COUPLED CORROSION AND FATIGUE EFFECTS IN REINFORCED CEMENT CONCRETE MEMBERS USING MULTI-PHYSICS APPROACH

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Abstract

Coupled corrosion fatigue phenomenon causes the reinforced concrete structures to fail prematurely, leading to a brittle type of failure. In this paper, numerical simulation using commercially available FE solvers is performed to understand the behaviour of reinforced cement concrete members under the coupled effects of fatigue and corrosion.

1. Introduction

Generally, reinforced concrete (RC) is the most preferred material for structural members in building, bridges, and offshore structures etc. Wide range of coastal RC structures, which includes RC bridges, offshore plates, and mobile drilling structures are subjected to cyclic loads in corrosive environment. Under the coupled effect of corrosion and fatigue, the structural performance deteriorates, and the fatigue life is significantly reduced, failure is sudden and without warning. Due to rapid urbanization, there is a steady increase in traffic, leading to a tremendous increase in loading on the existing infrastructures even after the design life of the structure, thereby putting a question mark on safety and stability issue. Both fatigue and reinforcement corrosion in concrete itself are very complex phenomenon to understand due to material non-linearity of concrete. There are very few studies which explores the effect of coupled corrosion fatigue and corrosion. This paper uses the Multiphysics FE solver to simulate above said coupled effect and predict the damage and residual life of reinforced concrete structures.

2. Results

In this work, a reinforced concrete strut of a prestressed bridge in Prague, which was tested after 32 years of service has been taken into consideration to investigate the coupled effect of corrosion and fatigue. As reported by Hajkova et al. [1], reinforced concrete strut is used to support the girder of bridge and exposed to de-icing salts regularly. De-icing salts are primary source of chlorides wherever used. Its lower part is simulated to study the effects due to chloride ingress. Firstly, the chemo-mechanical model proposed by Hajkova et al. [1] has been validated on a structural member subjected to chloride salts. Different crack widths are considered namely uncracked i.e. $w = 0$, $w = 0.05mm$, $= 0.1mm$. To introduce cracks in pedestal a deflection of $1mm$ is given in initial step. The geometry, material properties and chloride profile used are the same as reported by [1]. Measured value of chloride concentration at cover depth is 0.51% of binder content and reinforcement remaining ratio 0.95. In case of crack width 0.05mm the simulated results are in line with the measured values.

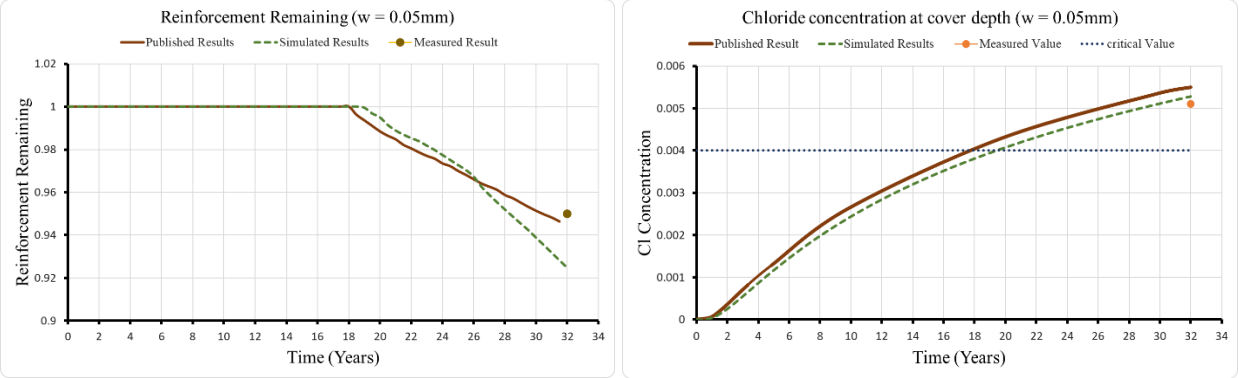

Fig.1 – Chloride concentration and reinforcement remaining ratio for crack width 0f 0.05 mm.

