent possible methods for which are discussed in types of composite failure further ahead in this report.

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6. TYPES OF FAILURE IN COMPOSITE STRUCTURES

There are various types of failure in a composite structure. Since a composite consists of three elements i.e. concrete, steel and the interface that connects the two. It can either be shear connectors or adhesive connectors. The failures incurred are of 4 types each of which will be discussed below in detail.

The four types of composite failures are as follows:

1. Steel-Connector Interface bond failure:

This is a type of failure in which the failure occurs at the bond of the Steel and connector. The failure can occur due to several reasons. Improper layer thickness in case of adhesive connectors and improper positioning in case of shear studs. The failure is absolutely not acceptable as the structure in this case would fail before reaching its ultimate failure design load. This also raises questions on the structural integrity of composites but research on this matter has shown that this type of failure can be avoided by changing the design or thickness of the interface layer whichever the case may be

2. Concrete-Connector Interface bond failure:

This is a type of failure in which the bond between the interface and concrete fails. This type of failure is acceptable and desirables out of the four as in this case the composite reaches maximum potential strength for which it is designed. This failure is the one which have tried to attain during our experimentation. It was previously inferred from the literature review that the optimum bond thickness is a must and the value is 3mm which we also used in our specimen. This type of failure occurs only after the design strength of the composite is reached that's why this more preferred.

3. Connector / Interface layer failure:

When failure is incurred in the connector that binds steel and concrete together it is referred to as the Connector or Interface layer failure. This type of failure can occur if the connector or the adhesive used is not of the optimum quality. This type of failure can also occur if the number of

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shear connectors is not optimum and the connector is unable to bear the oncoming load while transferring. This is the most drastic failure and avoiding it is the utmost priority.

4. Concrete failure:

This type of failure occurs in case of the concrete block failure. This can occur due to poor casting practices or improper compaction of concrete. This failure occurs as soon as the stress reaches the compressive strength of concrete block thus rendering the entire purpose of a composite useless. This leads to composite not attaining the desired strength hence defeating the purpose of building a composite structure all together

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7. TESTS FOR MIX DESIGNS

7.1 TESTS ON COARSE AGGREGATES

Water absorption and specific gravity test

Procedure:

1. We took 2 Kilogram of aggregate and rinsed completely and evacuate fines. Then we took this basket and submerged in water at a temperature of 24ºC.

2. We then took the wired basket with aggregates kept it dipped in water to remove bubbles and kept it in water for 24hrs

3. The container was weighed while suspended in water at room temperature of 24^0C. The weight while suspended in water was noted = W 1

4. After 24hrs we took the wired basket out of water and surface dried the aggregates with the help of a dry cloth then immersed the basket back in water and and weight was taken in water which is = W 2.

5. The cleaned aggregates were further dried with the help of a dry cloth and wiped a few times. The surface dried aggregate were then positioned on a gauging machine and weighed = W 3

6. Ten these aggregates were kept in a tray in oven to dry for 24 hrs at 105^0C. It was then expelled from the oven, after 24 hours and cooled in sealed shut compartment and weighed = W 4

Formulas:

(1) Specific gravity = W4 / (W 3 – (W 1 – W 2))

(2) Water Absorption = ((W3 – W 4) / W 4) X 100

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Observation table:

SNo.	Weight of	Values
1	Saturated aggregates + basket in water W1 (g)	3262
2	Basket in water W2 (g)	1728
3	Surface dried aggregates in air W3 (g)	2409
4	Oven dried aggregates in air W4 (g)	2397.02

Table 1 Observation for Water Absorption and Specific Gravity Test of Coarse Aggregates

Results:

(1) Specific gravity = 2.74

(2) Water Absorption = 0.5%

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7.2 FINE AGGREGATES TESTS

7.2.1 A SIEVE ANALYSIS TEST DETERMINING GRADE OF FINE AGGREGATES

Procedure:

