EFFECT ON ENERGY ABSORPTION IN TORSIONAL AND FLEXURAL MEMBER DUE TO CORROSION

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Abstract - *Modern infrastructure activities are not possible without the use of reinforced concrete and thus the strength and durability of these structures is important. Corrosion of reinforcing steel is been cited as the most detrimental effect and is thus endangering the structural performance in terms of load bearing capacity and durability. The corrosion affects the service life of structure. The bond between reinforcement and concrete is affected due to corrosion and thus the strength of RCC also deteriorates. Corrosion of reinforced concrete is a slow process. The concrete acts as a protective shield thus, it takes reasonably long time for corrosion initiation and progress. The accelerated corrosion technique is a method to assess causes and extent of corrosion. The diffusion of chlorides in concrete is recognized as one of the major cause for initiation of corrosion phenomenon. This report presents study on effect of corrosion on compressive strength, flexural strength and torsional strength of reinforced concrete beams. In this experiment M25 grade of concrete is used for casting of RC beams. Universal testing machine (UTM) is used for compressive strength test and flexural strength test and specially prepared setup is used for torsional strength.*

Key Words: Accelerated corrosion technique, RC beams, compressive strength, three point loading, torsional strength,

1.INTRODUCTION

Corrosion related problems are at alarming rate in a tropical country like India which has more than 3000 km of coastline and where approximately 80% of the annual rainfall takes place in time period of two monsoon months. Infrastructural activities without reinforced concrete is not possible. Reinforced concrete is considered as an economical and strong material in construction of civil engineering structures. Some external environmental conditions such as acid rain, chloride ingress, loading fatigue, and carbonization have adverse effect on reinforced concrete. This results in concrete deterioration and steel gets corrosion. The resulting corrosion products occupy volume 6 to10 times that of the steel volume. This increased volume induces tensile stresses in concrete which results in cracking, spalling and delamination of concrete surface. Due to concrete cracking, the reinforcements in concrete get exposed directly to environmental attack and this accelerates corrosion. Along with unpleasant appearance it also weakens the concrete structure as bond between steel and concrete is reduced. In this experimental work the effect of corrosion on strength of reinforced concrete beam has been studied. Corrosion is a slow process and progresses with time as, concrete acts as a protective shield over reinforcement. The corrosion for the purpose of testing is accelerated by using accelerated corrosion technique. This technique works on Faraday's law. Accelerated corrosion technique uses impressed current technique to achieve the desired level of corrosion within a short duration of time. The reinforced concrete beam is casted using M30 grade concrete, beam is casted such that the rebar of beam acts as an anode which is positive and stainless steel plate acts as a cathod which is negative. For electrolyte 5% NaCl solution is used and constant DC power is provided. Accelerated corrosion test by using the impressed current technique is confirmed to be a valid method to study the process of corrosion of reinforcement in concrete, and its effects on damage of concrete cover. In this study effect of Corrosion on compressive strength, flexural strength and torsional strength is tested. Flexural strength is a measure of resistance against failure in bending or tensile strength of OPC concrete. Torsional strength is a measure of ability of any member to resist twisting load. The beam is corroded by 4%, 8% and 12% using accelerated corrosion technique.

2. OBJECTIVE

- By using accelerated corrosion technique on steel bars, determine effect of corrosion on reinforced concrete beams.
- To develop a test set up to carry out load-test on RCC beam.
- To determine the effect of corrosion on strength of RCC beam.
- To study the load carrying capacity and torsional strength of beam by reducing losses due to corrosion

3. LITERATURE REVIEW

Adheena Thomas, Afia S Hameed(2017)
This investigation aims to study the combined effect of torsion and flexure on 2 beams. The test set up is specially designed for applying combined torsion and bending. In this study, Crack pattern, load- deflection characteristics, torque-twist response for the specimens are tested. The conclusion obtained from analysis was that the cracks propagated towards the top with increasing angle of inclination and

bottom faces. The beam at its ultimate stage formed a hinge along the four face, which is the compression face. This face was free from cracks. [1]

Suresh Bhalgamiya, Govind Tivadi, Mehul Jethva(2018)
This report presents a study on the mechanism of reinforcement corrosion, different Corrosion tests are utilized to monitor reinforcement corrosion. Methodology that was utilized for assessment of rate of corrosion is discussed in this report. For corrosion development of reinforcement bar in concrete accelerated corrosion test is employeed, causes of reinforcement corrosion is discussed including carbonation and chloride ingress. Various other methods of accelerating reinforcement corrosion are discussed in this paper.[2]

