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An Experimental Study on Flexural Strength and Corrosion Properties of Reinforced Concrete Beams

K. Venkateswara Rao,
Associate Professor,
Gudlavalleru Engineering College,
Gudlavalleru, India.

B. Devi Pravallika,
Post Graduate Scholar,
Gudlavalleru Engineering College,
Gudlavalleru.

K. Phani Krishna,
Post Graduate Scholar,
Gudlavalleru Engineering College,
Gudlavalleru India

Abstract: **In coastal environment reinforcement corrosion is an obvious cause of deterioration of concrete structures which affects the durability and service of reinforced concrete beams. Flexural strength is a measure of resistance against failure in bending and durability is the property of material against weathering action. The main aim of our study is to investigate and compare the flexural strength and theoretically estimated steel loss of corroded and un corroded reinforced concrete beams replaced with 0%, 10%, 20%, 30% fly ash with cement respectively. Accelerated corrosion technique using 5%Nacl and impressed current were adopted to corrode the beam experimentally. The important factors that influence the test results are grade of the concrete and percentage replacement of fly ash. At 10% replacement of fly ash there is a much reduction in the steel loss and as the replacement increases there is a little reduction in steel loss and considerable change in flexural strength.**

Key words: Corrosion, Flexure Strength, Fly Ash, Grade Of Concrete.

INTRODUCTION

General:

Flexure or bending is commonly encountered in structural elements such as beam sand slabs which are transversely loaded and the strength is a measure of tensile strength of OPC concrete. Although the probability of the structures being flexure deficient is low, failures have occurred due to a variety of factors: errors in design calculations and improper detailing of reinforcement, construction failures or poor construction practices, changing the function of a structure from a lower service load to a higher service load, seismic and wind action. Corrosion is caused by the destructive attack of chloride ions penetrating by diffusion or other penetration mechanisms from the outside. Carbonation of concrete or penetrations of acidic gases into the concrete causes of reinforcement corrosion. Besides these there are few factors, some related to the concrete quality, such as w/c ratio, cement content, impurities in the concrete ingredients, presence of surface cracking, etc. and others related to the external environment, such as moisture, bacterial attack, stray currents, etc., which will effect the properties of reinforcement corrosion(Castroetal.,1997). Uncontaminated cover concrete provides a physical barrier that prevents the direct exposure of the steel surface at the outside environment. It also provides a highly alkaline chemical environment that protects steel from corrosion.

Corrosion produces expansive products that generate tensile stresses in the concrete surrounding the reinforcing steel, which may cause concrete cracking and can increase the overall tensile strength and stiffness of the concrete structure.

Corrosive products are highly porous, weak and often form around reinforcing steel which decreases the bond strength between the reinforcement and concrete.

The expected costs of failure for serviceability were significantly higher than the expected costs of failure for ultimate strength limit states. This signifies the need for researching the area of corrosion and inclusion of concept of durability design in our codes with a greater relevance associated to it.

Objective and Basis of Study:

Many of the structures in field are found to be damaged to different levels due to different load history or due to different existing loads over these structures.

Different load histories as well as existing load levels affect the size and inter connectivity of the pore system. As a result the pore system get disturbed and modified affecting the durability depending upon the magnitude of the load flow mechanism get dominated in a varying amount over the diffusion of capillary action (which are the main actions in un-cracked situation for the transportation of the chloride ions towards the embedded steel surface in the concrete.

Hence the objective of the study is to primarily observe the effect of the presence of load induced cracks, effect of concrete quality, and effect of preliminary repairs of the load cracks on development and progression of corrosion activity and its associated effects.

Factors Affecting Strength of Concrete:

Concrete strength is affected by many factors, such as quality of raw materials, water/cement ratio, coarse/fine aggregate ratio, age of concrete, compaction of concrete, temperature, relative humidity and curing of concrete.

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1. Quality of Raw Materials
   - Cement
   - Aggregates
   - Water
2. Water/ Cement Ratio
3. Coarse/Fine Aggregate Ratio
4. Aggregate/Cement Ratio
5. Age of Concrete
6. Compaction of Concrete
7. Temperature

Durability:

Concrete durability has been defined as its resistance to weathering action, chemical attack, abrasion and other degradation processes. Construction and demolition was te contribute to solid waste going to landfills. The production of new building materials depletes natural resources and can produce air and water pollution. Most concrete and masonry buildings are demolished due to obsolescence rather than deterioration.

