PERFORMANCE ASSESSMENT OF STEEL-CONCRETE COMPOSITE BONDED SPECIMEN UNDER SLANT SHEAR

A THESIS

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

MASTER OF TECHNOLOGY

IN

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With specialization in

STRUCTURAL ENGINEERING

Under the supervision

of

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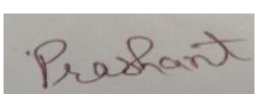
STUDENT’S DECLARATION

I hereby declare that the work presented in the Seminar report entitled **“PERFORMANCE ASSESSMENT OF STEEL-CONCRETE COMPOSITE BONDED SPECIMEN UNDER SLANT SHEAR”** submitted for partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. PANKAJ KUMAR**, **Assistant Professor (Senior Grade),** co-guided by **Mr. Abhilash Shukla, Assistant Professor Grade II**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my thesis report.



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CERTIFICATE

This is to certify that the work which is being presented in the seminar titled **“PERFORMANCE ASSESSMENT OF STEEL-CONCRETE COMPOSITE BONDED SPECIMEN UNDER SLANT SHEAR”** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in “Structural Engineering” and submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Prashant(182659)** during a period from July, 2019 to May, 2020 under the supervision of **Dr. Pankaj Kumar,** Assistant Professor(Senior Grade), Co-Guided by **Mr. Abhilash Shukla**, Assistant Professor Grade II Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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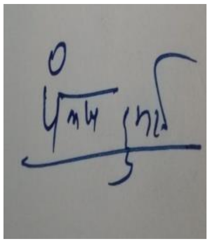

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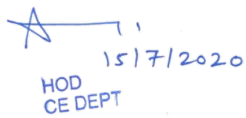

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ABSTRACT

Concrete is world's second most used material after water and it is most widely used in the construction industry due to its properties like compressive strength which is high and capacity to act as bonding agent and some other properties etc. Concrete which seems to be very simple but actually it is a complex material. Behavior of concrete with respect to bond, creep, fiber modified, fatigue concrete are few of the area in which active research is going on. However, concrete has one drawback, with time it deteriorates or become damaged which lead to reduce strength and stiffness of members and structure, so it is always in need of strengthening and repair. In today's world, the number of infrastructures that are deteriorating and can no longer meet the safety standard is increasing day by day. In strengthening and repair of the concrete structures the need to place new material next to old often arises, means concrete composite construction is necessary. A bond which is good helps the engineer to consider monolithic behavior and it also helps in preventing de-icing salts and water to transmit along the interface. Monolithic behavior increases the strength and efficiency of a structure. Repair to be done in such a way that allow member to act as it was originally designed. For that bonded interface must be capable of successfully transfer forces such as compression, tension and shear. Good adhesion on concrete of the repair material plays a vital importance in concrete patch repairs application. There are several tests in determining the bond strength between repair material and substrate. These test are classified into many categories, they are bond strength under tension stresses, bond strength under shear stresses, bond strength under combines shear and compressive stresses. All slant shear tests fall under combine state of stress that combines compression and shear. In slant shear test we use a cylindrical or a square prism sample made of two identical parts which are bond at an angle of 30° and under axial compression they are tested. Some experimental work is done in this thesis using concrete steel composite material using epoxy based bonding agent and performing slant shear test and finding out bonding strength and durability of the bond.

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LIST OF ACRONYMS AND ABBREVIATIONS

CA	Coarse Aggregate
FA	Fine Aggregate
PPC	Portland Pozzolana Cement
SST	Slant Shear Test
W/C	Water Cement Ratio
HSC	High Strength Concrete
FRC	Fiber Reinforced Concrete
UCS	Unconfined Compressive Strength
SCC	Self Compacting Concrete
MOR	Modulus of Rupture

CHAPTER 1

INTRODUCTION

1.1 Background

Concrete is a material which can be used as construction material and be used for different types of structures. “Twice as much concrete is used in construction around the world than the total of all other building materials including wood, steel, plastic and aluminum” stated by world business council for sustainable development 2015. There is some drawback about concrete, it is that concrete can deteriorate over time or can damage over time. So there is need to repair concrete. So, repair in concrete means bonding new concrete to old concrete.

Composite construction is accomplished when two or more materials are connected together so strongly that they act as a monolithic unit. Composite construction is often necessary to repair damaged structural members. Monolithic behavior is desirable because it increases the strength and efficiency of a structure, or a member within a structure, which typically leads to a more economical design. In order for a composite unit to perform monolithically, the bonded interface must be capable of successfully transferring forces such as compression, tension, and shear. Simple and straightforward standard tests exist to measure the compressive and tensile strengths of bonds but when it comes to shear, few methods have been formalized into standard tests (Helmick et al. 2016). For this reason, engineers need an effective method to experimentally determine the strength in shear at the interface bonded between old and new concrete for purpose of conducting repairs or applying overlays.

There are three different types of shear: direct, flexural, and torsional. Stress is defined as a force per unit area. Direct or general shear stress is the most basic and straightforward type and is simply the force applied divided by the cross-sectional area of the material.

In case of plain concrete, in roads the strength in shear in a bonded interface is arise mainly due to adhesion and also due to mechanical interlocking in the aggregate in the middle of base or bottom layer, which is mention as the substrate, and top layer is mention as overlay. So, according of this, we can assume that the rougher the surface, the shear capacity is more. This is a reason recognized by the International Concrete Repair Institute, Inc. (ICRI). In spite of many different methods to check different properties of a bond but there are very few methods for shear.

The strength of bond in the middle of concrete layers which are cast not at same times is important to check the monolithic etiquette of reinforced concrete composite members. Structural interfaces are crucial for:

i) repairing/strengthening of existing concrete structures; and

ii) Composite precast members of concrete with parts of cast-in-place. In these composite structures, the bond strength of the interface has to be higher than acting shear forces in order to achieve a monolithic behavior.

In today time, there are different experimental methods available to check the behavior of old concrete to fresh concrete bonding. Those methods could be differentiated based to the state of stresses at the bonding surface in the following groups: *i*) shear stress; *ii*) bending stres; and *iii*) tension. In the table below the tests available for stresses of the referred groups are listed.

Table 1.1: Tests to check bond strength

	Tests	Standards	Research
Tension	Pull off	(EN 1542, 2000) (ASTM C1583, 2004) (BS 1881: Part 207, 1992)	-
	Direct Tension	(ASTM C1404, 2003) (CAN/CSA A23.2-6B, 1990)	-
	Split Tensile	(EN 12390-6, 2004) (ASTM C496, 2004)	-
Bending	-	EN 12189, 2000 EN 12636, 2001	(Wall et al, 1986) (Abu-Tair et al, 1996)

			(Kunieda et al, 2000) (Kamada et al, 2000)
Shear	Direct Shear Test	-	(Li et al, 1997) (Chen et al, 1995)
	Bi surface Shear Test	-	(Momayez et al, 2005)
	SST	ASTM C882 2015	
	Push off	-	Hofbeck et al, 1969) (Mattock, 1974) (Crane, 2010)

1.2 Common Bond Strength Tests

One of the most common tests performed on bonded concrete is the pull-off test, formally standardized as ASTM C1583, where a pure tensile force acts on a bond. A core is drilled through an overlay and at least 1 inch or half the core diameter into the substrate. With the use of an epoxy, a steel puck is attached to the overlay. Once the epoxy has set, the testing apparatus is attached to the puck and an upward force is applied until failure occurs (ASTM C1583 2015). Other than a failure of the epoxy connection, there are three possible outcomes and each will indicate something regarding the tensile strength of the bond. This test can be done in the field and is very straightforward and easy to perform, hence its popularity. However, there are not very many situations in the real world that will apply this type of force alone to a bond so other tests are necessary to truly check the strength in shear at the interface which is bonded.

In studies related to concrete the tests based on direct shear has not done regularly in previous researches due to the reason of difficulties which are technical. Direct shear test methods used in the rock mechanic is very common in which ASTM D5607 has been used, and there are different study which are taken care base on this code. Thus, the test providing data which is acceptable data because of which the strength of bond can be contemplate as same as of the originalities of the studies. The technique consist of providing stresses such as normal and shear at the interface of the specimen which is composite, providing that a fixed value of the normal stress taken and there is gradual increase in the value of shear stresses. As the value of stresses in shear is gradually increases, the displacement of specimen is measured.

The Arizona Slant Test for shear, commonly called the slant shear test, has been formalized as ASTM C882 to specifically determine epoxy bond strength. For this test, core samples are taken of the overlay and substrate at an angle so the bonded interface is at a diagonal. Once the ends have been cut so that the core has flat top and bottom surfaces, a compressive force is applied at each end of the sample until failure occurs (ASTM C882 2015).Again, the different possible outcomes provide information specific to the strength of the bond but the clamping action that occurs makes it difficult to evaluate the shear strength alone without the influence of compression (Rosen 2016). Because of the clamping action and the angle at which the load is being applied relative to the interface surface, this is not a good test to evaluate strength in direct shear.

Based on order to appraise strength of bond in the shear, the Arizona Slant Test, has a broad spread use due to:

i) The simplicity of the experimental set-up

ii) The fact that the bonded surface is subjected to a combined compressive and shear stress state, similarly to what happens in real structures (Clímaco and Regan, 2001).

1.3 BRIEF HISTORY OF THE SLANT SHEAR TEST

To find out the strength of the bond based on a epoxy based resin in shear using SST kriegh in 1976 proposed a specimen which is cylindrical in shape originally. Later in 1978 Tabor adopted a prismatic version in spite of cylindrical section to studying the concrete to concrete interfaces the strength of bond. Following are sizes of specimen for SST given below.

Table 1.2: Standards Code sizes for the SST specimen

Code	Dimension of specimen	Height of specimen (H)	Angle (α)
BS EN 12615, 1999	100 × 100 mm^2	400 mm	30°
	40 × 40 mm^2	160 mm	30°
Italian standard (reported in Clímaco and Regan, 2001)	70 × 70 mm^2	200 mm	17°
NFP18-872 (reported in Clímaco and Regan, 2001)	100 × 100 mm^2	300 mm	30°
ASTM C882, 1999	75 mm diameter	150 mm	30°

Comparing these, it is observed that all adopt a 30º interface angle with the vertical, except the Italian Standard, and that major differences exist regarding the specimen geometry.

Two research works must be mentioned when referring to the SST geometry optimization:

i) Clímaco and Regan (2001), who studied the influence of the interface angle in the failure mode and *ii*) Santos, (2009), who performed had done a numerical study aiming to optimize the shape or size of the specimens, and height of the base of specimen.

Two different failure mechanisms can occur on a SST:

i) Cohesive or monolithic failure (see Figure 1)

ii) Adhesive or interfacial failure (see Figure 2)

Figure 1.1: Cohesive failure

Figure 1.2: Adhesive failure

These failure mechanisms are reported on different research studies

CHAPTER 2

LITERATURE REVIEW

2.1 General Introduction

In today time lot of the work have been done and published on the strength of the bond of the composite materials as well as effect on bond strength of different parameters such as temperature, bonding agent, curing time and type of curing. Good bond strength is the key factor to evaluate performance of concrete repairs. There are number of test to check the bond strength and also to find out the type of failure of the sample and find out whether the bond strength we find out is real or it is apparent bond strength based on the type of failure. To understand all these things we have to read and understand things about bond strength and things which affect it, for this we need to read the work which is previously performed on it and what are the advantages as well as disadvantages of the bond, composite material and bond between composite materials. For this we have to read all the work published on various journals about this and decide the topic on the basis of the work we have studied. We have decided to check the bond strength using slant shear test and decided to use cylindrical specimen in which half part is of steel and half part is of concrete and the slant angle is 30 degree and using epoxy based resin as bonding agent. This study is to find the strength in shear in the specimen and also bond strength of the specimen. Using, ASTM Code C882 for slant shear test and ASTM C881 code for type of bonding and based on type of bond we decide type of bonding agent to be used. For this we need to study some previous work and their future scopes. Here are some literature review which I have studied before starting of my project and deciding my topic and what are going to be my objectives which I have to achieve. The literature review which I have studied is given below and based on that I have decided my thesis topic.

