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Investigation on Load Carrying Capacity of Corroded NBS RC Beam Using Finite Element method

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ABSTRACT : *Chloride ingress into the concrete is à major cause of steel corrosion. This leads to breakdown of passive film layer present over the surface of steel bar and consequently initiation of corrosion take place. This reduces the strength and serviceability of RC structure. Present paper deals with the study of load carrying capacity and load deflection behavior of NBS RC beam under different levels of corrosion. To overcome the problems of time consuming and experimental cost, finite element methods are used to simulate the real life problems and analysis of present study is carried out using FE method. It is observed that for every percentage increase in corrosion level there is about 1.8% decrease in load carrying capacity.*
Keywords - *Load, Corrosion, Deflection, RC beam, Solid65, Link8, Concrete, Reinforcement*

1. INTRODUCTION

Reinforced concrete structures are widely preferred construction in civil engineering. At the same time maintenance of the structures is also important. But at the long run reinforcement corrosion directly affects the safety and durability of concrete structures. To understand and overcome these problems, study on effect of reinforcement corrosion is carried out.

The experimental method that produces real life response is often extremely time consuming and the use of materials can be quite costly [1]. To minimize these costs, use of finite element method (FEM) has become popular. However to get an idea about the finite element software complete understanding of experimental methodology is necessary.

Finite element analysis is a numerical approach widely applied to the concrete structures based on the use of the nonlinear behaviour of materials. An effective method to analyze the load carrying capacity of corroded reinforced concrete components is Numerical analysis [2].

As long as the discrete element size is suitable and the constitutive relation is correct, the model results will reach the real value and engineering requirements will be satisfied.

In the present paper an effort has been made to study the load carrying capacity and load deflection behavior of corroded specimens using FE method for National Bureau of Standard (NBS) beam. Corrosion rates of 0%, 2.5%, 5%, 7.5% and 10% were considered for the study.

2. FINITE ELEMENT MODEL

The FE model of a NBS RC beam is selected for the study on load carrying capacity and deflection of corroded RC beams [Fig. 1]. The beam span is 2.4m and the dimensions of its cross-section are 0.230m×0.457m. The concentrated load is applied on both sides of the mid-span and the distance from the mid-span to support section is 747mm.

2.1 Element for Concrete

To Model the concrete Solid65 element is used. This element has eight nodes with three degrees of freedom at each node – translations in the nodal X, Y, and Z directions. This element is capable of plastic deformation, cracking in three orthogonal directions, and crushing [3]. A schematic of the element is shown in Fig. 2.

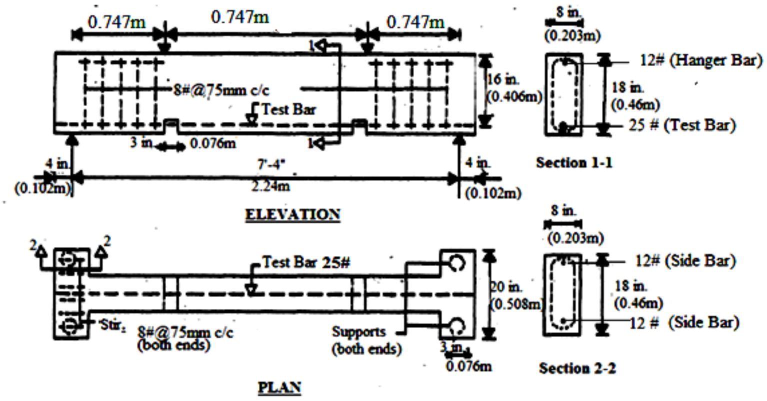

Fig. 1: Reinforcement details of NBS beam specimen

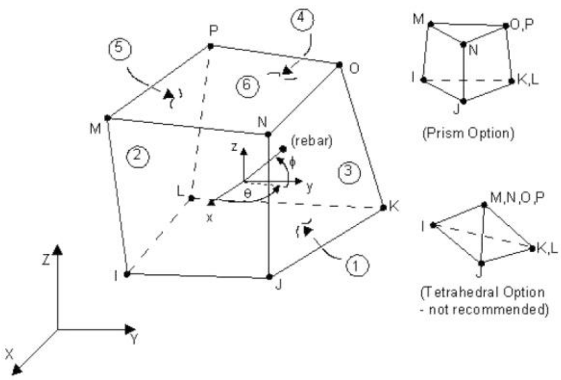

Fig. 2: SOLID65 Element

Steel reinforcement is modeled using Link8 element. This element is a 3D spar element and it has two nodes with three degrees of freedom – translations in the nodal X, Y, and Z directions [3]. This element is also capable of plastic deformation. This element is shown in Fig. 3. Due to corrosion there will be increase of slip at the bar concrete interface. To consider that effect nonlinear spring element combin39 is adopted.