Fig. 1 Bridge Subjected To Chloride Attack

Different concretes require different degrees of durability depending on the exposure environment and properties desired.

The chemical and physical factors which effect the durability of the concrete.

1. Alkali-Silica Reaction (ASR)
2. Chloride Resistance and Steel Corrosion
3. Seawater Exposure
4. Abrasion Resistance
5. Sulphate attack
6. Resistanceto Freezing and Thawing
7. Chemical Resistance

Corrosion:

Corrosion of steel reinforcing bars is an electrochemical process that requires a flow of current and several chemical reactions. The three essential components of a galvanic corrosion cell are

- Anode
- Cathode
- Electrolyte

The general relationship between components of a corrosion cell is illustrated in the figure 2

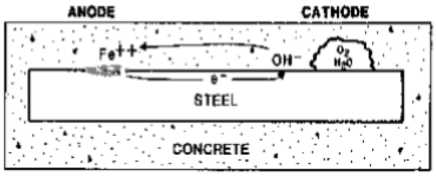

Fig.2 Electro chemical Corrosion Cell

The anode and cathode can be on the same steel reinforcing bar. The anode is the location of the steel reinforcing bar where corrosion is taking place and metal is being lost. At the anode the iron atom lost electrons to become iron ions (Fe^{+2}).This oxidation reaction is referred to as the anodic reaction. The cathode is the location on a steel reinforcing bar where metal is not consumed. At the cathode, oxygen, in the presence of water, accepts electrons to form hydroxyl ions (OH). This reduction reaction is referred to as the cathode reaction.

The electrolyte is the medium that facilitates the flow of electrons (electric current) between the anode and the cathode. Both the anodic and cathode reactions are necessary for the corrosion process to occur and they need to take place concurrently.

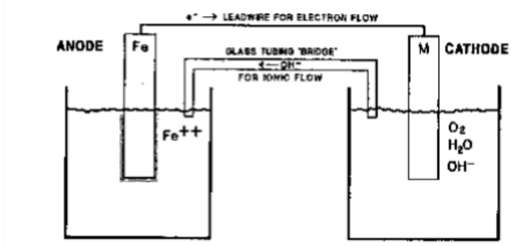

Fig.3 Corrosion Cell in Reinforced Concrete.

Factors Affecting the Corrosion Rate:

Factors influencing the corrosion rate of steel reinforcing bars embedded in the concrete include

- Availability of water and oxygen
- Ratio of steel surface area at the anode to that at the cathode
- Amount of chloride ions in pore water
- Resistivity of concrete
- Temperature
- Relative humidity
- Concrete micro structure

Corrosion Control Measures:

Corrosion-induced deterioration of reinforced concrete structures occurs when the environmental loading on the structure is greater than the ability of the structure to resist the environmental resistance. The main deterioration mechanism (chloride-induced corrosion of rebar) focus on there in reinforcement and its protection.

Corrosion can also occur as are sult of other deterioration processes: freeze-thaw cycles, expansive reactions, excessive deflections, fatigue, etc. These processes cause the concrete to crack, which subsequently allows water and chlorides easy access to the interior of the concrete and the steel reinforcing bars.

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The factors that influence the corrosion of steel reinforcing bars embedded in concrete are the amount of chloride ions at the steel level, there sistivity of the concrete, temperature, relative humidity (both internal and external), and the concrete micro structure. In general, by controlling these factors to an acceptable level, the corrosion of the steel reinforcing bars and resulting concrete deterioration can be minimized

LITERATURE REVIEW

IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 4 Ver. II (Jul- Aug. 2014), PP 98-109

By Naga Chaitanya. C and Vamsi Krishna. B

In this study, reinforced concrete beams are normally designed as under reinforced to provide ductile behavior such as the tensile moment of resistance. In coastal environment reinforcement corrosion is an obvious cause of deterioration of concrete structure, which affects the durability and service of reinforced concrete structure.. The corrosion was measured using Applied Corrosion monitoring instrument. Beam specimens are prepared using M20 grade concrete for OPC. Beam specimens casted are tested as vertical cantilever beam in specially prepared loading setup and load deflection behavior is studied.