2.2 Literature Survey

Austin et.al (1999) performs testing in bond of concrete repairing in shear. He said in application and performance of repair in concrete good adhesion between the material to be repaired and the concrete is required. He compares different methods and gets results of test of strength of bond that also include a tensile slant shear test. He find the failure of bond for repairs of concrete based on many tests such as pull off, Arizona slant shear etc test which shows stresses in compression and also state of pure tension. By utilizing this result compare to the previous tensile slant shear result, which are also in the different researches, we can find more logic in the failure shape of envelope in the regions of tension. In almost all the cases the mode of failure stresses are on the basis of the result analyze by peak FE. He find out that the polynomials curve of second order are best-fit because of exclude of the values of the pure tension which generate a cut off relationships which is given by the results of tension slant shear test. In an attempt to find an envelope of potential failures, it is useful to take in account the behavior of materials in a context wider compare to many theories which are established of failure. His engrossment in the combined as well as single shear/normal states of stresses leads instinctively to a approach known as Mohr-Coulomb. Also a classical alternative method to trafficking with the region in tension is done by applied Griffith fracture criteria's to the material which are brittle. Also, the addition in terms of shear to his theory from stress environments as well as normal stresses is in a parabolic relationship. He conclude that a study related to bond failure, which require cracking of the specimen at the interface of bond, may have a great chance of having natural empathy with respect to fundamentals failure of fractures criteria as compare to Mohr Coulomb relationships, which are distressed with the states of stress with in a materials preferably to the specimens which are bond together at the interface. Nonetheless, we can say that the purpose of this study is find an empirical bond failure case and to find out a common link to these two classical failure concepts.

Saldanha et.al (2012) to enforce adhesive failure he has done a modified slant shear test. He performed various test after bonded the old concrete with new one and gave rest up to 7 days providing the same conditions to the specimen such that of monolithic sample. He provides the results he obtained each for the SST sample as well as for Modified-SST sample, in respect of strength, also gives out the mean value, divergence as well as COV. For each test three numbers of samples were. By checking the failure type of samples, it was concluded that samples of SST test were find having failure of cohesive type, whereas M-SST samples have adhesive type failures. He also finds out that the COV in the samples of the Modified-SST samples which have appreciably lower as compare to the samples of SST. By analyzing the results shown by the samples of Modified-SST, he concluded that the high strength treatment helps in getting higher bond strength. He states that the result he was getting he anticipated that because the value of R_{vm} he got is more for the high strength treatment. He perform a numerical analysis which allow him to wind up that reinforcement inaugurate in pair of both parts in the sample of the Modified-SST sample, the stresses may not change at the bond surface. Following that, the practical work that he has performed have allowed him proving that the failure in adhesive state in M-SST can be obtained always, even in the case of the most unfavorable condition. By doing all this work he concluded that the Modified-Slant Test that is normally similar to the Slant Test except that the mode of failure is different because of the adhesive type failures. This helps as a major plus function because it enhance possibility to quantify always the real type of adhesion of interfaces of two different concrete and also lower guess not to the values of them as happen many time in case of SST.

Naderi et.al (2012) Naderi has done the analysis of slant shear test. He said that the SST test which concern with the interface between two semi-prisms bonded samples of fresh material and material to repair in a state of shear or compression single and combine is affirm to constitute the condition of stress of structures, also there are few major disadvantages in this test. The effects of adhesion, orientations, angle etc in a semi prisms samples or structures at the time of the making of samples and interlocking mechanically as well as the along the interface friction of repair in concrete are dispense. Also in the analysis which is done theoretically the factors which responsible for failure and a comparison of the practical results which comes from test performed with the outcome specify the existent of a critical angle at joint. Despite the fact that by this method the strength of bond in cementations also modified polymer repair systems measured did not match with the values obtained by means of method by friction transfer; however the strength of bond compare in the resinous systems tested were nearly same. Also the COV in the bond strength by slant shear was seen as to be nearly 23.5%. Correlation the results samples of vertically situated repair with those positioned horizontally at the time of the manufacture of the semi prisms which demonstrate about 20, 14, 131 and 82% rise in the axial stress failure for rubber of fiber reinforced sand/cement mortar and acrylic bond grouts, styrene which is butadiene modified mortar (c. mortar), acrylic mortar, acrylic modified cementations mortar etc. This rise may be arise due to the reason such as when concrete which is old is placed vertically around the implementations of the material which is cementitious, the particle which are colloidal are tried to travel in upward direction and try to cover the area which is bonded. The effect is compare with bleeding which we face sometimes when we work with plain concrete which we use sometimes. In correlation with the concrete surface which is old and which is placed horizontally about the utilization with the system to be repair, the best compacted also more interfacial particles densified will help prompting to bond strength which is higher. It could likewise said that shrinkage impact is important more in concrete which is place vertically in surface because of the systems which need to be repair tries to move away at the time of the shrinkage procedure. It ought to be prominent that the segregation viscosity, wetting, viscosity, penetration and evaporation into the pores with the help of bonding aid in to the surface of concrete are the most significant factors involving in the development of adhesion in concrete or repair interface. Related to the effect due to shrinkage, it should be observed that the applied pressure on the bonded area at the time of the testing stage it could reduce the stress inherent due to shrinkage, which is cause in the unreal readings in the bond strength. This impact likewise affected due to the Poisson proportion and Modulus of Flexibility in the materials. For additional examinations of the multifaceted nature in the worries along with the joints the peruse which is encouraged for counsel ASTM D 4896. The hypothetical pivotal disappointment worries alongside their particular exploratory qualities got for 50°, 30° and 45° joint points. The figure helps in finding that the normal trial pivotal disappointment stresses seem, by all accounts, to higher by the hypothetical qualities at 30° edge joint. Conceivable clarification to this can be the mechanical keying (because of infiltration in the fix framework otherwise holding layer in the pores in the sub strata) impact, which is overlooked during inference of condition. Aside from resinous fix frameworks, as the joint point expands, the contrasts between the exploratory and hypothetical qualities are decreased and when the joint edge comes to about 50°, the trial esteems become considerably littler than the hypothetical qualities. The fundamental explanation behind this might the way that readings of the security qualities got bigger at joint points are impacted by quality of material prompting blended disappointments, in such a case that the 100% security disappointments alone were to be thought of, because of the less estimation of security quality, the distinctions will have been much more (for example some portion of the bond which had not fizzled is more grounded than the cited esteem). As expressed before, breaking and halfway disappointment for joint edges more prominent than about 40◦ causes the bond quality of the framework to be thought little of.

In view of the trial and hypothetical assessment of the inclination shear test technique, he expressed that: A basic disappointment plane exist, at the edge which relies upon qualities in the fix, the bond of the material and concrete, and its normal point with stacking pivot were seen as an 26.5◦ angle. The edges between stacking pivot and splits along disappointment planes of sand/concrete mortar of 250 mm crystals are estimated in the scope of 21–32.8◦. For the advancement in disappointment plane, these points, the limiting impacts at the end platen ought to be thought of.

2. The COV of test outcomes got from concrete/sand mortars and solid crystals were seen as 11% and the individual incentive for inclination in shear tests technique was seen as 23%.

3. The quality of bond relies upon direction in the solid surface during the fixed procedure.

4. The attachment below zero ordinary tension (which could be consider as the genuine quality of bond in a fix framework) got in the inclination shear strategy were find to intently identify with pivotal disappointment stress acting at 30 degree joint edge yet didn't speak to the presentation of the fix under pressure and to have the option to appraise the grip of a fix framework under zero typical tension in any event three joint edges ought to be thought of.

5. For fix frameworks tried utilizing the inclination shear technique, direct associations with COV of 0.78 to 0.97 was found to subsist between the ordinary anxieties and shear following up the joint.

6. After effects in the inclination shear tests strategy rely upon qualities of the fix, concrete just as in the security and between the two contacts. Rubbing coefficient of the fix frameworks tried across fix/solid interfaces ran from 0.45 - 0.79. Expanding the joints edge builds chance of acquiring a high degree of blended disappointment.

Diab et.al (2016) diab has find bond strength using slant shear between old type concrete material and self-compacting type concrete. He takes out a cylindrical specimen of 150mm dia and300 mm height having minimum COV. He find out that the roughness of the substrate having a notable effects on the strength of bond and also on specimen of prism which shows more reliability in bond strength. In these study first parts shows reasons that affect bond strength in old type and new type of concrete and effect of, roughness in old type of concrete, effect of bonding agent and effect of providing polyprepene fiber also latex to SCC. In the second half slant-shear tests study is carried out.

By analyzing the result from the experimental or practical work and also from some analysis done theoretically he have drawn the following conclusion given below:

1. The slant shear bond value has been affected by used specimen geometry. The 300 mm height of cylinder and 150 mm dia. of cylinder have least COV as compared to that of a prism specimen or a cylindrical specimen of another dimension.
2. The diameter of flow of overlay of the concrete which is SC has a remarkable effect on the strength of bond in slant shear.
3. The bond strength using slant shear in new SC concrete and old concrete were grandiose with the overlays SCC compression strengths also affected by due to the ratio between new type and old type concrete compression strengths.
4. Substrate roughness in surface in concrete has remarkable effects on the bond strength in slant shear. An increase about 26% were obtain when we grove it with a 5 mm of height also the width also consider as roughness techniques.
5. Use of the similar type of coarse aggregates is preferred in the repair work (with common value of stiffness). Use of coarse aggregate which are same increases the strength in slant shear by approx 15% as compared to different type of coarse aggregates.
6. Adding of the latex approx 4% and 9% by weight of cement to overlay SCC increase the strength of bond in the slant shear.
7. Use of the fibers which are polypropylene in SCC overlay increases in 0.1% to 0.2% by vol. They increase the fraction strength in slant shear increases approximately 9% and 14% respectively.

8. Using of the prism shape specimen yield more reliable bond strength in slant shear as compared to specimen with cylindrical shape.

Wall et.al: He has performed test of strength of bond between hardened and fresh concrete. Four type of tests method, reviewing different states of stresses on the bonded part between the hardened and fresh type of concrete, are checked. The four type of method are an indirect tension tests, slant shear test and two types of flexure strength test which are different. He came to conclusion that, out of test performed the least variable and most sensitive method for the strength in bond testing and flexibility testing is the SST test. For mortar bonds in pozzolona cement, the thickness of the layer of mortar has a very high effect on strength of bond which is significant. A thick bond in excess would cause a reduction in strength of bond in considerable amount. The treatment of surface of bond in the concrete surface by doing pre-wetting emerges to get a small advantageous result on the strength of the bond. Co-polymer Poly Vinyl Alcohol happens to be a bonding agent who is poor over a mortar mix designs and wide ranges of curing condition. Underneath the employed laboratory condition, the Poly Vinyl Alcohol use manufacture consistently weak bonds compare to use of no bonding agents at all.

Robins et.al (1995): Robins differentiates the slant shear and patch test with the core pull off test as a method for evaluation of the bond of patch repair of shallow concrete. The effects of surface roughness, moisture condition, soundness, artificial partial de bonding and repair material property on performance of bond are checked; with refer to both material modeling and physical tests. The patch, pull off test were instituted to be sensitive to roughness of surfaces, soundness and also to the in-complete bonding. In contrast, the slant shear type test was observed to be insensitive to change in soundness and roughness of surface, and with rough surfaces was also insensitive to partial de bonding. The values of bond strength get from the two tests were not comparable directly because of stress rates are different along with the repair interface. A failure of bond envelope is proposed help in authorize a comparisons of results from different type of test procedure. The failure of bond envelopes is present for the two plain cement sand mortars, which highlight the bond performance superior of the one with the more W/C ratio. The failure of bond wrapping for two polymer materials which are modified, could not established because the failure of bond did not occur. The patch test, the core pull off test and the slant shear test have been used to know the study of the effect of repair material properties such as soundness and roughness of surface, artificial partial de bonding and moisture conditions on the bond performance. The patch test, pull off test were instituted to sensitivity to the roughness of the surface, soundness and also to the in-complete bonding. The patch test also sensitive to the presence of a de bonded and roughness of surface. The slant shear test found to be in sensitive to change in roughness of surface, soundness and with rough surfaces it also relatively in sensitive to partial de bonding. Both cores pull off and patch tests result proved that a superior performance of bond, but the slant shear results get no remarkable difference in two plain mortars performances. None of the three test method were able to qualify the strength of bond in the modified polymer mortar.