1. Arrange the sieves in order as given in IS 383-1970
2. Pass the 1Kg of fine aggregates from the sieve setup and put it in a sieve shaker for 15 minutes
3. After this weigh the quantity of fine aggregates remaining on each sieve separately
4. Put the values in the table as mentioned below to compare it with IS 383-1970 Table 4

Results and observations:

Sieve Size	Weight of remaining aggregate on sieve	Percent of weight remaining	Percent of Aggregates passing	Net percent remaining	Net passing
4.75mm	14.6	1.46	98.54	1.46	98.54
2.36mm	204.6	20.46	79.54	21.92	78.08
1.18mm	345.2	34.52	65.48	56.44	43.56
600µm	143.5	14.35	85.65	70.79	29.21
300 µm	131.1	13.11	86.89	83.89	16.11
150 µm	99.3	9.93	90.07	93.82	6.18
75 µm	50.9	5.09	94.91	98.91	1.09
Pan	9.4	0.94	99.1	99.85	0.15

From the above observations it is concluded that the fine aggregates are of Zone II.

Table 2 Results of Sieve Analysis for Fine Aggregates

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7.2.2 WATER ABSORPTION AND SPECIFIC GRAVITY TEST

Procedure:

1. A specimen of fine aggregates of 1 kg was taken in the plate and loaded up with water at a temperature of 24^0C. These aggregates were then stirred with a rod to remove air bubbles. The sample was kept inundated in water for 24 hours.
2. The water was then poured out of the container on filter paper and the material retained was completely dried with filter paper. The soaked and surface-dry sample was gauged (weight A).
3. Aggregate thus dried were then put in a pycnometer and was filled with water up to the level of aggregate. The pycnometer was then rotated to remove any air bubbles from the top of the pycnometer cone hole. The pycnometer was then filled to the top with refined water to expel any air pockets from the surface and the outside of the water in the gap was level. The pycnometer was then dried outwardly and gauged (weight B).
4. The pycnometer was emptied and then filled with water up to the top level, dried outwardly and gauged (weight C).
5. The sample was again dried with the help of filter paper the water in the sample was filtered then the aggregates were put in a oven for 24hrsto dry at 105^0C. The sample was then cooled in a sealed shut compartment after 24 hrs and gauged (weight D).

Formulas :

Specific gravity = D/A-(B-C)

Water absorption (percent of dry weight) = 100×(A - D)/D

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Observation table:

SNo.	Weight of	Values
1	Saturated surface-dry sample. A (g)	1000
2	Pycnometer containing sample and filled with distilled water. B (g)	1205.5
3	Pycnometer filled with distilled water only. C (g)	580
4	Oven dried sample. D (g)	990.1

Table 3 Observation for Water Absorption and Specific Gravity Test of Fine Aggregates

Results:

Specific gravity = 2.65

Water absorption (percent of dry weight) = 1%

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7.3 TESTS ON CEMENT

Specific gravity of cement

Procedure:

1. A specific gravity bottle was permitted to dry totally and made liberated from fluid and dampness. The heaviness of the unfilled container was taken as W1.
2. This bottle was loaded up with concrete to its half (Around 50gm of concrete) and shut with a plug. The course of action was weighed with plug and taken as W2.
3. Then kerosene oil was filled to the highest point of the bottle. The blend was blended completely and air bubbles were expelled. The bottle was loaded up with kerosene oil, concrete and plug is gauged and taken as W3.
4. Next, the bottle was purged and loaded up with kerosene and gauged esteem was taken as W4.

Formulas:

Specific gravity of Kerosene = 0.79

Specific Gravity of Cement = [(W2-W1) /(W2-W1)-(W3-W4)]×0.79

Observation table:

SNo.	Weight of	Values
1	Empty bottle W1 (g)	0.95
2	Bottle half filled cement W2 (g)	50.95
3	Bottle filled with kerosene and cement W3 (g)	60.19
4	Filled with kerosene W4 (g)	26.07

Table 4 Observation for Specific Gravity Test of Cement

Results :