Gayathri M, Hanna Paulose(2019)
In this paper flexural behaviour of RCC beams under 5%, 10% and 15% of corrosion is examined. To induce corrosion accelerated corrosion technique was used. Validation of accelerated corrosion test was done before corrosion was induced. M30 grade Beams of size 100 mm × 150 mm × 700 mm were used. The ultimate load carrying capacity of corroded beams and control beams were tested and it was found decreasing as percentage of corrosion increased. Corroded beams also had more deflection than control specimens.[3]

Naga Chaitanya C, Vamsi Krishna B(2014)
The main aim of this study was to analyze the strength of corroded beams experimentally. Accelerated corrosion technique was used for corrosion of beams. The corrosion was measured using Applied Corrosion monitoring instrument. Beam specimens were prepared using M20 grade concrete for OPC. Beam specimens casted were tested as vertical cantilever beam in specially prepared loading setup and load deflection behavior was studied. From the experimental investigation it was observed that the load carrying capacity of the beam is more for control beams, but Deflection is less for Control beams with respect to Corroded beams (2.5%, 5%, and 7.5%). It was then concluded that, as the rate of corrosion increases above 5%, the Ductility property of beam specimen goes on decreasing.[4]

Ashutosh S.Trivedi, R.P.Sharma, Sarvesh K Jain, S.S.Bhadauria, Abhishek Tiwari(2017)
In this paper various literatures are reviewed and various aspects of corrosion of the reinforcement embedded in concrete are studied. The various factors causing corrosion like moisture, permeability pH and temperature etc are studied. In this study various materials and methods used for controlling corrosion are found out. It is stated in this paper that for accurate prediction of corrosion rate both laboratory and field data should be used during model development.[5]

4. EXPERIMENTAL PROGRAM

In this experimental work the effect of corrosion of beams on flexural strength and torsional strength is to be investigated. For the progress of this study following methodology is considered,

1. To determine basic properties of constituent materials of concrete namely cement, fine and coarse aggregates and steel bars as per relevant Indian standard specifications.
2. Mix design for M25 grade of concrete.
3. Reinforcement detailing of beam.
4. Casting of beam.
5. Curing of beam
6. Corrosion of beam using Accelerated Corrosion technique.
7. Testing of corroded beam for compressive strength, torsional strength and flexural strength.
8. Result and conclusion.

4.1MATERIAL PROPERTIES

Cement

In this study 53 grade cement is used for M25 grade of concrete. Following are chemical compositions of cement,

Oxide	% Content
CaO	60-67
SiO2	17-25
Al2O3	3-8
Fe2O2	0.5-0.6
MgO	0.1-0.4
SO3	1-3
Alkalies	0.1-1.3

Table-1: Chemical Properties of cement

Fine aggregate
In this work river sand, which is clean, locally available, well dried and passing through IS sieve 2.36 mm is used as a fine aggregate in the concrete mix.

Coarse aggregate
Coarse aggregate of maximum size 20mm is used for preparation of desired concrete mix.

- Crushing value = 18.73%
- Aggregate impact value = 11.50%

Water
Water used for concreting purpose is free from any injurious quantity of soils, acids, alkalis or alternative organic or inorganic impurities. The water acts as a lubricating substance.

Steel Reinforcements

For this study Fe 415 steel is employed. So, Fe415 steel means that the reinforcement steel rods (or bars) that may safely stand up to a Yield Stress of 415N/mm^2. Diameter of reinforcement bars used is 12mm and stirrups of 8mm are used.

4.2MIX DESIGN

As per IS code specifications M25 grade concrete mix is designed. The properties of all materials are discussed above. The water cement ratio is taken for mild exposure condition is 0.5. Concrete mix proportion in kg/m^3 is
Cement = 383.2 kg/m3
Water = 191.6 kg/m3
Fine aggregates = 800.94 kg/m3
Coarse aggregate = 1087.75 kg/m3
The concrete mix ratio came out to be 1: 2.09: 2.83(cement: fine aggregate: coarse aggregate).