A PILOT INVESTIGATION FOR COMPARATIVE ASSESSMENT OF CORROSION DURABILITY OF REINFORCED CONCRETE BEAMS **Harish C. Arora,** Umesh K. Sharma, B. Kameshwar Rao and Anupam Chakraborty

This paper reports the results of an experimental program which was carried out on a few damaged reinforced concrete beams for the purpose of comparing their performance in terms of corrosion durability. The study aims to closely monitor the effect of important factors such as concrete type, mechanical loading history and minor surface repair effects on corrosion development.

INDIAN JOURNAL OF ENGINEERING AND MATERIALS SCIENCES VOL 17, APRIL 2010, PP.140-14C **Freeda Christy and D Tensing**

In this study they investigated fly ash as a replacement for cement and fine aggregate in cement mortar. This paper presents the results of cement mortar of mix proportion 1:3, 1:4, 1:5, 1:6 cement mortar in which cement is partially replaced with class f fly ash as 0%, 10%, 20%, 25% and 30% by weight of concrete.

*INTERNATIONAL JOURNAL OF ADVANCED ENGINEERING TECHNOLOGY E-ISSN 0976-39***Prof.** Jayesh kumar pitroda, Dr. L. B. Zala, Dr.F.S.Umrigar

In this experimental study they use fly ash in concrete formulations as a supplementary cementitious material was tested as an alternative to traditional concrete. The cement has been replaced by fly ash accordingly in the range of 0%, 10%, 20%, 30% and 40% by weight of cement for M-25 and M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive and split strength with in the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days and split strength for 56 days are task.

EXPERIMENTAL PROGRAM

The experimental program consists of the following steps

- Collection of materials
- Mix design
- Casting
- Curing
- Accelerated corrosion technique
- Testing

Collection of Materials:

Materials:

The constituent materials used in this investigation were procured from local sources. These materials are required by conducting various tests. From the test results obtained we selected the type of materials we are using which include cement, brick powder, coarse aggregate, fine aggregate, quarry dust, water, sulphuric acid.

Cement:

Ordinary Portland cement of C53 grade conforming to both the requirements of IS: 12269 and ASTMC 642-82type-I was used. From the test results obtained the conventional concrete can be designed according to IS10262-82(MIXDESIGN CODE). Finally M25 Grade concrete is designed.

Coarse Aggregate:

Normal aggregate that is crushed blue granite of maximum size 20mm was used as coarse aggregate.

Fine Aggregate:

Well graded river sand passing through 4.75mm was used as fine aggregate. The sand was air-dried and sieved to remove any foreign particles prior to mixing.

Fly Ash:

Fly ash is the waste produced from the thermal power plant industry. In our Project we collected the fly ash from the Vijayawada thermal power station, Vijayawada and it is replaced with cement.

Fig.4 Fly Ash

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Table.1 Physical Properties of Fly Ash

Property	Sample of VTPS	IS3812 Requirement	
		Grade I	Grade II
Fineness(Blaine Cm2/gm)	4069	3200	2500
Lime Reactivity N/mm2	09	4.0 min	3.0 max
Drying Shrinkage%	0.008	0.15 max	1.0 max
Auto Clave Expansion%	00.015	0.8 max	0.8 max

Table.2 Chemical Composition of Fly Ash

Name of the chemical	% by weight
Silica (SiO_2)	64.08
Alumina (Al_2O_3)	20.21
Ferric Oxide (Fe_2O_3 + Fe_3O_4)	04.17
Titanium Di Oxide (TiO_2)	0.42
Calcium Oxide (CaO)	6.20
Sulphate (SO_4)	1.24
Loss on Ignition (LOI)	1.07

Preparation of Moulds:

The moulds of inner dimension (50×10×10) are prepared using the wooden specimens. Two L-shaped beams are joined by using binding wires to form closed formwork. A total number of six such beams are prepared for experimental purpose.