Abu-Tair et.al (1995): Tair has done study the bond between the concrete type of substrate and the material to be repaired. Strength of bond of the material need to be repair to the substrate of concrete was checked. This study was aimed at finding the static loading and cyclic effect on bond and also on the bond strength the effect of different surface treatment. This investigation was also aimed to study the compatibility of slant shear test for checking cementations and cementitious modified material, resins material. A Modified MOR test was also checked as a dissimilar bond test method for the slant-shear test. Different ranges of roughness's of substrate were evaluate in the Modified MOR and slant shear test. The sample were tested to both fatigue and static type loading condition. The test have checked with cementitious material the suitability of standard slant shear test methods for use. Both the Modified MOR and slant shear test were sensitive measure of the effect of surface preparations on the bond strengths. The needle gun method for preparation of surface must be taken to be suspect as it could promote damage to the sub strate. The result from the cyclic test indicate at 50 % fatigue strength of repaire sample both for the Modified MOR and the slant shear bond test. This test has illustrated that the laboratory prepared OPC concrete material to be repair compared with the proprietary material. However, predominantly a bond failure is the mode of failure.

Ray et.al (2003) Ray has done assessments of interface of bi-layer overlay-concrete composites by a test method known as direct shear. Interface assessments of high performance overlay of concrete samples were cast at top face of one of NC samples which was made for the direct shear test methods. Two dissimilar type of surfaces preparation such as abrasions mechanically and the chemical type etching are followed in produce Sixty Four overlays bi layer substrate specimen.

The paper deals with materials property also the fabrications, evaluation of the bi-layer type specimen. Result shows that the bond characterization at the interface successfully was made feasible by the help of direct shear apparatus help. This method of the test seems suitable for the selection, screening of many overlay with substrate concrete for compatibility. Also, some changes is needed in the tools for evaluate the higher type bond capacity interfaces. Effect in the bond of the slurry must need farther studies. He conclude that bond characterization at successful interface was possible because of a new direct shear method. Precision of this method of test is important from point of view of the reasonably low coefficient of variations value get, from there arise opportunities to better the control of quality of the specimen preparation. The suggested test methods also beneficial in checking the strength of bond for many numbers of materials which are commonly used for overlay, which are important for the consistency in test results as well as the mode of the failure. Some form of the changes are also required to eliminate the tool rotation for checking of strength at interface of high bond capacity materials such as concrete which is polymer modified or LMC or for the bi-layer type material in which improve surface preparations technique for example scabbling or hydro-demolition are used in achieving solid interfaces. Effect of the slurry bond on the strengthening of interface must need to be evaluated in more comprehensive way. Further development of the present test method for the suitability must be needed.

Clímaco and Regan (2001), a Mohr-Coulomb failure model was received in choosing a basic point by selecting a critical angle to check adhesive failure. A 223 no of tests were done by embrace three types of different angles of 0°, 20°, and 26.7°. Despite a fact that 20°angle was characterized for always get an adhesive type of failure, cohesive type failure was also revealed. Furthermore, even when the angle is the lowest possible (0°), cohesive failures were still observed. From this study, he find out that:

i) In the mode of failure the role play by interface angle is important; and

ii) Obtaining failure of adhesive type is not every time possible by adequately defining this parameter.

Júlio et al. (2006), he checks differential stiffness due to shear in concrete bond interfaces by casting SST samples. The samples of concrete were kept constant, at a 30 MPa compressive strength, whereas three same types of concrete samples with different grades of concrete were used in the layer to be added of concrete having compressive strengths of: 30 MPa, 50 MPa and about 100 MPa. The roughness in the surface were increased by different methods such as sand-blasting, being observed that specimens with the same concrete at both halves give out adhesive type failures whereas the other samples gives failure of cohesive type, proving a influence due to differential stiffness on the type of failure.

Santos et al. (2011), in these literature two types of failure (adhesive as well as cohesive) are checked. Moreover, he noted that, rate of failure in cohesive condition increase because of increase in the surface roughness. He also came to a conclusion that increasing in the differential stiffness the number of failures in cohesive state rises. The differential shrinkage condition was analyzed by using dissimilar conditions of curing and different ages between the added concrete layer and the substrate. He also came to conclusion that this parameter determines the type of failure.

Emmons (2013), done the experiment to check the effect of moisture and different moisture conditions on the bond strength. He finds that moisture is also a critical factor in substrate in bond. He finds that too much water is absorbed by an excessively dry substrate from the material to be repair while if wetness is in excessive then the pores of the substrate may get clogged and it prevents in repair materials the absorption. Also, weak strength in bond is achieved due to too wet otherwise too dry surface of the interface of concrete substrate.

Macdonald et al. (1982), he has done research on strengthening of concrete structure by bonded steel plating. He states that sometimes to improve structural performances of concrete sometimes additional reinforcement of steel using epoxy adhesive can be bounded to hardened concrete due to reasons like increasing load carrying capacity of structure, correcting n error in design or in construction, to stop cracking or to constraint it. He conclude that when steel plates were externally bonded to the beam in tension faces a fully composite action could be achieved in concrete beam which were tested in 4 point bending. Also, using a wide plate achievement of a soft failure can be done. Also, corrosion in steel interface spread on all specimens which are exposed to the natural environment. This led to slightly decrease in the strength of the specimen compare to those specimens which are kept in laboratory under controlled condition.

Issa et al. (2007), Issa find out effect of epoxy repairing on cracks in concrete by doing experimental work. For the durability of concrete cracks always posed as a threat for the failure of concrete structures. Epoxy in crack can be filled either by gravity filling or injection method in order to restore structural integrity by bonding the crack. He had taken 15 samples out of which three samples with no cracks and six samples with cracks but without repair and another sic samples with repair done in cracks using epoxy by using method gravity filling. These samples were crushed by compressive loading and their compressive strength is find out.

He concluded that reduction caused in compressive strength of concrete by cracks is about 41%, where as the cubes in which epoxy in cracks is used is able to restore maximum strength loss due to cracks and the reduction in compressive strength is only about 8%. He concluded that with the increase in size of crack, there is progressively decrease in the strength of the concrete structures.

Swamy et al. (1896), He studied of property of adhesive which is epoxy resin in shear adhesion. He performed test to steel concrete adherents to investigate epoxy strength using shear bond strength. Double lap test and pull off test were carried out. It is found out that shear stress and longitudinal force distribution was exponential along the joint for both tests. Also variations in the thickness of both the specimen have zero affect in the double lap joint strength and in the pull-out test. At the ultimate point of load in pull out test with stresses in bond which are reduced to zero in them most of stressed end failed completely. Maximum shear stresses in double lag test remain unaffected. In lap shear test a combination of cohesive and adhesive failure shown by test failure.

Cross et al. (2005), he replaced 100 percent Class C type fly ash with cement in specimens of the pull-out test and getting strength in the bond which is lower for the HVFAC when the bond strength is differentiate to the CC bond strength.

Gopala Krishnan (2005), he performed pull-out specimen test to find out effect on bond strength by replacing 50% fly ash with cement sample. The specimens contain 20mm diameter bars in a 150 mm cube of concrete. He finds out the same strength in the bond for the CC as well as HVFAC specimens.

Arezoumandi et al. (2013) he replaces about Seventy percent of the fly ash of Class C with cement in a relatively excessive amount which is a highly cementitious (500 kg/m^3) mixture and he achieved the strength of bond higher for the HVFAC when it is correlate with CC in both of the splice beam and for the specimen in pull-out.

Zhang (2017), He finds bond stress for various positions which are derive which are established on the strain in the reinforcement. The crest which are two in number of the stresses in bond appears in the area of the loading as well as the free ends, and also the distributions in the stresses in bond is further constant in the sample with a large induced corrosion cracks widthwise. The crests of bond stress with increase in the load have a moving trend in the free ends.

Maragakis (2006), He finds out that the strength of bond in concrete and FRP rises with compare to strain rates as logarithmic functions. Equations were also developing on the basis of regressions analysis done for the bonded result.

In Volz (2015), the consequences of corrosion in typical bond-slip relationships and also in different modes of the failure in bond are checked at different levels of corrosions. Three failure modes were shown by the deformed bar specimen which are: pull-out failures with the load-induced cracks, pull-out failures along corrosions cracks and splitting failure. Two types of failure were shown by the smoothed bar specimen, they are: pull-out type failures and splitting type failures. Induced cracks due to corrosions have effects in the etiquette of bond which are significant.

2.3 Summary of Literature Review:

Based on the above literature review I summaries that the above review tells about the composite materials and bonding between repair materials, also importance of bonding and what is need of bonding between two materials. Various tests to check the bond stress and different factor or condition that affect the strength of the bond. Also it tells us about the different types of bonding agent and also properties of different bonding agent and also affect of thickness of bonding agent on the strength of the bond by experimentally test using different tests. There are some papers for the effect due to curing also for type of curing done on bond strengths. Also the use of the slant shear test to check the bond strength. Also importance of bond to increase strength of material and experimental studies to check all the factors mentioned above. From various literature it has been found out that to check bond strength slant shear test is most sensitive and also advantages and disadvantages of this test.

2.4 Objectives of the thesis:

By reading above literature review and finding research gap following are my objectives:

To design a mix of M30 and M40 grade of concrete specimen.

Performance Assessment of concrete-steel bonded specimen using slant shear test.

To find load Vs deformation curve for concrete-steel composite material under slant shear test.

To check the durability of the specimen under chemical attack

CHAPTER 3

METHODOLOGY

3.1 General

This project started with reading current things happening in civil engineering and after that deciding the area or field of thesis we want to work on. After deciding the field we decide topic and after that we start things firstly by reading some journals related to that topic to find out what other people have done in the past on this topic or what are things related to this topic have been done before and also find out what is the area which are least evaluated and what are future scope of this topic. After reading all about the topic we start our project firstly by collecting all data required and then finding about the material to be used. After arrangement in materials, sampling of the material starts. Then testing of samples is done taking all the precautions and follow procedures of experiments properly and accurately. After that results are obtained and we discuss them properly with future scope.

3.2 MATERIALS

3.2.1 CEMENT

The cement is basic material used in all type of construction in the world. Cement also have a property to act as a binder material between different materials. In our project we use Portland fly ash based pozzolona cement having IS code no IS 1489-1: (1991). Cement bags are collected from locally available shops.

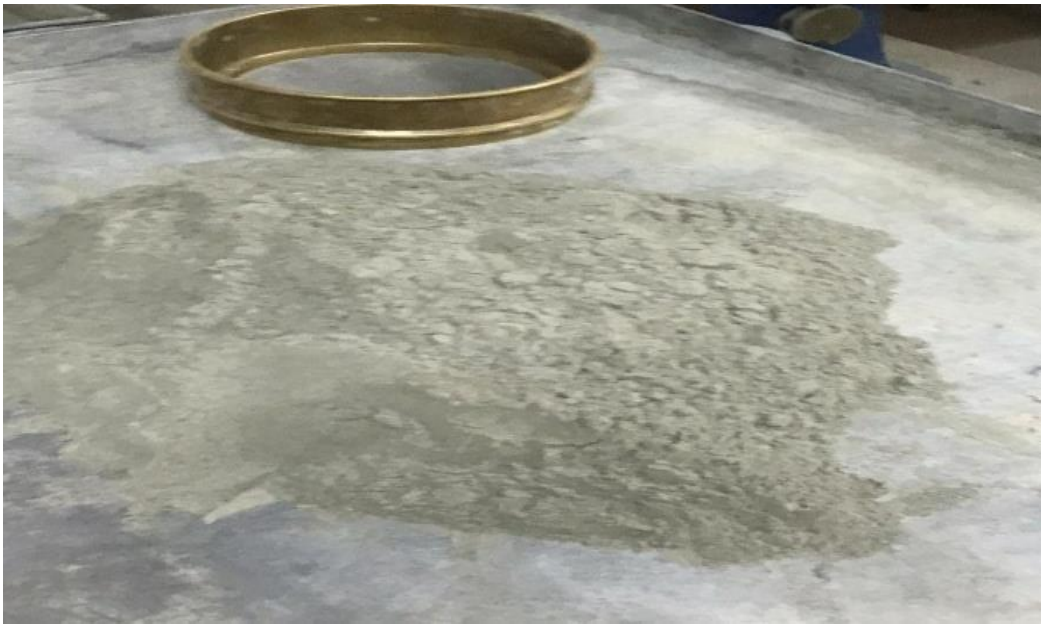


Figure 4.1: Cement Sample

3.2.2 SAND:

Sand is used to provide strength to the concrete and also it can sustain shear at rest and can without change in its properties it can undergo plastic deformations. There are four zones of sand from Zone 1 to Zone 4 where fineness of sand increases from zone 1 to zone 4.We use sand of zone 1 and zone 2 by first finding its fineness modulus by sieve analysis.