4.3BEAM DESIGN

To study behaviour of corroded beam on strength of beam, 12 beams are casted using M25 concrete and for reinforcement Fe-415 grade steel is used. The beams designed as under-reinforced concrete beams and span of beam was 700 mm, dimension 150 mm, depth 150 mm.

Top longitudinal main bars: 2 nos. 12 mm dia.
Bottom longitudinal main bars: 2 nos. 12 mm dia.
Stirrups: 2-legged 8 mm dia. stirrups at 120 mm C/C.

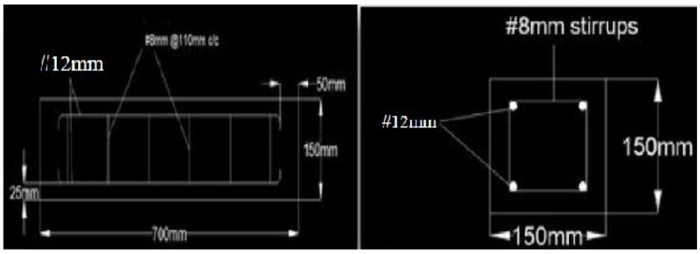


Fig 1- Beam Detailing

4.4CASTING OF BEAM

After obtaining the optimum design of the mix, the next procedure was the casting of specimens for testing. Beams of size 150 × 150 × 700 mm were casted for the experiment. The steel reinforcements were cut on-site to the required length and assembled in the cage ready for concrete casting. The concrete should be placed in layers into moulds. While casting these beams, the concrete should be filled in 3 layers, compacting each layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end). In this way 12 reinforced beams are casted and along with beams cubes and cylinders were also casted, as specified below,

Table-2: Specimen details

Specimen	Dimensions(mm)	No. of specimen
Beam	700X150X150	12
Cube	150X150X150	6

Fig 2- Casting of Beam

4.5CURING OF BEAM

The casted specimens are kept in mould for 24hours and then are removed from mould. The specimens are ready for curing. Curing is that the method of preventing the loss of wetness from concrete whereas maintaining a satisfactory temperature. The specimens are cured for 28 days within the present work.

Fig 3- Curing of Beam

4.6CORROSION OF BEAM (ACCELERATED CORROSION TECHNIQUE)

The corrosion of steel reinforcement is generally accelerated by means of the impressed current technique. This technique induces corrosion in reinforcement in a limited available time. This impressed current technique has been frequently used to study the effect of corrosion on the concrete cover cracking, bond behaviour, and load-bearing capacity of reinforced concrete members. This technique of corrosion acceleration has many advantages, one main advantage is saving in time and money. One advantage over other accelerated techniques is the ability to control the rate of corrosion, which usually varies due to changes in the resistivity, oxygen concentration, and temperature. In this study Equipment used for accelerated corrosion are voltmeter, ammeter, DC power supply etc. After 28 days of curing of beams they are put into 5% concentrated NaCl solution by weight of water in tank. Depth of water in tank is kept constant throughout the corrosion process. Steel bars in beam are used as anode and stainless-steel bar immersed in water act as cathode.

5. EXPERIMENTAL INVESTIGATION

The test specimen used in this experimental work are M 25 cubes of dimension 150 x 150 x 150mm and beams of dimension 700 x 150 x 150mm. For the study of compressive strength 3 cubes were tested and average compressive strength was obtained. For three point loading test and torsional strength test 12 beams are tested for obtaining required result. The beams are corroded before testing for different percentages using accelerated corrosion method.

6. RESULT

6.1 COMPRESSIVE STRENGTH

This test is a measure of compressive strength of concrete. For the purpose of testing M30 grade concrete cubes of standard size 150 x 150 x 150mm are casted. The test is carried out using Universal testing machine or Compression testing machine. Compressive strength result for cube(150 x 150 x 150mm) after 28 days is given in table below, The average compressive strength of M25 grade cubes is 31.55 N/mm^2.

Table-3: Compressive strength result

Samples	Compressive strength(N/mm^2)	Average Compressive Strength(N/mm^2)
Cube 1	32.67	
Cube 2	30.69	31.55
Cube 3	31.29	

6.2 ACCELERATED CORROSION TECHNIQUE

The beam corrosion is accelerated using this technique, this corrosion of beam take some time to get corroded. The time required for different percentage of corrosion is as given below.