Specific Gravity of Cement = 3.15

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7.4 MIX DESIGN

7.4.1 MIX DESIGN FOR CONTROL MIX (M40)

SPECIFICATION FOR PROPORTIONING

a) Grade Assignment: M40

b) Type of cement: OPC 43 agreeing to IS 1489 (Part 1)

c) Maximum ostensible size of aggregate: 20mm

d) Minimum cement substance and most extreme water-cement extent to be utilized as well as: Severe (for fortified solid) Exposure conditions according to Table 3 and Table 5 of IS 456

e) Workability: 100mm (droop)

f) Method of cement setting: Chute (Non siphon capable)

g) Degree of site control: Good

h) Type of aggregate : Crushed rakish aggregate

TEST DATA FOR MATERIALS

a) Cement utilized: OPC 43 complying with IS 1489 (Part 1)

b) Specific gravity of cement: 3.15

c) Specific gravity of

1) Coarse aggregate [at immersed surface dry: 2.74 (SSD) Condition]

2) Fine aggregate [at immersed surface dry: 2.65 (SSD) Condition]

3) Chemical admixture: 1.145

d) Water assimilation

1) Coarse aggregate: 0.5 percent

2) Fine aggregate: 1 percent

e) Moisture substance of aggregate [As per IS 2386 (Part 3)]

1) Coarse aggregate: Nil

2) Fine aggregate: Nil

TARGET STRENGTH FOR MIX PROPORTIONING

$f'ck = fck + 1.65 \times S$

Or on the other hand

$f'ck = fck + X$

`

Whichever is higher.

Where

f'ck = target normal compressive quality at 28 days.

fck = trademark compressive quality at 28 days.

S = standard deviation, and

X = factor dependent on evaluation of cement

From Table 2 IS 10262-2019, standard deviation, S = 5 N/mm2

From Table 1 IS 10262-2019, X = 6.5.

Consequently, target quality utilizing the two conditions, that is,

a) f'ck = fck + 1.65×S

= 40 + 1.65×5 = 48.25 N/mm2

b) f'ck = fck + 6.5

= 40 + 6.5 = 46.5 N/mm2

The higher worth is to be received. Consequently, target quality will be 48.25 N/mm2 as 48.25 N/mm2 > 46.5 N/mm2.

ESTIMATED AIR CONTENT

From Table 3 IS 10262-2019, the estimated measure of captured air not out of the ordinary in typical (non-air-entrained) concrete is 1.0 percent for 20 mm ostensible greatest size of aggregate.

DETERMINATION OF WATER CONTENT

The water-cement proportion required for the objective quality of 48.25 N/mm2 is 0.36 for OPC 43 Evaluation bend. This is lower than the greatest estimation of 0.5 recommended for 'serious' presentation plain concrete according to Table 5 of IS 456. Subsequently, 0.36<0.5, henceforth O.K.

DETERMINATION OF WATER CONTENT

From Table 4, water cement = 186kg (for 50mm Slump) for 20mm aggregate.

Assessed water content for 100mm droop

= 186 + 6×186/100

= 197.16 kg

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CALCULATION OF CEMENT CONTENT

Water-cement proportion = 0.36

Cement content = 197.16/0.36 = 547.6 kg/m3

From Table 5 of IS 456, least cement content for 'serious' introduction condition = 320 kg/m3

547.6 kg/m3, subsequently, O.K.

EXTENT OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 5 IS 10262-2019, the proportionate volume of coarse aggregate relating to 20mm size aggregate and fine aggregate (Zone II) for water-cement proportion of 0.50 = 0.62. In the current case water-cement proportion is 0.36. In this way, volume obviously aggregate is required to be expanded to diminish the fine aggregate substance. As the water-cement proportion is lower by 0.14, the extent of volume of coarse aggregate is expanded by 0.028 (at the pace of 0.01 for each ± 0.05 change in water cement proportion). Hence, revised extent of volume of coarse aggregate for the water-cement proportion of 0.36 = 0.62 + 0.0284 = 0.648. Volume of fine aggregate substance = 1 – 0.648 =0.352.