Wooden Moulds

Mix Design:

Mix design is the one of the most important step to be considered in any experimental program dealing with concrete. In this study we considered two different grades of concrete i.e, M 20 and M 30.The porosity of the concrete mainly depend upon the grade of the concrete, richer the mix higher the strength and durability.

Mix design is done according to IS 10262:2009. The amounts of the ingredients required are tabulated for respective mixes.

M 20 Mix Proportion Ratio

INGREDIENT	QUANTITY
Cement	372 kg/m^3
Fine aggregate	566 kg/m^3
Coarse aggregate	1100 kg/m^3
Water	186 litres
Mix proportion ratio C : F : CA : W	1 : 1.52 : 2.96 : 0.5

M 30 Mix Proportion Ratio

INGREDIENT	**QUANTITY**
Cement	465 kg/m^3
Fine aggregate	478 kg/m^3
Coarse aggregate	1202 kg/m^3
Water	195 liters
Mix proportion ratio C : F : CA : W	1 : 1.04 : 2.52 : 0.42

Different Mixes of Concrete:

A total number of 48 beams are casted of which 24 beams are of M_{20} grade and remaining 24 beams are of M_{30} grade and their respective classification is shown below.

- Conventional concrete of grade M_{20}(CCA-20)
- Concrete of grade M_{20} made by replacing 10%fly ash…..(CF10)
- Concrete of grade M_{20} made by replacing 20%fly ash…..(CF_{20})
- Concrete of grade M_{20} made by replacing 30%fly as.....(CF_{30})
- Conventional concrete of grade M_{30}(CCA-30)
- Concrete of grade M_{30} made by replacing 10%fly ash…..(CF10)
- Concrete of grade M_{30} made by replacing 20%fly ash…..(CF_{20})
- Concrete of grade M_{30} made by replacing 30%fly as.....(CF_{30})

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Accelerated Corrosion Technique:

For corrosion initiation the beams were placed inverted. for this purpose ponds were created on the tensile face of the beams by preparing 1.5 inch cement-sand barriers on this face. This was for the purpose of having a maximum of unidirectional flow of 5% Nacl from tensile face onwards embedded steel reinforcement. in addition after corrosion got initiated accelerated corrosion was propagated with a 9

Casting of Beams

Curing of Beam

volts impressed current by a constant direct current regulated power supply. The high salinity and impressed current were both used to create an especially aggressive environment by providing an abundance of chloride ions and by simulating an increased flow of electrons, respectively.

For having same electric potential a three of beams were placed parallel and subjected to one power supply. Fixed voltage was maintained across the anode which was

Corroded Rebar Due to the Accelerated Corrosion Technique.

Corrosion induced damage in the concrete beams was evaluated by measuring the corrosion current.

Current inflow in the present study in a particular beam throughout the accelerated corrosion test

Accelerated Corrosion Process

Testing:

Flexural strength test:

Here 24 beams are tested after completion of curing and for 28 days under UTM with a loading rate ranging from 1.2 N / (mm^2/min) to 2.4 N/ (mm^2/min).

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Flexural Strength Test Arrangement

Estimation of Steel Loss:

The applied potential was regularly monitored and adjusted if required time to time during the ongoing test. The current inflow in the different was measured with a multi-meter and the estimated steel loss was calculated as per faraday's law for determination of degree of induced corrosion in different beams.

$$\Delta w = \frac{MIt}{ZF}$$

Where Δw = mass of steel loss (in grams)
I = current (amperes)
t = time (seconds)
F = Faraday's constant (96,500 amperes seconds)
Z = valency of Fe (2)
M = atomic mass of Fe (56 grams/ mole)

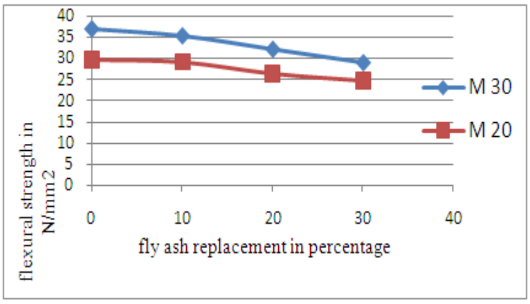
RESULTSAND DISCUSSIONS

Flexural Strength Results:

Flexural Strength for M_{20} Grade Concrete Beams (N/mm^2)