Table-4: Accelerated corrosion result

Percentage of corrosion	Current supplied (Amp)	Duration for corrosion (Hrs)
4	4	44.64
8	4	89.28
12	4	133.92

6.3 THREE POINT LOADING TEST

The results obtained for different percentage of corrosion for this test are as follows,

Beam specimen	Ultimate load (KN)	Average Ultimate load (KN)	Deflection (mm)	Average Deflection (mm)
0%	102.46 97.32 100.53	100.10	9.23 8.98 8.68	8.96
4%	93.23 86.54 91.21	90.32	8.27 7.29 8.15	7.90
8%	82.36 78.13 80.09	80.16	7.13 6.64 7.16	6.97
12%	72.27 66.45 71.18	69.96	6.31 5.73 6.25	6.09

Table-5: Three point loading result

Beam Specimen	Bending Moment (KNm)	Shear Force (KN)
0%	17.51	50.05
4%	15.80	45.16
8%	14.028	40.08
12%	12.243	34.98

Table-6: Bending Moment and Shear Capacity Of Beams

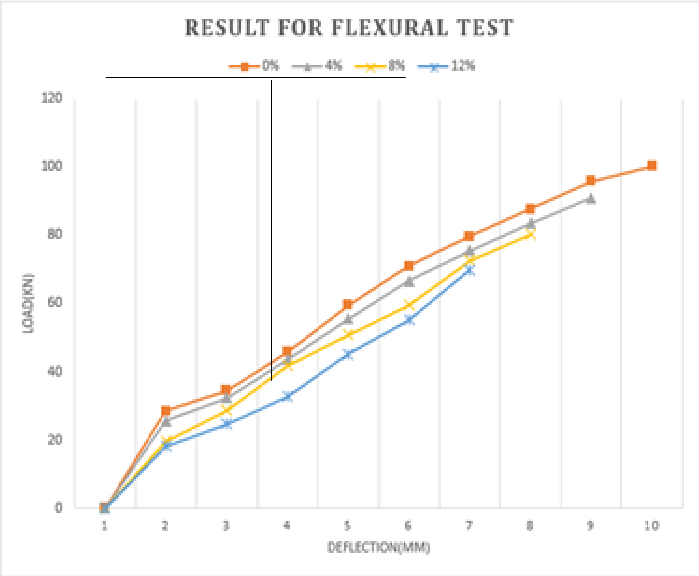


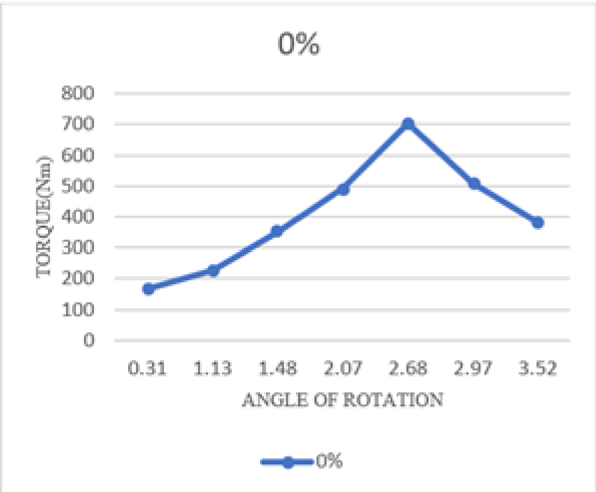
Chart 1- Load Deflection graph

6.4 TORSION TEST

Following are the results for torsional strength for different percent of corrosion.

0% corrosion	
TORQUE	ANGLE
168.9	0.31
225.4	1.13
350.8	1.48
491.7	2.07
703.8	2.68
508.3	2.97
381.9	3.52

Chart



2- Torsion v/s Angle of Rotation (0% corrosion)

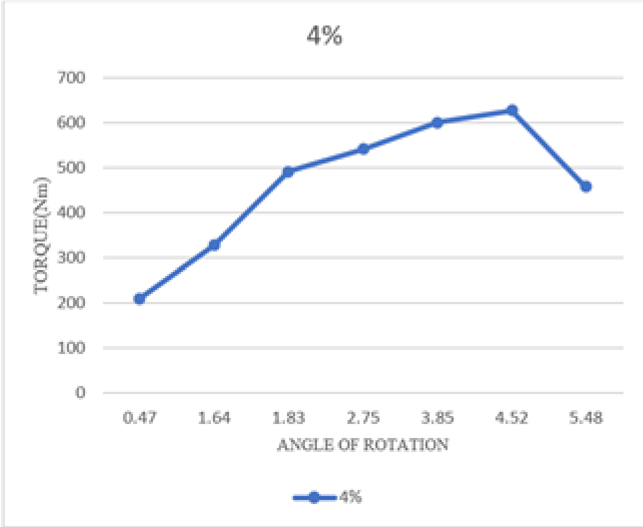


Chart 3- Torsion v/s Angle of Rotation (4% corrosion)