3.2.3COARSE AGGREGATE:

Aggregates crushed beneath 20mm in size from nearby crushing plant were taken. The aggregate brought from plants are firstly pass from a sieve of 20mm in size and aggregate retained on 10mm sieve are taken. Mostly aggregate size lies between 10mm to 12.5 mm are used.

Figure 4.2: Coarse Aggregate

3.2.4 WATER:

Water has a important part in providing the concrete the strength. For fully the process of the hydration it needs about 30% of its water by its weight. It is proven experimentally that least amount of W/C ratio 0.35 which is needed for concrete. Water helps in chemical process with particles of cement paste and cement is formed, which binds both the coarse as well as fine aggregate. If more amount of water is provided, bleeding and segregation take place, because of which strength of concrete decreases. If less amount of water provided, then workability needed is not achieved. Water which is fit for the purpose of drinking is used for concrete and it must a have pH value between6 to 9.

3.2.5 SUPER PLASTICIZER:

Super plasticizers use as a water reducers, are additives used in achieving high strength concrete. Super plasticizers reduce the need of water by 30% or more. These additives are caused at the level of a few weight percent. Plasticizers and super plasticizers help in retarding the curing of concrete. Use of super plasticizers allows the decrease of water to the extent nearly 30% without loss in workability

Figure 4.3: mixing of Super plasticizer in water

3.2.6 BONDING AGENT:

For epoxy based bonding agent ASTM C881 provide resin system best suited for a particular application. According to viscosity and sag resistance there are three grade of epoxy, they are grade 1, grade 2 and grade 3.Also according to the type of material to be bonded together there are seven types are presented from Type 1 to Type 7. Also epoxy system are further characterized by class according to temperature ranges, they are class A, class B, class C .According to the above categories we decided the type of bonding agent epoxy based used for bonding in our project and also thickness of bonding agent is given with the type of bond used. Once bonding agent epoxy based is open use it within 24hrs because once it opens it starts to set in presence of air. Some bonding agent start to set within 30 min and some bonding agent take up to a time of 24 hrs to set. After applying bonding agent on the surface allow to rest the sample for 14 days before testing of samples.

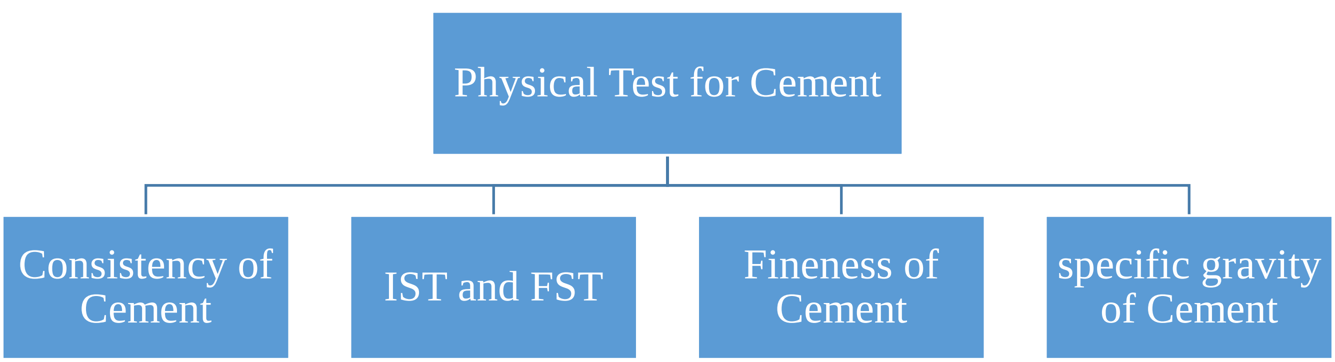
Figure 4.4: Bonding agent used (epoxy based)

3.3 TESTING OF MATERIALS, CONCRETE MIX AND SPECIMENS:

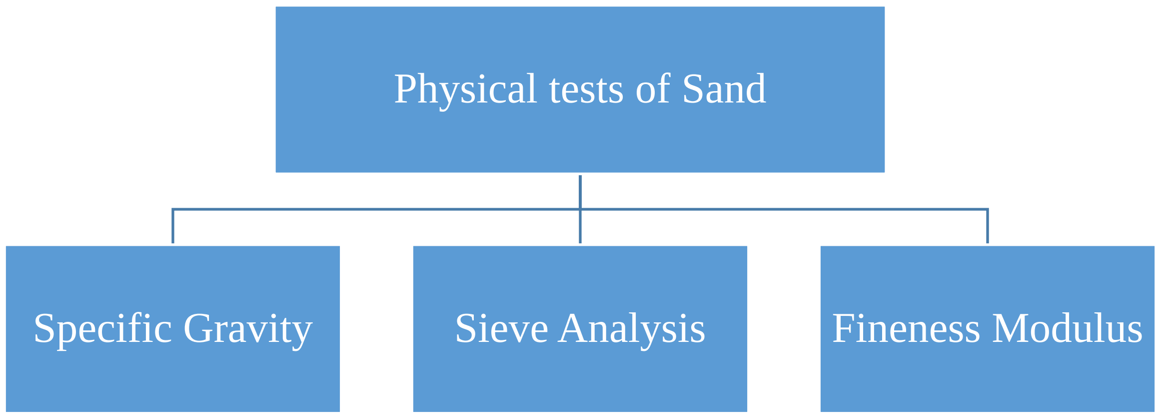
3.3.1 Testing of Materials:

Physical Testing of Materials

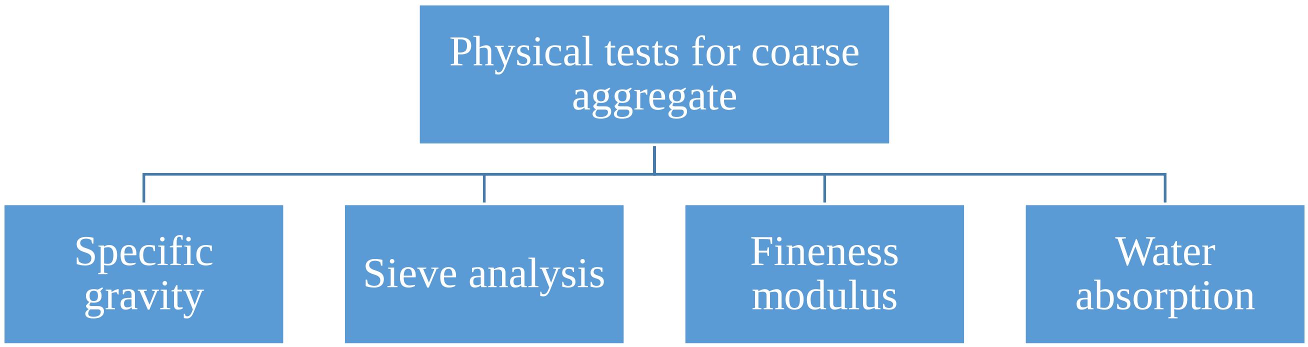
1. Cement



2. Sand



3. Coarse Aggregate:



The above mention tests are the physical test performed for the cement, sand and coarse aggregate according to there IS Codes and the result obtain and name of IS Codes are mentioned in the Result section.

3.3.2 Testing Of Concrete Mix

3.3.2.1 Preparation of Mix Design

1. Mix Design for M 40 with Water Cement Ratio 0.35 and using super plasticizer and 20mm size nominal aggregate

Characteristics strength =f_{ck} + 1.65 s

Where s = 5 N / mm^2

So characteristics strength = 48.25 N / mm^2

According to IS: 10262 when using 20 mm aggregates take water = 186 Kg

Using super plasticizer reduction of water = 25% (according to IS: 10262)

So water = 75% of 186 kg =139.5 kg

As water cement ratio taken = 0.35

So cement (PPC) = water / 0.35 = 139.5 / 0.35 = 398.57 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 2

Now for $1m^3$

Cement = 398.57 / (specific gravity x 1000) = 0.126 kg

Water = 139.5 / 1000 = 0.139 kg

Super plasticizer Volume = 0.006 m^3

Now Total Aggregate Volume = 1- 0.126 – 01.39 – 0.006 = 0.729 kg

Volume of Aggregate in coarse = 0.729 x .56 x 1000 x 2.69 = 1081.836 kg

Volume of Aggregate in fine = 0.729 x .44 x 1000 x 2.65 = 850 kg

Now ratio of cement: fine: coarse = 1: 1.9: 2.6

2. Mix Design for M 40 with Water Cement Ratio 0.4 and without using super plasticizer and 20mm size nominal aggregate

Characteristics strength =f_{ck} + 1.65 s

Where s = 5 N / mm^2

So characteristics strength = 48.25 N / mm^2

According to IS: 10262 when using 20 mm aggregates take water = 165 Kg

Estimated water for 100 mm slump = 175 kg

As water cement ratio taken = 0.4

So cement (PPC) = water / 0.4 = 175 / 0.4 = 437.25 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 2

Now for 1m^3

Cement = 437.25 / (specific gravity x 1000) = 0.138 kg

Water = 175 / 1000 = 0.175 kg

Volume of Super plasticizer Volume = 0.006 (assumed)

Total aggregate Volume = 1- 0.138 – 0.175 – 0.006 = 0.681

Coarse aggregate Volume = 0.681 x .56 x 2.74x 1000 = 1045 kg

Fine aggregate Volume = 0.681 x .44 x 1000 x 2.65 = 794 kg

Now ratio cement: fine: coarse = 1: 1.8: 2.38

3. sMix Design for M 40 with Water Cement Ratio 0.3 and using super plasticizer and 10mm size nominal aggregate

Characteristics strength =f_{ck} + 1.65 s

Where s = 5 N / mm^2

So characteristics strength = 48.25 N / mm^2

According to IS: 10262 when using 10 mm aggregates take water = 186 Kg

Using super plasticizer reduction of water = 30% (according to IS: 10262)

So water = 70% of 186 kg =130.20 kg

As water cement ratio taken = 0.3

So cement (PPC) = water / 0.3 = 130.20 / 0.3 = 434 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 1

Now for 1m^3

Cement = 398.57 / (specific gravity x 1000) = 0.137.7 kg

Water = 139.5 / 1000 = 0.130 kg

Super plasticizer Volume = 0.006 (assumed)

Now Total aggregate Volume = 1- 0.137.7 – 0.130 – 0.006 = 0.726 kg

Coarse Aggregate Volume = 0.726 x .6 x 1000x 2.69 = 1054.34 kg

Fine Aggregate Volume = 0.726 x .4 x 1000 x 2.65 = 770 kg

Now ratio cement: fine: coarse = 1: 1.77: 2.63

1. Mix Design for M 30 with Water Cement Ratio 0.45 and without using super plasticizer and 20mm size nominal aggregate

Characteristics strength = f_{ck} + 1.65 s

Where s = 5N/mm^2

So characteristics strength = 38.2N/mm^2

According to IS: 10262 when using 20 mm aggregates take water = 186 Kg

As water cement ratio taken = 0.45

So cement (PPC) = water / 0.45 = 186 / 0.45 = 413 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 2