MIX	CF	CF_{10}	CF_{20}	CF_{30}
Un corroded	29.74	29.15	26.32	23.12
corroded	26.34	26.12	23.45	21.20

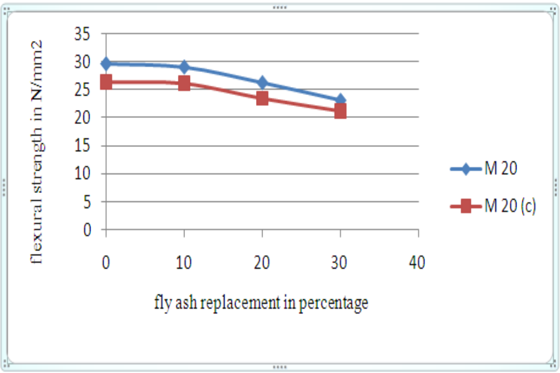
Flexural strength for M 20 grade concrete Beam



Flexural strength for M 20 grade concrete Beam

MIX	CF	CF_{10}	CF_{20}	CF_{30}
Un corroded	29.74	29.15	26.32	23.12
corroded	26.34	26.12	23.45	21.20

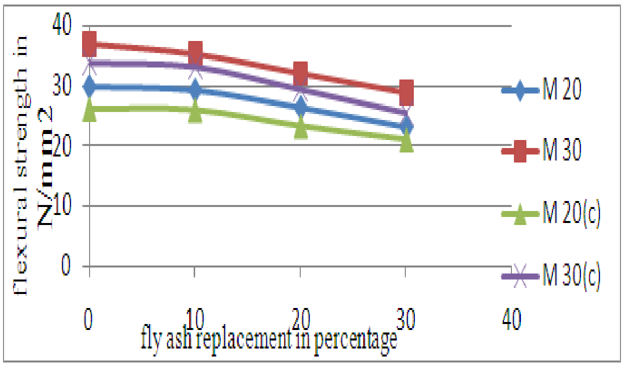
Flexural Strength for M_{30} Grade Concrete beams



Flexural Strength for M_{30} Grade Concrete beams

For the M 30 grade too the flexural strength values for corroded beams is less than the un corroded beams and change between 0% and 10% is very less

Comparison between M_{30} and M_{20}Grade Beam



Comparison of M_{20}And M_{30} Grade Concrete

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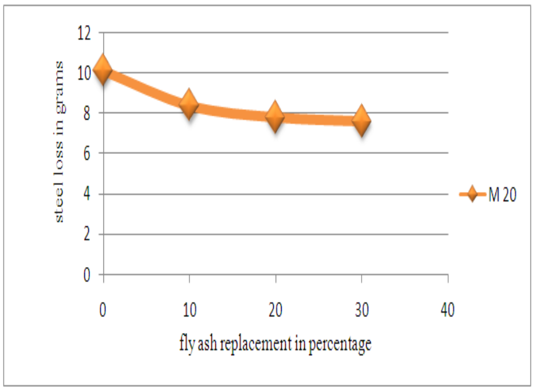
From the above graph we can judge that the flexural strength values for M 30 grade concrete beams is higher than M 20 grade beams and the corroded beams of M 30 grade concrete has little higher values than the un corroded M 20 grade concrete beams.

Theoretically Estimated Steel Loss Test Results:
Estimation of Steel Loss for M_{20} Grade Concrete Beams:

MIX	CF	CF_{10}	CF_{20}	CF_{30}
steel loss (in grams)	10.126	8.38	7.8	7.6

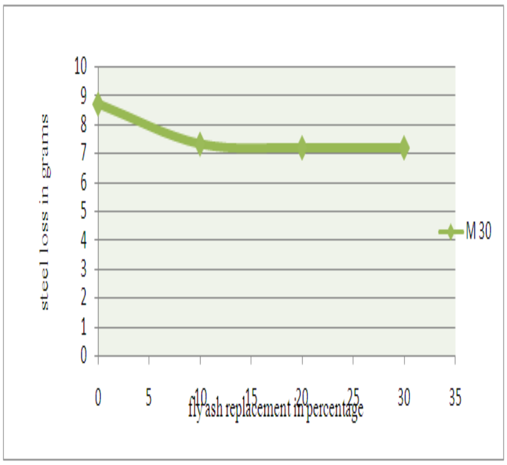


Estimation of Steel Loss ForM20Grade Concrete

Based on the above results we can judge that fly ash replacement is inversely proportional to the steel loss i.e., as fly ash percentage is going on increasing there is a decrease in the reduction in the steel