8% corrosion	
TORQUE	ANGLE
200.6	1.08
383.7	1.62
553.79	2.19
497.62	2.47
421.67	2.61
398.73	3.01

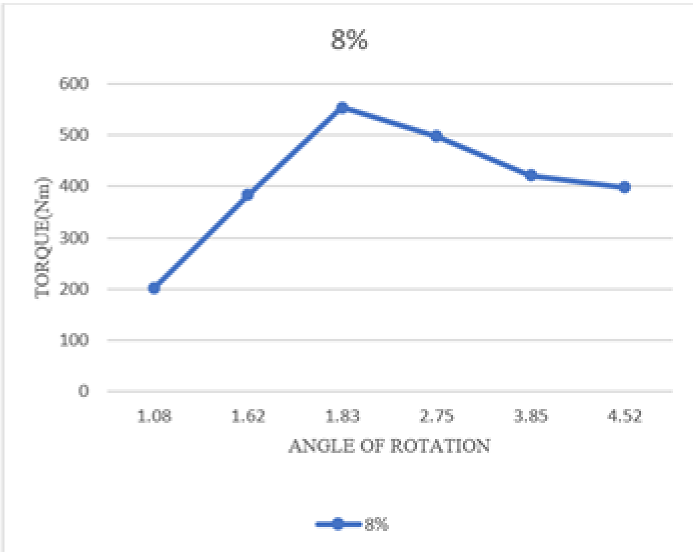


Chart 4- Torsion v/s Angle of Rotation (8% corrosion)

12% corrosion	
TORQUE	ANGLE
67.4	1.51
101.38	1.79
269.43	2.21
423.17	2.39
301.02	2.59
124.68	2.88

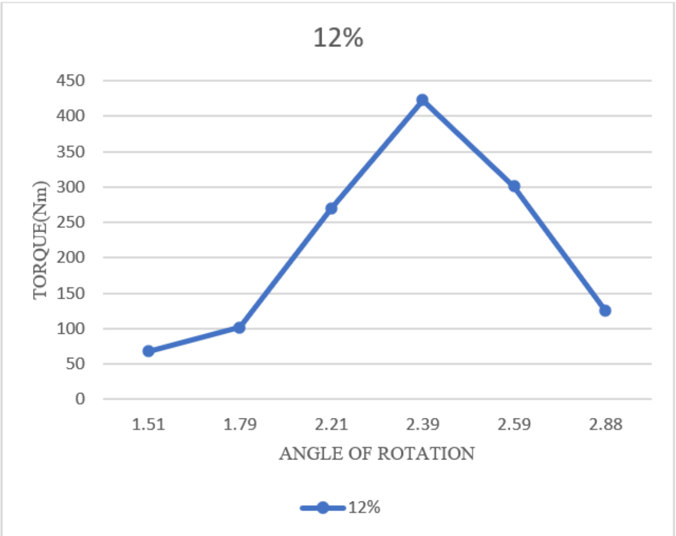


Chart 5- Torsion v/s Angle of Rotation (12% corrosion)

7. CONCLUSIONS

- From the study it is found that due to corrosion bending moment decreased by 9.76%, 19.88% and 30.08% for 4%, 8% and 12% corrosion.
- The bending moment decreased from 17.51 KNm for non corroded beam to 12.24 KNm for 12% corroded beam.
- Ultimate load at which beam experiences maximum deflection decreases from 100.10 KN to 69.96 KN as the percentage of corrosion in beam increases.
- From the torsional strength test it is observed that the maximu torque decreased by 10.65% for 4% corrosion, 21.31% for 8% corrosion and 39.87% for 12% corrosion respectively.
- The torque reduced from 703.8 Nm for 0% corrosion to 423.17 Nm for 12% corrosion.
- This study shows degradation in bond behaviour dur to corrosion.

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