Now for 1m^3

Cement = 413 / (specific gravity x 1000) = 0.147 kg

Water = 186/ 1000 = 0.186 kg

Now volume of Total aggregate = 1- .147 – .186 = 0.667 m^3

Volume of CA= 0.667 x .56 x 1000x 2.69 = 1004.768 kg

Volume of FA = 0.667 x .44 x 1000 x 2.65 = 777.72 kg

Now ratio of cement: fine: coarse = 1: 1.88: 2.43

2. Mix Design for M 40 with Water Cement Ratio 0.4 and without using super plasticizer and 20mm size nominal aggregate

Characteristics strength = f_{ck}+1.65s

Where s = 5N/mm^2

So characteristics strength = 38.2N/mm^2

According to IS: 10262 when using 20 mm aggregates take water = 165 Kg

Estimated water for 100 mm slump = 175 kg

As water cement ratio taken = 0.4

So cement (PPC) = water / 0.4 = 175 / 0.4 = 437.25 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 2

Now for 1m^3

Cement = 437.25 / (specific gravity x 1000) = 0.138 kg

Water = 175 / 1000 = 0.175 kg

Now volume of aggregate = 1- 0.138 – 0.175 = 0.687

Volume of CA = .687 x .56 x 1000x 2.69 = 1034.89 kg

Volume of FA = .687 x .44 x 1000 x 2.65 = 801 kg

Now ratio of cement: fine: coarse = 1: 1.83: 2.36

3. Mix Design for M 40 with Water Cement Ratio 0.45 and without using super plasticizer and 10mm size nominal aggregate

Characteristics strength = f_{ck} + 1.65s

Where s = 5N/mm^2

So characteristics strength = 38.2N/mm^2

According to IS: 10262 when using 10 mm aggregates take water = 180 Kg

As water cement ratio taken = 0.45

So cement (PPC) = water / 0.45 = 180 / 0.45 = 400 kg/m^3 (320 to 450 acc. to IS: 456)

Sand used is of zone 1

Now for 1m^3

Cement = 400 / (specific gravity x 1000) = 0.142 kg

Water = 180 / 1000 = 0.180 kg

Now volume of aggregate = 1- .142– .180 = 0.678 kg

Volume of Coarse aggregate = .678 x .6 x 10000 x 2.69 = 1094.34 kg

Volume of Fine aggregate = .678 x .4 x 1000 x 2.65 = 718.68 kg

Now ratio of cement: fine: coarse = 1: 1.79: 2.73

3.3.2.2 CASTING OF CONCRETE MIX SAMPLES

After preparing the mix for different combinations, then the casting of mix was carried out. The casting of mix procedure is given below.

1. Weighing of materials is done as per mix design.
2. Measure the required water for the mix along with super plasticizer.
3. Then the pouring of materials into the plate is done and dry mixing of materials for 2 minutes is done.
4. After that water is poured in to plate and mixing was done.
5. Now remaining water was pour in to the mix.
6. Standard size molds are used for casting. Make sure that the molds were tight and molds were greased properly. After sample is fill in molds allow them to vibrate at least for 2-3 minutes.
7. After resting them for 24 hours at the standard temperature de mold them and kept them in the curing water tank for curing.

Compression Strength Test

Cubes for all mix designs calculated were prepared for every mix design. After 7 days and after 28 complete days the strength in compression of all cubes samples was tested. Compressive testing is performed on the CTM with rate of approximately 1.8kN/mm²/min. The top surface of cube is measured by scale before putting it in CTM.

$$\text{Compressive strength} = \text{Load/Surface area } (N/mm^2)$$

Fig. 4.5 Compression Testing Machine

Figure 4.6 Dry Mixing of samples

Figure 4.7 Mixing Of Mix in Mixer

Figure 4.8: Casting of cubes

3.4 SLANT SHEAR TES

Slant shear test is performed with the of ASTM C882 code. This code gives us the idea of the dimension of the sample as well as how to measure bond strength of the sample. Firstly half specimen of concrete is casted in the sample using ratio of mix design. Then after curing the concrete sample for 28 days the second half which is of steel is bonded with this sample with the help of epoxy based bonding agent. Then allow it to cure for 14 days and then put the sample in UTM machine and find out the load at which sample fails and find whether it is true bond failure or apparent bond failure. Also plot Load Vs Deformation curve and also check mechanical properties of the sample.

Figure 4.9: SST mould and Steel Samples

Figure 4.10: Casting of sample

Figure 4.11 Samples After Bonded Togeather

Figure 4.12: Sample in UTM

CHAPTER 4

RESULTS

4.1 Evaluation and results

Various Tests have been performed in the lab on cement, coarse and fine aggregate and also concrete to obtain the physical properties of material. Also nominal mix is prepared and its compressive strength is tested to determine the grade of mix. Results and graph of the experimental work done is shown below:

4.1.1 Physical test of cement, fine and coarse aggregate

Following are the results of physical test of cement, Fine and coarse aggregates:

Table 5.1 Physical Test Results of cement (PPC)

Sr. No	Experiment Name	Test Result	IS Code
1	Consistency of cement	33%	IS 4031-part4 (1988)
2	Initial Setting Time	82 minutes	IS 4031-part5 (1988)
3	Final Setting Time	573 minutes	IS 4031-part 5 (1988)
4	Specific Gravity of cement	2.81	IS 2720-part3

5	Fineness of cement(% retained)	3%	IS 4031-part1 (1996)

Table 5.2 Physical properties test for fine aggregate which is used:

Sr. No	Experiment name	Test Result
1	Specific gravity	2.65
2	Fineness Modulus	2.54

Table 5.3 Physical property test for coarse aggregate

Sr. No	Experiment Name	Test Result
1	Specific Gravity	2.69
2	Fineness Modulus	2.71
3.	Water Absorption (%)	1.9

4.1.2 Compressive strength of concrete cube for different Grade

Table 5.4 Compressive strength for M30 Cube Samples

Sr No.	Ratio C:CA:FA	7 days (N/mm^2)	28 days (N/mm^2)	W/C ratio	Super plasticizer Used
1	1:1.88:2.43	20.21	32.4	.45	No
2	1:1.79:2.73	19.89	31.34	.45	No
3	1:1.83:2.36	21.67	33.23	.4	No

Table 5.5 Compressive Strength for M40 Cube Samples

Sr. No.	Ratio C:CA:FA	7 days (N/mm^2)	28 days (N/mm^2)	W/C ratio	Super plasticizer Used
1	1:1.8:2.38	18	29	.4	No
2	1:1.9:2.6	24.67	41.69	.35	Yes
3	1:1.77:2.63	27.91	43.4	.3	Yes

Slant Shear Test Result

Table 5.6 SST Result for M30 Grade

Sr. No.	Sample 1		Sample 2		Sample 3	
	Load (KN)	Deformation(mm)	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)
1	0	0	0	0	0	0
2	.5	0	.5	0	.5	0
3	1	0	1	0	1	0
4	1.5	0	1.5	0	1.5	0
5	2	0	2	0	2	0
6	2.5	0	2.5	0	2.5	0

7	3	0	3	0	3	0
8	3.5	0	3.5	0	3.5	0
9	4	0	4	0	4	0
10	4.5	0	4.5	0	4.5	0
11	5	0	5	0	5	0
12	5.5	0	5.5	0	5.5	0
13	6	0	6	0	6	0
14	6.5	0	6.5	0	6.5	0
15	7	0	7	0	7	0
16	7.5	0	7.5	0	7.5	0
17	8	0	8	0	8	0
18	8.5	0	8.5	0	8.5	0
19	9	0	9	0	9	0
20	9.5	0	9.5	0	9.5	0
21	10	0	10	0	10	0
22	10.5	0	10.5	0	10.5	0
23	11	0	11	0	11	0
24	11.5	0	11.5	0	11.5	0
25	12	0	12	0	12	0
26	12.5	0	12.5	0	12.5	0
27	13	0	13	0	13	0
28	13.5	0	13.5	0	13.5	0
29	14	0	14	0	14	0
30	14.5	0	14.5	0	14.5	0
31	15	0	15	0	15	0
32	15.5	0	15.5	0	15.5	0
33	16	0	16	0	16	0
34	16.5	0	16.5	0	16.5	0
35	17	0	17	0	17	0
36	17.5	0	17.5	0	17.5	0

37	18	0	18	0	18	0
38	18.5	0	18.5	0	18.5	0
39	19	0	19	0	19	0
40	19.5	0	19.5	0	19.5	0
41	20	0	20	0	20	0
42	20.5	0	20.5	0	20.5	0
43	21	.1	21	.1	21	.1
44	21.5	.2	21.5	.1	21.5	.1
45	22	.3	22	.2	22	.2
46	22.5	.3	22.5	.2	22.5	.2
47	23	.4	23	.3	23	.3
48	23.5	.4	23.5	.3	23.5	.3
49	24	.5	24	.4	24	.4
50	24.5	.5	24.5	.4	24.5	.4
51	25	.5	25	.4	25	.5
52	25.5	.5	25.5	.5	25.5	.5
53	26	.5	26	.5	26	.5
54	26.5	.5	26.5	.5	26.5	.5
55	27	.6	27	.5	27	.5
56	27.5	.6	27.5	.5	27.5	.5
57	28	.6	28	.5	28	.6
58	28.5	.6	28.5	.6	28.5	.6
59	29	.6	29	.6	29	.6
60	29.5	.6	29.5	.6	29.5	.6
61	30	.6	30	.6	30	.6
62	30.5	.6	30.5	.6	30.5	.6
63	31	.6	31	.6	31	.6
64	31.5	.6	31.5	.6	31.5	.6
65	32	.6	32	.6	32	.6
66	32.5	.6	32.5	.6	32.5	.6

67	33	.6	33	.6	33	.6
68	33.5	.7	33.5	.6	33.5	.6
69	34	.7	34	.6	34	.6
70	34.5	.7	34.5	.6	34.5	.7
71	35	.7	35	.7	35	.7
72	35.5	.7	35.5	.7	35.5	.7
73	36	.7	36	.7	36	.7
74	36.5	.7	36.5	.7	36.5	.7
75	37	.7	37	.7	37	.7
76	37.5	.8	37.5	.7	37.5	.7
77	38	.8	38	.7	38	.7
78	38.5	.8	38.5	.8	38.5	.8
79	39	.8	39	.8	39	.8
80	39.5	.8	39.5	.8	39.5	.8
81	40	.8	40	.8	40	.8
82	40.5	.8	40.5	.8	40.5	.8
83	41	.8	41	.8	41	.8
84	41.5	.8	41.5	.8	41.5	.8
85	42	.8	42	.8	42	.8
86	42.5	.9	42.5	.8	42.5	.8
87	43	.9	43	.8	43	.8
88	43.5	.9	43.5	.9	43.5	.8
89	44	.9	44	.9	44	.8
90	44.5	.9	44.5	.9	44.5	.9
91	45	.9	45	.9	45	.9
92	45.5	.9	45.5	.9	45.5	.9
93	46	.9	46	.9	46	.9
94	46.5	.9	46.5	.9	46.5	.9
95	47	1	47	.9	47	.9
96	47.5	1	47.5	.9	47.5	.9

97	48	1	48	1	48	1
98	48.5	1	48.5	1	48.5	1
99	49	1	49	1	49	1
100	49.5	1	49.5	1	49.5	1
101	50	1	50	1	50	1
102	50.5	1	50.5	1	50.5	1
103	51	1	51	1	51	1
104	51.5	1.1	51.5	1	51.5	1
105	52	1.1	52	1	52	1
106	52.5	1.1	52.5	1.1	52.5	1.1
107	53	1.1	53	1.1	53	1.1
108	53.5	1.1	53.5	1.1	53.5	1.1
109	54	1.1	54	1.1	54	1.1
110	54.5	1.1	54.5	1.1	54.5	1.1
111	55	1.1	55	1.1	55	1.2
112	55.5	1.2	55.5	1.1	55.5	1.2
113	56	1.2	56	1.1	56	1.2
114	56.5	1.2	56.5	1.2	56.5	1.2
115	57	1.2	57	1.2	57	1.2
116	57.5	1.2	57.5	1.2	57.5	1.2
117	58	1.2	58	1.2	58	1.3
118	58.5	1.3	58.5	1.2	58.5	1.3
119	59	1.3	59	1.2	59	1.3
120	59.5	1.3	59.5	1.3	59.5	1.3
121	60	1.3	60	1.3	60	1.3
122	60.5	1.3	60.5	1.3	60.5	1.3
123	61	1.3	61	1.3	61	1.3
124	61.5	1.3	61.5	1.3	61.5	1.4
125	62	1.4	62	1.3	62	1.4
126	62.5	1.4	62.5	1.3	62.5	1.4

