Effect of Ferrocement Jacketing on The Compressive Behaviour of Columns With Corroded Reinforcements

Dixant H. Ribadia
Department of Structure Engineering
L.J.I.E.T.

Abstract-*Corrosion of reinforcements is found to be one of the predominant reasons behind the limited service life of Reinforced Cement Concrete (RCC) structures, resulting in reduced load carrying capacity. Therefore, strengthening of deficient structural elements is necessary to increase the load carrying capacity and stiffness. Ferrocement jacketing is one of the efficient and cost effective techniques for strengthening deteriorated and weak columns. The present study deals with the behaviour of columns having corroded reinforcements of varying levels of corrosion such as 5%, 10% and 15% mass loss in reinforcements and the effect of ferrocement jacketing on its load bearing capacity. Total of 63 column specimens will be casted which will consist of 9 control specimen. The control specimen will be of non-corroded reinforcements in group of 3 each for concrete grade of M-20, M-25 and M-30. 27 columns will be casted with 9 columns in each grade of concrete. From 9 columns group of 3 columns for 5%, 10% and 15% corrosion reinforcement for same grade will be casted. Similar 9 columns for other two grades will be casted. For ferrocement jacketing another 27 columns will be casted and this will be jacketed with ferrocement and compared with the normal specimen for compressive strength of the specimen.*

Keywords-Corrosion,compressive behavior, retrofitting, ferrocement jacketing.

I. INTRODUCTION

For thousands of years, humans have taken advantage of ductile materials with high tensile strength in the reinforcement of brittle materials with high compressive strength. The ductile reinforcement transfers tensile loads in the structure, allowing the brittle material to crack without causing failure of the structure. Throughout the last two centuries, concrete has been developed into a construction material with ever increasing potential to support compressive forces. As the compressive capacity of concrete has increased and with it demands to support longer and larger and taller structures, stronger, more ductile and more tensile reinforcement has been required. Steel has been used to reinforce concrete since nearly its advent as a modern construction material, and is manufactured in the form of bars, plates, wire, and mesh. Ductility, strength, and chemical bond to concrete are just a few of the advantages steel provides as a reinforcing material. Unfortunately, steel is subject to corrosion in wet and salty environments, and the resulting damage causes the steel to weakenand lose some of its valuable properties. Encasing the steel in concrete increases the length of time before initiation of corrosion by forcing the chlorides to diffuse through the concrete to the depth of the steel. In the last fifty years, even this technique has proved to be inadequate, and corrosion induced deterioration of reinforced concrete structures has become a major issue. A Federal Highway Agency (FHWA) report from 1999 stated that "the cost of repairing or replacing deteriorated structures estimated to be more than $20 billion and to be increasing at $500 million a year has become a major liability for highway agencies”.

One technique that has been developed and implemented during the last thirty years involves coating the steel reinforcement with an epoxy polymer before the reinforcement is cast in the concrete. The coating provides an additional barrier that is resistant to corrosive elements and significantly increases the service life of reinforced concrete structures. Unfortunately minor drawbacks to this technique have also been encountered in evaluation of structures reinforced with epoxy-coated rebar in extremely harsh exposure conditions. Corrosion damage of reinforced concrete is a serious problem that needs to be addressed. This damage is a large drain on the economy. For exarnple, in 1986 the Ontario Ministry of Housing estimated there was a $1 billion plus cost for repair in the approximately 3000 existing parking structures.'-' Most of this damage is due to reinforcement corrosion. This is only one province and only refers to one type of structure, but shows the magnitude of the problem. Another exarnple would be the West Asia Gulf region where repairs, maintenance and reconstruction programs nui into the billions of dollars.'" Reinforced concrete corrosion is especially important as concrete is a widely used building material. By some estimates, approximately one ton of concrete is produced per person in the world per year.

