International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 07
June 2019

Behaviour of Reinforced Concrete In Case Of Corrosion under Serviceability According To Is 456

REKHA GUPTA & Dr. J N VYAS

Civil Engineering, RGPV/Mahakal Institute of Technology & Management, Ujjain M.P. ,India

guptarekha893@gmail.com

Civil Engineering, RGPV/Mahakal Institute of Technology & Management, Ujjain M.P. ,India

ABSTRACT

Reinforcement corrosion is a common cause of deterioration of cement in reinforced concrete. The corrosion mechanism involved and the consequent structural behaviour of deteriorated reinforced concrete members have been studied by several researchers. Nevertheless, the knowledge obtained is primarily based on experimental investigations of artificially corroded specimens whereas natural corrosion may affect structural behaviour differently. This paper aims to deepen the numerical understanding of the structural effects of natural corrosion deterioration with a focus on the remaining anchorage capacity between deformed bars and concrete, as well as the investigation of possible links between visual inspection data and structural damage.

INTRODUCTION

Current predictive models assume that the concrete is uncracked. However, it is generally accepted that cracks, which are normally present in field concrete, promote more rapid penetration of aggressive agents (carbon dioxide, chloride) and may thereby adversely affect long-term integrity.

When dealing with corrosion in cracks, two different mechanisms are possible:

• Microcell corrosion; the anodic and cathode processes take place only in the cracked zone. The anodes and cathodes are very small and can hardly be separated. The oxygen supply to the cathodes is through the crack.

• Macro cell corrosion; the reinforcement within the crack-zone acts mainly as an anode and the passive steel surface outside the crack acts as cathode. The oxygen transport to the cathode takes then place mainly through the uncracked concrete area.

Converting corrosion rate to cracking and delaminating rate requires assumptions about expansive oxide growth and stresses required for cracking. Of course, these simple time-to-cracking predictions are only indicative and should be used with

International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 07
June 2019

care. It is assumed an on-going uniform rebar corrosion and an average rust expansion ratio of 3 (relative to metallic iron), i.e. the volume of rust occupies three times that of the original steel. Further, it is assumed that 50 µm section losses gives rise to cracking. This is in the range of tests results reported by Broomfield [2003]. A schematic illustration is shown in Fig.1. Based on these simple assumptions and Eq. 2.6 ($V_{corr}=11.6\cdot i_{corr}$), corrosion rates can be converted to annual rust growths and the time needed to cause cover cracking by the expansive oxides.

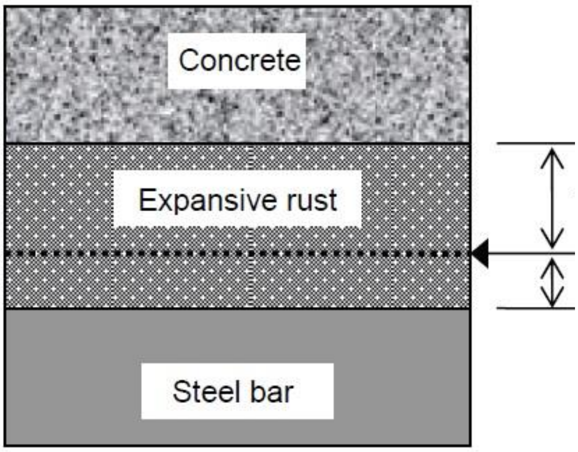

Figure1 Schematic illustration of corroding rebar and expansive rust: 50 µm section lossof steel. Rust volume is three times that of the corroded steel (150 µm)

Steel corrosion

Electrochemical process during which coupled anodic and cathodic reactions take place.In this paper will describe steel corrosion models for uniform and localized corrosion.

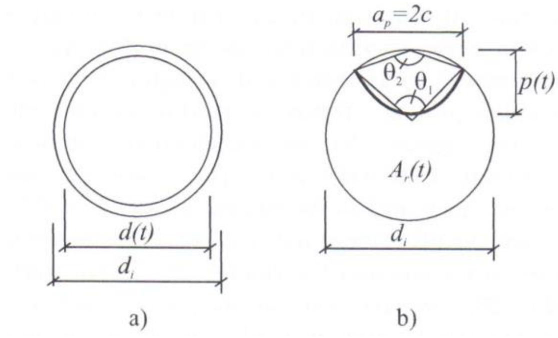

Figure2: a) uniform corrosion b) pitting corrosion

Model of corrosion 1

This model is used for the prediction of uniform corrosion. The formula for the time related net rebar diameter *d(t)* in exposure time *t* [years] reads