127	63	1.4	63	1.3	63	1.5
128	63.5	1.5	63.5	1.4	63.5	1.5
129	64	1.6	64	1.4	64	1.5
130	64.5	1.7	64.5	-	64.5	1.6
131	65	1.8	65	-	65	-

Table 5.7 for M40 Grade

Sr. No.	Sample 1		Sample		Sample 3	
	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)
1	0	0	0	0	0	0
2	.5	0	.5	0	.5	0
3	1	0	1	0	1	0
4	1.5	0	1.5	0	1.5	0
5	2	0	2	0	2	0
6	2.5	0	2.5	0	2.5	0
7	3	0	3	0	3	0
8	3.5	0	3.5	0	3.5	0
9	4	0	4	0	4	0
10	4.5	0	4.5	0	4.5	0
11	5	0	5	0	5	0
12	5.5	0	5.5	0	5.5	0
13	6	0	6	0	6	0
14	6.5	0	6.5	0	6.5	0
15	7	0	7	0	7	0
16	7.5	0	7.5	0	7.5	0
17	8	0	8	0	8	0
18	8.5	0	8.5	0	8.5	0
19	9	0	9	0	9	0
20	9.5	0	9.5	0	9.5	0

21	10	0	10	0	10	0
22	10.5	0	10.5	0	10.5	0
23	11	0	11	0	11	0
24	11.5	0	11.5	0	11.5	0
25	12	0	12	0	12	0
26	12.5	0	12.5	0	12.5	0
27	13	0	13	0	13	0
28	13.5	0	13.5	0	13.5	0
29	14	0	14	0	14	0
30	14.5	0	14.5	0	14.5	0
31	15	0	15	0	15	0
32	15.5	0	15.5	0	15.5	0
33	16	0	16	0	16	0
34	16.5	0	16.5	0	16.5	0
35	17	0	17	0	17	0
36	17.5	0	17.5	0	17.5	0
37	18	0	18	0	18	0
38	18.5	0	18.5	0	18.5	0
39	19	0	19	0	19	0
40	19.5	0	19.5	0	19.5	0
41	20	0	20	0	20	0
42	20.5	0	20.5	.1	20.5	.1
43	21	.1	21	.1	21	.2
44	21.5	.1	21.5	.2	21.5	.2
45	22	.2	22	.2	22	.2
46	22.5	.2	22.5	.2	22.5	.3
47	23	.2	23	.3	23	.3
48	23.5	.3	23.5	.3	23.5	.3
49	24	.3	24	.3	24	.4
50	24.5	.3	24.5	.4	24.5	.4

51	25	.4	25	.4	25	.4
52	25.5	.4	25.5	.4	25.5	.4
53	26	.4	26	.4	26	.4
54	26.5	.4	26.5	.4	26.5	.4
55	27	.4	27	.4	27	.4
56	27.5	.4	27.5	.4	27.5	.4
57	28	.4	28	.4	28	.5
58	28.5	.4	28.5	.5	28.5	.5
59	29	.5	29	.5	29	.5
60	29.5	.5	29.5	.5	29.5	.5
61	30	.5	30	.5	30	.5
62	30.5	.5	30.5	.5	30.5	.5
63	31	.5	31	.5	31	.5
64	31.5	.5	31.5	.5	31.5	.5
65	32	.5	32	.5	32	.5
66	32.5	.5	32.5	.5	32.5	.5
67	33	.5	33	.5	33	.6
68	33.5	.5	33.5	.6	33.5	.6
69	34	.6	34	.6	34	.6
70	34.5	.6	34.5	.6	34.5	.6
71	35	.6	35	.6	35	.6
72	35.5	.6	35.5	.6	35.5	.6
73	36	.6	36	.6	36	.6
74	36.5	.6	36.5	.6	36.5	.6
75	37	.6	37	.6	37	.6
76	37.5	.6	37.5	.6	37.5	.6
77	38	.6	38	.6	38	.7
78	38.5	.6	38.5	.7	38.5	.7
s79	39	.7	39	.7	39	.7
80	39.5	.7	39.5	.7	39.5	.7

81	40	.7	40	.7	40	.7
82	40.5	.7	40.5	.7	40.5	.7
83	41	.7	41	.7	41	.7
84	41.5	.7	41.5	.7	41.5	.7
85	42	.7	42	.7	42	.7
86	42.5	.7	42.5	.7	42.5	.7
87	43	.7	43	.7	43	.7
88	43.5	.7	43.5	.7	43.5	.7
89	44	.7	44	.7	44	.7
90	44.5	.7	44.5	.7	44.5	.7
91	45	.7	45	.7	45	.8
92	45.5	.7	45.5	.8	45.5	.8
93	46	.8	46	.8	46	.8
94	46.5	.8	46.5	.8	46.5	.8
95	47	.8	47	.8	47	.8
96	47.5	.8	47.5	.8	47.5	.8
97	48	.8	48	.8	48	.8
98	48.5	.8	48.5	.8	48.5	.8
99	49	.8	49	.8	49	.8
100	49.5	.8	49.5	.8	49.5	.8
101	50	.8	50	.8	50	.8
102	50.5	.8	50.5	.8	50.5	.8
103	51	.8	51	.8	51	.8
104	51.5	.8	51.5	.8	51.5	.8
105	52	.8	52	.8	52	.8
106	52.5	.8	52.5	.8	52.5	.8
107	53	.8	53	.8	53	.8
108	53.5	.8	53.5	.8	53.5	.8
109	54	.8	54	.8	54	.8
110	54.5	.8	54.5	.8	54.5	.8

111	55	.8	55	.8	55	.8
112	55.5	.8	55.5	.8	55.5	.8
113	56	.8	56	.8	56	.8
114	56.5	.8	56.5	.8	56.5	.8
115	57	.8	57	.8	57	.8
116	57.5	.8	57.5	.8	57.5	.8
117	58	.8	58	.8	58	.9
118	58.5	.8	58.5	.9	58.5	.9
119	59	.9	59	.9	59	.9
120	59.5	.9	59.5	.9	59.5	.9
121	60	.9	60	.9	60	.9
122	60.5	.9	60.5	.9	60.5	.9
123	61	.9	61	.9	61	.9
124	61.5	.9	61.5	.9	61.5	.9
125	62	.9	62	.9	62	.9
126	62.5	.9	62.5	.9	62.5	.9
127	63	.9	63	.9	63	.9
128	63.5	.9	63.5	.9	63.5	.9
129	64	.9	64	.9	64	.9
130	64.5	.9	64.5	.9	64.5	.9
131	65	.9	65	.9	65	.9
132	65.5	.9	65.5	.9	65.5	.9
133	66	.9	66	.9	66	.9
134	66.5	.9	66.5	.9	66.5	.9
135	67	.9	67	.9	67	.9
136	67.5	.9	67.5	.9	67.5	.9
137	68	.9	68	.9	68	.9
138	68.5	.9	68.5	.9	68.5	.9
139	69	.9	69	.9	69	1
140	69.5	.9	69.5	1	69.5	1

141	70	1	70	1	70	1
142	70.5	1	70.5	1	70.5	1
143	71	1	71	1	71	1
144	71.5	1	71.5	1	71.5	1
145	72	1	72	1	72	1
146	72.5	1	72.5	1	72.5	1
147	73	1	73	1	73	1
148	73.5	1	73.5	1	73.5	1
149	74	1	74	1	74	1
150	74.5	1	74.5	1	74.5	1
151	75	1	75	1	75	1
152	75.5	1	75.5	1	75.5	1
153	76	1	76	1	76	1
154	76.5	1	76.5	1	76.5	1
155	77	1	77	1	77	1
156	77.5	1	77.5	1	77.5	1
157	78	1	78	1	78	1
158	78.5	1	78.5	1	78.5	1
159	79	1	79	1	79	1
160	79.5	1	79.5	1	79.5	1
161	80	1	80	1	80	1
162	80.5	1	80.5	1	80.5	1
163	81	1	81	1	81	1
164	81.5	1	81.5	1	81.5	1.1
165	82	1	82	1.1	82	1.1
166	82.5	1	82.5	1.1	82.5	1.2
167	83	1.1	83	1.2	83	1.2
168	83.5	1.1	83.5	1.2	83.5	1.3
169	84	1.2	84	1.3	84	1.4
170	84.5	1.2	84.5	1.3	84.5	-

171	85	1.3	85	-	85	-

4.1.4 Slant Shear Test Result Under Sulphate Attack

Table 5.8 for M30 Grade

Sr. No.	Sample 1		Sample		Sample 3	
	Load (KN)	Deformation(mm)	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)
1	0	0	0	0	0	0
2	.5	0	.5	0	.5	0
3	1	0	1	0	1	0
4	1.5	0	1.5	0	1.5	0
5	2	0	2	0	2	0
6	2.5	0	2.5	0	2.5	0
7	3	0	3	0	3	0
8	3.5	0	3.5	0	3.5	0
9	4	0	4	0	4	0
10	4.5	0	4.5	0	4.5	0
11	5	0	5	0	5	0
12	5.5	0	5.5	0	5.5	0
13	6	0	6	0	6	0
14	6.5	0	6.5	0	6.5	0
15	7	0	7	0	7	0
16	7.5	0	7.5	0	7.5	0
17	8	0	8	0	8	0
18	8.5	0	8.5	0	8.5	0
19	9	0	9	0	9	0
20	9.5	0	9.5	0	9.5	0
21	10	0	10	0	10	0
22	10.5	0	10.5	0	10.5	0

23	11	0	11	0	11	0
24	11.5	0	11.5	0	11.5	0
25	12	0	12	0	12	0
26	12.5	0	12.5	0	12.5	0
27	13	0	13	0	13	0
28	13.5	0	13.5	0	13.5	0
29	14	0	14	0	14	0
30	14.5	0	14.5	0	14.5	0
31	15	0	15	0	15	0
32	15.5	0	15.5	0	15.5	0
33	16	0	16	0	16	0
34	16.5	0	16.5	0	16.5	0
35	17	0	17	0	17	0
36	17.5	0	17.5	0	17.5	0
37	18	0	18	0	18	0
38	18.5	0	18.5	0	18.5	0
39	19	0	19	0	19	0
40	19.5	0	19.5	0	19.5	0
41	20	0	20	0	20	0
42	20.5	0	20.5	0	20.5	0
43	21	.1	21	.1	21	.1
44	21.5	.2	21.5	.1	21.5	.1
45	22	.3	22	.2	22	.2
46	22.5	.3	22.5	.2	22.5	.2
47	23	.4	23	.3	23	.3
48	23.5	.4	23.5	.4	23.5	.3
49	24	.4	24	.4	24	.4
50	24.5	.5	24.5	.4	24.5	.4
51	25	.5	25	.5	25	.5
52	25.5	.5	25.5	.5	25.5	.5

53	26	.5	26	.5	26	.5
54	26.5	.5	26.5	.5	26.5	.5
55	27	.5	27	.5	27	.5
56	27.5	.5	27.5	.6	27.5	.5
57	28	.6	28	.6	28	.5
58	28.5	.6	28.5	.6	28.5	.5
59	29	.6	29	.6	29	.6
60	29.5	.6	29.5	.6	29.5	.6
61	30	.6	30	.6	30	.6
62	30.5	.6	30.5	.6	30.5	.6
63	31	.6	31	.6	31	.6
64	31.5	.6	31.5	.6	31.5	.6
65	32	.6	32	.6	32	.6
66	32.5	.6	32.5	.6	32.5	.6
67	33	.6	33	.6	33	.6
68	33.5	.7	33.5	.6	33.5	.6
69	34	.7	34	.6	34	.6
70	34.5	.7	34.5	.6	34.5	.7
71	35	.7	35	.7	35	.7
72	35.5	.7	35.5	.7	35.5	.7
73	36	.7	36	.7	36	.7
74	36.5	.7	36.5	.7	36.5	.7
75	37	.8	37	.7	37	.7
76	37.5	.8	37.5	.7	37.5	.7
77	38	.8	38	.7	38	.8
78	38.5	.8	38.5	.8	38.5	.8
79	39	.8	39	.8	39	.8
80	39.5	.8	39.5	.8	39.5	.8
81	40	.8	40	.8	40	.8
82	40.5	.8	40.5	.8	40.5	.8