BLEND CALCULATIONS

a) Total volume = 1m3

b) Volume of entangled air in wet cement = 0.01m3

c) Volume of cement

= (Mass of cement/Specific gravity of cement) × (1/1000)

= (547.6/2.88) × (1/1000)

= 0.189m3

d) Volume of water

= (Mass of water/Specific gravity of cement) × (1/1000)

= (197.16/1) × (1/1000)

= 0.197m3

e) Volume of all in aggregate = [(a - b) - (c + d)]

= [(1 - 0.01) – (0.189 + 0.197)]

= 0.603m3

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f) Mass of coarse aggregate

= e) × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

= 0.603 × 0.648 × 2.74 × 1000

= 1069.5 Kg

g) Mass of fine aggregate

= e) × Volume of fine aggregate × Specific gravity of fine aggregate × 1000

= 0.603 × 0.352 × 2.65 × 1000

= 561.3Kg

<u>CHANGE ON WATER, FINE AGGREGATE AND COARSE AGGREGATE (IF THE COARSE AND FINE AGGREGATE IS IN DRY CONDITION)</u>

a) Fine Aggregate (Dry)

= Mass of fine aggregate in SSD condition/(1 + (water ingestion)/100))

= 562.4/(1 + (1/100))

= 555.5 Kg/m3

b) Coarse Aggregate (Dry)

= Mass of coarse aggregate in SSD condition/(1 + Water ingestion/100))

= 1069.5/(1 + (0.5/100))

= 1064.6 Kg/m3

The additional water to be included for retention by coarse and fine aggregate,

1) For coarse aggregate

= Mass of coarse aggregate in SSD condition – mass of coarse aggregate in dry condition

= 1069.5 - 1064.6

= 6Kg

2) For fine aggregate

= Mass of fine aggregate in SSD condition – mass of fine aggregate in dry condition

= 561.3– 555.5

= 6Kg

The evaluated necessity for included water, accordingly, becomes

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= 197.16 + 6 + 6

= 208.76Kg/m3

MIX PROPORTIONS AFTER ADJUSTMENT FOR DRY AGGREGATES

Material	Quantity
Cement	547.6 Kg/m^3
Water (to be added)	208.76 Kg/m^3
Fine aggregate (Dry)	557 Kg/m^3
Coarse aggregate (Dry)	1064.6 Kg/m^3
Free water-cement ratio	0.36

Table 5 Mix Design for M40 Grade of Concrete

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7.4.2 MIX DESIGN FOR CONTROL MIX (M30)

SPECIFICATION FOR PROPORTIONING

a) Grade assignment : M30

b) Type of cement: OPC 43 fitting in with IS 1489 (Part 1)

c) Maximum ostensible size of aggregate: 20mm

d) Minimum cement substance and most extreme water-cement proportion to be received as well as: Severe (for fortified solid) Exposure conditions according to Table 3 and Table 5 of IS 456

e) Workability: 100mm (droop)

f) Method of cement setting: Chute (Non siphon capable)

g) Degree of site control: Good

h) Type of aggregate: Crushed precise aggregate

TEST DATA FOR MATERIALS

a) Cement utilized: OPC 43 fitting in with IS 1489 (Part 1)

b) Specific gravity of cement: 3.15

c) Specific gravity of

1) Coarse aggregate [at immersed surface dry: 2.74 (SSD) Condition]

2) Fine aggregate [at immersed surface dry: 2.65 (SSD) Condition]

3) Chemical admixture: 1.145

d) Water retention

1) Coarse aggregate: 0.5 percent

2) Fine aggregate: 1 percent

e) Moisture substance of aggregate [As per IS 2386 (Part 3)]

1) Coarse aggregate: Nil

2) Fine aggregate: Nil

TARGET STRENGTH FOR MIX PROPORTIONING

$f'ck = fck + 1.65 \times S$

Or then again

$f'ck = fck + X$

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Whichever is higher.

Where

f'ck = target normal compressive quality at 28 days.

fck = trademark compressive quality at 28 days.

S = standard deviation, and

X = factor dependent on evaluation of cement

From Table 2 IS 10262-2019, standard deviation, S = 5 N/mm2

From Table 1 IS 10262-2019, X = 6.5.