One reason for this large repair cost is that the role of chlorides in corrosion was ignored in standards until the 1970's. In the United Kingdom, there was no limit on the chloride content of concrete mix water until 1972, while the AC1 code did not limit it until 1974. Limits on the chloride content of admixtures and of the concrete mix did not exist until the 1980's.Before this time there were a large number of buildings and parking garages erected, especially during the 1970's construction boom. This has led to an ageing infrastructure, with these buildings now running into difficulty. Thus, the repair bill is taking larger and larger proportions of the construction dollar. Twenty years ago, approximately 30 % of construction expenditures were for repairs. This compares to the current level of 50 %, with indications that this will increase to the year 2000 and beyond.14 given this large expenditure, any improvement in the efficiency of evaluation techniques has the potential for large savings. Thus more information regarding how different corrosion levels corrosion affect a structural member's capacity would be useful. It would help in evaluating corroded structures and determining the optimum time for repair when performing a life-cycle cost analysis. Ferrocement is a type of thin wall reinforced concrete commonly constructed by hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials. The fineness of the mortar matrix and its composition should be compatible with the mesh and armature systems it is meant to encapsulate. The matrix may contain discontinuous fibers.

Parking garages are a type of structure that often runs in to problems with corrosion. They are normally unheated; so to prevent ice formation de-icing salts are employed. These de-icing salts contain chlorides that dissolve in the melt water. Also, water often is allowed to collect because of poor drainage conditions. This lack of drainage may be due to poor design - e.g. insufficient dope of the slabs, improper construction 3 practices - e.g. misplaced drains, or lack of maintenance - e.g. not cleaning out the drains properly. Chlorides will then penetrate the concrete from the water and are able to attack the reinforcing steel. This causes corrosion. The common parking garage structure is a continuous flat slab. Thus, the steel contained in the slab is the flexural reinforcement. Once the steel is attacked, the moment capacity of the slab will be affected. This is a condition regarding which more information is needed. Thus, an investigation on the effect of corrosion on the flexural capacity of reinforced concrete slabs was undertaken.

II. MATERIAL PROPERTIES AND MIX PROPORTION

Materials conforming to Indian specifications were used for the study. Portland Pozzolona cement, crushed stones of 20mm coarse aggregate, manufactured sand passing through sieve size of 4.75mm and confirming to zone II of IS 383-1970 as fine aggregates were used. The mix design was done as per IS 10626-2009, to obtain M20,M25 and M30 grade concrete. Columns of size 1000x150x150mm were to be casted.

III. EXPERIMENTAL STUDY

Materials conforming to Indian specifications were used for the study. Portland Pozzolona cement, crushed stones of 20mm coarse aggregate, manufactured sand passing through sieve size of 4.75mm and confirming to zone II of IS 383-1970 as fine aggregates were used. The mix design was done as per IS 10626-2009, to obtain M20,M25 and M30 grade concrete. First of all the corrosion was induced in the reinforcements through hydrochloric acid which was 30%w/w and the process on which the reinforcements were to be dipped in the barrel of hydrochloric acid was decided as under :

$$log_{10}\left(\rho\frac{gm}{cm^2 \times min}\right) = log_{10}k + B \times log_{10}\left(concentration \times \frac{mol}{litre}\right)$$

ρ= rate of mass loss per area
K,B = constants

Equation data obtained from research paper

K = 1.1592 × 10^{-4}
B = 0.56

Concentration = 30% w/w HCL
= 30 gram HCL in 100 gram solution

Moles of HCL = $(mass\ of\ \ HCL)/(molecular\ weight)$

= 30/ 36.5
= 0.8219 moles

Volume of solution = mass/density
= 100/1.1493
= 87.0095 ml
= 87.0097 × 10^{-3} litres

So, concentration of 30% HCL solution = molesof HCL/ vol of solution
= 0.8219/87.0095× 10^{-3}
= 9.4438 moles/litre