$(t)=\{di\varphi[di-0.0116icorrRcorr(t-ti)]$
$1)\leq ti$
$2)<t<ti+di/0.0116icorrRcorr$
$3)>ti+di0.0116icorrRcorr$

Where φ is the uncertainly factor of the model [-], *di* is the initial bar diameter [mm], *t* = *ti* + *tp* where *ti* is the time to corrosion initiation, i.e. depassivation, and *tp* is the time of corrosion propagation, parameter *Rcorr* [-] express the type of corrosion. For uniform corrosion the coefficient *Rcorr* equals 2. By the coefficient *Rcorr* also the effects of chloride concentration, pH level or other conditions may be described, whenever applicable. *icorr* is the current density (normally expressed in µA/cm2). For uniform corrosion, a mean value can be considered as 1 µA/cm2 or calculated according to (Petersson, 2004). This formula describes the dependence of *icorr* on time derived on the basis of experiments for RC flexular members as:

Model of corrosion 2

This model is used for localized corrosion. The studies by Gonzales show that the maximum rate of corrosion penetration in the case of pitting corrosion is 4-8 times that of general corrosion. The depth of pit *p(t)*[mm] at time *t* [years] can be estimated by the following equation

(t)=[0.0116$icorrRcorr(t-ti)$]

Where φ is the uncertainly factor of the model [-],$t = ti + tp$ where ti is the time to corrosion initiation and tp is the time of corrosion propagation. For $ti < tp$, $p(t) = 0$. Corrosion current *icorr* 9 is taken as 3 µA/cm2 to mm/years under the assumptions that steel (Fe) has $n = 2$ (number of electrons freed by the corrosion reaction), $M = 55.85$ g (atomic mass) and $d = 7.88$ g/cm3.

MODELLING & ANALYSIS

There is a growing need for reliable methods to predict the load-carrying capacity and remaining service life of deteriorated reinforced concrete (RC) structures as a decision basis for optimized maintenance and repair strategies. In an ongoing research project, the load-carrying capacity of deteriorated RC structures is studied. The part of the project presented herein is focused on deterioration due to the corrosion of reinforcement. The corrosion of steel reinforcement is one of the most common causes of deterioration of RC. The corrosion process transforms steel into rust, leading to

1) an area reduction of the reinforcement bars

2) volume expansion that generates splitting stresses in the concrete, which may crack and spall the concrete cover and affect the bond between the reinforcement and the concrete.

MATERIAL PROPERTIES

M-25 grade of concrete and Fe-415 grade of reinforcing steel are used for all the frame models used in the study. Elastic material properties of this material are taken as per Indian standard IS 456 (2000). The modulus of elasticity of concrete (E_c) of concrete is taken as.

$$E_c=5000\sqrt{fck}\text{ MPa.}$$

- Split or tensile strength of concrete shall be obtained as described in IS 516 and IS 5816 respectively.

Flexural strength, $F_{cr}=0.7\sqrt{fck}$ MPa.

- Mild steel and medium tensile steel bar conforming to IS 432 (part 1)
- The modulus of elasticity of steel shall be taken as 200 KN/mm^2

Table3.1 Material List (concrete)

Name	concrete	
Type	Homogeneous	
Colour		
Structural	Elastic Modulus	2.50000e+007
	Poisson's Ratio	1.50000e-001
	Coefficient	1.00000e-006
	Mass Density	2.40000e+000
	Ref. Temperature	2.70000e+001
Thermal	Conductivity	0.00000e+000

	Specific Heat	0.00000e+000
	Heat Gen.Factor	1.00000e+000
Factor of Safety Calculation	Failure Theory	Principal Stress (Brittle)
	Tension	3.50000e+003
	Compression	1.67500e+004
Damping Factors	Mass Proportional Damping	0.00000e+000
	Stiffness Proportional Damping	0.00000e+000
	Structural Damping Coefficient	0.00000e+000

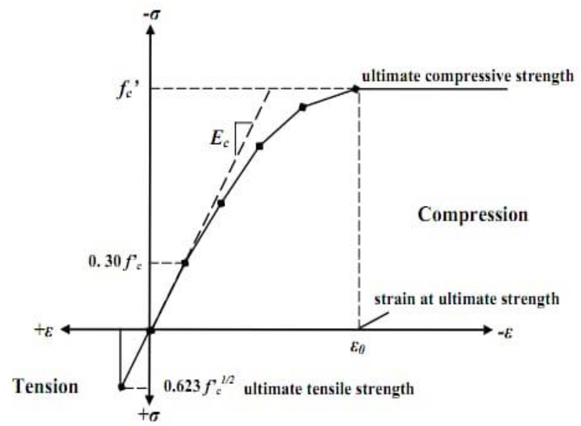

Figure3.1: Stress-Strain curve of concrete

Table3.2 Material List (Steel)