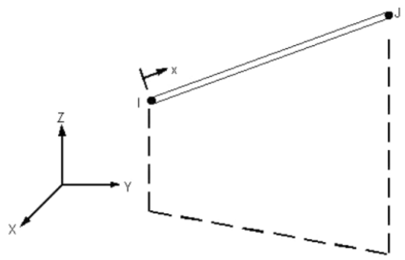

Fig. 3 LINK8 Element

2.2 Real Constant

Real constant set 1 is defined for the Solid 65 element. In the present study the beam is modelled using discrete reinforcement. Therefore, a value of zero is entered for all real constants, which turns the smeared reinforcement capability of the Solid65 element off. Real Constant Sets 2 is defined for the Link8 element. Values for cross-sectional area and initial strain are entered as follows,

- Set 2: Cross sectional area of 25 mm bar : 490.87mm^2
- Set 3: Cross sectional area of 12 mm bar: 113.10mm^2.
- Set 4: Cross sectional area of 8mm two legged stirrups: 50.27mm^2

A value of zero is entered for the initial strain because it is assumed that there is no initial strain in the reinforcement.

2.3 Material Models

In this model, the Solid65 element is adopted as concrete element whose initial elastic modulus is 29342.80N/mm^2. Poisson ratio is 0.2. Following equations is used to compute the multilinear isotropic stress-strain curve for the concrete [4].

$$f = \frac{E_c \varepsilon}{1 + \left(\frac{\varepsilon}{\varepsilon_0}\right)^2} \tag{1}$$

$$\varepsilon_0 = \frac{2 f_{ck}}{E_c} \tag{2}$$

$$E_c = \frac{f}{\varepsilon} \tag{3}$$

where; ε_0 =ultimate strain; f *is* the stress at any strain ε; E_c =Modulus of Elasticity of concrete; ε =Assumed strain values in between initial and final strain values, f_{ck} =characteristic compressive strength.

Multi linear isotropic stress-strain curve based on above calculation is shown in Fig. 4. The uniaxial compressive strength is 34.44 N/mm^2, the uniaxial tensile strength is 4.1N/mm^2, crack opening shear transfer coefficient is 0.3, crack closing shear transfer coefficient is 0.95.

Elastic modulus of Link8 element (rebar) is 2×10^5 N/mm^2 and its Poisson ratio is 0.3. The yield strength of the bottom bar is 485 N/mm^2 was adopted for the bar element. Combin39 element is incorporated between the reinforcement and concrete nodes.

For different levels of corrosion study i.e., 2.5%, 5%, 7.5% and 10%; cross-sectional area for rebar is reduced when compared with controlled beam model; due to corrosion of reinforcement the cross-sectional area was reduced [5]. NBS beam model in ANSYS is shown in Fig. 5.