In this way, target quality utilizing the two conditions, that is,

a) f'ck = fck + 1.65×S

= 30 + 1.65×5 = 38.25 N/mm2

b) f'ck = fck + 6.5

= 30 + 6.5 = 36.5 N/mm2

The higher worth is to be embraced. In this way, target quality will be 38.25 N/mm2 as 38.25 N/mm2 > 36.5 N/mm2.

ROUGH AIR CONTENT

From Table 3 IS 10262-2019, the rough measure of ensnared air not out of the ordinary in typical (non-air-entrained) concrete is 1.0 percent for 20 mm ostensible most extreme size of aggregate.

CHOICE OF WATER CONTENT

The water-cement proportion required for the objective quality of 38.25 N/mm2 is 0.4 for OPC 43 evaluation bend. This is lower than the most extreme estimation of 0.5 endorsed for 'serious' presentation plain concrete according to Table 5 of IS 456. Along these lines, 0.4<0.5, consequently O.K.

CHOICE OF WATER CONTENT

From Table 4, water cement = 186kg (for 50mm Slump) for 20mm aggregate.

Evaluated water content for 100mm droop

= 186 + 6×186/100

= 197.16 kg

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CALACULTION OF CEMENT CONTENT

Water-cement proportion = 0.4

Cement content = 197.16/0.4 = 492.9 kg/m3

From Table 5 of IS 456, least cement content for 'extreme' presentation condition = 320 kg/m3 492.9 kg/m3, consequently, O.K.

EXTENT OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 5 IS 10262-2019, the proportionate volume of coarse aggregate comparing to 20mm size aggregate and fine aggregate (Zone II) for water-cement proportion of 0.50 = 0.62. In the current case water-cement proportion is 0.4. Hence, volume obviously aggregate is required to be expanded to diminish the fine aggregate substance. As the water-cement proportion is lower by 0.1, the extent of volume of coarse aggregate is expanded by 0.02 (at the pace of 0.01 for each ± 0.05 change in water cement proportion). Along these lines, adjusted extent of volume of coarse aggregate for the water-cement proportion of 0.4 = 0.62 + 0.02 = 0.64. Volume of fine aggregate substance = 1 – 0.64 =0.36.

BLEND CALCULATIONS

a) Total volume = 1m3

b) Volume of captured air in wet cement = 0.01m3

c) Volume of cement

= (Mass of cement/Specific gravity of cement) × (1/1000)

= (492.9/2.88) × (1/1000)

= 0.171m3

d) Volume of water

= (Mass of water/Specific gravity of cement) × (1/1000)

= (197.16/1) × (1/1000)

= 0.197m3

e) Volume of all in aggregate = [(a - b) - (c + d)]

= [(1 - 0.01) – (0.171 + 0.197)]

= 0.622m3

f) Mass of coarse aggregate

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= e) × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

= 0.622 × 0.64 × 2.74 × 1000

= 1090.7 Kg

g) Mass of fine aggregate

= e) × Volume of fine aggregate × Specific gravity of fine aggregate × 1000

= 0.622 × 0.36 × 2.65 × 1000

= 593.4 Kg

<u>ALTERATION OF WATER, FINE AGGREGATE AND COARSE AGGREGATE (IF THE COARSE AND FINE AGGREGATE IS IN DRY CONDITION)</u>

a) Fine Aggregate (Dry)

= Mass of fine aggregate in SSD condition/(1 + (water assimilation)/100))

= 593.4/(1 + (1/100))

= 587.5 Kg/m3

b) Coarse Aggregate (Dry)

= Mass of coarse aggregate in SSD condition/(1 + Water ingestion/100))

= 1090.7/(1 + (0.5/100))

= 1085.3 Kg/m3

The additional water to be included for assimilation by coarse and fine aggregate,

1) For coarse aggregate

= Mass of coarse aggregate in SSD condition – mass of coarse aggregate in dry condition