So,

$$log_{10}\left(\rho \frac{gm}{cm^2 \times min}\right) = log_{10}(1.1592 \times 10^{-4}) + 0.56 \times log_{10}(9.4438 \times \frac{mol}{litre})$$

$$log_{10}\left(\rho \frac{gm}{cm^2 \times min}\right) = -3.4989$$

$$\rho = 3.1703 \times 10^{-4} \frac{gm}{cm^2 \times min}$$

Total mass of rod = $\frac{d^2}{162}$ kg

= 100/162 kg
= 617.284 grams

5.3.1 Time taken to induce 5% corrosion :

Mass to corrode= 5% of total mass

= 5/100 X 617.284 grams

= 30.864 grams

Surface area of rod = $2\pi rl + 2\pi r^2$

$= \pi dl + \frac{\pi}{2} d^2$

$= \pi \times 1cm \times 100cm + \frac{\pi}{2} \times 1^2 cm^2$

= 315.730 cm^2

Rate of mass loss per area, $\rho = \frac{\frac{mass}{Area}}{time}$

Time = $^{Mass}/_{Area \times \rho}$

= $^{30.864}/_{315.730 \times 3.1703 \times 10^{-4}}$

Time for corrosion = 308.345 min

= 5 hours 10 min approx.

1) 5.3.2 Time taken to induce 10% corrosion :

Mass to corrode= 10% of total mass

= 10/100 X 617.284 grams

= 61.72 grams

Surface area of rod = $2\pi rl + 2\pi r^2$

$= \pi dl + \frac{\pi}{2} d^2$

$= \pi \times 1cm \times 100cm + \frac{\pi}{2} \times 1^2 cm^2$

= 315.730 cm^2

Rate of mass loss per area, $\rho = \frac{\frac{mass}{Area}}{time}$

Time = $^{Mass}/_{Area \times \rho}$

= $^{61.72}/_{315.730 \times 3.1703 \times 10^{-4}}$

Time for corrosion = 616.60 min

= 10 hours 20 min approx.

2) 5.3.3 Time taken to induce 15% corrosion :

Mass to corrode= 15% of total mass

= 15/100 X 617.284 grams

= 92.59 grams

Surface area of rod = $2\pi rl + 2\pi r^2$

$= \pi dl + \frac{\pi}{2} d^2$

$= \pi \times 1cm \times 100cm + \frac{\pi}{2} \times 1^2 cm^2$

= 315.730 cm^2

Rate of mass loss per area, $\rho = \frac{\frac{mass}{Area}}{time}$

Time = $^{Mass}/_{Area \times \rho}$

= $^{92.59}/_{315.730 \times 3.1703 \times 10^{-4}}$

Time for corrosion = 925.1 min

= 15 hours 30 min approx.

After the inducing of corrosion the columns were casted in which the corroded reinforcements were used. Total 63 columns were casted in which the grade of concrete used were M20, M25 and M30. Nine control specimen of each grade were made

	5% corrosion	10% corrosion	15% corrosion
M-20	3	3	3
M-25	3	3	3
M-30	3	3	3
M-20 jacakted	3	3	3
M-25 jacaketed	3	3	3
M-30 jacaketed	3	3	3

The failure load of all the non jacketed columns were tested and then the columns were jacaketed with ferrocement with 1:2 ratio of cement and sand and wire mesh. After curing the jacaketed columns for 4 days and then the failure load of the jacakted columns were tested accordingly.