Name	Steel	
Type	Isotropic	
Colour		
Structural	Elastic	2.06940e+00
	Modulus	8
	Poisson's Ratio	2.88000e-001
	Coefficient	1.17900e-005
	Mass Density	7.82900e+000
	Ref. Temperature	2.00000e+001
Thermal	Conductivity	5.56720e+001
	Specific Heat	0.00000e+000
	Heat Gen.Factor	1.00000e+000
Factor of Safety Calculation	Failure Theory	Von Mises Stress (Ductile)
	Tension	2.57790e+005
	Compression	0.00000e+000
Damping Factors	Mass Proportional Damping	0.00000e+000
	Stiffness Proportional Damping	0.00000e+000
	Structural Damping Coefficient	0.00000e+000

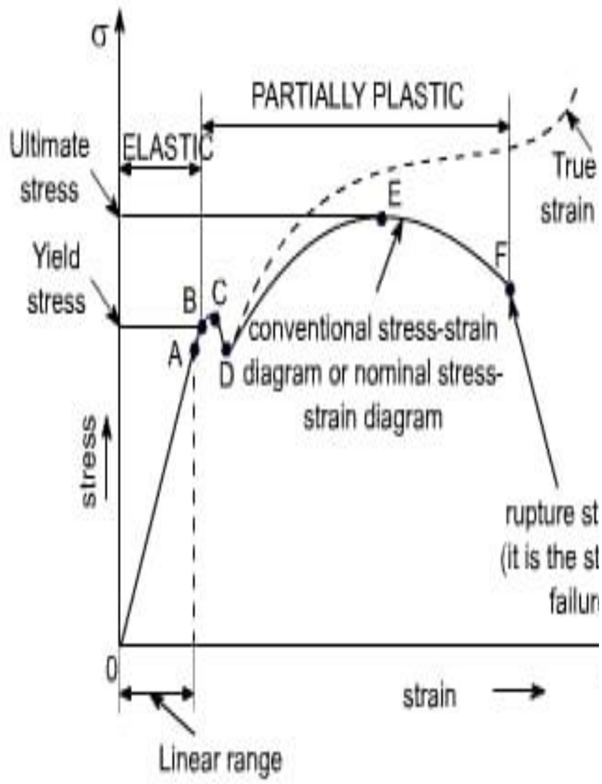

Figure3.2: Stress-Strain curve of steel

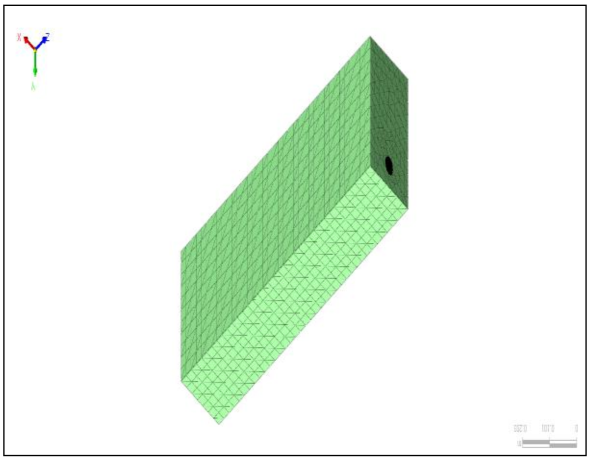

Figure3.3: Material property colour of concrete and steel in Midas NFX

RESULTS AND DISSCUTIONS

GENERAL

Finite element analysis conducted over all corroded and non-corroded Reinforced concrete models using Midas NFX. The different results are obtained after the analysis are presented and discussed in this chapter.

Case A. Fixed End Beam

Deflection Vs % Corrosion

According to IS 456:2000 deflection of a structure or part there of shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall generally be limited to the following

- The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.
- The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

Table 4.1: load vs deflection value of all models

Model	Beam specimen with corrosion level %	ultimate load (kN)	deflection at mid span (mm)
Model 1	0%	230	6.1
Model 2	5%	210	6.73
Model 3	7.50%	175	7.2
Model 4	10%	160	7.7