= 1090.7 - 1085.3

= 5.4Kg

2) For fine aggregate

= Mass of fine aggregate in SSD condition – mass of fine aggregate in dry condition

= 593.4 – 587.5

= 5.9Kg

The assessed necessity for included water, in this way, becomes

= 197.16 + 5.4 + 5.9

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= 208.46Kg/m3

MIX PROPORTIONS AFTER ADJUSTMENT FOR DRY AGGREGATES

Material	Quantity
Cement	492.9 Kg/m^3
Water (to be added)	208.46 Kg/m^3
Fine aggregate (Dry)	587.5 Kg/m^3
Coarse aggregate (Dry)	1085.3 Kg/m^3
Free water-cement ratio	0.4

Table 6 Mix Design for M30 Grade of Concrete

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7.5 TESTING MIX DESIGNS

The Mix designs were put to experimental testing to infer if theoretical values matched experimental readings. For this we performed compressive strength test on samples of both grades of concrete i.e. M30 & M40. 3 samples were tested for 7 day, 14 day and 28 day strength for both grades of concrete. The procedure and results of the following are listed below.

Procedure

a) Set up and grease 3 identical moulds of 150×150×150mm.
b) Pour freshly mixed concrete mix in the mould and leave it undisturbed for 24hrs.
c) Remove the cubes from the mould a put them for curing in curing tank.
d) Take once specimen out after 3 days for testing in Compression Testing Machine (CTM).
e) Note the value of the failure load.
f) Take the second and the third sample out of the curing tank after 14 and 28 days later respectively and note the failure load.
g) Calculate the compressive stress from the readings accordingly.

Fig1. Moulds filled with Concrete for Compression Strength Testing

Fig2. Testing Concrete blocks in Compression Testing Machine

Fig3. Concrete specimen after failure load

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Results:

Grade of Concrete M30			
Days	7days	14days	28 days
Failure load	479.25KN	648KN	760.5KN
Compressive strength	21.3 MPa	28.8MPa	33.8 MPa
Grade of Concrete M40			
Days	7days	14days	28 days
Failure load	646.65KN	886.5KN	965.25KN
Compressive strength	28.74MPa	39.4MPa	42.9MPa

Table 7 Results of Compression Test

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8. FINAL TESTING

8.1 MATERIAL USED

During the construction of the final specimen the material used were selected on the basis of the tests conducted above and the Mix Design. Some of the materials have not been covered yet so below mentioned are all the materials used for putting together the final testing specimen

1. Coarse Aggregate:

Coarse aggregate used were 20mm down size. But to increase bulk density we replaced 60% of total coarse aggregates with 10mm downsize aggregates.

2. Fine aggregates :

Fine aggregates used were of Zone II tests for which have already been mentioned above

3. Cement:

Cement used was Ordinary Portland cement Grade 43. The Quantity were strictly followed as mentioned in mix design

4. Mould:

Mould used for the construction of concrete blocks had be made since the dimension of the block were no regular. The dimension of the mould were 400×400×100mm

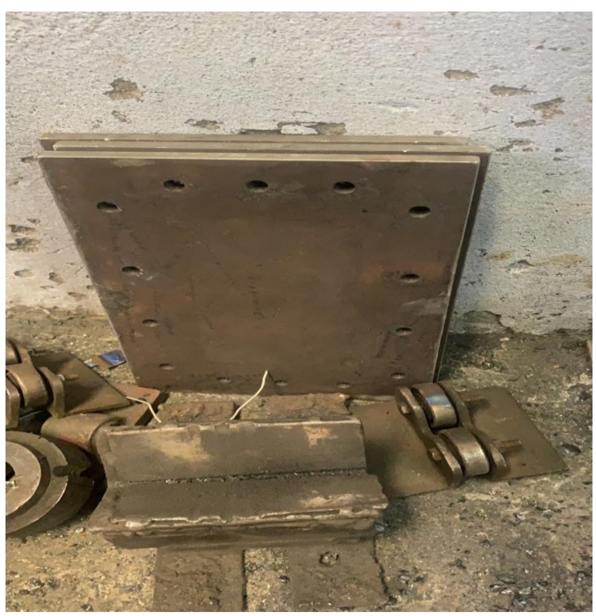

Fig4. Images of Steel plates for the base of Mould

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Fig5. Image showing side steel plates of the Mould

5. Concrete:

Concrete grades upon which the experiments were conducted were M40 & M30.