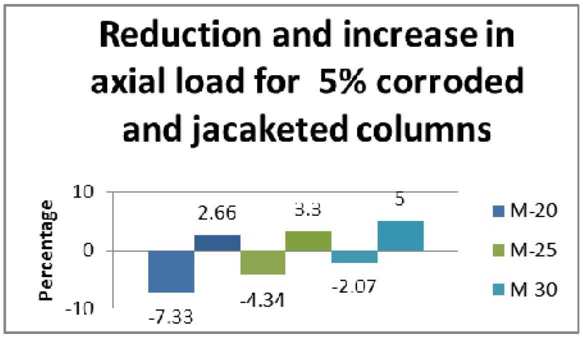
VI.RESULT

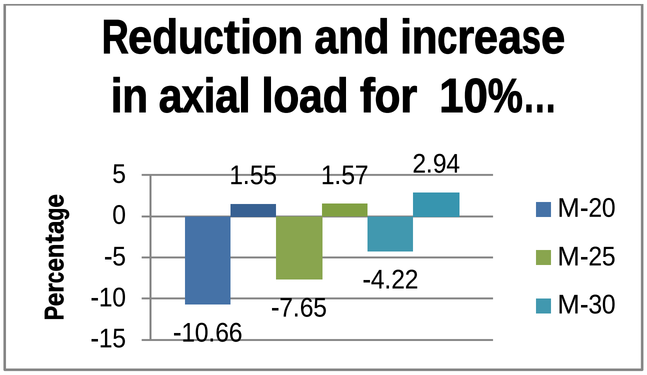
COLUMNS	M-20	M-25	M-30
Normal Specimen	450	575	678
5% corroded reinforcements	417	550	661
10% corroded Reinforcements	402	531	647
15% corroded reinforcements	378	517	621
5% corroded reinforcements jacketed with ferrocement	462	594	742
10% corroded reinforcements jacketed with ferrocement	457	584	726
15% corroded reinforcements jacketed with ferrocement	429	562	698

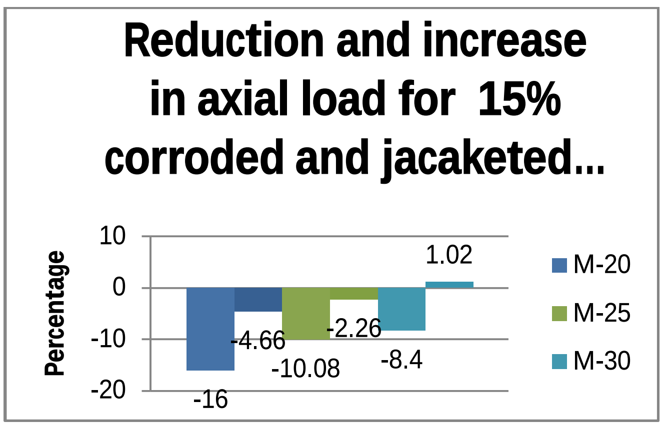
The test result of compressive strength obtained were as shown above.

V.CONCLUSION

The conclusion that has been obtained from above results is that corrosion on the higher grade of concrete is affected less than that of the lower grade of concrete. Also after ferrocement jacaketing on the columns the effect of it is more on 5% corroded specimens than on 15% corrosion because the failure load increases more than that of normal specimen had obtained.







REFERENCES

[1] A. B. M. Amrul Kaisha, M. R. Alamb," Ferrocement Jacketing for Restrengthening of Square Reinforced Concrete Column under Concentric Compressive Load", Published by Elsevier Ltd. , 2013

[2] Jin Xia, Ph.D. ; Wei-Liang Jin, Ph.D.," Performance of Corroded Reinforced Concrete Columns under the Action of Eccentric Loads", American Society of Civil Engineers, 2015

[3] Mohammad Ismail *, Bala Muhammad," Compressive strength loss and reinforcement degradations of reinforced concrete structure due to long-term exposure", elsweir, 2010.

[4] P. Paultre, M.ASCE1; R. Eid ; Y. Langlois"Behavior of Steel Fiber-Reinforced High-Strength Concrete Columns under Uniaxial Compression"ASCE, 2011

[5] Engr. Azam Amir, Dr. AmjadNaseer, Engr. Orooj Azam," Strengthening of Existing Building Column Using FRP Wrap& GI Wire Mesh", IJSE, 2013

[6] IS Code 456:2000

[7] IS Code 10262:2009