Estimation of Steel Loss For M_{30} Grade Concrete Beams:

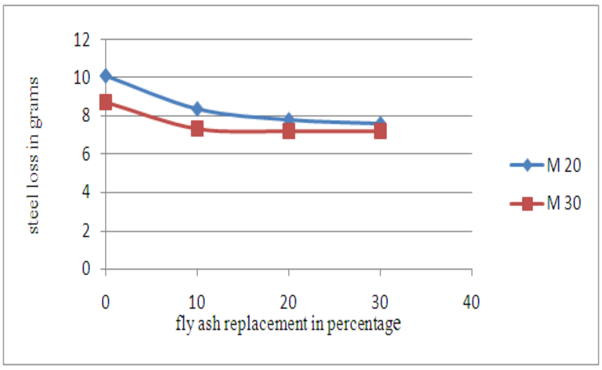
MIX	CF	CF_{10}	CF_{20}	CF_{30}
steel loss (in grams)	10.126	8.38	7.8	7.6



Estimation of Steel Loss For M_{30}Grade Concrete Beams

From this graph too we can notice that fly ash replacement is inversely proportional to steel loss but after certain percentage there is no much change in th steel loss

Comparison of M_{20} And M_{30} Grade Concrete Beam:



Comparison Of M_{20} And M_{30} Grade Concrete Beams
When we compare the both M 20 and M 30 grade concrete, the steel loss in M 30 grade is less than M 20 grade because the pores in previous grade is less than the later one. So the durability of a reinforced beam mainly depends on the grade of the concrete.

CONCLUSIONS

By completion of our experimental study we conclude these following points:

- From the flexural strength and theoretically estimated steel loss values we can conclude that flexural strength mainly depends upon the grade of the concrete whereas the estimated steel loss depends upon the replacement of fly ash.
- As the grade of concrete increases, the flexural strength of concrete increases and steel loss decreases.
- When the percentage of fly ash is increased there is a little change in the flexural strength and considerable reduction in the steel loss.
- The beams replaced with 10%fly ash is considered as optimistic because in flexure test there is no much difference between conventional and replaced and in steel loss test there is considerable change from conventional and replaced one.

Scope for Future Work:

- Study should be carried out in different exposure conditions such as, natural corrosion and sea corrosion, to study the effect of corrosion on strength and durability aspects of structures.
- Tests should be carried out on different beam sizes to verify the accuracy of the proposed method and to observe the size effect.

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REFERENCES:

[1] "An experimental study of flexural strength of reinforced concrete beams due to corrosion" by Naga chaitanya C and Vamsi Krishna B from IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)e-ISSN:2278-1684,p-ISSN:2320-334X,Volume11,Issue4Ver.II(Jul-Aug.2014),PP98-109 www.iosrjournals.org

[2] "A pilot investigation for comparative assessment of corrosion durability of reinforced concrete beams" by Harish c. Arora, Umesh k. Sharma, B. Kameshwar Rao and anupam Chakraborty

[3] "Effect of class-f fly ash as partial replacement with cement and fine aggregate in mortar" byC Freeda Christy and D Tensingfromindian journal of engineering and materials sciences vol 17, april 2010, pp.140-144

[4] "Experimental investigations on partial replacement of cement with fly ash in design mix concrete" by Prof. Jayesh kumar pitroda, Dr. L. B. Zala, Dr.F.S.Umrigar from international journal of advanced engineering technology e-issn 0976-3945

[5] "Fly ash class F:oppurtunities for developing low cost mortar" by rushabh A.shah, Jayesh kumar pitroda from international journal of innovation technology and exploring engineering

[6] For design purpose IS 456 : 2000,IS 10262 : 1982 are used

[7] Concrete technology by Dr.MS SHETTY

[8] Concrete technology by Dr. AMINUL ISLAM LASKAR