6. Connector / Interface layer:

The interface layer used was adhesive namely epoxy resin 3mm thick layer was used conforming to literature suggesting the optimum thickness of bond layer in case of epoxy adhesives.

7. Steel section :

The steel section used was UC-203 I column section. Details of the section are mentioned below

Serial size	Mass per meter	Depth of section	Width section	Thickness of web	Thickness of flange	Height of section
203×203×46	46.1Kg/m	203.2mm	203.6mm	7.2mm	11mm	450mm

Table 8 Details of UC-203 I-section of Steel

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8.2 PUSH OUT TEST

For the final testing we first prepared the specimen and then conducted the test on two specimen of each grade of concrete. The steps for the final testing are as follows

1. Preparing the concrete blocks:
   - First step was to cast the concrete blocks to be used in the specimen.
   - The dimensions of the block were 400×400×100mm
   - The concrete blocks were prepared in accordance with the Mix Designs
   - The aggregates were dry mixed in a mixer
   - The concrete was poured in the mould in three layers and compacted on a table vibrator
   - The blocks were allowed to set in mould for 24hrs then de-molded and cured for 28 days.
   - Since two concrete blocks were required for one specimen total of 8 blocks were casted for two grades of concrete making two samples for each

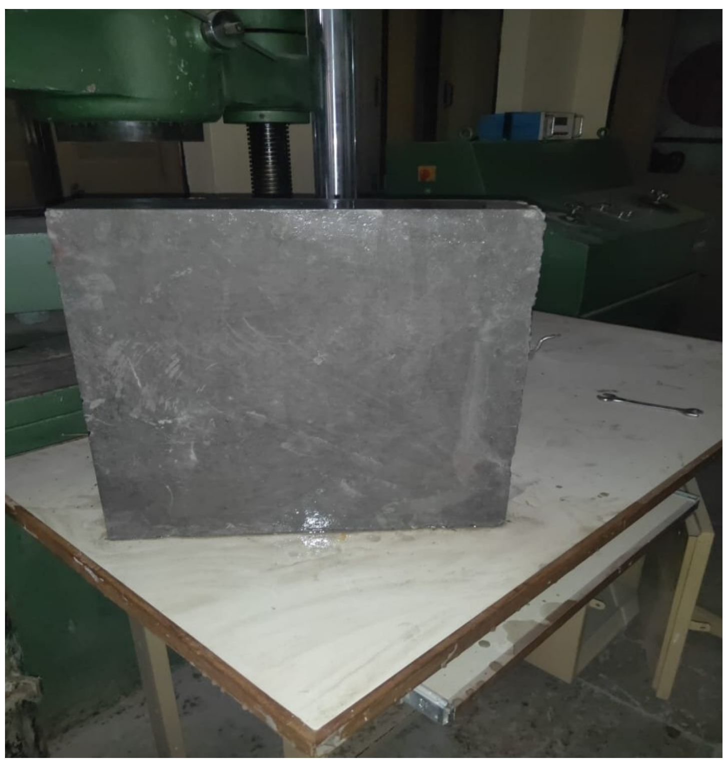

Fig.6 Image of Concrete block casted for specimen

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2. Setting up the specimen:
   - The specimen to be tested was a concrete-steel-concrete specimen this specimen consisted of two concrete blocks and the steel section and adhesive layer between them.
   - Epoxy layer of 3mm thickness was applied on the steel section up to 150 mm at then the portion was attached to the concrete blocks and the adhesive layer was allowed to set for 10 hrs
   - The specimen was the ready for testing