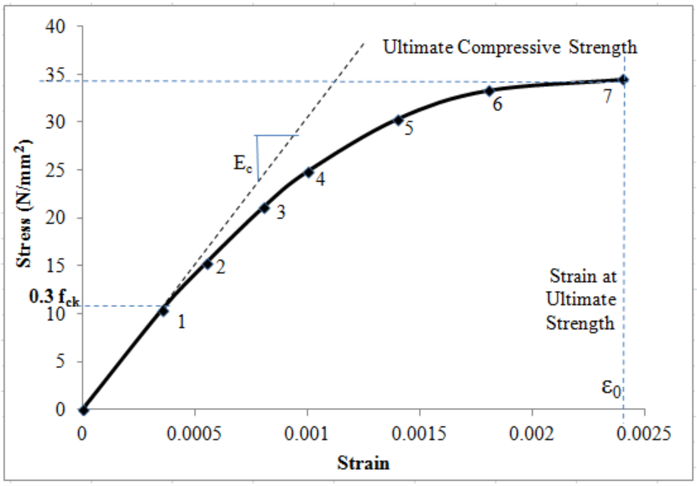

Fig. 4: Uniaxial Stress-Strain Curve

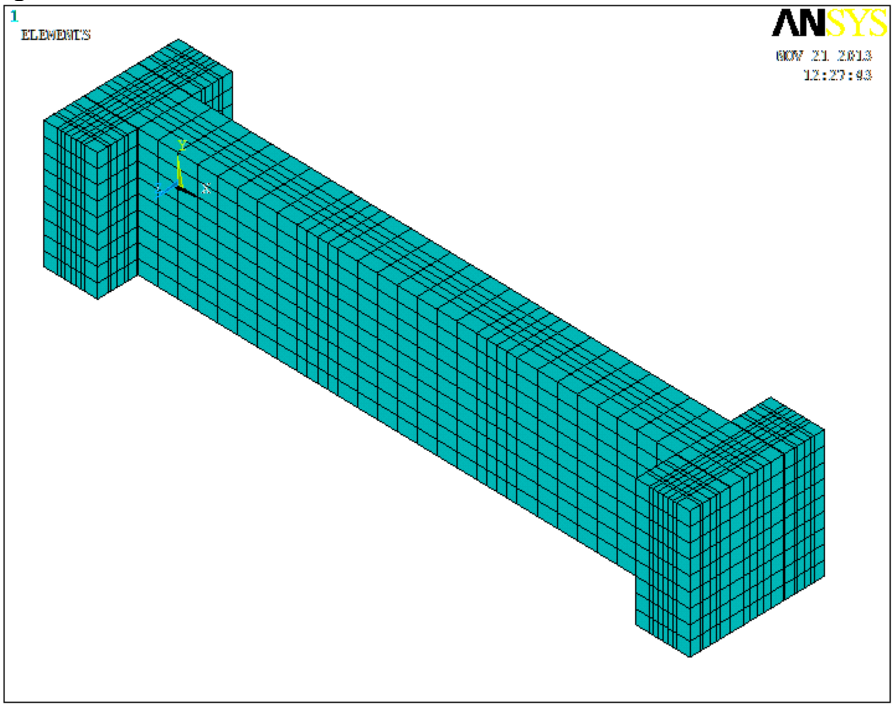

Fig. 5: NBS beam model in ANSYS

2.4 Loads and Boundary Conditions

To get the unique solution constraining the models using displacement boundary conditions same ways as that of experimental beam, accurate modelling of boundary conditions are very much necessary.

Supports are modelled such a way that a roller is created. A single line of nodes on the beam are given constraint in the Translation in Y and Z directions, applied as constant values of 0. By doing this, the beam will be allowed to rotate at the support and translations in X direction. Loading and support conditions are shown in Fig. 6.