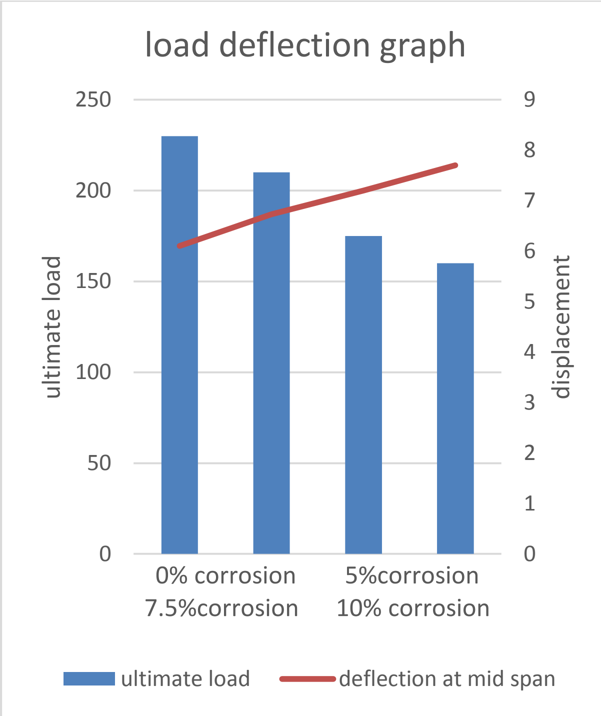

Figure 4.1: load vs deflection value of all models

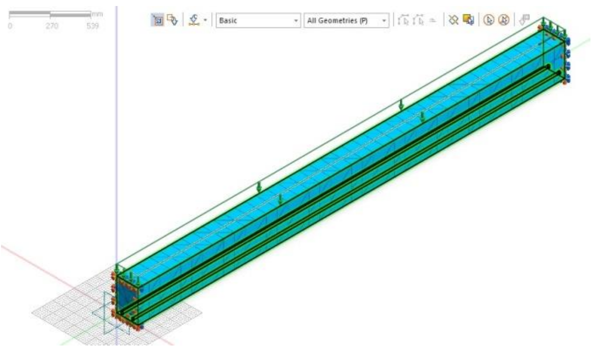

Figure 4.2: 3-D Load pattern in all models

TOUGHNESS

One measure of toughness in beams is the area under the load vs. deflection curve. A best fit line was calculated for each load-deflection curve, and then integrated over the range of the deflection. These values for toughness can be found in Table 4.2. It can be seen in Figure 4.3

Table 4.2: Toughness Vs corrosion

% Corrosion	Toughness
0%	701.5
5%	706.65
7.5%	630
10%	616

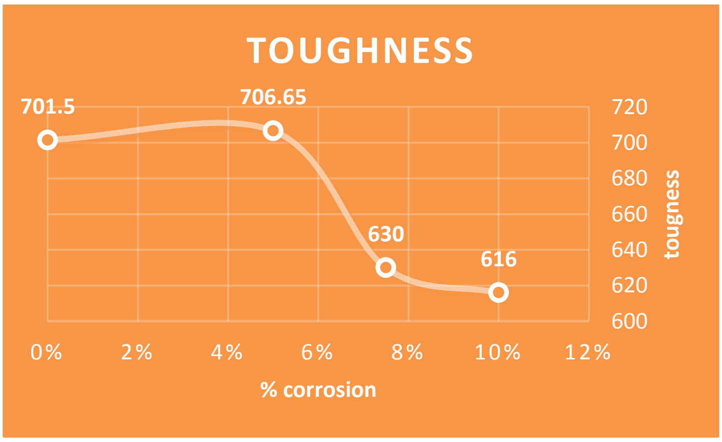

Figure 4.3: Toughness Vs corrosion

CONCLUSIONS

The results of 3-dimensional modelling of concrete beam structure from Midas NFX software with the help of IS1893. Eight different models having constant Beam Cross-sectional area and same plan section are prepared by software with the help of IS code and comparative analysis studied between them. This project has introduced corrosion in concrete structure which analysing to determine its structural performance.

- From corrosion analysis on all four models of fixed beam target deflection in **model4** in Z-direction are comparatively higher than of others all **models** due to the higher percentage of corrosion in model4 as compare to other models.

- From corrosion analysis on all four models of cantilever beam target deflection in **model4** in Z-direction are comparatively higher than of others all **models** due to the higher percentage of corrosion in model4 as compare to other models.
- Toughness of **model 2 in case of fixed beam** is 100.7% of model1, 112.16% of model3 and 114.69% of model4 because of load vs deflection of beam in model2 is higher as compare of other all models.
- Toughness of **model1 in case of cantilever** is 102.52% of model2, 104.28% of model3 and 100.74% of model4 because of load vs deflection of beam in model4 is higher as compare of other all models.

