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# *Constitutive Laws of Corroded RC Elements Repaired by FRP Sheet*

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***ABSTRACT***

Corrosion of reinforcement has very serious effects on structural behavior of reinforced concrete structures. Because of damages due to corrosion, several methods of reviving of such structures have been developed. Using of FRP sheets is one of them. In this research, the compression and tension behavior of corroded RC elements strengthened with FRP sheet is surveyed through modeling of these elements by the means of COM3 and WCOMD software developed at the University of Tokyo and a written program in FORTRAN code. Fixed smeared crack approach has been used for nonlinear analysis. In this method, the average behavior of materials (including concrete, reinforcing bar and FRP sheets) is applied in the modeling. After attaining the material constitutive laws of corroded RC elements and also repaired ones by FRP sheet, the consequences are verified through a comparison with laboratory test results.

***KEYWORDS***

Reinforced Concrete, Corrosion, FRP, Constitutive Laws

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## 1- BRIEF INTRODUCTION

Corrosion of reinforcement has very serious effects on structural behavior of reinforced concrete structures. Because of damages due to corrosion, several methods of reviving of such structures have been developed. Using of FRP sheets is one of them. In this research, the compression and tension behavior of "corroded RC elements repaired by FRP sheet" is surveyed through modeling of these elements.

There are several models have been introduced in order to consider reinforcement corrosion for modeling of a reinforced concrete element by smeared crack method.

One of these modeling methods presented by Toongoenthong and Maekawa [4]. In this method, modeling is made by considering impacts of corrosion (such as corrosion cracks in concrete, and reduction of reinforcement cross-sectional area) averagely in the constitutive laws of steel and concrete.

Another method which has been developed by Gambarova and Coronelli [5] is based on steel-concrete modeling and the interaction between these two, where the impact of corrosion is directly included in steel and concrete bond model.

In this research both of the above-mentioned viewpoints have been taken into account so that the impact of corrosion cracks and concrete-steel bond deterioration, could be considered in modeling at the same time.

## 2- METHODOLOGY

$Fe_2O_3$, produced from reinforcement corrosion is highly porous and occupies areas twice as much as steel. Considering this, reinforcement corrosion has three main impacts on the reinforced concrete element that are enumerated here:

1. Changing the bond strength between reinforcement and concrete
2. Creating longitudinal and transverse cracks in concrete
3. Reducing reinforcement cross-sectional area

In this research, "corroded RC elements repaired by FRP sheet" model is made by the means of "COM3" and "WCOMD" software developed at the University of Tokyo and a written program in FORTRAN code.

The behavioral equations used in above-mentioned software developed by Okamura and Maekawa [8] in which fixed smeared crack approach has been considered for nonlinear analysis of reinforced concrete element. In smeared crack method, the average behavior of materials (including concrete, reinforcing bar and FRP sheets) is applied in the modeling.

## 3- MAIN CONTRIBUTIONS

The main achievements of this research are as follows:

1- The compressive behavioral model of "corroded RC elements repaired by FRP sheet": here the following equation is presented to gain the compressive strength of corroded reinforced concrete element proportionate to the various percentage of corrosions:

$$\begin{cases} f'_{c,cor} = f'_{co} & ; \quad \gamma \le \gamma_{cr} \\ f'_{c,cor} = \dfrac{f'_{co}}{0.8+170k_{sh}\sqrt{\rho}(1-\sqrt{1-\gamma})} & ; \quad \gamma > \gamma_{cr} \end{cases} \qquad (1)$$

$$\gamma_{cr} = 1-(1-\frac{0.001}{k_{sh}\sqrt{\rho}})^2$$

Where :

$f'_{co}$ : Initial compressive strength

$\rho$ : Reinforcement ratio

$\gamma$ : Corrosion percentage

$k_{sh}$ : Shape coefficient (3.14 for circle, 4 for square)

$f'_{c,cor}$ : Compressive strength after corrosion

Once the compressive strength of corroded reinforced concrete element was calculated by equation (1), the result was put in the equations presented by Ghorbi [1] and the compressive behavioral model of “corroded RC elements repaired by FRP sheet” is gained.

2- The tensile behavioral model of “corroded RC elements repaired by FRP sheet”: first the bond stress between corroded reinforcement and concrete, and also between concrete and FRP is calculated, then tensile behavioral model of element has been determined by calculation of critical amount of reinforcement.

## 4- SIMULATION RESULT

After attaining the material constitutive laws of corroded RC elements and also repaired ones by FRP sheet, these constitutive laws were applied in "COM3" and "WCOMD" software which were used for modeling laboratory samples tested by Lee et al.[12]. Comparison between computational analysis and laboratory results verified the consequences achieved in this research. The following figures show this comparison.

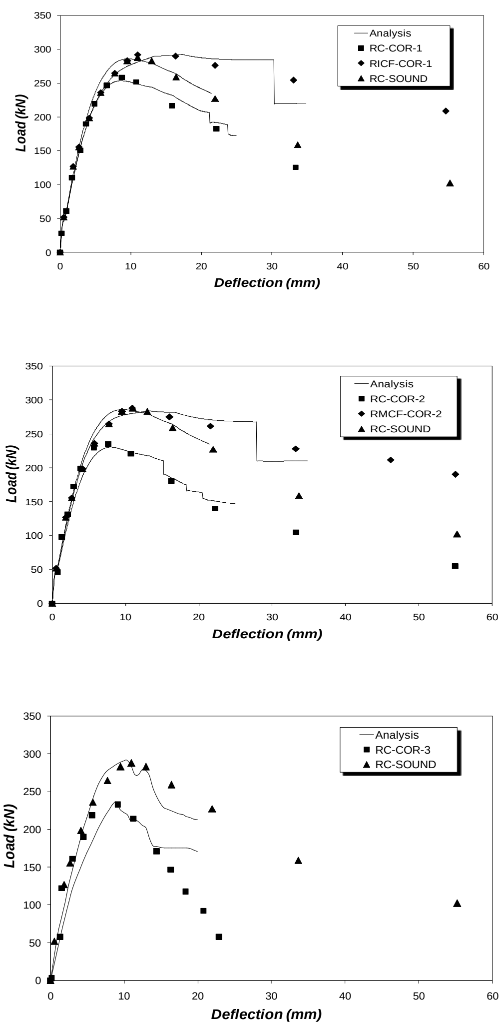


**Figure (1): Comparison between analysis and laboratory test results**

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