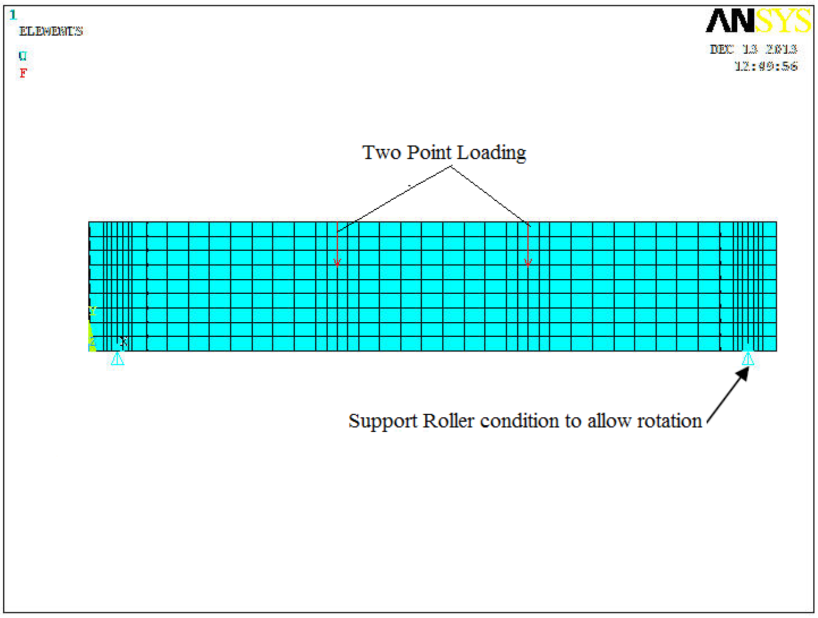

Fig. 6: Support and Loading conditions of NBS beam specimen

3. RESULTS AND DISCUSSION

Load deflection values are noted and results are shown in Fig. 7 and Fig. 9. View of deflection for control beam specimen is shown in Fig. 8.