References

[1] Andrade C, Alonso C. Cover cracking as a function of bar corrosion: part I – experimental test. Mater Struct 1993;26(8):453–64.

[2] Molina FJ, Alonso C, Andrade C. Cover cracking as a function of rebar corrosion: part 2 – numerical model. Mater Struct 1993;26(9):532–48.

[3] Bhargava K, Ghosh AK, Mori Y, RamanujamS.Modeling of time to corrosion induced cover cracking in reinforced concrete structures. Cement Concrete Res 2005;35(11):2203–18.

[4] Dagher HJ, Kulendran S. Finite element modeling of corrosion damage in concrete structures. ACI Struct J 1992;89(6):699–708.

[5] Li CQ, Melchers RE, Zheng JJ. Analytical model for corrosion induced crack width in reinforced concrete structures. ACI Struct J 2006;103(4):479–87.

[6] Ohtsu M, Yosimura S. Analysis of crack propagation and crack initiation due to corrosion of reinforcement. Constr Build Mater 1997;11(7-8):437–42.

[7] Hansen EJ, Saouma VE. Numerical simulation of reinforced concrete deterioration – part II: steel corrosion and concrete cracking. ACI Mater J 1999;96(3):331–9.

[8] Liu Y, Weyers RE. Modeling the time to corrosion cracking in chloride contaminated reinforced concrete structures. ACI Mater J 1998;95(6):675–81.

[9] Nam J, Hartt WH, Kim K. The effects of cement alkalinity upon the pore water alkalinity and the chloride threshold level of reinforcing steel in concrete. J Korea Concrete Inst 2004;16(4):549–55.

[10] Kranc SC, Sagu¨e´s AA. Detailed modeling of corrosion macrocells on steel reinforcing in concrete. Corr Sci 2001;43(7):1355–72.

[11] Isgor OB, Razaqpur AG. Modeling steel corrosion in concrete structures. Mater Struct 2006;39(3):291–302.

[12] Maruya T, Hsu K, Takeda H, Tangtermsirikul S. Numerical modeling of steel corrosion in concrete structures due to chloride ion, oxygen and water movement. J Adv Concrete Technol 2003;1(2):147–60.

[13] Raupach M, Warkus J, Yamaguchi T. Numerical modeling of reinforcement corrosion. Proceedings of the ESCS 2006, Espoo Finland; p. 282–88.

[14] Kranc SC, Sagu¨e´s AA. Computation of reinforcing steel corrosion distribution in concrete marine bridge substructures. Corr Sci 1994;50(1):50–61.

[15] Gulikers J. Numerical modeling of reinforcement corrosion in concrete. In: Corros Reinforced Concrete Struct. Woodhead Publishing Limited, CRC Press; 2005. p. 71–90.

[16] Oh BH, Jang BS. Chloride diffusion analysis of concrete structures considering effects of reinforcements. ACI Mater J 2003;100(2):143–9. [17] Hansen EJ, Saouma VE. Numerical simulation of reinforced

concrete deterioration – part I: chloride diffusion. ACI Mater J 1999;96(2): 173–80.

[18] Uhlig HH, Revie RW. Corrosion and corrosion control. John Wiley and Sons; 1985. p. 35–59.

[19] Papadakis VG, Vayenas CG, Fardis MN. Physical and chemical characteristics affecting the durability of concrete. ACI Mater J 1991;88(2):186–96.

[20] Oh BH, Jang SY. Prediction of diffusivity of concrete based on simple analytic equations. Cement Concrete Res 2004;34(3):463–80.

[21] Saleem M, Shameem M, Hussain SE, Maslehuddin M. Effect of moisture, chloride and sulphate contamination on the electrical resistivity of Portland cement concrete. Constr Build Mater 1996;10(3):209–14.

[22] Mohammed TU, Hamada H. Corrosion of steel bars in cracked concrete: very beginning to the early age of exposure. ACI SP 235, 2006. p. 103–23.

[23] Gonza´lez JA, Andrade C, Alonso C, Feliu S. Comparison of rates of general corrosion and maximum pitting penetration on concrete embedded steel reinforcement. Cement Concrete Res 1995;25(2):257–64.

[24] Torres-Acosta AA, Madrid MM. Residual life of corroding reinforced concrete structures in marine environment. J Mater Civil Eng 2003;15(4):344–53.

[25] Jang BS. Life time estimation method of reinforced concrete structures considering the effects of reinforcements on the chloride diffusion and the non-uniform corrosion distribution. Ph.D. Thesis, Department of Civil Engineering, Seoul National University, 2001.