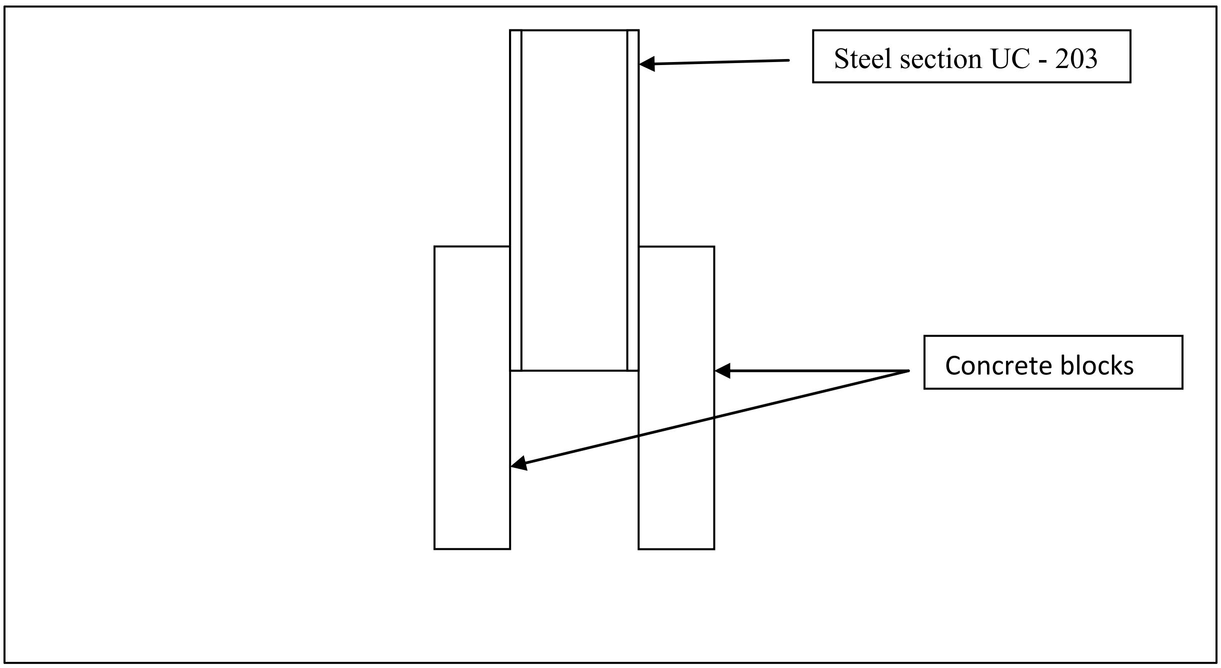

Fig7. Concrete-steel-concrete specimen assembly

3. Testing the specimen according to the guide lines of push out test specified in EuroCode 4. [15]
   - For testing the specimen was mounted on the Universal Testing Machine
   - Gradual loading rate was applied until the specimen failed
   - The test was conducted for two specimen for both grades of concrete

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8.3 RESULTS AND OBSERVATIONS:

Grade of Concrete M30		
Specimen	**Ultimate failure load**	**Type of failure**
Sample 1	**1678.3KN**	**Concrete-interface failure**
Sample2	**1677.5KN**	**Concrete-interface failure**
Grade of Concrete M40		
Specimen	**Ultimate failure load**	**Type of failure**
Sample1	**1920.5KN**	**Concrete-interface failure**
Sample 2	**1921.2KN**	**Concrete-interface failure**

Table 9 Results of Push Out Test

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9. CONCLUSION

- At the end of this project we can conclude by saying that all the objectives we had set earlier were achieved.
- We concluded by inferring the values of failure loads of different composite specimen
- We were also able to study and realize the importance of composites and how they provide a better scope than normal RCC structures.
- We also concluded with load values and failure type in cases of Concrete-steel-concrete composites
- We also inferred that the failure type for 3mm bond layer remains same as irrespective of the type of composite specimen.
- We also inferred that the failure type for 3mm bond layer remains same as irrespective of the type of Concrete Grade.
- We were also able to understand and practically infer the failure mechanism of steel concrete composite.

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10. REFRENCES

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