83	41	.8	41	.8	41	.8
84	41.5	.8	41.5	.8	41.5	.8
85	42	.9	42	.8	42	.8
86	42.5	.9	42.5	.8	42.5	.8
87	43	.9	43	.9	43	.8
88	43.5	.9	43.5	.9	43.5	.8
89	44	.9	44	.9	44	.8
90	44.5	.9	44.5	.9	44.5	.8
91	45	.9	45	.9	45	.9
92	45.5	.9	45.5	.9	45.5	.9
93	46	.9	46	.9	46	.9
94	46.5	.9	46.5	.9	46.5	.9
95	47	1	47	.9	47	.9
96	47.5	1	47.5	.9	47.5	.9
97	48	1	48	1	48	1
98	48.5	1	48.5	1	48.5	1
99	49	1	49	1	49	1
100	49.5	1	49.5	1	49.5	1
101	50	1	50	1	50	1
102	50.5	1.1	50.5	1	50.5	1
103	51	1.1	51	1.1	51	1
104	51.5	1.1	51.5	1.1	51.5	1.1
105	52	1.1	52	1.1	52	1.1
106	52.5	1.1	52.5	1.1	52.5	1.1
107	53	1.1	53	1.1	53	1.1
108	53.5	1.1	53.5	1.2	53.5	1.1
109	54	1.1	54	1.2	54	1.1
110	54.5	1.1	54.5	1.2	54.5	1.2
111	55	1.1	55	1.2	55	1.2
112	55.5	1.1	55.5	1.3	55.5	1.2

113	56	1.2	56	1.3	56	1.2
114	56.5	1.2	56.5	1.3	56.5	1.2
115	57	1.2	57	1.3	57	1.3
116	57.5	1.2	57.5	1.3	57.5	1.3
117	58	1.2	58	1.3	58	1.3
118	58.5	1.2	58.5	1.3	58.5	1.3
119	59	1.2	59	1.3	59	1.3
120	59.5	1.3	59.5	1.4	59.5	1.3
121	60	1.3	60	1.4	60	1.4
122	60.5	1.3	60.5	1.4	60.5	1.4
123	61	1.3	61	1.5	61	1.5
124	61.5	1.4	61.5	1.5	61.5	-
125	62	1.4	62	1.6	62	-
126	62.5	1.5	62.5	-	62.5	-
127	63	1.5	63	-	63	-
128	63.5	1.6	63.5	-	63.5	-
129	64	-	64	-	64	-
130	64.5	-	64.5	-	64.5	-
131	65	-	65	-	65	-

Slant Shear Test Result due to Sulphate Attack

Table 5.9 for M40 Grade

Sr No.	Sample 1		Sample		Sample 3	
	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)	Load(KN)	Deformation(mm)
1	0	0	0	0	0	0
2	.5	0	.5	0	.5	0
3	1	0	1	0	1	0
4	1.5	0	1.5	0	1.5	0
5	2	0	2	0	2	0

6	2.5	0	2.5	0	2.5	0
7	3	0	3	0	3	0
8	3.5	0	3.5	0	3.5	0
9	4	0	4	0	4	0
10	4.5	0	4.5	0	4.5	0
11	5	0	5	0	5	0
12	5.5	0	5.5	0	5.5	0
13	6	0	6	0	6	0
14	6.5	0	6.5	0	6.5	0
15	7	0	7	0	7	0
16	7.5	0	7.5	0	7.5	0
17	8	0	8	0	8	0
18	8.5	0	8.5	0	8.5	0
19	9	0	9	0	9	0
20	9.5	0	9.5	0	9.5	0
21	10	0	10	0	10	0
22	10.5	0	10.5	0	10.5	0
23	11	0	11	0	11	0
24	11.5	0	11.5	0	11.5	0
25	12	0	12	0	12	0
26	12.5	0	12.5	0	12.5	0
27	13	0	13	0	13	0
28	13.5	0	13.5	0	13.5	0
29	14	0	14	0	14	0
30	14.5	0	14.5	0	14.5	0
31	15	0	15	0	15	0
32	15.5	0	15.5	0	15.5	0
33	16	0	16	0	16	0
34	16.5	0	16.5	0	16.5	0
35	17	0	17	0	17	0

36	17.5	0	17.5	0	17.5	0
37	18	0	18	0	18	0
38	18.5	0	18.5	0	18.5	0
39	19	0	19	0	19	0
40	19.5	0	19.5	0	19.5	0
41	20	0	20	0	20	0
42	20.5	0	20.5	.1	20.5	.1
43	21	.1	21	.1	21	.2
44	21.5	.1	21.5	.2	21.5	.2
45	22	.2	22	.2	22	.2
46	22.5	.2	22.5	.2	22.5	.3
47	23	.2	23	.3	23	.3
48	23.5	.3	23.5	.3	23.5	.3
49	24	.3	24	.3	24	.4
50	24.5	.3	24.5	.4	24.5	.4
51	25	.4	25	.4	25	.4
52	25.5	.4	25.5	.4	25.5	.4
53	26	.4	26	.4	26	.4
54	26.5	.4	26.5	.4	26.5	.4
55	27	.4	27	.4	27	.4
56	27.5	.4	27.5	.4	27.5	.4
57	28	.4	28	.4	28	.5
58	28.5	.4	28.5	.5	28.5	.5
59	29	.5	29	.5	29	.5
60	29.5	.5	29.5	.5	29.5	.5
61	30	.5	30	.5	30	.5
62	30.5	.5	30.5	.5	30.5	.5
63	31	.5	31	.5	31	.5
64	31.5	.5	31.5	.5	31.5	.5
65	32	.5	32	.5	32	.5

66	32.5	.5	32.5	.5	32.5	.6
67	33	.5	33	.5	33	.6
68	33.5	.6	33.5	.5	33.5	.6
69	34	.6	34	.6	34	.6
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71	35	.6	35	.6	35	.6
72	35.5	.6	35.5	.6	35.5	.6
73	36	.6	36	.6	36	.6
74	36.5	.6	36.5	.6	36.5	.6
75	37	.6	37	.6	37	.6
76	37.5	.6	37.5	.6	37.5	.6
77	38	.6	38	.6	38	.7
78	38.5	.6	38.5	.7	38.5	.7
s79	39	.7	39	.7	39	.7
80	39.5	.7	39.5	.7	39.5	.7
81	40	.7	40	.7	40	.7
82	40.5	.7	40.5	.7	40.5	.7
83	41	.7	41	.7	41	.7
84	41.5	.7	41.5	.7	41.5	.7
85	42	.7	42	.7	42	.7
86	42.5	.7	42.5	.7	42.5	.7
87	43	.7	43	.7	43	.7
88	43.5	.7	43.5	.7	43.5	.7
89	44	.7	44	.7	44	.7
90	44.5	.7	44.5	.7	44.5	.8
91	45	.7	45	.7	45	.8
92	45.5	.7	45.5	.7	45.5	.8
93	46	.7	46	.8	46	.8
94	46.5	.8	46.5	.8	46.5	.8
95	47	.8	47	.8	47	.8

96	47.5	.8	47.5	.8	47.5	.8
97	48	.8	48	.8	48	.8
98	48.5	.8	48.5	.8	48.5	.8
99	49	.8	49	.8	49	.8
100	49.5	.8	49.5	.8	49.5	.8
101	50	.8	50	.8	50	.8
102	50.5	.8	50.5	.8	50.5	.8
103	51	.8	51	.8	51	.8
104	51.5	.8	51.5	.8	51.5	.8
105	52	.8	52	.8	52	.8
106	52.5	.8	52.5	.8	52.5	.8
107	53	.8	53	.8	53	.8
108	53.5	.8	53.5	.8	53.5	.8
109	54	.8	54	.8	54	.8
110	54.5	.8	54.5	.8	54.5	.8
111	55	.8	55	.8	55	.8
112	55.5	.8	55.5	.8	55.5	.8
113	56	.8	56	.8	56	.8
114	56.5	.8	56.5	.8	56.5	.8
115	57	.8	57	.8	57	.8
116	57.5	.8	57.5	.8	57.5	.9
117	58	.9	58	.8	58	.9
118	58.5	.9	58.5	.8	58.5	.9
119	59	.9	59	.9	59	.9
120	59.5	.9	59.5	.9	59.5	.9
121	60	.9	60	.9	60	.9
122	60.5	.9	60.5	.9	60.5	.9
123	61	.9	61	.9	61	.9
124	61.5	.9	61.5	.9	61.5	.9
125	62	.9	62	.9	62	.9

126	62.5	.9	62.5	.9	62.5	.9
127	63	.9	63	.9	63	.9
128	63.5	.9	63.5	.9	63.5	.9
129	64	.9	64	.9	64	.9
130	64.5	.9	64.5	.9	64.5	.9
131	65	.9	65	.9	65	.9
132	65.5	.9	65.5	.9	65.5	.9
133	66	.9	66	.9	66	.9
134	66.5	.9	66.5	.9	66.5	.9
135	67	.9	67	.9	67	.9
136	67.5	.9	67.5	.9	67.5	.9
137	68	.9	68	.9	68	1
138	68.5	.9	68.5	.9	68.5	1
139	69	1	69	.9	69	1
140	69.5	1	69.5	.9	69.5	1
141	70	1	70	1	70	1
142	70.5	1	70.5	1	70.5	1
143	71	1	71	1	71	1
144	71.5	1	71.5	1	71.5	1
145	72	1	72	1	72	1
146	72.5	1	72.5	1	72.5	1
147	73	1	73	1	73	1
148	73.5	1	73.5	1	73.5	1
149	74	1	74	1	74	1
150	74.5	1	74.5	1	74.5	1
151	75	1	75	1	75	1
152	75.5	1	75.5	1	75.5	1
153	76	1	76	1	76	1
154	76.5	1	76.5	1	76.5	1.1
155	77	1	77	1	77	1.1

156	77.5	1	77.5	1	77.5	1.1
157	78	1	78	1	78	1.1
158	78.5	1.1	78.5	1	78.5	1.2
159	79	1.1	79	1	79	1.2
160	79.5	1.1	79.5	1	79.5	1.2
161	80	1.1	80	1.1	80	1.3
162	80.5	1.1	80.5	1.1	80.5	1.3
163	81	1.2	81	1.1	81	1.4
164	81.5	1.2	81.5	1.1	81.5	-
165	82	1.3	82	1.2	82	-
166	82.5	1.3	82.5	1.2	82.5	-
167	83	1.3	83	1.3	83	-
168	83.5	1.4	83.5	-	83.5	-
169	84	-	84	-	84	-
170	84.5	-	84.5	-	84.5	-
171	85	-	85	-	85	-

Load Vs Deformation Curve for Different Grade of Concrete and Steel bonded Specimen