The proposed chemo-mechanical model is utilized to investigate the coupled effects of corrosion and fatigue using a simply supported reinforced cement concrete beam to study the deflection of span 2000 *mm* and cross-section of 100 *mm* × 150 *mm* under centre point bending. Beam is reinforced with four bars of 12 mm diameter each. The following three cases have been considered in the numerical simulation under coupled effect.

a. Only corrosion: Beam subjected to chloride exposure with self-weight only.
b. Only Mechanical: Beam subjected to a point load of 1kN at the centre of beam with no chloride exposure.
c. Coupled Corrosion and Mechanical: Beam subjected to load of 1 kN at the centre of beam with chloride exposure.

At first the load is applied monotonically on the beam to study the deflection of beam under above said cases and are plotted in figure 2. This static load is then replaced by a constant amplitude cyclic load to investigate the behaviour of the beam under coupled effect of corrosion and fatigue.

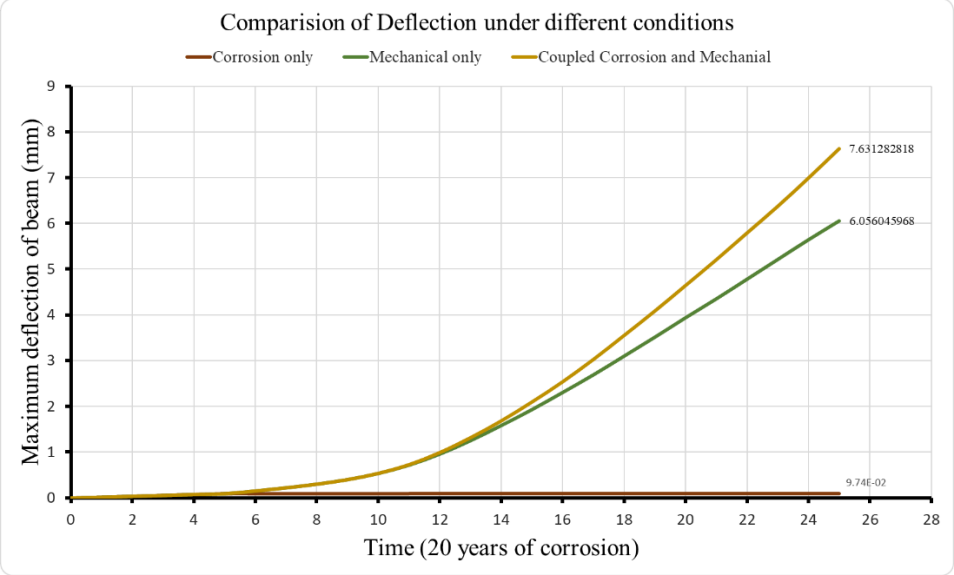

Fig.2 – Deflection under different case of loading.

In case (a), as the beam is subjected to only its self-weight and chloride, the total deflection of 0.00974 which is very small and deflection particularly due to corrosion is 0.00011 mm.

In case (b), where the beam is subjected only to its self-weight and a point load of 1 kN at the centre of the beam. The total deflection observed is 6.056 mm.

In case (c), when the beam is subjected to coupled loading conditions of 1 kN point load at centre of the beam and the chloride exposure at the bottom face of the beam. The total deflection at the centre of the beam observed is 7.630 mm, which is 26% more than the deflection observed in case (b). Degree of corrosion is also increased in coupled conditions where the max corrosion is 25.9% compared to 24% max corrosion in case (b). Results obtained in the simulation of three cases are in-line with the literature published in past.

3. Conclusions

Multiphysics simulation of coupled effect of corrosion and fatigue can predict the behavior of reinforced concrete elements. Careful modelling of fatigue loads and transport mechanism of corrosion process can be used in estimating the residual fatigue life of new reinforced concrete structures as well as the existing one.

Acknowledgements
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References

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