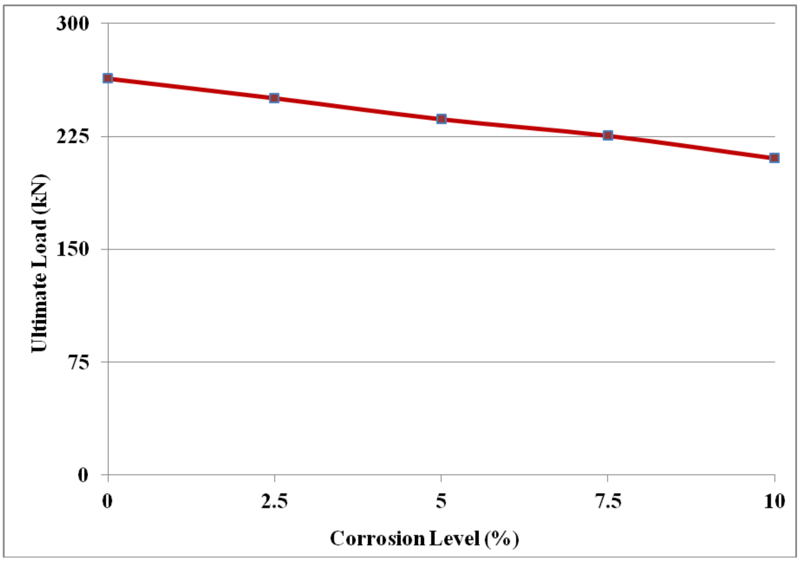

Fig.7: Effect of corrosion on ultimate load carrying capacity

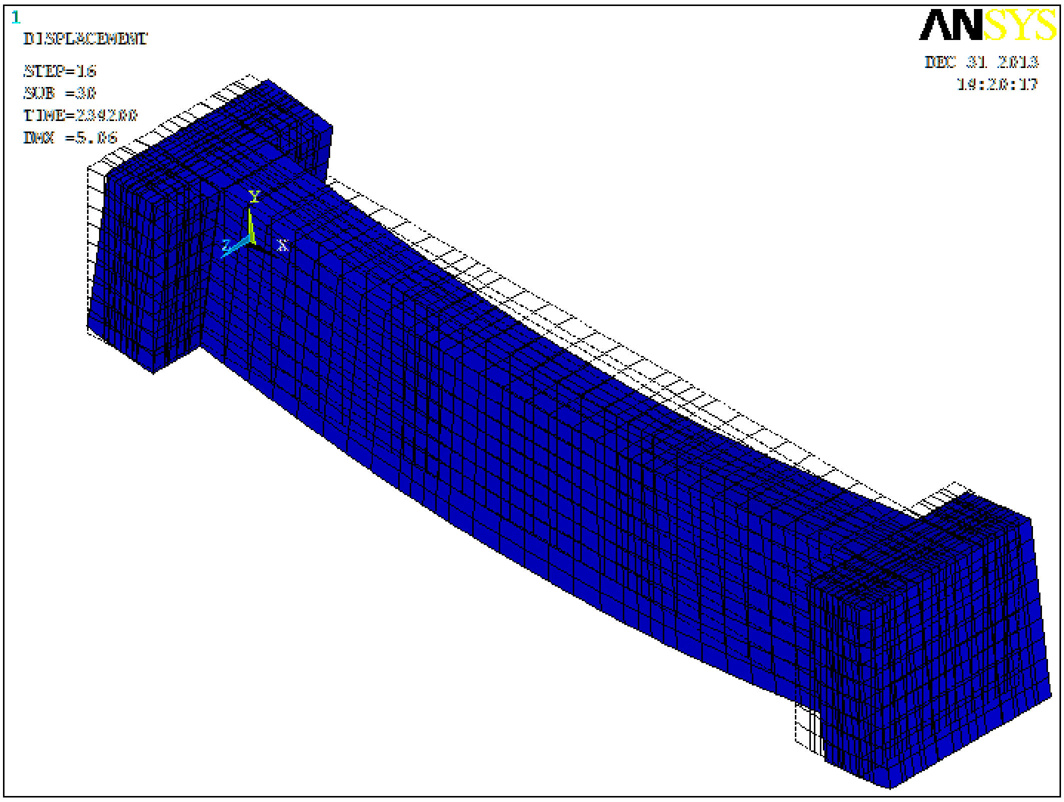

Fig. 8: View of Deflection for control beam specimen

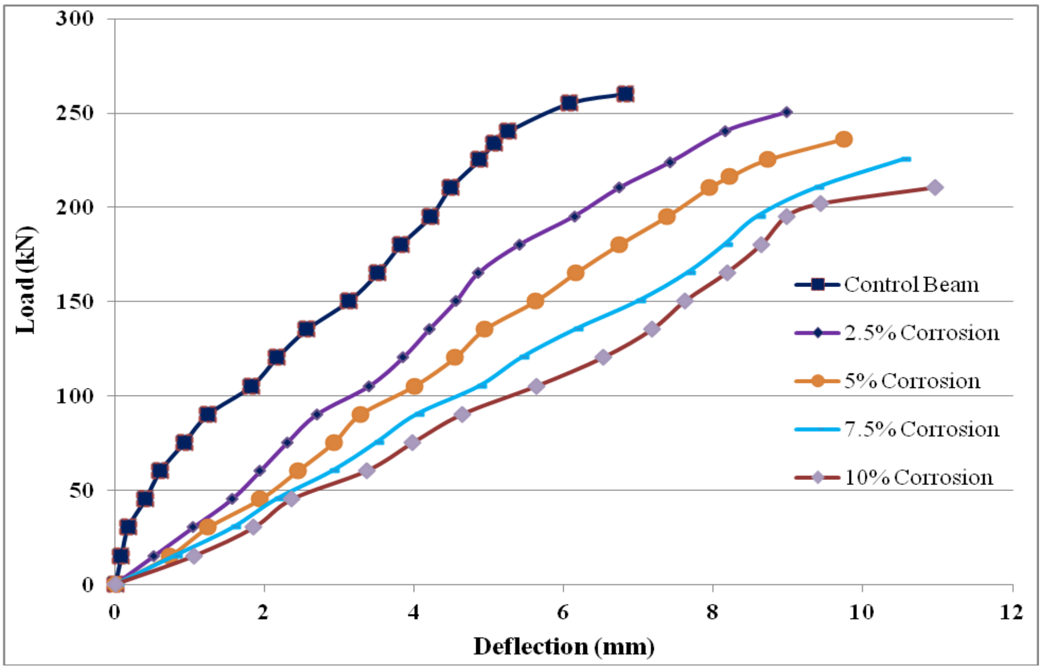

Fig. 9: Effect of corrosion on central deflection behavior of NBS beam specimens

From Fig. 7 it is observed that as the corrosion level increases load carrying capacity decreases. For every percentage increase in corrosion level there is about 1.5% decrease in the load carrying capacity. From Fig. 9 it is seen that as the load level increases, tensile cracks in the concrete appear and load-deflection curves change. Further deflection values increase rapidly. Control beam specimen performs better than corroded beam specimens. Also, as the corrosion level increases deflection value increases.

4. CONCLUSIONS

- As the corrosion level increases there is a reduction in load carrying capacity.
- For every percentage increase in corrosion level there is about 1.9% decrease in the load carrying capacity.
- Control beam specimen performs better than corroded beam specimens.
- As the corrosion level increases deflection value increases.

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