(a) Before Sulphate attack to the sample

(b) After Sulphate attack to the sample

Before Sulphate attack to the sample

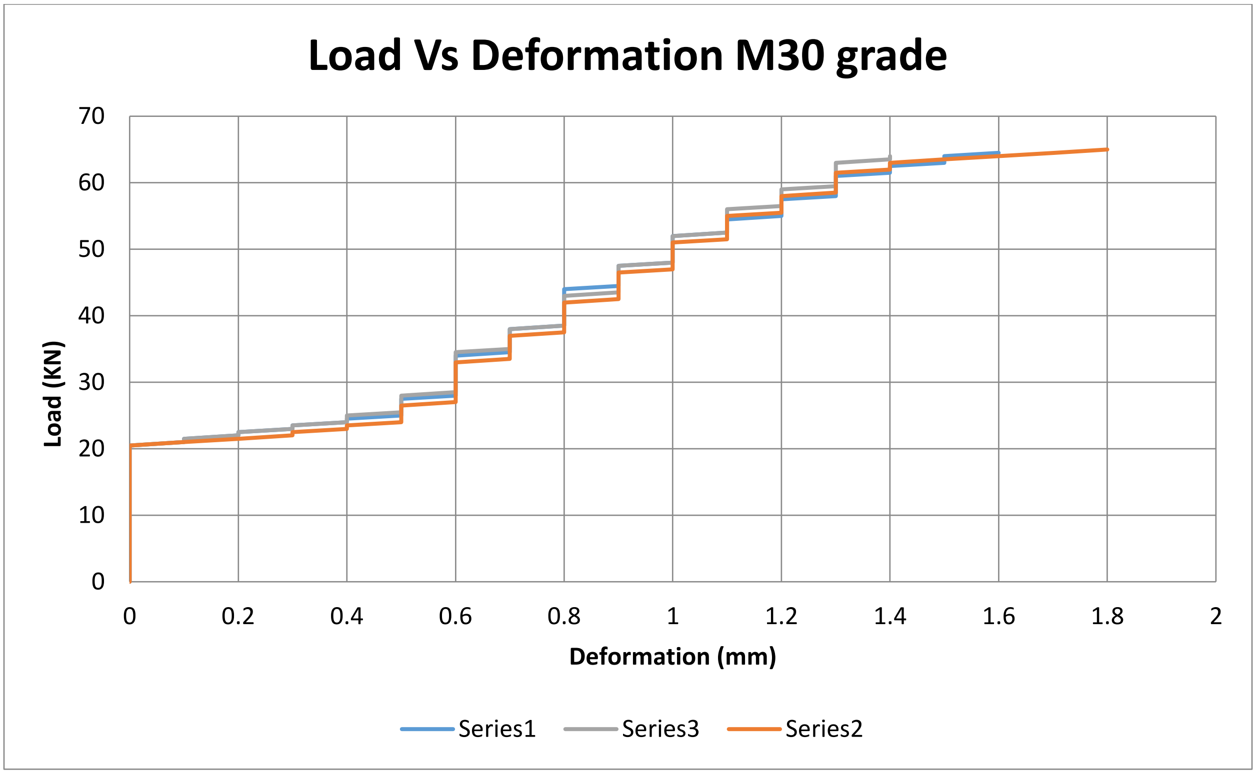

Figure 5.1 Load Vs Deformation M30 grade

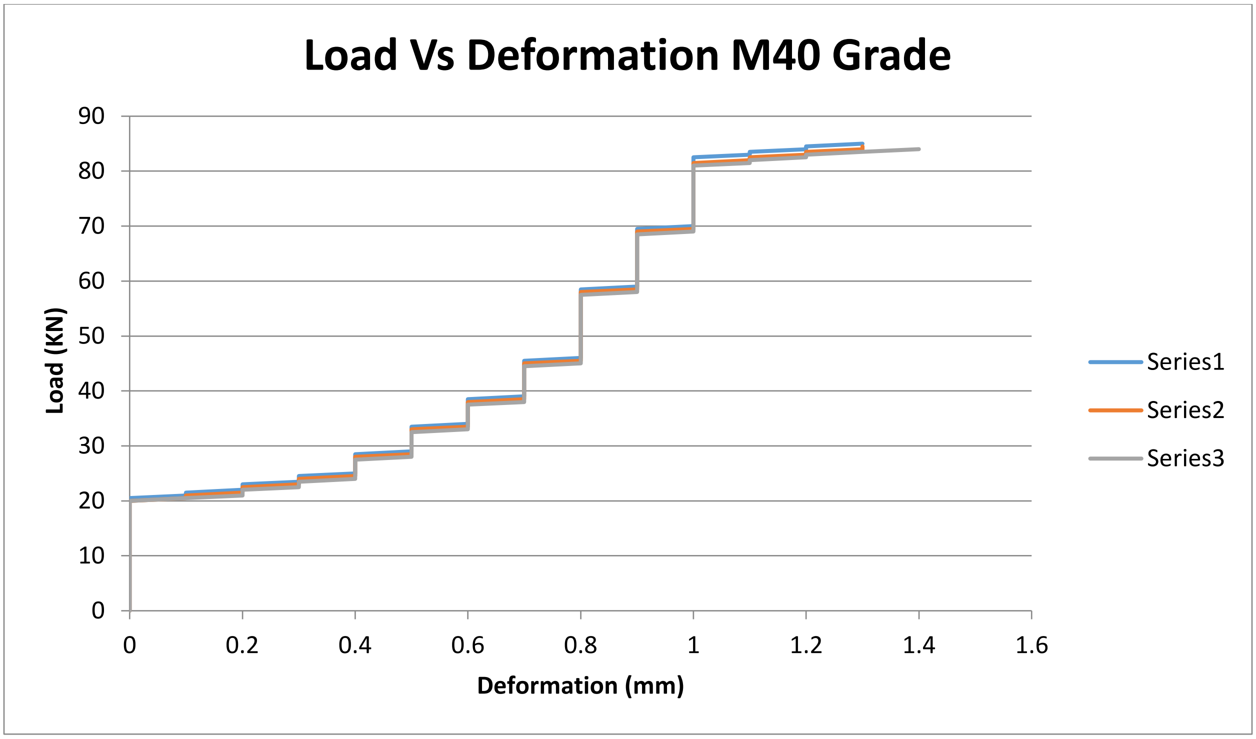

Figure 5.2 Load Vs Deformation M40 grade

After Sulphate Attack to the sample

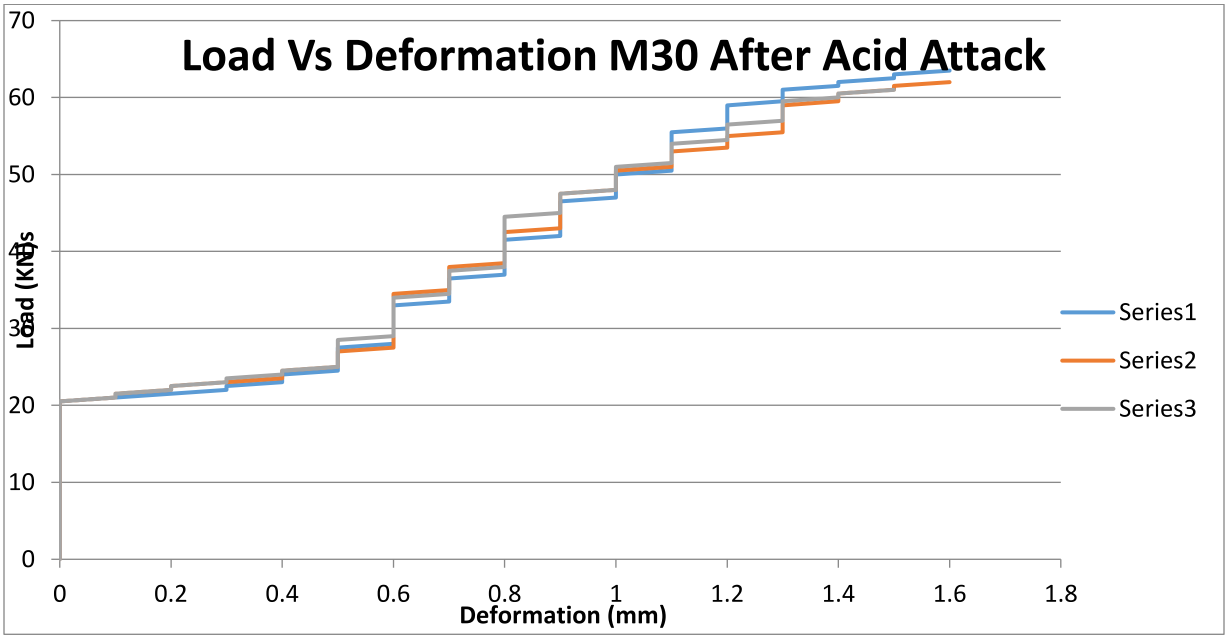

Figure 5.3: Load Vs Deformation M30 grade under Sulphate attack

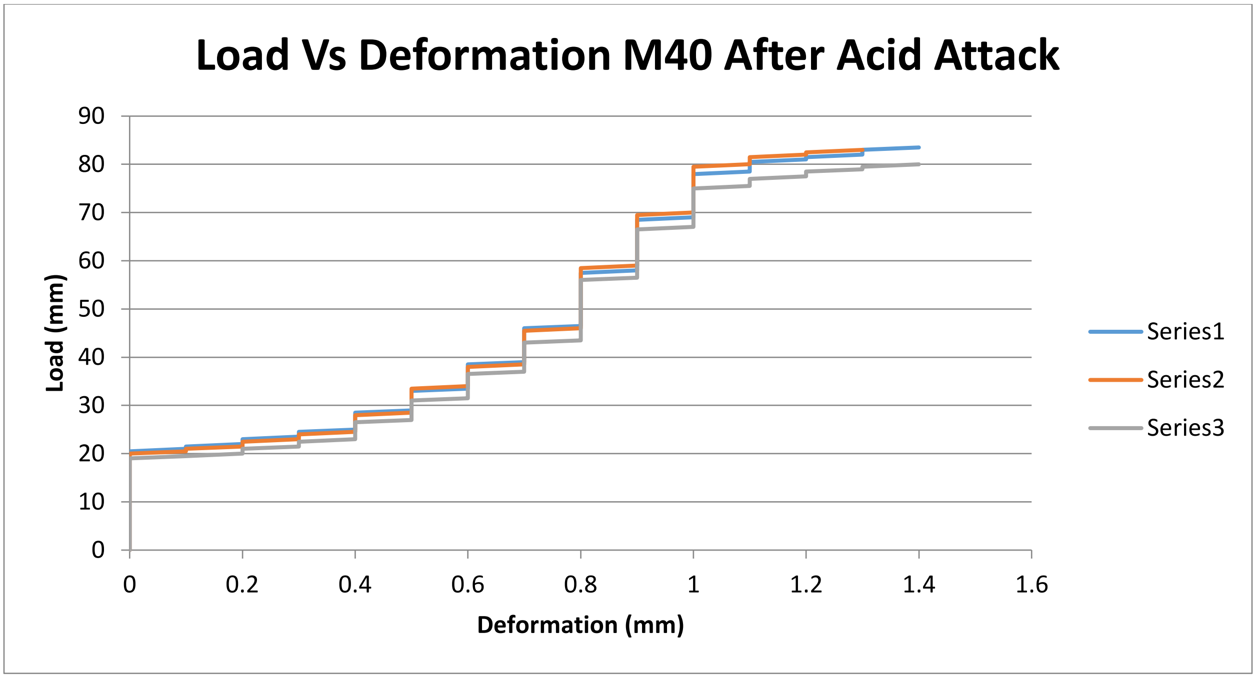

Figure 5.4 Load Vs Deformation M40 Grade under Sulphate Attack

Table 5.10: COMPRESSIVE AND SLANT SHEAR BOND STRENGTH

Sr. No.	Grade of concrete	Compressive Strength (N/mm^2)	Apparent Bond Strength (N/mm^2)	Type of failure
1	M30	33.1	19.95	Cohesive
		32.6	19.64	Cohesive
		32.86	19.8	Cohesive
2	M40	43.31	26.09	Cohesive
		42.8	25.7	Cohesive
		42.54	25.6	Cohesive

CHAPTER 5

CONCLUSION

5.1 General

This thesis focused on finding the bond strength between the steel and concrete specimen which are bond together with the help of epoxy based resin and also check the durability of the specimen under sulphate attack. Slant Shear Test under ASTM C882 is use to determine the bond strength in the specimen in which concrete specimen is of different grades. ASTM C881 is used to find out type of bond and type of bonding agent to be used.

5.2 Conclusion

Based on the experimental work I have performed following are the conclusion I have obtain which are written below:

1. There are many factors affecting bond strength such as curing conditions, cleanness at the specimen interface, cracks are present or absents, type of bonding agent etc are some factors which are considered major factor etc.

2. Different surface preparation techniques have different effect on the bond strength of the specimen.

3. The type of failure in the bond I have obtained is cohesive type of failure. This means that the concrete sample fails first and the bond did not break.

4. The type of failure is cohesive, so the bond strength obtain is not true bond strength. It is apparent bond strength between concrete and steel specimen.

5. The durability of sample is checked and finds out that the strength of sample is decrease but not that much, so durability of sample is good.

6. Compressive strength of bonded specimen is more than the concrete cube alone strength.

5.3 Future Scope

If there is any effect on bond strength on changing dimensions of specimen or changing contact bond area of the specimen.

In preparation of surface of specimen by different methods such as sand blasting technique, wire brushing methods etc, some damage are caused by these techniques. They need to be studied.

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